International Indian Ocean Expedition

Collected reprints VII

Published upon the recommendation
of the Scientific Committee on Oceanic Research (SCOR)
and the
Intergovernmental Oceanographic Commission (IOC)

Unesco, Paris 1971

International Indian Ocean Expedition. Collected reprints VII

Collected edition published in 1971 by the United Nations
Educational, Scientific and Cultural Organization,
Place de Fontenoy, 75 Paris-7e
Printed by Les Presses Saint-Augustin, Bruges

SC.70/D.37/7A
Printed in Belgium

Preface

The seventh volume of collected reprints of the International Indian Ocean Expedition consists of papers received by Unesco between December 1968 and January 1970.

For convenience of presentation the papers have been grouped, in a very approximate classification, under the following main headings:

I. Marine biology;
II. Physical oceanography and marine meteorology;
III. Marine geology and geophysics;
IV. Marine chemistry;
V. Papers presented by title or abstract only.

Author and subject indexes are now in preparation. Their publication is expected after termination of the series.

Collected reprints of the IIOE

List of reprints

Part I. Marine biology

Part II. Physical oceanography and marine meteorology

Part III. Marine geology and geophysics

Part IV. Marine chemistry

Part V. Papers presented by title or abstract only

Part I Marine biology

Reprinted from *Cahiers ORSTOM – Océanographie*, no. 6, 1963, p. 1-32

DEUXIÈME LISTE COMPLÉMENTAIRE DES POISSONS DU CANAL DE MOZAMBIQUE

DIAGNOSES PRÉLIMINAIRES DE 11 ESPÈCES NOUVELLES

par

P. FOURMANOIR et A. CROSNIER

En 1961, nous avons publié une première liste complémentaire de soixante et onze espèces. Nous la faisons suivre d'une seconde d'importance égale. Elle décrit de nouveaux poissons de provenances suivantes : flaques, chalut, contenus stomacaux de Thons, observés entre 1960 et 1962.

Famille des MYCTOPHIDES

Diaphus elucens Brauer

Une quinzaine de spécimens à larges photophores dans des contenus stomacaux de Thons jaunes L'exemplaire de *Diaphus* (Mém. I.R.S.M., 1957; Sér. F, p. 16), trouvé en 1955 dans l'estomac d'un Coelacanthe, avait des photophores très petits.

Famille des ZEIDAE

Zenion hololepis (Good et Bean)
SMITH, 1953, p. 145
D VI 25, A 26

Dix exemplaires de 3,6 à 4 cm dans des contenus stomacaux de Thons jaunes pris au large de Nosy-Bé et de Majunga en Juillet - Août.

Famille des CHIASMODONTIDAE

Chiasmodon niger Brauer
DE BEAUFORT, 1951, p. 9
D IX-X + 1 24-27, A 27

Peau dépourvue d'écailles, ligne latérale avec environ 70 pores. Longueur maximum 14 cm.

Coloration noire qui disparait rapidement par frottement.

Constitue une nourriture de base pour les gros Thons jaunes pris entre 4 et 10 milles de la rupture de pente continentale.

Famille des SYNODONTIDAE

Saurida undosquamis (Rich.)
Provenance : Nosy-Bé.

Famille des POMACENTRIDAE

Abudefduf zonatus (Cuv. et Val.)
SMITH, 1960, Icht. Bul. n° 19

Espèce très commune à basse mer moyenne dans les flaques pourvues d'herbiers. Une petite tache rouge-orangé sur l'opercule près de l'origine de la ligne latérale, base de la 2ème dorsale noire.

Abudefduf glaucus (Cuv. et Val.)

Petite espèce bleu-pâle présente dans la plupart des flaques.

Abudefduf dicki (Lienard)

Quelques exemplaires pris à Andila (N.W. de Nosy-Bé), flaques, basse-mer de vive eau.

Abudefduf xanthozonus (Bleeker)

Coloration brun-olive. Une tache jaune-orangé au bord operculaire supérieur rappelant la tache rouge-orangé de *A. zonatus*, iris traversé d'une bande noire verticale. Deux larges bandes transverses blanc-jaunâtre au milieu du corps et à l'origine du pédoncule caudal. Une tache noire entourée de bleu à la base de la dorsale molle débordant un peu sur la partie dorsale.

Provenance : quelques exemplaires dans les flaques de Nosy-Bé.

Abudefduf cingulum Klunzinger

Une seule bande transversale blanche au milieu du corps n'atteignant pas la région ventrale. Large ocelle noir entouré de jaune entre les quatre dernières épines dorsales, dont près des 2/3 débordent sur la région dorsale. Une tache noire dorsale à l'origine du pédoncule caudal et à l'origine de la pectorale. Coloration générale gris-olive.

Provenance : nombreux exemplaires dans les flaques de Nosy-Bé.

Note : *Abudefduf xanthozonus* a été nommée par erreur *A. leucozona* dans Fourmanoir, Mém. I.R.S.M., Sér. F, 1957, p. 197, elle était bien décrite sous le nom de *A. xanthozona* dans Sér. A, 1954, p. 226, Comores.

Abudefduf bankieri (Rich)
D XIII 10-11, A II 10-11, L.I. 15-18

Coloration violacée, quelques points bleus sur la tête. Un point noir à l'origine de la pectorale dont la base est gris-noir sur plus de la moitié. Origine de la ligne latérale avec un point bleu-violet. Caudale et partie distale du pédoncule jaune-orangé. Deuxième dorsale et anale jaunes dans l'intervalle des 4 à 6 derniers rayons. Reste des nageoires y compris les pelviennes bleutées. Pectorales incolores.

Provenance : Une trentaine d'exemplaires de 2 à 7 cm. dans une seule flaque à fond rocheux clivé, au pied du massif de Lokoubé (Nosy-Bé). Aucun ne présentait une coloration jaune sur les pelviennes.

Abudefduf annulatus (Peters) (Fig. 1)

Nombreux exemplaires de 1,5 à 6 cm. pris au poison, flaques d'Ambatoloaka (Nosy-Bé), basse-mer de forte vive eau.

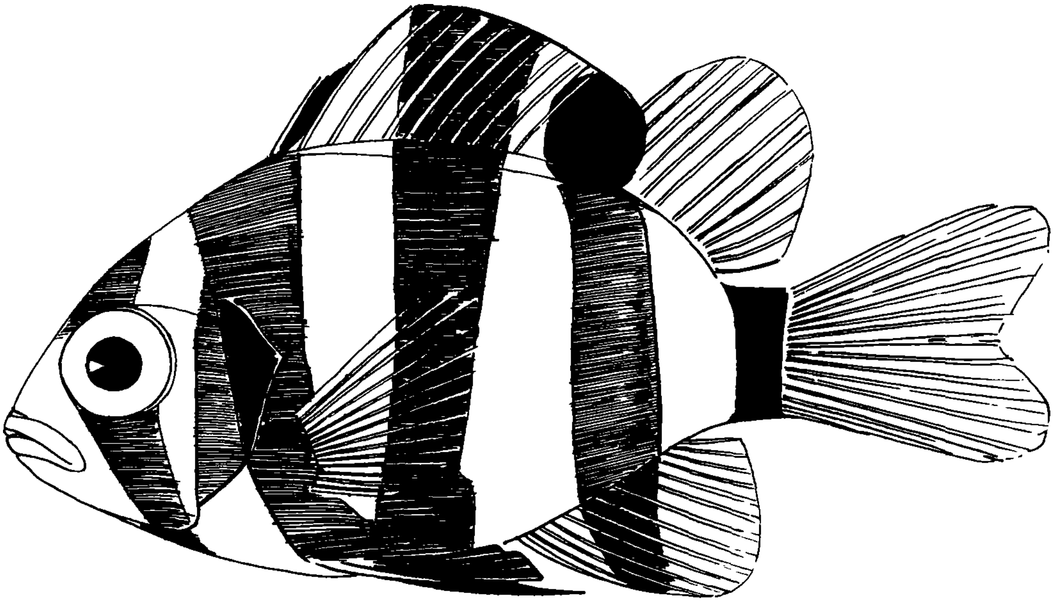


FIG. 1 - Abudefduf annulatus; 2,5 cm.

Pomacentrus tripunctatus (Cuv. et Val.)

Très abondant dans les flaques au niveau de basse-mer moyenne.

Pomacentrus pulcherrimus Smith

Seulement deux exemplaires de 2 et 3 cm., même provenance.

Décrite pour la première fois par Smith en 1960. Magnifique coloration bleu clair et jaune, la surface jaune étant ventrale et caudale.

Famille des APOGONIDAE

Fowleria aurita (Cuv. et Val.)
SMITH, 1961, Icht. Bul. n° 22

Ligne latérale incomplète 10-13, 22-23 séries d'écailles. Sur l'opercule une tache noire entourée d'une ligne jaune pâle postérieure. Ecailles tachées de brun-violet, 2ème dorsale, anale, caudale non ponctuées.
Provenance : exemplaires de 3 cm., flaque de Nosy-Bé.

Apogon fraenatus (Val.)

Une ligne longitudinale noire de l'œil au pédoncule caudal, un point noir au milieu de la base de la caudale. Deux exemplaires trouvés à Nosy-Bé.

Apogon nubilus Garman

Coloration gris-violacé avec bandes transversales contrastant plus ou moins chez les individus vivants. Un trait noir en travers du préopercule partant de l'œil, une tache gris foncé sur le dessus du pédoncule caudal atteignant sur les côtés la ligne latérale.

Provenance : Nombreux exemplaires de 3,2 à 4,8 cm. pris dans une flaque au pied du Massif de Lokoubé (Nosy-Bé).

Apogon variegatus nov. sp. (Fig. 2)

Coloration peu intense, brun-rouge ou brun-olive, avec 7 à 9 bandes verticales claires, peu distinctes, élargies ventralement. Ligne latérale partiellement éclaircie. Bord des écailles de la rangée supérieure noirci. Caudale très faiblement échancrée ou tronquée.

Provenance : Nombreux exemplaires pris au poison à Nosy-Bé, basse-mer vive eau, fonds variés, longueur 2,5 à 4 cm.

Apogon striatus nov. sp.

Coloration pâle, gris-rosé. Un trait noir part en-dessous de l'œil et se dirige en s'amincissant vers l'angle préoperculaire avec une faible obliquité. Dorsale épineuse et pelviennes noircies. Caudale arrondie faiblement échancrée.

Provenance : Nombreux exemplaires de 2 à 6 cm. pris à forte basse-mer à Ambatoloaka (Nosy-Bé).

L'espèce est voisine de *Apogonichtyoides fraxineus* Smith 1961.

Apogon ocellatus nov. sp. (Fig. 3)

Gris-rosé. Un trait noir part en-dessous l'œil et atteint l'angle préoperculaire. Un large cercle gris foncé au milieu du pédoncule caudal. Nageoires claires à l'exception de la première dorsale grise antérieurement.

Provenance : Deux exemplaires de 2,2 cm., Ambatoloaka (Nosy-Bé).

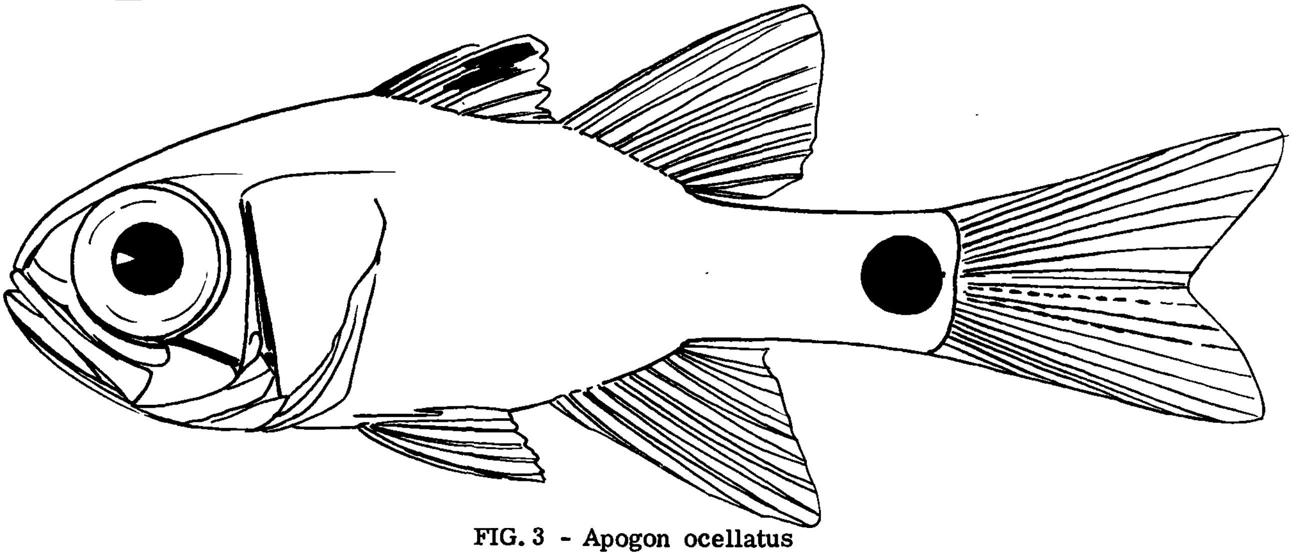


FIG. 3 - Apogon ocellatus

Paramia quinquelineata (Cuv. et Val.)

Cinq lignes longitudinales noir-violet, une tache noire intense à l'origine de la caudale au centre d'une large zone jaune citron du pédoncule caudal.

Nombreux exemplaires de petite taille pris au poison. Nosy-Bé.

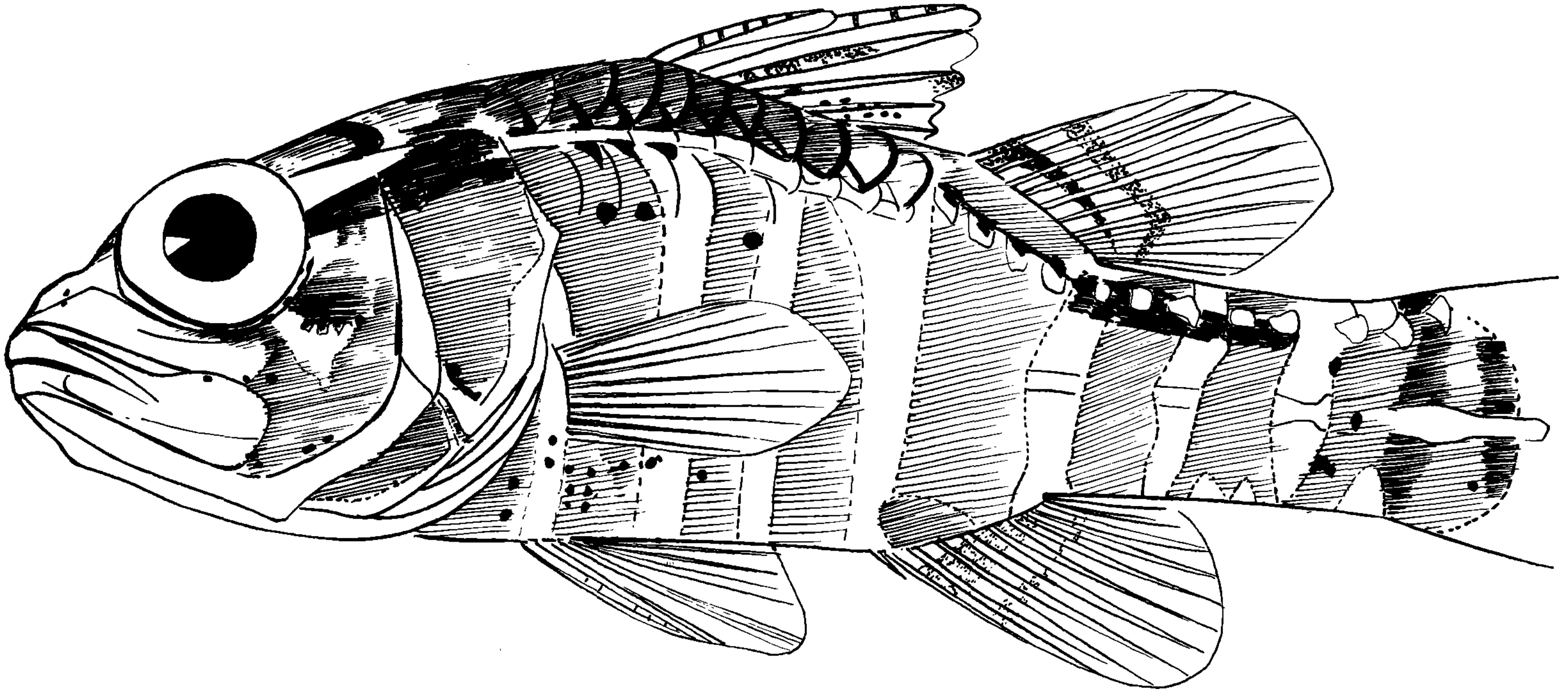


FIG. 2 - Apogon variegatus

Siphamia nigra nov. sp. (Fig. 4)
D VII 19, A 118 - 25 rangées d'écailles

Coloration très foncée, violet-noir uniforme. Base des rayons de la 4ème dorsale et de l'anale noire, épines de la 1ère dorsale noires, autrement nageoires transparentes.

Provenance : flaques d'Ambatoloaka (Nosy-Bé), forte vive eau, poison, 0,7 à 2,5 cm. de longueur.

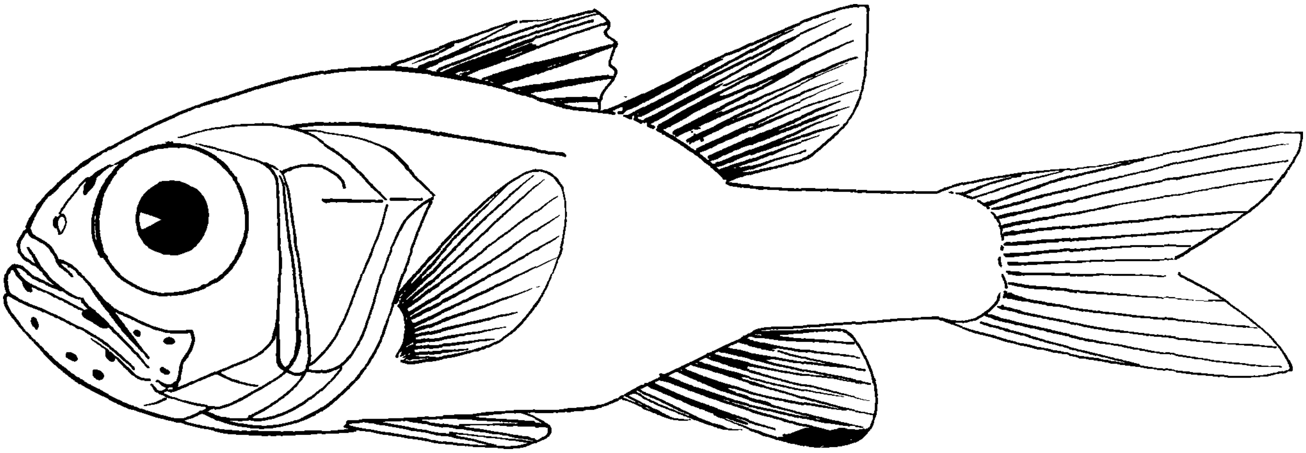


FIG. 4 - Siphamia nigra

Famille des SPHYRAENIDAE

Sphyraena quenie Klunz.
L. 1 ·120-130

Dessus du corps bleu-noir. 18 à 22 bandes transverses bleu-noir divisées en deux parties égales par la ligne latérale, intervalles un peu plus étroits que les bandes.

Cette espèce de grande taille (maximum 1,40 m.) se rassemble en bancs importants. En saison chaude, c'est le poisson le plus abondant du marché de Nosy-Bé.

Ordre des HETEROSOMES

Pardachirus pavoninus (Lacep.)
D 74, A 58

Fond de coloration brun clair. Environ huit séries de taches régulières claires de forme ovale, bordées de brun foncé, dont le grand axe est en général supérieur au diamètre de l'œil.

Provenance : Un exemplaire de 3,5 cm. pris au poison dans une flaque. Nosy-Bé.

Samaris cristatus Gray

Provenance : Chalutage près des îles Mitsio, quelques exemplaires.

Arnoglossus macrolophus (Alcock)
MUNRO, 1955, Fishes of Ceylon
D 90-92, A 67-70, L.I. 54-57

Les quatre premiers rayons de la dorsale sont prolongés, il y a deux taches noires à la base de la dorsale et de l'anale près de la caudale. D'autres taches grises équidistantes sont également présentes tout le long de la base de ces nageoires mais moins distinctes.

Provenance : Nombreux exemplaires de 6 à 8 cm., pris au chalut au large des îles Mitsio, profondeur 35 m.

Engyprosopon grandisquama (Schlegel)
D 80-82, A 59-61, L.I. 38-43

Une large tache noire ovale sur les deux bords de la caudale.

Provenance : Assez commun dans les fonds de 40 m. au large des îles Mitsio, longueur 7 à 8 cm.

Famille des BRAMIDAE

Brama raii (Bloch)
SMITH, 1953, p. 308
D III 30, A II 26, L/H 2,1, branchiospines 10

Au total environ 85 séries d'écailles. Bouche oblique armée de fines dents incurvées, deux canines plus fortes à la mâchoire inférieure. Longueur maximum 62 cm. Habitat 100 à 700 mètres.

Provenance : Un exemplaire de 19,2 cm., contenu stomacal d'un Thon jaune pris au large de Nosy-Bé et dix ex. de 3,5 à 4,5 cm. dans des Thons jaunes au large de Majunga (L/H 1,6).

Famille des STERNOPTYCHIDAE

Sternoptyx diaphana Hermann (Fig. 5)

Provenance : Un seul exemplaire, contenu stomacal de Thon jaune pris au large de Nosy-Bé.

Polyipnus spinosus Gunther

Provenance : quatre spécimens de 3 à 5 cm. provenant d'un Thon jaune pris au large de Majunga.

FIG. 5 - Sternoptyx diaphana

Famille des ANOTOPTERIDAE

A l'exception de la nageoire dorsale réduite à 10 rayons ou absente, les caractères sont ceux de la famille des Alepisauridae, cette dernière pourrait être seule retenue pour ces genres d'eau profonde à pectorales en position thoracique, pelviennes très reculées, dorsale adipeuse, caudale très échancrée.

Anotopterus pharao Zugmayer (Fig. 6, B)

Première dorsale absente, dorsale adipeuse bien développée. Anale 24. Corps très allongé et comprimé, L/H 20. Mâchoire supérieure avec 8 dents médianes croissantes vers l'arrière qui se logent dans l'étroite gouttière de la mâchoire inférieure. Dernière dent presque égale au diamètre de l'œil.

Un exemplaire de 33 cm. dont les autres mesures sont :

Hauteur	17 cm.
Tête	8 cm.
Œil	0,7 cm.
Museau	4,7 cm.

Bord inférieur de l'opercule et pelviennes noires.

Provenance : contenu stomacal de Thon jaune pris au large de Majunga en Août 1961.

Famille des SUDIDAE

Lestidium lanceolatus nov. sp. (Fig. 6, A)

D X, dorsale adipeuse bien développée. Anale, deux exemplaires avec 42 rayons, exemplaire le plus long avec 51 rayons. L/H 20-25. Deux séries de dents palatines à la mâchoire supérieure mais pas de dents médianes.

Trois exemplaires de 17, 18 et 23 cm. qui sont des formes jeunes.

Famille des VELIFERIDAE

Centropholoïdes falcatus Barnard

Dix exemplaires de 3 à 7 cm., contenu stomacal de Thon jaune, au large de Nosy-Bé.

Famille des ALEPISAURIDAE

Alepisaurus ferox Lowe (Pl. XIV, A)
D 42-43, A 16-17, dorsale adipeuse relativement large.

Les premiers rayons de la dorsale sont prolongés en longs filaments noirs. Les lobes de la caudale sont de même importance, les rayons extérieurs du lobe supérieur sont prolongés. Longueur maximum 2,30 m.

Provenance : Très abondant au large de la Côte Ouest de Madagascar et des Comores, pris à la ligne dérivante entre 50 et 150 mètres de la surface. Constitue une part importante de la nourriture des Thons jaunes.

Famille des GEMPYLIDAE

Gempylus serpens Cuvier

Provenance : Un exemplaire de 80 cm. pris à la traîne de surface de nuit au large des îles Radama (20 Juillet 1960).

Dix exemplaires de 12 à 20 cm., contenus stomacaux de Thons.

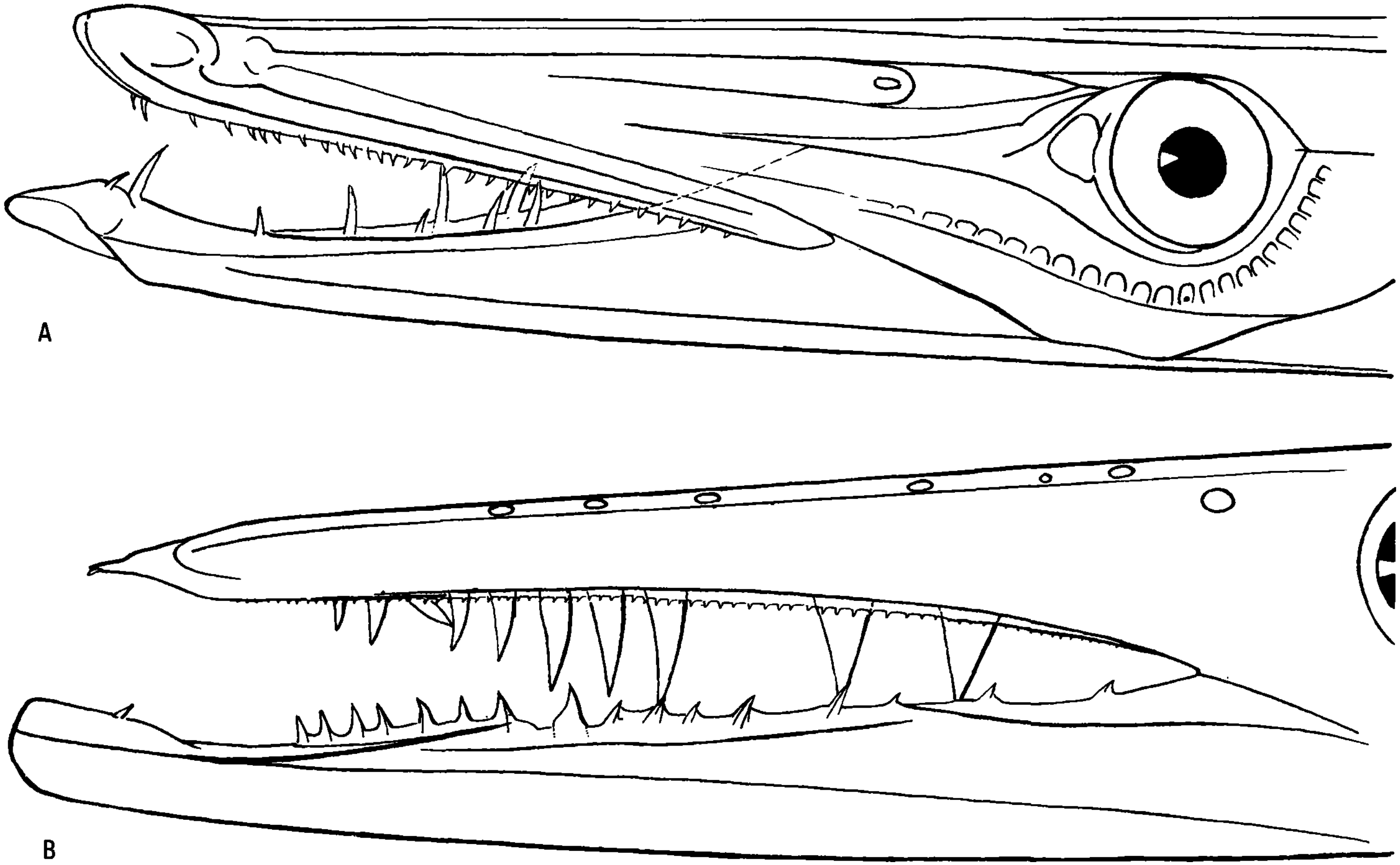


FIG. 6 - A, Lestidium lanceolatus x 15
B, Anotopterus pharao x 3,8

Famille des SCOMBRIDAE

Scomber japonicus Kishinouye

Nombreux en Avril à Fort-Dauphin; souvent associés aux *Rastrelliger*

Famille des ISTIOPHORIDAE

Istiompax indicus (Cuvier)

Marlin noir ou Marlin à pectorale rigide

Un "Marlin noir" pêché le 27 Octobre 1961 à la ligne dérivante au large de Nosy-Bé avait les mensurations suivantes :

Long. totale 2,99 m. , demi-tour maximum 62 cm. , poids 134 Kg,
Tête rostre compris 94 cm. , pointe du rostre à l'œil 63 cm. ,
Œil 5,8 cm. , pectorale 56 cm. , hauteur dorsale 41 cm. , pelviennes 42 cm. ,
Base de la 2ème dorsale 17 cm. , base de la 2ème anale 15 cm. ,
Côté antérieur de la 1ère anale 37 cm. , écartement des pointes caudales 101 cm. ,
Longueur des lobes de la caudale 63 cm.

A la capture coloration très foncée, apparition d'une couleur dorsale et antérieure violette et de zones irrégulières noires après embarquement.

Makaira nigricans Lacépède

Une cinquantaine de "Marlins bleus" dont le poids variait de 40 à 90 Kg. ont été pris en 1961 à la ligne dérivante. *Nigricans* est le terme retenu pour les Marlins bleus atlantique et indo-pacifique, *mazara, herscheli* (v. Mém. IRSM, Sér. F, p. 220, 1957) etc ... sont d'autres désignations du Marlin bleu maintenant abandonnées.

Famille des BLENNIIDAE

Omobranchus striatus (Iatzow et Lenz)
SMITH 1959, Icht. Bul. n° 14
D XII 19, A 23

Salarias fasciatus (Bloch)

Dix exemplaires de 3,3 à 12 cm. pris dans des flaques à fond d'herbier ou au voisinage d'herbiers à Nosy-Bé. L'espèce n'avait été observée jusqu'à présent qu'aux Comores.

Istiblennius andamanensis (Day)
D XIII-XIV 20-21, A II 20-21

Omobranchus et *Istiblennius* sont abondants à Nosy-Bé dans les flaques rocheuses au niveau moyen des hautes mers de morte eau.

Petroscirtes mitratus Rup. (Fig. 7)
D 25, A 17

Les trois premiers rayons allongés de la dorsale sont caractéristiques avec les petites taches oranges disposées sur les côtés du corps. Quatre ou cinq ocelles teintés de blanc équidistants dans la région dorsale.

Provenance : Nombreux exemplaires pris au poison à Nosy-Bé, flaques, sable et herbiers.

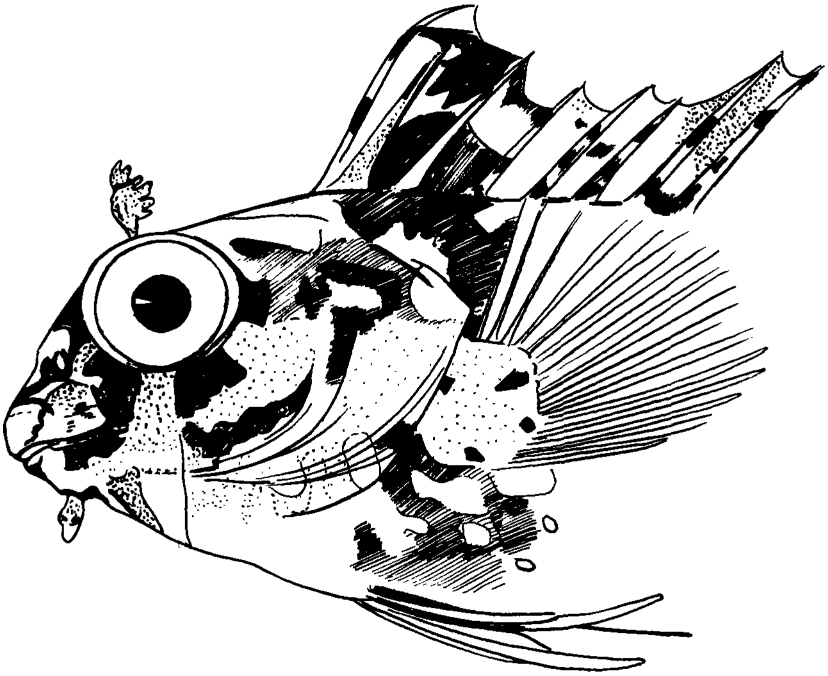


FIG. 7 - Petroscirtes mitratus

Tripterygion hudsoni Sord. et S. (Pl. A, 4)

Provenance : flaques, basse mer forte vive eau, exemplaires de 2 à 3 cm., Nosy-Bé.

Famille des HOLOCENTRIDAE

Myripristis botche Cuv. et Val.
Day, Fishes of India, 1958, p. 169
D X 15, A IV 13, L I. 28

Une des rares espèces de *Myripristis* immédiatement reconnaissable à la région distale des nageoires verticales qui est noire intense. La région dorsale de la bouche à la 1ère dorsale est noir-violacé.

Un exemplaire de 17 cm. pris à la ligne sur madrépore en région abritée (Nosy-Bé).

Holocentrus melanospilus Blkr.

Provenance : Anjouan (Comores).

Famille des SCORPIDAE

Neoscorpis lithophilus G. et T. (Pl. XVI, A)

Epines dorsales très réduites cachées dans une rainure, D 24, A 26, 103 séries d'écailles, L I. env. 92, branchiospines 13, L/H 2,1.

Pédoncule caudal élevé et comprimé, nageoire caudale faiblement échancrée, 7 à 9 bandes transversales gris-noir plus larges que les intervalles qui sont argentés. L'intensité des bandes diminue après la mort, celles-ci ne restant distinctes que dorsalement; la forme et la coloration argentée dominante rappellent alors *Monodactylus*.

Provenance : Un exemplaire de 30 cm. pris dans un filet sur fond de roches et algues brunes, profondeur 3 m., Fort-Dauphin, 25/4/63.

Signalé pour la première fois en dehors de la côte du Natal.

Famille des MULLIDAE

Upeneus moluccensis Blkr.

Nombreux exemplaires de 14 à 17 cm. pris au chalut sur le banc Pracel, 35 m.

Upeneus vittatus Forsk.(Fig. 8)

Quatre bandes longitudinales jaunes, deux bandes transversales sur le lobe caudal inférieur, la distale au moins deux fois plus large que la première.

Provenance : Comores.

Note : L'espèce que nous avons nommée par erreur *U. vittatus* p. 67 - Poissons du Canal de Mozambique 1957, est en réalité *Upeneus arge* J. et Ever.

Upeneus crosnieri n.sp. (Fig. 8 bis)

Mince bande jaune à jaune vert, très intense au milieu du corps.

Même provenance que *moluccensis*

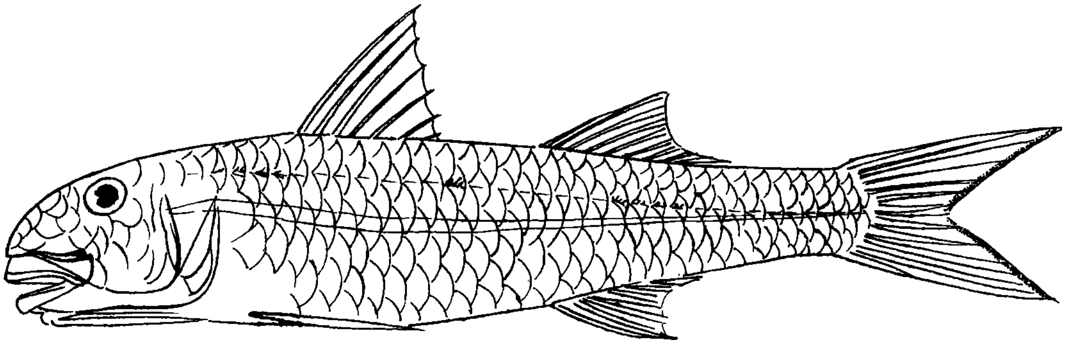


FIG. 8 bis - Upeneus crosnieri Fourm. et Guezé 1967

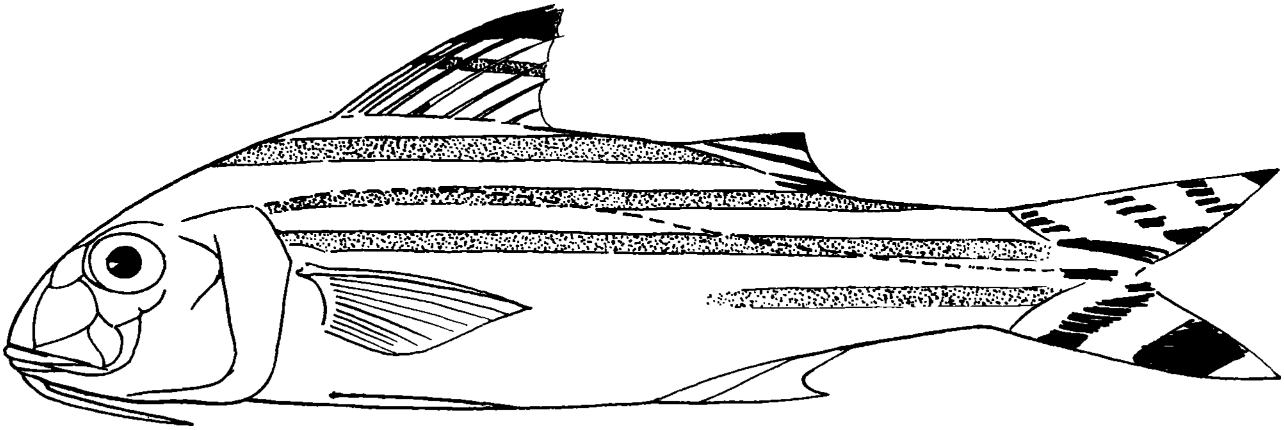


FIG. 8 - Upeneus vittatus

Mulloïdes vanicolensis (Val.) (Fig. 9)

L l. 39, branchiospines 20, L/H 3,7 - 4,1

Coloration générale rosée, une large bande jaune étendue de l'opercule à la caudale. Les nageoires dorsales, caudale, pelviennes et anale sont jaune-ocre. Les pectorales sont roses. Les barbillons sont rose-brun. Les bords postérieurs operculaires et préoperculaires sont jaune-doré. Une partie jaune s'étend également sous l'œil et derrière l'œil.

Le bord des écailles au-dessus de la bande est jaunâtre, les écailles de la ligne latérale sont jaune vif au milieu de leur contour.

Provenance : Nombreux exemplaires de 22 à 28 cm. pris au tramail à Anjouan (Comores). L'espèce a pû être confondue avec *Mulloïdes flavolineatus* Lacépède.

Famille des CAESIODIDAE

Caesio xanthurus Blkr.

Se présente en bancs importants en bordure du grand récif noyé du N. O. de Madagascar. Pris à la ligne à Domoni (Anjouan).

Caesio gymnopterus Blkr.

Petite espèce utilisée à la Grande-Comore comme appât vivant pour la pêche en dérive des Thons et Coryphènes. Les longs rayons extérieurs de la caudale sont noirs. Proche de *Caesio pisang* Blkr.

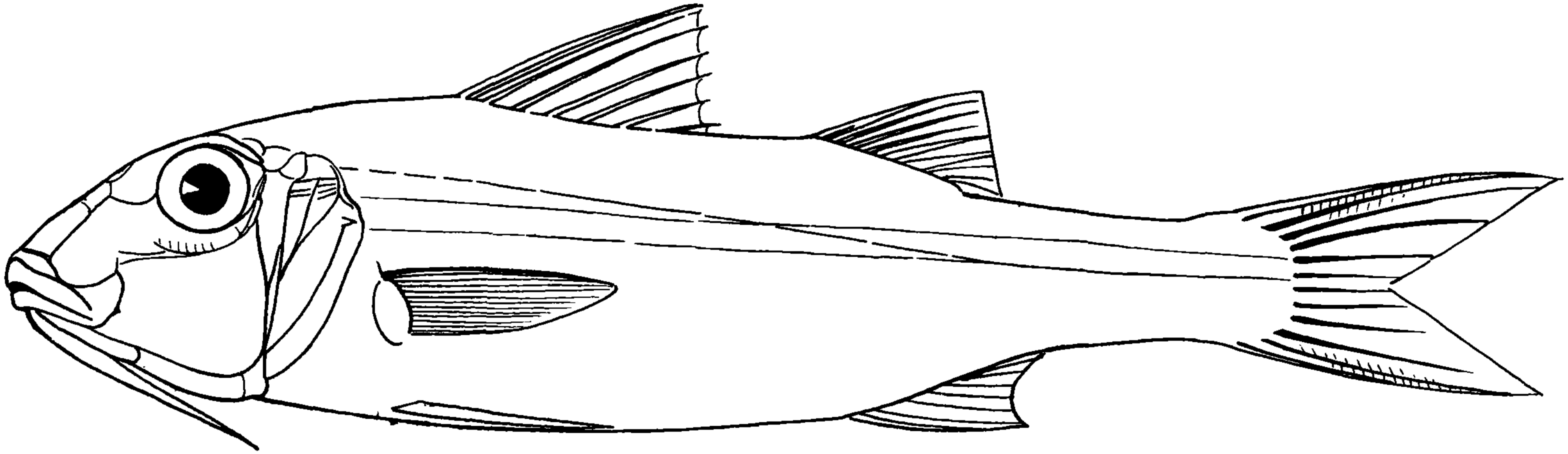


FIG. 9 - **Mulloïdes** vanicolensis

Famille des CARANGIDAE

Caranx dinema Bleeker (Pl. XIV, B)
WILLIAMS, 1958, An. Mag. Nat. Hist. Sér. 13, Vol. 1, p. 400.
D VIII + I 18-19, A II + I 16-17

Le premier rayon de la 2ème dorsale et de l'anale est prolongé en long filament. Longueur maximum 23 cm.

Provenance : Trois exemplaires pris au filet et à la ligne sur fond de vase de 3 à 15 mètres. Nosy-Bé.

Seriola nigrofasciata (Rup.)
SMITH, 1959, Icht. Bul. n° 15, p. 260

Longueur maximum 66 cm.

Trois exemplaires pris au filet sur les fonds de 9 à 15 mètres devant la station marine de Nosy-Bé en saison chaude (Mars et Mai 1962).

Trachinotus russeli (Cuv. et Val.)
SMITH, 1953, p. 222
D VI + 22-23, A II + I 20-21

Longueur maximum 50 cm.

Deux exemplaires de 30 et 32 cm. pris au filet en Avril 1962, devant la station marine de Nosy-Bé.

Chorinemus sancti petri (Cuv. et Val.)
WILLIAMS, 1958, An. Mag. Nat. Hist. Sér. 13, Vol. 1, p. 418-420
D I + VII + I 19-20, A II + I 17-18

Le récent travail sur les Carangidae de Williams laisse prévoir la synonymie *Chorinemus tolooparah Rupp*. *Chorinemus sanctipetri C.V.* Dans ce cas, la priorité pourrait être donnée à *tolooparah* le nom le plus ancien.

Famille des LETHRINIDAE

Lethrinus borbonicus Val.

6 écailles au-dessus de la ligne latérale, museau court, le maxillaire atteignant le niveau du bord antérieur de l'œil. L/H 2,7. Tête comprise 2,9 à 3 fois dans la longueur du corps.

Nageoires rougeâtres. Tête noir-olive.
Petite espèce (l. max. 20 cm.) prise en grande abondance dans les nasses posées sur les herbiers à proximité de madrépores. Régions abritées, profondeur maximum 12 m.

Lethrinus conchyliatus Smith 1960

5 écailles au-dessus de la ligne latérale. L/H 2,8.

Reconnaissable à la coloration rouge du bord operculaire et de la base de la pectorale, cette dernière montrant également au moment de la capture une région mauve intense. Corps argenté. Pris à la ligne en bordure du large du Récif Noyé de la côte N.O. de Madagascar entre 70 et 120 mètres.

Lethrinus variegatus (Val.)

5 écailles au-dessus de la ligne latérale. L/H 3,1.

Coloration très variable, à l'exception des lèvres mauves ou violettes et d'un point rouge à l'origine de l'opercule.

Espèce commune sur tout le Récif Noyé, sur corail et herbiers de 10 à 80 m. de profondeur.

Lethrinus coeruleus Val.

5 écailles au-dessus de la ligne latérale. Corps élevé, L/H 2,4.

Reconnu à la coloration du corps qui reste très pâle, gris et vert d'eau. On distingue également une zone rouge au-dessus de l'œil et la lèvre supérieure est rouge.

L'espèce qui atteint 40 cm. est pêchée dans les parties les moins profondes du Récif Noyé, elle est commune à Nosy-Iranja, 5 à 12 m.

Note : Notre description des Lethrinidae de 1957 doit être modifiée par les deux corrections suivantes :

Lethrinus xanthocheilus Klunz. à la place de *L. variegatus*.
Lethrinus crocineus Smith à la place de *L. mahsena.*

et dans la liste complémentaire de 1961.

Lethrinus aurolineatus nov. sp. = *Lethrinus obsoletus* (Forsk.).

Famille des SERRANIDAE

Epinephelus compressus Postel Fourmanoir et Guézé
D XI 15, A III 8, environ 95 rangées d'écailles, branchiospines 11., L/H 2,7 - 2,8 - Coloration violette. Corps comprimé et élevé. Dix fortes canines à la mâchoire supérieure, à l'inférieure, une paire de canines antérieure supplémentaire.

Provenance : Un exemplaire de 117 cm. pêché le 12 Août 1960 à Nosy Iranja en bordure du large du Récif Noyé à 150 m. de profondeur. Holotype 63 cm. provenant de la Réunion déposé au Muséum d'Histoire Naturelle de Paris.

Mesures : Tête 46, œil 5, hauteur 43 cm.

L'espèce est désignée à la Réunion sous le nom de "Plate", terme utilisé pour trois Serranidés d'eau profonde relativement comprimés.

Epinephelus posteli nov. sp. (Pl. XVI, C)

Matériel observé : trois exemplaires pris le 22 Avril 1961 à Fort-Dauphin.

Un exemplaire mesuré : Lt. 61 - L.s. 52 - Tête 20 - Œil 3 - Hauteur 14,7 - D XI 16, A III 8.

9 br. rudimentaires, environ 95 rangées d'écailles.

Les épines dorsales 2, 3, 4 les plus grandes sont sensiblement égales, la 2ème dorsale est aussi haute que la première. Présence d'une forte épine operculaire médiane.

Corps et tête couverts de taches hexagonales brunes disposées en mosaïque, séparées par des intervalles rouge-sang un peu éclairci. En avant de la tête les taches s'arrondissent.

Sur la première dorsale, il y a 5 séries de lignes parallèles légèrement arquées, de couleur brun-noir, elles sont très caractéristiques. Les taches sur la deuxième dorsale, la caudale et la pectorale sont hexagonales. Les rayons intérieurs des pelviennes sont noirâtres. L'anale a une large bordure noirâtre, une zone médiane gris-blanc et les rayons sont soulignés par les intervalles brun-rouge.

Cette nouvelle espèce est associée à *Epinephelus grammatophorus* dans la région de Fort-Dauphin.

Epinephelus fuscoguttatus (Forsk.) (Pl. XIII, A)

Est très voisin de *Epinephelus dispar* quand il est jeune; sa taille peut atteindre 1 m.

C'est le Serranidé le plus commun du grand Récif Noyé de la côte Ouest de Madagascar. Les jeunes se rencontrent à des profondeurs n'excédant pas 35 mètres, les adultes descendent jusqu'à 150 mètres.

On en prend toujours un certain nombre quand un bateau s'arrête au mouillage, ensuite, alarmés, ils ne sortent plus de leurs abris de corail.

On le distingue par l'aspect punctiforme des petites taches brunes; elles sont relativement plus larges et en réseau hexagonal chez *dispar*. Chez ce dernier également, on peut observer chez le vivant une dépigmentation presque totale de la région dorso-latérale, compensée par le noircissement de très larges taches régulièrement disposées, cette disposition masque alors le réseau hexagonal.

Epinephelus guaza Linné

Nous l'avons rencontré seulement dans le Sud-Est de Madagascar, où il est commun sur les fonds rocheux côtiers et sur les reliefs de 30 à 45 m. associé souvent à *Cheimeiridus nufar*.

D'après J. L. B. SMITH, cette espèce également répandue dans l'Atlantique tropical et la Méditerranée peut atteindre un poids de 50 Kg, le plus gros exemplaire observé dans la région de Fort-Dauphin pesait 12 Kg. Facilement reconnaissable à la coloration de la région ventrale jaune vif, corps brun-violet.

Epinephelus lanceolatus (Bloch) (Pl. XIII, B)

Alors que *Epinephelus tukula* peut être considéré comme le plus grand Serranidé des régions coralliennes du large, *Epinephelus lanceolatus* est le géant des régions abritées, baies et surtout estuaires de petites rivières étroites et profondes bordées de palétuviers.

La coloration est brun foncé ou brun-violet avec de nombreuses taches blanches très irrégulières, plus intenses et mieux délimitées sur la tête. Aucune de ces taches ne persiste après la mort.

Une douzaine d'exemplaires de 15 à 200 Kg ont été pris à Ambovatobe, Ampapamena et Nosy-Bé.

Note : J. F. C. MORGANS vient de publier la description de trois Serranidae souvent confondus : *Epinephelus dispar*, *E. fuscoguttatus*, *E. tukula* nov. sp. Cette mise au point amène les rectifications suivantes:

Epinephelus dispar (Playfair) a été décrit et figuré par Fourmanoir (1957, pl. IX, A) sous le nom de *E. tauvina*. *Epinephelus dispar* est une petite espèce qui ne dépasse pas 65 cm et qui vit surtout dans les régions coralliennes abritées à une profondeur n'excédant pas 20 mètres.

Epinephelus tukula Morgans (pl. XIII, C) est l'espèce décrite par Fourmanoir, Fowler et Smith sous le nom d' *E. fuscoguttatus*.

Famille des LEIOGNATHIDAE

Leiognathus elongatus (Günther)
Provenance : Nosy-Bé.

Famille des CALLIONYMIDAE

Diplogrammus infulatus Smith (Pl. A, 1)

Provenance : Nosy-Bé, abondant dans les flaques au niveau de basse-mer de vive eau.

Famille des GOBIIDES

Amblygobius albimaculatus (Rupp.)
D VI + I 13-15, A 12-14 - Ecailles 50 - 55.

Entre le bout du museau et le milieu de la 2ème dorsale, 5 rangées dorso-latérales de taches rouge brique, cet ensemble est complété par un trait lilas partant du milieu de l'œil, de même direction oblique que les rangées. Corps brun-gris avec quatre lignes verticales violet-noir équidistantes, de l'origine des pelviennes au tiers antérieur de l'anale. 6 bandes latéro-ventrales transverses bleues bordées d'un trait noir. Une douzaine de petites taches bleues sur les régions operculaires de la tête. Ponctuations et lignes rouge brique sur les deux dorsales. Œil bleu.

Provenance : Un exemplaire de 6 cm. pris au poison dans une flaque à une faible distance des grands herbiers immergés. Andila (Nosy-Bé).

Monishia sordida Smith (Fig. 10)
D VI + 19, A 18

Provenance : Nombreuses localités sur la côte N.O. de Madagascar.

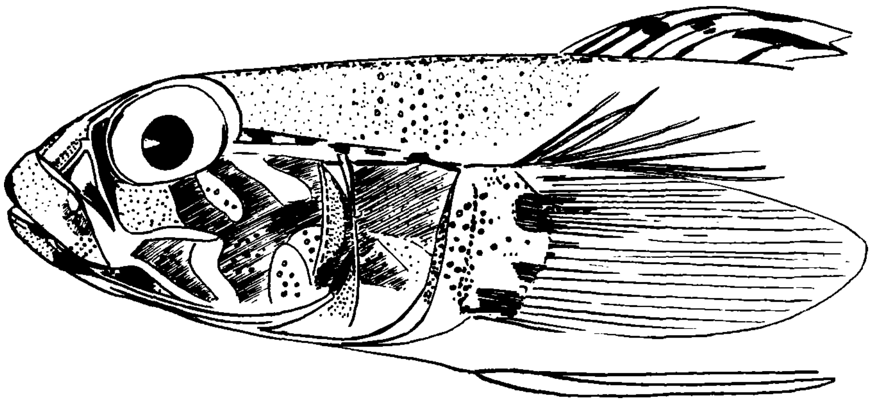


FIG. 10 - Monishia sordida

Obtortiophagus koumansi Whitley
D VI + I 10, A 19 - Ecailles 60 - 65

Sous la première dorsale un ocelle noir du diamètre de l'œil. Longueur 1,8 cm., rayons de la première dorsale non allongés.

Provenance : Flaque niveau 0,60 m., entourée de galets, fond de vase. Nosy-Bé.

Acentrogobius reichei (Bleeker)
D VI + 18, A 18 Ecailles 26 à 28. L/H 5,4

Provenance : Quatre exemplaires de 2,5 à 4 cm. Nosy-Bé.

Acentrogobius aestuarius Smith (Fig. 11)
D VI + I 10, A 19 - Ecailles 27

Une large bande claire parcourt la rangée d'écailles médiane. Sur la rangée placée au-dessous, trois paires de points brun-noir, un large point noir à l'origine de la caudale. Cinq lignes brun clair au contact des rangées longitudinales d'écailles.

Provenance : Nombreux exemplaires de 2 à 3,7 cm. Nosy-Bé.

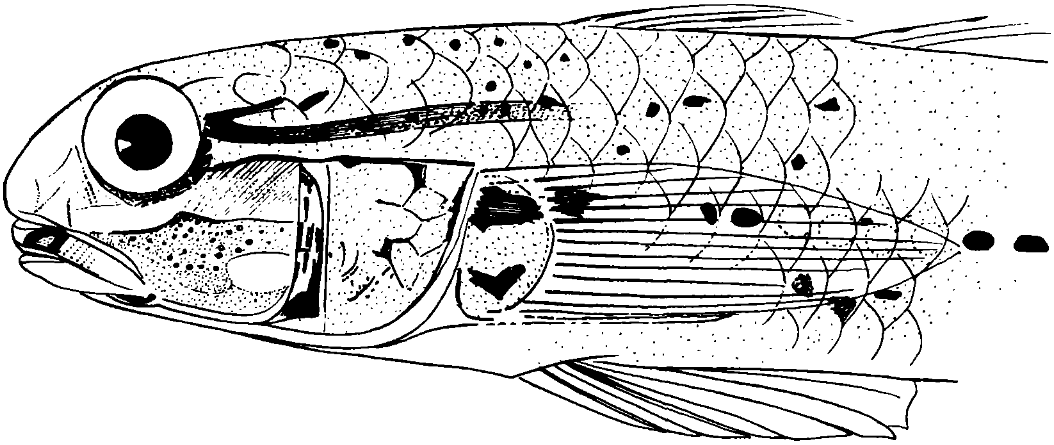


FIG. 11 - Acentrogobius aestuarius

Oxyurichtys ornatus nov. sp.
D VI + I 13, A I 14, environ 80 rangées d'écailles au total (19 prédorsales). P. 22, L/H 5,6.

Deuxième dorsale basse, un peu inférieure à la moitié de la hauteur du corps, 1ère dorsale sensiblement au même niveau.

De la région dorsale violet pâle partent 8 bandes verticales atteignant la région ventrale. Derrière l'opercule, quatre larges traits longitudinaux médians brun-noir croisent les bandes transverses atténuées, la bande qu'ils constituent se termine en arrière par une tache noire située à la base de la caudale. Traversant la région operculaire se prolongeant sur le dessus de la base pectorale, un large trait brun de même nature légèrement oblique. Museau et lèvre supérieure également foncés.

Première dorsale pigmentée de gris, avec trois ou quatre bandes longitudinales très peu distinctes, membrane de la 2ème dorsale traversée par une dizaine de bandes grises obliques. Anale à bordure gris foncé.

Caudale gris foncé uni dans sa partie inférieure, présentant quatre larges bandes à intervalles clairs à sa moitié supérieure.

Provenance : Un exemplaire de 5 cm. de L. s. , L. 6,5 cm. avec la caudale lancéolée. Tête 1,2 cm. Nosy-Bé.

Gobius fasciatus **Mac Leay** (Fig. 12)
D VI 13, A I 14, 58 rangées d'écailles environ

Quatre taches noires caractéristiques sur les nageoires. Une au centre de la première dorsale, trois sur la deuxième, la première placée sur le 4ème rayon, une tache enfin sur l'origine des rayons médians de la caudale.

Quatre bandes transversales brunes s'élargissant un peu vers le bas, entre le milieu de la 1ère dorsale et l'origine de la caudale. Quatre bandes moins distinctes partent de l'œil parallèlement au contour dorsal, les deux plus basses atteignent la caudale en se segmentant entre les bandes transverses.

La pupille est bleue, son diamètre est un peu supérieur à celui des taches. La disposition des taches et des bandes transverses est voisine de celle d'*Eleotris wardii* Playfair.

Deux exemplaires en collection, longueur 2,5 cm.

L'espèce parait commune dans les flaques au voisinage d'herbiers, au niveau de basse-mer de forte vive eau. Elle a été obtenue au poison. Nosy-Bé.

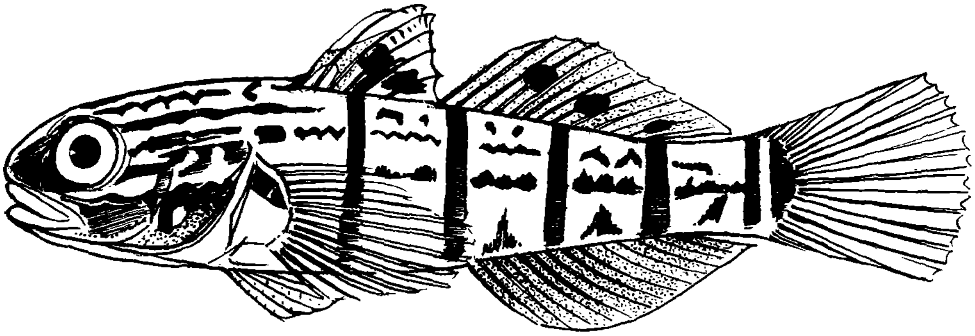


FIG. 12 - Gobius fasciatus

Famille des ELEOTRIDAE

Eleotriodes sexguttatus (Val.)
SMITH, 1958, Icht. Bul. n° 11
D VI + I 12, A I 11-12, Environ 90 écailles

Identifiable aux taches bleu-ciel operculaires, aux deux bandes allant de la tête à la caudale, la supérieure un peu brisée, rose doré, l'inférieure rectiligne, rose, toutes deux réunies par six à huit traits transversaux rosés, enfin par la pointe noire de la membrane de la 1ère dorsale entre les rayons III-IV.

Provenance : Nombreux exemplaires de 4,5 à 7 cm. pris au poison dans les flaques sableuses au voisinage d'herbiers. Nosy-Bé.

Pterelеotris tricolor Smith

Un adulte de 10 cm. environ, observé au N.O. de Nosy-Bé en pêche sous-marine à 3 m. de profondeur.

Famille des LABRIDAE

Peaolopesia gymnogenys Günther (Fig. 13)
D XII 8, A III 10, L 1.28, L/H 4

Epines dorsales croissant légèrement jusqu'à la 4ème, les suivantes égales. Première épine nettement plus petite que les deux autres. Deux fortes canines à la mâchoire supérieure, deux paires de canines inférieures dont la deuxième est tournée vers l'extérieur.

Provenance : Deux exemplaires de 6,7 et 9,2 cm. Chalutage sur sable, profondeur 30 m. devant les îles Mitsio. Décolorés par le formol.

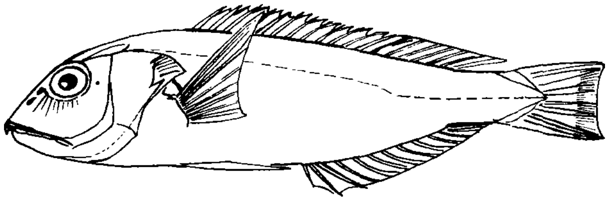


Fig. 13 - Peaolopesia gymnogenys

Famille des SCORPAENIDAE

Dendrochirus brachypterus (Cuvier)
SMITH, 1953, p. 374
D XIII 9-10, A III 5

Quatre exemplaires de 4 à 7 cm. pris au chalut au large des îles Mitsio par fond de 30 mètres.

Acanthodes fragilis nov. sp. (Fig. 14)

Dorsale avec quatre fortes épines antérieures complètement séparées du reste de la nageoire qui débute avec six épines acérées régulièrement décroissantes, anale avec trois épines courtes et épaisses.

Provenance : Basse-mer forte vive eau, Nosy-Bé, trois exemplaires de 2,4 cm.

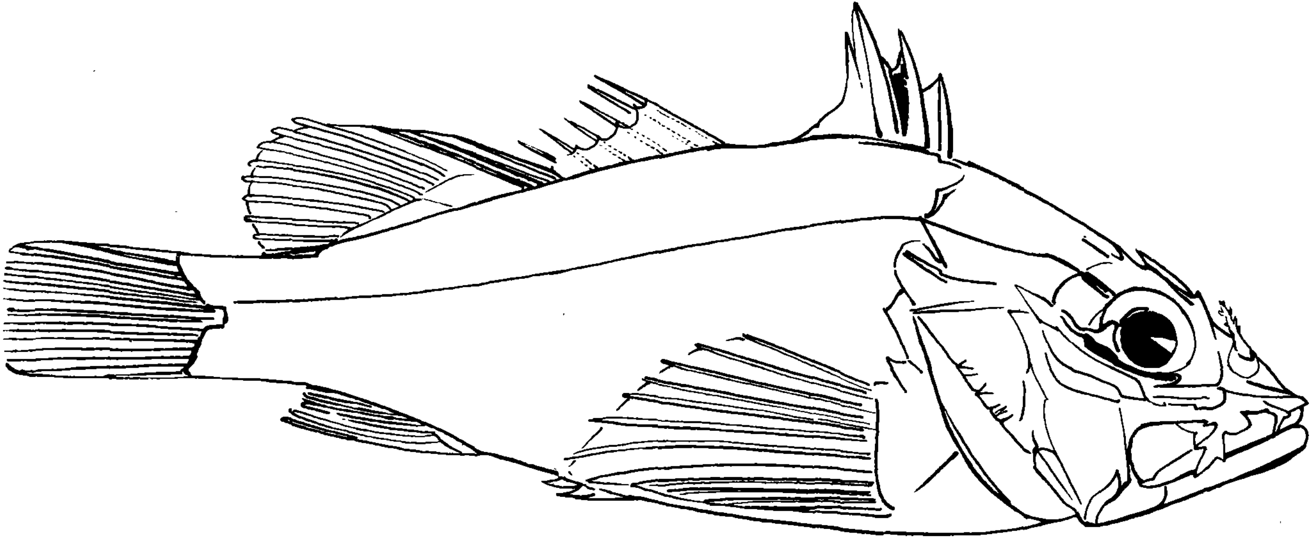


FIG. 14 - Acanthodes fragilis

Famille des MURAENIDAE

Lycodontis petelli (Blkr.) (Fig. 15)
SMITH, 1962, Icht. Bul. n° 23

15 à 21 bandes violet foncé prolongées sur la dorsale où la coloration devient noire et sur l'anale au moins postérieurement. Intervalles blancs inférieurs à la largeur des bandes, le 1er intervalle derrière l'œil est jaune citron chez un exemplaire de 25 cm. Présence d'une petite tache noire à la commissure des lèvres du côté inférieur.

Provenance : Quatre exemplaires de 8 à 25 cm. pris au poison dans les flaques d'Ambatoloaka (Nosy-Bé) à des niveaux différents.

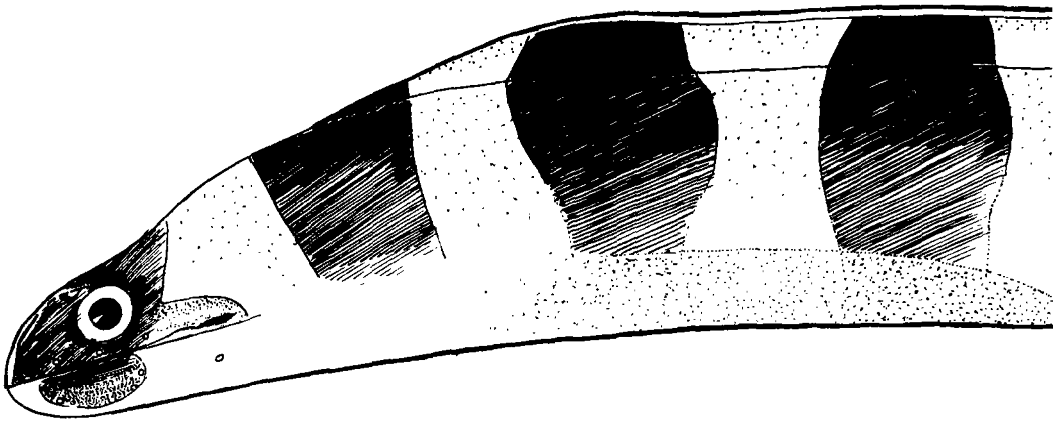


FIG. 15 - Lycodontis petelli

Lycodontis laysanus Steidachner

Coloration brun-jaune à brun en arrière avec de nombreux points bleuâtres plus espacés dans la région caudale. Antérieurement, un grand nombre de taches circulaires noires sont caractéristiques de l'espèce.

Provenance : Banc de corail noyé, profondeur 50 m. , Nord de Nosy-Bé, Longueur 45 cm.

Lycodontis javanicus

Cette espèce a été décrite par erreur sous le nom de *Lycodontis undulatus* (Lac.) dans notre mémoire IRSM,Sér. F,1957, p. 300.

Lycodontis undulatus est très commune sur tout le grand banc de corail noyé du N.O. de Madagascar en eau claire parcourue par des courants importants et parmi les lignes de madrépores côtiers, sa coloration est très variable.

Lycodontis javanicus demeure parmi les gros blocs de coraux isolés dans des baies abritées, sa coloration est constante.

Famille des ANTENNARIIDAE

Antennarius pinniceps Comm.

Quatre exemplaires pris au chalut devant les îles Mitsio.

Famille des SYNGNATHIDAE

Micrognathus brevirostris (Rup.) (Pl. A, 3)

Tronc avec 16 segments. Queue avec 30. Nageoire dorsale 19 rayons. Caudale arrondie avec de larges rayons dont les médians ont l'extrémité claire. Poche incubatrice étendue sur les 14 à 16 premiers segments de la queue.

Trois exemplaires pris à Nosy-Bé à basse-mer de vive eau, une femelle de 4,5 cm. et deux mâles de 5 cm. L'un de ces derniers, de coloration plus claire, présentait une coloration alternée lie de vin ventralement, pour les autres la pigmentation brun-noir dominait.

LISTE ALPHABETIQUE

Les espèces nouvelles sont précédées d'un astérisque

Abudefduf annulatus
bankieri
cingulum
dicki
glaucus
xanthozonus
zonatus

* Acanthodes fragilis

Acentrogobius aestuarius
reichei

Alepisaurus ferox

Amblygobius albimaculatus

Anotopterus pharao

Antennarius pinniceps

Apogon fraenatus
maculatus
nubilus
* ocellatus
* striatus
* variegatus

Arnoglossus macrolophus

Brama raii

Caesio gymnopterus
xanthurus

Caranx dinema

Centropholoides falcatus

Chiasmodon niger

Chorinemus sanctipetri

Dendrochirus brachypterus

Diaphus elucens

Diplogrammus infulatus

* Eleotriodes sexguttatus

Engyprosopon grandisquama

Epinephelus compressus
dispar
fuscoguttatus
guaza
lanceolatus
* posteli
tukula

Fowleria aurita

Gempylus serpens

* Gobius fasciatus

Holocentrus melanospilus

Istiblennius andamanensis

Istiompax indicus

Leiognathus elongatus

* Lestidium lanceolatus

Lethrinus borbonicus
coeruleus
conchyliatus
crocineus
variegatus
xanthocheilus

Lycodontis javanicus
laysanus
petelli

Makaira nigricans

Monishia sordida

* Mulloïdes auratus
vanicolensis

Myripristis botche

Neoscorpis lithophilus

Obtortiophagus koumansi

Omobranchus striatus

* Oxyurichtys ornatus

Paramia quinquelineata

Pardachirus pavoninus

Peaolopesia gymnogenys

Petroscirtes mitratus

Polyipnus spinosus

Pomacentrus pulcherrimus
tripunctatus

Ptereleotris tricolor

Salarias fasciatus

Samaris cristatus

Saurida undosquamis

Scomber japonicus

Seriola nigrofasciata

* Siphamia nigra

Sphyraena quenie

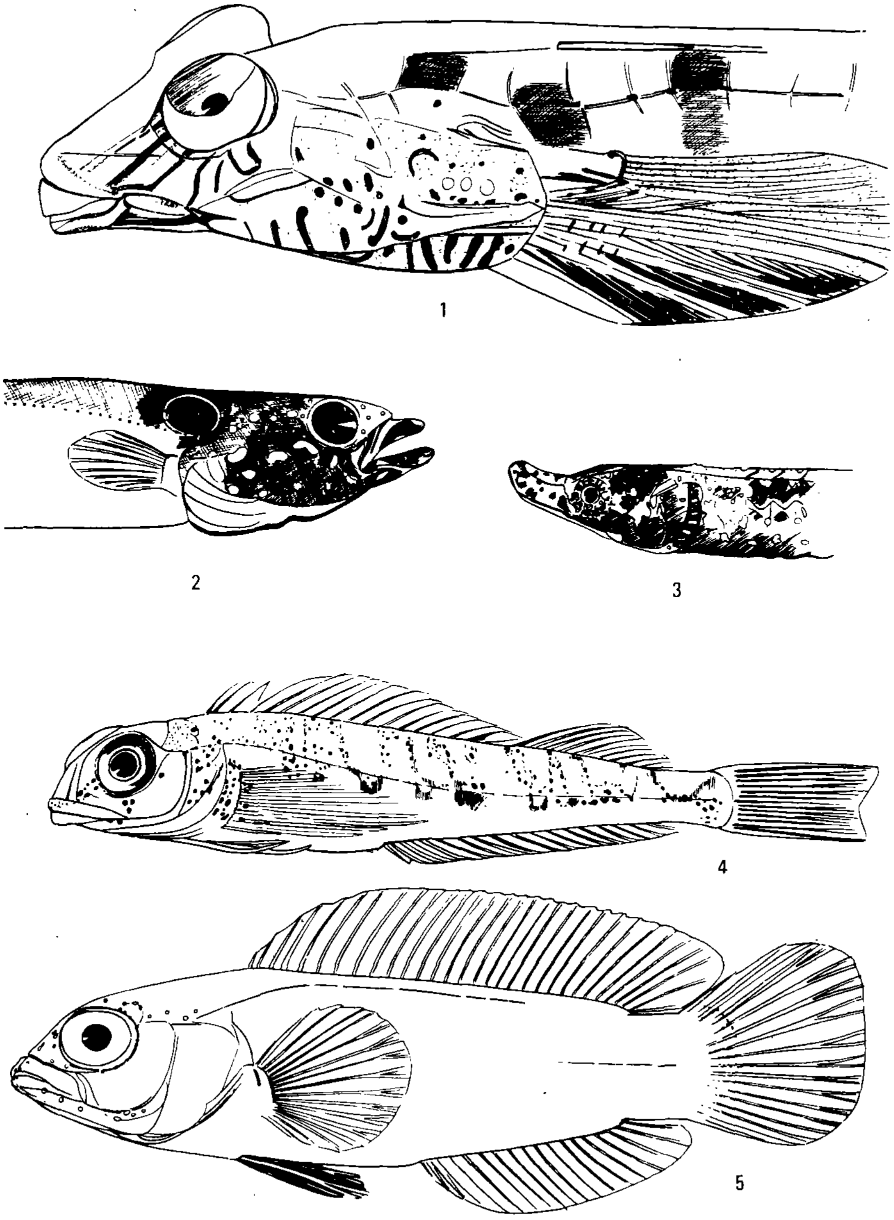
Sternoptyx diaphana

Trachinotus russeli

Tripterygion hudsoni

Upeneus arge
moluccensis
vittatus

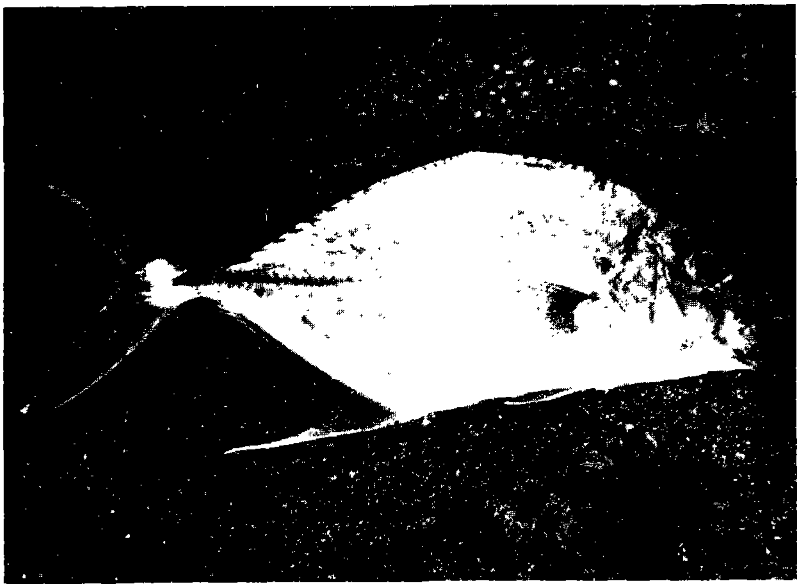
Zenion hololepis



1 *Diplogrammus infulatus* 2 *Halimuraena hexagonata* 3 **Micrognathus brevirostris**
4 *Tripterygion hudsoni* 5 *Pseudochromis sp.*

A, *Epinephelus fuscoguttatus* (Forsk)
B, *Epinephelus lanceolatus* (Bloch)
C, *Epinephelus tukula* Morgans
D, *Plectropomus marmoratus* Talbot

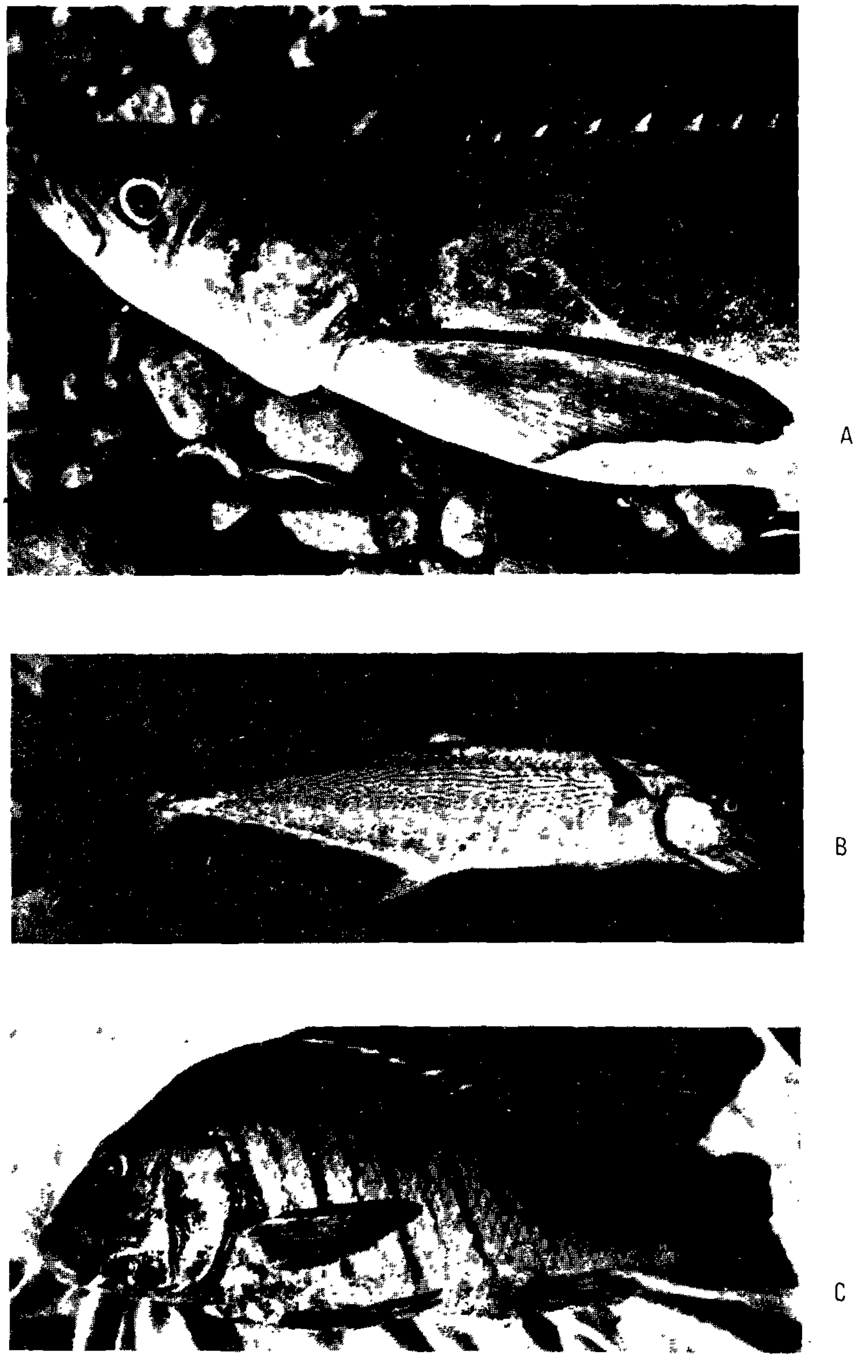
A



B

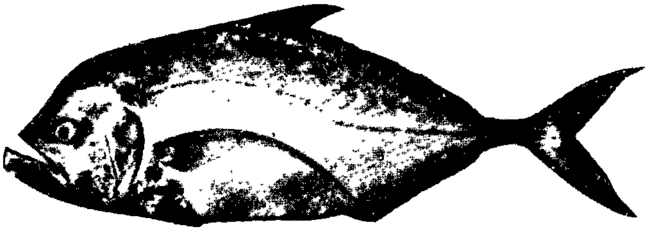
A, *Alepisaurus ferox*

B, *Caranx dinema*



A, *Rachycentron canadus*
B, *Cybium lineolatus*
C, *Gaterin plagiodesmus*

A



B

C

A, *Neoscorpis lithophilus*

B, *Caranx (Ulua) mandibularis* l. 45 cm

C, *Epinephelus posteli nov. sp.*

Nouvelles Corrections et Notes concernant les POISSONS du CANAL de MOZAMBIQUE

Mémoires IRSM 1957 et 1961

1957

p. 97

au lieu de *Diagramma maculatus* n. sp. lire *Diagramma (Gaterin) flavomaculatus* Ehr.

p. 99

Diagramma chaetodonoïdes

Notre description concerne en réalité celle d'une forme très jeune de *Gaterin orientalis* (Bloch).

p. 100

Pseudopristipoma obscurus nov. sp. est une forme jeune de *Pseudopristipoma (Gaterin) plagiodesmus* Smith.

p. 114

Caesio sp.(Fig. 84), lire *Caesio pisang* Blkr.

p. 147

Cephalopholis gibbus nov. sp. est identique à *Serranus sexmaculatus* Rüpp.

1961

p. 89

Lutjanus argentimaculatus

Lire *Lutjanus bohar* d'habitat ... au lieu de ... *bohar*. Habitat ...

Note : Il a été ajouté aux figures des espèces nouvellement citées treize dessins et photos d'espèces décrites dans les Mémoires de 1957 et 1961 pour lesquelles il n'avait pas été donné d'illustrations.

Reprinted from *Cahiers ORSTOM – Océanographie*, no. 6, 1963, p. 33-58

RAIES ET REQUINS-SCIE DE LA COTE OUEST DE MADAGASCAR

(Ordre des BATOIDEI)

par

P. FOURMANOIR

Les Elasmobranches SELACHII ont été décrits dans les mémoires de l'I.R.S.M. en 1961; l'étude sur les BATOIDEI, que nous aurions voulu aussi documentée que celle des Requins, a été abrégée par notre départ anticipé de Madagascar. Il y manque de nombreux détails sur la croissance et la reproduction, et cinq espèces côtières seulement entrevues n'ont pu être citées dans l'inventaire.

Nous avons suivi l'ordre de description suivant :

- **PRISTOIDAE** — une famille PRISTIDAE, un genre Pristis
- **RHINOBATOIDAE** — deux familles RHYNCHOBATIDAE et RHINOBATIDAE avec trois genres Rhynchobatus, Rhina et Rhinobatos
- **MYLIOBATOIDAE** — quatre familles MOBULIDAE, MYLIOBATIDAE, RHINOPTERIDAE, DASYATIDAE avec huit genres
- **TORPEDINIDAE** — avec le seul genre Torpedo

Famille des PRISTIDAE

Une seule espèce à Madagascar et aux Comores, noms vernaculaires : Vavano et Pampa Upanga; nom commun : Requin-scie.

Pristis perotteti Müller et Henle (Pl. VI A)

La nageoire caudale a un lobe inférieur bien défini, l'origine de la première dorsale est bien antérieure à celle des pelviennes.

Les Requin-scie sont pris régulièrement dans les barrages en région de Mangrove (niveau 1 m.) et dans les filets fixes ; ils peuvent atteindre 7 m. de long.

Deux exemplaires examinés :

L. t.	Scie	Bouche	D1	int. D1 D2	D2	Caud.	Provenance
333	70	19	42. 29h. 29	39	36. 20h. 29	63 31	3 m. baie Befotaka Filet
350	82 x 15		44. 35h. 34	40	39. 23h. 33	65 35	8 m. baie Ambato Chalut

Nous avons noté, chez l'exemplaire de 333 cm., les autres dimensions suivantes :

- largeur au niveau de la pointe des pectorales : 194 - côté antérieur des pelviennes : 21 - ouvertures branchiales : 6, 5 - poids : 145 kg dont 66 kg de chair consommable.

Famille des RHINOBATIDAE

Rhina ancylostoma Bloch et Schneider (Pl. I B)

Ange de mer

Présence de crêtes calcifiées en forme de triangle, élevées au-dessus de la tête, donnant des séries de relief caractéristique. Chez les exemplaires de moins de 1, 60 m il y a trois traits noirs contrastés entre les deux crêtes antérieures et des taches noires sur le disque, la coloration s'atténue avec l'âge.

Les rares captures ont eu lieu à la ligne ou au chalut dans des profondeurs supérieures à 5 mètres.

Matériel examiné, une large tête d'un *Rhina* de 2, 10 m. provenant de Nosy-Lava (1955), une femelle de 1, 97 m. pesant 60 Kg pris à la ligne par 15 m. de profondeur à Nosy-Bé, un exemplaire de 2, 03 m. pris au chalut par 8 m. à proximité de Nosy-Bé.

Disque	Bouche	D1 D2	D1	D2	Caud.	Br.
197. 112	20. 19		35, 5 15, 5 (h. 28)	29 12	42 34	6
203. 115	18. 18	28, 5	34	27	43 33	6

La distance entre les reliefs calcifiés supra-orbitaires était de 19 et 21 cm.

Rhynchobatus djeddensis (Forskal) (Pl. I A et Pl. II)

Raie guitare, Requin à museau en pelle
Noms vernaculaires : Tendraly, Pampa Fuanda

Les tubercules osseux sont toujours présents autour des yeux et sur la ligne médio dorsale, mais ils sont petits et coniques.
Chez les grands exemplaires, on en compte une quarantaine dont une dizaine plus importants devant la première nageoire dorsale, en arrière la série discontinue est formée de sept éléments de quatre tubercules.
Chez les jeunes jusqu'à 130 cm. , les taches circulaires blanches en petit nombre ne dépassent guère en arrière la première dorsale, une tache noire s'inscrit dans le premier quadrilatère de taches blanches. La tache noire s'atténue et disparait en cours de croissance en même temps que se multiplient les taches blanches disposées après l'origine de la première dorsale en quatre séries longitudinales de chaque côté du corps.

Espèce abondante en des milieux variés, herbiers, vase, sable, des palétuviers jusqu'à 30 m. de profondeur; elle ne se rencontre toutefois qu'en eau claire à salinité élevée. Les gros exemplaires sont pris de temps en temps à l'hameçon sur des palangres à requin. Les captures les plus courantes ont lieu dans les filets tramails et dans les barrages.

L'espèce atteint 2,7 m. A Nosy-Bé, nous n'avons pas observé d'exemplaires entre les tailles de 1,40 m. et 2 m.

La raie guitare de 2,38 m. (tableau) avait 6 œufs mesurant près de 4 cm. et une vingtaine non développés.

Chair appréciée par les Comoriens, interdite chez les Sakalaves.

Rhinobatos annulatus Muller et Henié

Petite raie guitare

Cette espèce, également très commune, est de petite taille; elle ne paraît pas dépasser 1 m. Elle est surtout localisée aux herbiers de 2 à 5 m. de profondeur.

Coloration ocre avec des taches lilas sur les ailes pectorales et sur les pelviennes.

Les dents sont petites, bien distinctes et pointues; nous en avons compté 32 à la mâchoire supérieure, 27 à la mâchoire inférieure, chez un exemplaire de 72 cm. de long.

L. t.	Disque	D1	D2	Bouche	i. ev.	Pelv.
67	22 25,4	6,3	6. 3,2			
70	20,5 25,5	6,5	6,7	4,1	3,1	11,4
72	23,5 28	6,8	7		3,5	12,2
76	23 27					

La maturité sexuelle est atteinte à 67 cm. Les fœtus ont été trouvés de janvier à avril, leur nombre moyen est de 3. Le 6/3/58, chez un Rhinobate de 72 cm. , leur longueur était de 17,9 cm. avec un disque de 7.8,1.

Taille minimum observée : 40 cm.

Capturées en abondance sur les herbiers avec les filets tramails. Plusieurs sont souvent trouvées en une même poche du filet.

RHYNCHOBATUS DJEDDENSIS

L. t.	Bouche		Disque		Or. D1	Côté	Base	D1 D2	D2		Pelv.	Caud.		i. o.	o.	Ev. sup.	inf.	Br.
74,5			30,5			11,5		15,5	9	4		13,5		4,7	4,5			
77				27		10,8	4,3		8,3								4	4
87			35	30	40	12,5	4,7	16,5	9	4	7	12	9			5	4,5	
97				34,5	45,5	13,5	6	17,5	10,3	4		14,5						
97	17	5,7		37	46	13,2			10		12p. 15,5	14,5				6		
98,5	18	6,2				14,5	6,5	19,5	11	4,6	14,4p.12,5	15		6	5,5		5,2	1,9
99				34	44	14		19				14					5,5	
117	21,7	7,8		45		18	8	24			p.25,5	20,7		6			6	2,3
114				39	.52	16	6,8				p.22	17	6,8					
123		6,5		42,5	53	17	8	23,5	13,3	5,3		19,5				6,7		
128		8	55	51	61	20		23,5	15	6		20					6,5	
200	34		84	80	92	30	14	37	23	9,5	t.26	30,5				11	9	
220	38	13	93	91		39,5	15		29	10,5	t.29	40	28		7		11	
238	45	17	117	106		46		38	34	11	t.33	49	32	12,4			12	5,5

Autres exemplaires mesurés :

←	1m,40	Ambanoro	4 Mai 1957
←	2m,40	Fort-Dauphin	Mai 1959
←	2m,45	Andavakotoko	5 Septembre 1956
←	2m,50	Ambatozavavy	21 Mai 1962

Les exemplaires mesurés en détail ont été pris au voisinage de la station marine de Nosy-Bé et à Nosy Kisimany à une douzaine de milles plus au sud.

Famille des MOBULIDAE

Diables de Mer

Bouche placée en dessous, dents sur les deux mâchoires - Mobula
Bouche terminale, dents à la mâchoire inférieure - Manta

Genre Mobula Rafinesque

Mobula diabolus (Shaw) (Pl. III)

Dos de coloration violette, ventre argenté, œil vert pâle. En général les côtés des pelviennes et le sommet de la dorsale sont blancs. Chez un exemplaire de 72 cm. nous avons compté 55 et 40 rangées de dents aux mâchoires inférieure et supérieure.

Provenance

Les exemplaires de 60 et 80 cm. sont pris dans les eaux claires peu profondes au filet-tramail; ils semblent plus nombreux en saison fraîche.

Un exemplaire de 1,50 m. a été pris à l'hameçon d'une ligne dérivant à 50 m., au-dessus de fonds de 1.000 m., à 6 milles du plateau continental. Un autre Mobula qui paraissait de la même espèce, bien que mesurant environ 2 m. a été pêché en juillet 60 par le même procédé mais il s'est libéré à la surface après une remontée difficile.

Chez *Mobula diabolus* il n'avait pas été observé jusqu'à présent d'exemplaires dépassant 1,30 m. de largeur.

Disque	Bouche	i. o.	o.	Dorsale	Br.	Pelv.	Caud.
70 x 43	9	13		4,6	4,5		58
71 x 42,5	8,7	12,8	1,3	4,9	4,3	7	49,5
75 x 48	9	13,5	1,4	5 4,7		7,5	52
150 x 97	20	33	3		10	17	

Note - La complexité du genre Mobula a été montrée par Cadenat en 1961. Les déterminations n'étant certaines qu'après examen du filtre branchial et de la bouche.

Genre Manta Bancroft (Pl. IV et V)

Les grands "Diables de mer" sont connus sur toutes la côte Ouest de Madagascar à l'exception des régions à forte dessalure et turbidité comme celle de Majunga.

Les rencontres les plus fréquentes ont lieu dans les baies et près de la côte (Nosy-Bé, St-Augustin) deux sont à signaler au-dessus de la rupture de pente du plateau continental (fonds de 100 - 500 m.) à neuf miles du rivage. Nos observations portent sur une vingtaine de Manta de 3,50 m. à 5,50 m. dont trois ont été capturées.

L'emploi des grands filets fixes en nylon destinés à la pêche de *Cybium lineolatus* et de certains Carangidae est gêné par le passage de ces énormes raies. Le moindre mal est l'usure du nylon sur le sable ou les madrépores voisins, plus souvent les filets entraînés ne sont pas retrouvés par leur propriétaire.

Les Manta observées dans les baies évoluent souvent une journée entière dans un espace restreint (500 mètres - 1 Km) en allers et retours incessants. Dans la baie Ambarahamay un boutre est parti en dérive à la suite du passage renouvelé d'une Manta sous l'haussière de mouillage (août 56).

Ce sont les seuls incidents dont on peut rendre responsables les paisibles Manta; il n'en reste pas moins que la vue en eau très claire d'une Manta à l'immense bouche ouverte et blanche est impressionnante.

Les bancs de petits crustacés nageurs qui fuient l'aspiration de la bouche peuvent être aperçus en eau calme, on voit en même temps les sauts groupés de ces petites "crevettes" de 0,5 à 1,5 cm. pourchassées; au large il doit s'agir de jeunes Pénéides, dans les baies de Sergestidés (Acetes, Lucifer).

Signalons enfin que les Manta sont plus souvent rencontrées isolées ou par deux, dans les zones où le courant de marée est sensible.

En raison du petit nombre d'exemplaires examinés dans l'Océan Indien et Atlantique, la distinction des espèces n'est pas certaine. Jusqu'en 1941, on reconnaissait une seule espèce à nombreuses formes *Manta birostris* (Walbaum); récemment il a été décrit deux autres espèces du Pacifique, *alfredi* et *hamiltoni*. *Manta birostris* serait finalement limitée à l'Atlantique.

Nous préciserons comme J. CADENAT deux types de coloration :

a) - coloration dorsale et bouche bleu-noir très foncé, face ventrale blanche avec taches allongées irrégulières gris-violet :

un exemplaire de 3,40 m. avec taches principales entre les branchies en arrière de la 2ème fente, quelques petites taches près du bord pectoral postérieur.

b) - coloration dorsale noirâtre ou gris-noir s'arrêtant à faible distance du bord de la bouche qui est blanche. Face ventrale sans taches.

Deux exemplaires mesurés de 3,45 m. et 4,60 m. d'envergure.

Disque	Corne	Bouche	Br.	Queue
3,40 x 1,65 (femelle)	51	49	37.24,5	1,65
3,45 x 1,74 (mâle)	37	54	35.37.35.31.23.	1,11

L'exemplaire à bouche noire de 3,40 m. a été pris à Nosy-Bé le 21/12/61 au filet simple à mailles 6 cm. de côté fil 1610 sur fond de 4 m. Le côté antérieur des ailes pectorales mesurait 1,56 m. ; le côté postérieur 1,64 m., la largeur maximum des cornes 22 cm. La peau du dos était lisse.

A la mâchoire inférieure nous avons compté 287 rangées de dents.

L'exemplaire à bouche blanche a été pris au filet tramail le 15/4/57 devant la station marine, fond de 6 m.

Le dos ainsi que la nageoire dorsale étaient très rugueux avec les denticules ou spicules espacés de 2 mm env. sur le dos.

Autres mesures : évent. 15 cm., organe copulateur 34 cm. avec ouverture de 22 cm., base de la nageoire dorsale 18 cm.

Une grande Manta du même type capturée avec un grand tramail de 6 m. de haut en baie d'Ambavatobé en juin 1956, avait une envergure de 4,60 m. Elle a figuré dans un film sur la station marine de Nosy-Bé, mais aucune mesure de détail n'a été prise.

Bibliographie J. CADENAT Bull. de l'I.F.A.N. T. XXII série A, n° 3, 1960.

Famille des MYLIOBATIDAE

Disque large en forme de losange dont le côté antérieur a son origine au niveau de l'évent. Tête projetée en avant du disque avec les yeux latéraux.

Aetobatus narinari (Euphrasen) (Pl. VI B)

Aigle de mer tacheté

Cette raie répandue dans toutes les mers tropicales est très commune le long des rivages malgaches.

Disque			Bouche	i. o.	i. ev.	Caudale
51		32	3			110
52	23			8,5	5,5	107
53	23	32				114. 4,2 (d)
60		36				131
62,5	27					116
70	31	44		10,5		150 et 124
73	31		5,5	10	7	134
76		47,5	6,5		9,8	136
79	35	50		11,7		150
80		60				116
86		59	7	17		
115		68		16,4	10,7	135

Plus de deux cents *Aetobatus* ont été pris dans nos filets au cours d'une année, les tailles extrêmes étaient 47 cm. et 130 cm. à travers le disque. Le fouet caudal est souvent coupé chez les plus grands exemplaires. Chez les jeunes les taches blanches sont nombreuses et régulièrement disposées et contrastent sur le fond noir tirant sur le vert, elles commencent souvent un peu en arrière du bord antérieur de l'aile. La dernière rangée constituée d'une ligne de taches plus petites suit de très près le bord postérieur. Chez les exemplaires de plus de 80 cm. , les taches un peu ternies manquent souvent dans la région médiane, elles peuvent présenter un centre foncé.

L'Aigle de mer remonte avec la marée vers les roches et les palétuviers couverts d'huitres qui sont sa principale nourriture. A basse mer il se retire de préférence dans les régions d'herbiers. Les plus gros ont été pris à Nosy-Iranza au-dessus d'herbiers touffus dont la croissance a lieu en eau claire et vive.

L'espèce a été signalée comme pouvant atteindre 2,5 m. d'envergure. Il est possible que les grands exemplaires de cette raie migratrice se trouvent dans le Sud de Madagascar.

La maturité sexuelle ne semble atteinte que chez les exemplaires de plus de 80 cm.

Des sangsues ont été trouvées dans la bouche à l'origine de la rape inférieure.

La chair, gris foncé, est médiocre.

Note : La troisième rangée verticale de disque indique les distances du bord postérieur du disque au bout du museau.

Famille des RHINOPTERIDAE

Tête bien dégagée des pectorales, divisée en deux lobes par une forte et profonde échancrure médiane. Corps épais. Queue longue en fouet armée d'une épine.

Rhinoptera javanica Müller et Henle (Pl. VII)

Coloration brun-noir - Peau lisse.

Un seul exemplaire de 90 cm. de large, pris dans un filet de surface en même temps que des *Chorinema*, profondeur 5 m. (juillet 1959).

Nom vulgaire : Raie-bœuf.

Famille des DASYATIDAE

Genre Taeniura Müller et Henle

Taeniura lymma (Forsk) (Pl. VIII)

Identifiable à la forme ovale du disque dont les bords latéraux sont épaissis.

La coloration est ocre avec taches bleu-clair ovales ou rondes régulièrement disposées. Sur chaque côté de la queue, il y a une large bande bleue.

Abondante dans les eaux claires à forte salinité, sur sable corallien ou vase molle, toujours au voisinage de formations coralliennes. Profondeur maximum 5 m.

Largeur maximum observée à Nosy-Bé : 32 cm.

Disque	Caudale	Dard	Pénis
15 16,5	18,5	12,9	
19,3 20,5	30,5	14 17	2
22,5 25,8	35	18	
24,2 27,5	39	18 21	6,2
26 30,5	40,5	20,5	6,5
26,5 30,9	41	20,7	
28,5 31	42	21	

L'exemplaire de 15 cm. est un nouveau-né pris en juillet avec un cordon ombilical de 21 cm.

Taeniura melanospila Bleeker (Pl. IX A et Fig. 16)

Forme arrondie, taches noires irrégulières et de toute taille sur fond gris bleuté. Peau rugueuse.

Les deux exemplaires pris à Nosy-Bé, de largeur de disque 1,33 et 1,40 m. sont les plus grands qui aient été signalés de cette espèce.

Au total trois exemplaires observés.

23. 12. 59	disque 133 x 109 - caudale 106 avec deux dards superposés de 21,5 et 9 cm. à 49 cm. de l'origine. Intervalle des évents 20, largeur 7. Bouche II - Fente branchiale 5. Pelvienne, longueur 25, largeur à l'origine 20, organe mâle 26. Poids environ 25 Kg. Prise par fond de 16 mètres, sur palangre à requins appatée avec des *Chorinema tol* entières. Baie abritée, eau claire, fond de vase.
13. 3. 61	Disque : largeur 1,40 m. - poids 40 Kg. Prise à la ligne à main sur le banc de corail noyé, profondeur 20 m.
Avril 1962	Disque : largeur 35 cm.

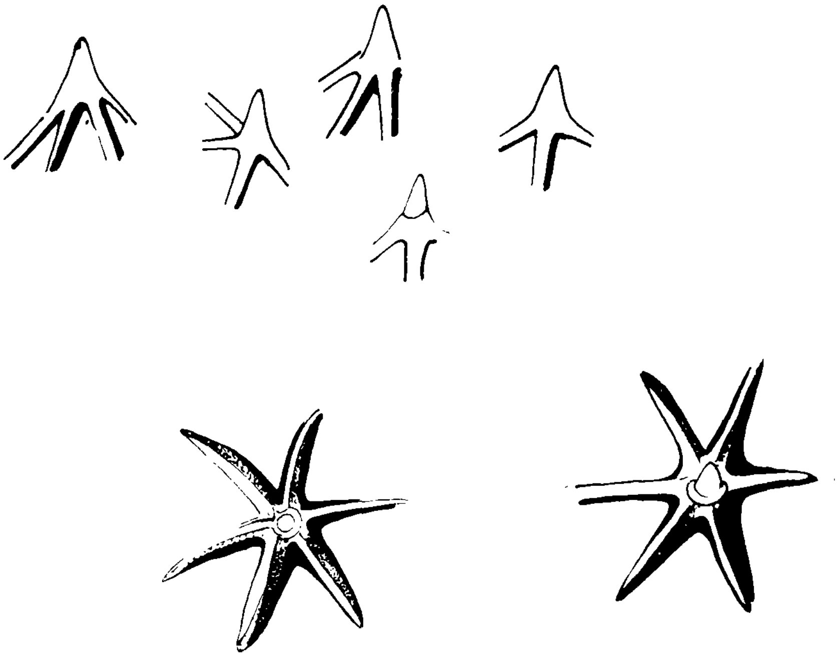


FIG. 16 - *Taenuria melanospila*. Détail des tubercules cutanés, vue de côté x 15 et de dessus x 20.

Genre Dasyatis Rafinesque

Dasyatis (Himantura) uarnak (Forskal) (Pl. X A)

Cette raie décorative, par la disposition en mosaïque des taches brunes polygonales, est rencontrée sur le sable vasard dans des profondeurs inférieures à 3 m., elle suit le mouvement de la marée. Dans le Nord-Ouest de Madagascar, elle est surtout abondante de Nosy Faly à Ambilobé sur le sable vasard couvert d'herbiers.

23.12.58 immature, disque 35 x 32, int. évent. 6,4, écartement branchial ant. 7, post. 4, bouche 3, caudale 92, épine 5,2 cm. à 13,5 cm. de l'origine

1.9.62 39 x 33, bouche 3,4, caudale 98, pelviennes 6,5.

Un exemplaire de 60 cm. de largeur de disque observé à Ambato et plusieurs non mesurés à Dzaoudzi (Comores).

Dasyatis (Himantura) bleekeri (Blyth)

Présence de tubercules osseux dorsaux et d'un bouton rostral. Fouet caudal très long lisse, fréquemment coupé. Coloration brune pouvant être nuancée de gris vert, fouet noir. Raie commune dans les baies profondes sur fond de vase inférieur à 10 m.

Disque	Bouche	Fouet	Pelvienne	i. o.
66,5 56	5,5	134		8
70 59	5,5		11	
73 63		145		10
74 66,5	6	95	13	11
77 66	8	170		

Les dards de l'exemplaire de 74 cm. étaient placés à 24 et 30 cm. de l'origine caudale.

Dasyatis sephen (Forskal) (Pl. IX B)

Caractérisée par la présence d'un large repli membraneux noir sur la caudale, la coloration brune à brun violet, la peau très rugueuse. Abondante dans le lagon de Mayotte sur les fonds de sable et d'herbiers de 2 à 8 m., plutôt rare à Madagascar.

Disque	Bouche	Caudale	Repli	i. o.	i. ev.
51	3,4	105		8,7	5,3
54	4,4	99		8,7	5,4
66		85	52		10,5
71	6	92	50		
114	9	117	66		15,5

Les dards mesuraient 15 et 8 cm. chez l'exemplaire de 66 cm.

Dasyatis kuhlii Müller et Henle (Pl. X B)

Cette raie, de forme presque carrée, supporte des eaux à faible salinité; elle est plus commune dans la région de Majunga qu'à Nosy-Bé.

La coloration est brun-ocre, le bord du disque est vineux. Des taches rondes violettes à centre clair dont le contour est indécis sont distribuées sans ordre sur la partie charnue et médiane. L'aspect de la caudale avec ses trois segments terminaux noirs séparés de blanc permet de reconnaître facilement *Dasyatis kuhlii.*

Quelquefois, les taches sont blanchâtres sans zone extérieure violette et des points noirs peuvent être présents.

Deux exemplaires ont été mesurés provenant de Katsépé (Majunga) et Nosy-Bé.

Disque 24,5 x 20 i.o. 3,9 i.ev. 3,3 caudale 25

" 41 x 32 " 5,3 " 47 avec la 2ème épine à 15 cm, de l'origine, longue de 7,5 - bouche 3,5 - pelvienne 8.

La queue porte un repli cutané dorsal court en arrière de l'épine et un repli ventral plus long.

Dasyatis sp.

Coloration gris beige à l'exception du bord postérieur du disque et du pourtour des pelviennes qui est blanc. Caudale noire à partir des épines. Très faible bouton à l'extrémité du museau. Caudale, ainsi que le disque dans la région médio dorsale, rugueux.

Un seul exemplaire mesuré à Nosy-Bé.

Disque : largeur 93 - i.ev. 12,4 - bouche 6 - caudale 173.

avec deux dards placés à 29 cm. de l'origine.

Famille des TORPEDINIDAE

Raie électrique, Raie Torpille

Torpedo sp

Front rectiligne
Coloration brun-noir
Trouvée occasionnellement dans les eaux dormantes de 1 à 10 m. sur vase. Prise au filet tramail.

Un des plus grands exemplaires mesurait 34,5 cm. avec une largeur de disque de 24 cm.

Torpedo fuscomaculata Peters

Coloration brun clair, marbrée ou tachetée. Moins commune que la précédente.

Un exemplaire en collection, longueur 26,5 cm. - largeur 18 cm.

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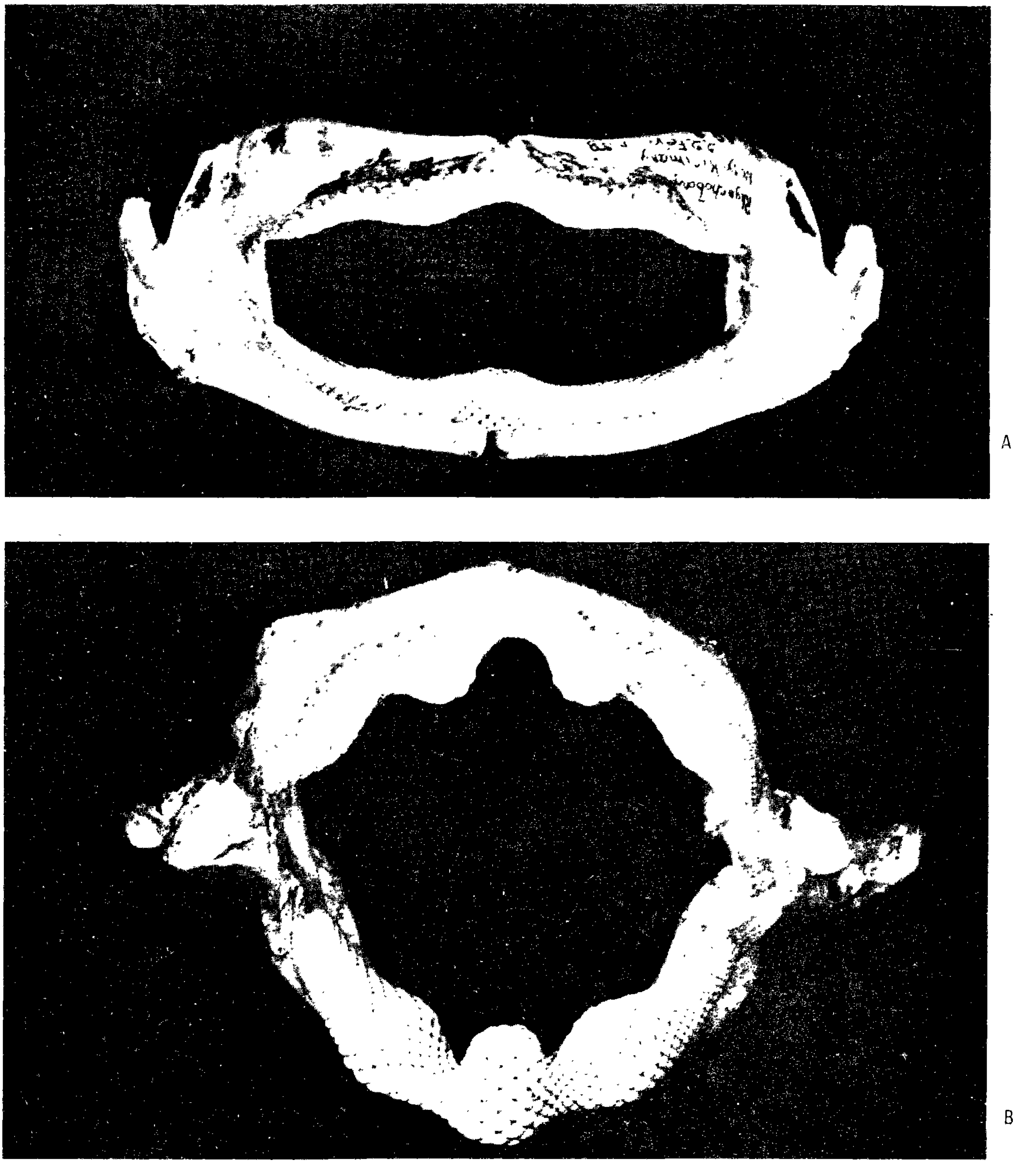
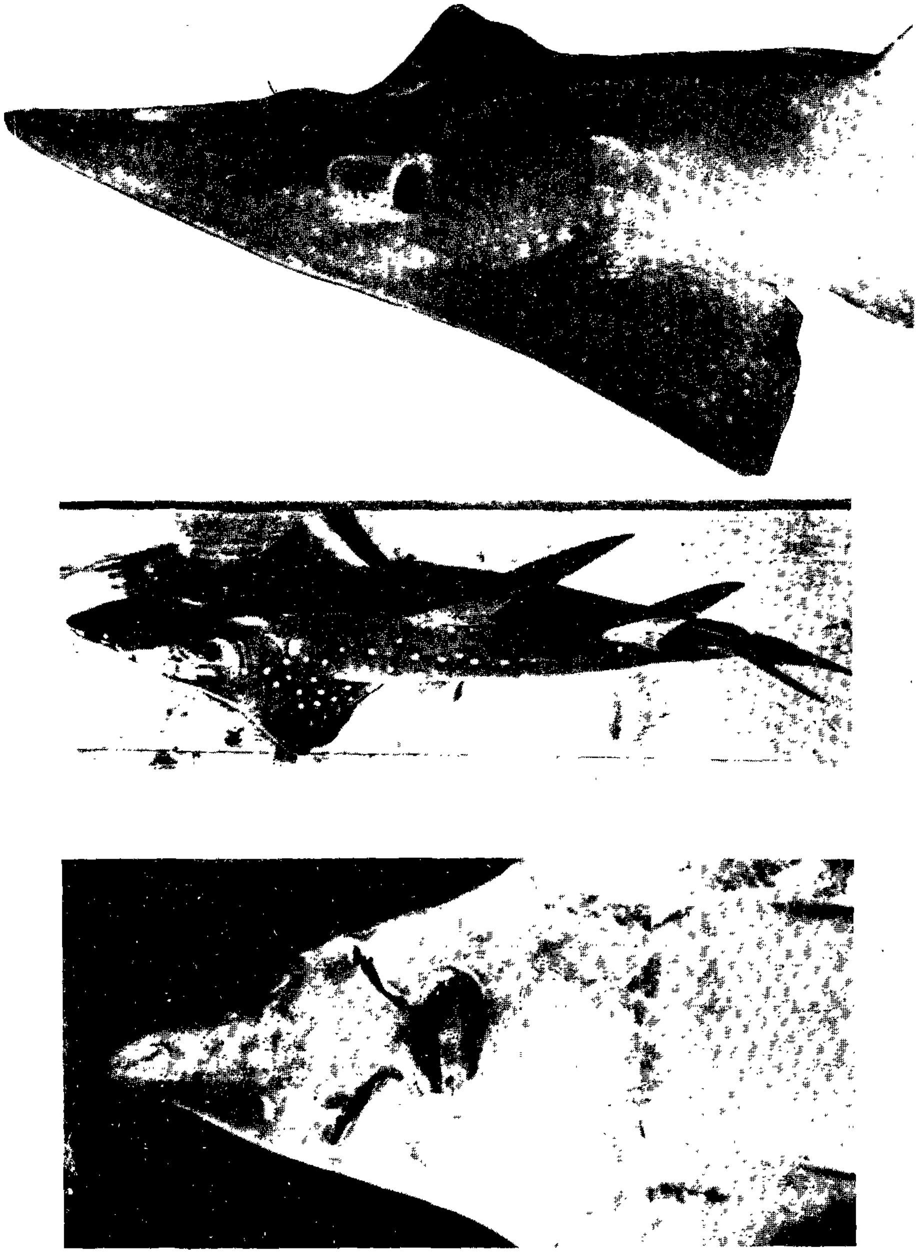
Note : Les mesures indiquées dans les tableaux sont en général pour le disque : la largeur et la longueur. D1 D2 indique l'intervalle entre les bases des deux dorsales, celles-ci sont définies par leur côté antérieur, hauteur (h), base ou par un chiffre unique qui désigne alors le côté antérieur (Nyliobatoidae). Or, D, est la distance du bout du museau à l'origine de la première dorsale. Dans le cas de *Rhynchobatus* l'indication t. dans la colonne Pelviennes précise la mesure transversale des deux nageoires réunies, autrement il s'agit de la longueur.



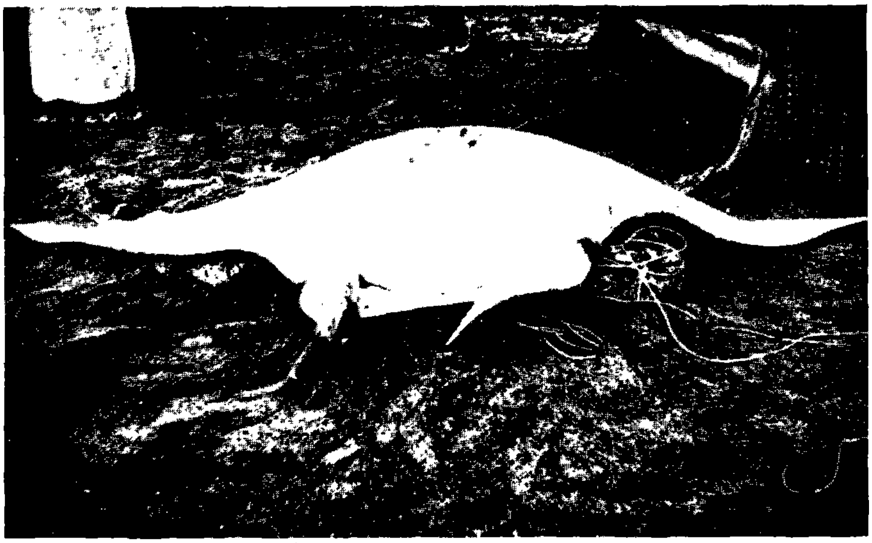
A, *Rhynchobatus djeddensis*, mâchoire
B, *Rhyna ancylostoma*, mâchoire

photos Mlle Faucheur

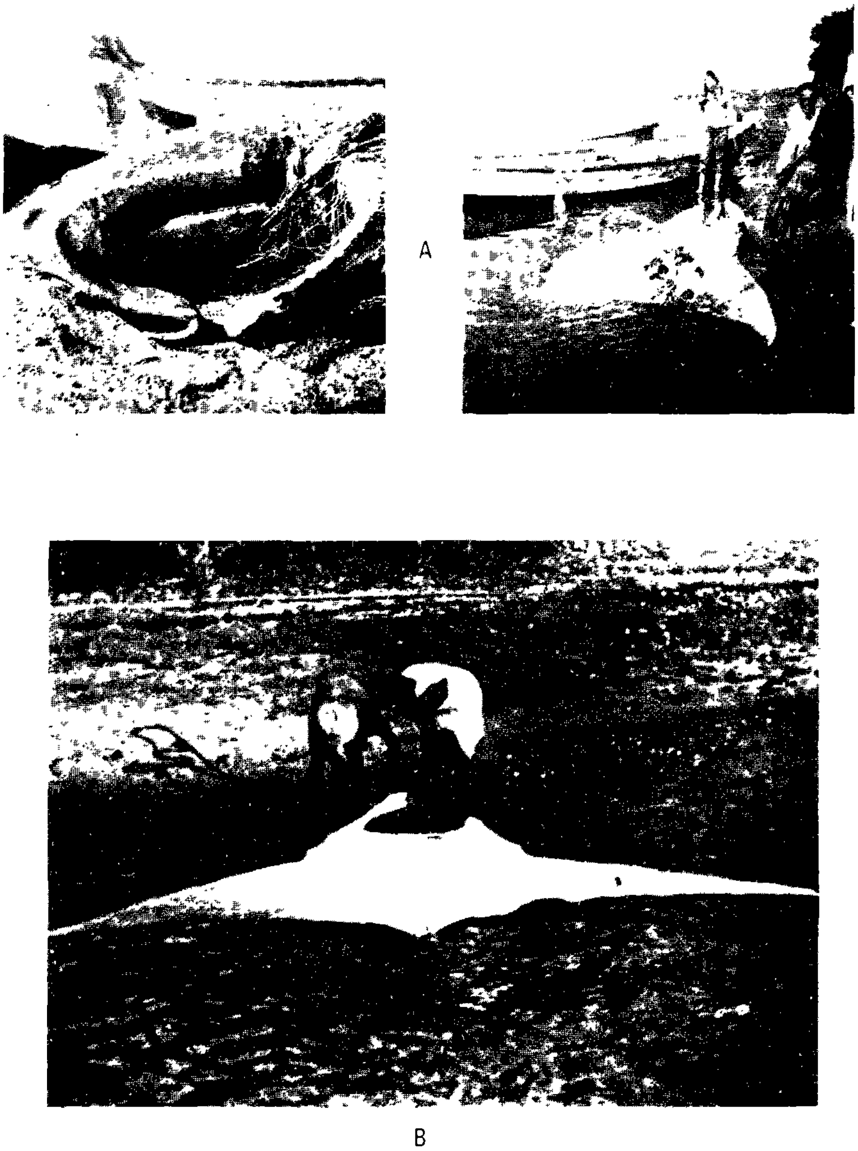


Rhynchobatus djeddensis

Mobula diabolus 0,75 m



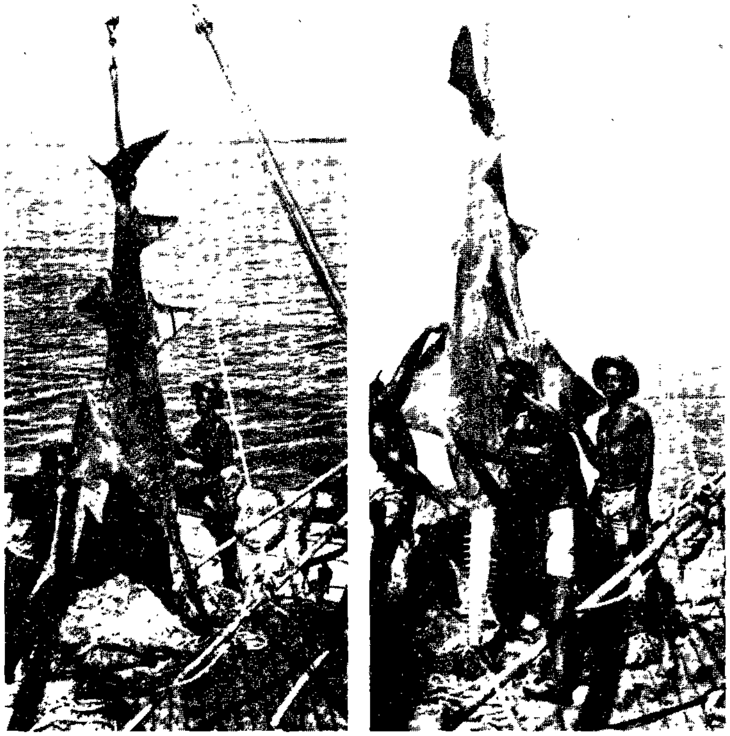
Manta à face ventrale tachetée et à bouche noire, larg. 3,40 m



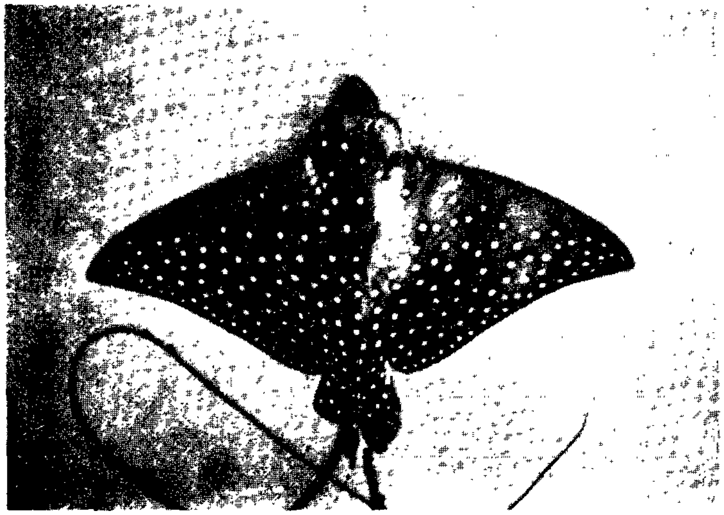
Manta à bouche claire

A, 3,45 m

B, 4,60 m



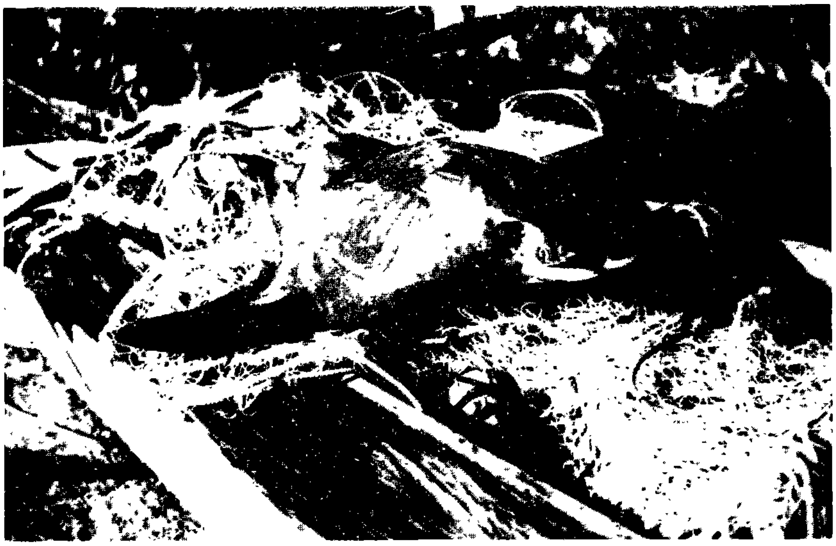
A

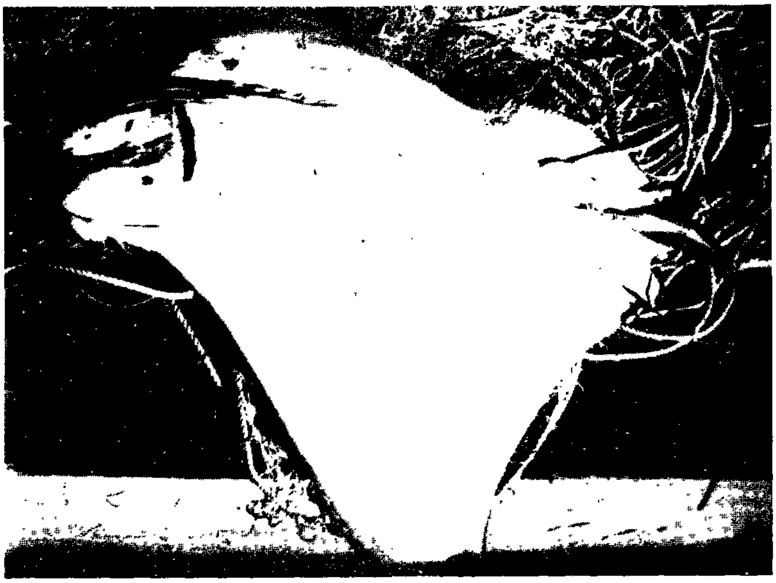


B

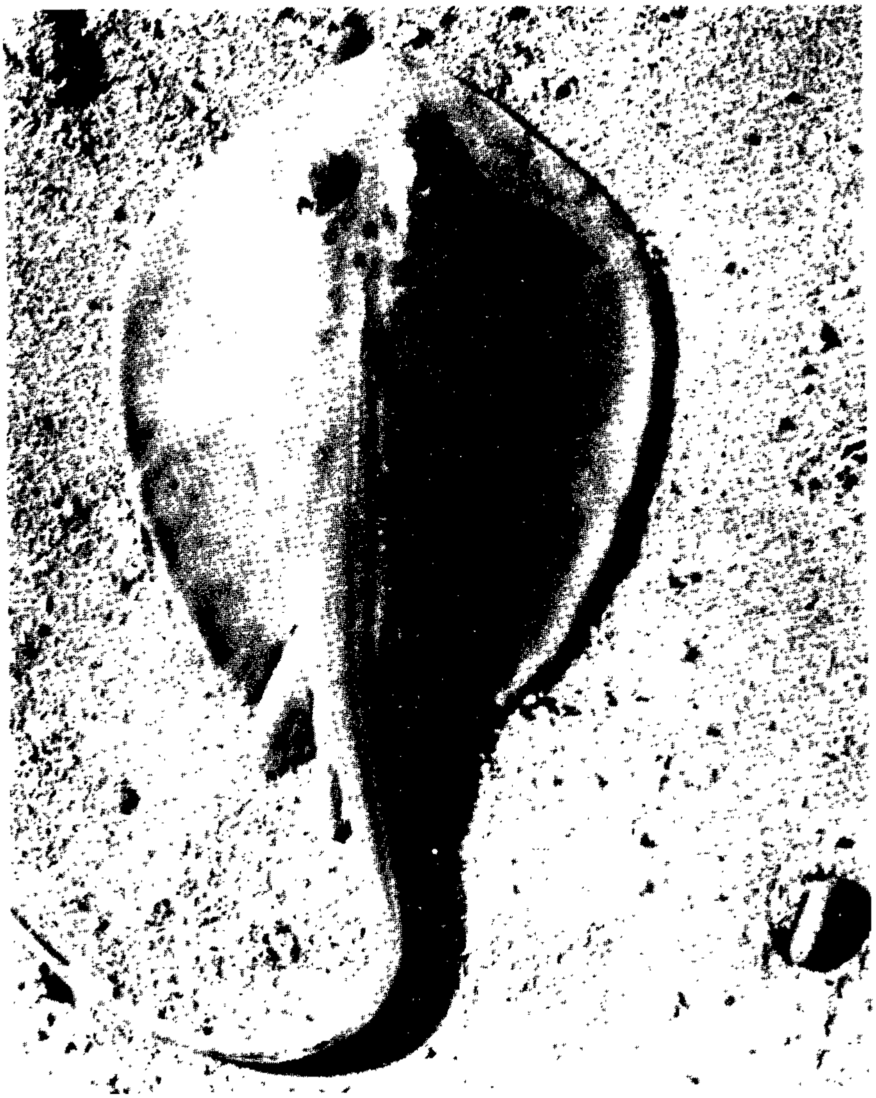
photos Crosnier ——→ **A**, *Pristis perotteti*, long. totale 3,50 m

B, *Stoasodon narinari*



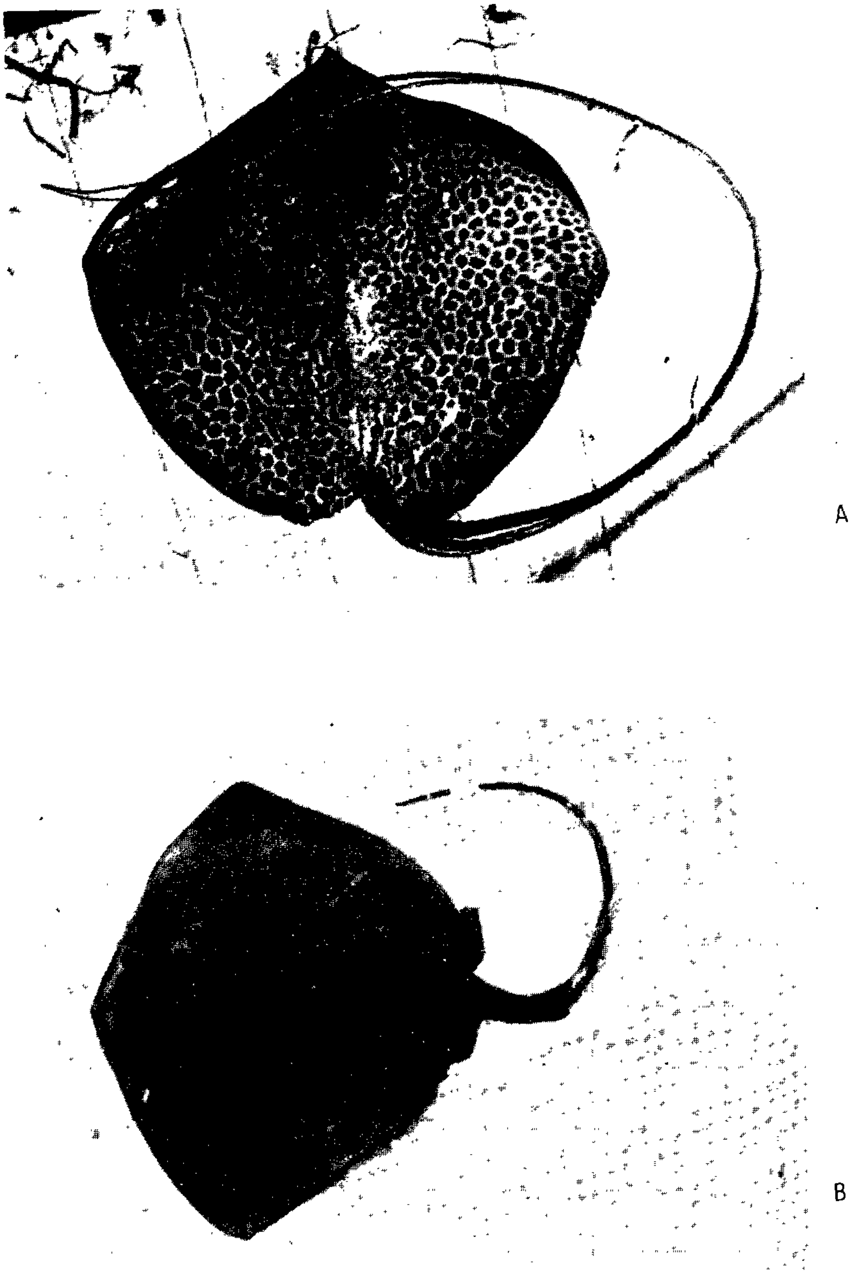


Rhinoptera javanica, larg. 0,90 m



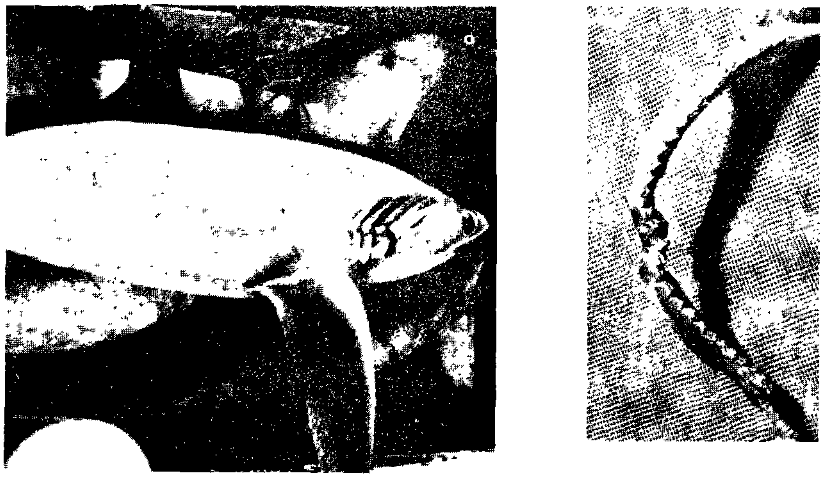
Taeniura lymna

A, *Taeniura melanospila*
B, *Dasyatis sephen*



A, *Dasyatis uarnak*
B, *Dasyatis kuhlii*

A



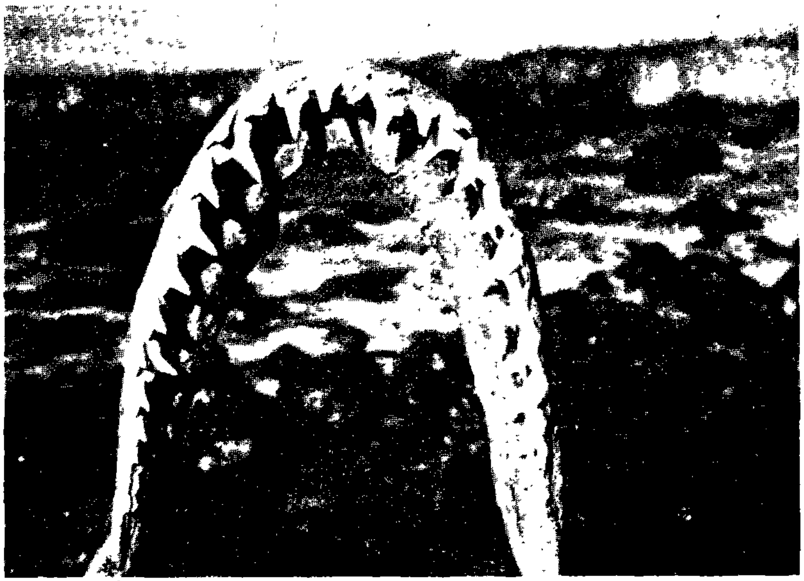
B

C

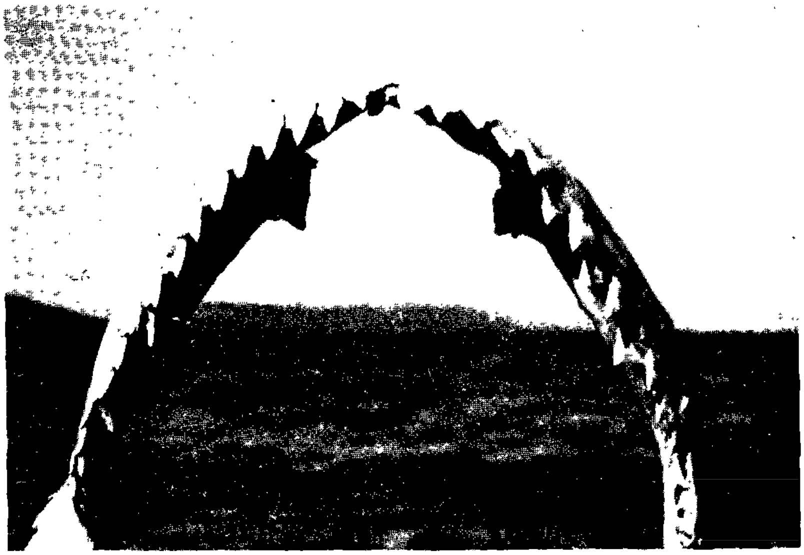
A, *Carcharinus obscurus*

B, *Alopias pelagicus* Long. totale 3,24 m vue côté et détail de dentition

C, *Alopias superciliosus*, fœtus



A



B

Mâchoire supérieure de A, *Negaprion madagascariensis*
B, *Carcharinus floridanus*

COMPLEMENT et CORRECTIONS concernant les REQUINS de la COTE OUEST de MADAGASCAR

(Mémoire I.R.S.M. - Série F - T. IV - 1961)

p. 15 Des notes concernant *Nebricus ferrugineus* attribuées par erreur "au Requin" n° 5 nous ont fait croire à la présence d'un évent comme caractère commun aux deux Requins des sables. Aussi au lieu d'introduire le genre Negaprion comme nous étions tentés de le faire, nous avons désigné le n° 5 sous le nom d'Odontaspis. La capture tardive de nouveaux spécimens ne nous a pas permis de signaler cette erreur de caractère (évent) ni de changer Odontaspis Madagascarieasis en Négaprion Madagascarieasis avant la publication.

p. 48 - fig. 39 Par suite d'une confusion la figure des dents de Triaenodon n'a pas été reproduite et la fig. 39 représente en réalité les dents d'un jeune exemplaire de Négaprion.

p. 40 **Carcharinus iranzae** nov. sp = **Carcharinus obscurus** Lesueur (Pl. XI, A)
Un retour récent sur l'île Iranza (près de Nosy-Bé) pour la pêche aux Requins nous a permis de constater l'identité des espèces *iranzae nov.* et *obscurus Lesueur*. *Carcharinus obscurus* n'avait jusqu'alors été identifié avec certitude que parmi les Requins pris à la ligne dérivante de type japonais opérant au large (n° 29).
Les nouveaux exemplaires ont été pris sur une ligne mouillée dans les fonds de 14 - 18 mètres avec les hameçons maintenus entre deux eaux par des flotteurs. Deux *C. leucas* ont été pris en même temps.

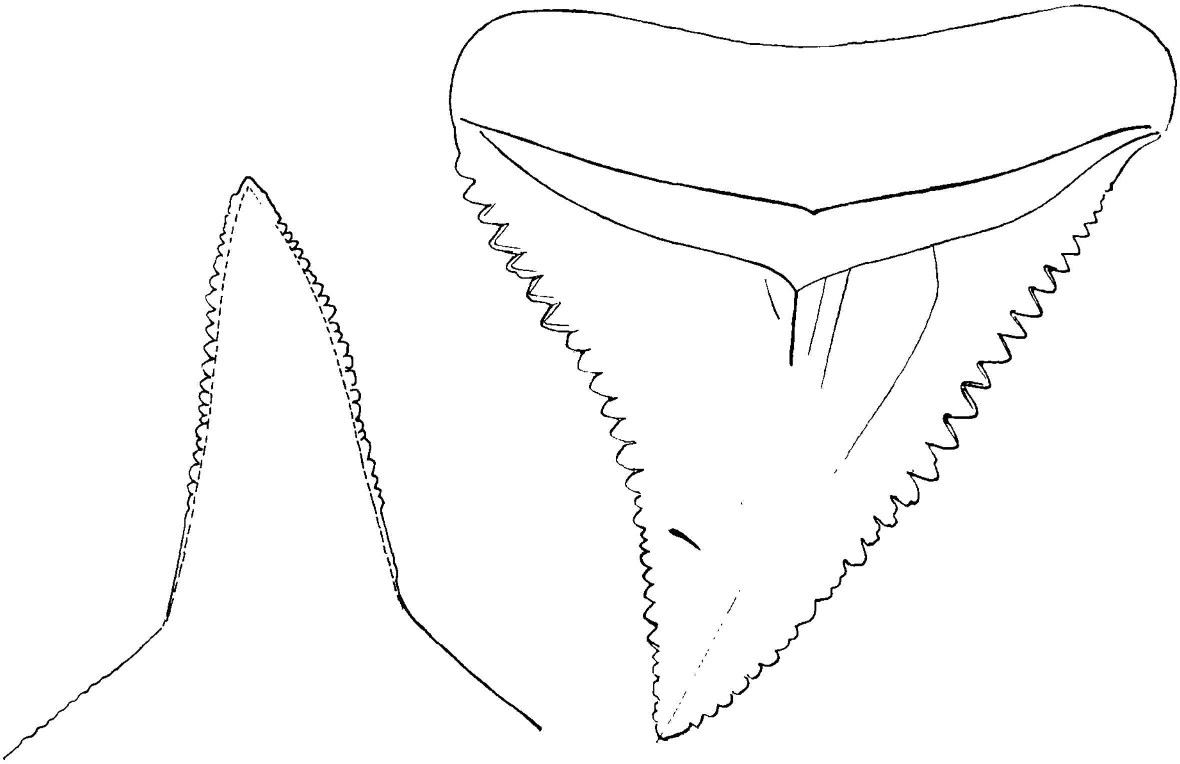


FIG. 17 - *Carcharinus obscurus*, 4e dent sup. et inf.

Pour *obscurus* nous avons observé au moment de la capture une coloration presque noire et pour *leucas* une coloration gris-violet à gris-brun qui fonce et devient proche de celle d'*obscurus* après un certain temps d'exposition au soleil.

Les fentes branchiales d'obscurus présentent un fort contraste des parties externes foncées et internes blanches, opposition qui rappelle celle observée chez *C. albimarginatus*. Le bord postérieur des pectorales est noir ainsi que la pointe du côté inférieur. *La ride médio-dorsale* bien marquée dépasse un peu le niveau postérieur de la base des pelviennes.
Le rapport des longueurs des lobes caudal inférieur et supérieur est de 44 % environ, il est avec celui de *C. platyodon* le plus faible observé chez les Carcharinus malgaches. La courbure du lobe caudal supérieur est accentuée.
La formule dentaire est $\frac{14 - 1 - 14}{13 - 1 - 13}$, les dents inférieures de nos exemplaires de grande taille ont une nette courbure subterminale du côté externe. Cette courbure n'a pas été signalée par BIGELOW pour les *obscurus* de la côte Atlantique américaine.

Signalons enfin la présence de 10 foetus (L. t. 52,5 - L. S. 38 cm.) chez un exemplaire de 3,40 m. pris en Juin 1962. Les foetus disposaient encore d'une réserve vitelline abondante, leur répartition était de 6 mâles et de 4 femelles. Un exemplaire de 3,31 m. pris le même jour ne présentait que 4 œufs disposés en 2 paires sur l'ovaire long de 70 cm. La reproduction doit donc s'étendre sur une longue période.
Obscurus a été souvent confondu avec *leucas* sur la côte américaine et à Madagascar car à vue d'œil seule la ride médio-dorsale permet de distinguer les deux espèces.
La dentition de *leucas* (var. malgache) $\frac{12 - 1 - 12}{11 - 1 - 11}$ bien que différente, n'est pas un caractère de séparation immédiat les replis cutanés de la gencive gênant l'observation directe.

CARCHARINUS OBSCURUS

Long. tot	Sexe	Or. Bouche Dim.	Or D1 Dim.	D1 D2	Dim. D2	Dim. A	Or. Pect. Long	Caudale	Int. or	Int. nar.	Br.
331	4 œufs	21 30 x 15	108 37(h 27)31	86	11 8	18 11	67	84 38	36 o. 3,3	20,5 n. 3,7	14
340	10 foetus 52,5 cm	22 34 x 14,5	110 40(h 28) 30	84	11 8	19 11	65 65	88 40	o. 3,3	20 n. 4	17

CARCHARINUS LEUCAS

218	mâle	14 26 x 12	67 34(h 24, 5) 24, 5	50	9 7	12 8	44 46	61, 5 29	29 o. 1,8		8
221	5 foetus 44 cm	15, 3 27 x 12	72, 5 37, 5(h 25) 28	47	9,8 8,2	11 9	47 53	57 31	o. 1,7	15 n. 4	8

Reprinted from *Cahiers ORSTOM – Océanographie*, vol. II, no. 2, 1964, p. 27-45

SUR UNE COLLECTION DE CRUSTACÉS PAGURIDES DE MADAGASCAR ET DES COMORES

par

Mme Michèle **DECHANCÉ**

Les Pagures étudiés ici ont été pour la plupart récoltés par A. Crosnier, océanographe biologiste de l'O.R.S.T.O.M., au cours de son séjour au Centre d'Océanographie et des Pêches de Nosy-Bé, de 1958 à 1962. Quelques spécimens proviennent des collections de l'Institut Scientifique de Madagascar; d'autres enfin ont été récoltés au cours de la Mission de R. Decary à Madagascar en 1932, et se trouvaient dans les collections du Muséum.

La plupart des échantillons ont été recueillis à la main, dans la zone intercotidale, ou par des chalutages à faible profondeur.

Nous avons examiné au total environ 300 spécimens, appartenant aux 32 espèces suivantes :

Famille des COENOBITIDAE

Coenobita brevimanus Dana
Coenobita perlatus H. Milne Edwards
Coenobita rugosus H. Milne Edwards

Famille des DIOGENIDAE

Aniculus aniculus (Fabricius)
Calcinus elegans (H. Milne Edwards)
Calcinus gaimardi (H. Milne Edwards)
Calcinus laevimanus (Randall)
Calcinus latens (Randall)
Calcinus rosaceus Heller
Clibanarius eurysternus Hilgendorf
Clibanarius laevimanus Buitendijk
Clibanarius longitarsus (de Haan)
Clibanarius merguiensis de Man
Clibanarius striolatus Dana
Clibanarius virescens (Krauss)
Dardanus asper (de Haan)
Dardanus brachyops Forest
Dardanus deformis (H. Milne Edwards)

Dardanus gemmatus (H. Milne Edwards)
Dardanus guttatus (Olivier)
Dardanus megistos (Herbst)
Dardanus sanguinolentus (Quoy et Gaimard)
Dardanus scutellatus (H. Milne Edwards)
Dardanus setifer (H. Milne Edwards)
Diogenes planimanus Henderson
Diogenes crosnieri nov. sp.
Paguristes abbreviatus Dechancé

Famille des **PAGURIDAE**

Anapagurus sp.
Pagurus janitor (Alcock)
Pagurus sp.
Catapagurus sp.
Spiropagurus spiriger de Haan

Les seuls travaux antérieurs notables sur la faune pagurienne de Madagascar sont ceux de Lenz et Richters (1881), Lenz (1910) et Gravier (1920) ; en ce qui concerne les formes des régions voisines, il faut citer les travaux de Hilgendorf (1869 et 1878) sur Mozambique et l'Ile Ibo, celui de Richters (1880) sur l'Ile Maurice et les Seychelles et celui de Bouvier (1915) sur les Décapodes marcheurs de l'Ile Maurice.

Les trois espèces de **Coenobitidae** citées ici avaient été signalées de Madagascar par les auteurs précédents. Sur les 24 espèces de **Diogenidae**, 16 seulement avaient été signalées du sud-ouest de l'Océan Indien, tandis qu'aucune espèce de **Paguridae** ne l'avait jamais été des eaux malgaches.

En ce qui concerne les **Coenobitidae**, terrestres, et les **Diogenidae**, les plus littoraux des Pagures, nous pensons que cette collection représente un bon échantillonnage de la faune malgache. Quant aux **Paguridae**, qui vivent généralement en eau plus profonde, et sont d'une taille souvent inférieure à celle des **Diogenidae**, cinq espèces seulement figurent ici, représentée chacune par un ou deux spécimens ; trois d'entre elles sont vraisemblablement des espèces nouvelles, dont nous différons la description comme telles à cause du nombre insuffisant ou du mauvais état des spécimens.

Il serait cependant prématuré de conclure à la rareté des **Paguridae** dans cette region : une étude, en cours, des larves de Pagurides du plancton des environs de Nosy-Bé, récolté par S. Frontier en 1962 et 1963, nous a montré l'abondance des zoés de cette famille ; 14 espèces ont été dénombrées, dont deux sont attribuées au genre **Pagurus**, une à **Anapagurus**, et quatre - avec doute - à **Catapagurus**, les sept espèces restantes étant réparties en trois ou quatre autres genres. Il est donc souhaitable que l'on pratique des récoltes en profondeur qui feront connaître les espèces de **Paguridae** certainement présentes dans cette région, et compléteront notre connaissance de la faune pagurienne malgache.

Les références aux auteurs cités plus haut n'étant généralement pas utiles pour la détermination nous ne citons cette référence qu'à propos de la distribution locale de chaque espèce. Lorsqu'une espèce est nouvelle pour Madagascar, nous indiquons la région la plus proche où elle a déjà été signalée.

COENOBITIDAE

Coenobita brevimanus Dana

Coenobita clypeata var. **brevimana** Dana, J.D., 1852, p. 473.

Coenobita hilgendorfi, Forest, J., 1954, p. 77.

Matériel. - Tany Kely (côte nord-ouest) : 1♂, 50 mm.

De la côte orientale d'Afrique aux Hawaï et aux Tuamotu. Signalé à l'Ile aux Prunes (côte est de Madagascar) (Lenz, sous le nom de **C.clypeatus**).

Coenobita perlatus H. Milne Edwards

Coenobita perlatus Milne Edwards, H., 1837, p. 242.

Coenobita perlatus, Alcock, A., 1905, p. 145, pl. XIV, fig. 3-3a.

Coenobita perlatus, Forest, J., 1954a, p. 78.

Matériel. - Ile Juan de Nova, Fourmanoir coll. : 2 ♂, 25 et 43 mm.

De la côte orientale d'Afrique aux Hawaï et aux Tuamotu. Signalé à l'Ile aux Prunes et à l'Ile Europa (Lenz).

Coenobita rugosus H. Milne Edwards

Coenobita rugosus Milne Edwards, H., 1837, p. 241.

Coenobita rugosus, Alcock, A., 1905, p. 143, pl. XIV, fig. 2-2a.

Coenobita rugosus, Forest, J., 1954a, p. 79.

Matériel. - Ile Juan de Nova, **Fourmanoir** coll. : 1 ♂, 30 mm, 3 ♀, 15 à 19 mm.

- Tany Kely (côte nord-ouest) 3 ♀, 15 à 16 mm.

- Ivontaka (côte est), **Crosnier** coll., févr. 1958 : 3♂, 11 à 23 mm.

De la côte orientale d'Afrique aux Hawai et aux Tuamotu. Signalé à Madagascar (Lenz et Richters).

DIOGENIDAE

Aniculus aniculus (Fabricius)

Pagurus aniculus Fabricius, J.C., 1787, p. 327.

Aniculus aniculus, Alcock, A., 1905, p. 94, pl. VII, fig. 6.

Matériel. - Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 7 ♂, 32 à 45 mm, 1♀, 33 mm.

De la côte orientale d'Afrique aux Tuamotu et aux Hawaï. Signalé de l'Ile Maurice (Richters, Bouvier) et de Mozambique (Hilgendorf).

Calcinus elegans (H. Milne Edwards)

Pagurus elegans Milne Edwards, H., 1836, p. 278, pl. XIII, fig. 2.

Calcinus elegans, Alcock, A., 1905, p. 55, pl. V, fig. 2.

Matériel. - Fort-Dauphin, Mission R. **Decary** à Madagascar, avril 1932 : 1 ♂, 6 mm.

De la côte orientale d'Afrique aux Hawaï et aux Tuamotu. Signalé de l'Ile Maurice (Richters, Bouvier).

Calcinus gaimardi (H. Milne Edwards)
Pagurus gaimardi Milne Edwards, H., 1848, p. 63.
Calcinus gaimardi, Alcock, A., 1905, p. 56, pl. V, fig. 3.
Matériel. - *Numa Choa (Mayotte) : 2♂, 6 et 7 mm, 1♀, 7 mm.*
- Fort-Dauphin, zone intercotidale, **Crosnier** coll., mai 1960 : 1♂, 16 mm.
- Nosy-Bé, zone intercotidale, **Crosnier** coll., avril 1962 : 5♂, 10 à 13 mm, 4♀ ovig., 5 à 7 mm, 1♀, 10 mm.

De la côte orientale d'Afrique (Dar es Salaam) aux Hawaï et aux Tuamotu. Signalé d'Afrique du Sud par **Barnard** (1950).

Calcinus laevimanus (Randall)
Pagurus laevimanus Randall, J.W., 1839, p. 135.
Calcinus herbstii, de Man, J.G., 1888b, p. 437.
Calcinus herbstii, Alcock, A., 1905, p. 53, pl. V, fig. 4.
Matériel. - Ile Europa, **Fourmanoir** coll. : 12♂, 8 à 14 mm, 1♀, 9 mm.
- Fort-Dauphin, mission **R. Decary** à Madagascar, 1932 : 3♂, 11 à 15 mm.
- Ile Europa, Inst. Sci. Madagascar, juin 1952 : 1♂, 11 mm.
- Nosy-Bé, zone intercotidale, **MacNae** coll., déc. 1958 : 1♂, 14 mm, 1♀, 7 mm.
- Tulear, **Crosnier** coll., oct. 1958 : 1♂, 13 mm.
- Nosy-Bé, zone intercotidale, **Crosnier** coll., avril 1962 : 2♂, 10 et 14 mm.

De la côte orientale d'Afrique aux Hawaï et aux Tuamotu. Signalé à Nosy-Bé (Lenz et Richters, sous le *nom de* **C. tibicen**) et à l'Ile aux Prunes (Lenz).

Calcinus latens (Randall)
Pagurus latens Randall, J.W., 1839, p. 135.
Calcinus latens, Alcock, A., 1905, p. 58, pl. V, fig. 5.
Calcinus latens, Forest, J., 1951, p. 94, fig. 14-18.
Matériel. - Fort-Dauphin, mission R. Decary à Madagascar, 1932 : 1♂, 7 mm.
- Ile Europa, Inst. Sci. Madagascar, juin 1952 : 2♂, 6 et 7 mm, 4♀, 4 à 7 mm, dont 1 ovig.
- Nosy-Bé, **Crosnier** coll., 1958 : 1♂, 6 mm.
- Nosy-Bé, zone intercotidale, MacNae coll., déc. 1958 : 6♂, 4 à 8 mm.
- Nosy-Bé, oct. 1959 : 2♀ ovig., 5 et 6 mm, 1 juv., 3 mm.
- Fort-Dauphin, zone intercotidale, **Crosnier** coll., mai 1960 : 6♂, 4 à 8 mm, 6♀, 6 à 8 mm.
- Nosy-Bé, zone intercotidale, **Crosnier** coll., janvier 1962 : 2♂, 6 et 8 mm, 2♀, 5 et 7 mm, dont 1 ovig.
- Nosy-Bé, **Crosnier** coll., avril 1962 : 4♂, 7 à 9 mm, 6♀ ovig., 5 à 8 mm.

De la côte orientale d'Afrique aux Hawaï et aux Tuamotu. Signalé de l'Ile Maurice (Richters, Bouvier), de Mozambique et Ibo (Hilgendorf).

Calcinus rosaceus Heller

Calcinus rosaceus Heller, C., 1861, p. 23, 1862, p. 253.

Calcinus rosaceus, Forest, J., 1956, p. 222, fig. 5-8.

Matériel. - Nosy-Bé, zone intercotidale, MacNae coll., janv. 1958 : 1♀ , 5 mm.

Golfe Persique et Ile Maurice (Bouvier, sous le nom de **C.nitidus** var. **australis**; le **C.nitidus** de Lenz et Richters, signalé à Madagascar, que Bouvier rattachait à sa variété **australis**, serait plutôt **C.latens**).

Clibanarius eurysternus, Hilgendorf

Clibanarius eurysternus Hilgendorf, F., 1878, p. 822, pl. III, fig. 9-10.

Matériel. - Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 1♀ , 7 mm.

De Mozambique (Hilgendorf) au Détroit de Torres.

Clibanarius laevimanus Buitendijk (fig. 1-3)

Clibanarius laevimanus Buitendijk, A.M., 1937, p. 254, fig. 3-6.

Matériel. - Maromandia, Mission R. Decary à Madagascar, 1932 : 3♂, 4, 5 et 7 mm.
- Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 1♀ , 5 mm.

Ces spécimens ont été attribués avec quelque hésitation à l'espèce de Buitendijk. Ils en diffèrent par des pédoncules oculaires plus courts (cf. fig. 1), des chélipèdes plus épineux et des pattes ambulatoires plus trapues ; Buitendijk mentionne que l'espèce appartient au groupe des **Clibanarius** dont le dactyle des pattes ambulatoires est plus long que le propode, alors que, chez nos spécimens malgaches, le dactyle est de même longueur ou un peu plus court que le propode.

Cependant l'examen de nombreux exemplaires (1) de cette espece, et de paratypes de Buitendijk, nous a montré que ces caractères présentaient une grande variabilité; par contre, la disposition des marques colorées sur les appendices thoraciques est caractéristique, notamment celle des bandes longitudinales des pattes ambulatoires. Ces bandes longitudinales, rouges dans l'alcool, sont au nombre de deux sur la face externe ; elles ne s'étendent pas sur toute la longueur du propode et du dactyle, ces articles présentant une zone blanche distale.

A cet égard, la figure de Buitendijk (p. 257, fig. 5) ne correspond pas à nos observations ; nous figurons ici la face externe de la troisième patte ambulatoire gauche d'un paratype de **Clibanarius laevimanus** (fig. 2), et celle d'un spécimen de Madagascar (fig. 3), qu'il ne paraît pas possible de rattacher à une espèce différente.

Cette espèce n'a pas été signalée depuis la description de Buitendijk, d'Indonésie.

Clibanarius longitarsus (de Haan) (fig. 4)

Pagurus longitarsus Haan, W. de, 1849, p.211, pl. 1, fig. 3.

Matériel. - Nosy-Bé, zone intercotidale, MacNae coll., janv. 1958 : 1♂, 11 mm, 2 ♀ ovig., 11 et 14 mm.
- Majunga, coll. Inst. Sci. Madagascar : 1♂, 18 mm.

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(1) Ces exemplaires appartiennent à la collection de Pagurides indo-pacifiques de l'U.S. National Museum, en cours d'étude.

Les trois exemplaires de Nosy-Bé avaient été identifiés à **Clibanarius padavensis** de Man par Barnard ; or, ils sont encore bien pigmentés et présentent la coloration typique de **C.longitarsus** : les pattes ambulatoires (fig. 4 : p3 gauche) possèdent sur leur face externe une large bande blanche, limitée par deux fines lignes rouges, sur une coloration de fond orangée ; les pédoncules oculaires sont d'une coloration uniforme.

Chez **C.padavensis** (fig. 5), on observe sur la face externe des pattes ambulatoires deux bandes rouges délimitant une bande plus claire ; d'autre part, les pédoncules oculaires présentent dorsalement une ligne longitudinale rouge ; la patte ambulatoire que nous figurons est celle d'un exemplaire provenant des Iles Mergui et déterminé par de Man.

Clibanarius longitarsus est connu de la côte orientale d'Afrique aux Philippines et au Japon ; il a été signalé à Madagascar (Lenz et Richters).

Clibanarius merguiensis de Man

Clibanarius aequabilis var.**merguiensis** de Man, J.G., 1888a, p. 247.

Clibanarius merguiensis, Forest, J., 1953, p. 438 ; p. 445, fig. 7.

Matériel. - Nosy-Bé, zone intercotidale, MacNae coll. déc. 1958 : 2♂, 7 et 8 mm.

- Ile Europa, Fourmanoir coll. : 1♂, 6 mm.

De l'Ile Maurice (Bouvier, sous le nom de ***C.aequabilis*** *var.****merguiensis****) à l'Indonésie.*

Clibanarius striolatus Dana (fig. 6)

Clibanarius striolatus Dana J.D., 1852, p. 463, pl. XXIX, fig. 3a-e.

Matériel. - Nosy-bé, zone intercotidale, MacNae coll., déc. 1958 : 4♂, 7 à 9 mm, 2♀, 8mm, dont 1 ovig.

- Nosy-Bé, zone intercotidale, MacNae coll., janv. 1959 : 2♂, 12 et 14 mm.
- Majunga, coll. Inst. Sci. Madagascar : 2♂, 12 et 16 mm, 1♀, 10 mm.

Certains de ces spécimens avaient été identifiés à **C.padavensis** par Barnard. **C.striolatus** se distingue de **C.padavensis** et de **C.longitarsus** par ses chélipèdes fortement épineux, et également par sa pigmentation caractéristique ; on observe sur les pattes ambulatoires (fig. 6 : p3 gauche) deux fines lignes rouge foncé, aux marges un peu irrégulières, sur une coloration de fond uniforme ; ces lignes se prolongent sur toute la longueur du propode et du dactyle, la bande inférieure de cet article étant la plus longue.

De la côte orientale d'Afrique au Japon et aux Tuamotu. Signalé à Tuléar (Lenz).

Clibanarius virescens (Krauss)

Pagurus virescens Krauss, F., 1843, p. 56, pl. IV, fig. 3.

Matériel. - Fort-Dauphin, Mission R.Decary à Madagascar, 1932 : 1♂, 14 mm.

- Fort-Dauphin, zone intercotidale, Crosnier coll., mai 1960 : 4♂, 10 à 12 mm, 1♀, 7 mm.
- Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 1♂, 7 mm.
- Amborosy, coll. Inst. Sci. Madagascar : 4♂, 8 à 9 mm.

De la côte orientale d'Afrique à l'Indonésie. Signalé de Mozambique et Ibo (Hilgendorf).

Dardanus asper (de Hacn)

Pagurus asper Haan, W. de, 1849, p. 208, pl. XLIV, fig. 4.

Pagurus asper, Alcock, A., 1905, p. 90, pl. IX, fig. 5.

Matériel. - Sainte-Luce, chalut, 60 m, sable coquillier, Crosnier et Fourmanoir coll., oct. 1958 : 1 ♂, 34 mm.

- Fort-Dauphin, dans une nasse à langoustes, 20 m, Crosnier coll., mai 1960 : 1 ♀ ovig., 37 mm.

- Numa Choa (Mayotte) : 1 ♀, 17 mm.

Ces trois exemplaires diffèrent de la forme typique de l'espèce par la présence d'une carène, peu accusée, à l'angle supéro-externe du propode de la troisième patte ambulatoire gauche, et par la face externe du dactyle de cette même patte, plus fortement carénée; ces caractères rapprochent ces spécimens de **Dardanus varipes,** mais par l'ensemble de leurs autres caractères, et notamment par la forme des yeux et du chélipède gauche, ils appartiennent bien à **Dardanus asper.**

D'Afrique du Sud et du Golfe Persique aux Hawaï. Signalé aux Maldives.

Dardanus brachyops Forest

Dardanus brachyops Forest, J., 1963, p. 365, fig. 1-3.

Matériel. - Fort-Dauphin, chalut, sable coquillier, 80 m, Crosnier et Fourmanoir coll., oct. 1958: 1 ♂, 62 mm.

Connu seulement des Hawaï et de Madagascar.

Dardanus deformis (H. Milne Edwards).

Pagurus deformis Milne Edwards, H., 1836, p. 272, pl. XIV, fig. 2.

Pagurus deformis, Alcock, A., 1905, p. 88, pl. IX, fig. 4

Matériel. - Ile Sainte-Marie, zone intercotidale, janv. 1954 : 1♀ ovig., 24 mm.

- Lagon de Mayotte, récif barrière interne, Crosnier coll., sept. 1954 : 1♂, 20 mm.
- Nosy-Bé, zone intercotidale, Crosnier coll., sept. 1958 : 1♂, 13 mm.
- Nosy-Bé, zone intercotidale, MacNae coll., déc. 1958 : 2♂, 13 et 24 mm.
- Nosy Iranja, Crosnier coll., avril 1959 : 1♂, 17 mm.
- Ile Mayotte, zone intercotidale, 1 m, Crosnier coll., sept 1959 : 1♀, 14 mm.
- Nosy-Bé, oct. 1959 : 1♀ ovig., 25 mm.
- Fort-Dauphin, zone intercotidale, Crosnier coll., mai 1960 : 1♂, 16 mm.
- Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 2♀, 10 et 19 mm.

De la côte orientale d'Afrique aux Hawaï et aux Tuamotu. Signalé à Madagascar (Lenz et Richters, Lenz, Gravier).

Dardanus gemmatus (H. Milne Edwards)

Pagurus gemmatus Milne Edwards, H., 1848, p. 60.

Pagurus gemmatus, Forest, J., 1953, p. 557, fig. 10-11.

Matériel. - Ile Mayotte, récif de M'zambourou, zone intercotidale, Crosnier coll., sept. 1959 : 1 ♂, 15 mm.

- Nosy-Bé, zone intercotidale, **Crosnier** coll., avril 1962 : 1♂, 24 mm.

Précédemment signalé de l'Ile Maurice (Richters, Bouvier) aux Tuamotu.

Dardanus guttatus (Olivier)

Pagurus guttatus Olivier, A.G., 1811, p. 640.

Pagurus guttatus, Alcock, A., 1905, p. 87, pl. IX, fig. 1.

Matériel. - Ile Europa, mai 1952 : 1 ♂, 18 mm.

- Lagon de Mayotte, récif barrière interne, Crosnier coll., sept. 1959 : 1♂, 45 mm.
- Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 3 ♂ , 13, 18 et 50 mm.
- Lagon de Mayotte, dragage, 50m, sable fin, Crosnier coll. : 1♂, 7 mm.
- Ile Europa, plateau rocheux corallien, niveau basse mer, Inst. Sci. Madagascar : 1♀ , 20 mm.

De la côte orientale d'Afrique aux Philippines. Signalé à Madagascar (Lenz et Richters, Gravier).

Dardanus megistos (Herbst)

Cancer megistos Herbst, J.F.W., 1804, p. 23, pl. LXI, fig. 1.

Pagurus punctulatus, Alcock, A., 1905, p. 81, pl. VIII, fig. 1.

Pagurus megistos, Forest, J., 1953, p. 559.

Matériel. - Grand récif de Tuléar, Crosnier coll., oct. 1958 : 1♂ , 40 mm.

- Nosy-Bé, zone intercotidale, MacNae coll., déc. 1958 : 1♂, 12 mm, 1 ♀, 13 mm.
- Nosy-Bé, zone intercotidale, Crosnier coll., avril 1962 : 2♂ , 18 et 22 mm.
- Nosy-Bé, Millot coll. : 1♂ , 50 mm.

De la côte orientale d'Afrique aux Hawai et aux Tuamotu. Signalé à Madagascar (Lenz et Richters, Gravier, sous le nom de **Pagurus punctulatus**).

Dardanus sanguinolentus (Quoy et Gaimard)

Pagurus sanguinolentus Quoy, J.R.C. et Gaimard, P., 1825, p. 532, pl. LXXIX, fig. 2.

Pagurus euopsis Dana, J.D., 1852, p. 452, pl. XXVIII, fig. 6 a-c.

Pagurus sanguinolentus, Forest, J., 1953, p. 559, fig. 12-14.

Matériel. - Nosy-Bé, zone intercotidale, MacNae coll., déc. 1958 : 1♀ ovig., 12 mm.

- Nosy-Bé, zone intercotidale, Crosnier coll.,avril 1962 : 1 ♂, 13 mm, 1 juv., 5 mm.
- Lagon de Mayotte, dragage, 51 m, sable grossier, Crosnier coll. : 1♂ , 9 mm.

De la côte orientale d'Afrique aux Hawai et aux Tuamotu. Signalé à l'Ile Maurice (Bouvier, sous le nom de **Pagurus euopsis**).

Dardanus scutellatus *(H. Milne Edwards)*

Pagurus scutellatus Milne Edwards, H., 1848, p. 62.

Pagurus scutellatus, Forest, J., 1953, p. 560.

Matériel. - Nosy-Bé, zone intercotidale, MacNae coll., déc. 1958 : 1♀ , 13 mm.

De la côte orientale d'Afrique aux Philippines et aux Tuamotu. Signalé de l'Ile Maurice (Bouvier) et d'Ibo (Hilgendorf, sous le nom de **Pagurus fabimanus**).

Dardanus setifer (H. Milne Edwards)

Pagurus setifer Milne Edwards, H., 1836, p. 274.

Pagurus setifer, Alcock, A., 1905, p. 83, pl. VIII, fig. 3.

Matériel. - Baie d'Ambaro (côte nord-ouest), chalut, vase molle, 5 m, Crosnier coll., juill. 1958 : 1♂, 20 mm.
- Ile Mitsio, chalut, sable fin, 40 m, Crosnier coll. févr. 1959 : 1♂, 18 mm.
- Baie de Tsimipaika (côte nord-ouest), chalut, sable vaseux, Crosnier coll., mars 1959 : 1♂, 20 mm.
- Ile Mitsio (côte nord-ouest), chalut, sable coquillier, 26 m, Crosnier coll., juin 1959 : 1♂, 19 mm.
- Banc de Pracel (côte ouest), chalut, sable, 55 m, Crosnier coll., juin 1959 : 1♂, 26 mm.

De la côte orientale d'Afrique à l'Indonésie et au Japon. Signalé d'Ibo (Hilgendorf, sous le nom de **Pagurus pavimentatus**, tandis que son **P. setifer** doit être rapporté à **Dardanus guttatus**).

Diogenes planimanus Henderson

Diogenes custos var. **planimanus** Henderson, J.R., 1893, p. 416, pl. XXXIX, fig. 5-6.
Diogenes custos var. **planimanus**, Alcock, A., 1905, p. 66, pl. VI, fig. 3.

Matériel. - Tuléar, sable littoral, Crosnier coll., oct. 1958 : 1♂, 13 mm.
- Nosy-Bé, MacNae coll., déc. 1959 : 8♂, 8 à 16 mm, 3♀, 7 à 10 mm, dont une ovig.
- Nosy-Bé, Crosnier coll., avril 1962, : 1♂, 12 mm.
- Baie d'Ambaro, chalut, 7 m, Crosnier coll., fév. 1959 : 1♂, 16 mm.
- Nosy-Bé, oct. 1954 : environ 50 juvéniles, 2 à 4 mm.
- Nosy-Bé, Crosnier coll., oct. 1959 : 26 juvéniles, 2 à 5 mm.

N'est connu avec certitude que du Golfe du Bengale et de Malaisie mais a pu être signalé sous le nom de **D. custos** qui a une large répartition indopacifique. Le **Diogenes custos** signalé à Tuléar (Lenz) est peut être un **planimanus**.

Diogenes crosnieri sp. nov. (fig. 7-10)

Matériel. - Nosy-Bé, faubert, 10 m, Crosnier coll., janv. 1962 : 2♀, 5 mm (holotype) et 3 mm (paratype), dans des cavités de coraux.

DESCRIPTION

Partie antérieure de la carapace (fig. 7) un peu plus longue que large ; région médiane du bord frontal faiblement convexe et beaucoup moins saillante que les épines latérales ; de part et d'autre de ces épines latérales frontales, une série de petites spinules, qui, du côté externe, se continuent jusqu'à l'angle antéro-externe de la carapace.

Pédoncules oculaires nettement plus courts que la portion antérieure de la carapace, dilatés dans la région proximale et dans la région cornéenne. Ecailles oculaires triangulaires, bordées sur leur côté antéro-externe par quatre à cinq dents aiguës et de taille croissante ; pièce interoculaire petite, simple, atteignant le milieu des écailles.

Pédoncules antennulaires grêles, la base de leur dernier article au niveau du bord postérieur des cornées, cet article sensiblement égal au précédent.

Deuxième article des pédoncules antennaires armé d'une épine interne et d'une épine externe ; la base du dernier article est au niveau des cornées et sa longueur égale à celle des trois précédents réunis ; écaille longue, triangulaire, à bords rectilignes, armée de deux épines aiguës sur son bord *interne ; elle n'atteint pas l'extrémité du quatrième article ; longueur du* fouet légèrement supérieure à celle de la carapace.

Maxillules avec endopodite non appendiculé (cf. Forest 1952, p. 11). Article principal de l'exopodite des deuxièmes maxillipèdes légèrement plus long que l'endopodite ; article principal de l'exopodite des troisièmes maxillipèdes grêle, atteignant le tiers proximal du carpe de l'endopodite, dont les trois derniers articles sont très allongés.

Chélipède gauche (fig. 8) beaucoup plus fort que le droit. Face supéro-externe du carpe limitée du côté interne par une ligne de six à sept dents épineuses de plus en plus aiguës vers le bord antérieur ; une seconde ligne d'épines moins fortes, parallèle à la précédente, sépare la portion externe de la portion supérieure de cette face ; le bord antérieur de cet article est armé d'une ligne de courtes épines.

Main deux fois plus longue que large ; bord préhensile du doigt fixe presque rectiligne, face supérieure de ce doigt déprimée ; bord supérieur du doigt mobile régulièrement arqué. La totalité de la face externe de la main est recouverte de tubercules coniques plus forts au voisinage du bord supérieur et sur la moitié distale du bord inférieur.

Sur le spécimen type qui venait de muer, les dents qui marquent le bord supérieur des trois derniers articles, et notamment celles du bord palmaire supérieur, sont beaucoup plus longues et plus aiguës.

Chélipède droit à doigts grêles, également recouvert de petits tubercules coniques, qui, sur le carpe, sont disposés en deux rangées longitudinales parallèles.

Pattes ambulatoires p2 et p3 (fig. 9 : p3 gauche) sensiblement de même longueur, plus courtes que le chélipède gauche ; dactyle un peu plus court que le propode ; elles sont inermes, à l'exception d'une petite épine distale sur le bord supérieur du carpe.

Propode des p4 court et globuleux.

Abdomen long, cylindrique et droit, avec les trois premiers pléopodes longs et biramés, le quatrième uniramé. Uropodes courts et symétriques (fig. 10).

Telson plus court que large, son bord libre arrondi, armé d'une rangée continue de courtes épines.

Pilosité. - Bords latéraux de la carapace couverts de longues soies plumeuses dans la région antérieure ; des soies longues et fines insérées sur les pédoncules oculaires, antennaires et antennulaires ; des soies très longues et très nombreuses sous le dernier article du pédoncule, et sous les articles des flagelles antennaires. Péréiopodes également hérissés de soies raides, très longues, plus nombreuses sur les régions supérieures et inférieures des articles, sauf sous le carpe et la main des chélipèdes ; ces soies sont fines et ne cachent pas l'ornementation du tégument. Abdomen recouvert de courtes soies, peu serrées.

REMARQUES.-

Cette espèce nouvelle appartient au groupe des **Diogenes** primitivement connus sous le nom de **Troglopagurus**, dont la pièce interoculaire est très réduite ; il appartient en outre au groupe II du genre **Diogenes** (Forest, 1952, p. 11), dont le palpe des maxillules n'est pas appendiculé, et dont l'article principal de l'exopodite de mxp2 dépasse le dactyle de l'endopodite.

C'est, de plus, la seule espèce du genre **Diogenes**, qui, à notre connaissance, possède un abdomen cylindrique et des uropodes symétriques ; ces caractères sont très probablement liés à son habitat : les deux spécimens connus ont été récoltés dans des cavités de coraux.

Paguristes abbreviatus Dechancé

Paguristes abbreviatus Dechancé, M., 1963, p. 297, fig. 3,6,9.

Matériel. - Nosy-Bé, faubert, 10 m, Crosnier coll., janv 1962 : 1 ♀ , 3 mm, dans un bloc de corail.

Golfe Persique et Madagascar.

PAGURIDAE

Anapagurus sp.

Matériel. - Banc de Pracel (côte ouest), drague, 35 m, Crosnier coll., juin 1959 : 1 ♂, 1,6 mm.

Ce petit exemplaire, mutilé, n'a pu être identifié à aucune espèce décrite.

Catapagurus sp.

Matériel. - Lagon de Mayotte, Crosnier coll., dragage, 56 m, sable : 1 ♀ ovig., 3,3 mm, dragage, 49 m, sable fin : 1 ♀ ovig., 2,9 mm.

Cette espèce de **Catapagurus**, représentée par deux femelles seulement, est proche de **C. ensifer** Henderson, dont elle diffère par des pédoncules oculaires moins larges, par des chélipèdes beaucoup plus grêles, aux doigts non défléchis ; elle est également voisine de **C. granulatus** Edmonson, dont elle diffère par des pédoncules antennaires plus courts, et par un telson moins échancré, aux lobes armés d'épines terminales.

Pagurus janitor (Alcock)

Eupagurus janitor Alcock, A., 1905, p. 132, pl. XI, fig. 6.

Matériel. - Nosy-Bé, zone intercotidale, MacNae coll., janv. 1954 : 1 ♂, 13 mm.
- Ile Bandéli (Comores) : 1 ♀ ovig., 11 mm.
Etait connu du Golfe Persique aux Philippines.

Pagurus sp.

Matériel. - Fort-Dauphin, drague, sable coquillier, 80 m, Crosnier coll., oct. 1958 : 1 ♀ ovig., 3,0 mm.

DESCRIPTION.-

Rostre acuminé, aigu, atteignant presque le milieu des écailles oculaires et dépassant largement l'alignement des dents latérales, qui sont bien marquées. Pédoncules oculaires plus courts que la région antérieure de la carapace, légèrement dilatés à leur base et renflés au niveau de la cornée. Pédoncules antennulaires dépassant les yeux par la longueur de la moitié de leur dernier article, pédoncules antennaires dépassant à peine l'extrémité des yeux, écaille atteignant le milieu du dernier article.

Chélipède droit beaucoup plus fort que la gauche; mérus muni d'une crête de cinq à six dents aiguës sur son bord inféro-externe ; face supérieure du carpe ornée de trois lignes longitudinales de fines épines . deux lignes divergentes vers le bord supéro-interne, la troisième, aux épines plus fines, dans la zone externe ; main oblongue, lisse, à l'exception de quelques petits tubercules sur son bord antérieur ; une fine crête de petites dents marque le bord palmaire externe jusqu'à l'extrémité du doigt fixe, une crête plus obtuse, le bord palmaire interne.

Chélipède gauche légèrement plus court que le droit ; mérus muni de crêtes de dents aiguës sur ses bords inférieurs interne et externe ; carpe avec une crête identique sur son bord inférieur externe, et deux lignes parallèles de fortes épines sur sa face supérieure ; main avec une forte crête longitudinale médiane sur la face supérieure de la paume, se prolongeant jusque sur le doigt fixe ; doigt mobile un peu plus long que le bord palmaire interne.

Pattes ambulatoires courtes, à peine plus longues que le petit chélipède, dactyle sensiblement égal au propode, terminé par une griffe aiguë ; une rangée d'épines cornées sur le bord inférieur du dactyle, et quelques-unes sur celui du propode.

Pilosité générale assez faible : des soies longues et fines sur les pédoncules oculaires et antennaires, et sur les appendices thoraciques.

Coloration non conservée.

Il s'agit ici probablement d'une espèce nouvelle, mais nous n'avons pas voulu décrire comme telle cet unique petit spécimen femelle ; il s'apparente par nombre de caractères (forme du rostre, des chélipèdes et des pattes ambulatoires, pilosité) aux espèces du sous-genre **Pagurixus** créé par G. Melin (1939) pour les espèces dont les coxae des cinquièmes péréiopodes sont asymétriques chez les mâles, et auquel appartiennent **P.boninensis** Melin, **P.maorus** Nobili, **P.anceps** Forest et **P.tweediei** Forest ; ces espèces présentent généralement un important dimorphisme sexuel, et c'est seulement lorsque nous serons en possession d'un spécimen mâle que nous pourrons décrire complètement l'espèce malgache.

Spiropagurus spiriger de Hăan

Spiropagurus spiriger Haan, W. de, 1849, p. 206, pl. XLIX, fig. 2.

Spiropagurus spiriger, Alcock, A., 1905, p. 118, pl. XIII, fig. 1.

Matériel. - Baie d'Ambaro (côte nord-ouest), chalut, sable vaseux, 15 m, Crosnier coll., avril 1959 : 1♂, 15 mm.

Du Golfe Persique aux Philippines et au Japon.

Laboratoire des Arthropodes
du Muséum national d'Histoire naturelle

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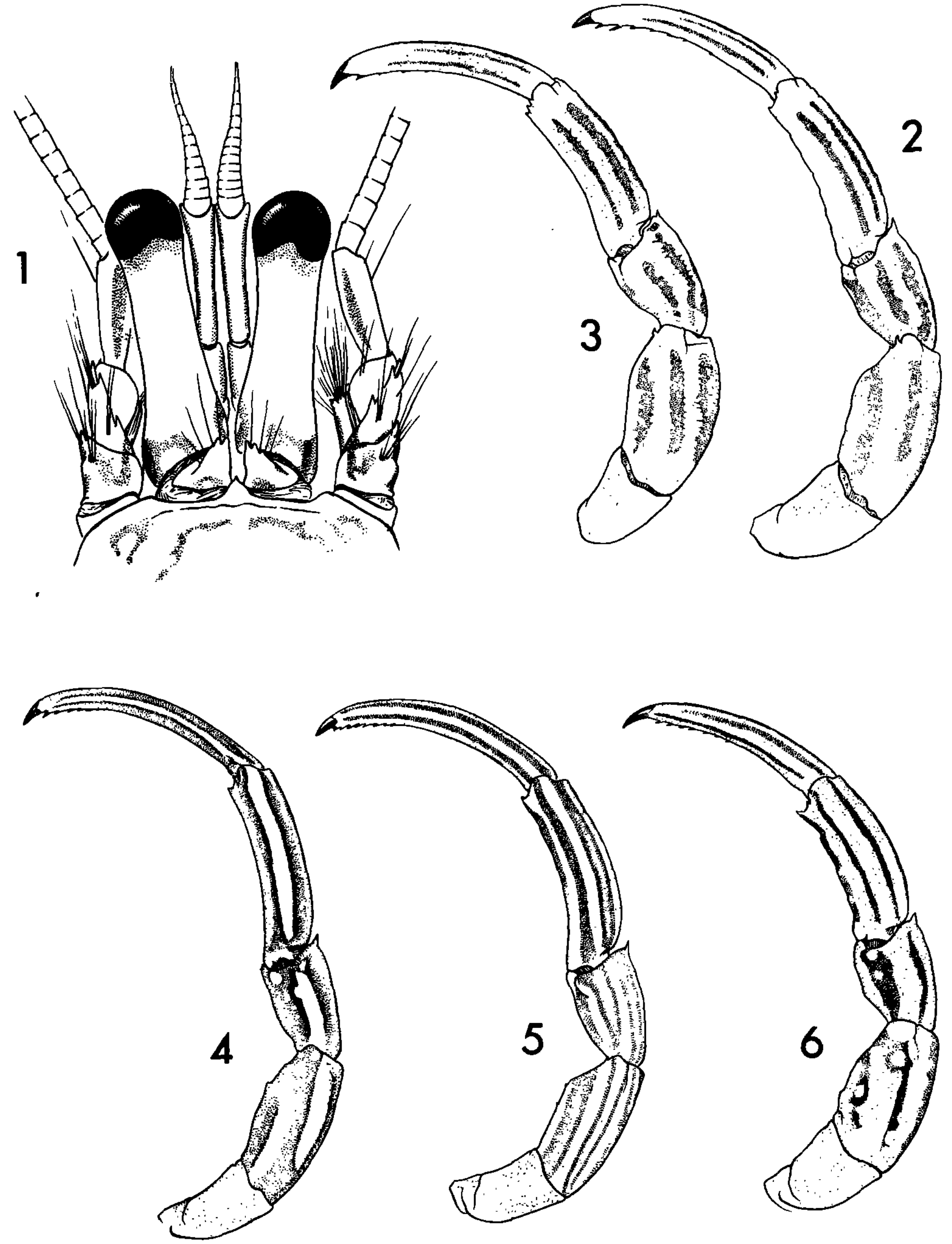
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LEGENDE DES FIGURES

(1 à 6)

Fig. 1 - **Clibanarius laevimanus** Buitendijk : bord frontal et appendices céphaliques, ♀ 5 mm, Madagascar, x 20;

Fig. 2 - **Clibanarius laevimanus** Buitendijk : troisième patte ambulatoire gauche, face externe, ♂ paratype, 9 mm, Maratoea, x 7;

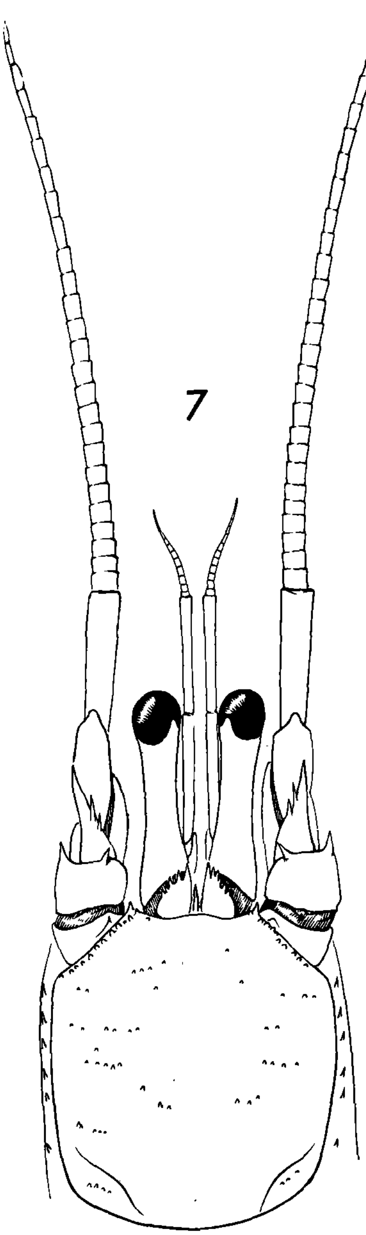
Fig. 3 - **Clibanarius laevimanus** Buitendijk : id., ♂, 7 mm, Madagascar, x 16.

Fig. 4 - **Clibanarius longitarsus** (de Haan) : id., ♂, 14 mm, x 4,5.

Fig. 5 - **C. padavensis** de Man : id., ♂, 12 mm, x 3.

Fig. 6 - **C. striolatus** Dana : id., ♂, 14 mm, x 4.

Les soies n'ont été représentées que sur la fig. 1.



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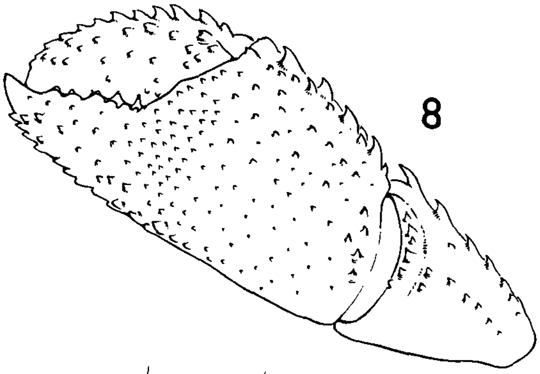

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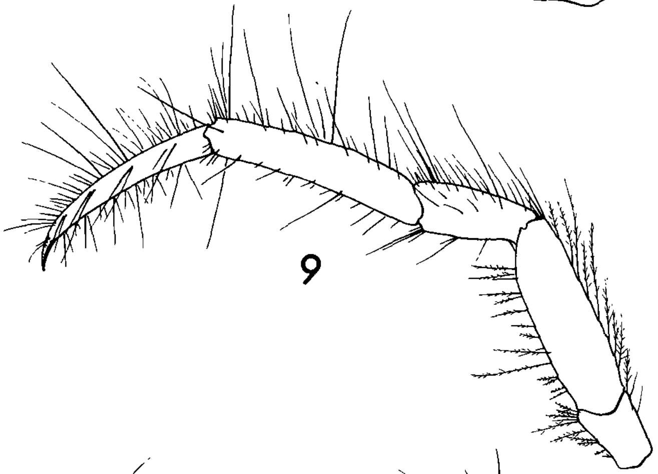

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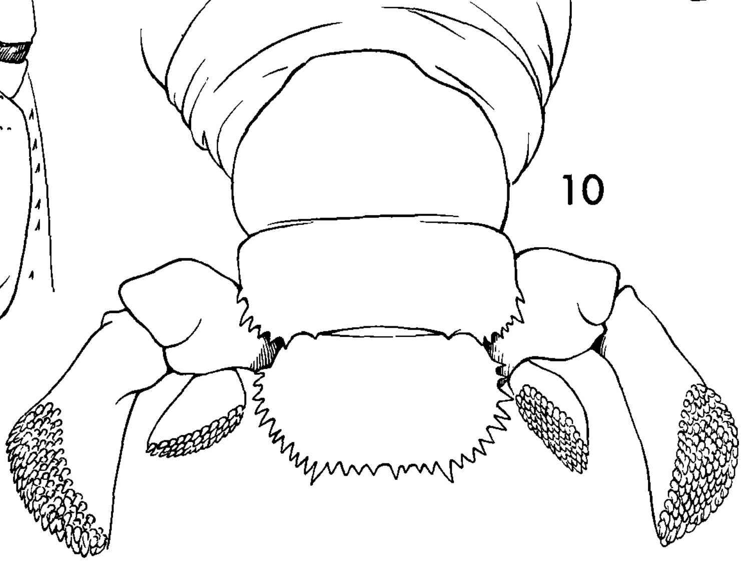

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LEGENDE DES FIGURES

(7 à 10)

Fig. 7 - **Diogenes crosnieri** sp. nov. : partie antérieure de la carapace et appendices céphaliques, ♀ type, 5 mm, x 20,

Fig. 8 - **Diogenes crosnieri** sp. nov. : région distale du chélipède gauche, ♀ paratype, 3 mm, x 20,

Fig. 9 - **Diogenes crosnieri** sp. nov. : troisième patte thoracique gauche, ♀ paratype, 3 mm, x 18;

Fig 10 - **Diogenes crosnieri** sp. nov. : extrémité de l'abdomen, uropodes et telson, ♀ type 5 mm, x 22.

Les soies n'ont été représentées que sur la fig. 9.

Reprinted from *Cahiers ORSTOM – Océanographie*, vol. II, no. 4, 1964, p. 55-98

CHAETOGNATHES DE MADAGASCAR
(Secteur de Nosy-Bé)

par

M.-L. FURNESTIN * et **J. RADIGUET**

Bien que le canal de Mozambique ait été compris dans l'itinéraire de plusieurs croisières océanographiques depuis une soixantaine d'années, le plancton de la région, et surtout celui des eaux malgaches, n'a fait encore l'objet que d'un petit nombre de travaux. Mais il semble qu'avec l'implantation de la station O.R.S.T.O.M. (Centre d'Océanographie et des Pêches) de Nosy-Bé et de la station de l'Université de Madagascar (Centre de Recherche de Biologie marine) à Tuléar, cette faune planctonique doit être plus largement étudiée dans un avenir proche.

En ce qui concerne les Chaetognathes, cette étude est la première en date. Il n'existe que des données très fragmentaires, presque élémentaires à leur sujet, et elles concernent de surcroît plutôt le canal de Mozambique ou la côte africaine que l'Ile proprement dite. Des recherches bibliographiques approfondies nous ont fourni les seules indications suivantes pour le canal de Mozambique : mention de *Sagitta bipunctata* et de *Sagitta enflata* dans sa partie sud (CLEVE, 1905), mention de *Sagitta enflata* à la latitude de Mozambique (FOWLER, 1906).

Ajoutons qu'ayant eu l'occasion de déterminer un lot de Chaetognathes récoltés dans la région de Tuléar (1), l'une de nous (**M.-L. Furnestin**) avait identifié : *Sagitta enflata, S. hexaptera, S. serratodentata pacifica et Pterosagitta draco;* mais ce bref inventaire n'a pas été publié.

LE MATERIEL

Les Chaetognathes que nous étudions ici proviennent de la région de Nosy-Bé. Ils nous ont été confiés par **M. S. Frontier** Océanographe-biologiste au Centre O.R.S.T.O.M. d'Océanographie de Nosy-Bé, que nous remercions de l'envoi de cette intéressante collection.

Les échantillons ont été recueillis du 11 octobre au 13 décembre 1960 à bord du navire de l'O.R.S.T.O.M. Le réseau des stations a couvert le secteur situé entre 12° 48' et 13° 36' de latitude sud d'une part, 47° 24' et 48° 24' de longitude est d'autre part (fig. 1).

Le nombre des stations est de 21, celui des pêches de 53, plusieurs de celles-ci ayant été faites aux mêmes points. La majeure partie a été effectuée en rade d'Hellville (point A) ; 10 autres viennent d'une zone à fonds très faibles de 20 à 40 m ; 3 ont été pratiquées à la limite du plateau continental et 6 au-dessus de fonds de 800 à 2000 m.

Les prélèvements s'échelonnant entre 19 h et 4 h 30 peuvent être considérés comme nocturnes pour la plupart. Ils ont été conservés dans un mélange d'eau de mer et de formol à 10 %.

Les caractéristiques des stations sont portées dans le tableau 1.

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(1) à la demande de G. SEGUIN.

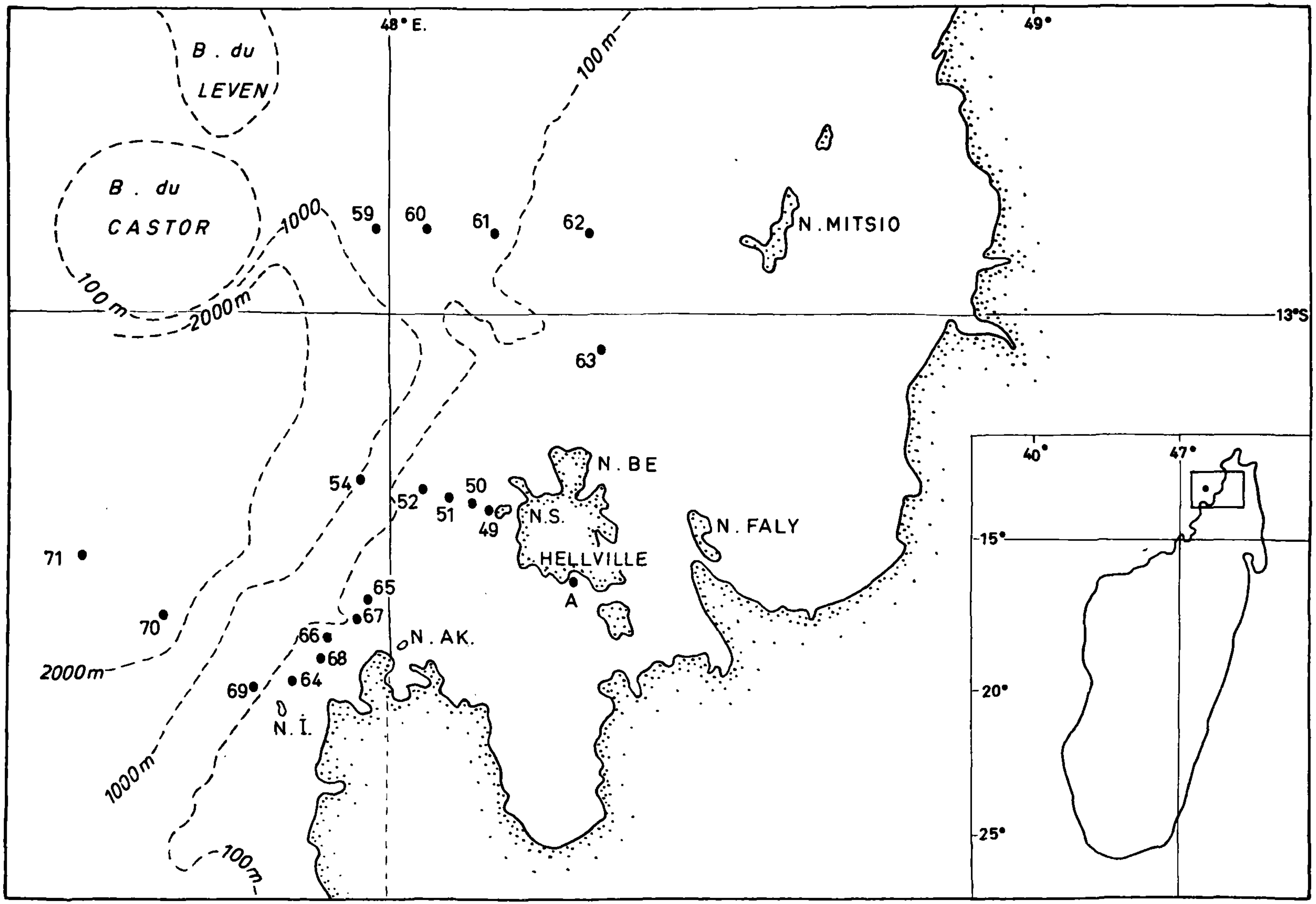

Fig 1 Position des stations de peches planctoniques (A stations 22 a 48,55 a 58 et 72 a 75).
N Nosy N.S Nosy-Sakatia; N AK. Nosy-Ankazoberavina; N I. Nosy-Iranja

N° Stations	Date 1960	Heure (début de pêche)	Lieu	Profondeur de la pêche	Sonde
22	11/10	19h 00	Rade d'Hellville	1 à 2m	20m
24	12/10	19h 00	" "	surface	"
25	"	18h 30	" "	3 à 4m	"
26	18/10	18h 10	" "	"	"
27	"	18h 35	" "	"	"
28	"	19h 00	" "	"	"
29	"	19h 50	" "	"	"
30	"	20h 15	" "	2 à 3m	"
31	19/10	20h 05	" "	3 à 4m	"
32	"	20h 30	" "	"	"
33	"	20h 50	" "	"	"
34	"	21h 15	" "	"	"
35	"	21h 40	" "	"	"
36	"	22h 00	" "	2 à 3m	"
37	20/10	23h 30	" "	3 à 4m	"
38	21/10	00h 00	" "	"	"
39	"	00h 30	" "	"	"
40	"	01h 00	" "	2 à 3m	"
41	28/10	02h 50	" "	3 à 4m	"
42	"	03h 30	" "	"	"
43	"	04h 00	" "	"	"
44	"	04h 30	" "	"	"
45	8/11	01h 20	" "	"	"
46	"	02h 00	" "	"	"
47	"	03h 30	" "	"	"
48	"	04h 15	" "	"	
49	10/11	22h 15	0,5 à 1 mille de N.Sak	Surface	36m
50	"	23h 30	2,5 à 3 milles "	"	40m
51	11/11	00h 10	4,5 à 5 milles "	"	23m
52	"	00h 45	6,5 à 7 milles	"	20m
54	"	02h 05	10,5 à 11 milles "	"	grands fonds
55	18/11	20h 30	Rade d'Hellville	3 a 4m	20m
56	"	20h 50	" "	"	"
57	"	21h 20	" "	"	"
58	"	21h 55	" "	"	"
59	25/11	00h 55	28,5 à 29 milles de Pointe Mitaraka N. Mitsio	Surface	grands fonds
60	"	01h 40	25 à 25,5 milles "	"	"
61	"	02h 30	21,5 à 22 milles "	"	100 - 200m
62	"	03h 30	18 à 18,5 milles "	"	30m
63	"	04h 00	13° 28' S. ; 47° 39' E.		60m
64	29/11	19h 00	Entre N. AK. et N.-I	"	24m
65	"	20h 00	"	"	29m
66	7/12	20h 05	"	"	24m
67	"	21h 10	"	"	29m
68	"	22h 15	"	"	19m
69	"	23h 30	1,5 à 2 milles de N. Iranja	"	100 - 200 m
70	8/12	00h 15	6 à 6,5 milles "	"	grands fonds
71	"	01h 30	9,5 à 10 milles "	"	"
72	13/1	21h 50	Rade d'Hellville	4 à 5m	20m
73	"	22h 15	" "	3 à 4m	"
74	"	22h 40	" "	2 à 3m	"
75	"	23h 00	" "	1 à 2m	"

Tableau n° 1 - Caractéristiques des stations de pêches planctoniques.
(N. Sak. = Nosy-Sakatia ; N. AK. = Nosy-Ankazobéravina ; N. I. = Nosy- Iranja).

QUELQUES CARACTERISTIQUES DE LA REGION

Nous ne rapporterons ici que les notions nécessaires à l'interprétation des résultats de l'analyse des prélèvements.

Topographie générale et bathymétrie.

On sait que la côte nord-ouest de Madagascar est très découpée, comportant, outre des récifs coralliens, plusieurs îles rocheuses, dont la plus importante est précisément Nosy-Bé. Des promontoires isolent de nombreuses baies, plus ou moins vaseuses, parmi lesquelles celle d'Hellville, sur la côte sud de Nosy-Bé, où ont été faits 35 des prélèvements (fig. 1).

Le plateau continental (plateau corallien) déborde à l'ouest de Nosy-Bé et de Nosy-Mitsio où se prolonge la zone des fonds faibles ou moyens (10 à 50 et 100 m) quel'on retrouve, au nord-ouest du secteur, sur les bancs du Leven et du Castor (fig. 1).

Les grands fonds ne sont pas loin cependant, le plateau continental tombant très rapidement vers les profondeurs de 1000 à 2000 m qui dessinent un chenal médian dirigé sud-ouest nord-est (fig. 1).

On peut donc s'attendre à trouver dans la région prospectée, une association plus ou moins étroite d'espèces néritiques et pélagiques.

Régime hydrologique.

A/ Température et salinité.

Le Centre de Nosy-Bé nous a fourni en même temps que la collection à examiner, une série de données hydrologiques provenant de 10 stations faites en juin 1962 dans la même région. Mais ces données sont difficilement utilisables car elles ne se rapportent pas à la même saison que les prélèvements (1). Aussi avons-nous extrait des travaux de MENACHE (1957) sur l'eau de surface dans la rade de Nosy-Bé les moyennes mensuelles de température et de salinité pour octobre, novembre et décembre de l'année 1955.

	Moyennes diurnes	
Mois	T° C	Sal. o/oo
Octobre	27,40	35,18
Novembre	28,45	35,11
Décembre	29,10	34,89

Des résultats de la première croisière océanographique du "Commandant **Robert** Giraud" dans le canal de Mozambique (octobre-novembre 1957), nous tirons également des valeurs très voisines des précédentes pour le secteur de Nosy-Bé ; température de 27 à 29°, salinité d'environ 35,20 p. 1000 (MENACHE, 1962).

Les pluies de mousson abondantes étant susceptibles de faire diminuer la salinité de façon appréciable dans certains secteurs de l'océan Indien (côte de Malabar et région de Madras), au point de gêner les populations de Chaetognathes (DONCASTER, 1902 et GEORGE, 1952), nous donnons aussi quelques précisions sur le régime des pluies à Madagascar.

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(1) Les temperatures et les salinites de surface relevées en saison froide sur les stations hydrologiques les plus proches des stations planctoniques de 1960 s'echelonnent respectivement entre 26° 83 et 27° 83, 34, 75 et 35,05 p. 1000.

D'une manière générale, les précipitations les plus fortes ont lieu pendant la saison chaude. Mais, pour la zone de Nosy-Bé, elles sont sensiblement plus abondantes dans l'ensemble et surtout restent notables en saison froide :

saison chaude (novembre-avril) : 1894 mm
saison froide (mai-octobre) : 894 mm

Il s'ensuit que les variations de salinité attribuables au facteur pluie y sont sans doute moins marquées. L'analyse des teneurs obtenues pour les deux saisons au cours des années 1955-1956 (les seules dont nous disposions au complet), nous a indiqué les extrêmes suivants :

saison chaude : 33,64 p. 1000
saison froide : 35,18 p. 1000

L'écart est appréciable mais les moyennes pour les deux saisons ne diffèrent en fait que très peu : 34, 39 pour la saison chaude, 34,95 pour la saison froide (1).Il semble donc difficile de tenir compte de ces variations comme facteurs de distribution des Chaetognathes.

B/Courants.

Les parages nord-ouest de Madagascar paraissent être à l'abri du courant équatorial sud, qui, doublant l'île au nord, se divise en deux branches dont l'une remonte le long du continent africain et l'autre se dirige vers le sud, sous le nom de courant du Mozambique, mais en restant très éloignée de la côte malgache.

En revanche, ils seraient intéressés par un tourbillon tournant autour des Comores et créant un courant portant au nord-est au large de Nosy-Bé. Ce dernier se rapproche plus ou moins de la côte suivant les saisons et, en particulier pendant les mois d'octobre, novembre et décembre, semble n'être qu'à une trentaine de milles. Il est par ailleurs très influencé par les coups de vent locaux.

En dehors de cela, la zone côtière de Nosy-Bé est surtout affectée par les courants de marée portant alternativement à l'est puis à l'ouest et qui peuvent donc à certains moments travailler dans le même sens que le courant comorien, c'est-à-dire amener les eaux du large sur le plateau continental.

Nous verrons que ces déplacements de masses d'eau interviennent dans la répartition locale des Chaetognathes.

LES CHAETOGNATHES

Parmi les 3719 spécimens constituant la collection, 13 espèces ont été identifiées dont 12 du genre *Sagitta* et 1 du genre *Pterosagitta*.

Espèces	Nombre	Pourcentage
S. enflata	1893	50,74
S. robusta	611	16,40
S. bedoti	303	9,08
S. hispida	282	7,51
S. serratodentata	155	4,09
S. regularis	104	2,70
P, draco	103	2,68
S. pulchra	95	2,47
S. hexaptera	75	2,03
S. bipunctata	42	1,06
S. ferox	36	0,87
S. planctonis	19	0,41
S. minima	1	0,01

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(1) Notons que, d'après les données du Centre de Nosy-Bé, la moyenne pour la saison froide en 1962 est de 34,96, chiffre tout à fait similaire.

Les pourcentages précédents n'indiquent que les proportions relatives des espèces dans ces pêches ; nous estimons qu'ils fournissent cependant une idée assez exacte du peuplement local des eaux de surface.

Renvoyant en annexe les données morphologiques, nous allons envisager ci-après comment se comporte chacune des espèces dans le secteur de Nosy-Bé.

Pour cette étude écologique, elles seront d'emblée séparées en deux groupes d'après leur appartenance habituelle au domaine néritique ou pélagique (1), afin de faciliter la discussion des résultats. Dans chaque groupe, sauf exceptions, elles seront prises par ordre d'abondance décroissante.

Le tableau II donne leur répartition numérique par station.

Stations / Espèces	A (35 st.)	49	51	54	59	60	61	62	63	64	65	66	67	68	69	70	71	Total des spécimens
S enflata	1670	10	5	5	6	12	5	15	83	10		4	4	3	2	13	46	1893
S robusta	532		4	2		1						3	4			4	61	611
S. bedoti	192	11				6	1	1	33							26	33	303
S hispida	162	2	1	8	5	3		7	7	51	1	9	7	7		5	7	282
S serratodentata	105	20	4	4	1			6	8	1						2	4	155
S. regularis	78	3		6		6			7	2							2	104
P draco	56	1	1	19	1	3	1		18			1					2	103
S pulchra	57			1	4	5	1	7	3			3		1	6		7	95
S hexaptera	34	3	4	7	4	6	1	6		1		3	2		3		1	75
S bipunctata	16		5		4			7	2	2			2				4	42
S. ferox	36																	36
S planctonis	9											2		3			5	19
S minima									1									1
Total general																		3719

Tableau n° 2 - Répartition des Chaetognathes aux différentes stations et total des spécimens par espèce.

1) Espèces néritiques et semi-néritiques

Sagitta enflata Grassi, 1883

Très répandue dans les mers chaudes, en Méditerranée et en Afrique tropicale par exemple, *S enflata* est également très abondante ici où elle constitue presque la moitié des récoltes.

Elle a d'ailleurs été mentionnée dans le canal de Mozambique ou dans des zones plus ou moins voisines (eaux indiennes) par plusieurs auteurs (**Clève** et **Fowler** déjà cités, **George** 1952) D'après leurs observations, il semble que les périodes de concentration de l'espèce varient d'un lieu à un autre en fonction de la saison des pluies. La densité du peuplement diminuerait en saison humide en raison de l'abaissement des salinités consécutif aux précipitations.

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(1) Sans préjuger de leur comportement local

A Nosy-Bé, la saison des pluies se place de novembre à avril. C'est donc à ce moment qu'on devrait enregistrer une diminution de la population. La richesse des prélèvements de novembre à décembre, légèrement supérieure à celle des prélèvements d'octobre, ne marque en fait aucune raréfaction.

	Octobre	Novembre	Décembre
Nombre moyen de spécimens par station	3,4	4,5	4,5

Pour conclure fermement, il faudrait pouvoir comparer des prélèvements du plein des *saisons sèche et humide ; mais, comme nous l'avons noté, les précipitations étant appréciables* toute l'année dans le secteur de Nosy-Bé et les salinités à peu près constantes, il est peu probable que la densité du peuplement de *S. enflata* soit très différente d'une période à l'autre.

Stade I : 42,6%
Stade II . 22,5%
Stade III : 34,8%

En ce qui concerne la répartition des stades de maturité sexuelle, on constate la prédominance des jeunes. Il faut souligner cependant que les prises renferment très généralement un mélange de sujets de tous âges.

Il y a en fait des variations mensuelles dans les proportions numériques des individus aux différents stades. Les adultes sont les plus nombreux en octobre et les jeunes en novembre. Il y aurait donc une ponte en octobre d'où résulterait une augmentation des jeunes stades le mois suivant. En décembre, la population serait à peu près équilibrée (fig. 2).

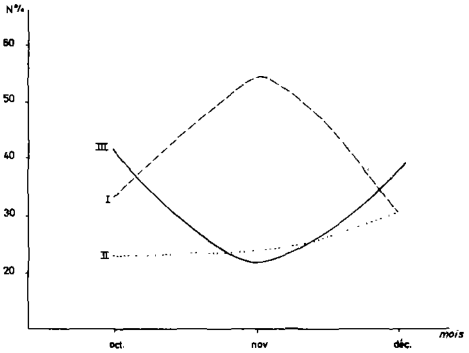

Fig.2 Variations mensuelles du nombre de spécimens de *Sagitta enflata* aux différents stades de maturité sexuelle (I, II, III).

Les températures favorables à *S. enflata* sont élevées ; on place son optimum autour de 20° mais on l'a observée par 28° (**M.-L. Furnestin**, 1957) et même 32° (**Vannucci** et **Hosoe**, 1952). Les moyennes de surface que nous possédons pour octobre, novembre et décembre dans la région de Nosy-Bé (de 27 à 29° environ) entrent donc dans la marge des températures convenant à l'espèce.

La salinité semble avoir moins d'importance pour elle. Si elle prospère particulièrement par des teneurs de 35 à 37,6 p. 1000, on l'a également mentionnée dans des eaux de salure supérieure (39,7 en Méditerranée orientale) ou inférieure (33,3 dans le golfe de Guinée). On peut dire que les valeurs relevées dans le secteur malgache pour la saison correspondant aux récoltes (autour de 35 p. 1000) sont voisines de celles de la zone tropicale africaine où *S. enflata* pullule.

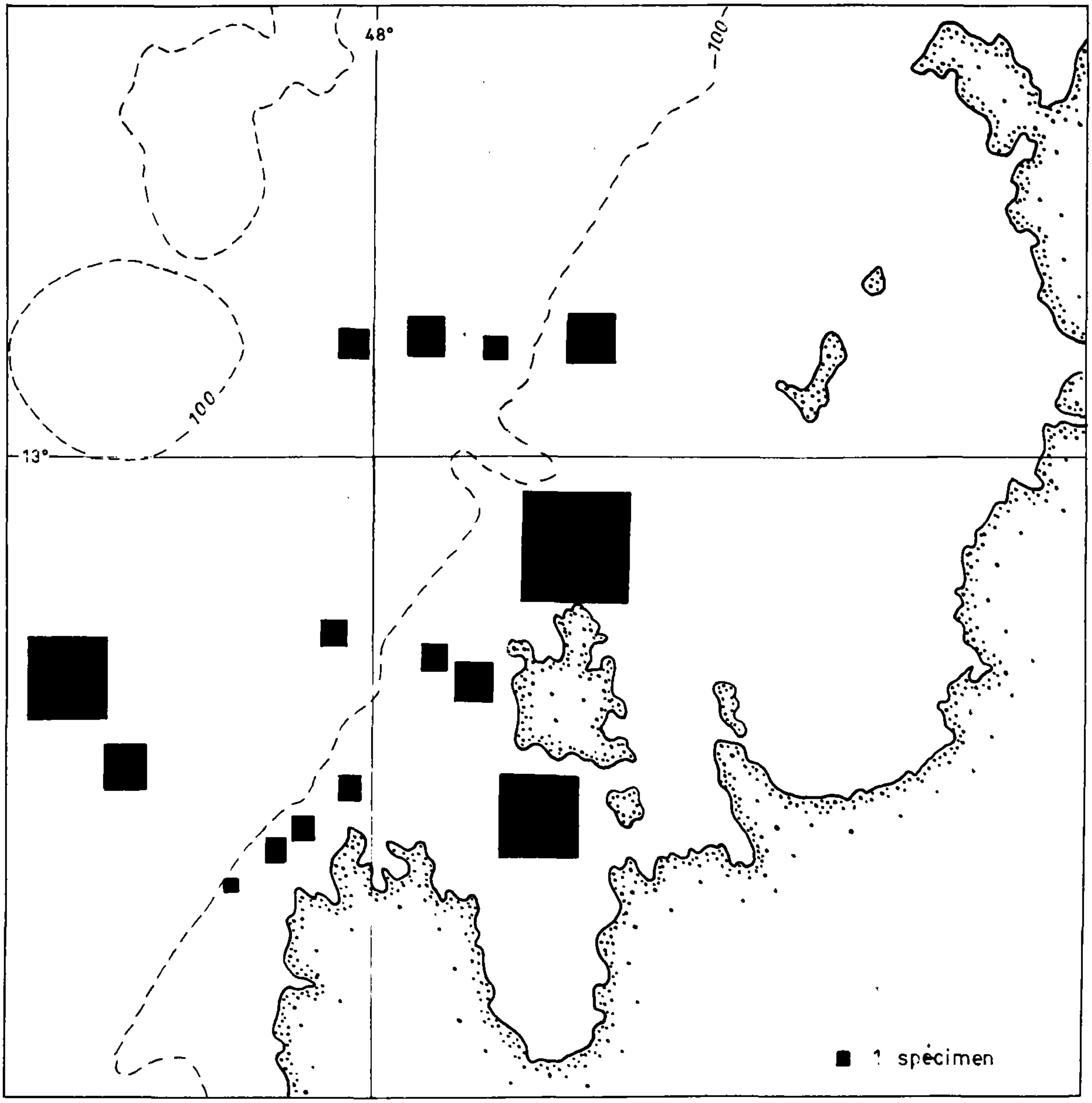

Fig 3 Répartition de *Sagitta enflata* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Sur le plan de sa distribution locale, on remarque que l'espèce est présente sur tout le secteur puisqu'elle figure dans tous les prélèvements, sauf trois en rade d'Hellville où elle est par ailleurs abondante (fig. 3). Or, nous savons que parmi les prélèvements, certains se situent au-dessus de fonds très faibles, d'autres au-dessus de grands fonds. Il est donc intéressant de chercher à déterminer dans quelle zone *S. enflata* se tient de préférence. Le tableau suivant, où est porté le nombre moyen de spécimens par pêche pour les fonds de 20 à 200 m d'une part et de 1000 m ou davantage d'autre part, révèle sa prédilection pour la zone des fonds faibles ou moyens.

Fonds	Nombre		
	de spécimens	de pêches	moyen de spécimens par pêche
20 - 200 m	1801	48	38,0
≥ 1000 m	82	5	16,4

Ces résultats sont en accord avec le caractère semi-néritique qu'on lui reconnaît dans d'autres secteurs tropicaux, l'Atlantique africain par exemple.

Sagitta robusta DONCASTER, 1902

C'est une forme tropicale et subtropicale typiquement indo-pacifique, qu'il est bien normal de trouver dans les eaux malgaches.

Dans le nord de l'Océan Indien, elle est sujette à de grandes variations saisonnières : elle présente un maximum d'abondance pendant l'automne et le début de l'hiver autour des îles Maldives et Laquedives (DONCASTER) et sur la côte de Malabar (GEORGE), un maximum en été dans les parages de Madras d'où elle disparaît en octobre (DONCASTER).

En ce qui concerne le secteur de Nosy-Bé, nous ne pouvons donner d'indications que pour le début de l'été (été austral), sans préjuger de variations saisonnières possibles. Au début de la saison chaude, *S. robusta* est bien représentée ; elle vient en deuxième position dans notre inventaire.

Pour préciser les températures favorables à l'espèce, disons que d'après THOMSON (1947), dans le sud-est australien, elle serait abondante de 24° à 25°, un peu moins entre 24° et 18°, rare entre 18° et 15°, et inexistante en deça de 15°. Les températures du secteur de Nosy Bé (27° à 29°) doivent donc convenir à cette forme d'eaux chaudes.

La carte de sa répartition locale (fig. 4), comme l'analyse des résultats de cette série de pêches, révèle un comportement peu tranché. On voit que *S. robusta* se rencontre à peu près indifféremment et dans des proportions voisines dans les prélèvements côtiers et ceux de haute mer .

Position des stations	Nombre moyen de spécimens par pêche
Zone néritique en-deça de 200 m	11,3
Zone pélagique au-delà de 200 m	13,6

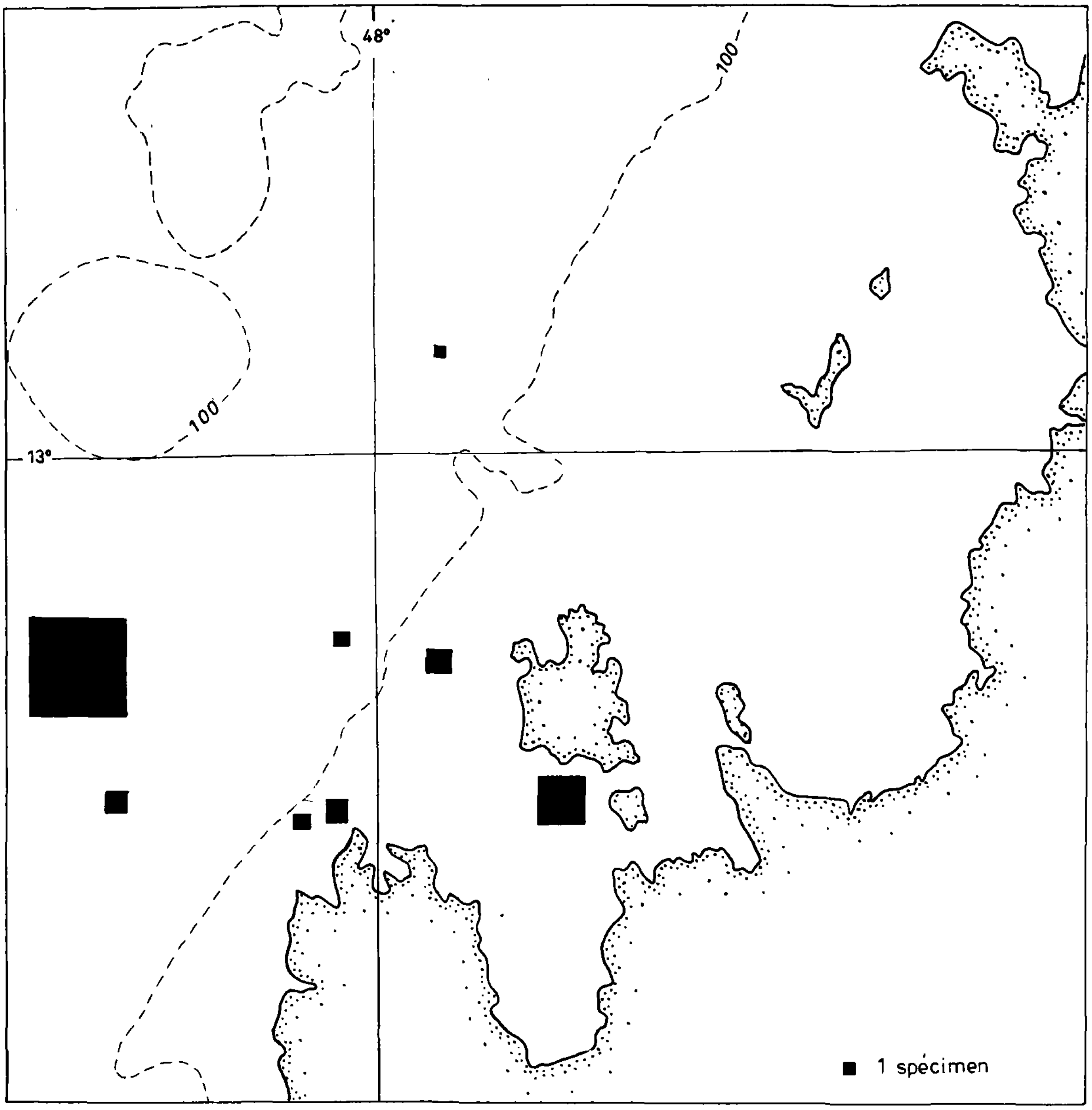

Fig. 4 Répartition de *Sagitta robusta* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au Point A.

Inversement, il est des pêches au large, aussi bien que des pêches côtières, dont elle est absente. Par suite, on doit reconnaître que le caractère néritique qui marque l'espèce en d'autres lieux (côtes de l'Inde, par exemple) ne se retrouve pas absolument ici mais qu'on ne saurait en faire non plus une forme pélagique comme y inciteraient les données de **Thomson** et **Tokioka** (1959). Son comportement reste donc à préciser par de nouvelles observations

Stade I : 47,1 %
Stade II : 36,0 %
Stade III : 16,4 %

On constate que les trois stades de maturité sexuelle sont dans des proportions décroissantes, les immatures formant le groupe le plus important, ce qui tendrait à faire considérer les mois d'octobre à décembre comme une des périodes de reproduction de l'espèce dans la région. Par ailleurs, les prélèvements, quelle que soit leur situation (rade d'Hellville ou haute mer), renferment un mélange d'individus à tous âges. Ceci, joint à la présence de jeunes en nombre élevé, conduit à penser que *S. robusta* constitue un élément permanent de la faune du secteur.

Sagitta bedoti BERANECK, 1895.

Espèce de l'Indo-Pacifique et de la Mer Rouge, *S. bedoti* est très abondante dans l'Océan Indien (**Tokioka**, 1959); pour ne parler que de la partie ouest de ce dernier, citons la côte des Somalies, les îles Malaives, les versants occidental et oriental de l'Inde.

Bien qu'elle occupe le troisième rang dans notre liste, la densité du peuplement n'est pas très forte dans les eaux malgaches.

On la trouve à la fois en rade d'Hellville, sur diverses autres stations néritiques et sur des stations au-dessus de grands fonds (fig 5) **Tokioka** et **Thomson** fournissent des indications similaires quant à sa répartition dans l'ensemble de l'Océan Indien et plus particulièrement au sud-est de l'Australie

C'est une forme épiplanctonique selon les données de **Ritter-Zahony** (Expédition du Gauss, 1911) et de **Tokioka**. De même, à Bombay, **Lele et Gae** (1936) la mentionnent comme fréquente toute l'année, de la surface à 50 m de profondeur Ici, elle a été récoltée en surface également.

D'après les auteurs, elle paraît relativement euryhaline et eurytherme. Les températures et salinités enregistrées sur les stations de pêche vont en effet de 26°6 à 29°5 et de 20,79 à 34, 16 p. 1000 pour les eaux est-indiennes (**Satyanarayana Rao** et **Ganapati**, 1958), de 9° à 27° et de 27,9 à 34,8 p. 1000 pour le Pacifique tropical est (**Sund** et **Renner**, 1959); la température et la salinité les plus basses des stations positives en Mer Jaune relevées par **Tokioka** sont de 11°5 et de 30,95 p. 1000. S'il fallait cependant la caractériser, il semble qu'on puisse la qualifier de forme des eaux chaudes assez peu salées Dès lors, les températures (27 à 29°) et salinités (voisines de 35 p. 1000) du secteur de Nosy-Bé doivent lui convenir.

Stade I : 64,5 %
Stade II : 16,0 %
Stade III : 18,5 %

Les trois stades de maturité sexuelle sont très inégalement représentés, bien que souvent associés dans une même prise. Le nombre des jeunes est très supérieur à celui des adultes. Cela peut venir de ce que l'époque des prélèvements correspond à une période de reproduction, comme nous l'avons suggéré pour les deux premières espèces. Mais la rareté des adultes et des individus au stade II peut tenir aussi à ce qu'ils sont moins épiplanctoniques que les immatures, comme cela arrive très souvent chez les Chaetognathes, même en dehors des formes profondes.

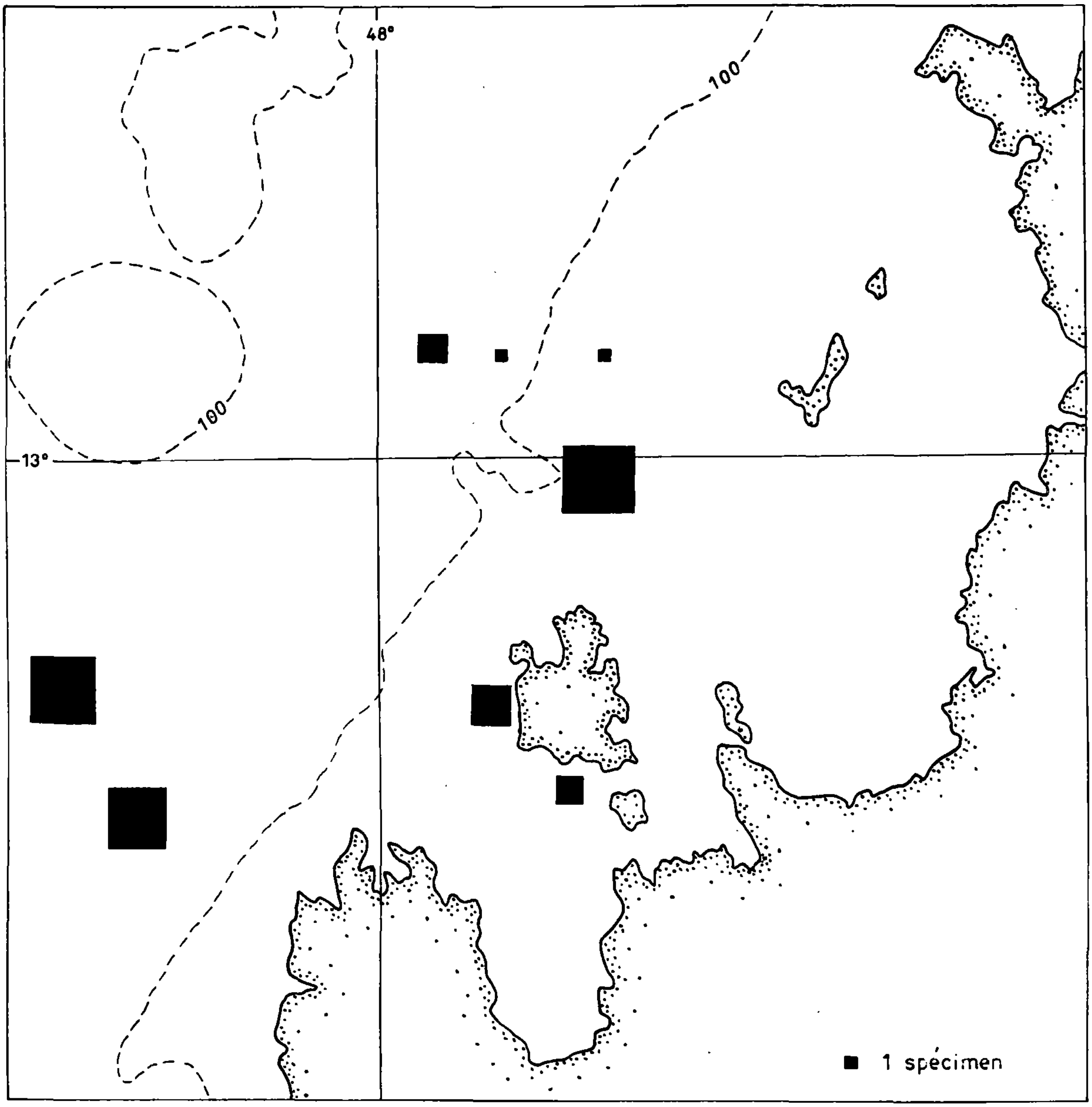

Fig.5 Répartition de *Sagitta bedoti* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Helleville représente la moyenne des récoltes effectuées au point A.

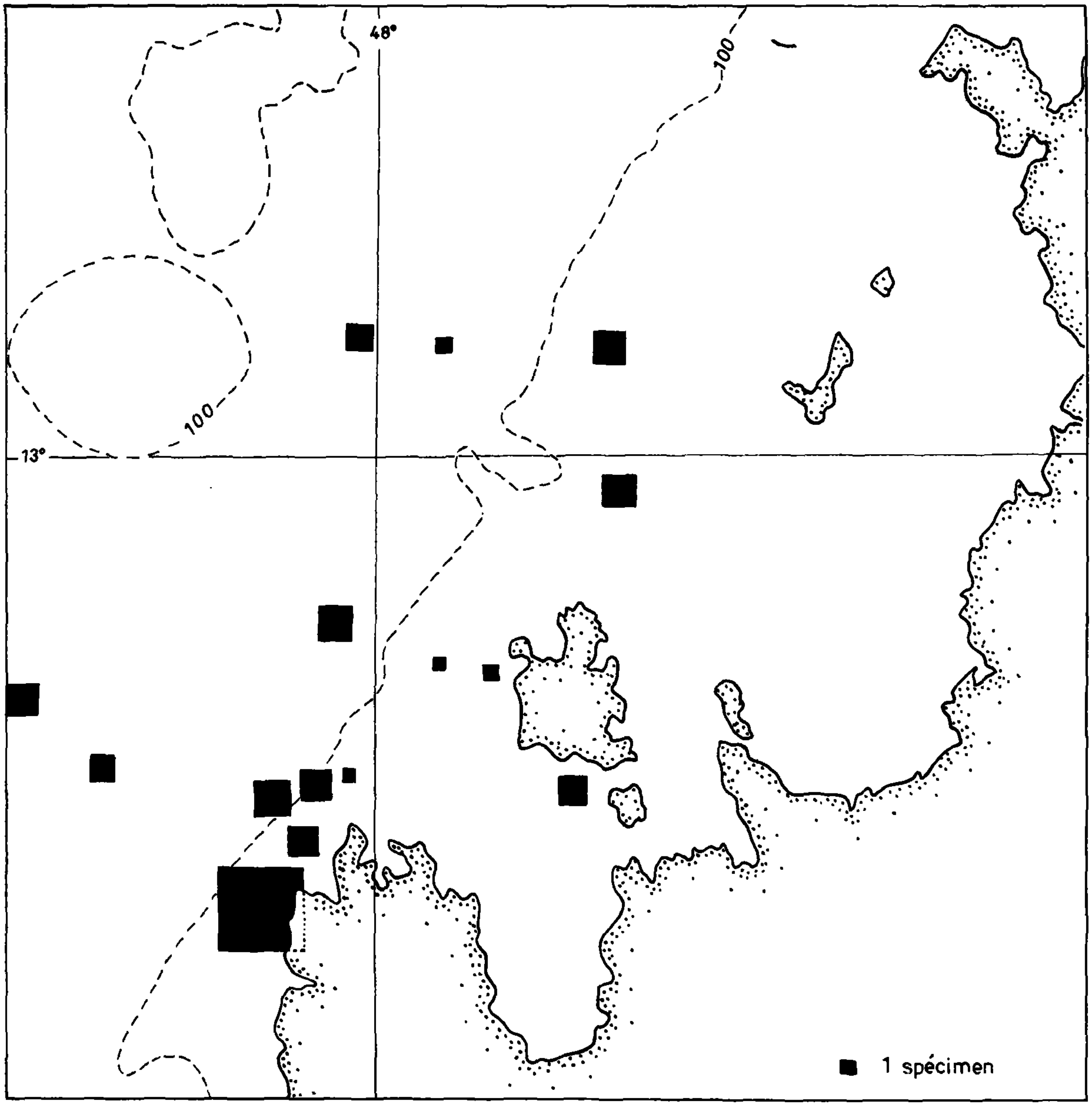

Fig.6 Répartition de *Sagitta hispida* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Sagitta hispida CONANT, 1895

De répartition plus vaste que les deux espèces précédentes, vu que, outre les océans Indien et Pacifique, elle peuple aussi l'Atlantique chaud, *S. hispida* serait donc moins caractéristique de l'Indo-Pacifique. La mention la moins éloignée de Madagascar qui la concerne est celle de DONCASTER (1902) aux îles Maldives et Laquedives.

C'est un hôte habituel de l'épiplancton du secteur de Nosy-Bé puisqu'elle existe, au moins en petit nombre, dans presque tous les prélèvements (fig. 6). On ne sait pas, du reste, pourquoi elle manque dans six d'entre eux (st. 28, 33, 43, 45, 47, 48) dont les conditions (heure et niveau de pêche) n'ont pas différé de celles des stations positives voisines. On peut y voir simplement un effet du hasard qui joue un grand rôle dans les récoltes planctoniques. En revanche, son absence des stations 61 et 69 pourrait s'expliquer par le fait que celles-ci se placent à la limite du plateau continental, alors que *S. hispida* vit habituellement en-deça de la ligne des 100 m. Mais comme nous l'observons ici par des fonds supérieurs à 1000 m (st. 54, 59, 60, 70, 71), nous devons conclure que, comme *S. robusta* et *S. bedoti*, elle ne manifeste pas un comportement bien tranché dans cette région. C'est ce que traduisent aussi les valeurs moyennes très proches des récoltes effectuées en-deça et au-delà de la ligne des 200 m, que l'on peut prendre comme limite entre les zones néritique et océanique.

Fonds	Nombre moyen de spécimens par pêche
de 20 à 200 m	5,8
> 200 m	5,6

Les températures et salinités précédemment notées pour le secteur de Nosy-Bé correspondent à peu près à celles de la zone tropicale africaine où *S. hispida* pullule. Sa présence ici n'a donc rien que de très normal.

Stade I : 38,5 %
Stade II . 35,6 %
Stade III . 25,5 %

D'après la répartition numérique des différents stades de maturité sexuelle, on constate que cette population comporte une majorité de jeunes. Néammoins, on observe généralement des individus aux trois stades dans chaque prise, signe que l'espèce se reproduit et effectue son développement complet en tous points de la zone prospectée.

Sagitta regularis AIDA, 1897

Avec *S. regularis* nous avons une forme de l'Indo-Pacifique et de la Mer Rouge, dont la mention la plus proche de Madagascar a été faite aux îles Maldives et Laquedives par DONCASTER qui note sa faible abondance.

Elle n'est pas très nombreuse non plus dans les eaux malgaches : une centaine d'individus dans ces collections. Ils se répartissent en sept stations de part et d'autre de la ligne des fonds de 100 m. Le point A dans la rade d'Hellville en groupe le plus grand nombre (78). Douze spécimens viennent de trois stations au-dessus de fonds inférieurs à 100 m ; enfin, trois pêches effectuées dans le chenal profond ont rapporté quatorze individus (fig. 7). Ces chiffres inviteraient à la classer plutôt parmi les formes côtières.

De toute manière, il n'est pas douteux que ce soit un hôte de l'épiplancton, comme l'indiquent aussi **Thomson** (1947) pour les eaux australiennes (abondante de 0 à 50 m et en nombre un peu plus faible jusqu'à 100 m) et **Sund** (1961) pour le Pacifique oriental (où elle n'excéderait pas 50 m de profondeur).

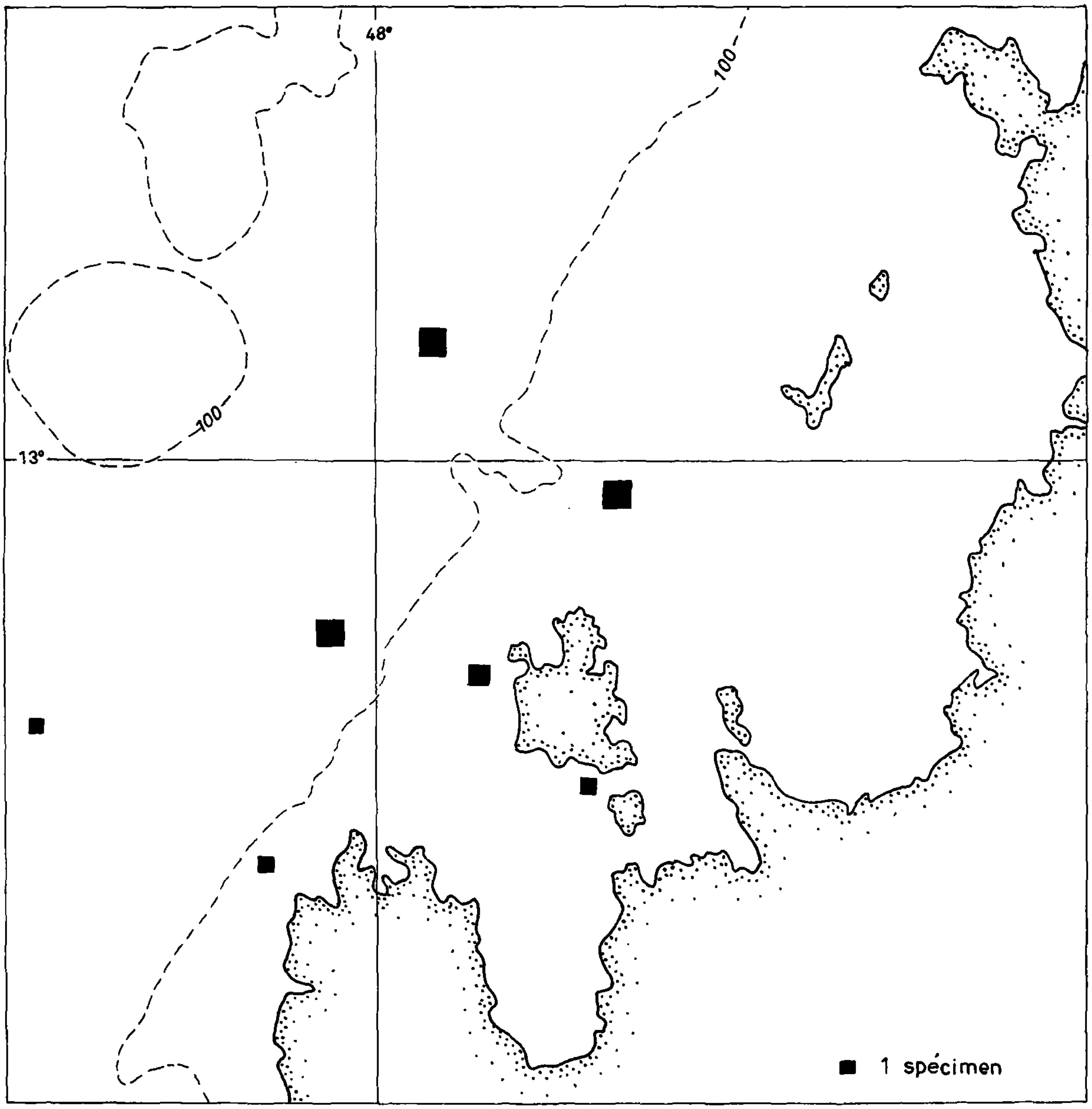

Fig.7 Répartition de *Sagitta regularis* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

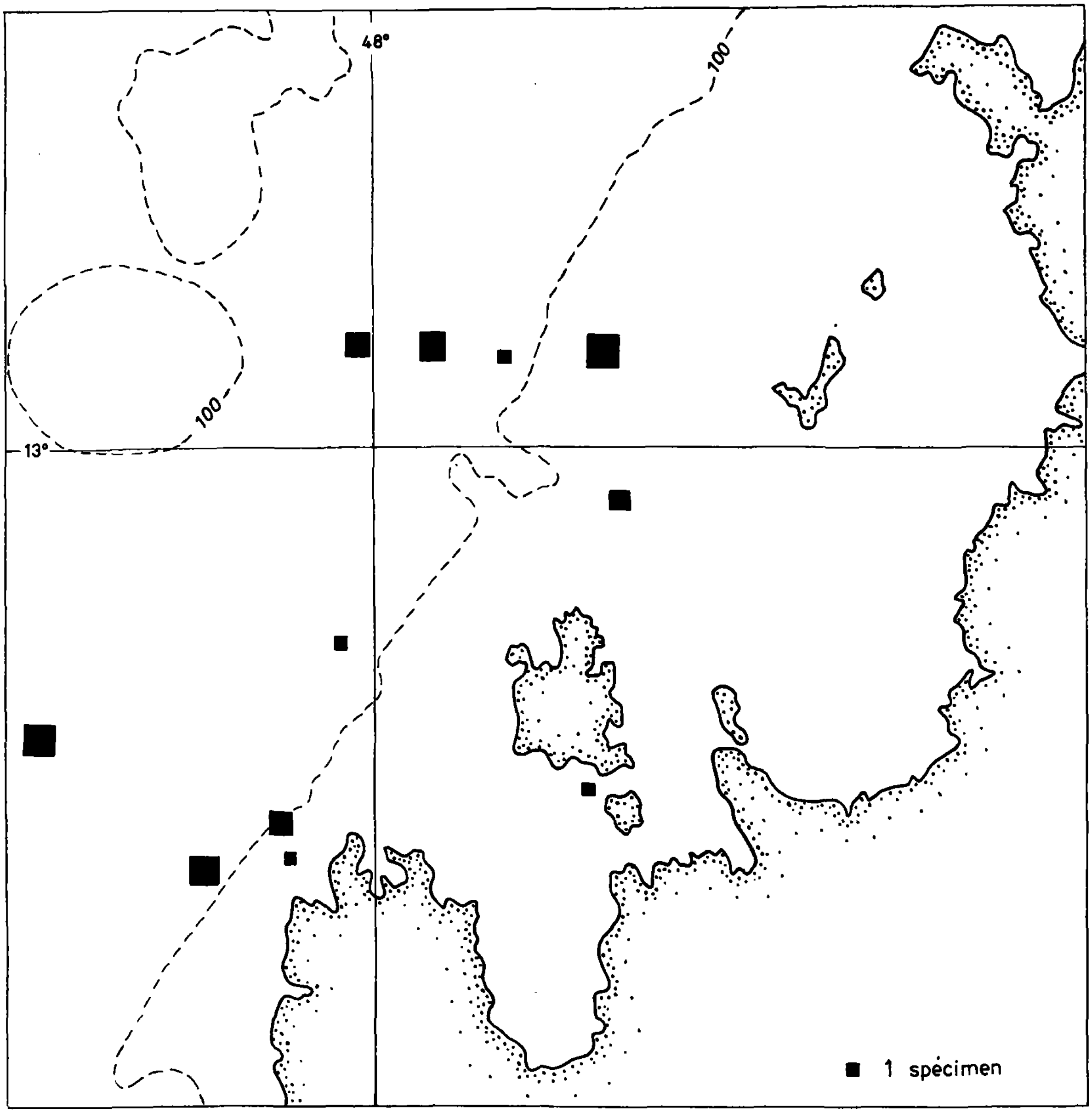

Fig.8 Répartition de *Sagitta pulchra* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Stade I : 67,5%
Stade II : 21,5%
Stade III : 11,0%

La population est constituée essentiellement de jeunes, ainsi que le traduisent les pourcentages des spécimens aux trois stades de maturité sexuelle. On pourrait supposer que les adultes sont moins épiplanctoniques ou moins néritiques que les immatures et donc moins facilement capturés. Or nous avons remarqué qu'ils ne se rencontrent pas indifféremment sur toutes les stations mais surtout en rade d'Hellville, soit sur les fonds les plus faibles, ce qui est en contradiction avec l'idée précédente. Nous nous bornons donc à présenter les faits (tabl. suivant).

Stations en rade d'Hellville n°	26	27	32	37	38	39	40	41	55	56	58	72	73
Stade I	1	4	5	8	2	1	15	2	4	1	1	3	2
Stade II	1		3	6			2	1				7	1
Stade III	2	1		3					1			2	1

Stations sur fonds supérieurs	sur le plateau continental			au-delà du plateau continental		
n°	49	63	65	54	60	71
Stade I	2	7	7	4	4	2
Stade II	1			2	1	
Stade III					1	

Répartition des individus aux différents stades de maturité sexuelle par station, dans la zone littorale, sur le plateau continental et au large.

Sagitta pulchra DONCASTER, 1903

Bien que mentionnée en divers points de la région indo-pacifique, Mer Rouge comprise, *S. pulchra* est une des espèces dont le comportement paraît le plus mal connu. Nous relevons sa présence dans l'ouest de l'Océan Indien aux îles Maldives et Laquedives, où, d'après DONCASTER, elle ne serait pas très abondante. Dans le secteur de Nosy-Bé, elle est aussi en nombre relativement faible : une centaine.

Stade I : 29,2%
Stade II : 30,3%
Stade III : 40,3%

Les trois stades de maturité sexuelle sont à peu près également représentés et répartis de façon assez uniforme sur l'ensemble de l'aire étudiée. Nous avons donc affaire à une population en place et équilibrée, vraisemblablement pérenne.

Les spécimens ont été recueillis pour plus de la moitié en rade d'Hellville (1) : 57 individus sur un total de 95. Onze autres ont été trouvés également sur des stations néritiques et 27 seulement au-dessus de fonds supérieurs à 100 m (fig. 8).

On peut donc supposer que l'espèce est à tendance néritique. Néanmoins on doit dire que, d'après **Thomson** sa répartition entre les stations océaniques et néritiques n'est guère plus nette sur les côtes sud-est de l'Australie.

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(1) Rappelons que 35 pêches sur 53 y ont été effectuées.

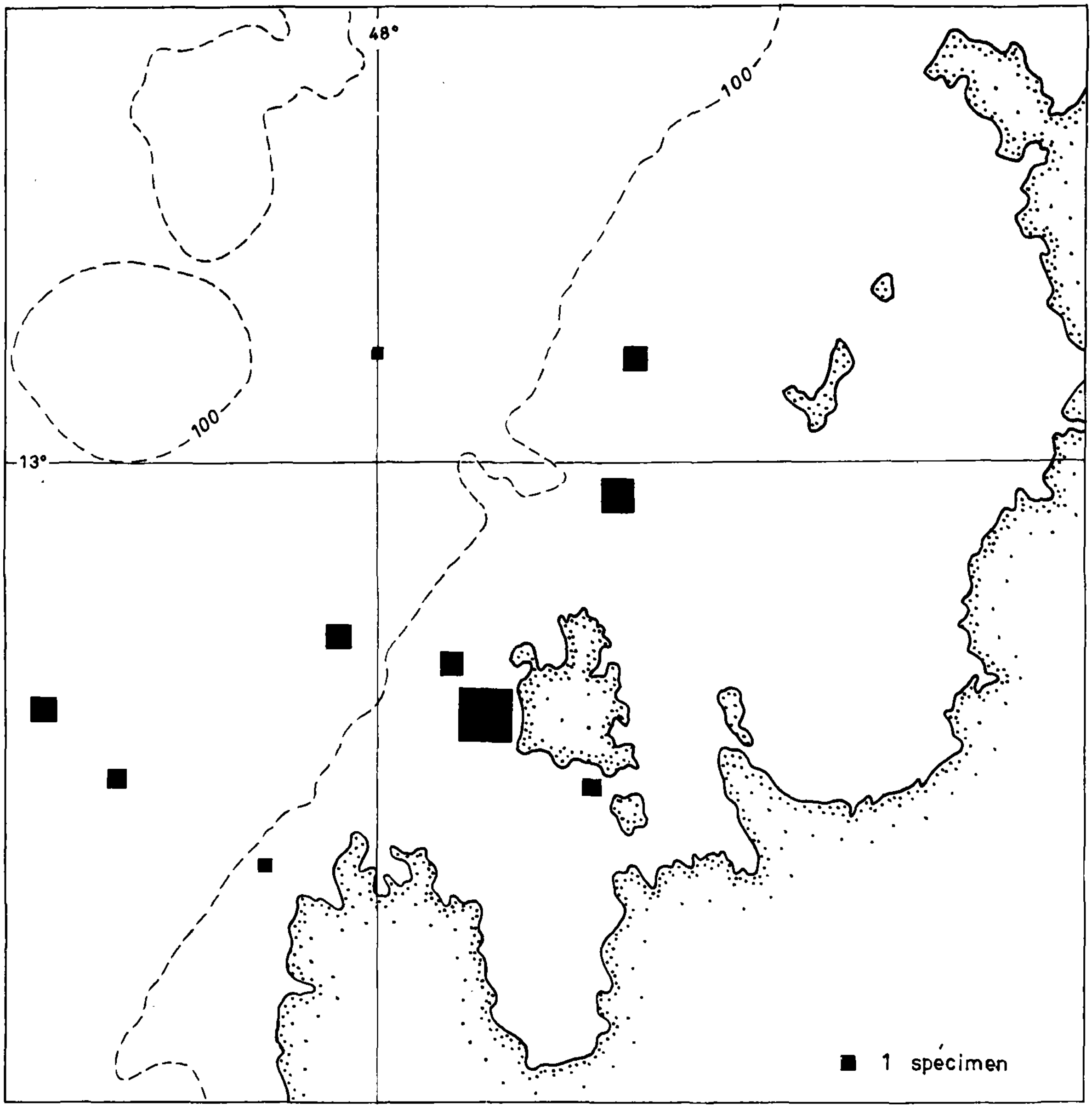

Fig. 9 Répartition de *S. serratodentata pacifica* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Sa répartition verticale y est en revanche bien tranchée ; les individus, nombreux de 0 à 50 m, sont absents des couches sous-jacentes. De même, selon **Ritter - Zahony** (1910), elle se cantonne dans l'épiplancton dans les eaux tropicales de l'Indo-Pacifique. Tout ceci s'accorde avec nos résultats, les récoltes ayant été faites en surface dans le secteur de Nosy-Bé.

Sagitta ferox DONCASTER, 1902

On trouve *S. ferox* dans une grande partie de l'Océan Pacifique, dans l'Océan Indien et en Mer Rouge. On pouvait donc **a priori** penser la rencontrer dans le secteur de Nosy-Bé. Elle y existe effectivement mais en nombre restreint (36 spécimens) et, comme le montrent les chiffres suivants, ce sont surtout des jeunes qui figurent dans ces collections.

Stade I : 38,3 %
Stade II : 41,5 %
Stade III . 19,7 %

D'après les observations faites dans le sud-est australien, *S. ferox* est un peu plus abondante dans les stations océaniques que dans les stations néritiques. Rien de tel n'apparaît ici puisqu'elle n'a été prise qu'en rade d'Hellville. Cependant, on ne peut tirer de conclusion quant à son comportement réel d'une seule pêche positive.

C'est une espèce d'eaux chaudes. **Sund** l'indique sur des stations de 24 à 28° ; pour **Thomson**, abondante de 22 à 25°, elle devient plus rare de 22 à 12°, pour disparaître au-dessous de 12°. Les températures des eaux malgaches devraient donc lui convenir et ce n'est pas le facteur thermique qui est responsable de sa rareté.

Si l'on ajoute qu'elle fait partie de l'épiplancton (abondante de 0 à 100 m d'après les auteurs), elle devrait pouvoir être plus nombreuse dans ces prélèvements superficiels.

A l'issue de cette courte analyse, on ne peut donc que constater, sans l'expliquer, la faible abondance dans le secteur nord-ouest de Madagascar de cette espèce pourtant typiquement *indo-pacifique*.

2) Espèces pélagiques ou à tendance pélagique

Sagitta serratodentata pacifica TOKIOKA, 1940

Il s'agit de la forme à crochets serrulés caractéristique des régions indo-pacifiques (1). Elle est la seule a être représentée dans le secteur de Nosy-Bé et elle est en bonne place dans notre inventaire.

D'après **Thomson** (1947), *elle serait, comme l'ensemble des formes à crochets serrulés,* plus fréquente dans les stations du large. Cela ne ressort nullement de la carte de répartition (fig. 9) ni des résultats chiffrés suivants qui rendent compte de captures plus fortes en moyenne sur le plateau continental qu'à l'extérieur.

Fonds	Nombre moyen de spécimens par pêche
20 - 200 m	3
≥ 1000 m	2,4

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(1) Forme reconnaissable aux dents chitineuses que portent latéralement les vésicules séminales.

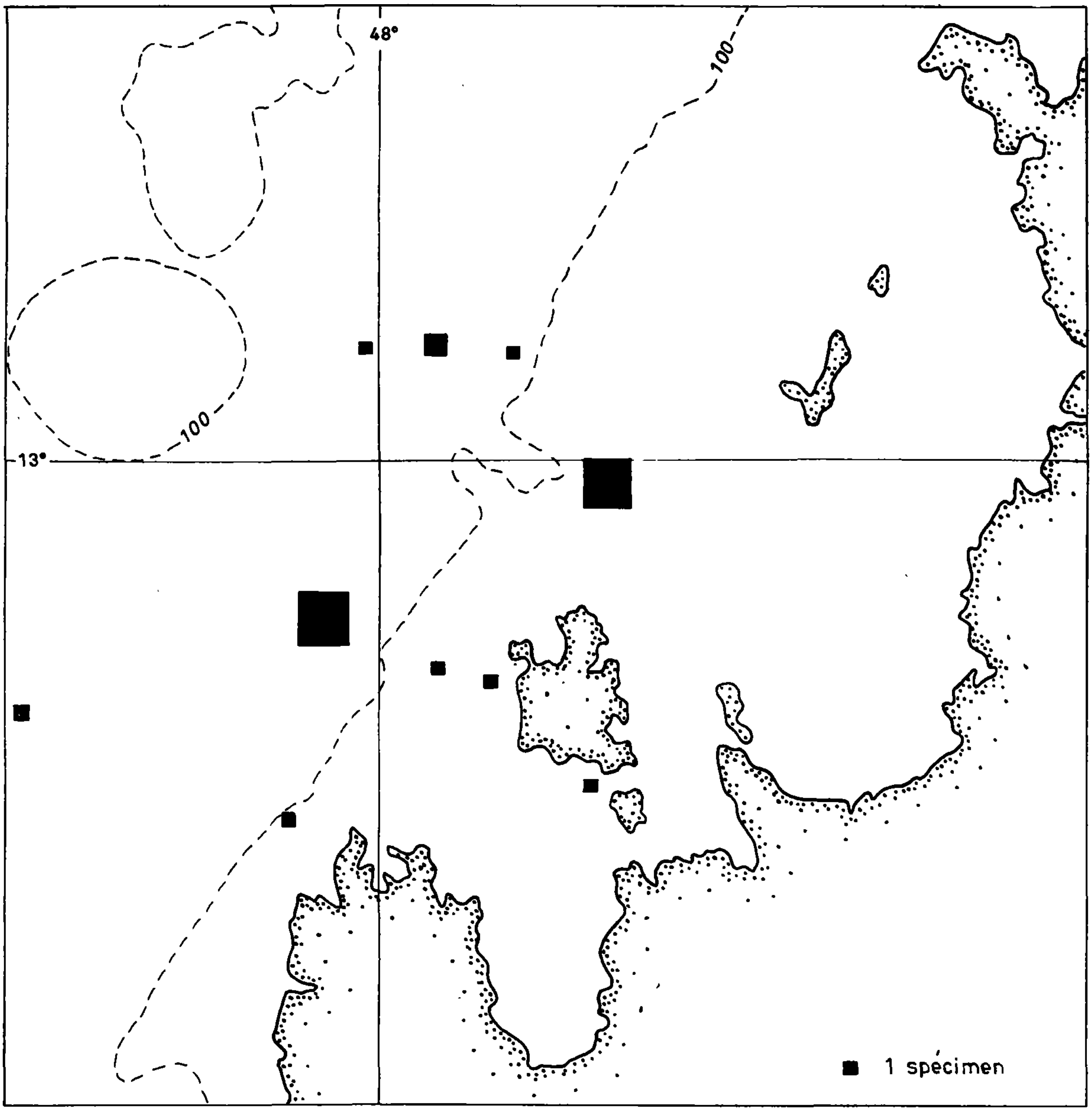

Fig.10 Répartition de *Pterosagitta draco* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Nous verrons qu'il en est ainsi de la plupart des espèces pélagiques rencontrées dans le secteur et nous dirons plus loin ce qu'il faut en penser.

Selon les auteurs, c'est un élément du mésoplancton (abondant de 100 m à 500 m). On peut cependant en rencontrer un nombre important en surface la nuit à la faveur de migrations nycthémérales. C'est la raison de son abondance relative dans ces pêches, toutes superficielles mais nocturnes.

Stade I . 68,6 %
Stade II . 18,4 %
Stade III : 12,8 %

Il semble que les jeunes se tiennent en général à des niveaux beaucoup moins bas que les adultes (**M.-L. Furnestin**, 1957), donnée que confirment celles-ci car nous constatons que le stade I est de loin le plus nombreux dans notre échantillonnage de surface.

Des *individus aux trois stades de maturité sexuelle n'ont été observés conjointement* qu'en rade d'Hellville, avec toutefois une forte prédominance du stade I (67 %, contre 15 et 17% pour les stades II et III).

Quant aux autres stations, quelle que soit leur position par rapport à la côte, elles ne comportent pas d'adultes. Cette répartition est assez surprenante pour une forme pélagique dont on verrait mieux les individus à leur complet développement au large, c'est-à-dire dans le milieu habituel de l'espèce.

S. s. pacifica est un organisme des eaux chaudes, prospérant, par exemple, entre 15 et 25° d'après **Thomson**, 22 et 25° d'après **M.-L. Furnestin**. Elle rencontre des températures de cet ordre dans le secteur malgache.

Sténohaline, elle ne survivrait pas au transport dans des eaux de salinité inférieure à 35 p. 1000 (**Vannucci** et **Hosoe**, 1952) Les teneurs indiquées pour Nosy-Bé, autour de 35 p. 1000, seraient donc juste à la limite de sa viabilité. Mais on doit rappeler que **Clève** (1901) et **Sund** (1961) en ont récolté dans des eaux à 32,4 et 32,6 p. 1000 dans l'archipel Malais et le Pacifique tropical, ce qui laisse supposer que l'on connaît mal encore les caractéristiques de son biotope et qu'il faut se garder de généraliser d'un secteur à l'autre.

Pterosagitta draco KROHN, 1853.

Pterosagitta draco possède une aire de répartition relativement vaste comprenant les régions chaudes des trois grands océans, la Mer Rouge et la Méditerranée. Elle peut être fréquente dans les prises pour une zone donnée mais on la trouve rarement en grand nombre au même point. Aussi considèrerons-nous qu'avec 103 spécimens le secteur de Nosy-Bé est riche.

Les pourcentages des individus aux différents stades de maturité sexuelle montrent une très forte majorité d'immatures. Ceci peut indiquer que l'espèce vient de se reproduire ou bien que, comme en d'autres régions (Atlantique par exemple), les adultes sont beaucoup moins communs en surface que les jeunes, *P. draco étant une forme du mésoplancton.*

Stade I : 84 %
Stade II . 6 %
Stade III : 10 %

Son abondance relativement grande dans ces prélèvements superficiels tient d'ailleurs à ce qu'ils ont été faits de nuit, alors qu'une partie de la population se livre à sa migration nycthémérale.

Il n'en reste pas moins assez étonnant de rencontrer une forme semi-pélagique comme *P. draco* sur des fonds aussi faibles que ceux de la rade d'Hellville par exemple (20 m). Il faut, pour l'expliquer, invoquer l'existence d'un courant en provenance du large qui transporte jusqu'à Nosy-Bé certains éléments plus ou moins pélagiques. Nous développerons cette idée à propos de *S. bipunctata*, Chaetognathe franchement pélagique qui fréquente de la même façon la zone eulittorale aux abords de Madagascar.

En somme, *P. draco* ne paraît pas "à sa place" sur des stations aussi côtières. Du reste, si l'on compare sa répartition (fig. 10) à celles d'espèces réputées néritiques, comme *S. hispida*, ou semi-néritiques, comme *S. enflata* (fig. 6 et 3), on voit que la rade d'Hellville en est beaucoup moins riche. Il semble donc bien qu'elle n'y constitue pas un peuplement permanent mais que sa présence soit le résultat d'un transport.

Pour en terminer avec sa distribution locale, signalons sa coexistence avec *S. minima* (st. 63). On admet en effet que ces deux Chaetognathes, qui dépendent des eaux de pente, ont un comportement similaire et se trouvent souvent dans les mêmes prises. Le fait se vérifie ici.

Les températures dans le secteur de Nosy-Bé sont légèrement supérieures à celles que mentionnent généralement les auteurs pour les stations à *Pterosagitta*, la limite supérieure indiquée par **Thomson** pour les eaux australiennes étant de 25°. En fait, depuis, on a récolté l'espèce en Côte d'Ivoire par 28 à 29°, températures qui sont de l'ordre de celles de l'aire prospectée. On sait d'ailleurs que lorsque la température superficielle devient trop forte (supérieure à 25°), *P. draco* est susceptible de migrer en profondeur (**Thiel**, 1938). Il est donc possible que le peuplement en soit plus dense aux niveaux intermédiaires dans le secteur de Nosy-Bé.

Quant aux salinités de ce dernier (34,89 à 35,15 p. 1000), elles correspondent à celles que les auteurs notent le plus souvent pour l'espèce, mises à part certaines teneurs de la Côte d'Ivoire (33,58) et de la Méditerranée (37) qui paraissent représenter des valeurs extrêmes.

Sagitta minima GRASSI, 1881

L'aire de répartition de *S. minima*, qui s'étend classiquement de 40° N (1) à 40° S, comprend les océans Atlantique, Pacifique et Indien, la Mer Rouge et la Méditerranée.

Nous la signalons pour la première fois du canal de Mozambique mais en un seul exemplaire (st. 63) qui, malgré son état de développement peu avancé (stade I), revêt la forme typique de l'espèce.

S. minima est un organisme à tendance pélagique, ce qui justifierait sa rareté dans ces pêches dont la plupart on été faites dans la partie néritique du secteur considéré, si d'autres Chaetognathes de même tendance n'y figuraient en quantité notable. Sa rareté tient sans doute davantage au fait qu'elle vit plus ou moins en essaims localisés et que des coups de filet isolés peuvent fort bien n'en capturer aucun spécimen s'ils ne touchent pas lesdites concentrations.

Par ailleurs, c'est au-dessus des fonds de 200 - 300m qu'on aurait eu les plus grandes chances d'en rencontrer des peuplements assez denses. Or les prélèvements dans cette zone ont été très limités. Il vaut donc mieux conclure à une absence motivée de l'espèce dans ces pêches qu'à sa rareté effective dans le canal de Mozambique.

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(1) En fait, 45° N dans le Pacifique (BIERI, 1959) et 48° N dans l'Atlantique (J. REYSSAC, 1963)

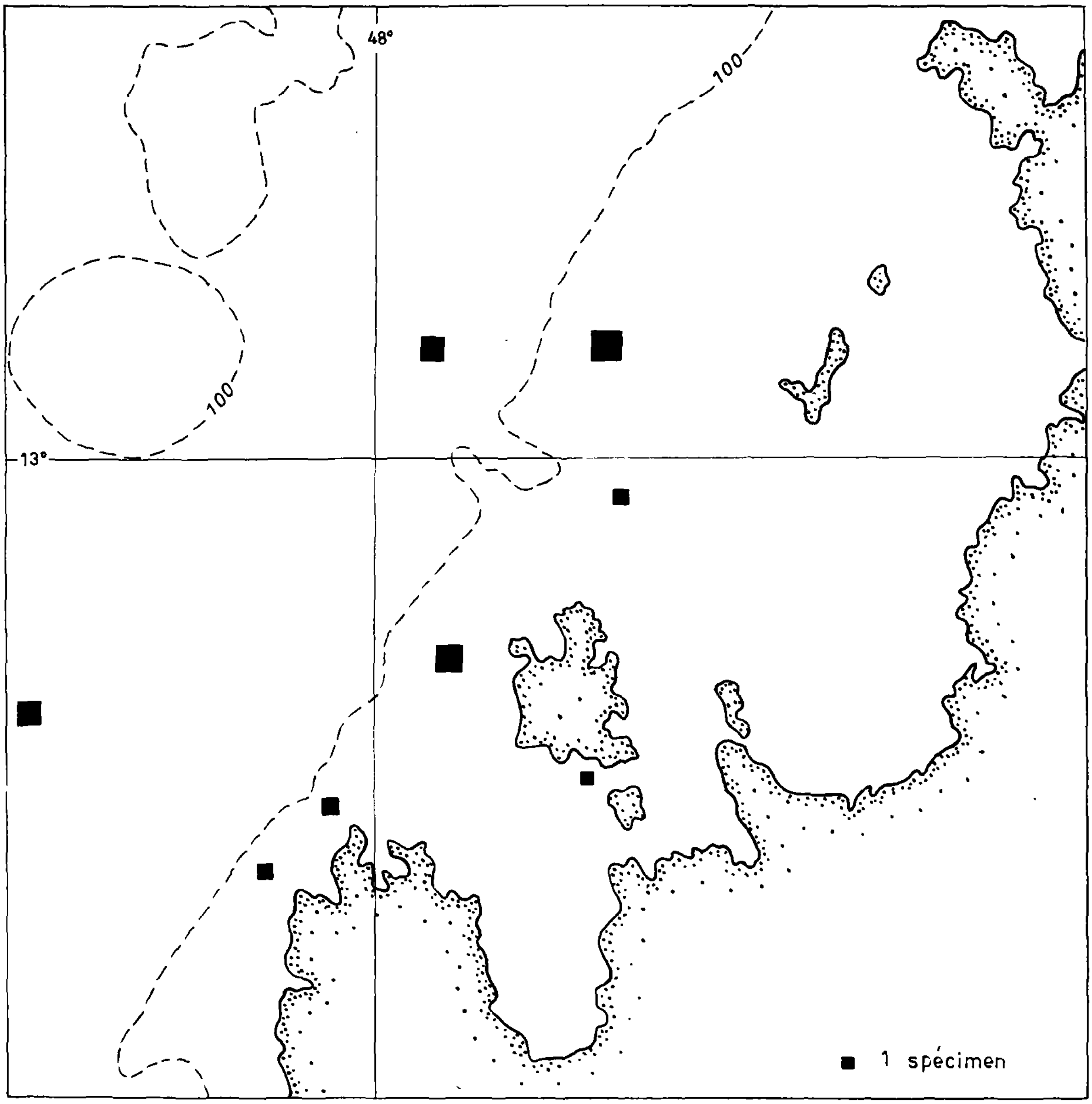

Fig. 11 Répartition de *Sagitta bipunctata* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Il faut remarquer aussi que les températures enregistrées sur l'aire prospectée pendant une période similaire à celle des récoltes (moyennes de 27 à 29°) dépassent celles qui sont reconnues favorables à ce Chaetognathe des eaux tempérées-chaudes (15-20° pour les côtes sud-est de l'Australie, 10-20° dans l'Atlantique, par exemple). Ceci laisserait supposer qu'on pourrait en prendre davantage sur les mêmes lieux en saison "froide".

En accord avec ce que nous disions plus haut de son habitat, soulignons que l'unique spécimen a été capturé à proximité du bord du plateau continental dont la limite s'infléchit précisément à l'est au niveau de la station 63 (fig. 1).

Notons en outre qu'il s'agit d'une pêche nocturne ; en effet, on ne recueille guère *S. minima* en surface que la nuit, moment où elle quitte le talus continental à l'occasion d'une migration nycthémérale relativement régulière.

Sagitta bipunctata QUOY et GAIMARD, 1827

Encore plus vaste que celle de *S. minima*, l'aire de répartition de *S. bipunctata* s'étend normalement de 40° N (1) à 50° S et englobe les trois grands océans, la Méditerranée et la Mer Rouge.

Elle est considérée comme une espèce des eaux tempérées-chaudes de 15 à 25° ; mais elle a été souvent observée par des températures supérieures, de l'ordre de celles du secteur de Nosy-Bé. En revanche, la salinité de son habitat est généralement élevée ; une teneur de 35 p. 1000 semble en être la limite inférieure dans les cas les plus courants. Ce pourrait être une des raisons de sa rareté relative ici où les salures oscillent autour de cette valeur. On peut à ce sujet rappeler qu'elle est également rare dans le golfe de Guinée où les taux de sel sont faibles.

En conditions normales, son abondance et sa fréquence sont toujours plus grandes *dans les stations du large qu'à proximité de la côte ; elle est le type-même des formes pélagiques* de surface. Or, sur les cinq stations de pêche pratiquées au-dessus des grands fonds dans le secteur, deux seulement comportent *S. bipunctata*. Tous les autres spécimens ont été récoltés soit en rade d'Hellville, soit sur le plateau continental (fig. 11). Comment expliquer cette distribution ?

Il faut invoquer les phénomènes hydrologiques caractéristiques de la région. Nous avons indiqué en effet que la zone côtière de Nosy-Bé est influencée par le courant comorien qui amène les eaux du large en direction du sud ouest - nord est et par des courants de marée relativement puissants dont le flux porte à l'est. C'est dans ce déplacement des eaux du large vers la côte qu'il faut voir l'origine de l'existence de *S. bipunctata* aux stations précitées.

Son caractère pélagique demeure néanmoins apparent si l'on fait le calcul du nombre moyen de spécimens pris par station sur le plateau continental et au-delà.

Position des stations	Nombre moyen de spécimens par stations
Sur le plateau continental	0,7
Au-delà du plateau continental	1,6

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(1) La latitude de 58° 50, donnée par FRASER, marquerait la limite extrême de son extension vers le nord sous l'influence de la dérive atlantique.

Les pourcentages des trois stades de maturité sexuelle montrent la prédominance nette du stade I, les immatures représentant plus de la moitié de la population. On peut donc penser que les mois d'octobre à décembre correspondent à une période de reproduction de l'espèce.

Stade I : 52,9 %
Stade II : 23,5 %
Stade III : 23,5 %

On remarque enfin (tabl. ci-après) que les adultes sont pratiquement absents de la rade d'Hellville et localisés au contraire dans une zone moins néritique, ce qui est en accord avec le caractère pélagique de S. *bipunctata*.

N° Stations / Stades	en rade d'Hellville								non situées dans la rade						
	26	29	30	32	36	37	39	44	51	60	62	63	64	67	71
I	1	3	1	1	1	1	1	2	1	1	3	2	1	1	3
II			1	2					2	2	1		1	1	
III				2					2	2	3		1		1

Sagitta hexaptera d'ORBIGNY, 1843

L'appartenance de S. *hexaptera* au mésoplancton profond, voire au bathyplancton, en fait une forme cosmopolite qui vit communément dans les océans Atlantique, Pacifique et Indien, ainsi qu'en Mer Rouge et en Méditerranée.

Elle n'est pas très abondante dans ces pêches (75 spécimens), ce qui n'infirme pas cependant sa présence en quantité plus grande dans le secteur, mais en profondeur. On peut en effet considérer qu'elle n'a été capturée ici qu'à la faveur de la migration nocturne qui amène en surface un certain nombre d'individus, parmi les jeunes surtout. Et l'on note d'ailleurs la prépondérance de ces derniers (stade II, notamment) dans l'échantillonnage, avec des pourcentages de :

21,4 pour le stade I
59,7 pour le stade II
18,8 pour le stade III

Forme profonde, elle apparaît d'ordinaire rarement dans les eaux côtières. Or, elle se rencontre ici à la fois dans les stations néritiques et celles du large, de sorte qu'un regard sur la carte de répartition (fig. 12) la révèle présente pratiquement sur toutes les stations, bien qu'en faible quantité sur chacune. Toutefois, le nombre moyen de spécimens par prélèvement au large (4) est un peu plus élevé qu'en zone côtière (2,6). De plus, il semble que les adultes ou les individus proches de la maturité soient plus nombreux au-dessus de fonds importants (1,33 en moyenne par station) que près de la côte (0,41), fait très normal puisque c'est en profondeur que l'espèce effectue son développement complet.

Cette prédominance de S. *hexaptera* au-delà du plateau continental, bien que légère, laisse penser que les spécimens recueillis en zone néritique y ont été transportés à la faveur des courants déjà invoqués à propos des espèces se trouvant dans des conditions similaires.

Bien que **Fowler** (1906) en fasse une forme eurytherme entre les limites inférieure de 6° et supérieure de 29°, il semble qu'elle soit plutôt, du fait de son appartenance normale au mésoplancton, adaptée à des températures moyennes, comme le traduisent les chiffres suivants : 14°5 à 21°7 (**Tokioka**, 1940); 14° à 22° (**Thomson**, 1947), 14°8 à 21°4 (**M.-L. Furnestin**, 1957), qui concernent les couches superficielles où les auteurs cités l'ont également récoltée. Sa capture d'octobre à décembre dans les eaux malgaches de surface, beaucoup plus chaudes, est vraisemblablement due à la situation nocturne des pêches, l'espèce pouvant se maintenir aux niveaux superficiels en dehors des heures d'ensoleillement.

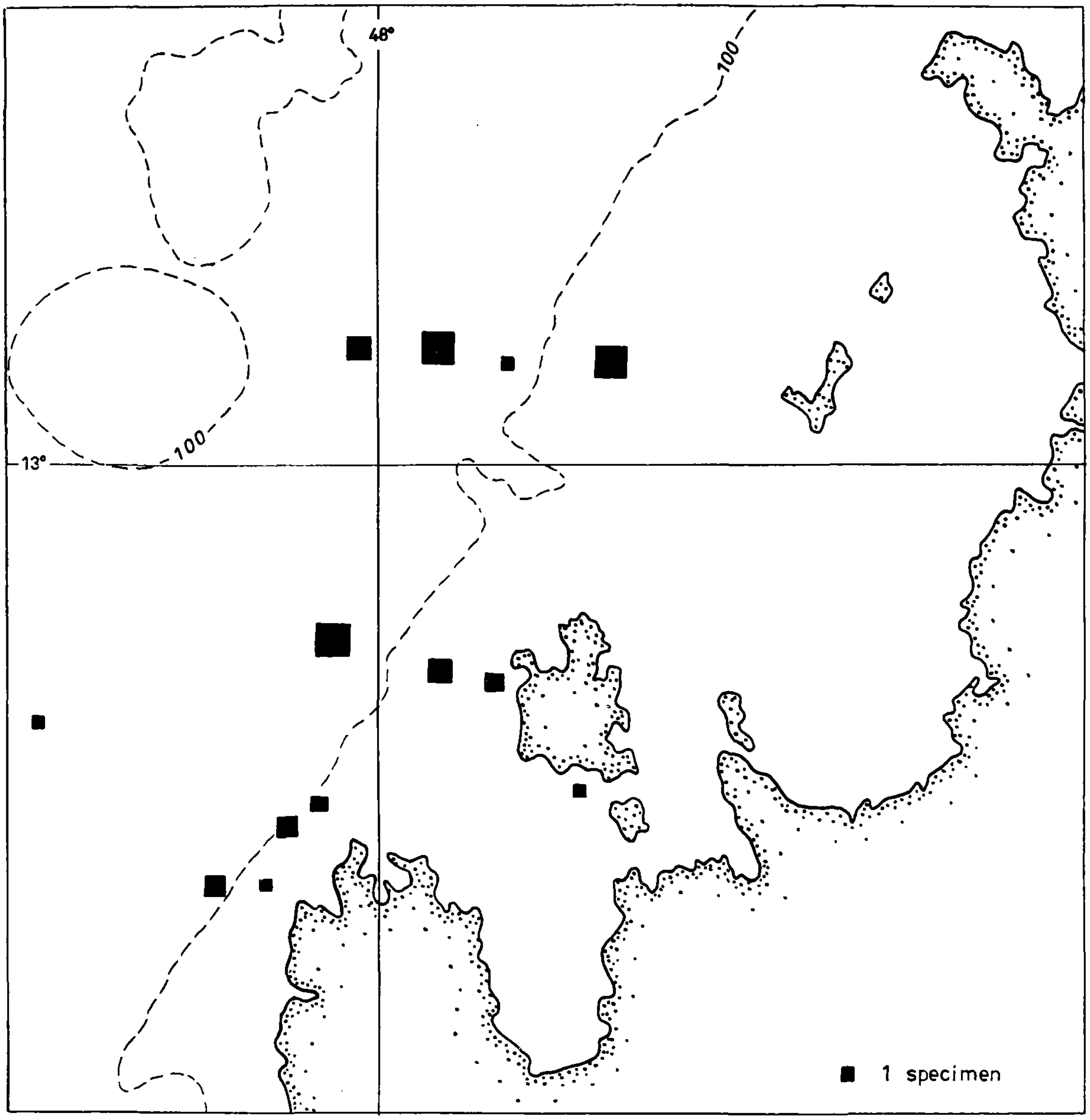

Fig.12 Répartition de *Sagitta hexaptera* dans le secteur de Nosy-Be. Le nombre de specimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

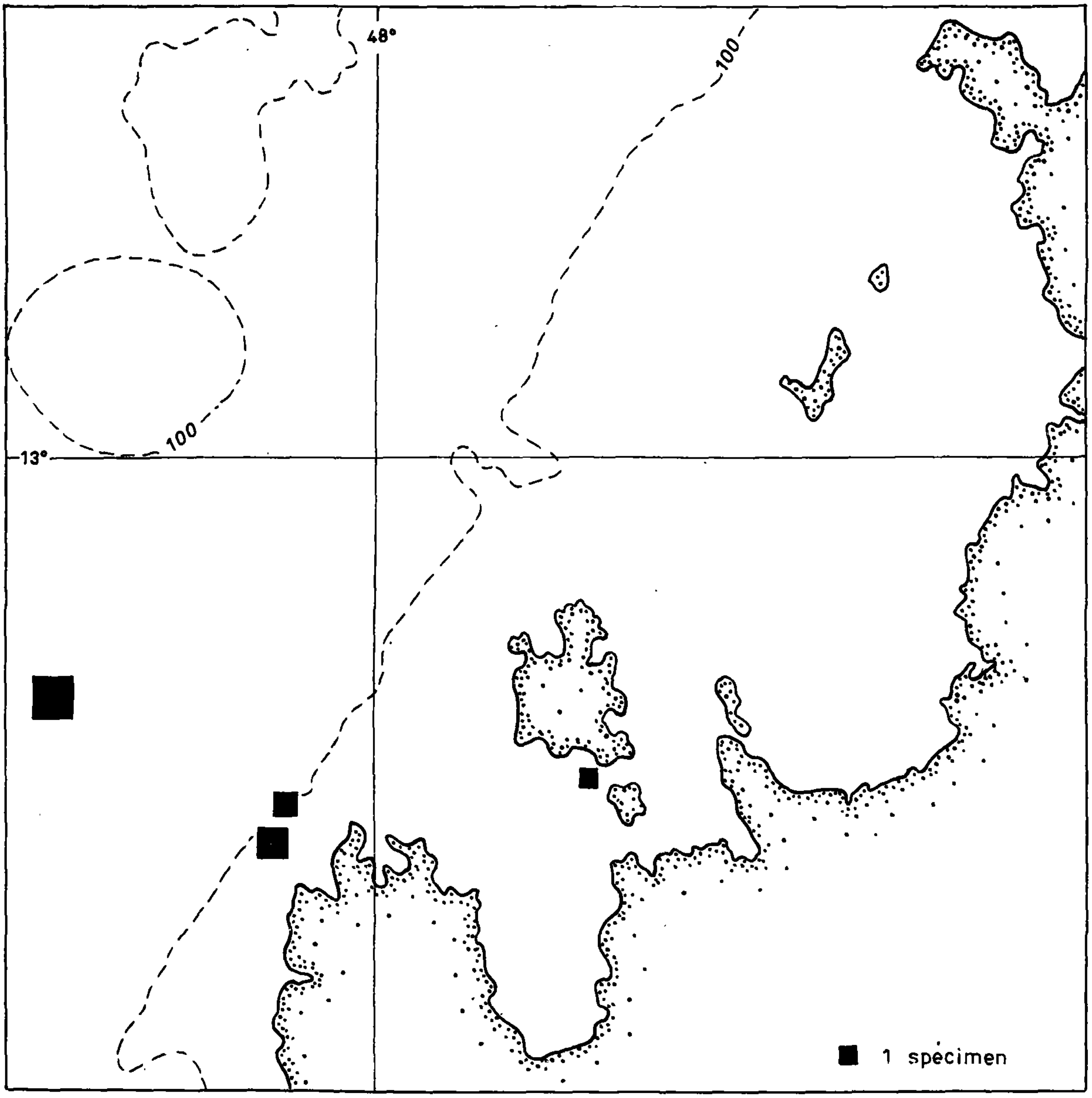

Fig.13 Répartition de *Sagitta planctonis* dans le secteur de Nosy-Bé. Le nombre de spécimens indiqué en rade d'Hellville représente la moyenne des récoltes effectuées au point A.

Sur le plan de la salinité, elle exigerait des conditions assez strictes. **Fowler** et **Tokioka** la considèrent comme sténohaline ; ce dernier indique des teneurs inférieures à 35 p. 1000 pour quelques stations positives ; elle manifeste cependant une certaine tolérance, au moins dans ses stades jeunes, que l'on observe par des salinités excédant 36 p. 1000. Quoi qu'il en soit, les teneurs voisines de 35 p. 1000 du secteur de Nosy-Bé, sont proches de l'optimum qu'on lui prête.

Sagitta planctonis STEINHAUS, 1896

Ubiquiste, *S. planctonis* peuple les trois océans, la Mer Rouge et la Méditerranée.

C'est une des espèces les moins bien représentées dans ces prélèvements (19 spécimens).

Elle est généralement tenue pour une forme du mésoplancton et ne se rencontre pas *normalement dans les stations côtières. Or 14 spécimens du secteur de* Nosy-Bé *ont été* pris au-dessus de petits fonds, dont 9 en rade d'Hellville (fig. 13). Comme pour *S. bipunctata*, *S. serratodentata pacifica*, *P. draco* et *S. hexaptera*, il faut donc faire intervenir les courants dirigés du large vers la côte (sud ouest-nord est) pour expliquer cette répartition

Organisme des couches intermédiaires, elle est adaptée à des températures moyennes. D'après **Thiel**, elle serait rare au-dessous de 10°, nombreuse de 10 à 15° et diminuerait d'abondance de 15 à 20° pour se raréfier encore de 20 à 25°. Dans ces conditions, il n'est pas étonnant que les eaux malgaches de surface en abritent peu pendant la saison chaude.

Les captures ayant eu lieu de nuit, on peut penser que le rafraîchissement superficiel nocturne favorise la montée en surface de quelques éléments à partir des niveaux sous-jacents où il est permis de supposer que la population est plus dense, au moins dans la zone des fonds importants. C'est là que doivent se trouver en particulier les adultes, comme c'est la règle pour les formes profondes de Chaetognathes. Et très rares sont, ici comme ailleurs, ceux qui obéissent au rythme nycthéméral responsable de la migration ascendante des jeunes. Ces derniers constituent en effet l'essentiel des prises, les pourcentages des stades de maturité sexuelle le précisent :

Stade I	: 78,8 %
Stade II	. 15,7 %
Stade III	. 5,3 %

CARACTERES DE LA FAUNE DE CHAETOGNATHES DU SECTEUR DE NOSY-BE

Nous voudrions à présent dégager à partir de nos résultats quelques aspects du peuplement de Chaetognathes de cette région, en relation avec ses principales caractéristiques topographiques, hydrologiques et climatiques.

Ce peuplement est varié, sinon très abondant. En effet l'inventaire, bien que restreint à la région nord-ouest et donc très limité dans l'espace, a permis de mentionner 13 espèces, dont 11 sont citées pour la première fois du canal de Mozambique (seules *S. enflata* et *S. bipunctata* y étaient connues).

Cette variété tient à la proximité des grands fonds, de laquelle résulte aux abords de l'Ile une association complexe de formes néritiques et pélagiques.

L'analyse de la répartition de ces formes donne lieu par ailleurs à des observations assez surprenantes à première vue :

- d'abord, le fait de rencontrer dans la zone eulittorale (rade d'Hellville notamment) des Chaetognathes à tendance pélagique, comme *P. draco*, *S. s. pacifica*, ou foncièrement pélagiques, comme *S. bipunctata*, *S. hexaptera* et *S. planctonis*.

Certes, la topographie sous-marine révélant un chenal profond entre la côte malgache et les bancs situés au nord-ouest de l'Ile, donc au voisinage du secteur de Nosy-Bé, incitait à penser que l'on trouverait une association plus ou moins étroite d'espèces pélagiques et néritiques. Mais, pour expliquer une telle pénétration d'organismes de haute mer à l'intérieur de rades vaseuses, *il faut recourir aux phénomènes hydrologiques locaux. C'est ainsi qu'on peut attribuer* leur présence à un apport d'eau du large en direction sud-ouest-nord-est, vraisemblablement sous l'influence du courant comorien.

Il est assez significatif de noter à ce propos que les Hétéropodes et Ptéropodes se comportent de la même façon que les Chaetognathes et qu'on rencontre, notamment en rade d'Hellville, au moins à certains moments, un mélange tout à fait similaire de formes, les unes relativement côtières, les autres franchement pélagiques (FRONTIER, 1964).

Sans rien vouloir enlever à la réalité du transport précité, il ne faut pas oublier la disproportion accusée entre le nombre de pêches effectuées au large d'une part et dans la zone néritique d'autre part. Cette disproportion fausse quelque peu les résultats. Il est bien évident, en effet, qu'on finira par recueillir un certain nombre d'éléments pélagiques dans un secteur côtier (si léger que soit le transport à la côte) si l'on y multiplie les pêches. Or, il y a eu 35 *récoltes en rade* d'Hellville *contre 6 seulement au-delà du plateau continental*.

- Autre fait surprenant, la répartition quasi-uniforme des espèces dites néritiques (*Sagitta hispida*, en particulier) sur l'ensemble du secteur qui comporte cependant des fonds importants.

Il semble que pour expliquer cette uniformité de distribution, il faille invoquer la bathymétrie propre à la région qui apparaît comme une zone de fonds faibles ou très faibles entaillée par une fosse profonde mais relativement étroite passant par les stations 71, 54 et 59. Les espèces néritiques se trouvant en permanence et en abondance dans les secteurs favorables de part et d'autre de cette fosse, il se peut que des éléments isolés soient entraînés au-dessus des profondeurs plus grandes, donnant l'impression d'un peuplement sans solution de continuité de l'est à l'ouest. Quelques pêches sur les hauts fonds à l'ouest auraient montré sans doute une densité accrue de ces formes côtières par rapport au chenal médian.

En définitive, que ce soit pour des raisons topographiques ou hydrologiques, la faune de Chaetognathes du secteur nord-ouest de Madagascar est difficile à caractériser : il y a coexistence sur bon nombre de stations de formes néritiques et pélagiques de surface ou de profondeur, et, si l'on fait le "bilan" des unes et des autres, on voit qu'elles sont aussi bien représentées :

Espèces néritiques et semi-néritiques	*Sagitta hispida* *Sagitta regularis* *Sagitta robusta* *Sagitta ferox* *Sagitta enflata* *Sagitta pulchra* *Sagitta bedoti*

Espèces à tendance pélagique et pélagiques	*Pterosagitta draco* *Sagitta minima* *S. serratodentata pacifica* *Sagitta bipunctata* *Sagitta planctonis* *Sagitta hexaptera*

Le fait que toutes les récoltes aient été pratiquées de nuit devait d'ailleurs accentuer ce mélange en assurant la capture d'individus du mésoplancton soumis au rythme nycthéméral.

Néanmoins, parmi cet ensemble complexe, un élément se distingue par sa très grande abondance et sa présence sur toutes les stations ; c'est *S. enflata* dont on peut dire qu'elle est, et de loin, l'espèce dominante du secteur.

On a remarqué d'autre part qu'en dehors même des formes profondes, telles que *S. hexaptera* et *S. planctonis* dont il est normal de n'observer en surface qu'un nombre minime d'adultes, il y avait ici, pour la plupart des espèces, une très forte prédominance d'immatures (stade I) ou au moins de jeunes (stade II). Si bien que l'on peut envisager de placer aux mois d'octobre, novembre et décembre, c'est-à-dire au début de la saison chaude et pluvieuse, une période de reproduction pour de nombreux Chaetognathes, notamment *S. robusta, S. bedoti, S. enflata, S. bipunctata.*

Les quelques aspects sous lesquels nous venons de décrire la faune de Chaetognathes du secteur de Nosy-Bé concernent bien entendu uniquement la saison correspondant aux prélèvements, soit les premiers mois de l'été austral. Il se peut qu'en hiver, avec l'inversion du régime des moussons, dont l'influence sur le milieu marin n'est pas négligeable, sa composition se modifie sensiblement et il serait du reste intéressant de pouvoir le vérifier par l'examen de pêches hivernales.

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ANNEXE

Données morphologiques

Parmi les treize espèces identifiées dans ces prélèvements, plusieurs, qui ont été souvent et longuement décrites d'après des spécimens d'origine très différente, sont bien connues. Il ne reste guère à dire sur leurs caractères morphologiques et nous nous bornerons à renvoyer aux travaux dans lesquels elles ont été particulièrement étudiées, ou qui concernent plus spécialement des exemplaires de l'Indopacifique (1).

Ces espèces sont les suivantes :

Sagitta enflata
Sagitta hispida
Sagitta bipunctata
S. s. pacifica
Sagitta minima
Sagitta planctonis
Sagitta hexaptera
Pterosagitta draco

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(1) On pourra consulter à leur propos les auteurs ci-après qui figurent en bibliographie :
DAVID (1956) - FURNESTIN (1957, 1958, 1959)
GEORGE (1952) - GHIRARDELLI (1948)
JOHN (1933) - JOHNSTON et TAYLOR (1929)
MICHAEL (1911) - RITTER-ZAHONY (1909, 1913)
SUAREZ CAABRO (1955) - THOMSON (1947) - TOKIOKA (1955, 1959).

Fig.14 *Sagitta pulchra*. De gauche à droite, spécimens aux stades I, II, et III de maturité sexuelle (x 12).

Fig.15 *Sagitta pulchra.* Tête montrant les crochets écartés les dents antérieures et postérieures (estompées) et le pharynx par transparence (x 35).

Fig.16 *Sagitta pulchra.* Collerette vue de la base de la tête à la partie antérieure du tronc (x 270). On remarque un bouton sensoriel marginal et les ponctuations caractéristiques.

Les cinq autres espèces, en raison de leur absence des eaux atlantiques et méditerranéennes, ont été l'objet d'un nombre de travaux plus restreint et nous sont moins familières. Nous leur avons donc consacré une attention particulière et donnons pour chacune les caractères propres aux échantillons malgaches, accompagnés de photographies et dessins pour la plupart inédits.

Sagitta pulchra

On fera une description assez complète de *S. pulchra* (fig. 14) dont la morphologie n'a été encore qu'assez succintement analysée (1).

Le corps, *transparent, rappelle un peu celui de S. enflata mais il est plus rigide.* Il est recouvert de papilles sensorielles, très nombreuses dans sa moitié antérieure. La taille des spécimens va de 11 à 18 mm.

Le segment caudal représente moins de 20 % de la longueur totale chez l'adulte. La constriction au niveau du septum caudal est légère.

La tête (fig 15) est courte, relativement large; cependant elle ne déborde pas la partie supérieure du tronc quand les crochets sont repliés . Dimensions moyennes : hauteur : 4,5 % LT ; largeur au sommet : 1,8 % LT ; largeur à la base : 5,9 % LT.

Les yeux occupent une position basale. Ils ont une tache pigmentaire massive bordée, sur la face externe, de cellules allongées et, sur sa face interne, de cellules triangulaires plus petites (fig. 25 A).

Les dents antérieures (4 à 6) sont courtes, incolores, souvent difficiles à compter ; **les dents postérieures** (9 - 12) sont jaune clair et beaucoup plus longues. Les crochets (6 - 7), *indifféremment repliés contre la tête ou écartés en éventail sur les exemplaires fixés,* sont jaunes et légèrement renflés à la base.

Il n'y a pas de **diverticules intestinaux.**

Le cou est peu marqué. Il est doublé d'une **collerette** étroite, de structure voisine de celle de *S. bipunctata* . elle présente des ponctuations régulières qui apparaissent comme les noyaux granuleux de cellules arrondies (fig. 16) , elle est parsemée sur toute sa surface de boutons épidermiques garnis de poils sensoriels et s'étend du cou à l'extrémité antérieure du ganglion ventral, soit sur près de 25 % LT, mais elle ne dépasse en aucun cas le ganglion.

Les nageoires antérieures prennent naissance au niveau de la base du ganglion nerveux ou légèrement en avant et font près du tiers de la longueur totale. Elles se prolongent jusqu'au voisinage du sommet des ovaires lorsqu'ils sont mûrs. Elles sont dépourvues de rayons dans la zone attenante au corps ; leur longueur fait plus du double de celle de la paire postérieure.

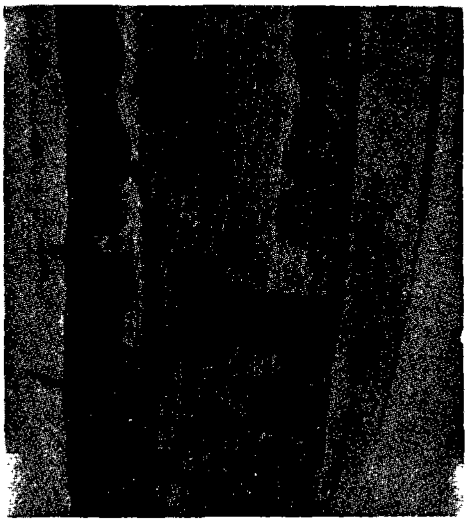
Les nageoires postérieures sont triangulaires et dépourvues de rayons le long du corps, *dans la partie antérieure. Elles atteignent au maximum* 14,0 % LT *et se trouvent pour moitié au* moins situées sur le segment caudal.

La rame caudale, outre les rayons qui la soutiennent, porte 8 boutons épidermiques : 4 sur sa marge postérieure et deux paires de part et d'autre de la pointe de la queue.

---

(1) Voir cependant FOWLER (1906), RITTER-ZAHONY (1913), JOHNSTON et TAYLOR (1929), GHIRARDELLI (1948), GEORGE (1952).

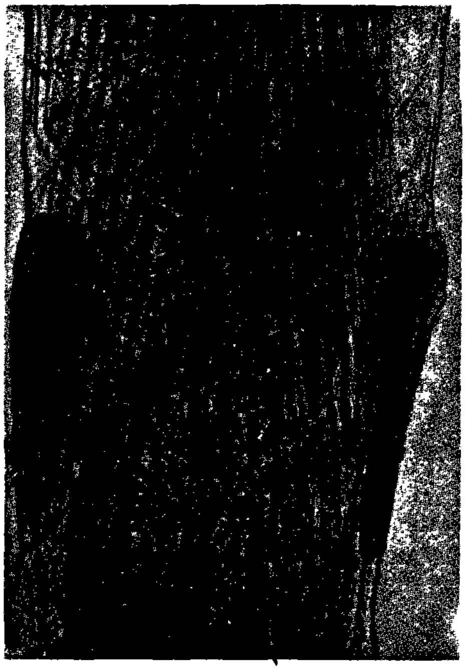
a)



b)

Fig.17 *Sagitta pulchra*. Ovaire (x 40) : a) à gauche, stade II (ovocytes accompagnés de quelques œufs mûrs ; réceptacles séminaux) ; b) à droite, stade III (œufs mûrs nombreux, ovocytes rares).

Fig.18 *Sagitta pulchra*. Vésicules séminales (x 100) : a) à gauche, stade II ; b) à droite, stade III.



a)

b)

Les ovaires mûrs restent minces et de longueur moyenne (moins de 25% LT) puisqu'ils se terminent à peu près au niveau de la base des nageoires antérieures. Au stade I, les ovaires étant filiformes et très courts, les ovocytes ont tous mêmes dimensions (0,02 mm de diamètre) Au stade II, on distingue un mélange d'ovocytes plus ou moins gros, les plus volumineux ayant 0,21 mm de diamètre et les petits, plus nombreux, 0,03 mm. Les réceptacles séminaux sont alors bien visibles (fig. 17a). Au stade III, les ovaires sont presque complètement remplis de gros oeufs, de diamètre assez variable cependant, puisque, chez certains spécimens, ils sont moins volumineux qu'au stade précédent, avec 0,12 mm de diamètre seulement. On peut donc supposer que les premiers ovocytes arrivés à maturité sont immédiatement expulsés. Les oeufs mûrs sont régulièrement disposés sur toute la longueur de l'ovaire, généralement sur une seule file (fig. 17b).

Les vésicules séminales sont représentées au stade I par un simple épaississement épidermique ; minces et allongées au stade II, elles sont presque sphériques à maturité (fig. 18a et b). *Elles sont en contact avec la rame caudale mais non avec les nageoires postérieures.*

Mensurations et numérations		stade I	stade II	stade III
Longueur totale (mm)		11	15 - 17	17 - 18
Hauteur de la tête	%LT	4,9	4,4	4,2
Segment caudal		23,8	19,2	17,9
Nageoires antérieures		28,5	34,8	32,1
Nageoires postérieures		14,0	13,4	12,1
Ovaires		3,8	13,2	21,4
Nombre de crochets		6 - 6	6 - 7	6 - 6
Nombre de dents antérieures		4 - 4	5 - 6	5 - 5
Nombre de dents postérieures		9 - 10	11 - 12	9 - 10

Quelques caractéristiques de *S. pulchra* du secteur de Nosy-Bé, aux différents stades de maturité sexuelle.

Sagitta bedoti

S. bedoti est assez bien représentée dans cette collection pour que nous puissions indiquer quelques-uns de ses caractères.

Les individus mesurent de 9 à 11 mm. Le corps est opaque. La tête (fig. 19), quoique peu volumineuse, possède une armature importante comprenant 7 à 8 crochets, 10 à 13 dents antérieures et 20 à 30 dents postérieures. Le nombre élevé des dents est du reste un de ses meilleurs caractères de diagnose parmi les espèces indo-pacifiques.

Les yeux sont placés à distance à peu près égale entre le sommet et la base de la tête. La tache pigmentaire vue de face se divise en trois branches, 2 branches verticales épaisses, digitées aux extrémités et une, latérale, plus mince. Elle est bordée de cellules allongées et espacées (fig. 25B).

Les avis des auteurs divergent quelque peu quant à l'existence d'une collerette chez *S. bedoti*. Ces spécimens portent au niveau du cou un épaississement tégumentaire plutôt qu'une véritable collerette.

Fig.19 *Sagita bedoti.* Tête (x 40). On distingue les yeux, les dents postérieures très nombreuses et la base de quelques crochets.

Fig.20 *Sagitta bedoti.* Ovaires au stade II, remplis d'ovocytes (x 35).

Fig. 21 *Sagitta bedoti.* Vésicule séminale droite, au stade III (x 140). Noter les relations entre les nageoires postérieures, les vésicules et la rame caudale.

Fig. 22 *Sagitta ferox*. Tête et partie antérieure du tronc. Latéralement, on distingue la collerette.

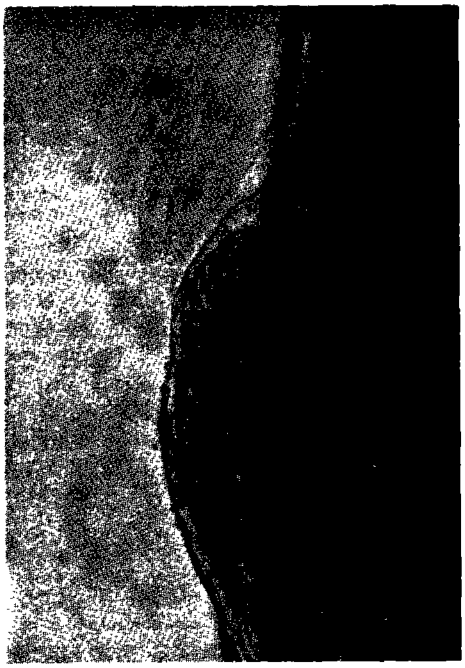


Fig. 23 *Sagitta ferox*. Vésicule séminale gauche, au stade II. Noter les relations entre les nageoires postérieures et les vésicules.

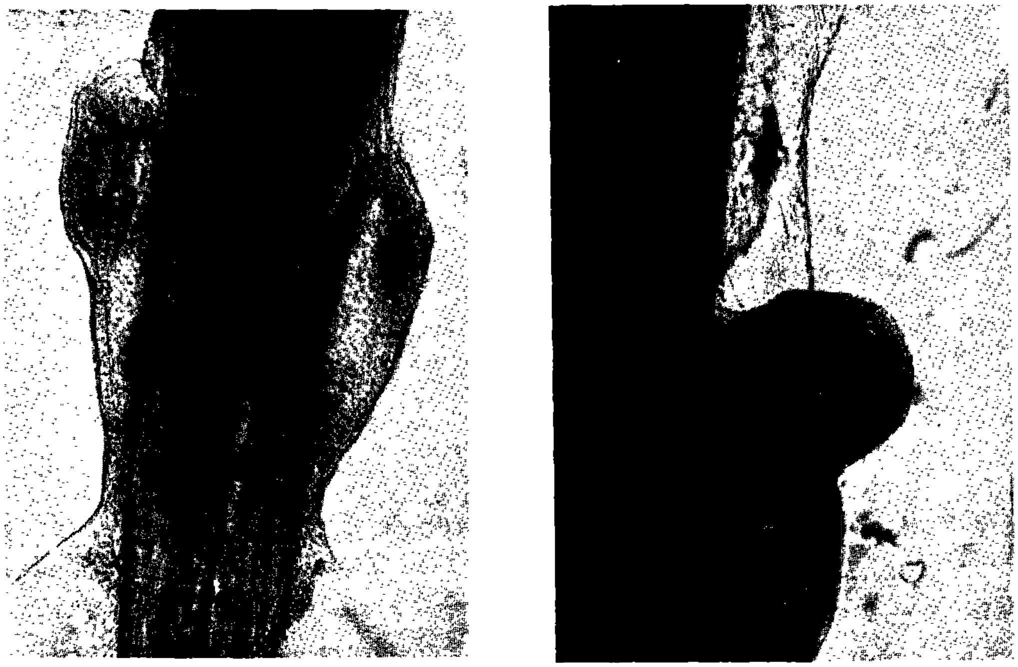


Fig. 24 *Sagitta robusta*. Vésicules séminales (x 110) : a) à gauche, stade II ; b) à droite, stade III. Noter les relations entre nageoires postérieures et vésicules ainsi que le bourrelet formé par la collerette au-dessus de ces dernières.

On n'observe pas de diverticules intestinaux.

Les nageoires antérieures, longues, commencent à l'extrémité postérieure du ganglion ventral. Sur les nageoires postérieures, qui s'étendent pour une bonne part sur le segment caudal, on compte des boutons épidermiques en nombre variable, le plus souvent 4. Les deux paires de nageoires sont dépourvues de rayons le long du corps dans leur moitié antérieure. La rame caudale, triangulaire, présente en général 8 boutons épidermiques.

Chez les individus dont les organes génitaux mâles sont à leur maximum de développement, nous n'avons observé que des ovaires courts remplis d'oeufs, petits et très nombreux (fig. 20) ; la protérandrie paraît donc accentuée chez *S. bedoti* car, bien que nous n'en ayons pas vu de plus développés, il semble que de tels ovaires ne représentent pas le stade III.

Les papilles génitales s'ouvrent au niveau de la zone dépourvue de rayons des nageoires postérieures. Les vésicules sont très proches de ces dernières mais on peut considérer qu'elles ne les touchent pas exactement, alors qu'elles sont en contact avec la rame caudale par une bandelette tégumentaire. Au stade III, elles sont très saillantes et globuleuses, sans "tête" différenciée (fig. 21).

Sagitta robusta DONCASTER et ***Sagitta ferox*** DONCASTER

Créées en 1902 par le même auteur, ces deux espèces ont plus tard été mises en synonymie mais sont actuellement à nouveau distinguées. Un travail récent (**A. Alvarino**, 1962) leur a été consacré, qui fait état des données antérieures (**Doncaster, Michael**, **Fowler**, , **Tokioka**) et auquel nous renvoyons pour l'etude comparative d'ensemble des deux espèces. Nous ne signalerons ici que quelques particularités apparentes sur nos spécimens et qui peuvent aider à séparer ces deux Chaetognathes très voisins.

Les nageoires antérieures sont plus courtes que les nageoires postérieures chez *S. robusta* ; elles sont plus longues chez *S. ferox*.

- La collerette, bien développée jusqu'au ganglion ventral (fig. 22), se prolonge plus "discrètement" jusqu'aux vésicules séminales, au dessus desquelles elle s'épaissit chez *S. robusta* en une sorte de bourrelet (1) (fig. 24 b) dont la présence est irrégulière (sinon contestable) chez *S. ferox*.

Le contact des vésicules séminales avec les nageoires postérieures est étroit chez *S. robusta* et se manifeste dès le stade II dans la zone d'insertion des nageoires (fig. 24 a). Par la suite, il y a même recouvrement de la tête des vésicules par le bord externe plus ou moins effilé des nageoires (fig. 24 b). On peut admettre au contraire qu'il n'y a pas véritable contact des vésicules séminales et des nageoires postérieures chez *S. ferox* (fig. 23) ; ce serait une différence notable entre les deux formes.

- Les vésicules séminales mûres ont, en outre, une tête plus saillante chez *S. robusta*.

- La tache pigmentaire de l'œil de *S. robusta* est assez typique . divisée en cinq branches épaisses, dont quatre presque coalescentes, et bordée de cellules allongées très caractéristiques sur sa face externe, de cellules beaucoup moins hautes et plus régulièrement disposées sur sa face interne (fig. 25 C).

Sagitta regularis AIDA

Bien que *S. regularis* ait été décrite de façon détaillée (**Fowler** 1906, **Johnston** et **Taylor** 1929, **Ghirardelli** 1948, **George** 1952, **M.-L. Furnestin** 1958), nous relèverons quelques-uns des caractères des échantillons malgaches.

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(1) Un bourrelet de ce type existe aussi chez *S. bipunctata*, mais il n'est pas recouvert par les nageoires postérieures, comme chez *S. robusta*

Ceux-ci mesurent de 7 à 10mm. Le corps est rigide, opaque, garni de nombreuses papilles sensorielles.

La tête est munie de 7 crochets, 5 dents antérieures, 9 - 10 dents postérieures. Les yeux ont des taches pigmentaires étoilées, volumineuses, entourées de petites cellules arrondies (fig. 25D).

La collerette forme capuchon autour de la tête et s'étend au moins jusqu'au ganglion ventral. Elle porte des soies sensorielles raides fixées sur des boutons épidermiques à base large.

Les nageoires antérieures sont courtes ; celles de la paire postérieure sont une fois et demie plus longues ; elles se trouvent pour les trois quarts sur le segment caudal et sont séparées des premières par un intervalle égal au tiers environ des nageoires antérieures. La rame caudale possède 6 boutons épidermiques.

Le tube digestif présente des diverticules intestinaux.

Les ovaires peuvent aller jusqu'au ganglion ventral à maturité. Le diamètre moyen des œufs est de 0,16mm au stade III.

Les vésicules séminales sont allongées, même à leur complet développement ; elles sont en contact avec les nageoires postérieures et caudale.

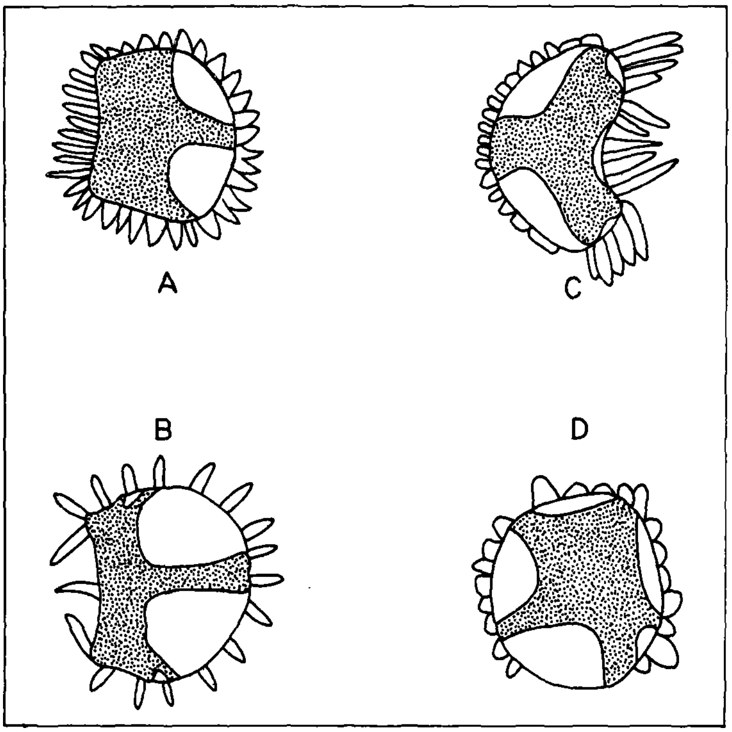


Fig.25 Détail de l'œil
A : *Sagitta pulchra* (x 1 300). B : *Sagitta bedoti* (x 1 200).
C : *Sagitta robusta* (x 1 000). D : *Sagitta regularis* (x 1 200).

TABLE DES FIGURES

Reprinted from *Ibis*, no. 108, 1966, p. 224-264

THE SEA-BIRDS OF THE SOUTHEAST COAST OF ARABIA

Roger Bailey

Received on 7 April 1965

INTRODUCTION

No systematic work on the oceanic ranges of sea-birds or their ecology has previously been undertaken in the tropical Indian Ocean. This is reflected in the scant knowledge of most species which occur there, and in the fact that two forms of Procellarii, new to science, have been described from the Indian Ocean in the past 11 years. One of these, Jouanin's Petrel *Bulweria fallax*, is known to occur in the area considered in the present paper (Jouanin 1957).

The ornithology of the northern Arabian Sea is important for two reasons. Large concentrations of sea-birds are known to occur there (Bourne 1963) and several forms of sea-birds are endemic to the area. Although no detailed accounts have been published, several observations have suggested that increased organic production resulting from upwelling of sub-surface water, first described by Bobzin (1922), ultimately supports the large populations of sea-birds (Brongersma 1947, Parquin 1951, Meinertzhagen 1954, Jouanin 1957, Bourne 1963).

The purpose of the present work has been to describe the marine avifauna of southeast Arabia and to examine the relationships between sea-bird distribution and an upwelling area off the Arabian coast. This has been made possible by my participation in an oceanographical survey of the area on board the R.R.S. ' Discovery ' during the International Indian Ocean Expedition.

The area considered in the present paper extends along the Arabian coast from Ras Fartak to Ras al Hadd (52° E. to 60° E.) and to about 200 miles offshore (Fig. 1). As the seaward limit, thus defined, is not a natural one, frequent references have been made to adjacent sea areas. Peters' (1931, 1934) nomenclature has been used throughout except as mentioned in the section on species' distribution. Although new English vernacular names have recently been proposed for several species I have decided to use those given by Alexander (1955). All references to seasons of the year apply to those of the northern hemisphere.

MATERIAL AND METHODS

The present paper is based on my own observations from ' Discovery ', but also summarizes other published and unpublished data. From 23 June to 20 August 1963, a survey was carried out on the ' Discovery ' along the southeast coast of Arabia. In the first month of the survey five sections were planned to run from close inshore to about 200 miles from the Arabian coast at intervals of about 150 miles (Fig. 2). Having delimited the areas of upwelling, an area around the Kuria Muria Islands was investigated in greater detail during the second month to examine the mechanism of the upwelling (Fig. 3). This programme was terminated prematurely after seven days and another area off Ras Fartak was studied for five days. In addition, the ship repeated the section off the Kuria Muria Islands (section III in Fig. 2) 10–13 March 1964 and again 25–29 May 1964 (Fig. 4).

Throughout the surveys I made watches of about an hour for birds on an average of four times a day, 05.30–08.00, 09.30–11.00, 11.30–12.30 and 15.30–18.00 hours. They were made from the highest deck of the ship at 13 m. above sea level, where an almost

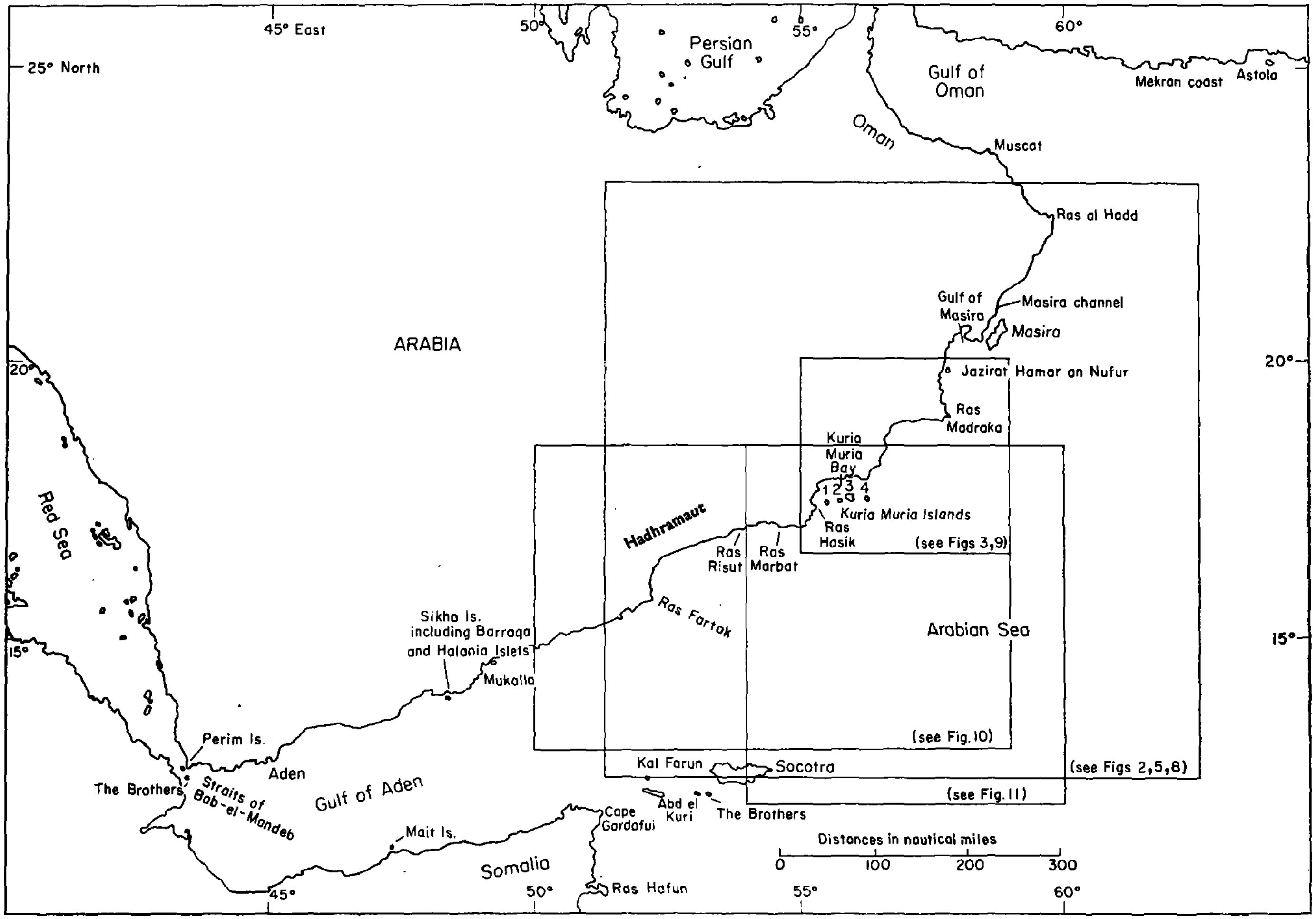


FIGURE 1. The southeast coast of Arabia.
The Kuria Muria Islands: 1, Hasikiya; 2, Suda; 3, Hallaniya; 4, Qibliya.

clear all-round view was obtained. During the 1963 survey, 205 counts were made off Arabia (Figs. 2 and 3) and in 1964 an additional 14 and 15 were made in March and May

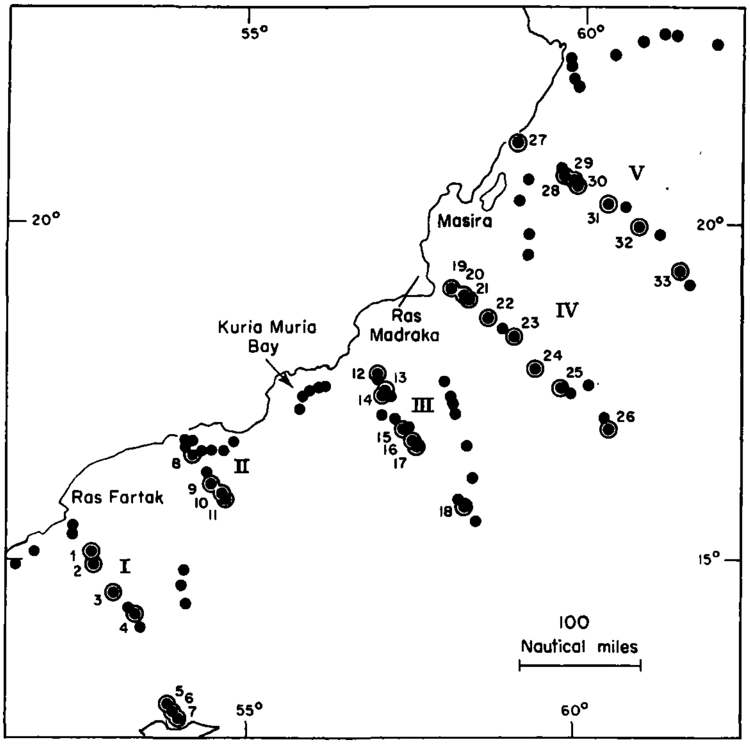


FIGURE 2. Mean positions of 1 hr. observations, 25 June–20 July 1963. Sections referred to in text are shown by roman numerals. Arabic numerals refer to observations used in Appendix Table A2. Key: ●, 1 hr. observations; ○, plankton samples.

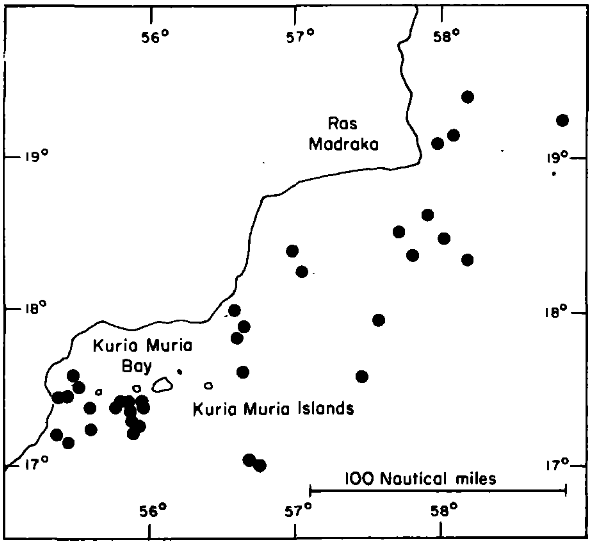


FIGURE 3. Mean positions of 1 hr. observations, 30 July–7 August 1963.

respectively (Fig. 4). The results of these watches have been used in the present paper as an index of the relative abundance of birds. Their analysis is described in the Appendix.

Although observing birds from the ship unavoidably formed most of the ornithological work, 14 specimens of seven species of sea-birds were collected. All of them had been attracted by the ship's lights during overcast conditions at night. A small number of breeding sea-birds was also collected during a visit of a few hours duration to Hasikiya in the Kuria Muria Islands on 10 March 1964. All the specimens have been presented to the British Museum (Natural History). Weights (accurate within 10%) and measurements of birds were made by me personally and are given in gm. and mm. respectively, but full details of all of them are not yet available. On capture most specimens were placed in the ship's deep-freeze after the stomach contents had been removed and preserved in formalin. Dr Malcolm Clarke of the National Institute of Oceanography has very kindly identified the less fragmented remains of cephalopods in this material.

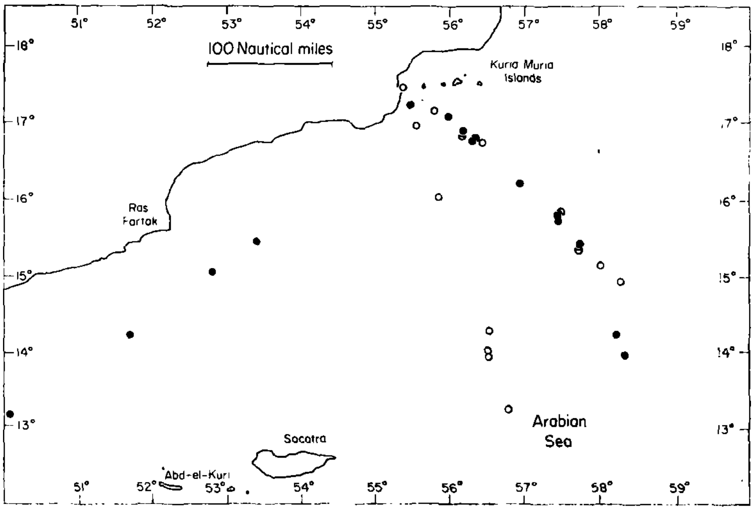


FIGURE 4. Mean positions of 1 hr. observations in 1964.
Key: ●, 8–13 March; o, 25–28 May.

During the surveys on board ' Discovery ' many variables of the physical environment were measured at frequent intervals and the sea temperature was recorded continuously (Royal Society 1963). Plankton samples were taken at almost every station in the first month of the 1963 survey and at all stations in the surveys in March and May 1964 (Figs. 2 and 4). A quantitative assessment of the standing crop of zooplankton at different depths was made using nets 70 cm. in diameter and 200 μ mesh-size, metered for depth and flow (Currie & Foxton 1957). The displacement volumes of the samples were measured on board.

Abundance of plankton at the surface was measured at the completion of most stations by towing a neuston net (David 1965) for 15 min. This net, which was originally designed to sample organisms available to surface-feeding sea-birds, consists of a net 30×15 cm. wide at the mouth, supported between two ski-boards arranged so as to keep the net at the surface when towed from a boom projecting from the ship's bows. It was towed at 5 knots, at which speed it kept clear of the bow wave. The displacement volumes of these samples were also measured. In addition to sampling surface plankton the net caught varying numbers of larger organisms, including fish and squid, especially at night.

During the systematic watches for birds I kept a watch for large schooling fish and cetaceans. The order of magnitude of flying-fish (Exocoetidae) abundance was also estimated.

During the writing-up of the present work I have been fortunate in having been given access to the sea reports of the Royal Naval Bird-watching Society, as well as of other observers, many of which cover the area under discussion. These have provided a valuable background of information, but the identifications vary greatly in reliability, and only the better-documented records have been included in the present paper. Judgement of their validity is mine, although much assistance was gained from published notes on these records (Bourne 1961, 1964, 1965, Bourne & Radford 1962).

GEOGRAPHICAL DESCRIPTION

The following summarized account of the southeast Arabian coast is based on the reports of the ' Discovery ' cruises (Royal Society 1963, 1965). Only those parts relevant to the present paper have been included.

Along most of its length the coastline is exceedingly dry and barren and no permanent streams drain into the sea. Much of the coast is low and sandy, although there are cliffs, especially around the most prominent headlands. Fig. 1 shows the islands off the coast, most of which are very small and all practically without vegetation. The only islands of note are Masira and the Kuria Muria Islands.

The climate of the Arabian Sea is dominated by the two monsoons, which are accompanied by marked changes in the physical environment and in the abundance of living organisms. Whereas from May to September the wind is predominatly from the southwest and the humidity is high, from November to March the wind is from the northeast and the air is dry. Between these two seasons light variable winds prevail.

The effect of the southwest monsoon is to set up a clockwise system of surface currents in the Arabian Sea. At certain points off the coast, surface water tends to drift away from the shore and cool subsurface water, rich in nutrients, upwells to the surface. At the opposite season of the year, upwelling ceases and warm oceanic water, which is lacking in nutrients, occurs at the surface close to the Arabian coast. During the period of upwelling, that is from June to September, the high surface nutrient concentrations near the coast facilitate increased growth of phytoplankton and, in turn, an increase in the abundance of zooplankton and organisms higher in the food chain. A preliminary look at the ' Discovery ' data suggests that a succession of communities develops as the surface water drifts away from the shore.

The survey in 1963 (end June to late August) was carried out during the period of greatest intensity of the southwest monsoon. Offshore the wind was remarkably constant in direction, blowing from 210–220° with an average strength of force 5–6, but reaching force 9 at times far offshore and around the Kuria Muria Islands. During the survey at the end of May 1964 the monsoon was not fully developed; winds offshore were predominantly southwest or west-southwest, force 4, but close inshore the wind dropped. The survey earlier in 1964, in March, apparently coincided roughly with the waning of the northeast monsoon. More than 100 miles from land the wind was between northeast and southeast, whereas inshore it was southwest, possibly the result of local convection currents.

From June to August 1963, the direction of the surface currents was somewhat variable, but the tendency was northeastward along the coast, turning towards southeast farther offshore. There were indications of eddies in Kuria Muria Bay and off Ras Madraka. At a depth of 100 m. there appeared to be movement towards the coast, especially at stations near the continental slope, at about 30–40 miles offshore, indicating vertical circulation, with upwelling occurring near the coast.

The area of upwelling can best be delimited by the properties of the surface water, particularly the surface temperature (Fig. 5). From June to August the coldest surface water (18–19° C) was confined to the immediate proximity of the coast and especially to Kuria Muria Bay and to the east of Ras Madraka. Further offshore the temperature rose somewhat irregularly to about 25° C in the Arabian Sea and there were clear indications of fairly large eddies at some points. In March 1964, the sea surface temperature was 25°–26° C over most of the area but, even in the absence of strong offshore winds, the inshore water was about 1° C cooler. By late May 1964, the sea surface temperature prevailing in the Arabian Sea had reached 29°–31° C. The temperature profiles nearing the coast showed little sign of upwelling but, in Kuria Muria Bay, the surface temperature was 25°–26° C, suggesting that upwelling had begun to take place.

In June and July 1963, phosphate and nitrate concentrations were high in deeper layers but extremely low above 100 m., except near the coast on sections III, IV and V. The richest phytoplankton at the time was found close to the coast near Ras Fartak and

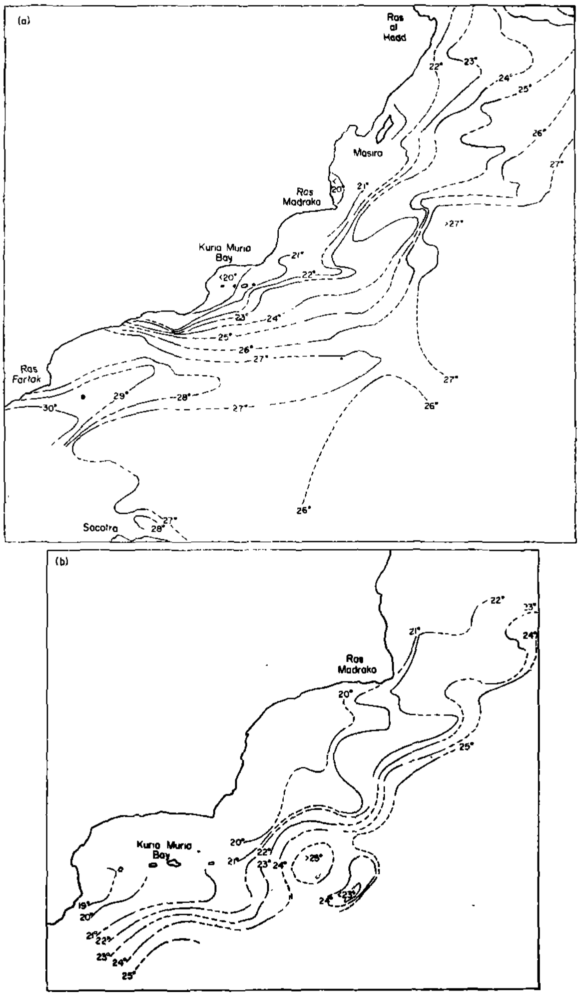
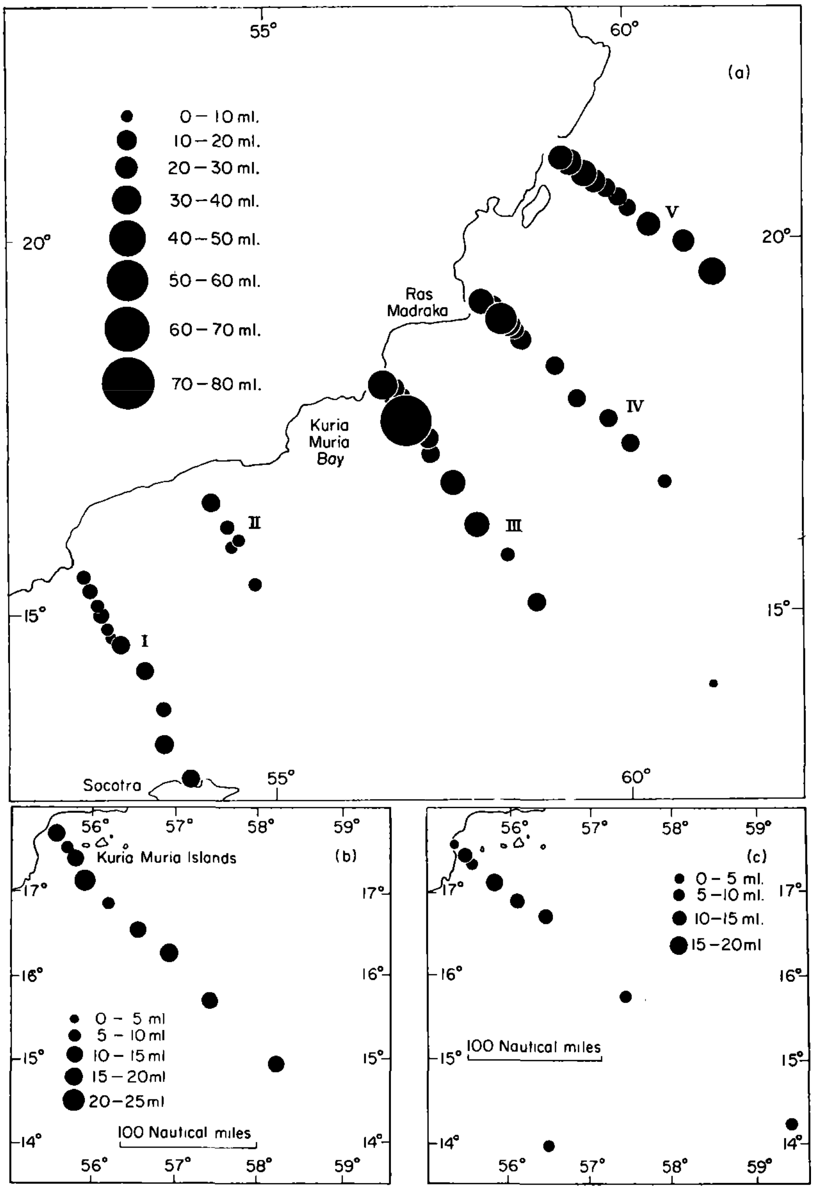


FIGURE 5. Sea-surface temperature °C.
(a) 25 June–20 July 1963. (b) 30 July–7 August 1963.

(a)



(b) (c)

FIGURE 6. Volume of zooplankton collected in 70 cm. net, vertical hauls from 0–200 m.
(a) 25 June–20 July 1963. Roman numerals refer to sections mentioned in the text;
(b) 8–13 March 1964;
(c) 25–28 May 1964.

in Kuria Muria Bay. In general, all stations near the coast were comparatively rich at the surface but, beyond 20–30 miles from land, phytoplankton became more sparse. The seas off Arabia were notable for the abundance also of zooplankton, the highest surface concentrations of which occurred at stations on the continental shelf, especially along sections III, IV and V (Fig. 6), the richest area of all being at the shoreward end of section III. In the top 200 m. of the water column, however, zooplankton was richest just off the edge of the continental shelf, i.e. further offshore than the peak of phytoplankton abundance.

Although zooplankton was considerably less abundant in March 1964 than in July 1963, there were signs that phytoplankton was fairly abundant inshore, for the water there was still quite green. By late May 1964, there had been little change in zooplankton abundance, except at stations close inshore where it had increased (Fig. 6).

From June to August 1963, flying-fish were seen almost exclusively in warm oceanic water outside the upwelling area (Fig. 7). Shoals of large fish, which were probably species of tuna, were seen rather infrequently and were common only off the Kuria Muria Islands and up to 100 miles from land on section III (Fig. 7). Dolphins were seen occasionally in the upwelling area, almost always close to land, and whales of several species were seen on fewer than ten occasions. In March 1964 there was little evidence of the abundance of life observed in the previous July and August. In May, however, several shoals of large fish were seen there, together with a few schools of whales and dolphins.

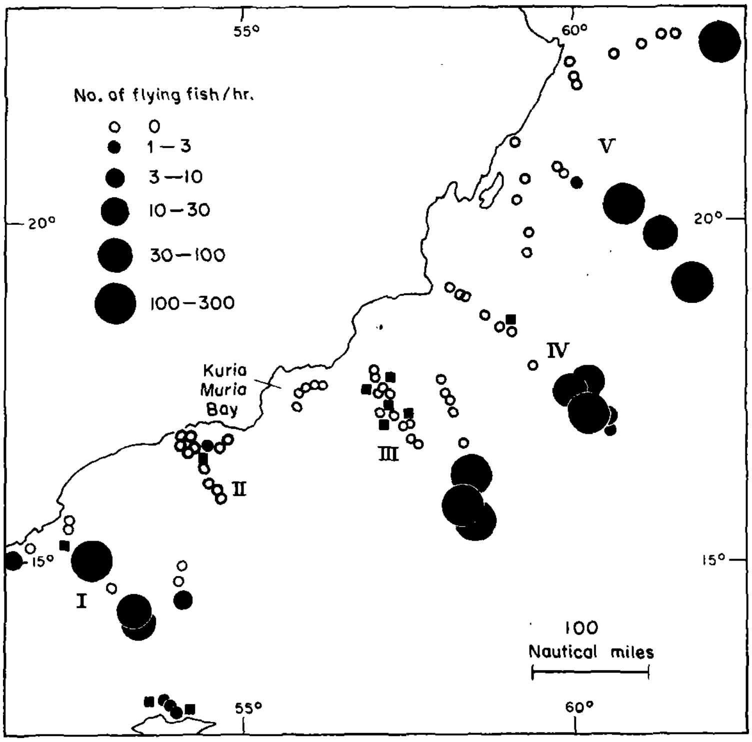


FIGURE 7. Abundance of flying-fish (*Exocoetidae*) and shoals of fish at the surface, 25 June–20 July 1963. Roman numerals refer to the sections mentioned in the text.
Key: ■, approximate position of shoals of large fish.

PREVIOUS WORK

Much of the available information about the ornithology of southeast Arabia has been summarized by Meinertzhagen (1954). In general, almost all the published information is in the form of isolated records made on short visits, and Aden colony is the only locality for which long-term observations exist.

The only islets off southeast Arabia that have aroused the interest of marine ornithologists are the Kuria Muria Islands. They were visited on several occasions in the middle of the last century when reports of guano deposits led to a short-lived guano trade (Hutchinson 1950). Von Heuglin (1873), the only ornithologist to visit the islands, reported sea-birds of several species there in vast numbers. Although there have been several recent unpublished reports of concentrations of birds in the offshore seas during the southwest monsoon, the islands themselves have not been visited at that time of year, when landing would be very difficult. The only reported landing by an ornithologist in the present century was on 9 April 1954 by David (1956), who landed on Qibliya. No sea-birds were recorded by P. R. D. Kimm (pers. comm.) in a short visit to Hallaniya in March 1963.

There is even less information about the birds which occur on offshore islets other than the Kuria Muria Islands. Owen (1857) reported that Arabs collected dung on " Ul Hummer ", which is possibly Jazirat Hamar an Nufur, an islet in the Gulf of Masira which has apparently never been visited by an ornithologist. The only other known sea-bird breeding stations in the adjacent areas of the Arabian Sea are the group of islands including Sikha Island in the northern Gulf of Aden (Smith 1956); Mait Island in the southern Gulf of Aden (von Heuglin 1873, North 1946); Astola, off the Mekran coast (Butler 1877) and Kal Farun to the north of Abd-el-Kuri (Hutchinson 1950). It is conceivable that several breeding stations remain undiscovered.

Although the southeast coast of Arabia has been investigated so scantily, there are published sight-records of sea-birds for every month of the year along the regular shipping routes across the central Arabian Sea. A few transects through the seas off southeast Arabia have also been published (Alexander 1929, 1931; Maclaren 1946, Phillips 1947).

In addition to the published work, a large body of data, summarized in ' Sea Swallow ' (1947–1964), has been collected by members of the Royal Naval Bird-watching Society. In particular, the thorough reports of G. S. Willis, based on ten years' observations in the Arabian Sea, are worthy of mention. Although it is intended to incorporate many of these unpublished records in a later paper, they have formed much of the background material for the summaries of oceanic distribution in the present paper.

Despite the large number of scattered observations of sea-birds in the Arabian Sea, the only attempt to describe its avifauna as a whole is that of Bourne (1963). Most prominent among the reviews of single groups in these areas are those of the Procellarii. Junge (1941) reported on a collection of petrels from the northwest Indian Ocean in the Leiden Museum. Alexander (1954) summarized the existing records of the Réunion Petrel *Pterodroma aterrima* but, almost immediately afterwards, Jouanin (1955) cast doubt over the identification of all dark petrels in the Arabian Sea when he described a new species, *B. fallax*. Later, the same author reviewed the problem of dark petrels in the Arabian Sea (Jouanin 1957) and, since then, Bourne (1960) has added considerably to our knowledge by reviewing a large number of unpublished records. Some other works are concerned with storm-petrels only, the most important being those of Roberts (1940) and Gibson-Hill (1948).

Outside the Procellariiformes few reviews have been attempted. Records of phalaropes (Phalaropodidae) seen on voyages across the Arabian Sea have been summarized and reviewed by the Mörzer-Bruijns (1957) and the status of tropic birds (Phaethontidae) in the Indian Ocean has been reviewed by Gibson-Hill (1952). The only reviews of other groups are those of Archer & Godman (1937) and Meinertzhagen (1954).

SPECIES DISTRIBUTION

The following section describes the oceanic distribution of sea-birds off Arabia as seen from ' Discovery ' and from previous published and unpublished records. In addition, the method of identification is given because I think it is important that subsequent workers should be able to evaluate my records in the light of new observations.

PUFFINUS CARNEIPES. Pale-footed Shearwater

A common visitor to the Arabian Sea during the southwest monsoon, presumably from southwest Australia where it breeds Sep.–Jan.

One was collected on board ' Discovery ' at 02.00 hours on 22 July 1963 at 23° 57′ N., 66° 08′ E. The only specimen previously collected in the Arabian Sea was captured at 10°N., 62° E. in June 1925 (Junge 1941). The measurements (gm. and mm.) of my specimen are as follows:—

Sex	Weight	Wing	Tail	Bill	Tarsus	Plumage
♂	540	308	110	42	50	Body and tail in moult

I agree with Warham (1958) that *P. carneipes* is fairly easy to separate from other dark petrels at sea. Its large size, large pale bill, and heavy flight close to the water, with slow stiff wing-beats, were usually obvious at some distance. It is possible that some solitary birds were sometimes misidentified but I do not think this source of error is great.

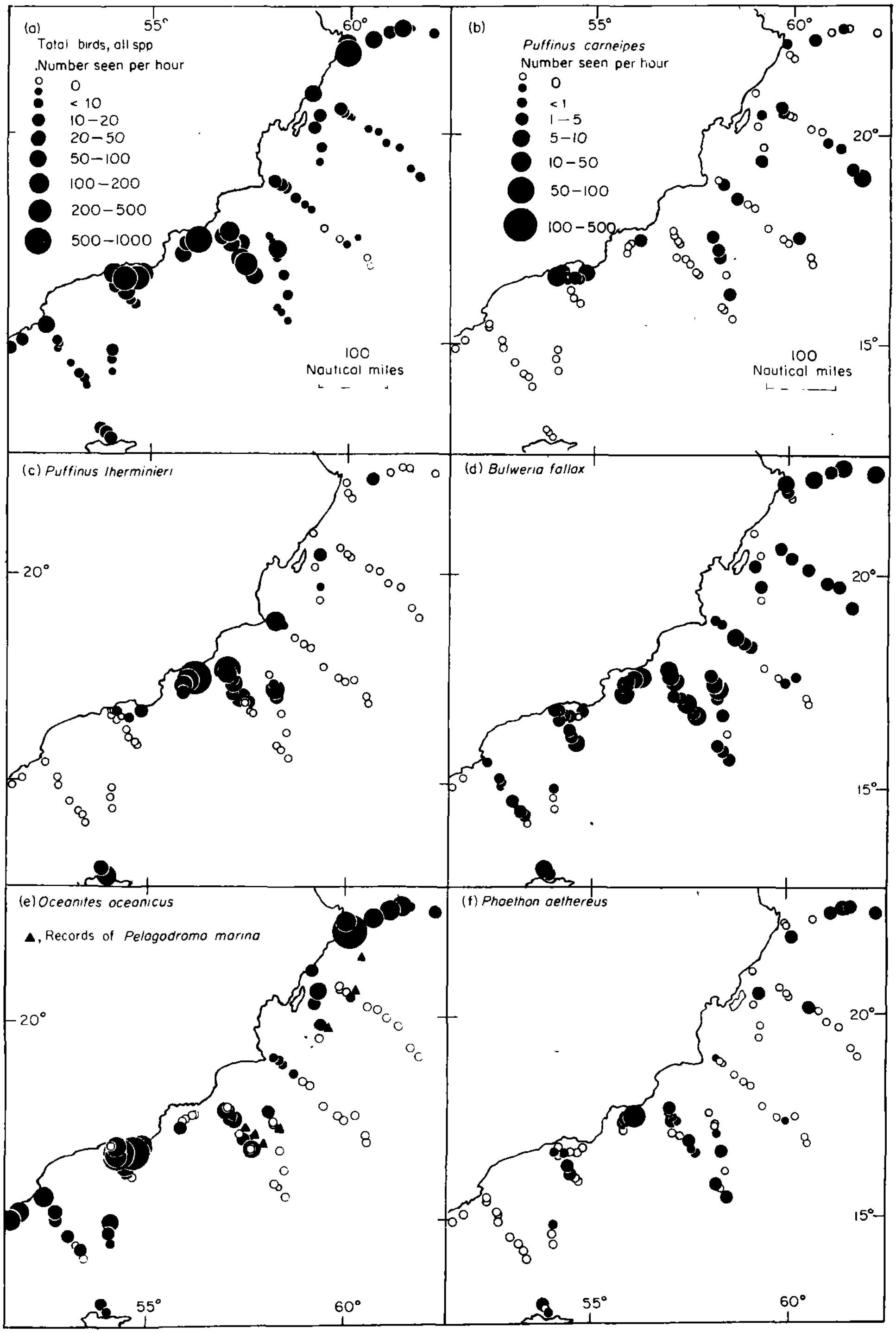
I obtained no records of *P. carneipes* in March, but in late May, flocks were seen south of the Laccadive Islands heading northwest possibly towards the upwelling area off Arabia.

Off southeast Arabia itself, I saw small numbers at the very end of May, but it was common only from late June to mid-August (Figs. 8 and 9). The largest numbers were seen close to land in the area of coldest surface water, but a few were seen almost 200 miles from land in warm oceanic water (see Table 2). Close to land in the upwelling area it was often seen in parties and occasionally in large flocks, but only rarely with other species. It may have been less common within 50 miles of the Kuria Muria Islands and, unlike some resident species, its distribution was not centred at any particular point along the coast. These facts suggest that *P. carneipes* was associated with, but not entirely restricted to, the upwelling area. As the presence of land, as such, is unlikely to be an important factor, it seems reasonable to suggest that it is primarily attracted to the areas of cold water.

In the Arabian Sea past sight records have shown that *P. carneipes* is a common and regular migrant from April to October inclusive, the earliest recorded date being 18 April 1961 (Willis unpub.). In May, records off Arabia increase but include no large concentrations. There are few records for June but in July records are numerous from Ras Fartak to Ras al Hadd and include a few observations of large concentrations. By August, most records come from closer to the coast and there are even more records of large flocks. In September occurrences are still widespread, but fewer, though large flocks have been reported then off Ras Fartak and Ras Madraka. There are three records for October—Alexander (1931), Cheshire & Fisken, quoted in Bourne (1964).

PUFFINUS PACIFICUS. Wedge-tailed Shearwater

Nests, mainly in the northern winter, on islands south of the equator in the tropical Indian Ocean. Its status in the Arabian Sea is still not clear, for most previous records are unsubstantiated and probably refer to *B. fallax* (*q.v.*). There are, at present, only three records of its capture in the northwestern Indian Ocean and none are in the area covered by the present paper. One was collected at 10° N., 62° E. in June 1925 (Junge 1941), another was captured and photographed at 9½° N., 66½° E. in May 1960 (Bailey & Bourne 1963) and, finally, Medhurst (in prep.) has reported collecting one at Aden.


(a)
55°
60°
Total birds, all spp
Number seen per hour
0
< 10
10–20
20–50
50–100
100–200
200–500
500–1000
100
Nautical miles
(b)
55°
60°
Puffinus carneipes
Number seen per hour
0
< 1
1–5
5–10
10–50
50–100
100–500
20°
15°
100
Nautical miles
(c) *Puffinus lherminieri*
20°
(d) *Bulweria fallax*
20°
15°
(e) *Oceanites oceanicus*
▲, Records of *Pelagodroma marina*
20°
55°
60°
(f) *Phaethon aethereus*
20°
15°
55°
60°

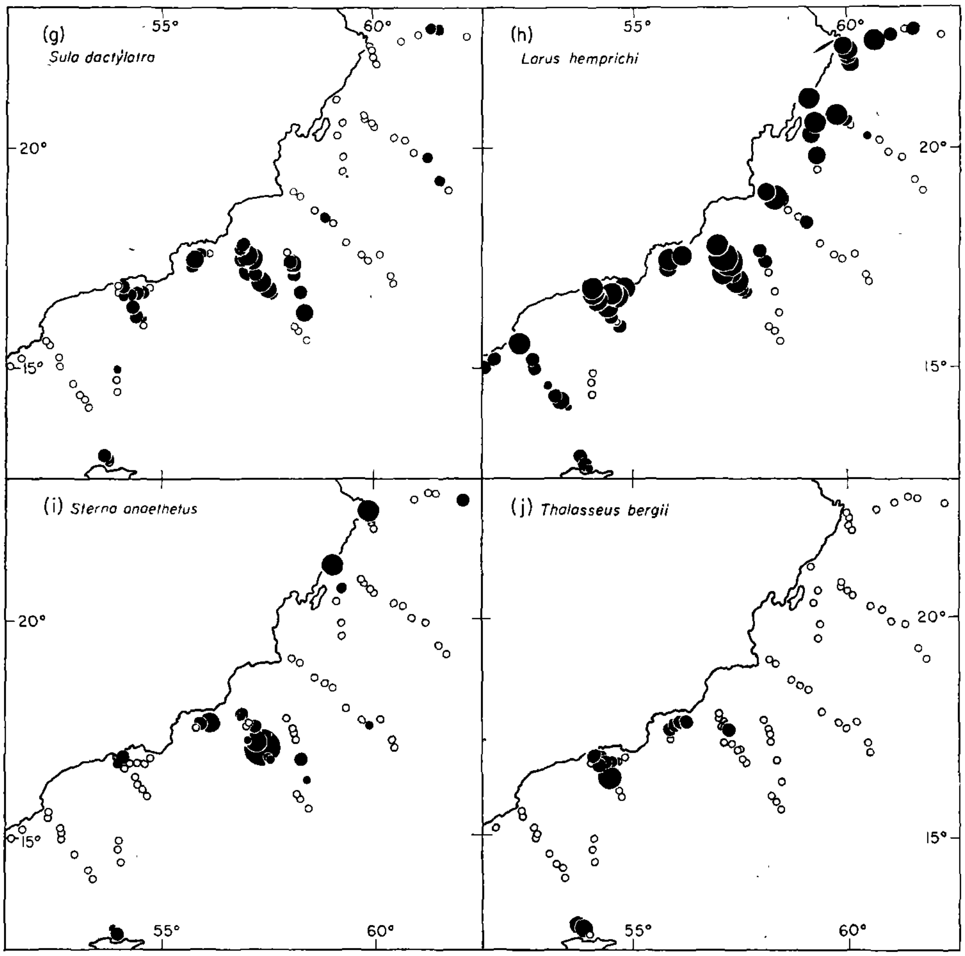


FIGURE 8. Number of birds seen/hr. 25 June–20 July 1963.

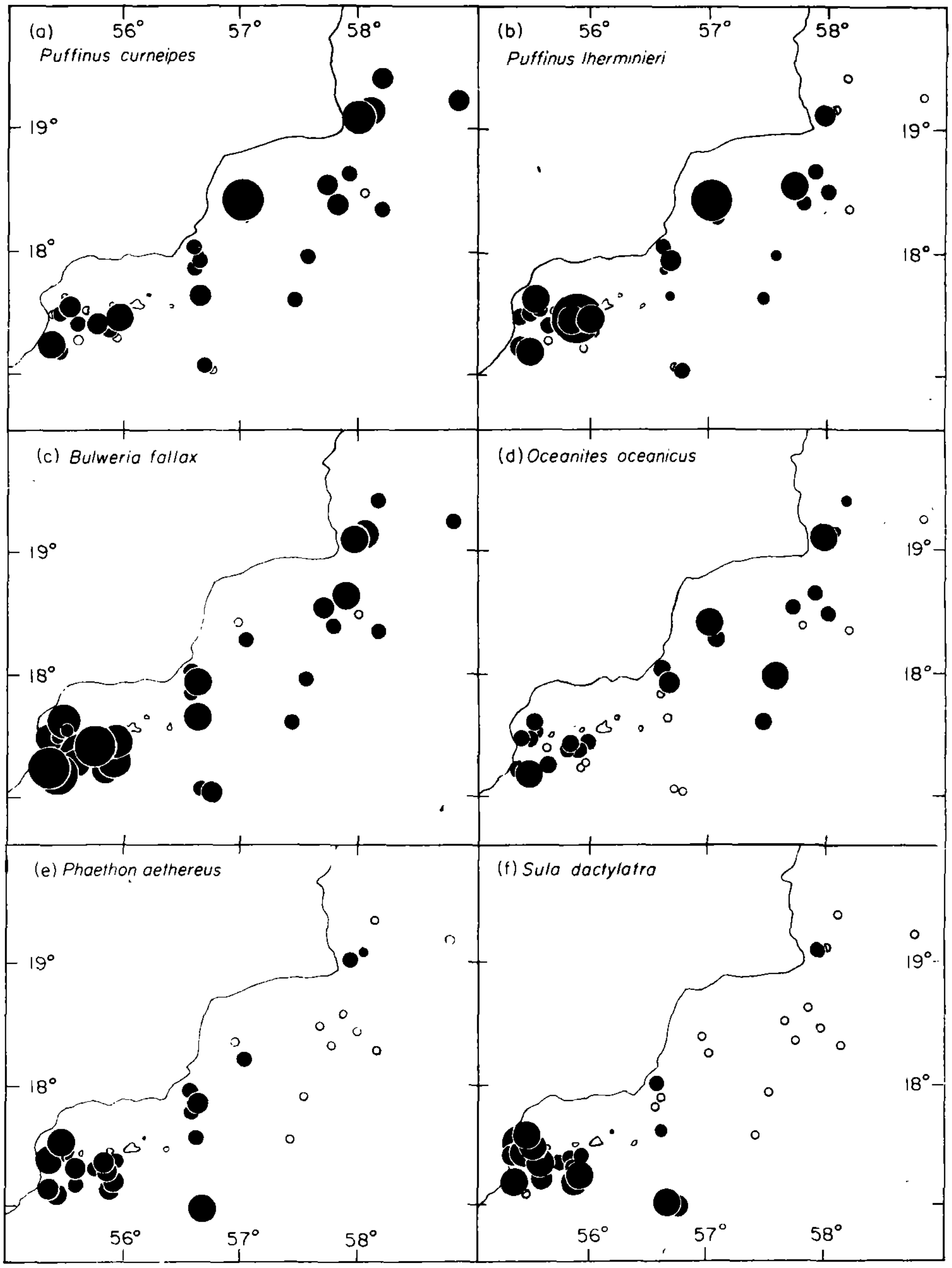
(a) Total birds, all species	(f) *Phaethon aethereus*
(b) *Puffinus carneipes*	(g) *Sula dactylatra*
(c) *Puffinus lherminieri*	(h) *Larus hemprichi*
(d) *Bulweria fallax*	(i) *Sterna anaethetus*
(e) *Oceanites oceanicus*	(j) *Thalasseus bergii*

(For key and scale of (c) to (j) see (b)).

The identification of *P. pacificus* at sea presents some difficulties, for it is roughly intermediate in size between *P. carneipes* and *B. fallax*. The most reliable character seems to be the longish slender grey bill, which appears quite dark in the field. This character is only visible at short range, however, and is of little use in rough seas. Although differences in flight between this and *B. fallax* have been described (Bourne 1960), they seem to be poorly-marked in winds stronger than force 3.

There is no unequivocal evidence for the occurrence of *P. pacificus* in the upwelling area off southeast Arabia. From its breeding distribution in the western Indian Ocean (Alexander 1955), it would seem more likely that it is restricted to warm water areas.

At the end of May and again during July and August, I saw several shearwaters which I thought were *P. pacificus* well offshore off Arabia, but none was seen sufficiently


(a) Puffinus curneipes
(b) Puffinus lherminieri
(c) Bulweria fallax
(d) Oceanites oceanicus
(e) Phaethon aethereus
(f) Sula dactylatra
56°
57°
58°
19°
18°

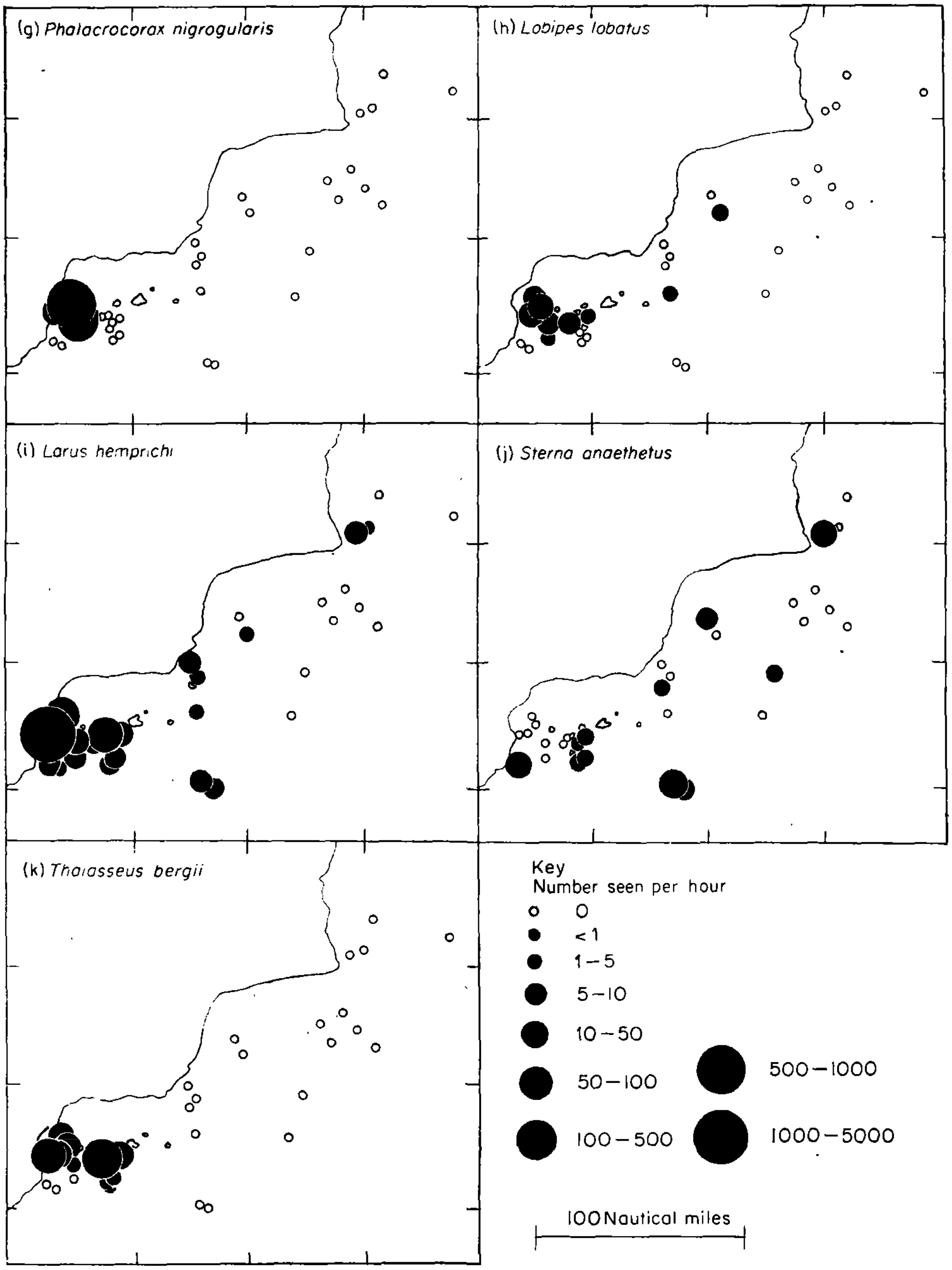


FIGURE 9. Number of birds seen/hr. 30 July–7 August 1963.

(a) *Puffinus carneipes*
(b) *Puffinus lherminieri*
(c) *Bulweria fallax*
(d) *Oceanites oceanicus*
(e) *Phaethon aethereus*
(f) *Sula dactylatra*
(g) *Phalocrocorax nigrogularis*
(h) *Lobipes lobatus*
(i) *Larus hemprichi*
(j) *Sterna anaethetus*
(k) *Thalassus bergii*

closely for certain identification—certainly it can only be rare in this sea area during the southwest monsoon.

Until a satisfactory means of identification can be found, records from the northern Arabian Sea should be substantiated by specimens or photographs and descriptions of captured birds.

PUFFINUS LHERMINIERI. Audubon's Shearwater

I accept the view of Phillips & Sims (1958) that the Persian Shearwater *Puffinus persicus* should be regarded as conspecific with *P. lherminieri*, from which it differs only in having a slightly longer bill. *P. lherminieri* is a pantropical species, represented in the northwestern Indian Ocean by *P. l. persicus.* Although it is a common resident from the Somali coast to northwest India and in the Persian Gulf, its breeding stations are unknown.

Five specimens of *P. l. persicus* have been collected previously in the Arabian Sea, and one was collected on board ' Discovery ' at 01.40 hours on 18 August 1963 at 15° 47′ N., 52° 25′ E. measuring (gm. and mm.):—

Weight	Wing	Tail	Bill	Tarsus	State of plumage
195	202	74	29	37·5	No moult; brood spot present

So far as is known, *P. l. persicus* is the only black and white shearwater occurring regularly in the northern Arabian Sea. Its small size and fast wings beats make it easy to distinguish at long range.

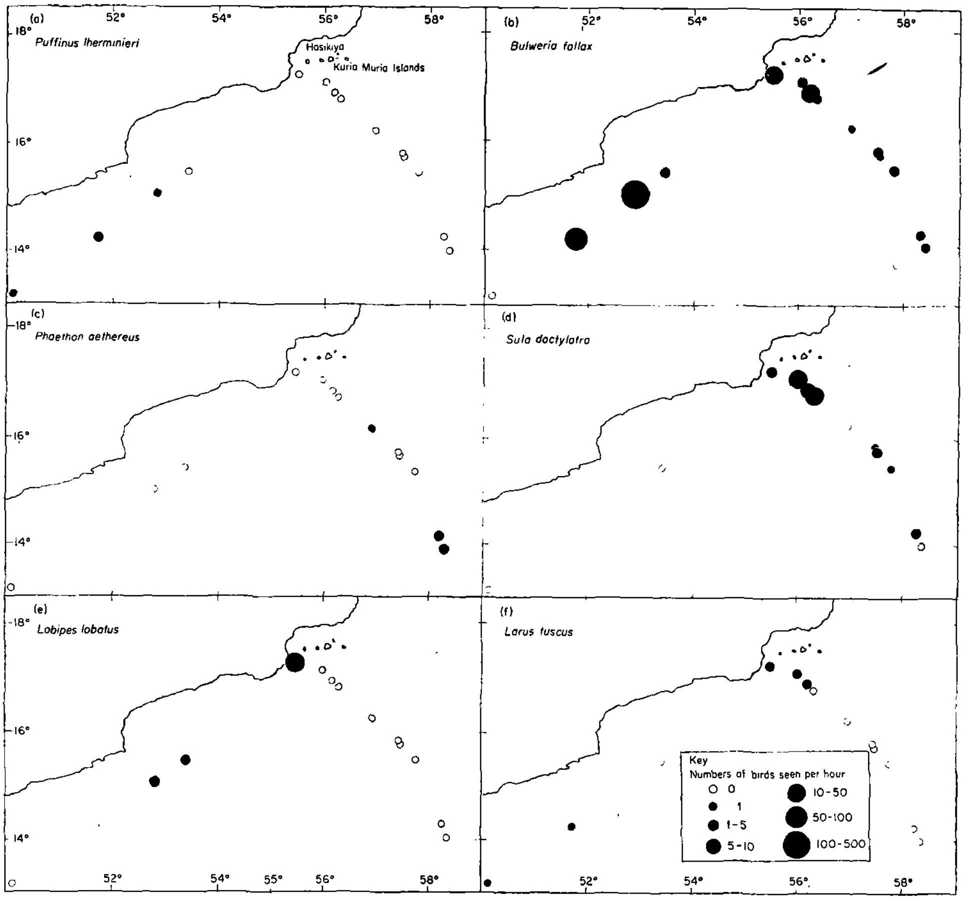
In March I did not record *P. lherminieri* in the Arabian Sea, but small numbers were seen in the Gulf of Aden (Fig. 10). Large numbers have been recorded at this time of year in the straits of Hormuz at the mouth of the Persian Gulf and in the southern Gulf of Aden (Bourne 1961). By May I found evidence that it had begun to move to the upwelling area; it was recorded twice, once in Kuria Muria Bay and once about 80 miles offshore.

From June to August I found *P. lherminieri* was common off Arabia especially close to land off the Kuria Muria Islands (Figs. 8, 9, Table 2). It was almost entirely confined to the area of cool water and was not seen in water warmer than 27°C (see Table 2). This suggests that *P. l. persicus* is typically confined to upwelling areas, at least at that time of year. The largest concentrations were seen in the seas around Suda Island in the Kuria Muria group. Flocks of several hundred were seen about three miles offshore, and smaller flocks were seen up to about 70 miles from land.

P. lherminieri has been reported frequently in the past, in the Gulf of Aden and the Arabian Sea, especially near the Arabian coast and Socotra, in which areas Phillips (1954) and Bourne (1960) respectively have suggested it may breed. Neale (see Bourne 1961) has reported seeing birds moving inshore at night in March around islands in the Straits of Hormuz. From December to April, inclusive, most records are from the entrance to the Persian Gulf and the Gulf of Aden. In May and June there is evidence of a progressive shift towards the upwelling area off southeast Arabia, where most records come from in July and August. Records in September and October are very few, but by November and December some birds appear to have moved west to the Gulf of Aden, others northeast to the Gulf of Oman and the Persian Gulf. By comparison there are few records off southeast Arabia from September to March, inclusive, suggesting that *P. lherminieri* migrates from the upwelling area when upwelling ceases to be active. It has been suggested (Bourne 1963) that it inhabits other upwelling areas in the winter but there is little definite evidence.

BULWERIA FALLAX. Jouanin's Petrel

Endemic in the northwestern Indian Ocean (Jouanin 1957). Although there are still few formal records, *B. fallax* has been recorded from the Gulf of Aden, the coast of southeast Arabia, possibly the southern Red Sea, and throughout the Arabian Sea south



Bailey 18/8 108(2)
fig 10

FIGURE 10. Number of birds seen/hr. 8–13 March 1964.

(a) *Puffinus lherminieri*	(d) *Sula dactylatra*
(b) *Bulweria fallax*	(e) *Lobipes lobatus*
(c) *Phaethon aethereus*	(f) *Larus fuscus*

to the coast of Kenya and possibly east to India (Jouanin 1957). Despite its abundance in some areas, its breeding stations are still unknown.

Jouanin (1957) has described the earlier specimens but did not note that there are two in the American Museum of Natural History (Bourne, pers. comm.). Eight were collected on board ' Discovery ', all off the Arabian coast, measuring (gm. and mm.):—

Date	Position	Sex	Weight	Wing	Tail	Culmen	Tarsus	Plumage
25 June '63	15° 36′ N., 52° 24′ E.		180	249	115	30	32	Brood spot
20 June '63	22° 16′ N., 60° 12′ E.	♀	170	243	118	30	30	Brood spot
14 Aug. '63	15° 34′ N., 52° 33′ E.		175	239	119	28	31	Abraded, body moult around brood spot
14 Aug. '63	15° 34′ N., 52° 33′ E.		175–180	246	119	28·5	33·5	Brood spot
15 Aug. '63	15° 34′ N., 52° 33′ E.	♂ gonads quite large	175	238	113	31	31	Abraded, Brood spot
18 Aug. '63	15° 47′ N., 52° 25′ E.		185	246	118	28	32·5	Brood spot
18 Aug. '63	15° 47′ N., 52° 25′ E.	♀	150–155	235	110	28	32	Brood spot
27 Aug. '64	13° 08′ N., 50° 18′ E.		168	241	108	28·5	32	Brood spot, abraded, tail moult

B. fallax was often difficult to identify for certain for its flight characteristics varied considerably in different wind speeds. With fairly close sightings, however, it was usually possible to see the black bill, thicker and shorter than that of *P. pacificus.* Sightings on birds in which this character was not observed have been excluded below.

In March I saw *B. fallax* commonly off the coast of Arabia (Fig. 10), especially off Ras Fartak in warm oceanic water; off the Kuria Muria Islands it was scarcer and its numbers gradually diminished with distance from the shore. In late May, *B. fallax* was concentrated in Kuria Muria Bay, where upwelling had apparently begun, but a few extended far into the Arabian Sea (Fig. 11). From June to August the distribution appeared little different, and *B. fallax* appeared to be the commonest and most widespread sea-bird off southeast Arabia. Although it was most numerous close to the coast in the cool water area, I saw it commonly up to 200 miles from land (Figs. 8, 9, Table 2). It was commonest of all near the Kuria Muria Islands (Table 2), and breeding there is suggested by the fact that concentrations were seen close offshore on several early mornings. Large flocks of *B. fallax* were seen only once, off Ras Fartak on 18 August 1963; usually, when large numbers were seen, they occurred in dispersed parties.

Jouanin (1957) and, later, Bourne (1960) recognized that *B. fallax* must have often been reported erroneously as *Pterodroma aterrima* and *Puffinus pacificus* in the past. Recently, *B. fallax* has been captured in the central Arabian Sea (see Bailey & Bourne 1963, Bourne & Radford 1962) and at Aden by Medhurst (in prep.). In addition, many others have been reported, especially from around Socotra and the Kuria Muria Islands (' Sea Swallow ' 1959–62), but few of them have been substantiated by a critical description.

Although its movements are not yet clear, there seems little doubt that *B. fallax* is common off the southeast Arabian coast throughout the year, extending into the Gulf of Aden, the Gulf of Oman and far into the Arabian Sea. There is also some evidence of a southward dispersal, for one was collected in Kenya in December 1953 (Jouanin 1957), but its extent and regularity is not known.

OCEANITES OCEANICUS. Wilson's Storm-petrel

An abundant visitor to seas off southeast Arabia during the southwest monsoon; rare in winter. The origin of birds seen in the northern Indian Ocean is not known, but collected specimens exhibit the full range of variation of the species, suggesting that both antarctic and subantarctic populations are involved.

Two specimens captured on board ' Discovery ' on 3 July 1963 off southeast Arabia at 16° 44′ N., 54° 05′ E. are the first to be collected in the area discussed in this paper (although two in the British Museum were collected in the Gulf of Aden in November 1907), and measure (gm. and mm.):—

Weight	Wing	Tail	Bill	Tarsus	Plumage
ca. 24	142	63	12	36	Body moult, brood spot
ca. 24	153	66	12·5	33	Body moult

It seems particularly interesting that one specimen still had a prominent brood spot, suggesting that the growth of feathers on the abdomen is postponed until after the northward migration. Although body moult was progressing in both specimens, wing and tail moult apparently takes place later (Bourne 1960). Several specimens have been collected previously elsewhere in the Arabian Sea and a large number has been collected off southern India during the southward migration in October and November.

As *O. oceanicus* is the only black storm-petrel with a white rump known to occur in the Arabian Sea it cannot be mistaken. I did not see *O. oceanicus* in March and only small numbers off Arabia in May. Most were seen far offshore and it seems likely, therefore, that migration was still in progress at the end of May.

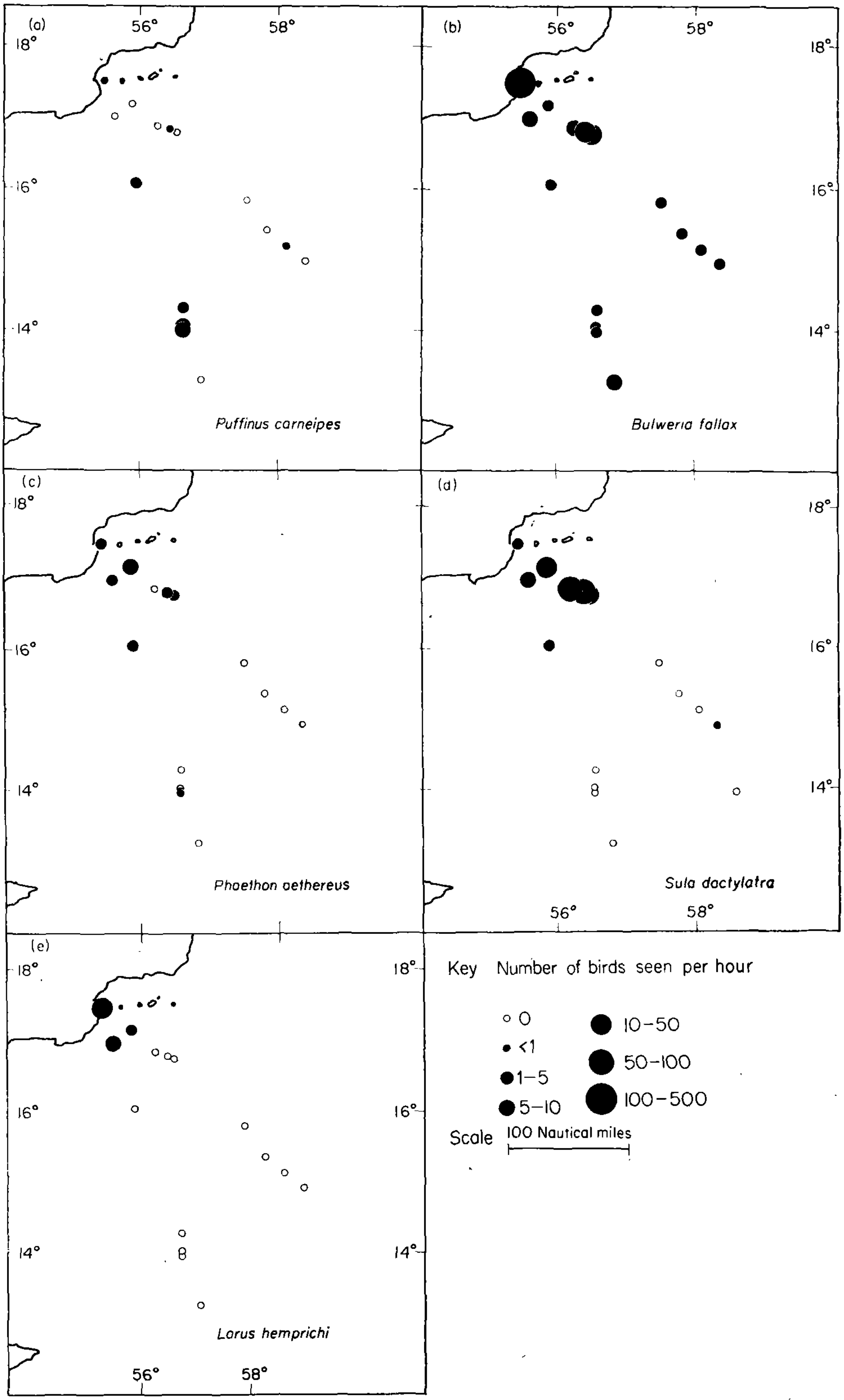


Figure 11. Numbers of birds seen/hr. 25–28 May 1964.

(a) *Puffinus carneipes*
(b) *Bulweria fallax*
(c) *Phaethon aethereus*
(d) *Sula dactylatra*
(e) *Larus hemprichi*

During July and August, I found *O. oceanicus* common along the whole coast of southeast Arabia, but especially on the edge of the continental shelf (Figs. 8 and 9). Very small numbers were seen more than 50 miles from land (Table 2). The largest concentrations were seen between Ras Fartak and Ras Marbat and off Ras al Hadd but, unlike some other sea-birds, rather small numbers were seen in the centre of upwelling around the Kuria Muria Islands (Table 2). *O. oceanicus* occurred in water of a wide range of temperatures but with perhaps a preference for 23–24° C (Table 2). Bourne (1963) considers that this species concentrates in the upwelling areas, but my findings show that it is commoner outside them, so it may avoid the coldest water.

The huge concentrations of *O. oceanicus* reported off Arabia in the summer (e.g. Brongersma 1947) show clearly that it is the commonest migrant sea-bird there. Its distribution has been reviewed by Roberts (1940), Gibson-Hill (1948), and Bourne (1960). Most arrive during May and from June to July it is common off Arabia and extends into the central Red Sea. In August the records become concentrated close to the Arabian coast prior to the departure which begins in September and continues into October and November, when large numbers have been seen migrating south off southern India (Phillips 1954). It is rare in the winter but has been recorded from the Arabian Sea in every month of the year except January (Ticehurst 1927, Maclaren 1946, Gibson-Hill 1948, Willis unpub.).

PELAGODROMA MARINA. White-faced Storm-petrel

A regular migrant to the Arabian Sea during the southwest monsoon, presumably from southwest Australia where it breeds during the northern winter.

Previously, eight specimens have been collected in the Arabian Sea during the southwest monsoon, and most of them were in moult (Junge 1941, Mörzer Bruyns & Voous 1964). One was collected on board ' Discovery ' on 19 July 1963 at 21° 09′ N., 60° 26 ′E., measuring (gm. and mm.):—

Weight	Wing	Tail	Culmen	Tarsus	Plumage
46	150	(69)	18·5	38	Wing, tail and body moult

At sea *P. marina* is easily distinguished from all other storm-petrels by its grey upperparts and white underparts and by its characteristic flight, in which it appears to spring from the sea surface and to sail several feet on motionless outspread wings before touching the water again. It seems likely that this type of flight is dependent on fairly strong winds, but I never saw the species in calm weather.

I did not see this species in March but in mid-May a few were seen south of the Laccadive Islands heading northwest, and in late May it was again seen far offshore in small numbers. During July I occasionally saw *P. marina* off southeast Arabia, almost always between 50 and 100 miles from land (Fig. 8), that is some way off the continental shelf; five of the six observations were in water of about 24° C.

Previous records of *P. marina* in the Arabian Sea suggest that it migrates to the northern periphery of the Indian Ocean in late May and departs in September, being present there in much smaller numbers than *O. oceanicus* and further offshore (Bourne 1960, 1963). From May to July it has been recorded fairly frequently off southeast Arabia, but not in August and September in the area reviewed in the present paper. There have been several recent records from the Arabian Sea (Bailey & Bourne 1963, Mörzer Bruyns & Voous 1964).

FREGETTA TROPICA. Black-bellied Storm-petrel

There is only one formal record in the central Arabian Sea, but it appears to be common there during the southwest monsoon, presumably migrating from the southern Indian Ocean where it breeds in the southern summer (Bourne 1960). It is rare in Arabian coastal seas.

There is a specimen from the Bay of Bengal in the British Museum, but the only definite record from the Arabian Sea is of a bird captured and photographed by N. Bailey at 8° N., 73° E. on 9 September 1960 (Bailey & Bourne 1963). To identify *F. tropica* at sea, a view of the black line down the abdomen is essential; it is apparently never present in *F. grallaria* (Bourne 1960). The latter has been reported in the Arabian Sea by Jones (1964) and Norris (see Bourne 1965), but the variation in the plumage of *F. tropica* makes all identifications of *F. grallaria* doubtful, and there would seem to be no unequivocal proof of its occurrence in the northern Indian Ocean.

I did not see *Fregetta* spp. in March, but I saw them in numbers off Arabia in late May, most of which I identified as *F. tropica.* During July I saw a species of *Fregetta* on three occasions off Arabia, all more than 30 miles from land in warm (24–27° C.) oceanic water: 3 July 1963, 16° 20′ N., 54° 26′ E. (doubtful); 6 July 1963, 16° 43′ N., 57° 33′ E.; 13 July 1963, 17° 36′ N., 60° 11′ E. On two of the birds I saw the black line down the abdomen clearly and concluded that they were *F. tropica.* These records strengthen Bourne's (1960, 1963) view that *Fregetta* spp. occur further offshore than *P. marina.*

A species of *Fregetta* was first reported in the Arabian Sea by Phillips (1947) who saw what he thought were *F. tropica* about 200 miles off Arabia in July 1945. Several subsequent reports of birds on which the black line down the abdomen was distinguished suggest that it occurs in the central Arabian Sea from May to August inclusive, but that it rarely enters the upwelling area.

OCEANODROMA MONORHIS. Swinhoe's Storm-petrel

Breeds on islands in the western Pacific Ocean; ranges west regularly to Singapore and has been recorded in Ceylon, in the Arabian Sea and in the northern Red Sea. Apparently a vagrant to seas off Arabia.

One was captured on board 'Discovery' at 15° 47′ N., 52° 25′ E. on 18 August 1963, measuring (gm. and mm.):—

Weight	Wing	Tail	Culmen	Tarsus
40	152	75	14	23

Apart from the specimen collected, *O. monorhis* was not seen off Arabia except that, on 28 May 1964, a bird which I thought was this species was seen at 13° 09′ N., 56° 47′ E. Previous records of *O. monorhis* in the western Indian Ocean are extremely few (Bourne 1960, 1965), though a black storm-petrel seen by Norris (1952) off Aden in August 1951 may have been this species. An exhausted bird was captured at the head of the Gulf of Aqaba in January 1958 (Merom 1960).

PHAETHON AETHEREUS. Red-billed Tropic-bird

A pantropical species represented in the northern Arabian Sea, the Red Sea and the Persian Gulf by a resident endemic subspecies, *P. a. indicus,* which has been recorded breeding between March and November. It is the only tropic-bird known to occur in the northern part of the Arabian Sea, although it is conceivable that *P. lepturus* may wander north occasionally. Adults are easily separated by the length of the tail feathers, (shorter than in *P. lepturus*) and by the colour of the bill (red in *P. aethereus* and yellow in *P. lepturus*); but immature birds are difficult to distinguish at sea.

In March I saw *P. aethereus* in very small numbers, all far offshore (Fig. 10), but by late May it was present in generally larger numbers off Arabia, and more were seen inshore around the Kuria Muria Islands (Fig. 11).

From June to August I found adult *P. aethereus* widespread off Arabia to the east of Ras Fartak (Figs. 8 and 9), usually occurring singly or in pairs. There was some evidence (Table 2) that they were commonest within 20 miles of the Kuria Muria Islands in the coldest water, but further out there was no noticeable diminution in numbers with increasing distance offshore (Table 2). Clearly it was not restricted to the upwelling area.

Although *P. aethereus* is resident in the northern Arabian Sea, there is a considerable amount of evidence to suggest that it regularly concentrates off southeast Arabia in April and May: among many other reports, David (1956) saw large numbers around the Kuria Muria Islands in April 1954. Large numbers have been seen in the upwelling area up to August but by September there is some evidence of a dispersal out to sea. During the winter, reports off southeast Arabia are few and there are proportionately more records from the Gulf of Oman. There is as yet no definite proof that it breeds on the Kuria Muria Islands, but it has been reported there by von Heuglin (1873).

SULA DACTYLATRA. Blue-faced Booby

A pantropical species represented in the Indian Ocean by *S. d. melanops*. In the Arabian Sea it is resident, breeding on Mait Island (Heuglin 1873), the Kuria Muria Islands, Kal Farun (Hutchinson 1950) and in the southern Red Sea (Morris 1962). The breeding season appears to be extensive, lasting from about March to November.

Six adult males with enlarged testes were collected on Hasikiya Island in the Kuria Muria group (17° 28′ N., 55° 36′ E.) on 10 March 1964, measuring (gm. and mm.):

Weight	Wing	Tail	Culmen	Tarsus
1570	420	176	99	58
1550	421	180	100	56
1500	430	180	97	52
1660	425	169	103	51
1630	407	175	104	55
1480	420	177	101	58

In March and May its distribution appeared to be much as in July and August; in March it was common around the Kuria Muria Islands and extended in small numbers far offshore (Fig. 10), whereas in late May it seemed to have concentrated nearer the coast (Fig. 11). During July and August I saw adult *S. dactylatra* in large numbers only off the Kuria Muria Islands, especially around Hasikiya Island (Figs. 8 and 9, Table 2); elsewhere most seen were in immature plumage. There was a gradual decrease in numbers with increasing sea temperature; very few were seen in water warmer than 27° C. (Table 2).

Two to three thousand adults were seen on Hasikiya Is. in the Kuria Muria group on 10 March 1964. There were many empty nests surrounded by white patches of excreta but only some 50 occupied nests contained eggs C/1 or C/2 in roughly equal proportions, but all clutches might not have been complete.

Unpublished records suggest that *S. dactylatra* is resident in the seas off southeast Arabia throughout the year. There is no evidence to suppose that any adults leave the upwelling area when upwelling ceases during the northeast monsoon, for large numbers have been seen during most months off the Kuria Muria Islands, usually flying towards or away from them. Breeding has been reported in the past by von Heuglin (1873), and David (1956) photographed breeding birds on Qibliya Is. in April 1954.

SULA LEUCOGASTER. Brown Booby

A pantropical species represented in the northwest Indian Ocean by *S. l. plotus*, which breeds on islands in the Red Sea and on Mait Island. When not breeding it occurs on the Arabian coast, but rarely to the east of Ras Fartak.

I saw one definite example of *S. leucogaster* in Kuria Muria Bay about two miles offshore, on 4 August 1963, (distinguished from immature *S. dactylatra* by its clearly demarcated underwing pattern and pale bill), and another, possibly of this species, off the north coast of Socotra in late June. Clearly *S. leucogaster* is rare in the upwelling area.

PHALACROCORAX NIGROGULARIS. Socotra Cormorant

Endemic in the northern Indian Ocean, breeding on islands in the Persian Gulf in March, and possibly off Socotra and southeast Arabia. In the non-breeding season it extends west at least to Aden.

On 10 March 1964 one adult and three immatures were seen on the shore on Hasikiya but the only evidence that they had nested there was a few bones found near the shore, including one poorly-ossified skull, almost certainly the remains of a pre-fledging juvenile. In May 1964 it was not seen off Arabia, but insufficient time was spent there to make sure that it was absent. During July and August, *P. nigrogularis* was seen only in Kuria Muria Bay (Fig. 9), in water of 19° C or below. The only large flocks were seen between Hasikiya Is. and Ras Hasik on the Arabian mainland.

P. nigrogularis has frequently been recorded in the northern Gulf of Aden. Smith (1956) was told locally that it nests on Sikha Island, and Hines (pers. comm.) has confirmed that cormorants are abundant in the seas around this island. There is also one record just to the west of Ras Fartak (Bates 1938), but there have hitherto been no records of cormorants from the area covered in the present paper, except for a dubious record from Masira reported as *Phalacrocorax carbo* (de Schauensee & Ripley 1953). In the eastern Persian Gulf *P. nigrogularis* is an abundant breeding species.

LOBIPES LOBATUS. Red-necked Phalarope.

An abundant winter visitor to the northern Arabian Sea from its breeding grounds in the northern Palaearctic.

An adult, moulting out of summer plumage, was collected on 'Discovery' on 17 August 1963 at 15° 49′ N., 53° 00′ E., measuring (gm. and mm.):—

Weight	Wing	Tail	Culmen	Tarsus	Plumage
ca. 32	109	47	22·5	19	Abdomen feathers in pin, summer plumage still prominent

Although Grey Phalaropes *Phalaropus fulicarius* have been reported in the Arabian Sea (Meinertzhagen 1925, 1937, 1954; Bourne 1961), I feel that there is no certain evidence of their occurrence, since it is almost impossible to see phalaropes at sea close enough for identification and the few collected specimens of phalaropes have all been *L. lobatus.*

In 1963 we first saw phalaropes off southeast Arabia on 2 August. By the middle of the month numbers had increased considerably and a few flocks of 200–300 were seen in the cold water areas off Ras Fartak and in Kuria Muria Bay (Fig. 9). In March I saw a few off Arabia, the only flock being close inshore near Kuria Muria Bay (Fig. 10).

Previous records have shown that phalaropes are abundant winter visitors to the Arabian Sea. The earliest autumn record is at 15° 18′ N., 52° 12′ E. on 27 July 1961 (Harrison—see Bourne & Radford 1962), but most appear to arrive in August and September, when large numbers have been seen, especially near Ras Fartak. In the winter the largest numbers have been recorded from the Gulf of Aden and the Gulf of Oman (e.g. the Mörzer-Bruijns 1957), but only small numbers are usually present off southeast Arabia at this time. Most appear to leave the Arabian Sea in April but there are a few records in May, the latest being 20 May 1960 in the Gulf of Oman (Neale & Miles unpub.).

CATHARACTA SKUA. Great Skua

A rare visitor to the Arabian Sea, from the antarctic and subantarctic, mostly during the southwest monsoon (Mörzer Bruyns & Voous 1965). None has been collected, so it is not clear which subspecies have occurred.

In 1963, *C. skua* was seen on five occasions (in no case was the subspecies determined), all within the upwelling area and mostly near the Kuria Muria Islands: 3 July 1963 at

16° 24′ N., 54° 21′ E.; 1 August 1963 at 17° 56′ N., 57° 32′ E.; 2 August 1963 at 17° 19′ N. 56° 40′ E.; 3 August 1963 at 17° 25′ N., 55° 33′ E.; 7 August 1963 at 17° 14′ N., 55° 55′ E.

Although Alexander (1931) reported *C. skua* in the Arabian Sea in September 1929, evidence that it occurs there regularly during the southwest monsoon has been published only recently (Mörzer Bruyns & Voous 1965). It has been reported in the area covered by the present paper between March and September inclusive.

STERCORARIUS POMARINUS. Pomarine Skua

A migrant from the north, commonest in winter but regular in small numbers throughout the year. Although adults occur in winter, most summering birds are immatures and can only be identified by their heavy build.

A few immature skuas which I believe were *S. pomarinus* were seen off southeast Arabia as follows: 30 June 1963 at 16° 34′ N., 54° 05′ E.; 15 July 1963 at 23° 04′N., 59° 04′ E.; 30 July 1963 at 19° 06′ N., 57° 56′ E.; 31 July 1963 at 18° 26′ N., 57° 24′ E.; 26 May 1964 at 17° 08′ N., 55° 48′ E.

There are few published records of *Stercorarius* spp. in the Arabian Sea (e.g. Elliot 1952, Smith 1956) although Medhurst (in prep.) has recorded both *S. pomarinus* and the Arctic Skua *S. parasiticus* in quite large numbers at Aden. The unpublished records suggest that skuas are quite common off southeast Arabia especially in the winter, but that the largest numbers occur in the Gulf of Oman. In the upwelling area skuas thought to be *S. pomarinus* have been reported from January to July inclusive and in September. It seems likely, therefore, that *S. pomarinus* occurs off Arabia regularly during the winter in small numbers and that a few young birds remain through the summer. It appears to be rare in the upwelling area during the upwelling season.

LARUS HEMPRICHI. Hemprich's Gull

Endemic in the northwest Indian Ocean, breeding in the summer on islands off Kenya, on the eastern Somali coast, off the Mekran coast, on islands at the foot of the Gulf of Aden, in the southern Red Sea and possibly in the northern Gulf of Aden. Although some Hemprich's Gulls are resident off the Arabian coast throughout the year many appear to migrate south in the winter.

In March I saw *L. hemprichi* off southeast Arabia only in the Gulf of Aden. In May, small flocks were seen in Kuria Muria Bay and a little further offshore (Fig. 11), but there were no large flocks (presumably birds gather there later in the year). From June to August I found it abundant close to the shore off the entire coast of southeast Arabia (Figs. 8 and 9), but especially in Kuria Muria Bay, where flocks of several thousand were seen (Table 2). Up to about 50 miles from land, and 90 miles on section III, flocks of up to 50 were frequently seen, usually, but by no means always, following the ship.

L. hemprichi is extremely common at Aden and there are several records from the Arabian coast within the limits of the upwelling area. Browne (1950) found it common at Masira in June and September, and near Ras Risut in June; and Smith (1956) has reported that it may breed in July and August on Halania Island in the northern Gulf of Aden. The unpublished records suggest it is common off southeast Arabia throughout the year, though there are few records of large concentrations outside the Gulf of Aden, all of them during the southwest monsoon.

LARUS FUSCUS. Lesser Black-backed Gull

A winter visitor to the coasts of the Arabian Sea, small numbers remaining throughout the summer. At least three subspecies occur, of which *L. f. fuscus* and *L. f. heuglini* are common while *L. f. taimyrensis* is rare (Meinertzhagen 1954).

From June to August I saw *L. fuscus* only at Aden, but small numbers of immatures and adults, most of which appeared to be *L. f. heuglini* from their sooty grey mantle colour, were seen off the Kuria Muria Islands and in the Gulf of Aden in March (Fig. 10). Previous records show it is extremely common at Aden in the winter but much rarer in the summer (Meinertzhagen 1954). Along southeast Arabia there are numerous records of small numbers but it appears to be less common than in the Gulf of Aden and the Gulf of Oman. It appears to be rare in the upwelling area during the summer, but has been recorded on Masira and near Mukalla in September (Browne 1950).

LARUS ICHTHYAETUS. Great Black-headed Gull

A rare winter visitor to the coasts of the Arabian Sea. Recorded on Masira in February (de Schauensee & Ripley 1953).

LARUS GENEI. Slender-billed Gull

Breeds near the Mekran coast and in the Persian Gulf. Small numbers have been recorded at Aden in the winter. Recorded on Masira in September (Browne 1950).

HYDROPROGNE TSCHEGRAVA. Caspian Tern

A passage migrant and winter visitor in small numbers to southern Arabia. Recorded on Masira in September (Browne 1950).

STERNA REPRESSA. White-cheeked Tern

Endemic in the northwest Indian Ocean breeding in summer in the Red Sea, the Persian Gulf, off Kenya, possibly off western India and at the foot of the Gulf of Aden. Mostly migrates south in the winter. Recorded as extremely common on Masira in June and September (Browne 1950).

STERNA ANAETHETUS. Brown-winged Tern

A pantropical species represented in the northern Arabian Sea by *S. a. fuligula*, which breeds in the summer on islands off Kenya, in the Persian Gulf, the Gulf of Aden and the Red Sea. Mostly migrates south in the winter.

Although it is possible to confuse *S. anaethetus* with *S. fuscata* at sea, I found the paler colouration of *S. anaethetus*, and its more direct flight close to the sea, useful field characters.

In early March I recorded only one off Ras Fartak, and none at all off the Kuria Muria Islands in May. From June to August I saw small numbers off Arabia except near the Kuria Muria Islands where it was then common (Figs. 8 and 9, Table 2). The largest numbers were seen close to land but flocks were seen up to about 80 miles offshore (Table 2).

There are few published records in southeast Arabia (Barnes 1893, Browne 1950, Meinertzhagen 1954) but the unpublished records suggest that it is extremely common in the Gulf of Aden and the Gulf of Oman from March to October. There are very few records in the winter and it seems certain that most migrate south, as suggested by Meinertzhagen (1954). Off southeast Arabia it seems to be rather local, although it has been recorded off the Kuria Muria Islands, Masira and Ras al Hadd mainly during the southwest monsoon (e.g. Browne 1950).

STERNA ALBIFRONS. Little Tern

Represented in the northern Indian Ocean by *S. a. saundersi* as a breeding bird, and by *S. a. albifrons* as a winter visitor. In the Arabian Sea, *saundersi* breeds in the summer off the Mekran coast, in the Persian Gulf, on Masira, in the Red Sea and on the coast of eastern Somalia.

A flock of seven *S. albifrons* was seen off Masira on 14 July 1963 at 20° 15′ N., 59° 07′ E., and several other flocks thought to be this species were seen within a few miles. There was no evidence that it was common in the upwelling area although it could have been commoner closer inshore than we observed. Although there have been several reports of *S. albifrons* at Aden, further east on the Arabian coast few have been recorded (Ticehurst & Cheesman 1925, Guichard & Goodwin 1952). In June, Browne (1950) found several nests on Masira, and noted that the species seemed to be less common there in September of the same year.

THALASSEUS BERGII. Crested Tern

An Indo-Pacific species represented in the northwest Indian Ocean by *T. b. velox* which breeds in the summer off India and Pakistan, in the Gulf of Aden and in the southern Red Sea.

I saw none in March but at the end of May a flock was seen off the Kuria Muria Islands. From June to August I saw small numbers off southeast Arabia west of 58° E. (Figs. 8 and 9), especially off the Kuria Muria Islands (Table 2). It was apparently restricted to within about 50 miles of land and seemed slightly commoner in the cold water area (Table 2).

T. bergii is common at Aden throughout the year, and especially so in the summer (Browne 1950, Medhurst in prep.). It has also been recorded at Masira and at other points on the southeast coast of Arabia in June and September (Browne 1950), but there are few reports at sea, most of them in summer, none in winter.

THALASSEUS BENGALENSIS. Lesser Crested Tern

A mainly Indian Ocean species represented in the Arabian Sea by *T. b. bengalensis*, which breeds in the summer in the Persian Gulf, the Gulf of Aden and the Red Sea, and mostly migrates south in winter.

Four terns which I thought were *T. bengalensis* were seen at 21° 04′ N., 59° 04′ E. on 15 July 1963, but no others outside the Gulf of Aden. At Aden it is abundant in summer but scarce in winter. There have also been a few reports further east, including some at Masira in June and September (Browne 1950), but none have definitely been recorded at sea and it seems fairly certain that it does not frequent the upwelling area. There is some evidence that large numbers migrate south to east Africa in winter (Meinertzhagen 1954); certainly there is no other likely reason for their scarcity further north at this time.

THALASSEUS SANDVICENSIS. Sandwich Tern

A winter visitor and passage migrant in unknown numbers. Recorded on Masira in June and September (Browne 1950); regular at Aden on passage (Medhurst in prep.).

ANOUS STOLIDUS. Common Noddy

A pantropical species which breeds in the summer on Mait Island and possibly in the southern Red Sea and on Socotra. It was also reported to nest on the Kuria Muria Islands by von Heuglin (1873), but this record remains unconfirmed. I never saw the species off the Arabian coast, but there have been a few recent reports off southeast Arabia. Smith (1956) recorded two birds which he thought were this species on the northern shore of the Gulf of Aden in December, and Meinertzhagen (1954) reported a sight record at Aden in November. There are also two sight records off the Kuria Muria Islands in January 1959 (Colquhoun, unpub.) and July 1960 (King, unpub.). All these birds could have been vagrants from Mait Island where they breed (Heuglin 1873, North 1946).

GENERAL ASPECTS OF SEA-BIRD DISTRIBUTION

SEA-BIRD SPECIES

Throughout the world large numbers of birds frequent upwelling areas (Murphy 1936, Hutchinson 1950). Although the sea-bird fauna of the Arabian coast upwelling area has never been described accurately, several authors have commented on the abundance of birds there, while my evidence for 1963 shows that the greatest numbers of birds are to be found in the area of cool water during the southwest monsoon.

In 1963 only 12 species were common off Arabia, while another seven were seen in very small numbers. *O. monorhis* was added to the species known to have occurred off southeast Arabia. Bourne (1963) listed 16 for the summer and two more further offshore (Table 1), but in my view five are rare in the upwelling area: *S. albifrons* was seen only in small numbers, *P. pacificus* and *T. bengalensis* were doubtfully recorded, and *L. genei* and *S. repressa* were not recorded at all. It is quite possible, however, that the four Laridae were restricted to the inshore zone (Wynne-Edwards 1935) not fully covered by the survey.

TABLE 1. *The avifauna of the southeast Arabian coast upwelling area.*

Species and subspecies where known	Status off S.E. Arabia given by Bourne (1963)	June–August 1963	March 1964	May 1964
Puffinus carneipes	S	***	–	*
Puffinus pacificus	(S? R?)	?	–	?
Puffinus lherminieri persicus†	R	***	–	*
Bulweria fallax††	R	***	**	***
Oceanites oceanicus	S	***	–	*
Pelagodroma marina	S	**	–	*
Fregetta tropica	S	*	–	*
Oceanodroma monorhis	—	*	–	–
Phaethon aethereus indicus†	R	**	*	**
Sula dactylatra melanops	R	***	***	***
Sula leucogaster	R	*	–	–
Phalacrocorax nigrogularis††	R	***	*	–
Phalaropus fulicarius	(N?)	–	–	–
Lobipes lobatus	N	**	*	–
Catharacta skua	Vagrant	*	–	–
Stercorarius pomarinus	N	*	–	*
Stercorarius parasiticus	Passage migrant	–	–	–
Larus hemprichi††	R. N.	***	–	**
Larus fuscus	N	–	*	–
Larus ridibundus	N	–	–	–
Larus genei	R. N.	–	–	–
Sterna dougalli	(R?)	–	–	–
Sterna repressa††	R	–	–	–
Sterna anaethetus fuligula†	R	***	–	–
Sterna fuscata	R	–	–	–
Sterna albifrons	R (N?)	*	–	–
Thalasseus bergii velox†	R	**	–	**
Thalasseus bengalensis	R	?	–	–

Notes. R Resident, S Visitor in southwest monsoon, N Visitor in northeast monsoon, † Endemic subspecies, †† Endemic species, – not recorded, * recorded, ** common, *** abundant, ? status doubtful.

The 12 common species during the 1963 survey consisted of three apparently resident off Arabia (the gad-fly petrel, the booby and the tropic-bird), five which apparently migrate a fairly small distance within the tropical Indian Ocean (the small shearwater, the cormorant, the gull and two terns), three which breed in the southern hemisphere and moult in the Arabian Sea (the large shearwater and the two storm-petrels) and one migrant from the north (the phalarope).

I saw more birds during the southwest monsoon in 1963 than in March 1964. Of the twelve species common in 1963, only five were seen in March 1964 and most of those were in reduced numbers. Only *L. fuscus* was seen in March but not at any other time. The winter distribution of species characteristic of the upwelling area is poorly documented, and little is known for certain about the winter quarters of *P. lherminieri*, *P. nigrogularis*, *L. hemprichi*, *S. anaethetus*, or *T. bergii*, though it has been suggested that *L. hemprichi* and *S. anaethetus* migrate south to the coasts of east Africa during the northern winter, for they are certainly rarer in the north at that time (Archer & Godman

1937, Meinertzhagen 1954). The available information suggests that *P. lherminieri* and *P. nigrogularis* migrate to the Gulf of Oman and the Gulf of Aden, where large numbers have been reported in winter (Bourne 1964, 1965, Bourne & Radford 1962).

By the end of May 1964, i.e. before upwelling was fully established, most of the birds which were characteristic of the upwelling area in 1963 had begun to arrive off the Kuria Muria Islands (Table 1). The only exceptions were *P. nigrogularis* and *S. anaethetus*, but insufficient time was spent there to confirm their absence.

BREEDING DISTRIBUTION

At present there is evidence that seven species of sea-birds may breed or have bred along the south coast of Arabia from Aden to Ras al Hadd: *P. aethereus*, *S. dactylatra*, *P. nigrogularis*, *L. hemprichi*, *S. albifrons*, *T. bergii* and *A. stolidus*. The main breeding stations appear to be the Kuria Muria Islands and a group of islands in the northern Gulf of Aden.

On the Kuria Muria Islands

von Heuglin (1873) recorded *S. dactylatra*, *A. stolidus* and possibly *P. aethereus* breeding. The only observations since then are David's (1956), of *S. dactylatra* breeding on Qibliya, and my own, also of *S. dactylatra* on Hasikiya, though breeding is likely there for *P. nigrogularis* also (see above). The only evidence for the breeding of other species on the Kuria Muria Islands is my own observation of a pair of *T. bergii* carrying food towards Hasikiya in August 1963.

While on Hasikiya in March 1964, I searched for potential nesting sites of other species. On the steep sides of gullies, crevices (½–1 m. deep) were found which might afford sheltered sites for tropic-birds and petrels. No evidence was found that such places were used, though it seems reasonable to suggest that they might be.

In sum, evidence that *S. dactylatra* breeds on the Kuria Muria Islands is definite, and is suggestive for *P. aethereus*, *P. nigrogularis* and *T. bergii*. In the case of *A. stolidus* there is only one report, from the middle of the last century, and nesting may no longer occur.

Elsewhere along the Arabian coast

in the upwelling area, there is only one record of breeding sea-birds, *S. albifrons* nesting on Masira (Browne 1950). An observation suggestive of breeding, however, is that of Owen (1857) who reported " myriads of sea-birds " on Jazirat Hamar an Nufur, an island in the Gulf of Masira.

In the Gulf of Aden, but outside the area covered by the present paper, *P. nigrogularis* and *L. hemprichi* may nest on Sikha Is., Barraqa Is. and Halania Is. (Smith 1956).

On Mait Island (Heuglin 1873, North 1946) *S. dactylatra*, *P. aethereus*, *S. fuscata*, *A. stolidus* and probably *S. anaethetus* breed.

On Kal Farun, *S. dactylatra* and probably *P. aethereus* breed (Hutchinson 1950; Forbes-Watson,. pers. comm.).

Elsewhere on the Arabian coast and in the northwestern Arabian Sea there is no evidence of breeding for any sea-birds; but it could take place on some of the inaccessible cliffs of the mainland, and possibly on the Brothers Is. off southern Socotra (Forbes-Watson, pers. comm.). There are besides many islands used by sea-birds for breeding in the Persian Gulf, the Red Sea, at the foot of the Gulf of Aden off the Somali coast, and off the Mekran coast.

BREEDING SEASONS

(*a*) *S. dactylatra* had eggs on the Kuria Muria Islands in April 1954 and March 1964. If the incubation and fledging periods were similar to those reported for this species on Ascension Is. (Dorward 1962), the young would have hatched from late April to mid-May and would have left the nest sometime after mid-August. From late June to August 1963, only one immature *S. dactylatra* was seen off the Kuria Muria Islands which indicates that the main departure from the colonies certainly does not occur before mid-August. On Mait Island most nestlings seem to be almost or completely fledged by November (North 1946) and in the southern Red Sea young of all stages have been found on the Haycock Islands in November (Morris 1962).

(*b*) *B. fallax* breeding stations are unknown, but Jouanin (1957) inferred from the feather condition of specimens that breeding runs from August to November, while in addition the seven specimens collected between 25 June and 18 August 1963 on board ' Discovery ' had brood spots. The available evidence thus suggests a laying period starting around June, that is during the period of greatest intensity of the southwest monsoon. If the incubation and fledging periods are similar to those reported for Procellariidae of similar size, then the young might be expected to hatch by mid-August and leave the nest after the end of October. The period in the nest would thus roughly coincide with the latter part of the southwest monsoon and the young would leave the nest well after its cessation. Although it is possible that this stage of the cycle is timed to occur when food is most abundant, it is also possible that egg production is delayed by insufficient food until well into the upwelling season.

(*c*) *P. lherminieri persicus* may breed at the same time of year as *B. fallax* but the evidence is even more tenuous and rests on the capture of a single specimen with a broodspot on 18 August 1963. Of the specimens in the British Museum, those caught in summer have an abraded plumage, while those in the winter have fairly fresh plumage. This accords with the view that *P. l. persicus* breeds in the late summer and moults soon afterwards.

(*d*) Although there is no definite evidence that *P. aethereus* breeds on the Kuria Muria Islands it appears to collect inshore there some time between March and May. If it does breed on the islands it seems unlikely that the young leave the nest before late August because no juveniles were seen in the seas off the islands up to mid-August 1963. On Mait Island it must breed in the late summer, for North (1946) recorded young almost ready to fly in November. In the Persian Gulf the breeding season seems to be much earlier for young have been found in March. For the Red Sea the evidence is conflicting for birds have been recorded breeding both in March and in the summer (Clapham 1964).

There is very little evidence from which to infer the breeding seasons of other sea-birds in the northwestern Arabian Sea. Pairs of *T. bergii* were seen carrying food towards Hasikiya in early August which suggests that young may have been hatched by that month. Elsewhere in the Arabian Sea it breeds from May to August. In the Gulf of Aden at Sikha Is. *P. nigrogularis* has been reported to nest in the summer, whereas in the Persian Gulf it breeds in the winter (Ticehurst *et al.* 1925). On Halania Is., also in the Gulf of Aden, *L. hemprichi* is reported to breed in July and August (Smith 1956). Elsewhere this species nests from June to September. On Masira *S. albifrons* has been recorded breeding in June.

The sum of the information suggests, therefore, that the breeding seasons of sea-birds in the northern Arabian Sea are mostly in the summer, i.e. during the southwest monsoon.

FOOD AND FEEDING

Some information on food was gained from stomach contents of sea-birds collected on the ' Discovery '.

(*a*) *P. carneipes*. The stomach contents included otoliths, fish vertebrae, and squid beaks which were larger than those found in *B. fallax*. Palmer's (1962) records suggest that it is a versatile feeder, for crustaceans, fish and cephalopods have been reported in its diet.

(*b*) *P. lherminieri.* There were no remains of food in the one specimen obtained. There seem to be no records of the food of *P. l. persicus.*

(*c*) *B. fallax.* Seven of the eight specimens contained fragments of squid beaks, one of which was identified as that of an Ommastrephid. In addition, fragments of a crustacean exoskeleton and a small gizzard stone were found in two other birds. How far these few specimens are representative it is impossible to say, but if *B. fallax* is predominantly a squid-eating species it may feed mostly at night. The only previous records of the food of *B. fallax* were from one captured at night which vomited a 2 cm. squid (Bailey & Bourne 1963), and from a specimen also collected at night by Berlioz (1955) which regurgitated two small fish.

(*d*) *O. oceanicus.* The two stomachs obtained held a gelatinuous egg-case and some very small crystalline lenses and gizzard stones. There appear to be no published accounts of its food in the northern Indian Ocean (Roberts 1940).

(*e*) *P. marina.* The one stomach obtained held small otoliths and a few small gizzard stones. Mörzer Bruyns & Voous (1964) have also recorded otoliths in the stomachs of two specimens from the northern Indian Ocean. *P. marina* has been recorded feeding its young on euphausiids, although other organisms have been reported in the stomachs of adults (Palmer 1962).

(*f*) *O. monorhis.* The stomach contents were not identifiable, but included a few small gizzard stones and what appeared to be chitinous material.

(*g*) *S. dactylatra.* Of the six specimens collected on Hasikiya, one contained a few unidentifiable squid beaks, while the distended pouch of another contained fairly complete remains of fish about 7–8 cm. in length, one of which has been identified tentatively as a garfish (*Hemirhamphus* sp.). In most parts of its range *S. dactylatra* is reported to feed principally on flying-fish (Palmer 1962).

(*h*) *L. lobatus.* The stomach contents consisted mostly of debris, with fragments of a minute gastropod similar to *Ianthina.*

From direct observations of sea-birds feeding it was rarely possible to identify the food taken. *P. carneipes* was recorded carrying a fish about 5 cm. in length and *B. fallax* was seen on two occasions with fish about 5 and 7 cm. in length respectively. One *P. aethereus* was seen to catch an 8 cm. fish, and *S. anaethetus* caught one of about 4 cm. *T. bergii* was also observed to catch a 5 cm. fish. This fragmentary information is quite insufficient to define the food range of any species. It may be misleading, moreover, for the food recorded in this way was, of necessity, during daylight and several species may feed at night on organisms which migrate to the surface then. It may be significant that some species, particularly *B. fallax* and *P. carneipes,* were rarely recorded feeding during the day.

It is clear that the main foods of sea-birds off Arabia are still almost completely unknown. The information collected on the ' Discovery ' cruises gives, at best, some slight indication of the specific differences and the degree of overlap between the diets of different species. However, a difference in feeding methods, rather than a difference in food preference, may be more important to many sea-birds in avoiding competition with one another.

In the most productive areas, especially off the Kuria Muria Islands, large flocks of birds of a few species were frequently seen following shoals of large schooling fish, whose importance in driving food to the sea surface was realized by Murphy & Ikehara (1955) and Ashmole (1963). Close to land most flocks consisted of hundreds of *P. lherminieri* swimming and feeding on the surface among shoals of fish which were presumably driving their prey to the surface. On other occasions the birds were seen to take prey apparently from the surface by flying slowly into the wind low over the water and dropping feet first every few metres. On one occasion two birds immersed their heads and swam rapidly along the surface in the manner described for prions *Pachyptila* spp. (Murphy 1936).

The flocks of *P. lherminieri* close to land were always accompanied by smaller numbers of *T. bergii*, *S. anaethetus* and *L. hemprichi* flying above the shearwaters. *L. hemprichi* seems to feed from the surface by flying into the wind and by dropping down to the water to pick up food with a sudden dip of the head. Occasionally it was also seen dropping feet first into the water and, on two occasions, it pursued *B. fallax* and *P. aethereus* forcing them to drop their food; while once *L. hemprichi* was chased unsuccessfully by *S. pomarinus.*

About 50 miles off the Kuria Muria Islands, shoals of fish were accompanied by flocks of *S. anaethetus* with only small numbers of *P. lherminieri.* The terns seemed to feed from the surface by swooping down among the fish. Only one was seen to plunge head-first into the water and then from about 1 m. above the surface, and apparently without submerging completely. Once one was chased without success by *S. pomarinus.*

Small flocks of *T. bergii* were also seen swooping over the sea catching their food by a sudden turn of the head. In May 1964, off the Kuria Muria Islands, flocks of *T. bergii* were seen feeding among flocks of *S. dactylatra*, sometimes by plunging feet first into the water and sometimes by swooping down close to the surface apparently to take flying fish.

Off Ras Fartak and Ras Madraka, flocks of *P. carneipes* and smaller numbers of *P. lherminieri*, *B. fallax*, *L. hemprichi* and, once, *O. oceanicus*, were seen following schools of dolphins and occasionally whales. *P. carneipes* were rarely seen feeding, but on one occasion, a small flock appeared to take food from the surface while swimming among a shoal of fish. Flocks of 50 or more seen on another occasion descending on small areas of water also seemed to take their food at the surface.

Unlike the shearwaters, *B. fallax* was rarely in flocks and was rarely seen feeding for certain. On one occasion, however, about a thousand were seen off Ras Fartak with *P. carneipes* and *P. lherminieri*, feeding among shoals of small fish. *B. fallax* was occasionally seen to alight or to hover over the water like a feeding storm-petrel, and apparently investigate floating objects, and one was seen to swallow food taken in this way. It seems unlikely, however, that this behaviour would have enabled it to catch fish and squid in large numbers in daylight, so it may well be that *B. fallax* is a predominantly nocturnal feeder.

Another source of food for sea-birds appeared to be oil slicks, seen mainly close to land and often visible over a mile away The source of these was not investigated, but they may have resulted from the decay of algal blooms as reported by Sieburth & Conover (1965), or possibly from fuel oil from ships. Off Arabia, they seemed to attract large numbers of *O. oceanicus* and small numbers of *L. hemprichi*, which could conceivably have been feeding on organisms trapped in the surface film. *O. oceanicus* was also frequently seen feeding in the wake of the ' Discovery ', especially in the Gulf of Aden on the main shipping routes, but the largest concentrations were seen feeding independently of ships, suggesting that the ecological significance of the latter is small.

The observed feeding behaviour of *P. marina* differed from that of *O. oceanicus* in that *P. marina* appeared to feed much more slowly and deliberately. It is possible that this behaviour may be an adaptation to feeding in areas where food is less abundant than in those occupied by *O. oceanicus.*

Few sea-birds off Arabia were seen to dive for food. Inshore in the upwelling area, *P. nigrogularis* was seen in huge flocks, and although they were not certainly seen feeding, they were occasionally seen to dive.

S. dactylatra was seen fishing on only three occasions in July and August 1963, and it may well be that it usually feeds in the blue oceanic water outside the upwelling area. In contrast to Murphy's (1936) suggestion that the distribution of *S. dactylatra* in other oceans coincides roughly with that of flying-fish, few of them were seen within the observed range of flying-fish off Arabia (see Figs. 7 and 8). Nevertheless, on one occasion in May 1964, small flocks were watched circling over shoals of flying-fish, usually diving obliquely into the water from not more than about 3 m.

P. aethereus was observed feeding by diving head-first from heights of about 10–30 m. However the feeding areas did not seem to be restricted to the oceanic water of high transparency, as suggested for this species in the Atlantic Ocean by Murphy (1936), for they were seen on several occasions diving in the opaque water near the Kuria Muria Islands. The fact that they remained submerged for less than a second suggests that they were catching food very near the surface.

ANALYSIS OF SEA-BIRD DISTRIBUTION

From June to August 1963, I kept 205 watches of about an hour during which I recorded all birds seen. The results of these counts, expressed as the number of birds seen per hour, have been used as an index of bird density, and they have been analysed in relation to three environmental parameters which appeared to affect the distribution of some species (Table 2), namely the sea surface temperature, the distance from the Kuria Muria Islands and the distance from the nearest land. The reasons for choosing these parameters are summarized briefly below.

The sea surface temperature can be considered to be a rough index of the zooplankton density, for the two are inversely correlated ($P > 0{\cdot}999$—see Appendix), and therefore presumably of food availability. Secondly, evidence given earlier suggested that the Kuria Muria Islands may be a breeding station for more than one sea-bird species so, if breeding were occurring at the time of the survey, it seemed likely that their observed distribution would be affected by the islands' proximity. In case the islands' significance was merely an incidental result of the species' dependence on land for purposes other than breeding, however, a separate analysis was undertaken in relation to distance from the nearest land, whether this was the Kuria Muria Islands or not.

The results of each analysis and a multiple analysis designed to separate the association with each factor, are presented in Table 2 and in Appendix Table A1. The methods of analysis are described in the Appendix, and the results are summarized briefly below.

There is no doubt that total bird numbers were highest where the sea surface temperature was less than 24° C, i.e. in the area regarded as the upwelling area. In the present survey, the median number of birds in water less than 24° C. was 54, compared with only 14 in warmer water, a difference which is highly significant. However, not every species conformed to this pattern of distribution.

Most of the common species off southeast Arabia during the southwest monsoon in 1963 were commonest close to land in the cool water area around the Kuria Muria Islands (Table 2), and some, namely *P. lherminieri*, *P. nigrogularis*, *L. hemprichi* and *T. bergii*, were almost entirely confined to within 50 miles of land. There were three exceptions: *P. marina* seemed to be restricted to between 50 and 100 miles of land, i.e. largely outside the range of *O. oceanicus* (Fig. 8); there was no evidence that *O. oceanicus* was commonest in the cool water area; and although *P. carneipes* was commonest in the upwelling area there was some evidence that it was less common within 50 miles of the Kuria Muria Islands. These exceptions suggest that there was a general difference in distribution between non-breeding migrants from the southern hemisphere and species thought to breed in the Arabian Sea region.

Despite the strong association of the cool water area with the vicinity of the Kuria Muria Islands, the multiple analysis (Appendix Table A1) suggests that *B. fallax*,

TABLE 2. *Analysis of bird numbers in the Arabian Sea* (*southwest monsoon* 1963).

	MILES FROM THE NEAREST LAND						MILES FROM THE KURIA MURIA ISLANDS					SEA-SURFACE TEMPERATURE			
	0–10	10–20	20–30	30–50	50–90	Over 90	0–50	50–100	100–200	200–300	Over 300	18–20° C	21–23° C	24–26° C	26–30° C
No. of 1 hr. counts	36	38	25	33	37	36	43	31	43	46	42	36	50	73	48
PUFFINUS CARNEIPES															
Mean no./hr.	31	8	3	0·7	0·6	0·8	3	10	4	20	0·6	8	22	2	0.3
Median no./hr.	1·5	0	0	0	0	0	0	3	0	0	1	1	0	0	0
% of 1 hr. counts on which sp. was seen	56%	44%	33%	30%	24%	29%	41%	65%	32%	25%	26%	65%	43%	33%	11%
PUFFINUS LHERMINIERI															
Mean no./hr.	114	8	4	3	1	0·8	95	11	0·5	4	0·1	117	7	0·8	0·6
Median no./hr.	3	0	0	0	0	0	3	1	0	0	0	3	0	0	0
% of 1 hr. counts on which sp. was seen	69%	42%	32%	39%	22%	8%	84%	55%	12%	28%	5%	86%	48%	21%	10%
BULWERIA FALLAX															
Mean no./hr.	49	16	6	8	5	2	30	6	4	26	5	28	27	8	3
Median no./hr.	9·5	2	3·5	4	3	1	20	3	3	1	3	13	3·5	3	1
% of 1 hr. counts on which sp. was seen	86%	76%	82%	91%	87%	64%	100%	87%	79%	64%	75%	89%	86%	81%	66%
OCEANITES OCEANICUS															
Mean no./hr.	6	42	89	8	3	2	2	87	3	5	33	12	22	35	9
Median no./hr.	1	2	6	2	0	0	0	4	0	0·5	4	2	1	0	0·5
% of 1 hr. counts on which sp. was seen	57%	65%	70%	61%	39%	26%	42%	70%	44%	50%	60%	61%	54%	46%	51%
PHAETHON AETHEREUS															
Mean no./hr.	4	2	0·5	0·7	0·5	0·9	5	0·5	0·6	0·5	0·7	4	1	0·8	0·4
Median no./hr.	1	0·5	0	0	0	0	3	0	0	0	0	2·5	0	0	0
% of 1 hr. counts on which sp. was seen	63%	50%	32%	21%	27%	36%	79%	35%	33%	17%	29%	78%	30%	32%	25%
SULA DACTYLATRA															
Mean no./hr.	4	2	0·5	3	2	0·8	8	3	0·4	0·04	0·2	5	3	1	0·1
Median no./hr.	0·5	0	0	0	0	0	3	1	0	0	0	1·5	0	0	0
% of 1 hr. counts on which sp. was seen	50%	32%	20%	30%	27%	31%	81%	55%	16%	2%	14%	61%	36%	29%	6%
LARUS HEMPRICHI															
Mean no./hr.	160	8	10	17	3	0·5	130	10	6	11	8	149	20	5	6
Median no./hr.	16·5	5	1	6	0	0	9	4	0	2	0	10	8	0	0
% of 1 hr. counts on which sp. was seen	100%	92%	52%	67%	46%	14%	93%	71%	40%	72%	36%	89%	80%	45%	46%
STERNA ANAETHETUS															
% of 1 hr. counts on which sp. was seen	33%	21%	19%	16%	20%	11%	43%	30%	12%	9%	13%	37%	21%	17%	14%
THALASSEUS BERGII															
% of 1 hr. counts on which sp. was seen	58%	22%	12%	9%	0%	0%	53%	20%	2%	7%	5%	53%	14%	7%	8%

P. aethereus, *S. dactylatra*, *S. anaethetus* and possibly *P. lherminieri* were associated with the islands as such. *L. hemprichi* appeared to be concentrated close to land along the whole coast of southeast Arabia. In the case of the other species there was insufficient evidence to separate the degree of association with each factor.

In addition to the analyses summarized above, it was originally intended to relate sea-bird density to an index of available food, but the difficulty of sampling small fish and squid, which seem to be important in the diet of many sea-birds off Arabia, quantitatively, made this impossible. Instead, the data were tested for correlations between sea-bird density and abundance of zooplankton. Altogether 57 series of vertical plankton hauls using the 70 cm. net and a further 56 using the neuston net were carried out at biological stations. Observations for birds were made at, or very near, 33 and 35 of them respectively (Appendix Table A2). In testing for correlation with zooplankton density the volumes collected in the neuston net and the vertical nets have been used in separate analyses. Migration of zooplankton to the surface at night, considered to occur from a maximum depth of roughly 200 m., caused marked diurnal fluctuations in its abundance at the surface (David, in prep.). It seems most advisable therefore, to use the volume of zooplankton collected in the top 200 m. as an index of plankton abundance, for this is likely to remain more or less constant over 24 hr. The methods of analysis and the results are presented in the Appendix Tables A3 and A4. There were three main conclusions:—

(*a*) A significant correlation was shown to exist between the total number of sea-birds (all species) and the volume of zooplankton from 0–200 m.

(*b*) The weighted mean of correlation coefficients, using the same data but separately for each section (see Fig. 2), was also significant, and the same was true for the individual species *B. fallax*, *O. oceanicus* and *L. hemprichi.*

(*c*) There was no evidence of correlation between sea-bird density (all species) and abundance of surface zooplankton measured during the day and night. (In the case of night hauls the bird observation made nearest to the neuston net haul was used so long as it was not more than 10 miles away.) Correlation coefficients calculated separately for each section (Fig. 2) showed no evidence of correlation either.

In sum, it is clear that sea-bird numbers were correlated with the general abundance of zooplankton in the surface layers of the sea, but not with its abundance at the surface itself, either during the day or night. This will be discussed later.

DISCUSSION

Although the southeast Arabian coast is part of the tropical zone of the Indian Ocean, its resident sea-bird fauna is highly distinctive; of the ten species I saw in large numbers off the Arabian coast, three are endemic and four are represented by endemic subspecies (Table 1). Of the subspecies, three have conspecific relatives elsewhere in the tropical Indian Ocean and it seems the simplest and more likely suggestion that the Arabian Sea forms have been derived directly from them, rather than vice versa.

Of the three endemic species, *B. fallax* may conceivably have evolved from a population of the smaller Bulwer's Petrel *B. bulwerii*, occurring in the north Atlantic and north Pacific Oceans; it may have evolved by " character displacement " (Brown & Wilson 1956), that is by becoming morphologically adapted to fill an ecological niche which is divided between two species in other areas, in this case namely the Soft-plumaged Petrel *Pterodroma mollis* and *B. bulwerii* which are sympatric in the subtropical north Atlantic Ocean (Bourne 1963), and between which *B. fallax* is roughly intermediate in size.

In addition *P. aethereus*, which occurs only in the northwestern part of the Indian Ocean, may have reached there from the Atlantic Ocean.

The other two common endemic species in the Arabian Sea are land-based sea-birds which have probably evolved from Palaearctic forms. *L. hemprichi*, together with

L. leucophthalmus, endemic in the Red Sea, is thought to have evolved from the *Larus argentatus/fuscus* group of gulls (Fogden 1964). The ancestry of *P. nigrogularis* has not been investigated, but it could conceivably have evolved from the Shag *P. aristotelis* which breeds in the Mediterranean Sea.

It seems likely that the distinctive resident sea-bird fauna of the Arabian Sea has been derived from three sources: four forms from tropical Indian Ocean ancestors, two from ancestors which entered the Indian Ocean from the tropical zone of other oceans, and two from Palaearctic species. Of these, the last four have evolved into separate species. In contrast with the same latitudes in other oceans, none of the Arabian Sea sea-birds have evolved from ancestors inhabiting the southern subtropical zone. Although a species of shearwater and a storm-petrel migrate regularly to the Arabian Sea from southwest Australia, neither have evolved separate subspecies in the northern Indian Ocean; yet in the northern Atlantic Ocean, *P. marina* is represented by an endemic subspecies (*P. m. hypoleuca*). Serventy (1956) has suggested that the absence of resident representatives of southern subtropical sea-birds in the northern Indian Ocean is due to the absence of cool water refuges during the winter. It seems likely that the seasonal changes in the environment, particularly the cessation of upwelling off Arabia, preclude the possibility of their remaining there throughout the year, and indeed none have been reported in the Arabian Sea during the northern winter.

Another peculiarity of the Arabian coast is the apparent absence of most of the pantropical species which breed elsewhere in the tropical Indian Ocean, namely *Puffinus pacificus*, *Phaethon lepturus* and *P. rubricauda*, *Sula sula* and *S. leucogaster*, *Fregata minor* and *F. ariel*, *Sterna dougalli* and *S. fuscata*, *Anous stolidus* and *A. tenuirostris* and finally *Gygis alba*. The high degree of endemism of Arabian coast sea-birds and the absence of those species named above suggest that the seasonal changes in the environment off Arabia demand considerable adaptation. The resulting sea-bird fauna is typical of neither a tropical nor a subtropical fauna of other oceans.

Evidence presented earlier shows that all but three of the species found off Arabia during the southwest monsoon move elsewhere when upwelling ceases to be active. While some of them migrate south, *P. lherminieri*, *P. nigrogularis* and possibly *L. hemprichi* and *T. bergii* apparently migrate to the Gulf of Aden and the Gulf of Oman. Bourne (1963) has suggested that they inhabit areas where upwelling occurs during the northeast monsoon, but as yet there is little definite evidence.

At least it is clear that the seas off southeast Arabia can only support their distinctive sea-bird fauna during the southwest monsoon. Sea-birds of most species were commonest in the upwelling area during this period in 1963 and the evidence shows that this happens regularly every year. The fact that planktonic and other organisms were more abundant during the upwelling season suggests very strongly that food for sea-birds was also abundant at that time. In sum, the sea-birds of the Arabian coast upwelling area may be regarded as constituting a seasonal (southwest monsoon) cool water avifauna within the tropical zone of the Indian Ocean, breeding apparently when upwelling occurs and when it may be inferred that food is most abundant.

In several areas within the tropical zones of other oceans, upwelling of cold water and an associated high rate of organic production are the main factors making possible the development of vast populations of sea-birds; the guano trade in these areas has been almost entirely dependent upon this phenomenon (Hutchinson 1950). However, although sea-birds were abundant off southeast Arabia during the southwest monsoon in 1963, their numbers nowhere nearly approached those found in the Peru coastal current described by Murphy (1936). I would suggest that the difference can be explained primarily by the seasonal nature of upwelling off Arabia, although the scarcity of offshore islands may also be important. Off Peru there is convincing evidence that the sea-birds depend on a continual process of upwelling because, together with other organisms, they die in vast numbers when the cool water areas are invaded by warm water at irregular intervals of many years.

Although there is no doubt that upwelling off Arabia is of the utmost importance to sea-birds, their precise pelagic distribution must depend on several factors, including the position of breeding stations, such as the Kuria Muria Islands. Fig. 8 and Table 2 amply demonstrate the concentration of many sea-birds, particularly the putative breeding species, off these islands, the only known sea-bird breeding station for several hundred miles along the coast. As the main centre of upwelling in 1963 coincided with this area, it is difficult to assess the relative importance of the breeding islands and the highly productive seas in attracting birds there; but the multiple analysis (Appendix Table 1) suggests that the presence of the islands may have been the more important in the cases of *B. fallax*, *P. aethereus*, *S. dactylatra*, *S. anaethetus* and possibly *P. lherminieri*.

Pelagic distribution must also depend on the distribution of food. Although it was possible to detect a correlation between the density of sea-birds of all species and an index of zooplankton abundance, it cannot be stressed sufficiently that this is a correlation between the abundance of organisms at least two trophic levels of the food chain apart, and is therefore more a correlation with the productivity of the sea that with the abundance of available food. In his classic work in the Atlantic Ocean, Jespersen (1929) likewise demonstrated the existence of a correlation between sea-bird density and zooplankton abundance. The present study is little further advanced than his, except that it was undertaken in a much smaller area and therefore demonstrates on a much smaller scale that sea-birds congregate in areas of highest productivity (as measured by the standing crop of zooplankton). This may suggest that some sea-birds at least have a behavioural mechanism enabling them to locate areas of high productivity, but whether this is by random searching or by making use of environmental parameters, such as the sea temperature, is at present purely speculative.

As a correlation was demonstrated between sea-bird density and the standing crop of zooplankton from 0–200 m., it seems anomalous that no such correlation existed with the abundance of zooplankton at the sea surface. A preliminary investigation of the neuston net samples suggests that zooplankton is extremely patchy at the surface (David, in prep.). If food available to sea-birds also has a patchy distribution, then this might explain why sea-birds are so often found in localized concentrations. Direct observation of the behaviour of sea-birds at sea suggests that many species spend much time scanning the ocean surface alone or in small parties. Evidence given earlier, and many previous reports, show that large numbers are attracted to feed in a small area when a local concentration of food is located; this has been termed feeding by local enhancement by Hinde (in Marshall 1961). Surface plankton appears to be unimportant in the diet of most species off Arabia, and I suggest that sea-birds will be found to be commonest in areas of high productivity rather than in areas where surface plankton as such is most abundant.

ACKNOWLEDGMENTS

I would like to thank Dr D. Lack, my supervisor, and Mr R. I. Currie for their invaluable advice and for making available every facility at the Edward Grey Institute and on board ' Discovery ' respectively. I would also like to thank Mr R. E. Moreau and Dr W. R. P. Bourne for their continued encouragement and help. To all of them I am grateful for criticising this paper in manuscript.

I am most grateful to the many members of the crew and scientific staff of the ' Discovery ' who aided me in my work. I have also been helped by several members of the staff of the National Institute of Oceanography, particularly Dr M. Clarke to whom I am most grateful for identifying the cephalopod material from birds' stomachs, and Mr P. M. David for helpful criticism during the field work. While I was at Aden Mr H. P. Medhurst kindly offered me hospitality and gave me invaluable information on the birds of Aden for which I am most grateful.

I would also like to thank Captain G. S. Tuck, D.S.O., R.N., for giving me access to the reports of the Royal Naval Bird-watching Society; to Dr M. Bulmer, of the unit of Biometry at Oxford, for advice on the statistical treatment of my data; and to Mr J. D. Macdonald who has given me access to the collection of skins at the British Museum (Natural History). My special thanks are also due to my wife who typed and corrected several drafts of the manuscript.

Finally I wish to thank the Nuffield Foundation and the British Ornithologists' Union who financed my work from January 1963 to March 1965 and from April to September 1965 respectively. I am most grateful for their generous support.

SUMMARY

The present study of an upwelling area off the southeast coast of Arabia, between 52° and 60° E., is based primarily on observations on board the R.R.S. ' Discovery ' during the International Indian Ocean Expedition. During oceanographic surveys off the Arabian coast from June to August 1963 and in early March and late May 1964 I made 234 counts of birds of about an hour each, the results of which have been used as an index of bird density. In this area, the only offshore islands known to be important to sea-birds are the Kuria Muria Islands, which were apparently at the centre of an upwelling area. The upwelling of cold water along the Arabian coast during the southwest monsoon from May to September greatly increases organic production in the sea, and large populations of organisms at every level of the food chain develop there.

Previous work in Arabia and the Arabian Sea is reviewed. Little is recorded about the ecology of sea-birds there, but the composition of the fauna is quite well-known.

The distribution of every sea-bird species recorded from 52° E. to 60° E., and within 200 miles offshore, is described, with particular reference to my own observations. Details are given of the distribution of common species during the southwest monsoon of mid-June–mid-August 1963 and in March and May 1964. Specimens collected on the ' Discovery ' are recorded together with their measurements. Of 12 sea-bird species seen commonly off Arabia during the southwest monsoon in 1963, 11 were seen in late May 1964, but only five in March.

There is certain evidence that two species have bred on the Kuria Muria Islands and suggestive evidence for a further three. Information on breeding seasons in the Arabian Sea is based on short visits to breeding colonies, mostly outside the breeding season, and on the plumage condition of specimens. Nevertheless, the sum of the evidence suggests that breeding is regular at the same time every year, and in most species seems to be in the northern summer.

The food of sea-birds in the Arabian Sea, determined from stomach contents and visual observation, only serves to stress the lack of knowledge on this subject. A brief summary of feeding methods recorded by me suggests that they may be important in avoiding interspecific competition, for there seems to be little overlap.

The density of sea-birds during the southwest monsoon 1963, expressed as the number of each species seen per hour, was analysed in relation to: (i) the sea surface temperature, which was inversely correlated with the zooplankton density from 0–200 m. (ii) the distance from the Kuria Muria Islands, the only likely breeding station; (iii) the distance from the nearest land which may have been important to land-tied sea-birds.

All the abundant species were commonest close to land in the cool-water area and, with the exception of migrants from the southern hemisphere, most were concentrated around the Kuria Muria Islands in the centre of upwelling. A multiple analysis suggested that the islands were of real importance to some species. A separate analysis also demonstrated the existence of a correlation between sea-bird numbers and the abundance of zooplankton from 0–200 m. depth, but not the abundance of zooplankton at the sea surface.

During the southwest monsoon the southeast Arabian coast is inhabited by a distinctive cool-water fauna within the tropical zone of the Indian Ocean. The high degree of endemism, the high proportion of migrants, including some from the southern hemisphere, and the absence of most pantropical species, suggest that the marked changes in the environment off southeast Arabia demand considerable adaptation. A brief discussion of the possible origins of the Arabian coast sea-bird fauna shows that it is not typical of either a subtropical or a tropical community in other regions.

The likelihood that sea-birds breed in the summer, the concentration of most species in the upwelling area at that time and their absence during the winter, clearly demonstrates the importance of the upwelling. However, the results of the analysis suggest that some species were concentrated around the Kuria Muria Islands in the centre of the upwelling because the islands had a real importance to them, possibly as a breeding station.

The correlation between sea-bird density and zooplankton abundance in the top 200 m., but not at the surface, may be explained if sea-birds concentrate in areas of high productivity rather than in areas of abundant surface plankton, which is largely irrelevant as food.

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APPENDIX

Statistical analysis of bird-counts

Many factors combine to decrease the numerical accuracy of densities estimated by counting birds at sea. These include principally the range at which they can be identified in different sea conditions and the speed of the birds and the ship. From first principles it is possible to derive a formula for assessing the densities of birds from the results of line transects taking into account these variables. In this way Yapp (1955) has shown that the density of birds is given by:—

$$D = \frac{z}{2R\,(\bar{u}^2+\bar{w}^2)^{\frac{1}{2}}}$$

where D = density, z = number of sightings in unit time, R = maximum distance at which birds can be seen and identified, $\bar{u}$ = the average speed of the birds, and $\bar{w}$ = the average speed of the observer.

Previous estimates have suggested that many sea-birds fly at from 25–35 knots (Meinertzhagen 1955), so it seems safe to assume that most sea-birds in the Arabian Sea fly at over twice the speed of the ' Discovery ' which was 10–12 knots. On the basis of Yapp's formula, therefore, estimated densities would differ by not more than about 10% whether the ship were moving or stationary. Assuming that the errors due to the speed of the ship and to the speed of the birds and to differences in environmental conditions are of this order, the density of sea-birds is roughly proportional to the number seen per hour. Although it was impossible to check the last of these assumptions, the wind speed and wave height were remarkably constant over much of the survey area (see above).

TABLE A1. *Multiple analysis to separate the effects of three factors on the distribution of sea-birds off Arabia during the southwest monsoon,* 1963.

Species	Ranges for which difference in frequency of occurrence was tested*	All counts§	Probability of difference in observed frequency of occurrence in the two ranges compared†‡		
			Eliminating the effect of:		
			distance from land	distance from Kuria Muria Islands	sea-surface temperature
Puffinus carneipes	*a* <10 cf.>10	0·98	—	0·9	0·1
	b <100 cf.>100	0·99	0·9	—	0·5
	c <23° cf. 24–26°	0·95	0·5	0·9	—
	24–26° cf.>27°	0·98	0·8	0·8	—
Puffinus lherminieri	*a* <10 cf. 10–50	0·99	—	0·3	0·3
	10–50 cf.>50	0·99	—	0·8	0·7
	b <50 cf. 50–100	0·98	0·8	—	0·3
	50–100 cf. 1–300	0·999	0·98	—	0·9
	1–300 cf.>300	0·95	0·7	—	0·5
	c <20° cf. 21–23°	0·999	0·99	0·5	—
	21–23° cf.>24°	0·999	0·99	0·8	—
Bulweria fallax	*a* <10 cf. 10–90	0·998	—	0·05	0·5
	10–90 cf.>90	0·999	—	0·99	0·99
	b <50 cf. >50	0·999	0·999	—	0·99
	c <23° cf. 24–26°	0·99	0·3	0·05	—
	24–26° cf. >27°	0·999	0·5	0·5	—
Oceanites oceanicus	*a* <90 cf. >90	0·99	—	0·99	0·98
	b 50–100 cf.<50	0·95	0·9	—	0·9
	50–100 cf.>100	0·95	0·3	—	0·5
	c No significant differences				
Phaethon aethereus	*a* <20 cf.>20	0·999	—	0·98	0·3
	b <50 cf.>50	0·999	0·999	—	0·99
	c <20° cf.>21°	0·999	0·99	0·8	—
Sula dactylatra	*a* <10 cf.>10	0·98	—	0·01	0·2
	b <50 cf. 50–100	0·998	0·8	—	0·98
	50–100 cf.>100	0·999	0·999	—	0·999
	c <20° cf. 21–26°	0·99	0·95	0·01	—
	21–26° cf.>27°	0·99	0·9	0·2	—
Larus hemprichi	*a* <10 cf. 10–20	0·999	—	0·02	0·1
	10–20 cf. 20–90	0·99	—	0·98	0·99
	20–90 cf.>90	0·999	—	0·98	0·999
	b <50 cf. 50–100	0·98	0·1	—	0·8
	50–100 cf. 1–200	0·98	0·5	—	0·98
	2–300 cf. 1–200	0·99	0·7	—	0·95
	2–300 cf.>300	0·99	0·5	—	0·99
	c <23° cf. >24°	0·999	0·5	0·99	—
Sterna anaethetus	*a* No significant differences				
	b <100 cf.>100	0·999	0·999	—	0·98
	c <20° cf.>21°	0·98	0·8	0·9	—

Notes * *a* Distance from the nearest land in nautical miles.
b Distance from the Kuria Muria Islands in nautical miles.
c Sea-surface temperature in °C.
§ Probabilities based on two-tailed tests.
† Minimal probabilities based on one-tailed tests obtained from Fisher tests of the exact probabilities.
‡ Columns 4–6 show the probability that the observed frequency of occurrence within the first range of values was greater than the second in column 2.

TABLE A2. *Plankton density and abundance of birds at stations off Arabia.*

Observation number (cf. Fig. 2)	Volume of Plankton from 0–200 m.	No. of birds seen/hr.	No. of *B fallax*/hr.	No. of *O. oceanicus*/hr.	No. of *L. hemprichi*/hr.
1	4·9	16	3	6	3
2	4·3	4	1	1	2
3	19·9	10	2	2	1
4	10·9	14	2	2	6
5	13·6	38	8	1	3
6	10·1	12	1	0	4
7	3·8	7	1	0	1
8	12·8	60	3	44	9
9	7·0	15	3	2	3
10	3·5	10	5	0	0
11	5·0	10	1	1	4
12	27·2	95	8	0	15
13	72·7	78	30	0	37
14	60·6	76	8	1	45
15	19·9	40	7	1	15
16	23·0	16	4	0	3
17	23·3	61	27	11	5
18	8·5	5	2	0	0
19	13·9	22	2	1	8
20	40·0	43	2	1	35
21	21·5	31	0	1	30
22	15·0	18	10	1	0
23	16·5	6	3	0	2
24	11·2	0	0	0	0
25	11·2	0	0	0	0
26	6·4	0	0	0	0
27	28·5	81	0	8	44
28	15·7	19	1	0	16
29	16·3	3	0	0	3
30	18·6	4	1	1	0
31	25·8	5	3	0	1
32	10·9	5	4	0	0
33	24·7	7	5	0	0

Note. Volume of zooplankton collected in vertical hauls of 70 cm. from 0–200 m.

TABLE A3. *Spearman ranking correlation coefficients between numbers of birds seen off Arabia per hour and zooplankton volume from* 0–200 *m. depth.*

Species	Ranking correlation coefficient r_s	Probability of correlation	Weighted mean of r_s over 5 lines of stations	Standard deviation	Probability of correlation
Total birds (all spp.)	+0·52	>0·99	+0·75	0·186	>0·999
B. fallax	+0·32	<0·95	+0·43	0·186	>0·95
O. oceanicus	+0·07	<0·95	+0·56	0·186	>0·99
L. hemprichi	+0·50	>0·99	+0·61	0·186	>0·998

TABLE A4. *Spearman ranking correlation coefficients between numbers of birds seen off Arabia per hour and volume of zooplankton collected in neuston net at surface.*

Species	Ranking correlation coefficient r_s	Weighted mean of r_s over 5 lines of stations	Standard deviation
Total birds (all spp.)	+0·091	+0·02	0·18
B. fallax	+0·225	+0·24	0·18
L. hemprichi	+0·155	−0·03	0·18

Any variation that occurred, furthermore, would have been likely to depress the differences in numbers of birds observed rather than exaggerate them, because the wind speed was in general greatest in areas where most birds were seen, namely off the Kuria Muria Islands.

To demonstrate the relationship between sea-bird density and distance from land, distance from the Kuria Muria Islands and sea surface temperature, several analyses were undertaken involving grouping the counts of seabirds into several arbitrary divisions of the respective variable. Table 2 shows the mean and median values of the counts in each division, together with the frequency with which each species was seen.

The assymetric distribution of counts, shown by the large difference between mean and median values, necessitated using a ranking statistical method, the Mann-Whitney U-test (Siegel 1956), to test the difference between the distribution of counts in each division. However, the above test requires that the data should have an underlying continuous distribution and was therefore applicable only when the median value in each division was greater than zero. In all other cases the difference in proportion of counts on which the species was seen was tested by calculating $2\times 2\chi^2$ values, based on presence and absence at each count. Results of both the above tests, in which the probability of a difference is greater than 0·95 are shown in Appendix Table A1.

As the parameters in the above analyses were not fully independent, a multiple analysis was undertaken whose aim was to determine with which parameter the density of each sea-bird species was most closely associated. It is not proposed to consider the method of this analysis in detail, but a brief summary is given below and the results are summarized in Appendix Table A1.

The χ^2 values over 95% significant in the original analyses were recalculated throughout the range of variation of the other two parameters in turn. As the numbers of counts were very small, the Fisher exact test was used to calculate the exact probability of a difference in frequency of observation in each division. From this a one-tailed χ^2 with two degrees of freedom was calculated using the expression:—

$$\chi^2 = -2 \log p$$

where $\log p$ is the natural logarithm of the probability. The sum of the χ^2 values calculated in this way throughout the range of variation of the second variable gave the probability of a difference between the counts in the two divisions having eliminated the effect of the latter.

To test for correlation between sea-bird density and zooplankton abundance (see data in Appendix Table A2), the Spearman coefficient of ranking correlation (r_S) was used (Siegel 1956). In this test an observed value of r_S of $+1{\cdot}0$ denotes complete positive correlation one of $-1{\cdot}0$ complete negative correlation and one of zero shows a complete lack of correlation. The results of these tests are given in Appendix Tables A3 and A4.

Although it was impossible to carry out a complete multiple correlation analysis using ranking methods, separate correlation coefficients were calculated for each of the five sections in the survey (see Fig. 2). The weighted mean of these coefficients showed the degree of correlation, having eliminated the possible effect of distance from the Kuria Muria Islands.

Finally a Spearman coefficient of ranking correlation was calculated between the abundance of zooplankton from 0–200 m. and the sea surface temperature ($r_S = -0{\cdot}83$), ($P > {\cdot}999$). On the basis of this test it seems safe to assume that the sea surface temperature can be used as a rough index of the abundance of zooplankton of the size range sampled by the vertical nets.

Reprinted from *Ibis*, no. 108, 1966, p. 421-422

MIGRANT LAND-BIRDS IN THE MEDITERRANEAN AND RED SEAS AND THE INDIAN OCEAN

In the course of four voyages between Great Britain and the Indian Ocean on R.R.S. ' Discovery ', during the International Indian Ocean Expedition, I passed through the Mediterranean and Red Seas and the Gulf of Aden in June and November 1963, and in February and September 1964. As only the last of these passages was during a recognized season of bird-migration it may be of some interest to record the land-birds seen on these passages and some others seen in the Indian Ocean. Collected specimens have been presented to the British Museum (Natural History). Records of waders in the Indian Ocean have been excluded and will form the subject of a later paper.

Very few land-birds were recorded in the Arabian Sea; but since we spent very little time there in the northern spring and autumn, this is not surprising. Nearly all the records were close to land off Arabia, but a swallow (probably *Hirundo rustica*) was seen in the central Arabian Sea in September (see below). No land-birds were seen off eastern Somalia during the migration period August–September 1964, in an area where Moreau (1938 *ibid*) recorded quite large numbers in November 1936.

The list which follows excludes harriers *Circus* sp., Quail *Coturnix coturnix*, Turtle Dove *Streptopelia turtur*, wheatear *Oenanthe* spp., Redstart *Phoenicurus phoenicurus*, Spotted Flycatcher *Muscicapa striata*, White Wagtail *Motacilla alba* and Yellow Wagtail *Motacilla flava*, which were seen at dates and in areas expected from previous authors' observations.

Grey Heron *Ardea cinerea*. One flying N.W. at 07.00 on 10 September 1964 in the Red Sea at 19° 08′ N., 39° 06′ E., roughly 100 miles east of Port Sudan.

Cattle Egret *Ardeola ibis*. Three small flocks of egrets (2–20 birds) which I thought were Cattle Egrets, because of the buff colouration around their heads, were seen flying S.S.W. between 11.00 and 14.00 on 10 September 1964 at approximately 19¾° N., 38¾° E., about 100 miles east of Port Sudan. This species has previously been recorded in the Red Sea in January (Elliot & Monk 1952) and April (Tuck 1961).

Garganey *Anas quequedula*. A flock of 12 flying S.S.W. at 11.10 on 13 September 1964 at 26° 54′ N., 34° 28′ E., about 70 miles south of the tip of Sinai. Three birds (2♂♂, 1♀) from a flock, collided with the ship's mast at 04.30 on 14 September 1964 in the Gulf of Suez at 29° 10′ N., 32° 46′ E. Two flocks of about 20 each flying between S.W. and S.S.W. low over the sea between 07.50 and 08.10 on 16 September 1964 in the Mediterranean Sea at about 32° N., 30½ E., i.e. about 70 miles N.E. of Alexandria. R. E. Moreau (pers. comm.) tells me that these are among the first records of ducks migrating over the Red Sea and Mediterranean Sea, respectively. They provide evidence, furthermore, for both diurnal and nocturnal migration in this species.

Peregrine *Falco peregrinus*. One which landed on board at 11.30 on 17 June 1963 at 18° 24′ N., 39° 47′ E., about 150 miles E.S.E. of Port Sudan, later flew off to the W.S.W. This species has been recorded previously in the Red Sea in May, June and August (Moreau 1938; Tuck 1960, 1961). Another large falcon was seen at 12.00 on 17 August 1963 at 15° 45′ N., 53° 05′ E., some 60 miles east of Ras Fartak off southeast Arabia. Owing to the presence of buff patches on the bird's nape, I think it was probably the Barbary Falcon *F.p. peregrinoides*. It was attempting, quite unsuccessfully, to catch Red-necked Phalaropes *Lobipes lobatus* which were flying low over the sea surface.

Black-winged Stilt *Himantopus himantopus*. One at 12.20 on 12 September 1964 at 19° 48′ N., 38° 43′ E., some 100 miles east of Port Sudan.

Palm Dove *Streptopelia senegalensis*. One which was captured on board at 03.10 on 18 August 1963 about 10 miles off the southeast Arabian coast at 15° 47′ N., 52° 25′ E. has been identified as *S.s. senegalensis*, which occurs throughout western Arabia. Its weight was roughly 95 gm. There has been no previous suggestion that the local birds are migratory but Moreau (1938) reported a record of the eastern subspecies *S.s. cambayensis* in the eastern Arabian Sea between Bombay and Karachi in April. I am indebted to Mr D. Goodwin for determining the subspecies of my specimen.

Grey-headed Kingfisher *Halcyon leucocephala*. One landed on board at 10.35 on 13 November 1963 at 12° 29′ N., 47° 07′ E. some 100 miles east of Aden. This species has been reported previously in the Red Sea in April and May (Moreau 1938).

Hoopoe *Upupa epops*. One in the Gulf of Aden at noon on 5 September 1964 at 12° 09′ N., 50° 04′ E. attempted to fly practically at sea-level under the ship's side, presumably to keep in the shade of the ship.

Swallow *Hirundo rustica*. One landed on board at 10.40 on 14 August 1963 at 15° 34′ N., 52° 40′ E., off Ras Fartak in the Arabian Sea. A swallow was reported to me at 07.45 on 1 September 1963 at 05° 25′ N., 61° 50′ E. Although I did not see it myself, its description agreed exactly with that of *H. rustica*. The position of this record, which is about 700 miles from land, is almost as far from land as it is possible to get in the Arabian Sea.

Olivaceous Warbler *Hippolais pallida.* A ♀ (weight about 9 gm.) collected on board at 12.50 on 6 June 1963 at 37° 18′ N., 05° 05′ E., about 40 miles off Algeria, seems exceptionally late for a spring migrant. Another, almost certainly this species, landed on board at 12.15 on 12 September 1964 at 23° 47′ N., 36° 32′ E., about 100 miles west of Yenbo in the Red Sea.

Garden Warbler *Sylvia borin.* One landed on board at 17.45 on 9 June 1963 at 35° 30′ N., 16° 25′ E., about 100 miles E.S.E. of Malta. Its weight was about 18 gm. This date seems very late for spring migration.

Spectacled Warbler *Sylvia conspicillata.* Three small warblers which I believed were this species landed on board at dawn on the early date of 23 February 1964, after drizzle had developed during the night. The ship's position was roughly 36½° N., 12½° E., i.e. about 70 miles south of Sicily and 80 miles east of Tunisia.

Starling *Sturnus vulgaris.* One circled around the ship at 11.30 on 22 September 1964 at about 37° N., 1° E., about 30 miles north of Algeria. According to Moreau (1953), this species has rarely been recorded at sea in the western Mediterranean, and this record would appear to be exceptionally early for a migrant so far south.

Wattled Starling *Creatophora carunculata.* A juvenile landed on board at 08.40 on 8 August 1963 at 16° 38′ N., 54° 40′ E. about 50 miles S.E. of Salala off southeast Arabia. At the time I identified it tentatively as a Rose-coloured Starling *Pastor roseus*, but H. P. Medhurst (pers. comm.) has kindly informed me that the pale rump is diagnostic of the Wattled Starling. Another juvenile (weight about 65 gm.) was collected on board at 07.00 on 9 August 1963 at 14° 34′ N., 50° 27′ E. about 80 miles east of Mukalla in the northern Gulf of Aden. The skin was identified for me by H. P. Medhurst. Although Meinertzhagen (1954) refused to accept the earlier records of this species in Arabia, both Ennion (1964) and Medhurst (pers. comm.) have recorded it recently at Aden. The early dates of my records suggest that they may have been young birds wandering in search of food, rather than true migrants. *C. carunculata* is among the species known to follow locust swarms, and these records were obtained at a time when large numbers of insects, including a few locusts, had been seen out to sea off southeast Arabia.

Trumpeter Bullfinch *Bucanetes githagineus.* A bird was captured on board on 2 December 1963 off southern Portugal. Where it landed on board is not clear, but it must have been somewhere off northwest Africa and possibly in the Mediterranean Sea. Although its origin is unknown this record is particularly interesting because the Trumpeter Bullfinch has been recorded so rarely in Europe. It seems interesting, if inexplicable, that it should be found at sea, north of its known breeding range, in December.

Cretzschmar's Bunting *Emberiza caesia.* A ♂ landed on board at 10.10 on 1 March 1964 at 21° 21′ N., 38° 10′ E. about 50 miles west of Jedda in the Red Sea. This is the second record of this species in the Red Sea in the early spring, the first being that of Phillips (1953) at 16½° N. in February 1953.

In conclusion, the fact that so many records of interest were obtained during only eight weeks in the Mediterranean and Red Seas, mainly out of the migration season, is worth stressing. Clearly, there is still a great deal to be learned in these areas.

I am most grateful to Mr R. E. Moreau for pointing out the interest of some of these records and for reading and criticizing the manuscript. I wish to thank the National Institute of Oceanography, for including my work in the programme of the 'Discovery'. I am also indebted to scientists on board 'Discovery' & especially to Mr R. I. Currie, Dr J. C. Swallow and the late Dr M. N. Hill, the Principal Scientists on board the 'Discovery', for giving me every facility necessary for my work. During my time on board 'Discovery' and during the writing-up I was generously supported by the Nuffield Foundation and the British Ornithologists' Union respectively.

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Reprinted from *Ibis*, no. 109, 1967, p. 437-439

MIGRANT WADERS IN THE INDIAN OCEAN

While working on the R.R.S. " Discovery " during the International Indian Ocean Expedition in 1963 and 1964, I observed small numbers of waders at sea in the Indian Ocean. Details of the ship's itinerary can be found in reports published by the Royal Society (1963, 1964, 1965, ' International Indian Ocean Expedition, R.R.S. " Discovery " Cruise Reports ' 1–3), but a brief summary of our cruises during the recognised seasons of migration is given here to indicate the extent of our coverage. In the autumn of 1963, the " Discovery " was working primarily in the central Arabian Sea and in the seas between the Seychelles Is. and East Africa; in spring 1964, the ship was working primarily in mid-ocean; while in autumn 1964, the ship undertook a survey of the eastern Somali coast. My observations of land-birds other than waders have been published elsewhere (Bailey 1966, ' Ibis ' 108: 421–422).

Several species of waders are, clearly, regular and abundant non-breeding migrants to the islands of the western Indian Ocean. Earlier published records (mostly summarized by Watson, Zusi & Storer 1963, ' Preliminary Field Guide to the Birds of the Indian Ocean '. Smithsonian Inst.) show that eight species are particularly widespread, namely the Turnstone *Arenaria interpres,* the Grey Plover *S. squatarola,* the Greater Sand-plover *Charadrius leschenaultii,* the Whimbrel *Numenius phaeopus,* the Curlew *N. arquata,* the Greenshank *Tringa nebularia,* the Common Sandpiper *Actitis hypoleucos,* the Sanderling *Crocethia alba,* and the Curlew Sandpiper *Erolia testacea.* Of these, the Turnstone is probably the most abundant. For all these species the islands of the Indian Ocean are clearly an important wintering area.

Usually, waders were seen singly at sea. Often they circled around the ship several times before heading away; only once did a wader (a Whimbrel) alight on the ship and then it remained for a few minutes only. As there are very few records of waders at sea in the Indian Ocean, all my records are listed later.

In addition to my records at sea, I saw quite large numbers of waders during short visits to mid-oceanic islands. Visits on which I recorded waders were as follows: Mahé, Seychelles Is., 2–5 Oct. 1963, and 9–12 Jun. 1964; Desnoeufs Is., Amirante group, 11 Oct. 1963; Bird Is., Seychelles group, 4 Nov. 1963; Hasikiya Is., Kuria Muria Is. off southeast Arabia, 10 Mar. 1964. My observations of waders on these islands are summarized in the following list.

ARENARIA INTERPRES Turnstone

Seven records at sea: one at 12.10 on 1 Oct. 1963 at 02°19′S. 57°12′E., some 150 miles N.E. of the Seychelles Is.; one at 12.00 on 6 Oct. 1963 at 06°30′S. 54°12′E., about 60 miles east of the Amirante Is.; five at 08.25 on 7 Oct. 1963 at 06°16′S. 54°07′E.; one at 12.10 on 8 Oct. 1963 at 06°21′S. 54°28′E.; four at 11.00 on 15 Oct. 1963 at 02°32′S. 44°54′E., about 180 miles off East Africa; one at 12.20 on 15 Oct. 1963 at 02°32′S. 44°54′E.; one at 10.30 on 22 Oct. 1963 at 02°09′S. 41°27′E., about 20 miles off the Kiunga archipelago, Kenya. All the above records were in October and none were seen in the same areas in September 1963. This may indicate that the main arrivals on the Indian Ocean islands occur from October onwards.

Turnstones were also recorded on islands as follows: one on Mahé, Seychelles on 2 Oct. 1963; ca. 10 on Mahé from 9–12 Jun. 1964; 2–300 on Desnoeufs Is., Amirantes, on 11 Oct. 1963; common on Bird Is., Seychelles, on 4 Nov. 1963. On Bird Is. several birds were seen feeding among coconut trees in the centre of the island, while others were feeding in the Sooty Tern *Sterna fuscata* colony.

SQUATAROLA SQUATAROLA Grey Plover

None were certainly seen at sea, but small numbers were seen on the islands as follows: one on Mahé, Seychelles, on 2 Oct. 1963; two feeding on a mud-flat near Port Victoria, Mahé, from 9–12 Jun. 1964; two on Bird Is., Seychelles, on 4 Nov. 1963.

CHARADRIUS LESCHENAULTII Greater Sand-plover

Sand-plovers, thought to be this species, were seen at sea off East Africa as follows: 12 at 17.05 on 15 Sep. 1963 at 03°47′S. 40°06′E., about 20 miles off Mombasa; one flying west at 11.35 on 18 Sep. 1963 at 02°21′S. 43°25′E., about 100 miles off East Africa; one flying west at 07.10 on 19 Sep. 1963 at 02°40′S. 43°27′E., about 140 miles off East Africa.

One fairly large sand-plover was seen on Mahé, Seychelles, on 2 Oct. 1963; another, which was probably the present species, was seen there from 9–12 Jun. 1964. About ten sand-plovers were also seen on Desnoeufs Is., Amirantes, on 11 Oct. 1963, but all of them may not have been *C. leschenaultii* because birds of two sizes seemed to be present. (The others may have been *C. mongolus*). Finally, four were seen on Bird Is., Seychelles, on 4 Nov. 1963; they were about the same size as Turnstones and so were probably the present species.

NUMENIUS PHAEOPUS Whimbrel

Five records at sea, as follows: one between 06.50 and 07.55 on 30 Aug. 1963 at 05°36′N. 61°53′E., in the southern Arabian Sea, about 600 miles from land; one flying southwest at 17.10 on 24 Sep. 1963 at 03°30′S. 49°35′E., about 250 miles northwest of the Amirante Is., two at 12.25 on 10 Oct. 1963 at 06°07′S. 54°26′E., about 50 miles east of the Amirante Is.; one at 11.55 on 31 Oct. 1963 at 03°34′S. 51°30′E., about 150 miles northwest of the Amirante Is.; one flying south at 09.50 on 17 Aug. 1964 at 07°54′N. 50°43′E., about 50 miles off Somalia.

No Whimbrels were seen on islands except on Bird Is., Seychelles, on 4 Nov. 1963, when about 20 were seen in the coconut plantation.

LIMOSA LAPPONICA Bar-tailed Godwit

One was seen in the coconut plantation on Bird Is., Seychelles, on 4 Nov. 1963. Loustaulalanne (1963, 'Sea and shore birds of the Seychelles'. Seychelles Society, occasional publ. no. 2). records it as a regular migrant in the colony.

TRINGA NEBULARIA Greenshank

One was heard in foggy conditions at night on 17/18 Aug. 1963 at 15°47′N. 52°25′E., about 20 miles off Ras Fartak, southeast Arabia.

My only record on an island in the Indian Ocean was of one at Port Victoria, Mahé, Seychelles, on 2 Oct. 1963.

TRINGA OCHROPUS Green Sandpiper

Two were heard in foggy conditions at night on 17/18 Aug. 1963 at 15°47′N. 52°25′E., some 20 miles off Ras Fartak, southeast Arabia; two seen at 09.30 on 27 Aug. 1964 at 12°58′N. 48°06′E., in the centre of the Gulf of Aden; one seen at 05.50 on 7 Sep. 1964 close offshore near Aden. So far as I am aware there are no records of this species on mid-oceanic islands in the Indian Ocean.

Xenus cinereus Terek Sandpiper

One was seen feeding on a small mud-flat about 100 m. from the sea, on Mahé, Seychelles, on 2 Oct. 1963. Although this species has been recorded on Providence and the Comoro Is. (Watson *et al.* 1963; Benson 1960, ' Ibis ' 103b: 5–106), it is clearly a rare migrant to the mid-oceanic islands. This record is the only recent one for the Seychelles Is., where the species was recorded by Oustalet (1878, ' Bull. Soc. Philomath. Paris ' (7) 2: no. 4), and the furthest from the mainland coasts of the Indian Ocean. The bird was identified by its quite long upturned bill, its yellow legs, the thin white trailing edge of its wings, and its thin trisyllabic call.

Actitis hypoleucos Common Sandpiper

One record at sea: one flying west at 07.05 on 16 Sep. 1963 at 01°55'S. 42°10'E., about 30 miles off East Africa.

In addition, I recorded three Common Sandpipers on Hasikiya Is., Kuria Muria group, on 10 Mar. 1964. This would appear to be the first record for these islands.

Crocethia alba Sanderling

None were seen at sea, but one was seen on Desnoeufs Is., Amirantes, on 11 Oct. 1963, and three were seen on Bird Is., Seychelles, on 4 Nov. 1963.

Erolia temminckii Temminck's Stint

One was seen in the Sooty Tern colony on Bird Is., Seychelles, on 4 Nov. 1963. The bird was identified by its white outer tail feathers, the lack of markings on its back, and by its markedly dull-brown plumage. This record appears to be the first for the Seychelles Is., and the first for any of the islands in the extreme western Indian Ocean. Phillips (1963, ' J. Bombay nat. Hist .Soc. ' 60: 546–584), however, has reported several records for the Maldive Is.

Erolia testacea Curlew Sandpiper

Two records at sea: one at 13.00 on 11 Sep. 1963 at 03°10'S. 42°51'E. about 100 miles off East Africa; one at 17.10 on 21 Oct. 1963 at 02°05'S. 41°30'E., about ten miles off northern Kenya.

In addition, I recorded the species on islands as follows: ca. 20 seen at Port Victoria, Mahé, Seychelles, from 9–12 Jun. 1964; ca. 10 on Desnoeufs Is., Amirantes, on 11 Oct. 1963; two on Bird Is., Seychelles, on 4 Nov. 1963, of which one had remains of summer plumage.

Dromas ardeola Crab Plover

The status of this species in the Indian Ocean is not clear, but it has been suggested that it may breed on a number of islands. I recorded it once: a flock of ten was seen on Bird Is., Seychelles, on 4 Nov. 1963; but there was no evidence that they were breeding or had bred.

Glareola pratincola Pratincole

A pratincole, which I believe was this species, was seen on Bird Is., Seychelles, on 4 Nov. 1963. It was brown above, and paler below with reddish axillaries. The only previous record for the Seychelles Is. is Oustalet's (1878), although it has previously been recorded on Mauritius, and on islands much further east in the Indian Ocean (Watson *et al.* 1963).

To summarize, it is clear that the species seen most frequently at sea were those which are known to occur in large numbers on the Indian Ocean islands. The fact that I saw the largest numbers in September and October 1963 off East Africa, but very few off the Somali coast in August and September 1964, suggests that the main arrivals take place after mid-September. This seems surprising in view of the fact that Fogden (1963, ' Ibis ' 105: 112–113) found quite large numbers of migrant waders in Kenya as early as late July 1961. Finally, it is of some interest that so many waders were seen on the Seychelles in early June 1964; this indicates that a small percentage of the wintering population remain as non-breeders, as has been shown to occur in Madagascar (Homes 1947, ' Ibis ' 89: 517–518). Fogden (*ibid.*) suspected this was true of waders on the coast of Kenya also.

I am most grateful to the National Institute of Oceanography for including my work in the programme of the " Discovery " during the International Indian Ocean Expedition. In particular, I would like to thank Mr. R. I. Currie, Dr. J. C. Swallow, and the late Dr. M. N. Hill, who gave me every facility for my work. I would also like to thank Mr. C. W. Benson, who drew my attention to Oustalet's work on the Seychelles Is. While on the " Discovery ", I was financed by the Nuffield Foundation to whom I am most grateful.

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4 October 1966.

Reprinted from *Cahiers ORSTOM – Océanographie*, vol. V, no. 1, 1967, p. 47-58

POISSONS NOUVEAUX OU PEU CONNUS PROVENANT DE LA RÉUNION ET DE MADAGASCAR

par P. FOURMANOIR* *et* P. GUÉZÉ**

I. DESCRIPTION DE DEUX NOUVEAUX *MULLIDAE* RÉUNIONNAIS ET D'UN NOUVEAU *MULLIDAE* MALGACHE

1. *Parupeneus posteli* nov. sp. (fig. 1/a).

Il existe à La Réunion une petite espèce rarement capturée vu son site profond, entre 150 et 250 m, et sa taille exiguë. Nous n'en avons pris jusqu'à présent qu'une dizaine d'exemplaires, dont un seul exemplaire dépassant 150 mm de longueur standard.

Cette espèce est remarquable par un anneau vermillon de 3 écailles de large environ qui entoure l'extrémité postérieure du pédoncule caudal, par la longueur de ses barbillons qui atteignent la base des ventrales. Sa caudale est généralement jaune vif, mais parfois rose, son corps allongé, robuste, est rouge ainsi que toutes ses autres nageoires.

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Elle partage la plupart de ces caractéristiques avec deux autres espèces, l'une décrite par Bleeker en provenance d'Indonésie sous le nom de *janseni* et l'autre par Jordan et Seale en provenance d'Hawaï sous le nom de *chrysonemus*.

Comme ces deux autres espèces, elle a en outre la faculté de porter parfois une bande longitudinale qui, au lieu d'être orangée à la frange avec le centre rose est foncée, brun verdâtre ou noirâtre sur les bords.

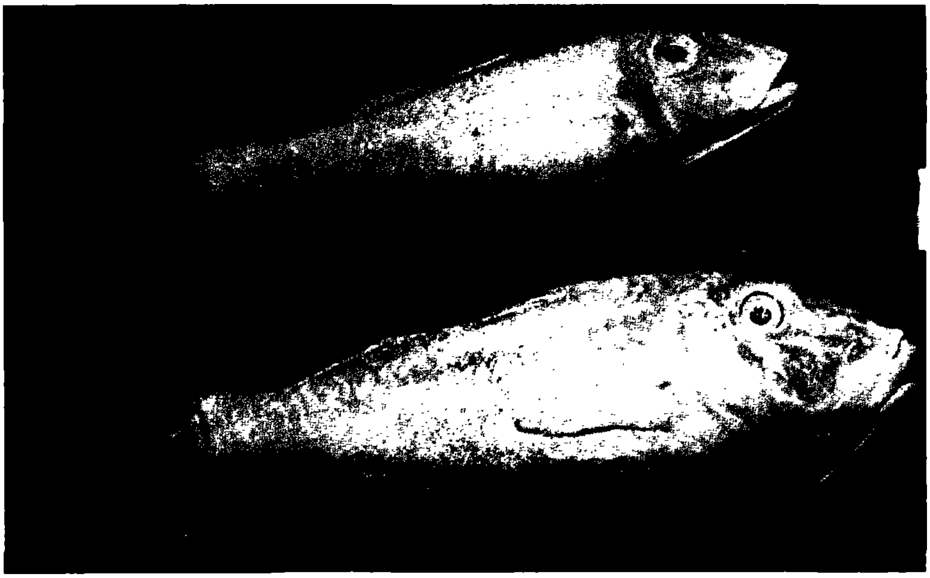

Fig. I/a. — en haut, *Parupeneus posteli* nov. sp. (holotype) Guézé *coll.* (en collection Mus. Nat. Hist. Nat. Paris) Long. standard 164 mm (origine La Réunion)
en bas, *Parupeneus chrysonemus* (Jordan et Seale) Ballieu *coll.* (en collection Mus. Nat. Hist. Nat. Paris) Long. standard 204 mm (origine Hawaï).

Nous avons eu la chance d'avoir entre les mains 8 exemplaires de l'espèce de Bleeker, une dizaine de la nôtre et deux seulement de celle de Jordan, ce qui nous a permis d'esquisser le tableau des différences morphologiques des trois espèces.

L'espèce d'Hawaï est signalée constamment comme une espèce de taille appréciable atteignant au moins 225 mm ; les autres ne semblent pas dépasser de beaucoup 165 mm. L'espèce hawaïenne a un pédoncule caudal nettement plus élevé que les deux autres et est la seule espèce de Mullidae où les branchiospines soient habituellement plus longues que les branchies qui sont particulièrement courtes ; elle paraît très comprimée par rapport aux deux autres qui sont au contraire très robustes.

A taille égale, les yeux de l'espèce de La Réunion sont plus gros que ceux des deux autres espèces et cette espèce, comme celle d'Hawaï, a environ 33 à 34 branchiospines au total, tandis que celle de Bleeker n'en a pas plus de 25 à 27 ; les filaments branchiaux semblent s'allonger avec la taille dans l'espèce de La Réunion.

L'espèce de La Réunion semble intermédiaire entre celle de Bleeker et celle de Jordan, par ses mesures biométriques. On ajoutera enfin que l'espèce de Bleeker a des barbillons moyens, alors que les deux autres ont des barbillons très longs.

Comparaison des mesures biométriques
du *Parupeneus posteli* nov. sp.
avec celle des *Parupeneus janseni* Bleeker et *chrysonemus* Jordan

L mm	L/H	L/h	H/E	L/T	100 do/T	100 P/V	100 C/V	100 V/T	Bsp	100 bsp/T	100 bch/T	Nb éch	
Parupeneus janseni Bleeker													
74	5,3	12,3	1,5	3,5	23,5	100	—	70				1	Collections Muséum de Leiden dont collections Bleeker Indonésie
75-100	4,75	11,9	1,6	3,35	23	90	110	70	$5/1/19_7$	6,5	13	3	
100-125	4,45	12,5	1,65	3,1	21,5	105	111	64	6/1/19 à 21	8	16	4	
135	4,15	11,2		3,05	21,5	103	106	66					gravure holotype Bleeker
Parupeneus posteli nov. sp.													
88	4,15	11,9	1,7	3,3	23	98	98	80				1	nos captures à la Réunion
100-125	4,4	12,6	1,6	3,15	28	101	101	74	7/1/26	11	13,5	3	
125-150	4,25	11,7	1,55	3,15	24,5	103	99	73	7/1/24 à 26	9,5	14	5	
164	4,45	11,0	1.6	3,2	22,5	105	106	65	5/1/26	12	19,5	1	holotype
Parupeneus chrysonemus Jordan													
147	3,35	9,2	3,0	3,0	22	99	92	78					gravure holotype d'après Jordan Hawaï.
156	3,9	11,7		3,0	17,5	95	100	75	(34)	bsp	bch		photo paratype d'après Schultz Hawaï.
179	3,8		2,0	2,9	21,5	98	102	80	6/1/26	11,5	9,5	1	Collections Ballieu d'Hawaï). Muséum Paris
204	4,0	10,4	2,0	3,05	20,5	95	96	78	6/1/27	10,5	8,5	1	

Il y a évidemment beaucoup d'analogies entre les trois espèces, mais les différences mises ci-dessus en évidence nous conduisent à éliminer l'hypothèse d'une identité pour ne retenir à la rigueur que celle d'une convergence.

L : Longueur standard en millimètres.
H : hauteur en avant de la première dorsale.
E : épaisseur au-dessus de l'aisselle des pectorales.
h : hauteur minima du pédoncule caudal.
T : longueur de la tête de la pointe de la lèvre supérieure à l'extrémité postérieure de la pointe ou de la crête operculaire.
do : diamètre de l'œil.
P : longueur de la pectorale de l'insertion supérieure de l'aisselle à l'extrémité du plus long filament.
V : longueur de la ventrale de l'insertion à l'extrémité du plus long filament.
C : longueur du lobe caudal supérieur, de la base du premier filament supérieur à l'extrémité du plus long filament.
Bsp : formule des branchiospines sur le premier arc branchial.
bsp : longueur des plus longues branchiospines.
bch : longueur des plus longs filaments branchiaux.

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2. *Upeneus mascareinsis* nov. sp. (fig. I/b).

Cette espèce, très abondante à l'Ile de La Réunion, paraît en collection assez voisine de l'espèce que nous appelons *Upeneus bandi* (Shaw), plus connue sous le nom de *vittatus* (Lacépède on Forsskal) également présente à La Réunion.

Ses couleurs en vie, son écologie, ses caractères biométriques différents suffisent à en faire une espèce nettement distincte.

Aspect en collection.

Voir photo holotype de 155 mm. Origine Réunion, en collection au Museum de Paris (Guézé coll.).

Fig. I/b. — *Upeneus mascareinsis* n. sp. (holotype). — Guézé *coll.* (en collection Mus. Nat. Hist. Nat. Paris). Long. standard 155 mm (Origine La Réunion).

Signes distinctifs.

— 4 à 6 paires de chevrons noirs et blancs sur le lobe caudal supérieur, les noirs plus larges que les blancs.

— 3 à 4 paires sur l'inférieur ; le nombre de chevrons de chaque lobe augmente avec l'âge. Le 3e noir inférieur est très élargi, mais moins que sur le *bandi.*

— Ligne latérale (L 1) prolongée par la limite entre le premier chevron noir inférieur et le chevron blanc suivant du lobe caudal supérieur, alors que c'est un chevron blanc qui prolonge L 1 sur le *bandi.* Elle divise le pédoncule caudal en 2 parties d'égale hauteur.

— très allongé, très robuste, tête moyenne, *œil énorme*, *ventrales courtes*, pédoncule caudal très peu élevé.

— des bandes foncées longitudinales apparaissent fréquemment en collection, elles peuvent amener à confondre les deux espèces.

Aspect à l'état frais.

Robe moirée brun vineux sur le dos, blanc nacré sur le ventre.

Les dorsales sont grisâtres avec 3 chevrons horizontaux foncés sur chacune, le supérieur de la première dorsale étant très noir.

Les pectorales sont grisâtres, les ventrales, l'anale et les barbillons blanc verdâtre. Aucune bande longitudinale n'apparaît généralement sur la robe, sauf parfois au sortir de l'eau un mince trait jaunâtre.

Les chevrons foncés de la caudale sont noirs à la partie intérieure du V de la caudale et brun rougeâtre sur les bords extérieurs de cette nageoire.

Écologie.

Vit depuis la côte jusqu'à 400 mètres de profondeur sans changer ni de robe ni de forme. Mord très bien aux lignes en toute saison. La taille moyenne est 120 mm, la longueur standard maximum est 177 mm ; c'est de beaucoup la plus abondante espèce de Mullidae de La Réunion, et malgré sa petite taille, nous en trouvons toujours des centaines dans nos trémails à n'importe quelle profondeur, alors que nous ne trouvons le *bandi*, beaucoup plus gros, que rarement et seulement à proximité du rivage, dans des fonds ne dépassant pas 12 mètres.

Nom vernaculaire à La Réunion : Capucin Maurice du large.

Répartition géographique.

Très abondant à La Réunion, non signalé ailleurs.

MESURES BIOMÉTRIQUES MOYENNES

L mm	L/H	L/h	H/E	L/T	100 do/T	100 P/V	100 C/V	100 V/T	Bsp	100 bsp/T	100 bch/T	Nb. chev. sup/inf	éch. nb.
						Upeneus mascareinsis nov. sp.							
50-75	5,05	12,9	1,75	3,35	23,5	117	147	54			—	4/3	1
75-100	5,05	12,7	1,7	3,3	28	127	143	57				4/3	11
100-125	4,4	12,1	1,65	3,3	30	128	145	56	7/1/17 à 18	9,5	12,5	5/3	6
125-150	4,25	12,4	1,55	3,35	30	124	140	58				5/4	11
150-175	4,25	12,5	1,6	3,3	28	124	147	54				5/4	7
175-178	4,55	12,3	1,65	3,25	27	118	132	57					
						Upeneus bandi Shaw ou *vittatus* (non Forskal)							
50-75	4,7		2,25	3,5	24								3
75-100	4,45	11,0	1,85	3,5	25	121	154	61					11
100-125	4,1	11,1	1,7	3,4	27	124	159	58				4/3	5
125-150	4,05	10,5	1,85	3,35	25	125	169	57	7/1/17 à 18	9,5	15,5		3
150-175	4,05	11,1	1,7	3,6	25,5	127	161	61					9
175-200	3,85	10,6	1,7	3,55	25,5	136	152	61				5/3	7
200-225	3,55		1,75	3,3	24,5	117							2

Upeneus mascareinsis est plus allongé et plus robuste que *Upeneus bandi* avec la tête et les yeux plus gros. Par contre, les nageoires et les filaments branchiaux sont plus courts que chez *bandi*.

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WEBER (M.), BEAUFORT (L. F.), 1931. — The fishes of the Indo-australian archipelago, vol. VI. Leiden.

3. *Upeneus crosnieri* nov. sp. (fig. I/c).

Justification de l'appellation.

Holotype et deux autres exemplaires provenant du banc Pracel à Madagascar. Crosnier *coll.* En collection au Museum National d'Histoire Naturelle de Paris.

Aspect en collection.

Voir photo de l'holotype.

Fig. I/c. — *Upeneus crosnieri* n. sp. (holotype). — Crosnier *coll.* (en collection Mus. Nat. Hist. Nat. Paris). Long. standard 139 mm (origine Banc Pracel, Madagascar).

Signes distinctifs en collection.

Cette espèce est allongée, très robuste. Sa tête et ses yeux sont plus petits que ceux d'*Upeneus bensasi* Temminck et Schlegel.

Les lignes de dents vomériennes et palatines sont très minces et peu visibles sans loupe binoculaire. Les dorsales ne portent aucune trace de chevrons.

En collection, les différences morphologiques entre cette espèce et *Upeneus bensasi* Temminck et Schlegel sont peu évidentes, mais elle se distingue facilement d'*Upeneus moluccensis* Bleeker qui lui est associée.

Upeneus crosnieri est aussi très proche par ses indices d'*Upeneus guttatus* Day, que nous avons reconnu en Mer Rouge parmi les espèces récoltées par le Professeur Dollfus, mais en diffère notablement par son pédoncule caudal plus élevé et par un nombre de branchiospines moins important pour *crosnieri* que pour *guttatus.*

Aspect frais.

U. crosnieri se distingue facilement de *U. guttatus* et de *U. bensasi* à l'état frais, mais est plus proche du premier que du second à ce point de vue.

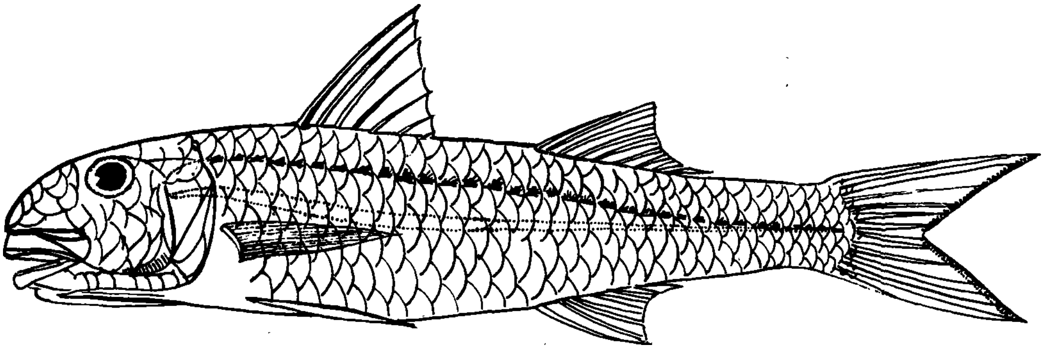

Fig. I/d. — Upeneus crosnieri n. sp. — Long. standard 12,5 cm.

U. crosnieri a le corps gris rosé avec une mince bande longitudinale jaune vif teinté de vert pâle. La bande part près de l'origine supérieure du préopercule et, après avoir marqué une nette convexité vers le bas et un élargissement sous les derniers rayons de la première dorsale, elle atteint l'origine de la caudale à la hauteur de la ligne latérale. La courbure, l'étroitesse et le trajet sous la ligne latérale de la bande sont caractéristiques. Nageoires claires, bord de l'échancrure de la caudale gris-noir.

U. guttatus porte pratiquement la même robe que *U. bensasi* avec lequel il est très habituellement confondu. Les seules différences sont que *U. guttatus* porte sur ses dorsales et sa caudale des chevrons souvent plus marqués que ceux de *U. bensasi*, mais surtout *crosnieri* et *guttatus* portent des barbillons blancs, tandis que ceux de *U. bensasi* sont jaune-orangé très vif et ce détail est extrêmement apparent.

Écologie.

U. crosnieri a été capturé au chalut par A. Crosnier en juin 1959 sur le banc Pracel à l'ouest de Madagascar par fond de 35 m.

Il était associé à *Upeneus moluccensis* Bleeker, cette dernière étant l'espèce dominante.

INDICES BIOMÉTRIQUES MOYENS PAR TAILLE

L	L/H	L/h	H/E	L/T	100do T	100 P/V	100 C/V	100 V/T	Bsp	100 bsp	100 bch	Nbre écha.	Marques en collection
Upeneus guttatus (Day)													
50-7,5	4,7	11,1	1,8	3,6	23	95	—	68	6/1/19 à 20	19	17	2	parfois des traces de chevrons grisâtres sur les lobes de la caudale et sur les deux dorsales
75-100	4,9	11,1	1,75	3,7	24	100	127	73				8	
100-125	4,65	11,1	1,7	3,65	22	107	126	70				6	
125-133	4,55	11,1	1,7	3,6	22,5	105	126	67				3	
Upeneus crosnieri nov. sp.													
114	4,55	10,1	1,5	4,05	22	97	118	77	7/1/16	9	15,5	1	aucune marque ni sur les dorsales ni sur les lobes de la caudale
125	4,45	10,7	1,5	3,85	21	108	137	73	7/1/16	9	12	1	
139	4,45	10,7	1,5	3,85	21	108	137	67	6/1/17	8,5	14,5	1	
Upeneus bensasi Temminck & Schlegel													
50- 75	4,4	10,2	2,05	3,55	27,5	95	120	78	6 à 7/1/15 à 18	7,5	15,5	12	généralement pas de marque sur la caudale sauf sur les exemplaires récemment mis en collection
75-100	4,4	10,2	1,7	3,6	25,5	97	118	73				12	
100-125	4,4	10,4	1,75	3,7	25	103	121	72				12	
125-150	4,4	10,2	1,8	3,55	24,5	110	115	70				2	
150/172	4,4	10,2	1,6	3,95	23	100	129	71				2	

32 écailles sur la ligne latérale
4 — entre D_1 D_2 pour les 3 espèces
10 — entre D_2C

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FOURMANOIR (P.), CROSNIER (A.), 1963. — Liste complémentaire des poissons du Canal de Mozambique. Cah. ORSTOM, sér. Océanogr., nº 6 (sér. Nosy-Bé).

L'espèce y a été décrite sous le nom de *Mulloïdes vanicolensis* (non Val.), les dents vomériennes et palatines étant passées inaperçues lors d'un premier examen.

TEMMINCK (C. J.), SCHLEGEL (H.), 1842. — Fauna japonica (Part. 1 R, Pisces).

Description et gravure d'*Upeneus bensasi*. Les proportions et couleurs sont exactes.

DAY (F.), 1867. — New Fishes of Madras. *Proc. Zool. Soc. London.*

Description d'*Upeneus guttatus*. Nos indices moyens d'*Upeneus bensasi* et *guttatus* ont été établis d'après les échantillons des Museums de Paris, Londres et Leiden, y compris les holotypes des 2 espèces.

La majeure partie des échantillons provient de Mer Rouge pour les 2 espèces Dollfus *Coll.*, soit :

— 8 *guttatus* sur 19
— 33 *bensasi* sur 40

II. DESCRIPTION COMPLÉMENTAIRE D'UN LABRIDAE DE LA RÉUNION

Lepidaploïs bourboni Fourmanoir et Guézé (fig. II/a).

L'espèce trouvée par Fourmanoir (un seul exemplare) a été décrite dans « Poissons de la Réunion. II. Famille des Labridés » (Publ. de l'Inst. Rech. Sci. de Madagascar, 1961), mais aucune mesure n'était mentionnée.

Un deuxième exemplaire pris au filet par P. Guézé à 80 m de profondeur en 1965 nous permet de donner le complément de diagnose nécessaire à la reconnaissance de l'espèce et de nouvelles mesures.

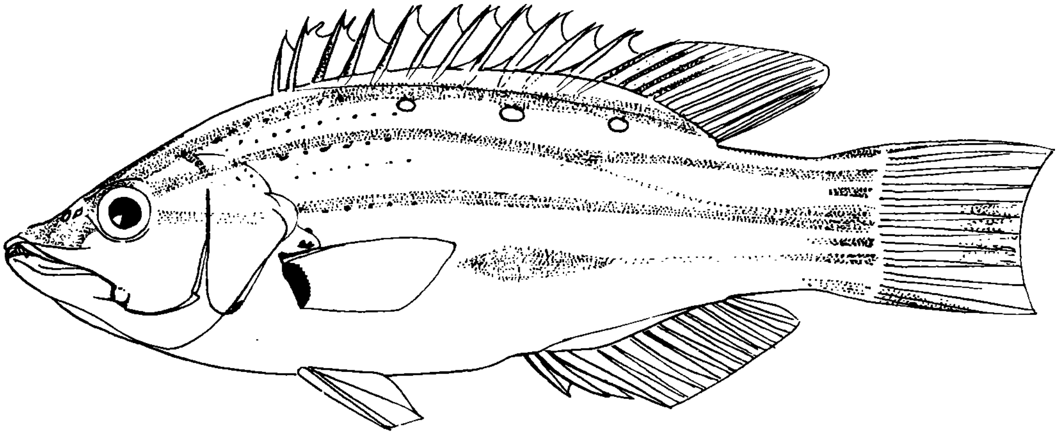

Fig. II/a. — *Lepidaploïs bourboni* Four. et Guézé. Long standard 117 mm.

D X II 10 . A III 12 . L. l. 32
Forme relativement élevée (L/H 2,8), museau pointu moyennement allongé. Denticulations

de préopercule très fines, non distinctes à l'œil nu. La canine inférieure latérale est la plus grande. *La base de la pectorale porte une tache noire en demi-cercle du côté externe ; intérieurement*, la tache plus étendue apparaît presque circulaire quand la nageoire est dirigée vers l'avant. Les écailles antérieures, placées au-dessus de la base de la pectorale, présentent un point noir près de leur origine. Six rangées paraissent ainsi marquées jusqu'à une position ne dépassant pas la dixième écaille antérieure.

Fraîchement capturée, on distingue trois taches blanchâtres disposées comme chez *Lepidaploïs diana* au-dessus de la ligne latérale et trois bandes rouge-orangé partant de l'œil devenant presque parallèles et longitudinales en arrière de la tête. Cette disposition des bandes rappelle celle de *Lepidaploïs trilineatus.*

Dimensions des deux exemplaires en collection :

	L. t.	L. s.	tête	Œil	H. péd. caud.	hauteur
ex. 1 (1).........	21,5	17,7	6	1,15	2,7	6,3
ex. 2 (1).........	19,2	17	5,7	1,15	2,6	5,8

III. SEPT ESPÈCES INTÉRESSANTES TROUVÉES RÉCEMMENT DANS LES EAUX MALGACHES ET RÉUNIONNAISES

A. *FAMILLE DES GEMPYLIDAE*

1. *Thyrsitoïdes marleyi* Fowler. (1).

D XVIII 12+5. A 13+4 L/H 9

Première épine de la dorsale aussi haute que le corps. Ligne latérale médiane branchée à la ligne latérale supérieure dorsale sous la quatrième épine de la dorsale.

Au moment de la capture, la coloration est argentée, un brunissement un peu moindre que celui observé chez une espèce voisine, *Prometichtys prometheus* (Cuvier) apparaît peu après. La partie distale des rayons de l'anale et de ses nageoirettes demeure blanche, la deuxième dorsale ne présente pas de partie claire.

L'espèce n'était connue que de trois exemplaires d'origine sud-africaine.

L. S. d'un exemplaire pris à la ligne à La Réunion : 75 cm (non conservé).

2. *Rexea solandri* (Cuvier) (2).

L/H 5

Espèce voisine de *Thyrsitoïdes marleyi* par sa dentition et sa double ligne latérale (dont la dérivation se place sous la cinquième épine de la dorsale) et de *Promethichtys prometheus* (Cuvier) par sa forme relativement élevée et la disparition presque totale des nageoires ventrales. En plus de la double ligne latérale, la distinction avec cette dernière espèce est aisée en observant les trois nageoirettes détachées de la dorsale et de l'anale et la curieuse tache noire placée en avant de la dorsale épineuse entre le premier et le troisième rayon.

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(1) L'exemplaire n° 1 est au centre d'Océanographie ORSTOM de Nosy-Bé (type).L'exemplaire n° 2 est en collection à l'Université de Grahamstown (Department of Ichthyology).

(2) P. GUÉZÉ *Coll.*

Un exemplaire de L. s. 20 cm pris au filet à La Réunion à 110 m de profondeur (en collection Mus. Hist. Nat. Paris).

Fig. III/a. — *Rexea solandri* (Cuvier).

3. *Ruvettus pretiosus* Cocco (1).

Ce Gempylidé de grande taille, à répartition atlantique, indienne et pacifique caractérisé par ses écailles rugueuses, sa coloration brune et sa chair huileuse, vient d'être pris pour la première fois à La Réunion. Les captures de *Ruvettus* sont fréquentes aux Comores entre 150 et 400 mètres de profondeur, pendant la nuit. Il n'a pas été signalé avec certitude à Madagascar.

L'exemplaire est en collection au Musée de La Réunion (L. S. 100 cm).

B. *Famille des ANTHIIDAE*

4. *Anthias bimaculatus* Smith 1961 (1).

Cet *Anthias* a été décrit d'après les exemplaires de Pinda (Mozambique), les seuls connus jusqu'à présent.

La prise d'un exemplaire femelle au tramail à La Réunion, par 75 m de fond, justifie l'hypothèse de Smith d'une large répartition géographique en eau moyennement profonde.

Un exemplaire de L. s. 12 cm (en collection au Mus. Hist. Nat. Paris).

C. *Famille des BERYCIDAE*

5. *Ostracoberyx tricornis* Matsubara (fig. III/b).

D IX 9. A III 7. P. 14.

Cette curieuse espèce n'avait été signalée qu'au Japon. Nous en avons trouvé une douzaine d'exemplaires de petite taille, 2,5 à 2,8 cm, dans les contenus stomacaux de Thon jaune *(Neothunnus albacora)* pris au large de Nosy-Bé en 1961.

(En collection au centre ORSTOM de Nosy-Bé).

D. *Famille des SCORPAENIDAE*

6. *Peloropsis frondosus* (Günther) (2) (fig. III/d).

C'est la troisième référence à *Peloropsis* au sud de l'Équateur (3).

Un exemplaire L. s. 13 cm, pris au filet à La Réunion par 90 m de fond.

(En collection Mus. Hist. Nat. Paris).

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(1) P. Guézé *Coll.*

(2) P. Guézé *Coll.*

(3) Nous venons de recevoir la description du premier exemplaire africain pris à Durban en 1966, dans J. L. B. Smith, *Occasional paper N° 7.*

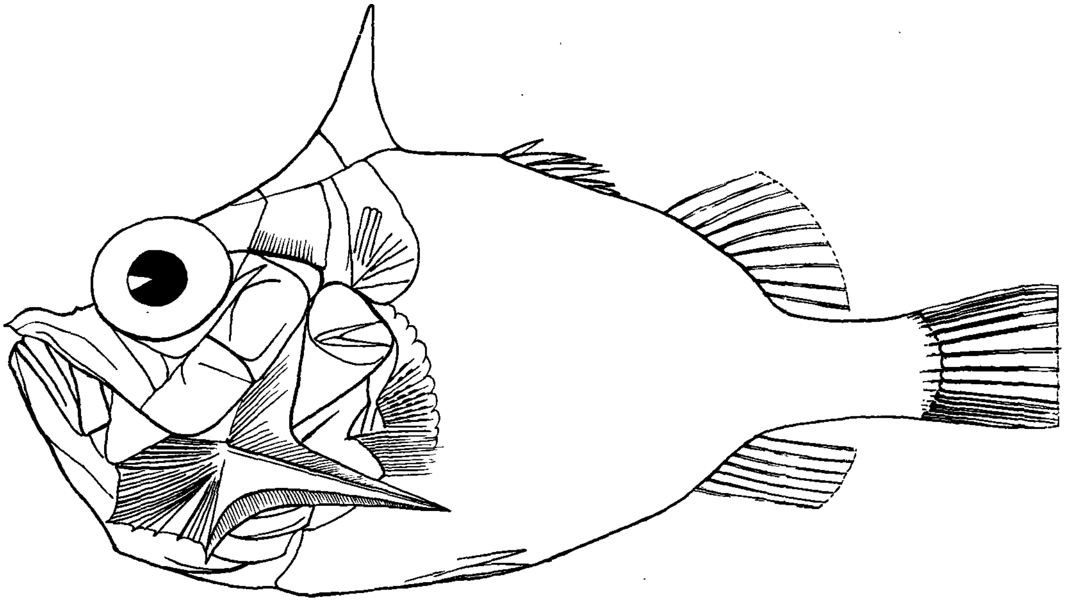

Fig. III/b. — *Ostracoberyx tricornis* Matsubara Long. standard : 27 cm.

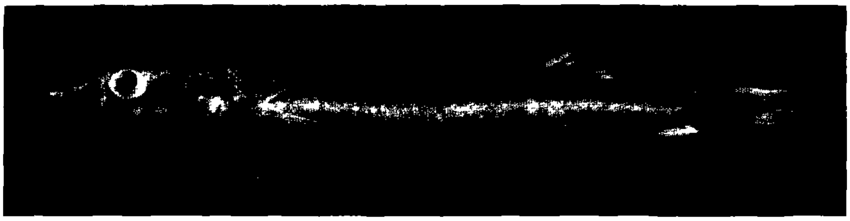

Fig. III/c. — *Gonorhynchus gonorhynchus* (Linné).

Fig. III/d. — *Peloropsis frondosus* (Günther).

E. *Famille des GONORHYNCHIDAE*

7. *Gonorhynchus gonorhynchus* (Linné) (1) (fig. III/c).

Ce poisson de fond sableux, connu dans les eaux relativement froides indo-pacifiques jusqu'à 150 m de profondeur, a été pris en avril à La Réunion à une profondeur modérée (90 m). Cette capture est en relation avec la remontée du niveau de la thermocline pendant les mois de faible alizé.

Un exemplaire L. s. 23 cm (en collection Mus. Hist. Nat. Paris).

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(1) P. GUÉZÉ *Coll.*

Reprinted from *Cahiers ORSTOM – Océanographie*, vol. V, no. 4, 1967, p. 31-45

CARACTÈRES GÉNÉRAUX DES PEUPLEMENTS BENTHIQUES DES RÉCIFS ET LAGONS DE L'ILE MAURICE (Océan Indien)

par Michel M. PICHON[*]

RÉSUMÉ

*Au cours d'une mission faite en janvier-février 1964 à l'Ile Maurice, dans le cadre de l'Expédition Internationale dans l'***Océan Indien** *(I. I. O. E., U. S. program in biology) l'auteur a pu effectuer en plongée, quelques observations de* **bionomie benthique** *dans les lagons et sur les pentes des* **récifs coralliens** *de l'Ile Maurice. Après un bref rappel des conditions de milieu naturel, et des particularités locales des récifs et des lagons, les principales unités de peuplement observées sont brièvement décrites, en insistant notamment sur la répartition des* **Scléractiniaires :** *Rive littorale du lagon, zone détritique et herbiers littoraux, zone à* Pavona, *passées sableuses à Phéophycées, zone à* Acropora, *Platier récifal, pente externe (Peuplement des contreforts et des sillons).*

L'interprétation de la succession des peuplements est faite en utilisant le schéma général proposé récemment par J. PICARD, *pour le classement des grandes unités de peuplement benthique dans les mers tropicales.*

ABSTRACT

During an expedition to Mauritius, sponsored by the International **Indian Ocean** *Expedition (U. S. program in biology) in January and February 1964, the author has had the opportunity to dive (skin diving scuba and diving in the lagoons and along the* **coral reef** *slopes of Mauritius (which is an example of a « high reef rimmed volcanic island »). Some marine biological data have thus been recorded, specially in the field of* **benthonic bionomy**.

The environment conditions are briefly summarized. After a short outlining of the typical features of the coral reefs and lagoons in Mauritius, the main benthonic communities are described, with special reference to the order **Scleractinia :** *Landward shore of the lagoons, detrital zone and sand flats covered with sea weeds,* Pavona *zone, sands tracks with* Pheophyceae, Acropora *zone, reef flat, outer slope (spurs and butresses animal communities).*

A tentative explanation of the sequence of the communities encountered across the reefs and lagoons refers to the general scheme suggested by J. PICARD *in a recent paper, dealing with the universal features of the continental shelf benthonic bionomy, in tropical seas including coral reefs.*

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[*] Chargé de Recherches à l'O.R.S.T.O.M. Centre d'Océanographie de Nossi-Bé et Station marine d'Endoume-Marseille.

Общие черты бентических фаун рифов и лагун Острова Маврикого (Индийский океан)

Мкшель М. ПИШОН.

Во время миссии совершаемой в январе и феврале 1964-ого года, в Маврике острове, в рамках международной экспедиции в Индийский океан (I.I.O.E., U.S. program in biology), автор смог совершить в нырянии в лагунах на берегу моря и на откосах коралловых рифов, несколько замечаний относяшихся к бентической биономии. После того как он бегло напомнил условия естественной среды и местные особенности рифов и лагун, автор описывает самые важные биоценозы, которые он наблюдал, выдвигая на первый план, между прочим, расположение мадрепоровых кораллов : приморская сторона лагуны, детритная зона и морские явнобрачные, зона с *Pavona*, песчаные пути с бурыми водяными, растениями, зона с *Acropora*, плоская поверхность рифа, внешний откос (фауна отрогов и борозд).

Автор толкует чередование биоценозов, употребляя схему которую недавно предложил Ж. Пикард для распределения важных бентических биотопов в тропических морях.

I. *INTRODUCTION*

L'objet de la présente note est de présenter sous une forme condensée, les principaux résultats qui ont été obtenus au cours d'une mission effectuée à l'Ile Maurice en janvier et février 1964, dans le cadre de l'Expédition Internationale dans l'Océan Indien.[*]

La majorité des stations prospectées a été l'objet d'investigations pratiquées en plongée : plongée en scaphandre (système Cousteau-Gagnan), plongée libre (avec masque et tuba). Cette méthode de travail, faisant appel à l'observation directe se révèle, en effet, particulièrement efficace pour l'exécution des recherches taxinomiques ou écologiques dans les milieux rocheux ou récifaux.

Il a été effectué au total seize plongées, complétées par quelques marées littorales, l'ensemble se répartissant en dix-neuf stations : (voir carte). Les stations ont été échelonnées tout le long du littoral de l'Ile Maurice, avec un maximum de densité sur la côte ouest (partie de l'île située sous le vent). Il a été possible ainsi d'obtenir un panorama général des zones récifales de l'Ile Maurice, permettant certaines comparaisons avec les biotopes correspondants du littoral malgache occidental, et apportant divers compléments à l'étude des unités de peuplements des récifs et des lagons du sud-ouest de l'Océan Indien.

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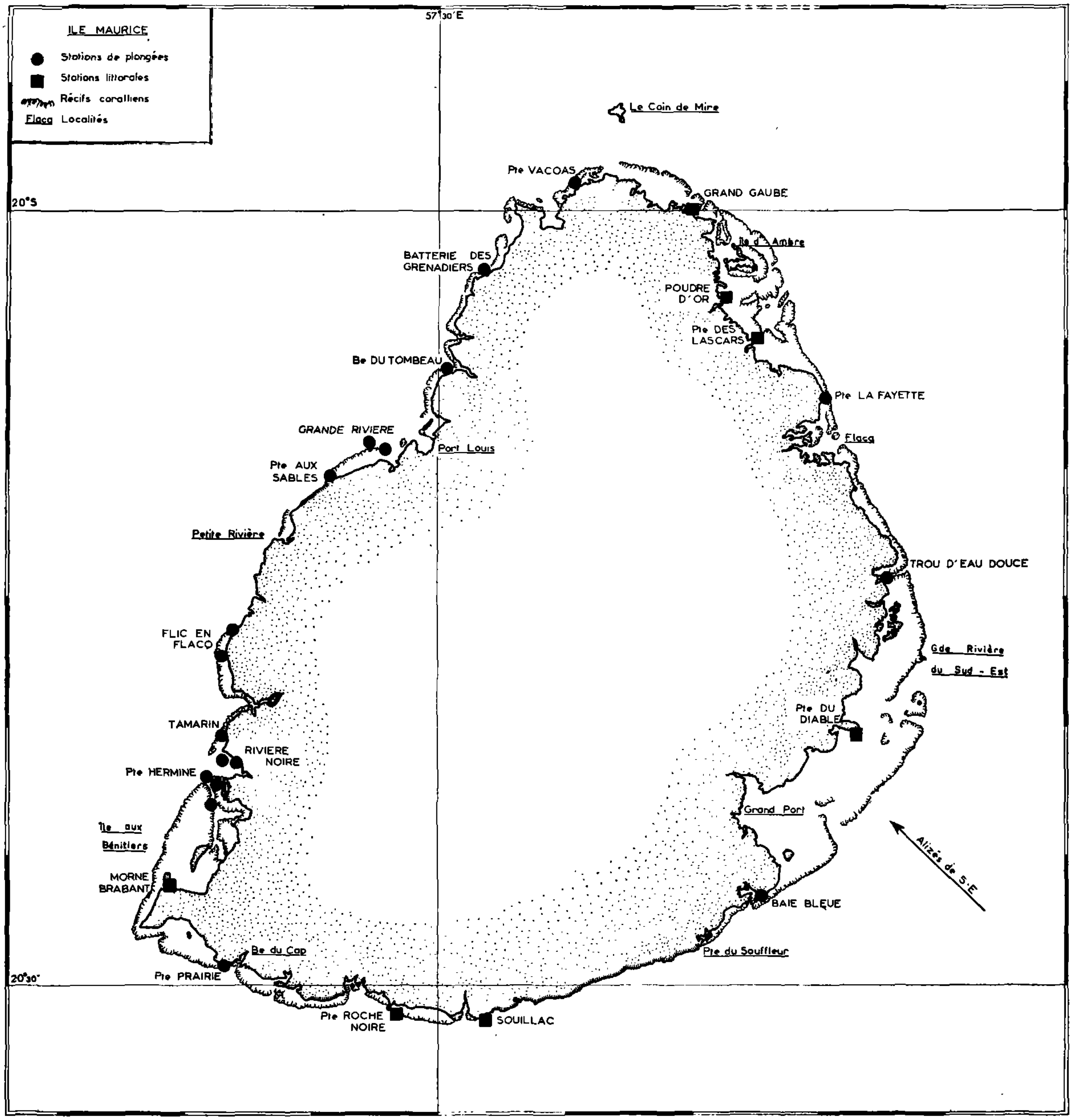
[*] Je tiens à remercier le Professeur A. G. Humes, chef de l'expédition américaine à Nossi-Bé (Madagascar) de m'avoir offert de participer à cette mission, ainsi que le Dr J. H. Stock (Zoölogisch Museum, Amsterdam), qui m'accompagna constamment pendant les sorties en mer ou sur le littoral, et pendant les plongées en scaphandre.

Que MM. J. Vinson et C. Michel, du Mauritius Institute, J. de Baissac, Momple, et L. Gueho, du Fisheries Office, dont l'aide constante nous fut des plus efficaces, soient assurés de notre sincère reconnaissance.



Carte 1

II. *GÉNÉRALITÉS CONCERNANT LE MILIEU NATUREL*

L'Ile Maurice constitue avec la Réunion et Rodrigue le groupe des Mascareignes, qui sont toutes les trois des îles océaniques volcaniques situées dans la région sud-tropicale.

La position géographique de l'Ile Maurice (19° 58' à 20° 32' de latitude Sud et 57° 17' à 57° 46' de longitude Est) la localise dans la zone des alizés du Sud-Est et dans un secteur océanique caractérisé par l'existence de récifs coralliens. Si l'on ajoute à ces deux caractéristiques la nature éruptive du relief, nous avons énuméré les éléments fondamentaux qui permettent d'expliquer la morphologie et les principaux traits des peuplements benthiques littoraux, notamment des récifs et des lagons.

a. **Géologie.**

L'Ile Maurice est formée par un système de caldeiras d'effondrement, dont les restes (série ancienne) constituent les chaînons montagneux qui, sauf au Nord, se dressent à peu de distance de la côte. Ce système qui constitue l'armature géologique de l'île (en dehors du socle primitif, dont la nature n'est pas encore connue), a été comblé par des laves basaltiques au cours de deux phases principales de volcanisme de type hawaïen (série moyenne, série moderne). Certaines des coulées de la série moyenne ou moderne ont pu franchir la ligne de relief constituée par les restes de la caldeira centrale, et sont parvenues jusqu'à la mer, surtout sur le littoral Est et Sud-Est. A la dernière phase de volcanisme (série moderne, vraisemblablement du quaternaire récent), est à rattacher la plaine du Nord, qui se trouve en dehors de la caldeira centrale, et se prolonge sous la mer par une plate-forme précontinentale d'où émergent un certain nombre d'îles également volcaniques.

b. **Climat.**

Les principaux caractères climatiques de l'île Maurice sont dus à sa situation dans la zone des alizés du S. E. et également sur le trajet des dépressions estivales à caractère cyclonique. Les alizés du S. E., qui soufflent avec constance pendant la plus grande partie de l'année, sont relativement violents et chargés d'humidité pendant l'hiver austral ; ils sont plus modérés et plus secs pendant l'été. Les cyclones tropicaux, qui peuvent se produire de novembre à avril, sont accompagnés de vents très violents et d'abondantes chutes de pluies.

Les pluies montrent une nette répartition en fonction de l'altitude, les régions côtières recevant, en moyenne moins de 2 m d'eau par an. Les pluies sont également assez bien localisées dans le temps (les précipitations estivales dues aux orages et aux cyclones étant quantitativement beaucoup plus importantes que celles qui accompagnent les alizés, en hiver).

c. **Le régime marin.**

Les marées. Les marées, à l'île Maurice, sont du type semi-diurne, avec toutefois une inégalité diurne notable. L'amplitude en morte eau est de 0,3 m environ, et de 0,6 m en vive eau. En raison de l'étroitesse du précontinent, ces marées entraînent cependant l'existence de courants réversibles intenses autour de l'île, à l'extérieur de la barrière corallienne (leur vitesse peut atteindre 4 à 5 nœuds en vive eau). Par ailleurs, les passes qui mettent les lagons en communication avec la mer, sont le siège de courants centrifuges de vidange (évacuation de l'eau des lagons ou de l'eau ayant pénétré dans ceux-ci par déferlement au dessus de la barrière récifale).

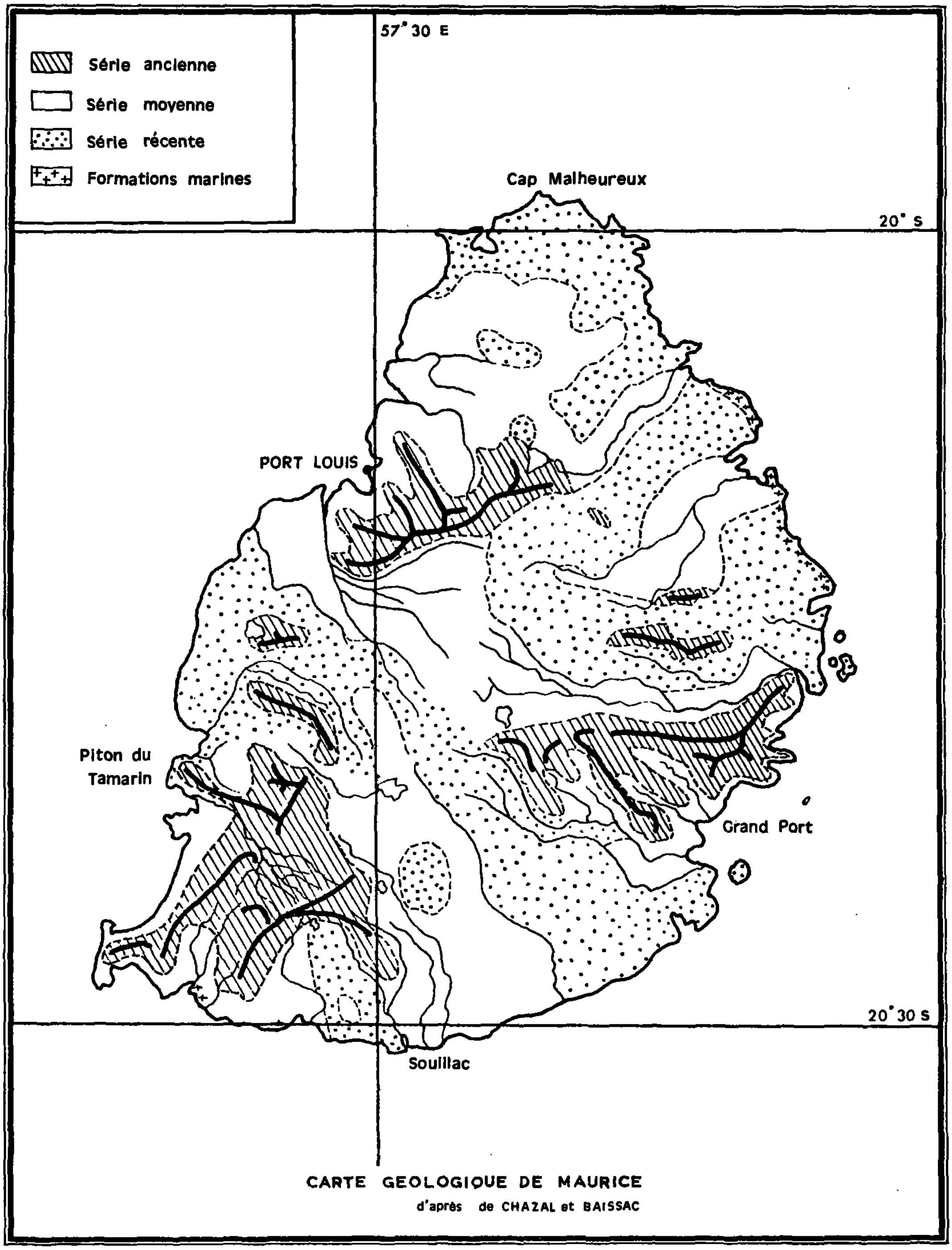
La houle. Les côtes de l'île Maurice sont battues par une houle océanique, engendrée par les vents alizés. Cette houle dominante du Sud-Est permet de diviser le littoral en deux secteurs :

— Un secteur battu (correspondant à la partie « au vent » de l'île).

— Un secteur abrité (correspondant à la partie « sous le vent » de l'île), et comprenant tout le littoral occidental.

L'action de la houle et du déferlement est, sur une grande partie du littoral, atténuée par la présence d'une barrière récifale qui sert de brisant, quel que soit l'état de la marée.

Température et salinité. Les données concernant l'hydrologie des eaux de surface autour de l'île Maurice sont peu nombreuses. Les résultats dont nous avons pu prendre connaissance indiquent des températures variant entre 22° C (août-septembre) et 27° C (janvier à avril). Ces valeurs sont donc inférieures de 2 à 3° C à celles que l'on observe à Nossi-Bé (côte Nord-Ouest de Madagascar). Les eaux des lagons ont une amplitude de variation légèrement supérieure à celle de la


Série ancienne
Série moyenne
Série récente
Formations marines
57°30 E
Cap Malheureux
20° S
PORT LOUIS
Piton du Tamarin
Grand Port
20°30 S
Souillac
CARTE GEOLOGIQUE DE MAURICE
d'après de CHAZAL et BAISSAC

Carte 2

mer ouverte. JONES (1954) indique, pour les salinités des eaux de surface au voisinage des récifs, des valeurs comprises entre 35 et 35,5 %. Les résultats obtenus pour les lagons restent très voisins ou légèrement inférieurs à ceux de la mer libre.

III. *RÉCIFS ET LAGONS*

a. **Généralités.**

Les côtes de l'île Maurice sont, sur une grande partie de leur longueur, ceinturées par un récif corallien. Celui-ci n'est absent que :

— à l'embouchure des principaux fleuves.

— lorsque la côte est formée par une ligne de falaises au-delà desquelles la profondeur des fonds marins augmente rapidement.

Ces côtes à falaises, remarquables par l'absence de récifs coralliens, même frangeants, sont dues à la grande épaisseur des coulées basaltiques (référables à la série moyenne), ayant atteint la mer à ces endroits :

La côte Sud-Est, est formée d'une longue ligne de falaises très abruptes. Le littoral est ici directement exposé à l'action de la houle du Sud-Est, dont l'effet hydrodynamique est maximal contre ces parois verticales. Le peuplement est d'ailleurs très fortement raréfié par suite de la violence du mode.

La côte Ouest présente également entre Flic-en-Flac et Pointe-aux-Sables une ligne de falaises, moins régulières que celles de la côte Sud-Est. De plus ces falaises sont bordées vers le large, soit par une plate-forme littorale horizontale, située 2 à 3 m au-dessus du niveau de la mer, soit par un amas de boules basaltiques consolidées par un ciment calcaire. (Lorsque l'épaisseur des coulées a été plus faible, les falaises sont remplacées par un estran de pente plus douce montrant aussi des formes d'érosions en boule : les pointes rocheuses de Flic-en-Flac, Pointe-aux-Caves, Pointe-aux-Sables en sont des exemples.)

b. **Les récifs.**

Les récifs de l'île Maurice sont généralement décollés du littoral, ce qui entraîne l'existence d'un « lagon » entre le récif et la côte. L'un des caractères les plus remarquables de ce récif est son étroitesse relative (plus précisément étroitesse du platier). Sa largeur, en effet, ne semble pas excéder 20 à 25 mètres, et nous avons même observé des dimensions inférieures en de nombreux endroits. Le platier se présente donc comme un mince ruban sur lequel il paraît difficile de distinguer plusieurs zones de peuplement ; l'ensemble serait l'homologue de la partie la plus extérieure d'un platier externe (zone à Madréporaires-Mélobésiées). Le niveau de la partie horizontale du récif (platier) est situé aux environs du niveau des basses mers de vive eau, ou légèrement en-dessous. La pente externe peut présenter plusieurs types de configurations. Dans toutes les stations que nous avons effectuées au dehors de la barrière, la profondeur augmente de façon rapide, mais graduelle, en avant du récif, et nous n'avons jamais observé de tombant subvertical.

c. **Les lagons.**

Le terme de « lagon » est peut-être impropre pour désigner le plan d'eau séparant le ruban corallien du littoral ; l'expression « chenal d'embarcation » que l'on pourrait lui substituer n'étant pas non plus exempte de critiques, nous conservons provisoirement le mot « lagon », lequel, en outre, est d'un usage *courant à l'île Maurice.* La largeur du lagon varie suivant les endroits de quelques mètres ou dizaines de mètres à plus de 4 milles. Les faibles profondeurs observées dans les lagons sont tout à fait remarquables : moins d'un mètre au-dessous du zéro, sauf autour de la pointe nord de l'île (entre la Batterie des Grenadiers et Grand-Gaube), où les profondeurs moyennes sont de l'ordre de 2 à 4 mètres.

Un certain nombre d'accidents topographiques viennent rompre l'uniformité des profondeurs des lagons. Il s'agit :

— de sillons ou chenaux dont l'existence est à mettre en rapport avec la présence de sources ou résurgences (Trou-d'eau-douce) ou de l'estuaire d'un fleuve (Grande Rivière du Sud-Est, entrée Sud de Grand-Port). Dans ces deux derniers cas, au moins, les courants de sortie des eaux semblent devoir être rendus responsables du creusement du plancher du lagon.

— de vasques, de tracé plus ou moins régulier, dont les dimensions sont de l'ordre du mille marin, et qui forment dans les lagons des dépressions profondes d'une dizaine de mètres. Les principales de ces vasques sont :

— au nord-est : la vasque de l'île d'Ambre, et la vasque située entre Poudre d'or et la Pointe des Lascars. Cette dernière communique avec la mer par deux passes dont l'une au moins est barrée par un seuil sur lequel la profondeur n'est plus que de 1 à 2 m ;

— au sud-ouest : la vasque s'étendant depuis l'île-aux-Bénitiers jusqu'à l'estuaire de la Rivière Noire. Cette dernière, longue de près de trois milles montre des profondeurs régulièrement croissantes depuis son extrémité, située près du littoral, jusqu'à son ouverture vers la mer, au sud de l'estuaire de la Rivière Noire. Il n'y a donc pas de seuil entre les fonds de cette vasque et les fonds voisins situés en dehors du ruban récifal.

Le bord de ces vasques est généralement (ainsi que l'indique d'ailleurs la carte marine) peuplé par de nombreux Madréporaires. Nous avons toutefois constaté que le versant ouest de la vasque Ile-aux-Bénitiers - Rivière Noire était parfois une simple pente sableuse de forte déclivité jusque vers 10 à 12 m suivie par un talus sableux ou sablo-vaseux de faible pente entre 12 et 25 m environ.

Pour en terminer avec les généralités concernant les lagons, il convient de signaler que ceux-ci perdent leur individualité au niveau des estuaires des principaux fleuves, là où le ruban récifal est lui-même interrompu (Grande Rivière du Nord-Est, Rivière Noire, Baie du Cap, par exemple).

IV. *LES PEUPLEMENTS*

a. **Peuplement du lagon.**

Nous allons étudier le peuplement du lagon dans le cas où la rive littorale de celui-ci est constituée par un substrat meuble, ce qui est le cas le plus fréquent. En quelques endroits, toutefois, des coulées basaltiques de faible épaisseur ont pu atteindre la mer, et former ainsi des pointes rocheuses s'avançant dans le lagon. Ces roches volcaniques présentent alors, dans la zone intertidale, un type de peuplement caractéristique des substrats solides en mode calme. Dans le cas plus général d'un substrat meuble, la partie terrestre du littoral est constituée par une dune de sable, portant des formations de *Casuarina equisetifolia*. Nous avons observé, dans l'une de ces dunes, située entre la Pointe-Prairie et la Baie-du-Cap, une très belle formation de « grès dunaire » d'ailleurs très fortement lapiazée. Dans la zone intertidale, ce « grès dunaire » donne naissance à un visor bien développé, formant un surplomb et un rentrant de 80 cm environ. La plate-forme inférieure du visor est remplacée par la plage sableuse qui est l'aboutissement littoral des fonds du lagon.

En dehors de ce cas exceptionnel, la dune littorale se continue vers la mer par une plage de pente assez forte. Ce substrat sableux peut se prolonger jusqu'à la profondeur de 1 m au-dessous du niveau des basses mers. Il montre généralement un système de ripple-marks. En d'autres cas (Baie-du-Tombeau, lagon de Flic-en-Flac) nous observons dans cette zone une ceinture étroite d'algues Chlorophycées (Entéromorphales, *Caulerpa*).

La zone détritique et les herbiers littoraux.

La première zone du fond du lagon peut être représentée soit par un substrat meuble plus ou moins grossier, montrant en abondance divers Échinodermes (Holothuries, notamment Synaptes), soit par un herbier de Phanérogames marines, lorsque le substrat montre une granulométrie plus fine. L'influence des apports terrigènes ne paraît pas déterminante pour expliquer l'implantation des herbiers. Ceux-ci peuvent s'étendre plus ou moins loin vers le centre du lagon, suivant la rapidité de la pente du substrat. Ces herbiers littoraux, dont la présence n'est pas absolument constante, sont constitués exclusivement par une espèce de *Diplanthera.*

Les herbiers de fond de lagon.

A l'inverse des peuplements monospécifiques précédents, occupant des surfaces comparativement restreintes, et localisées sur la remontée des fonds, côté terre, les herbiers de fond de lagon présentent les caractères suivants :

— les surfaces occupées peuvent être considérables (lagons de la côte Est, par exemple) et s'étendre sur presque toute la surface horizontale du fond du lagon.

— Deux espèces de Phanérogames sont représentées : *Syringodium isoetifolium*, qui occupe souvent les parties les moins profondes (notamment du côté du littoral, où il peut former une véritable ceinture) et *Cymodocea ciliata* qui existe fréquemment en peuplements purs, lorsque la profondeur est plus grande (Pointe Vacoas).

La faune de ces herbiers est déjà très riche. Nous avons notamment remarqué la présence d'Échinodermes (Synaptes), d'Éponges (Halichondrines), de Pélécypodes fouisseurs *(Pinna)* d'Hydrozoaires *(Millepora sp).* Les herbiers peuvent parfois montrer la présence de quelques colonies disséminées de Madréporaires *(Porites, Pavona).* Dans certaines stations, la couverture de Phanérogames est interrompue, pour faire place à des petites taches sableuses en forme de cuvette. Dans celles-ci s'observent des petites colonies de Madréporaires : *Acropora*, *Pavona*, *Pocillopora*, et beaucoup plus rarement *Stylophora pistillata.*

La zone à Pavona.

Faisant quelquefois suite immédiatement à l'herbier après une brève région de transition, s'étend une zone dont le peuplement est uniquement constitué par une espèce de Madréporaire du genre *Pavona* (du groupe *divaricata*). Cette espèce forme des colonies plus ou moins foliacées, les frondes très étroites ayant un sens préférentiel de croissance nettement vertical. Ces formations denses montrent fréquemment un taux de recouvrement de 100 % sur plusieurs centaines de mètres carrés. Seule la partie supérieure des branches de *Pavona* est vivante, sur une dizaine de centimètres environ), la base de la colonie étant toujours nécrosée. L'ensemble des frondes mortes forme un réseau extrêmement dense qui constitue un refuge parfait pour toute une faune de petite taille : Sipunculides, Annélides Polychètes, Crustacés.

Au fur et à mesure que la profondeur du lagon augmente, ce peuplement perd son homogénéité. La surface couverte par les *Pavona* est de plus en plus bosselée et devient discontinue. Deux espèces de Madréporaires commencent à apparaître à ce niveau : une autre espèce de *Pavona (P. decussata?)*, qui a des frondes plus larges et donne des colonies en forme de coussinets, et *Galaxea fascicularis.*

La zone des passées sableuses à Phéophycées.

Entre les colonies des diverses espèces de Madréporaires que nous venons d'indiquer, la surface couverte par le substrat sableux devient de plus en plus importante lorsque l'on se rapproche de la barrière récifale. Progressivement les dernières taches d'herbiers disparaissent (lorsque ceux-ci sont présents), de même que les colonies de *Galaxea* et de *Pavona*. Il convient de remarquer que le sédiment présente une fraction granulométrique grossière relativement importante. De plus, le substrat est parsemé de restes de colonies mortes de Madréporaires, très attaquées, et qui servent de support aux Phéophycées *Turbinaria ornata* et *Sargassum* sp. Le degré d'extension de cette zone des passées sableuses est très variable. Dans certains cas, elle peut se prolonger jusqu'au voisinage immédiat du platier récifal. En d'autres endroits, les blocs à *Turbinaria* et *Sargassum* sont peu nombreux et sont partiellement remplacés par une faune de Madréporaires divers (notamment plusieurs espèces du genre *Acropora*). Assez souvent enfin, cette zone peut être totalement absente, et au peuplement à *Pavona* fait alors directement suite un type de peuplement très fréquemment représenté dans les lagons : la zone à *Acropora*.

La zone à Acropora.

La partie la plus externe du lagon qui montre encore un peuplement à dominance de Madréporaires, est la zone à *Acropora*. Dans celle-ci, en effet, le substrat est recouvert par une formation buissonnante très dense due à une grande espèce branchue d'*Acropora (A. pharaonis?)* qui constitue l'élément caractéristique du peuplement. En dehors de cette espèce on trouve, parmi les Madréporaires : *Galaxea fascicularis*, *Montipora foliosa*, et plusieurs représentants du genre *Fungia*. De même que pour les *Pavona*, seule l'extrémité des branches d'*Acropora* est vivante (sur 30 cm en moyenne) ; la base des branches est morte, mais suffisamment épaisse pour résister un temps assez long à l'action des agents biologiques. L'épaisseur de cette formation peut aussi être importante (70-80 cm). La base des colonies sert de refuge à une faune nombreuse (faune sessile composée d'Éponges, Tuniciers, Bryozoaires, faune vagile représentée par des Crustacés et des Poissons, faune sédentaire comprenant des Mollusques Opisthobranches et des Ophiures).

Cette zone à dominance d'*Acropora* doit être considérée comme étant la dernière partie du lagon dont le peuplement montre une dominance de Madréporaires. En effet, en se rapprochant de la barrière récifale, le substrat montre un taux de recouvrement en espèces sessiles beaucoup plus faible. Seule l'abondance des Echinides *Echinometra mathaei* s'accroît. En ce qui concerne la flore algale, les Phéophycées *Turbinaria sp* et *Sargassum sp* sont très fréquentes, fixées sur des blocs de Madréporaires morts, de plus en plus nombreux également.

Il convient de remarquer que nous assistons, dans ce dernier horizon à *Echinometra*, à une nette remontée du substrat, laquelle s'était déjà légèrement amorcée dans la zone précédente. On peut donc considérer que l'horizon à *Echinometra* est établi sur la face interne de la barrière (back reef slope).

b. **La barrière récifale**.

La barrière récifale, qui s'étale sur une largeur d'une vingtaine de mètres au plus, peut, dans son ensemble être assimilée au platier externe d'un récif tel que celui de Tuléar (Madagascar), et plus précisément à la zone à Madréporaires-Mélobéisées du platier externe.

Le récif lui-même est généralement bordé du côté du lagon par un secteur en pente, plus ou moins large, dans lequel les blocs coralliens arrachés au front du récif viennent s'accumuler. Le haut de la pente post-récifale, sur laquelle se sont déposés ces blocs pourrait donc être considéré comme l'équivalent de la levée détritique de certains récifs. Il convient de remarquer cependant que les positions altitudinales comparées sont très différentes : si parfois, à l'île Maurice, quelques rares blocs peuvent être à un niveau légèrement supérieur à celui du platier, jamais, en tout cas, ils n'atteignent la limite inférieure de l'Étage médiolittoral (alors que ceci est fréquent lorsque la levée détritique est strictement épirécifale). Les blocs sont l'objet d'une intense dégradation de la part d'agents biologiques. Ils présentent à leur face inférieure une faune très importante d'Échinodermes (Ophiures), Ascidies *(Didemnidae)*, Éponges encroûtantes. Les Phéophycées (g *Turbinaria*, *Sargassum*), et l'Echinide *Echinometa mathaei* sont extrêmement abondants dans tout ce secteur, qui, vers le lagon se raccorde aux zones décrites précédemment.

Le platier récifal est une étroite plate-forme sensiblement horizontale, située légèrement au-dessus du niveau des grandes basses mers. Les Madréporaires vivants y sont peu nombreux et montrent très souvent des colonies « rabougries » ou aplaties. Nous pouvons citer les genres : *Platygyra*, *Leptoria*, *Pocillopora*, *Acropora*, *Favites*, *Favia*. Les Mélobésiées sont, par contre, extrêmement abondantes, et leurs formations calcaires constituent un véritable ciment dans lequel sont noyées les concrétions dues à des Madréporaires (actuellement morts) ainsi qu'à divers autres organismes constructeurs. Bien que les algues calcaires soient très importantes, sur les récifs, nous n'avons pas observé de formation typique de « crête algale », malgré la présence certaine de *Porolithon onkodes*.

La partie externe du récif (le « front »), montre la présence de structures en contreforts, éperons et sillons. Les contreforts et éperons ont généralement une largeur de plusieurs mètres à leur enracinement. Leur face supérieure n'est pas dans le prolongement horizontal du plan du platier, mais s'incline légèrement vers le large, en formant une surface convexe.

Les sillons, au contraire des contreforts, sont très étroits, vers le platier récifal. Ils forment généralement une entaille de 1,5 à 3 m de profondeur, qui va en s'élargissant doucement vers l'extérieur, et dont le fond, en pente modérée, est tapissé de sable grossier. En ce qui concerne le peuplement, il est indissoluble de celui de la zone suivante : la pente externe.

c. **La pente externe.**

Nous n'avons pu observer que la partie supérieure de la pente externe, jusqu'à une profondeur de 10 à 15 m environ. On doit constater, tout d'abord, que dans les stations que nous avons effectuées (Flic-en-Flac, Grande Rivière du Nord-Est, Batterie-des-Grenadiers), la pente externe ne se présente pas comme une muraille verticale ou subverticale, mais au contraire présente une inclinaison que l'on doit considérer comme modérée. Il faut sans doute voir dans ces particularités morphologiques, le rôle des coulées volcaniques qui se prolongent sous la couverture sédimentaire organogène des lagons, et que l'on voit d'ailleurs réapparaître sous forme de grandes dalles, ou de grands polyèdres, à des profondeurs supérieures à 5 m, à l'extérieur de la barrière (Flic-en-Flac).

Les résultats d'observations que nous allons donner, concernant le peuplement, ont trait, d'une part à la pente externe elle-même, d'autre part aux sillons du platier récifal, dont l'étude faunistique ne peut être séparée de celle de la pente externe.

Peuplement de la partie supérieure des contreforts et éperons.

Il existe un peuplement particulier commun à l'extrême bordure externe du platier récifal, et à la partie des éperons voisine de leur enracinement. Ce peuplement est défini par la présence d'une espèce du genre *Pocillopora*, donnant de petites colonies, dont l'extrémité des branches est arrondie et colorée en rose vif, avec laquelle on trouve diverses espèces digitées du genre *Acropora*, également très caractéristiques.

Il est à noter que dans certains cas, les arêtes des entailles réalisées par les sillons dans le platier, montrent un peuplement monospécifique de *Millepora platyphylla*, présentant l'aspect caractéristique de « honeycomb ».

Peuplement des parois des sillons.

Le peuplement des parois des sillons peut être analysé en trois catégories distinctes qui comprennent :

— les formes encroûtantes ou foliacées sur les surfaces verticales ;

— les formes massives de la base des parois ;

— les formes sciaphiles des surplombs.

Dans la première catégorie nous avons noté les Madréporaires suivants (1) :

Montipora
Hydnophora
Oxypora
Echinopora
Leptoria

Les formes massives de la base des parois sont principalement :

Favia
Favites
Alveopora
Porites

Les microsurplombs qui s'ouvrent à divers niveaux dans les parois verticales montrent curieusement une faune à affinités sciaphiles plutôt pauvre : les Éponges et les Ascidies y sont rares. On observe seulement de façon courante :

- des petites formes de Gorgonaires ;
- des Madréporaires *Dendrophylliidae* ;
- des Hydrocoralliaires *Stylasteridae* (gen. *Distichopora*).

Vers le large, les éperons perdent leur individualité, et se résolvent en amas de plus en plus distincts de Madréporaires qui font le passage aux formations massives isolées, observées tout à fait vers l'extérieur. Nous avons pû reconnaître les genres suivants :

Montipora
Alveopora
Favia
Favites
Pocillopora
Acropora
Hydnophora
Platygyra
Leptoria
Pachyseris
Porites (formant souvent de gros « pâtés »)
Lobophyllia (L. hemprichi, L. costata, L. corymbosa)

Les sillons sont, surtout au voisinage de leur origine dans le platier, tapissés de sable corallien pur. Lorsque l'on se dirige vers le large, leur fond présente parfois des éléments grossiers et même une certaine quantité de blocs morts. En d'autres secteurs, le fond des sillons montre au contraire une certaine abondance de Madréporaires (les espèces sont généralement les mêmes que celles qui sont trouvées à la base des parois latérales des sillons : *Acropora spp. Lobophyllia corymbosa*, *Lobophyllia costata*, *Favites virens*, *Favia spp*). Il convient de remarquer, en outre, la présence de belles colonies de *Galaxea fascicularis* (à une certaine profondeur, lorsque le mode n'est pas trop battu).

Outre les Madréporaires, la zone à éperons et sillons se caractérise aussi par la présence d'Alcyonaires (principalement *Sarcophytum*, mais aussi *Lobophytum*), d'Hydrocoralliaires *Milleporidae*, d'Échinodermes *(Stomopneustes)*, et de très nombreux Poissons.

Le peuplement de la véritable pente externe elle-même (au delà-de la zone à éperons et sillons) n'a pu être étudié, car nos observations ont été limitées à des profondeurs de 15 m environ.

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(1) Sauf exception, les Madréporaires n'ont encore été déterminés que de façon générique.

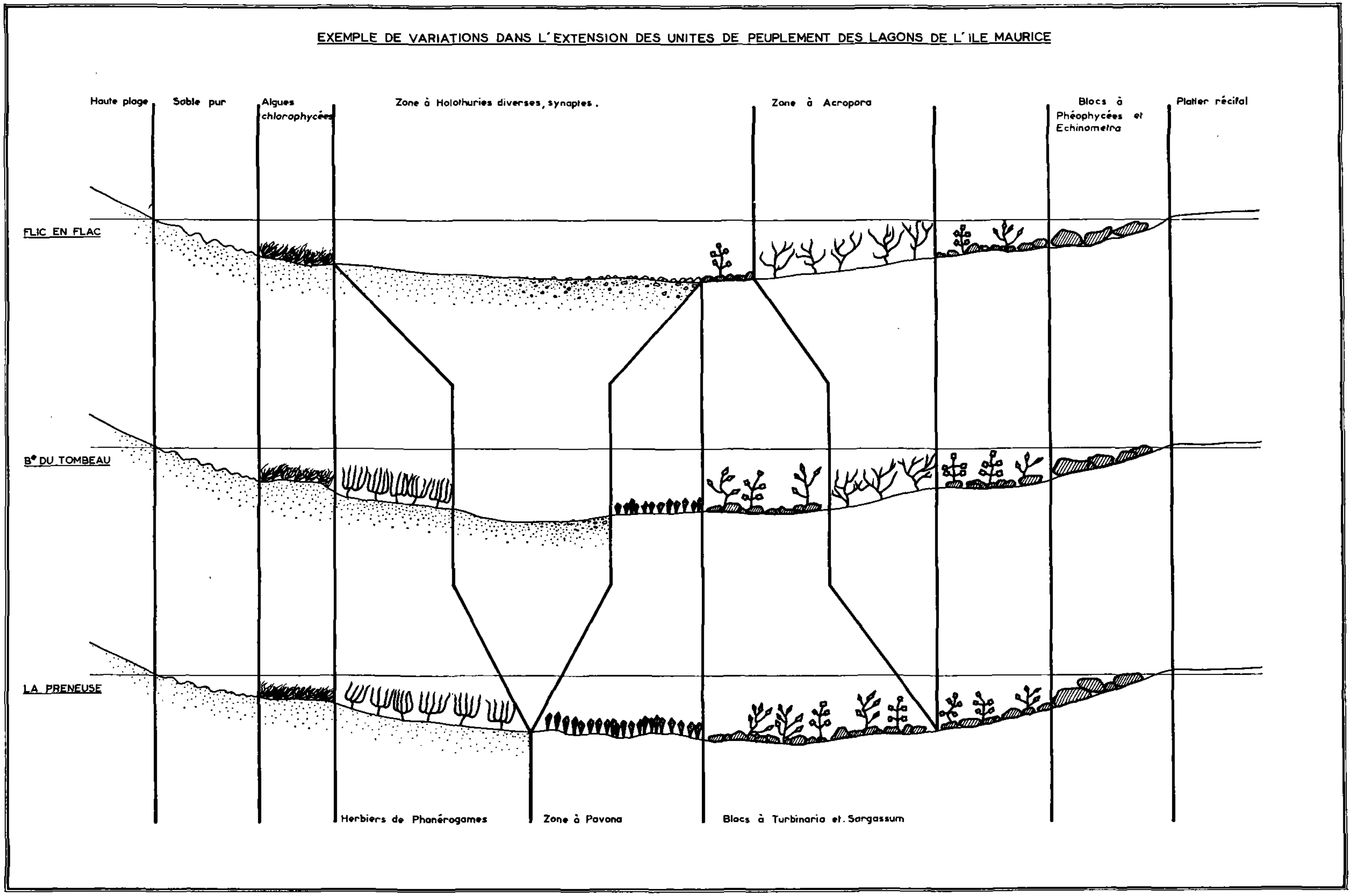
EXEMPLE DE VARIATIONS DANS L'EXTENSION DES UNITES DE PEUPLEMENT DES LAGONS DE L'ILE MAURICE
Haute plage
Sable pur
Algues chlorophycées
Zone à Holothuries diverses, synaptes.
Zone à Acropora
Blocs à Phéophycées et Echinometra
Platier récifal
FLIC EN FLAC
Bᵉ DU TOMBEAU
LA PRENEUSE
Herbiers de Phanérogames
Zone à Pavona
Blocs à Turbinaria et Sargassum

Fig. 3

V. *INTERPRÉTATION DES OBSERVATIONS*

Les particularités à retenir des récifs et lagons de l'île Maurice sont les suivantes :

— étroitesse du platier récifal, simple ruban d'une vingtaine de mètres de large, au maximum. (Outre sa faible largeur, le platier est encore remarquable par son peuplement, dans lequel dominent les Mélobésiées) ;

— faible profondeur des lagons, en règle générale, malgré une extension horizontale souvent importante.

L'application aux récifs de l'île Maurice, du schéma général proposé par J. Picard, pour le classement des milieux benthiques tropicaux, présentant des formations d'Anthozoaires conduit à l'interprétation suivante :

— le platier récifal est, dans sa totalité, référable à l'Ensemble fronto-récifal (zone « 3 » ou zone du « platier frontal ») ;

— la partie externe (extrême bord du platier, contreforts et sillons) est, de même, référable à l'Ensemble fronto-récifal (zone « 2 », équivalente de la zone de la « terrasse à éperons et sillons », lorsqu'elle existe).

— la première zone de l'Ensemble fronto-récifal (pente corallienne externe) n'a pas été observée. Selon toute vraisemblance, elle existe néanmoins, à des profondeurs supérieures à 20 mètres.

La succession des peuplements observés dans les lagons, depuis le ruban récifal jusqu'au littoral peut être résumée de la façon très schématique suivante :

. Épandage de blocs détritiques, sur la face interne inclinée du récif (avec *Echinometra*, et les algues Phéophycées *Turbinaria* et *Sargassum sp*).

.. Fonds à dominance de Madréporaires : *Acropora*, *Pavona*, avec passées sableuses plus ou moins importantes.

... Herbiers de Phanérogames.

Cette succession présente d'étroites analogies avec celle qui caractérise l'Ensemble épirécifal des formations coralliennes complètes (Grand récif de Tuléar, par exemple). Malgré une similitude apparemment indiscutable, nous préférons cependant adopter l'hypothèse suivant laquelle les peuplements observés dans les lagons de l'île Maurice sont à rattacher à l'ensemble postrécifal. Les raisons en sont les suivantes :

Le substratum sur lequel sont déposés les sédiments des lagons ne paraît pas être de nature corallienne. En d'autres termes, les lagons ne résultent pas du creusement d'un appareil récifal dont le niveau primitif serait indiqué par la cote actuellement atteinte par le récif. Cette opinion est appuyée par le fait que nous avons observé, en plusieurs endroits, des blocs basaltiques émergeant de la couverture organogène, soit dans le lagon, soit au niveau du ruban récifal. A l'extérieur du récif, également, nous avons pu observer (à Flic-en-Flac et à la Batterie-des-Grenadiers notamment) que des coulées de laves apparaissent à des profondeurs relativement faibles (vers 5 m). Dans cette hypothèse, le récif lui-même peut-être considéré comme un épais bourrelet organogène algo-corallien, établi en bordure d'épanchements volcaniques actuellement submergés. Ceux-ci constitueraient le substratum sur lequel se sont déposés les sédiments qui portent les divers peuplements observés dans les lagons.

Si donc l'on considère les formations des lagons comme référables à l'Ensemble postrécifal, nous distinguerons dans celui-ci trois zones, chacune englobant les peuplements suivants :

. Zone 1 (Pente interne du récif) : Blocs à Phéophycées et *Echinometra*.

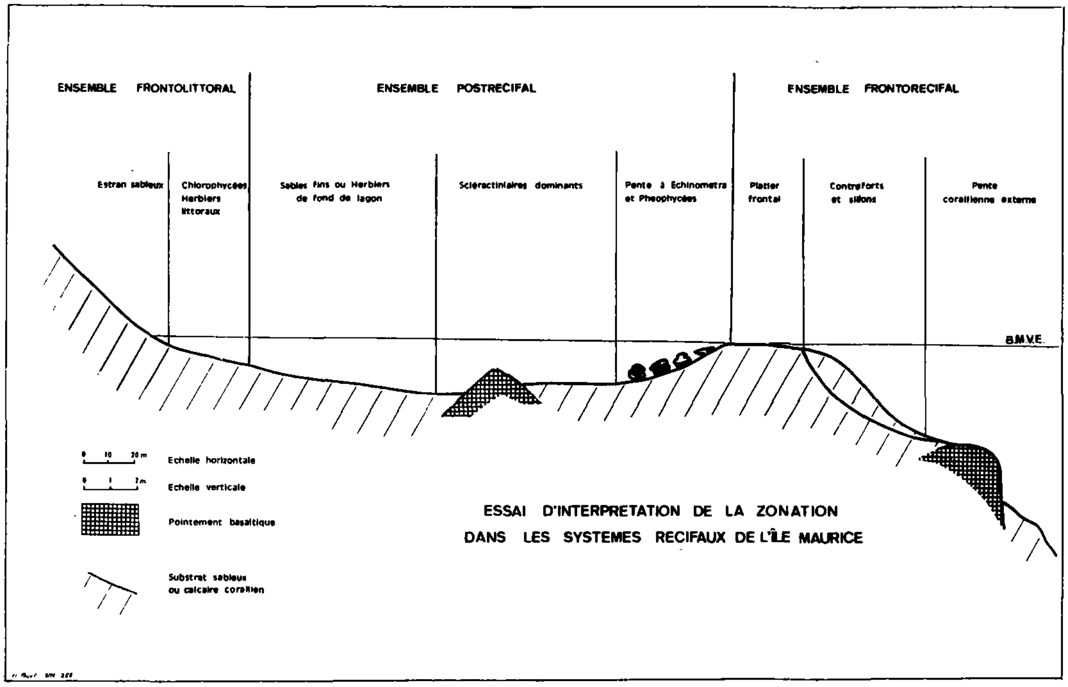

Fig. 4

.. Zone 2 (Fonds subhorizontaux du lagon) : peuplements à base de Madréporaires (*Acropora, Pavona)*, herbiers de *Cymodocea ciliata* et *Syringodium isoetifolium*, et passées sableuses.

...Zone 3 (remontée des fonds vers le littoral) : Herbiers à base de *Cymodocea ciliata* et ceinture de *Syringodium.*

L'Ensemble frontolittoral est représenté de la façon suivante :

. Zone 1 : Herbiers de *Diplanthera*, Sables à Chlorophycées, Sables sans épiflore ;

.. La zone 2 (banquettes d'algues filamenteuses et Mangroves) n'est rencontrée que de façon tout à fait exceptionnelle à l'île Maurice (dans le fond de certaines baies bien abritées de la côte Est).

... La zone 3 peut être soit une plage de sable organogène se terminant par une dune à *Casuarina*, soit un estran de nature basaltique.

VI. *CONCLUSIONS*

Nous observons, à l'île Maurice, la succession des Ensembles et zones suivantes :

ENSEMBLE FRONTORÉCIFAL
- zone de la pente corallienne externe (non étudiée),
- zone des éperons et sillons,
- zone du platier frontal,

ENSEMBLE POSTRÉCIFAL	Pente interne détritique à Phéophycées et *Echinometra*, Biotopes à dominance corallienne du lagon, Herbiers et passées sableuses, Ceintures de *Cymodocea* et *Syringodium*, sables fins sans végétation.
ENSEMBLE FRONTOLITTORAL	Zone à Chlorophycées, Herbiers de *Diplanthera*, Mangroves (éventuellement), Plage sableuse ou estran rocheux Supra et Médiolittoral.

Les récifs et lagons de l'île Maurice peuvent donc être caractérisés :

— Par l'absence de l'Ensemble épirécifal, ce qui se traduit par l'étroitesse, que nous avons indiquée, du « récif » lui-même.

— Par l'extension que prennent en certains secteurs, les peuplements à base d'Anthozoaires développés dans l'ensemble postrécifal. La composition particulière de ces biotopes coralliens est une conséquence à la fois des modes calmes et des faibles profondeurs rencontrées dans les lagons (en raison notamment de leur influence sur les phénomènes de sédimentation).

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Reprinted from *Bull. Sea Fish. Res. Sta., Haifa,* no. 49, 1968, p. 3-7

ISRAEL SOUTH RED SEA EXPEDITION, 1962, REPORTS
No. 28

ELEOTRID GOBIES COLLECTED DURING THE ISRAEL SOUTH RED SEA EXPEDITION (1962), WITH A KEY TO RED SEA SPECIES*

by
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During the 1962 Israel South Red Sea Expedition, nine species of eleotrid type gobies, totaling nearly 500 specimens, were collected in the Dahlak Archipelago, Ethiopia, during March and April. Of these species, four are new records for the Red Sea: *Eviota stigmapteron*, *Coryogalops anomolus*, *Mucogobius flavobrunneus*, and *Ptereleotris microlepis*. This brings the number of species of eleotrids known from the Red Sea to 12. These species may be separated by the following key. The work on this key and species determinations was greatly facilitated by the comprehensive study of SMITH (1958) on Western Indian Ocean species of the family Eleotridae.

When gobies are separated into the families Eleotridae and Gobiidae, the species indicated in this paper as *Mucogobius flavobrunneus* could be placed in the family Gobiidae in the genus *Callogobius* (KOUMANS, 1953) and is obviously closely allied there, as are many species often classified as eleotrids. The separation of these two families on the basis of the divided or united ventral fins has long been recognized as not satisfactory (GINSBURG, 1933, p. 13) and has resulted in some unnatural groupings as has been pointed out by BÖHLKE and ROBINS (1960, p. 87) and ROBINS and BÖHLKE (1961, p. 122). For the purposes of this report, however, the apparently artificial group of gobies usually referred to the family Eleotridae is treated as a separate group following, in general, the classification of SMITH (1958) until a more extensive analysis of Red Sea gobiid fishes can be made. It should be cautioned that several species of Red Sea gobies with united or partly united ventral fins and therefore not included here (e.g. species in the genera *Zonogobius* and *Quisquilius*), occasionally have an individual with separate ventrals (CLARK, in m.s.), a confusing situation when only one such specimen is examined for identification.

In the list of species following the key I have included, in addition to the collections of the Israel South Red Sea Expedition, specimens not otherwise reported, from collections I made at Ghardaqa, Egypt, in 1951 (now in the Marine Biological Station at Ghardaqa) and at Eilat, Israel, in September 1960 and September 1964 (now at the Hebrew University).

Received: June 1966.

* This study was supported by the following: U.S. National Science Foundation, Washington, D.C. through its contribution to IIOE participants and through grants G-6468 and GB 2736; Oceanic Biology Branch, Office of Naval Research, Washington, D.C., under contract N 62558-4556 and F 61052 67 C 0043 (Contractor Department of Zoology, Tel-Aviv University.) The author gratefully acknowledges also the help and comments of Dr. Heinz STEINITZ during the preparation of this manuscript.

All the fishes in this report were collected using rotenone poison in shallow water (less than 3 meters) in areas with corals. There are undoubtedly many more species of gobies with divided ventral fins in the Red Sea which will be found when poison collections are made in more localities and in deeper water.

KEY TO SPECIES OF ELEOTRID[1] GOBIES IN THE RED SEA

A. First gill slit at least partly open; scales present.

B. Less than 20 soft rays in dorsal and anal fins.

C. Pelvic fins with I, 4; individual rays separate and "feathery"; 20–25 scales.

D. In life greenish with red markings on head; 7 dark incomplete vertical bands on sides of body, the last on the caudal peduncle has a black spot in the center; 2 prominent black spots behind the eye . . . . *Eviota prasinus.*

DD. In life pale grey with orange brown spots; 2 prominent black spots at the base of the pectoral fin . . . . . *Eviota stigmapteron.*

CC. Pelvic fins with I, 5; rays in each fin joined by membrane, not feathery.

E. Scales less than 50.

F. No spines at preopercle angle; no greatly elongated dorsal spines or rays.

G. Nape and interorbital naked; a series of about 7 dark spots on each side of chin and throat stopping under hind end of preopercle; head smooth, without papillate flaps . . . . *Coryogalops anomolus.*

GG. Nape and interorbital scaly; head with marked papillate flaps giving it a rough appearance; in life yellowish with brown and orange brown irregular markings . . . . *Mucogobius flavobrunneus.*

FF. 1–9 small spines at preopercle angle; third dorsal spine greatly elongated; in life, a drab, blue grey with smokey markings and small inconspicuous ocellated spots in 4 or 5 rows along cheek and lower sides of body *Asterropteryx semipunctatus.*

EE. Scales 50 or more.

H. Teeth in upper jaw in only one row; scales about 80; a prominent black spot at tip of first dorsal fin; in life the following inconspicuous colors are also discernible on large specimens: about 8 blue spots on pale yellow cheek; snout between upper lip and eye dusky pink; body white with a dusky pink horizontal line on lower side of body from pectoral base onto caudal peduncle; tiny pink spots on end of caudal peduncle and on

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[1] Gobies with separate or almost completely separate pelvic fins.

proximal parts of dorsal, anal, pectoral and caudal fins forming 2 lines on lower half of second dorsal and anal fins; pectoral fins with pale yellow base. A black edge develops on anal fin of large specimens (over 58 mm) . . . . *Eleotriodes sexguttatus.*

HH. Teeth in upper jaw in several rows.

I. Head compressed; scales 70–80. (Doubtful record*) . . . . *Amblyeleotris periophthalmus.*

II. Head depressed; scales about 60; 13 vertical, dusky bands on upper part of body; a black spot at central base of caudal; both dorsals, anal and caudal fins striped. In life, belly orange yellow, a pink line from lips through eye, pink on body at upper edge of bands under 2nd dorsal, and a prominent pink crescent around anterior part of black caudal spot . . . *Xenisthmus polyzonatus.*

BB. More than 20 soft rays in both dorsal and anal fins. In life body pink, base of dorsal yellow, rest pink; caudal pale yellow with orange on upper edge; anal, pectorals and ventrals pink, pectoral with a black base . . . . *Ptereleotris microlepis.*

AA. First gill slit completely closed by membrane; throat, chest, and belly naked.

J. No scales on head or body.

K. Pelvic fins with outwardly directed digitate margin . . . *Lioteres vulgare.*

KK. Pelvic fins normal . . *Lioteres simulans.*

JJ. Body with small cycloid scales embedded and difficult to see. Head naked; 7–9 poorly defined cross bars not reaching belly, that below first dorsal spine sharpest; a bar from eye to lower edge of operculum . . *Hetereleotris diadematus.*

1. *Eviota prasinus* (KLUNZINGER, 1871)

21 specimens,	11–16 mm, standard length,	Ghardaqa; 1951.
1 specimen,	15 mm, E60/39,	Eilat, 4 May, '60
2 specimens,	8–9 mm, ISRSE E62/275	Landing Bay, Entedebir; 14 March, '62.
1 specimen,	15 mm, ISRSE E62/417t	Cundabilu; 25 March, '62.
3 specimens,	5–13 mm, ISRSE E62/490	Entedebir; 7 April, '62.
55 specimens,	9–15 mm, ISRSE E62/507	Entedebir; 7 April, '62
8 specimens,	12–20 mm, ISRSE E62/3678q	Um Aabak; 6 April, '62.
32 specimens,	8–15 mm, ISRSE E62/4313	Entedebir; 7 April, '62.

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* See KOUMANS (1953) and SMITH (1958).

2. *Eviota stigmapteron* SMITH, 1958

3 specimens,	10–16 mm,	ISRSE E62/514	Entedebir; 7 April, ’62.
1 specimen,	14 mm,	ISRSE E62/4323	Entedebir; 7 April, ’62.

3. *Coryogalops anomolus* SMITH 1958

1 specimen,	26 mm,	ISRSE E62/417,p3	Cundabilu; 25 March, ’62.
1 specimen,	22 mm,	ISRSE E62/4314	Entedebir; 7 April, ’62.

4. *Mucogobius flavobrunneus* SMITH, 1958

Most of our specimens show evidence of slight fusion near the base of the two pelvic fins in the form of a delicate membrane easily split when trying to spread these fins. In no case, however, was the fusion more than 10% of the length of the inner margins of the fins. This species could be referred to *Callogobius hasseltii* (BLEEKER) of the Pacific and Eastern Indian Ocean, but as our specimens agree closely with SMITH's (1958) detailed descriptions and figures of Western Indian Ocean specimens I chose to follow his nomenclature.

1 specimen,	28 mm,	ISRSE E62/417,p2	Cundabilu; 25 March, ’62.
2 specimens,	32 & 42 mm,	ISRSE E62/442a	Cundabilu; 25 March, ’62.
1 specimen,	27 mm,	ISRSE E62/36681	Um Aabak; 6 April, ’62
20 specimens,	19–38 mm,	ISRSE E62/3678m	Um Aabak; 6 April, ’62.
1 specimen,	32 mm,	ISRSE E62/4321	Entedebir; 7 April, ’62.

5. *Asterropteryx semipunctatus* RÜPPELL, 1828

Numerous specimens to 31 mm,			Ghardaqa; 1951.
2 specimens,		ISRSE E62/626	Cundabilu; 20 March, ’62.
119 specimens,	7–28 mm,	ISRSE E62/1283	Nocra; 18 March, ’62.
103 specimens,	10–29 mm,	ISRSE E62/3678b	Um Aabak; 6 April, ’62.
2 specimens,	19–23 mm,	ISRSE E62/3711	Entedebir; 7 April, ’62.
1 specimen,	24 mm,	ISRSE E62/4392	Um Aabak; 6 April, ’62.

6. *Eleotriodes sexguttatus* (VALENCIENNES, 1837)

14 specimens,	22–52 mm,		Ghardaqa; 1951.
3 specimens,	57–62 mm,	ISRSE E62/353	Cundabilu; 14 March, ’62.
1 specimen,	20 mm,	ISRSE E62/417u	Cundabilu; 25 March, ’62.
39 specimens,	17–63 mm,	ISRSE E62/475	Entedebir; 7 April, ’62.
49 specimens,	18–76 mm,	ISRSE E62/582	Um Aabak; 23 March, ’62.
23 specimens,	17–55 mm,	ISRSE E62/1255	Nocra; 18 March, ’62.
15 specimens,	19–57 mm,	ISRSE E62/1288	Cundabilu; 20 March, ’62.
1 specimen,	22 mm,	ISRSE E62/3211,1a	Enteraia; 24 March, ’62.
59 specimens,	18–57 mm,	ISRSE E62/3235	Cundabilu; 25 March, ’62.
46 specimens,	17–58 mm,	ISRSE E62/3616b	Enteraia; 26 March, ’62.
7 specimens,	31–58 mm,	ISRSE E62/3678d	Um Aabak; 6 April, ’62.
6 specimens,	20–37 mm,	ISRSE E62/4142	Entedebir; 7 April, ’62.
1 specimen,	18 mm,	ISRSE E62/4701	Nocra; 18 March, ’62.

7. *Amblyeleotris periophthalmus* (BLEEKER, 1853)

SMITH (1958) lists "one doubtful record" from Eritrea, Red Sea. I have seen none in our collections.

8. *Xenisthmus polyzonatus* (KLUNZINGER, 1871)

1 specimen,	40 mm,	Ghardaqa; 1951.

9. *Ptereleotris microlepis* (BLEEKER, 1856)

2 specimens,	41 & 74 mm,	ISRSE E62/1287	Nocra; 18 March, '62.
3 specimens,	42–69 mm,	ISRSE E62/3238	Cundabilu; 25 March, '62.

10. *Lioteres vulgare* (KLUNZINGER, 1871)

3 specimens,	ca. 22 mm,		Ghardaqa; 1951
3 specimens,	18 to 22 mm,	ISRSE E62/417,–p.1	Cundabilu; 25 March, '62.
1 specimen,	20 mm,	ISRSE E62/563,b	Nocra; 22 March, '62.
1 specimen,	14 mm,	ISRSE E62/3211,–1b	Enteraria; 24 March, '62.
12 specimens,	13 to 21 mm,	ISRSE E62/4316	Entedebir; 7 April, '62.

11. *Lioteres simulans* SMITH, 1958

No specimens seen. The type is from the Gulf of Suez and SMITH points out that KLUNZINGER (1871) and KOSSMAN and RAUBER (1877) have confused this species in the Red Sea with *Heterelectris diadematus*.

12. *Heterelectris diadematus* (RÜPPELL, 1828)

6 specimens,	15 to 22 mm,	ISRSE E62/4315,	Entedebir; 7 April, '62.

SUMMARY

Nine known species of eleotrid fishes were collected by the ISRSE. Four of these are new records from the Red Sea. Altogether 12 species of eleotrids are now recorded from the Red Sea.

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Reprinted from *Bull. Sea Fish. Res. Sta., Haifa*, no. 49, 1968, p. 8-17

ISRAEL SOUTH RED SEA EXPEDITION, 1962, REPORTS
No. 29

THE MILLEPORINA AND STYLASTERINA OF THE ISRAEL SOUTH RED SEA EXPEDITION*

by
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Together with the Hydroida of the Israel South Red Sea Expedition a few Milleporina and Stylasterina of this expedition and some specimens from the Gulf of Aqaba were sent for identification to Dr. W. VERVOORT of the Leiden Museum, who turned the specimens of the last-mentioned two groups over to me for further examination. The corals give occasion to the following remarks.

MILLEPORINA

KLUNZINGER (1879) and CROSSLAND (1941) have shown that the genus *Millepora* is represented in the Red Sea by three well-defined species, viz., *M. exaesa* FORSKÅL, *M. dichotoma* FORSKÅL, and *M. platyphylla* HEMPRICH & EHRENBERG. In a revision of the genus (BOSCHMA, 1948) and in a later paper (BOSCHMA, 1949) there are numerous data on the occurrence of the three species in the Red Sea, and on their distribution in other areas of the Indo-Pacific region. While it appears to be an established fact that *M. platyphylla* has been found in its typical form of growth in a great many localities in the Indo-Pacific, it remains doubtful whether or not the specimens of *M. exaesa* and of *M. dichotoma* from localities other than those in the Red Sea really belong to those species as most of the recorded specimens differ in certain respects from the typical Red Sea representatives. A similar difficulty presents itself in regard to some of the corals of the present collection, which in their form of growth show a certain resemblance to *M. dichotoma* but differ from specimens of the typical form of growth. One of these has here been identified with *M. tenera*, of the other the identification must remain uncertain it has here been named "*Millepora* cf. *tenera*" to point out the resemblance to this species and to indicate that the name is to be regarded as provisional only.

Millepora platyphylla HEMPRICH & EHRENBERG

MATERIAL. NS 860 and NS 861. Eilat, Gulf of Aqaba, x. 1952, leg. CH. LEWINSOHN and L. FISHELSON, two large fragments.

One of the fragments is a plate-like growth with a height of 170 mm, a breadth of 123 mm, and (in its basal part) a thickness of 20 mm. The greater part of the

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Received: June 1966.

* Study aided by Contract No. 62558-3335 between the U.S. Office of Naval Research, Department of the Navy, and Tel-Aviv University.

surface is densely covered with small, low-conical warts of a diameter of about 2 mm, each wart showing in the centre of its top a gastropore which is surrounded by a ring of dactylopores; on account of this arrangement of the pores the cyclosystems remain rather distinctly separate. In some places the small warts are united to form protuberances of larger size, with several cyclosystems on their topmost parts. In other places the coral has lost its regular appearance through groups of closely joining barnacles (*Pyrgoma* spec.) rising over the surface. The general appearance of the smoother parts of the surface of this coral is very much alike to that of a specimen in the Leiden Museum (BOSCHMA, 1948, Pl. V, fig. 2).

The other fragment is a plate-like growth with a height of 200 mm, a breadth of 108 mm, and (in its basal part) a thickness of 20 mm. From the almost straight upper margin to about 1½ cm below the margin the surface of the coral is almost smooth. Below this upper part there is a region of a width of about 3 cm in which the surface is covered with densely packed small warts of a diameter of about 2 mm, each with a central gastropore. Below this region the surface is covered with much larger warts, corresponding in shape with those of a specimen in the Leiden Museum (BOSCHMA, 1948, Pl. XV, fig. 5) and those of the coral described and figured by MILNE EDWARDS (1857, Pl. F2, fig. 1; 1860, p. 227) as *Millepora verrucosa*, later shown to be a synonym of *M. platyphylla* (cf. BOSCHMA, 1948, p. 35). In specimen NS 861 the surface does not show any deformation by barnacles.

Millepora dichotoma FORSKÅL

MATERIAL. NS 862. Eilat, Gulf of Aqaba, x. 1952, leg. CH. LEWINSOHN and L. FISHELSON, one colony.

The name *Millepora dichotoma* and its synonyms *M. cancellata* and *M. reticulata* all refer to the peculiar form of growth of the coral, starting as cylindrical finger-shaped branches, dichotomically dividing at their tops, the end branches uniting again to form reticulate plate-like growths. The specimen from Eilat has the typical form of growth of the species (fig. 1), the colony has a height of 130 mm and a breadth of 145 mm. Its basal part is attached to the dead branches of another coral, partly encrusting them, forming here a rather solid mass without indications of specific pecularities (fig. 2).

Another coral from Eilat (BOSCHMA, 1964) was somewhat hesitatingly identified with *Millepora dichotoma*, because its form of growth is not as distinctly reticulate as in typical specimens and the terminal branches are comparatively broad (l.c., fig. 2). The occurrence of *M. dichotoma* of the typical form of growth in the same locality gives support to the identification of the slightly aberrant specimen.

Millepora tenera BOSCHMA

MATERIAL. E62/3131. Cundabilu, Dahlak Archipelago, southern Red Sea, 16.iii.1962, one colony.

The colony (fig. 3) is spreading in one plane, height 58 mm, transverse diameter 97 mm. It is composed of comparatively thin branches radiating from one centre,

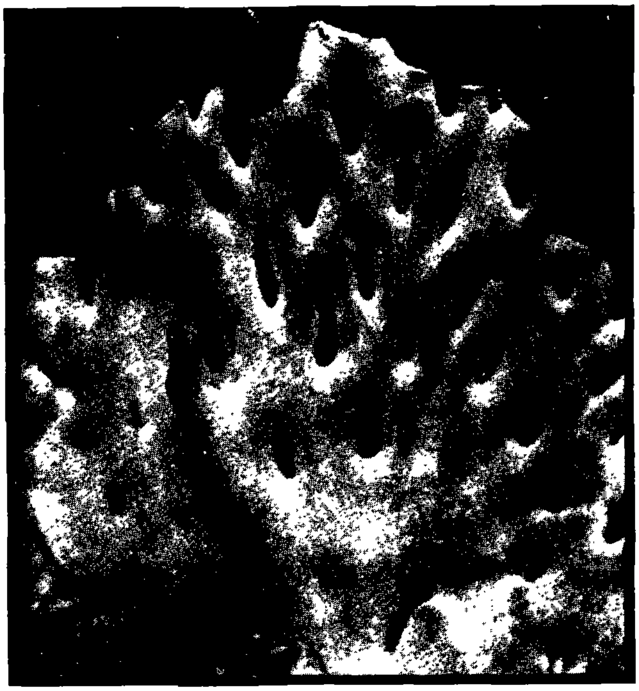

Fig. 1. *Millepora dichotoma* Forskål, top part of a colony from Eilat. Natural size.

Fig. 2. *Millepora dichotoma* Forskål, basal part of the colony of fig. 1, forming an encrusting layer on a dead madreporarian coral. Natural size.

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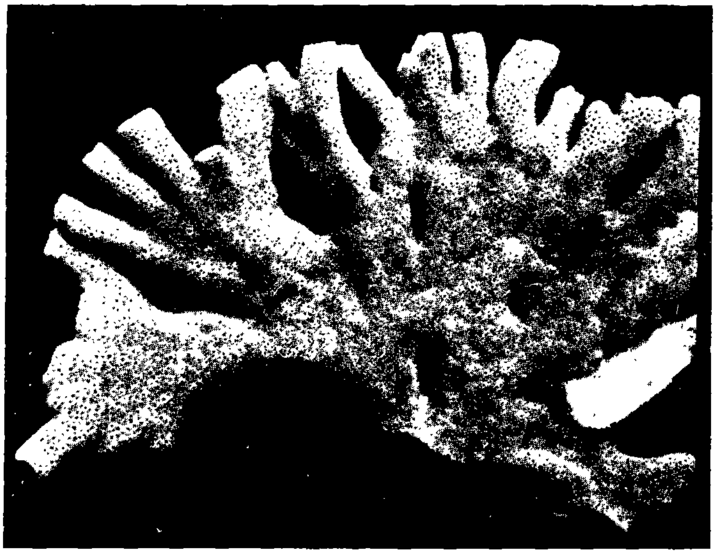

Fig. 3. *Millepora tenera* Boschma, colony from Cundabilu, Dahlak Archipelago. Natural size.

closely united in their basal parts and free only at their extremities. All the top parts of the branches have broken off; they appear, therefore, in the figure as much more truncated than they were before being collected. The colony is rather strikingly similar to certain specimens of *Millepora tenera* (cf. Boschma, 1948, Pl. XIV, fig. 1), the shape and the radial manner of growth of the branches being entirely alike. In its manner of branching the fragment differs from *M. dichotoma* (fig. 1) in not showing a pronounced tendency to dichotomous division and the subsequent formation of a reticulate frond.

The close similarity of the specimen to corals that undoubtedly belong to *Millepora tenera* seems to warrant the identification with this species. *M. tenera* is widely distributed in the Indo-Pacific area but was not known to occur in the Red Sea. The locality, Cundabilu in the Dahlak Archipelago, is in the southernmost part of the Red Sea where perhaps penetration of species from the Indian Ocean might be expected.

Millepora cf. *tenera* Boschma

Material. E62/3106. Entedebir, Dahlak Archipelago, southern Red Sea, 15.iii.1962, one colony.

The fragment (fig. 4) consists of a compact basal part with four robust branches all extending in one plane, and a fifth (not shown in the figure) forming an angle of about 45 degrees with the rest. The total height is 123 mm, the transverse diameter 85 mm. The main branches are strongly flattened, their greater diameter being 10 to 15 mm, their smaller diameter about 8 mm. At their tops they are divided into a

Fig. 4. *Millepora* cf. *tencra* BOSCHMA, colony from Entedebir, Dahlak Archipelago. Natural size.

Fig. 5. *Distichopora violacea* (PALLAS), two young colonies from Um Aabak, Dahlak Archipelago, on a piece of dead madreporarian coral. The upper arrow points to the basal part of a colony of white colour, the lower arrow to the basal part of a colony of violet colour. × 2.

number of smaller branchlets (nearly all with damaged, broken-off ends). The colony shows some resemblance to rather robust specimens of *Millepora tenera* but of this species not a single colony has been figured showing the same form of growth. The main branches extend upwards more or less parallel to each other; they do not show a tendency to a radial manner of growth as it generally occurs in *M. tenera*. A definite specific identification of the coral is not to be given. Among the Indo-Pacific species it seems to correspond most closely with *M. tenera* but this resemblance remains superficial only.

Millepora spec.

MATERIAL. E62/1654. Padina Bay, Entedebir, Dahlak Archipelago, southern Red Sea, 12.iii.1962, one fragment.

E62/3789. Manta Cliff, Entedebir, Dahlak Archipelago, southern Red Sea, 25.iii.1962, one fragment.

The specimen from Padina Bay forms a thin encrusting layer on a piece of dead madreporarian coral, roughly showing the structure of the surface of this substratum. The dimensions are about 80 by 59 mm. The form of growth does not show any indications for a specific identification.

The specimen from Manta Cliff again is an encrustation on a fragment of dead madreporarian coral, of about 80 by 45 mm. On its upper surface there are some incipient branches of a height of up to 25 mm, of rather nodular appearance. It must remain undecided to which of the three Red Sea species of *Millepora* the coral belongs, for each of the three might start with the form of growth as represented by this young colony.

STYLASTERINA

Stylasterine corals that were supposed to come from the Red Sea were vaguely described by NARDO (1844a, b, 1845) as *Distichopora cinnabarina*, the chief specific character being their pronouncedly red colour; to all appearances the name is a synonym of *D. violacea* (PALLAS). There are several colonies of *D. violacea* in the collection of the Paris Museum showing a red colour (BOSCHMA, 1959). KLUNZINGER (1879) was the first to record the coral *D. violacea* from the Red Sea, BOSCHMA (1959) published notes on several specimens from this locality.

Distichopora violacea (PALLAS)

MATERIAL. E62/2286 and E62/2287. Um Aabak, Dahlak Archipelago, southern Red Sea, 24.iii.1962, some small colonies on two fragments of dead madreporarian coral.

The basal plates of the colonies have a spreading in width of up to 32 mm, the branches extend in height to about 12 mm. The very small colonies are of rather bushy appearance, not showing a tendency to flabellate arrangement of the branches (fig. 5). Some of the branches are densely covered with (male?) ampullae, often in continuous patches. The most striking peculiarity is that some of the colonies are creamy white, others of a very pale pinkish-violet colour, and again others of a pronouncedly dark violet colour with the tops of the branches white. In their form of growth the colonies are strongly similar to the figure of DE BLAINVILLE (1830, Pl. 35, fig. 2, cf. also BOSCHMA, 1959, fig. 1c). They belong to the form *tenella*, the most common form of growth of *Distichopora violacea* in the Red Sea.

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Reprinted from *Bull. Sea Fish. Res. Sta., Haifa*, no. 49, 1968, p. 15-31

ISRAEL SOUTH RED SEA EXPEDITION, 1962, REPORTS
No. 30

OBSERVATIONS ON A COASTAL FISH COMMUNITY, DAHLAK ARCHIPELAGO, RED SEA*

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INTRODUCTION

As a part of the program of the Israel South Red Sea Expedition, we attempted to gain an idea of the number of fish species, their abundance, and biomass in the shallow coastal waters of the Dahlak Archipelago. For this purpose we selected a convenient area with sand, rocks and corals near the Expedition camp site (Figs. 1 and 2). During a series of underwater observations estimates were made of the fish population by visual counts. Finally a collection of fishes in this area was made using rotenone. This collection was studied and analyzed to supplement the data from the visual counts.

No previous attempts to estimate the numerical abundance of the fish fauna in any habitat of the Red Sea have been made although a survey of the fish fauna, combined with diving observations, has been conducted at Ghardaqa (ABEL, 1960). ROGHI and BASCHIERI (1957) have given a popular account of the Italian National Underwater Expedition of 1952–53 in the Dahlak area which gives some descriptions of the fish life. This book and scientific reports on some of the fish fauna observed and collected (BASCHIERI-SALVADORI, 1953, 1954a, 1954b, 1955; TORTONESE, 1936, 1947, 1954, 1955 and 1957) give some indications of the abundance of certain fishes in this region.

By means of tagging, visual counts, and other observational methods population studies have been made in certain restricted communities in the littoral waters of the Atlantic and Pacific in areas similar to the one we have studied. An important contribution in Atlantic waters was made by BARDACH (1959) who studied the summer

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Received: October 1964; revised, December 1966.

*This project was materially aided by the sponsoring agents of the ISRSE, by the National Science Foundation through the U.S. Program in Biology of the International Indian Ocean Expedition administered through Dr. J. H. Ryther (Grant G–6468), and by the U.S. Office of Naval Research (Contracts N62558–2985 and N62558–3335 with Tel-Aviv University).

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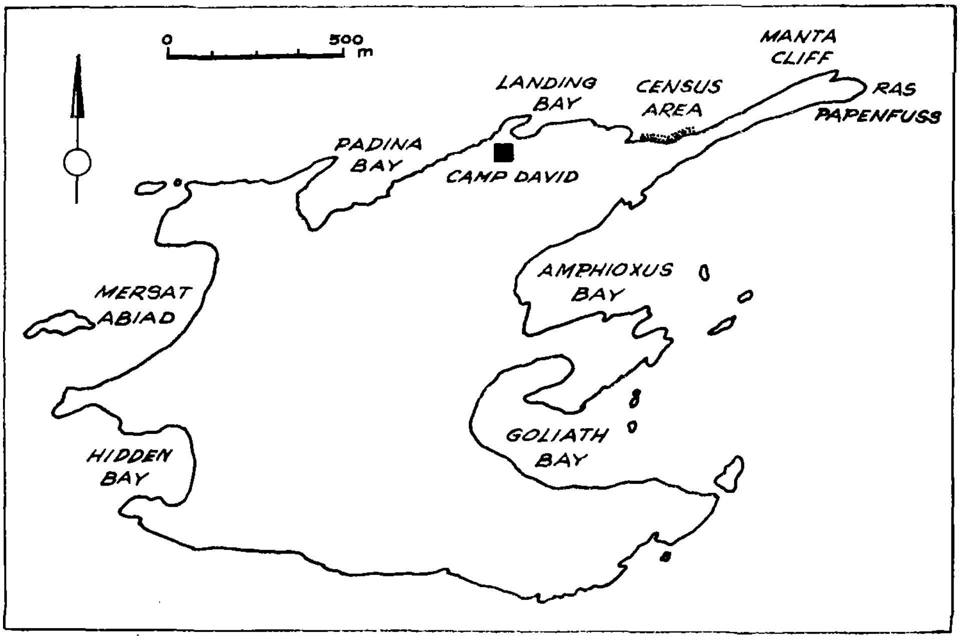

Fig. 1. Map of Entedebir with census area indicated.

standing crop of fish on a shallow Bermuda reef. Divers took repeated visual counts in a familiar area where other related studies (Bardach and Menzel, 1957; Bardach, 1958) were also conducted. The divers were thus familiar with the reef area and its inhabitants which Bardach considers an important factor before visual counts can be made. A recent contribution has been made by Randall (1963) studying fish populations in the Virgin Islands who made visual observations, but counts were based on rotenone collections.

The American Littoral Society in cooperation with the U.S. Fish and Wildlife Service has, as one of its major aims, a program to train divers to recognize the fishes of their diving area and to take fish counts similar to the methods used by bird watching groups. Over 100 skin divers in areas along the coast from Maine to Florida made a census of some 23,000 identified fish (Anonymous, 1962 and 1963). Fish counts on a large scale are severely handicapped by many factors. The number of fish species is much greater than that of birds and the field identification of even common fishes has not been worked out satisfactorily as it has in birds and mammals.

Some idea of the population of coral reef fishes which enter traps has been ascertained from the tagging studies of Randall (1962) in the Virgin Islands and Springer and McErlean (1962) in South Florida. The analysis of a Connecticut coastal fish population by Merriman and Warfel (1944) based on regular biweekly haul-seine collections over a period of one year shows seasonal variation correlated with temperature changes.

In the Pacific Brock (1954) estimated reef fish populations in nine localities in Hawaii by using, for the first time, the technique of divers wearing self-contained breathing apparatus (*Scuba*) to make counts. ODUM and ODUM (1955) studied the entire trophic structure and productivity of a reef in Eniwetock, and SARGENT and AUSTIN (1954) studied productivity of a reef at Bikini. The studies of HIATT and STRASBURG (1960) in several of the Marshall Islands revealed a great deal about the composition and feeding habits of coral reef fish communities. OKUNO (1964), also using *Scuba*, compared the taxonomic aspects of a reef fish population in Japan, over a period of nine years, with those reported by HIATT and STRASBURG (1960) and found remarkable similarities at levels of the orders and families but vast differences at the species level. In neither of these studies, however, was an attempt made to calculate the biomass.

Fish census studies have also been undertaken in freshwater. BALON's papers (1963, 1964) include extensive data of lake and river population with biomass studies.

DESCRIPTION OF AREA STUDIED

The area specifically covered, in which actual counts of fishes were made, was a region along the northern side of Manta Cliff, a distance of 350 meters from the shore of Landing Bay on Entedebir (Fig. 1). The census area covered a strip of ittoral zone approximately 150 meters along the shore and extending an average width of 22 meters from the low tide line to a depth of 3 meters.

This area (Fig. 2) of approximately 3,300 square meters at low tide and 4,400 square meters at high tide included sandy bottom along the small, narrow beaches which lay under shoreline rock (smooth worn fossil reef) and was covered with water at high tide except for the small beach ("A") indicated on Figure 2. A number of large and small rocks protruded out of the water near the shore line. Away from

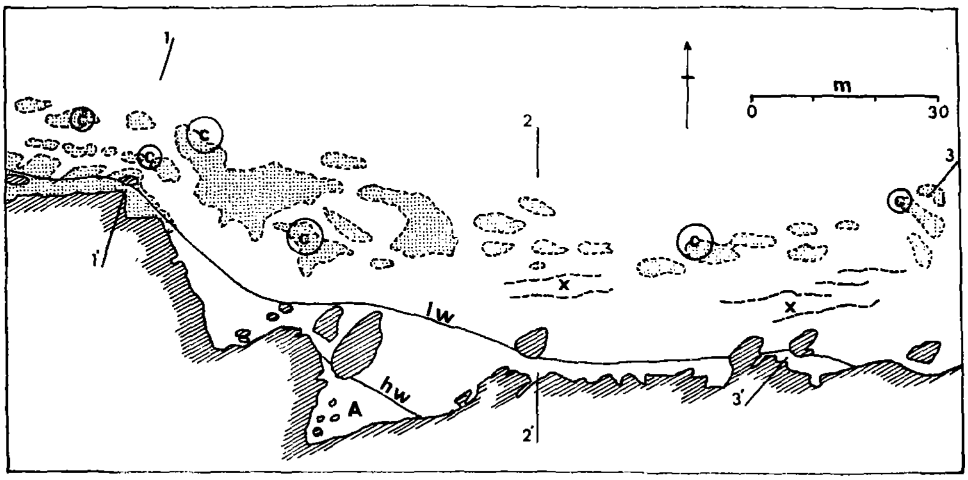

Fig. 2. Map of census area with shoreline drawn at the high water level (edges shaded) and reefs shown in stippled areas. *A* = sandy beach above high water; *C* = cleaning station; *X* = rocky bottom with gullies; *lw* = low water; *hw* = high water. Guide lines (1 — 1'; 2 — 2'; 3 — 3') refer to the respective cross sections of the census area, presented in fig. 3.

shore and projecting from the sand bottom, particularly on the eastern end of the area, was a flat rock in which cracks and small gullies, some over 10 meters long, were formed roughly parallel with the shore line. Just outside this area of cracks among which lived many gobies, were clusters of dead and live corals, indicated in stippling on Figure 2. Between the coral clusters, particularly near the deepest part of the census area, there were again sizeable patches of smooth sandy bottom. The recent coral formations were not of the active reef building type but mostly of scattered madrepore, *Stylophora* and a lobate *Porites* being conspicuous forms. Small patches of octocorals, including xeniids were present. At the bases of the stony and soft coral clumps were patchy layers of dead *Galaxea*. Details of this biotope have been discussed by WAINWRIGHT (1964).

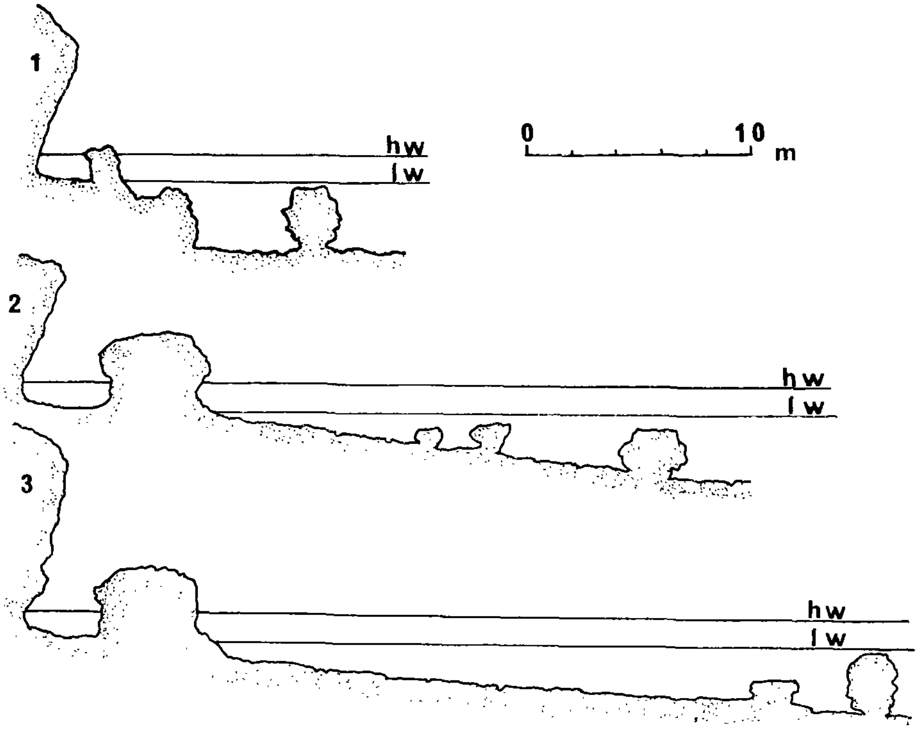

Fig. 3. Cross sections of census area; compare Fig. 2, guide lines.

The flat, rocky bottom with cracks and gullies near shore covered less than 1/3 of the area and was mostly on the eastern side. The sandy bottom covered over 1/3 and the corals less than 1/3 of the bottom. This census area was in a partly sheltered coastal area of the island where the water was usually calm and protected from afternoon winds.

METHODS

The visual counts were made by two of us (A.B. and E.C.) at the same time or by one of us working alone. If working together one of the divers would start at one end and the other at the opposite end. The east and west ends of the census area were marked off by paint on shore line rocks; distinctive coral heads and a clear sand bottom marked the outer margin. As the area was not wide each diver swam slowly along the length of the census area near the outer corals in a zig-zag line and then back across the sandy area along the shore. Records were made on a stiff 10″ × 12″ sheet of pale green plastic with an ordinary lead pencil attached to the sheet by string. *Scuba* was used for part of the counts, especially when concentrating on small fishes and those hiding in crevices. However, as the water was shallow it was found convenient to do most of the visual counts wearing only face mask, snorkle tube, foot flippers and weight belt as diving aids. In spite of the warm water a shirt or short wet suit was helpful as we became quite chilled by the end of each count.

When two of us counted at the same time we later compared notes to make the final estimates for the day. One or two visual counts were made for each of six days with a total of 15 man hours of observations during 7 counting periods, each varying from 1 to 2½ hours per person. Counts were done only during the day between 10 am and 5 pm. Except for the record of the manta made on March 9 all fishes were counted during the last two weeks of the expedition from March 31 to April 7 after we had been diving and collecting fishes rather extensively in coastal areas of the Dahlak Archipelago and had become familiar with the fishes.

After the last visual count on April 7 we poisoned the census area during the late morning using twelve gallons of S.B. Penick Company's Pro-Noxfish containing 5% emulsifiable rotenone. The water in the census area during the poisoning had practically no currents. *Scuba* was used to facilitate and speed up collecting fishes fallen to the bottom. Seven swimmers aided in collecting the specimens.

The number of fishes reported for each species in Table 1 as "seen" represents the maximum number of individuals counted (or estimated, in the case of large numbers) for each species at any one time, even if the species was seen only once in the area. In the case of estimations we believe the figures given are minimal.

In biomass determinations the fresh weight of fishes collected was not taken in the field. It was found, however, that fish preserved in alcohol two weeks or more lose on the average nine to ten per cent of their fresh weight. Therefore we weighed the collected fish after formalin-to-alcohol preservation and added a correction factor for this difference (10%) which we feel is sufficiently accurate for our purposes.

For determining the approximate biomass of fishes observed but not collected the following considerations were used. Most of the groups or schools consisted of fish of about the same size. Whenever there was a range of sizes, the maximum and minimum sizes were estimated and the median size of the group was used. In order to obtain the estimated weight of these fishes the formula $W = KL^3$ was used, where W is the weight of the fish in grams, L is the standard length in centimeters, and K is the coefficient of the species. The species coefficient was established from data based on specimens from areas in the following preferential order of availability:

census area; other areas of the Dahlak Archipelago; other Red Sea localities. In the rare cases when no specimens of the species in question were available, those of another species of the same genus were used whose habitus could safely be con-considered equal. They were measured and weighed (adding the correction factor mentioned above for specimens preserved in alcohol). K was obtained by dividing W by L^3.

RESULTS AND DISCUSSION

General Fish Fauna

Table I summarizes the census figures. The number of species observed and collectep in the census is totalled at 128. This probably represents almost all of the permanent residents and most of the daytime transients for that time of year. Among the collected specimens are at least 5 new species and 5 new records of Indian Ocean species. The new species of the genus *Siokunichthys*, *S. bentuviai*, has been described by CLARK, in 1966; those of the genera *Apogon*, *Tripterygion*, *Zonogobius* and *Quisquilius* will be described in other reports of this ISRSE series* which will eventually cover check lists of all fishes collected. The new records for the Red Sea are one syngnathid, three gobiids, and one brotulid: *Syngnathus* sp. (see footnote 4 to Table I), *Eviota stigmapteron*, *Coryogalops anomalus*, *Mucogobius flavobrunneus*, *Seychellea hectori*, *Dinematichthys iluocoeteoides*.

An estimated minimal total number of fishes in the census area from visual counts combined with specimens taken with poison is about 2,200 not counting larvae.** The total weight (wet biomass) is estimated at 136.0 kg and a dry biomass weight would therefore be 34.0 kg assuming that water makes up approximately 75 per cent of the weight of fish (VINOGRADOV, 1953). The manta's weight is not included but was an estimated 100 kilograms.

As all the fishes could not be identified to species, and variations in age and sex, etc. may have resulted in some misidentifications, the total numbers of species listed in Table I is not exact. It is also probable that several species present in the census area escaped detection entirely. Some rarer eels, for example, might have been brought out with a repeated poisoning after several hours. Also a number of transient species, especially nocturnal forms such as the common stingray, *Taenia lymma*, were undoubtedly missed.

We feel, however, that the combined results of visual counts and poisoning give a fairly good picture of the fish species present in the area investigated during the short period of study. The numbers of individual fishes estimated in the census area is of course even less accurate, especially the estimates for small species which died inside crevices after the poisoning and were not collected by divers. These, however, because of size, do not greatly affect the estimate of the total biomass.

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*Regarding the new gobiid fishes, see References: CLARK, in preparation.

**The *Spratelloides* indicated in No. 3 of Table I, were larval stage fishes. Their number (1000 +) s not considered here.

TABLE I

Fishes of Census Area, Entedebir

No.	Family	Species	Habitat[1]	ISRSE No.	No. of individuals			Mm size[3] range	
					Seen	Coll.	T.[2]	Seen	Coll.
1	Mobulidae	*Manta ehrenbergi* (Müll. & Henl.)	P	—	1	0	1	2000+	—
2	Chanidae	*Chanos chanos* (Forsk.)	P	—	1	0	1	800	—
3	Clupeidae	*Spratelloides delicatulus* Benn.	P	—	1000+	0	1000+	10	—
4	Muraenidae	*Echidna zebra* (Shaw)	C	489	1	1	1		583
5		*Gymnothorax hepaticus* (Rüpp.)	C	481a	1	18	18	1000+	69–478
6		*Siderea geometrica* (Rüpp.)	C	481b	0	1	1	—	140
7	Belonidae	*Strongylura crocodila* (Lesueur)	P	504	1	2	2	350	320–355
8	Hemiramphidae	*Hemiramphus* sp.	P	—	1	0	1	200	—
9	Soleidae	*Aseraggodes sinus-arabici* Chab.	OS	3377	0	1	1	—	27
10	Holocentridae	*Holocentrus ruber* (Forsk.)	C	567	2	4	4	90	90–98
11	Syngnathidae	*Corythoichthys flavofasciatus* (Rüpp.)	C	491	5	4	5	80	39–82
12		*Siokunichthys bentuviai* E. Clark	C[4]	492	0	4	4	—	50–55
13		*Syngnathus* sp.[5]		493	0	1	1	—	24
14	Mugilidae	*Crenimugil* sp.	P, S	—	20	0	20	90	—
15		*Mugil* sp.	P, S	—	40+	0	40+	160	—
16	Carangidae	*Caranx auroguttatus* (Val.)	P,S,OS	503	5+	2	5	190	185–190
17		*Caranx* sp. a	P,S,OS	—	1	0	1	200	—
18		*Caranx* sp. b	P,S,OS	—	1	0	1	200	—
19		*Trachinotus blochii* (Lac.)	S	3375	0	1	1	—	37
20	Mullidae	*Pseudupeneus barberinus* (Lac.)	S,OS		30+	1	31	150–180	70
21		*Upeneus vittatus* (Forsk.)		4067	0	3	3	—	70
22	Siganidae	*Siganus rivulatus* (Forsk.)	C,OS,S	3376	20	4	24	100–150	14–60
23		*S. stellatus* (Forsk.)	C	—	1	0	1	150	—
24	Serranidae	*Cephalopholis argus* (Schn.)	C	496	5	82	87	100–150	34–136
25		*Epinephelus areolatus* (Forsk.)	C	—	1	0	1	250	—
26		*E. summana* (Forsk.)	C	566	2	2	3	200–300	173–230
27	Pseudochromidae	*Pseudochromis olivaceus* Rüpp.	C	515	0	7	7	—	23–50
28	Plesiopsidae	*Plesiops caeruleolineatus* (Rüpp.)	C	502b	0	8	8	—	33–35
29		*P. nigricans* (Rüpp.)	C	502a	0	2	2	—	49–94
30	Lutianidae	*Lutianus russelli* (Blk.)	S,OS	494	25	2	27	120–150	110–111
31	Scolopsidae	*Scolopsis ghanam* (Forsk.)	S	—	5	0	5	140	—
32	Caesiodidae	*Caesio caerulaureus* Lac.	OS	—	300+	0	300+	160	—
33	Gerridae	*Gerres* sp.	S	—	20	0	20	80–100	—
34	Lethrinidae	*Lethrinus harak* (Forsk.)	S,OS	—	5	0	5	200	—
35		*L. mahsenoides* Val.	OS	—	2	0	2	250	—
36	Sparidae	*Acanthopagrus bifasciatus* (Forsk.)	C,OS	—	1	0	1	200	—
37	Apogonidae	*Apogon* sp. a	C	474	0	69	69	—	12–40
38		*Apogon* sp. b	C	3370	0	1	1	—	20
39		*Lepidamia multitaeniata* (C. V.)	C	480	0	1	1	—	103
40		*Paramia quinquelineata* (C. V.)	C	—	2	0	2	50	—
41		*Pristiapogon frenatus* (Val.)	C	3371	0	5	5	—	47–75
42		*Ostorhynchus annularis* (Rüpp.)	C	3373	0	4	4	—	13–75
43		*O. nubilus* J.L.B. Smith	C	3374	0	10	10	—	13–40
44	Chaetodontidae	*Anisochaetodon semilarvatus* (Ehrbg.)	C	—	1	0	1	150	—
45		*Chaetodon larvatus* C. V.	C	—	19	0	19	130	—
46		*C. mesoleucas* Forsk.	C	—	3	0	3	130	—
47		*Heniochus acuminatus* (L.)	C	—	2	0	2	150	—
48		*Pomacanthus asfur* (Forsk.)	C	446	3	1	3	80–180	80
49		*P. maculosus* (Forsk.)	C	—	2	0	2	250	—
50	Acanthuridae	*Acanthurus gaham* (Forsk.)	C,OS	—	30+	0	30+	150	—
51		*A. sohal* (Forsk.)	C,OS	—	50+	0	50+	160	—
52		*Ctenochaetus strigosus* (Klz.)	C,OS	—	20+	0	20+	150	—
53		*Zebrasoma veliferum* (Bloch)	OS	—	1	0	1	180	—
54		*Z. xanthurum* (Blyth)	C,OS	—	2	0	2	130	—

TABLE I (Cont.)

FISHES OF CENSUS AREA, ENTEDEBIR

No.	Family	Species	Habitat[1]	ISRSE No.	No. of individuals Seen	Coll.	T.[2]	Mm size[3] range Seen	Coll.
55	Monacanthidae	*Pervagor melonocephalus* (BLK.)	C	510	5	1	6	100	32
56	Balistidae	*Balistapus assasi* (FORSK.)	C	—	4	0	4	180	—
57	Tetraodontidae	*Arothron diadematus* (RÜPP.)	C	461	3	1	3	200	180
58	Ostraciontidae	*Ostracion cubiceps* L.	C	468	1	1	1	20	18
59		*O. cyanurus* RÜPP.	C	592	6	1	7	80	54
60	Pomacentridae	*Abudefduf azysron* sensu BASCHIERI-SALVADORI	C	4334 4335	0	4	4	—	16–37
61		*A. biocellatus* (Q. & G.)	C	459 4336	50+	32	82+	25–60	16–62
62		*A. lacrymatus* (Q. & G.)	C	—	1	0	1	80	—
63		*A. saxatilis* (L.)	C,S,OS	591a 4333a	100+	5	105+	25–100	15–43
64		*A. sexfasciatus* (LAC.)	C,S,OS	591b 4333b	100+	7	107+	25–100	14–44
65		*Amphiprion bicinctus* RÜPP.	C	—	1	0	1	40	—
66		*Chromis caeruleus* C. V.	C	—	2	0	2	50	—
67		*Pomacentrus tripunctatus* C. V.	C	460 467 4327	80+	83	163+	20–70	11–71
68	Scorpaenidae	*Parascorpaena aurita* (RÜPP.)	C	568	0	3	3	—	50–71
69		*Scorpaenodes guamensis* (Q. & G.)	C	590	0	28	28	—	23–52
70	Platycephalidae	*Platycephalus tentaculatus* RÜPP.	S	498	0	1	1	—	53
71	Gobiidae	*Acentrogobius* sp.	S	4317	0	15	15	—	18–30
72		*Amblygobius albimaculatus* (RÜPP.)	G	3372	4	1	5	60	31
73		*Bathygobius fuscus* RÜPP.	G	4324	0	1	1	—	53
74		*Cryptocentrus caeruleopunctatus* (RÜPP.)	S,G	—	2	0	2	60	—
75		*Ctenogobiops maculosus* (FOURMANOIR)	S,G	509 4322	2	4	4	50	15–41
76		*Ctenogobius* sp.	S	4325	0	2	2	—	21–23
77		*Oplopomus oplopomus* (VAL.)	S	4348	0	1	1	—	30
78		*Paragobiodon echinocephalus* (RÜPP.)	C	485 4311a	0	5	5	—	10–12
79		*Quisquilius* n. sp.	C	508	0	3	3	—	14–15
80		*Seychellea hectori* J.L.B. SMITH	C	506	0	2	2	—	21–24
81		*Zonogobius semidoliatus* (VAL.)	C	500 4312	0	10	10	—	13–19
82		*Zonogobius* n. sp.	C	482	2	67	67	15	10–19
83		*Asterropteryx semipunctatus* RÜPP.		3711	0	2	2	—	19–23
84		*Coryogalops anomalus* J. L. B. SMITH		4314	0	1	1	—	22
85	Eleotridae	*Eleotriodes sexguttatus* (VAL.)	C	475 4142	20+	45	65+	20	17–63
86		*Eviota prasinus* (KLZ.)	C	490;507 4313	30+	90	120+	15	5–15
87		*E. stigmapteron* J.L.B. SMITH	C	514 4323	0	4	4	—	10–16
88		*Heteroeleotris diadematus* (RÜPP.)		4315	0	6	6	—	15–22
89		*Lioteres vulgaris* (KLZ.)		4316	0	12	12	—	13–21
90		*Mucogobius flavobrunneus* MCCULLOCH		4321	0	1	1	—	32
91	Blenniidae	*Cirripectus variolosus* (VAL.)	C	3710 4043	0	7	7	—	27–55
92		*Dasson kochi* (M. WEBER)	C	3707 4037	0	2	2	—	46–47

TABLE I (Cont.)

Fishes of Census Area, Entedebir

No.	Family	Species	Habitat[1]	ISRSE No.	No. of individuals			Mm size[3] range	
					Seen	Coll.	T.[2]	Seen	Coll.
93–95		*Ecsenius* [*frontalis* (Val.); *nigrovittatus* (Rüpp.); spec.]	C	3701a 4041. 3701b 3708 3709. 4044	27+	72	99+	50–80	15–46
96		*Lophalticus kirkii magnusi* (Klausewitz)	C	4039	0	1	1	—	44
97		*Petroscirtes temmincki* Blk.	C	4332	0	1	1	—	26
98–101		*Rahabdoblennius* [*australis* Fraser-Brunner; cornifer (Rüpp.); *hypenetes* (Klz.); spec.]	C	4038 4331 4359c. 4359a. 4031 4047. 3702 4359b	5	65	70	40	12–48
102–104		*Salarias* [*edentulus* Schn.; *fasciatus* (Bloch); *flavoumbris* Rüpp.]	SR	4033a 4040a 4349. 3704. 4033b 4040b 4042 4045 4046	50+	56	106+	80	14–84
105	Clinidae	*Tripterygion abeli* Klausewitz	C	4330	0	2	2	—	16–17
106		*T. obtusirostre* (Klz.)	C	499; 4319	0	32	32	—	8–24
107		*T. pusillum* (Rüpp.)	C	4318	0	1	1	—	18
108		*Tripterygion* sp.	C	4329	0	7	7	—	10–18
109	Congrogadidae	*Haliophis guttatus* (Forsk.)	C	476	0	1	1	—	29
110	Brotulidae	*Dinematichthys iluocoeteoides* Blk.	C	478	0	16	16	—	22–68
111	Labridae	*Cheilinus trilobatus* Lac.	C	4339	1	1	2	120	92
112		*Duymaeria* sp. (xanthic form)	C	—	1	0	1	210	—
113		*Halichoeres marginatus* Rüpp.	C	501	10	6	16	30	17–33
114		*H. scapularis* (Benn.)	S	469 4328	50+	46	56+	20–70	20–73
115		*Labrichthys cousteaui* Roux-Esteve & Fourmanoir	C	4326	6+	4	10	35	17–44
116		*Labroides dimidiatus* (C. V.)	C	—	1	0	1	40	—
117		*Stethojulis axillaris* (Q. & G.)	C	4340	2+	1	3+	90	91
118		*S. strigiventer* (Benn.)	S	4320	2	1	3	40	42
119		*Thalassoma lunare* L.	C	3378	0	11	11	—	20–63
120		*T. purpureum* Forsk.	S	—	2	0	2	60	—
121	Scaridae	*Bolbometopon muricatus* (Val.)	C,OS	—	1	0	1	800	—
122		*Callyodon ghobban* (Forsk.)	C,OS	—	1	0	1	240	—
123		*C. marshalli* (L.P. Schultz)	C,OS	—	20+	0	20+	200–230	—

TABLE I (Cont.)

FISHES OF CENSUS AREA, ENTEDEBIR

No.	Family	Species	Habitat[1]	ISRSE No.	No. of individuals Seen	Coll.	T.[2]	Mm size[3] range Seen	Coll.
124		*Callyodon niger* (FORSK.)	C,OS	—	3	0	3	300	—
125		*Hipposcarus harid* (KLZ.)	C,OS	—	20+	0	20+	200–250	—
126		*Xanothon bipallidus* J.L.B. SMITH	C,OS	—	50+	0	50+	150–200	—
127		*Xanothon* sp. a	C,OS	4337	0	1	1	—	33
128		*Xanothon* sp. b	C,OS	4338	0	1	1	—	45

[1] C = Corals; G = Gullies in sand, sand conglomerate and rocks; OS = Outer sand patches; P = Pelagic; S = Sand bottom near shore; SR = Shore rocks.

[2] Total number of individuals of any one species, considered as being present in the area at the time of the census.

[3] Size is standard length of fish except in the case of the manta which is given as width between tips of pectoral fins. Size is approximated for fishes seen only, not collected.

[4] Stony coral with *Xenia* growing with it.

[5] This is a new record for the Red Sea and may be the young of an undescribed species or a species known from outside the Red Sea. The fin ray counts (D22, A4, P12–13), body ring counts (15–35) and subdorsal rings (1–5) do not fit that of any species known from the Red Sea although this specimen is closest to *S. macrophthalmus* DUNCKER.

[6] Possibly the young of *X. bipallidus*.

The most noticeable parts of the fish population, present in large numbers every time census observations were taken, were the scarids. Large schools of sizeable scarids were of mixed species and sexes and were also the main group of fishes observed as visitors at the "cleaning stations." Three main cleaning stations and at least four smaller ones were noted in the census area. The wrasses *Labrichthys cousteaui* and *Labroides dimidiatus* were the cleaner fishes, the former being reported as such for the first time here.

During the repeated counts we became familiar with many fishes as individuals. Among these were some of the "cleaning" wrasses and chaetodontids, some of the gobies, *Cryptocentrus* and *Ctenogobiops* living in burrows commensal with the shrimp *Alpheus*; all of the *Arothron*, *Balistapus*, *Pervagor*, *Ostracion* (which were present in few numbers); the large *Gymnothorax* and the single *Acanthopagrus*. Each of these individuals was always seen in the same general area; in the case of the three specimens of *Arothron* and the single *Gymnothorax* and *Acanthopagrus* they were located during each count in a specific protected spot, under a ledge or in a crevice.

It is interesting to compare the results of visual field counts with the rotenone collection. Forty-two species were seen during field counts but not collected. Of these the manta, *Chanos*, and *Bolbometopon* obviously were not in the area when the rotenone collection was made. The common forms that escaped the rotenone were the sizeable, free, fast-swimming *Mugil*, *Crenimugil*, *Caranx*, *Lethrinus*, *Scolopsis*, *Caesio*, *Gerres*, and even some of the common coral inhabitants of the families Chaetodontidae and Acanthuridae and the less territorial Scaridae.

Some common forms were seen in the area but only one or comparatively few individuals were collected by rotenone such as *Upeneus*, *Abudefduf saxatilis* and *A. sexfasciatus*. These examples show how disproportionately a rotenone collection can sample a fish population.

On the other hand, the rotenone collection which included 87 species altogether, revealed the presence of more than 50 species, some in abundance, which the divers had not detected during visual field counts. Especially among this group are relatively small demersal fishes that live in interstices of corals such as the scorpaenids, clinids, some species of gobies and blennies and the tiny *Siokunichthys* which lives in xeniids. Some nocturnal forms such as *Holocentrus* could easily be seen by divers when looking under ledges but other smaller forms, brotulids, some apogonids and *Plesiops* were missed entirely by divers as were some species which burrow in the sand such as flatfish and *Platycephalus*.

Noticeably absent in our records of this census area but commonly seen in other nearby similar areas studied in much less detail are *Pempheris*, which is probably genuinely absent as there were only a few deep ledges or caverns among the corals and rocks, the elasmobranchs *Taenia lymma*, and *Carcharhinus melanopterus* which undoubtedly occurred as transients.

A number of food fishes were encountered in the census area. 25 of the more important species are: *Chanos chanos*, *Manta ehrenbergi*, *Strongylura crocodila*, *Hemiramphus* sp., *Mugil* sp., *Caranx auroguttatus*, *Caranx* sp. a and b, *Siganus rivulatus*, *Cephalopholis argus*, *Epinephelus areolatus*, *E. summana*, *Lutianus russelli*, *Caesio coerulaureus*, *Lethrinus harak*, *L. mahsenoides*, *Acanthopagrus bifasciatus*, *Chaetodon larvatus*, *Heniochus acuminatus*, *Pomacanthus asfur*, *Acanthurus gaham*, *A. sohal*, *Ctenochaetus strigosus*, *Callyodon marshalli*, *Xanothon bipallidus*.

Chanids, belonids, carangids, lethrinids, lutianids and caesioids are taken in the area of Dahlak Archipelago, by gill net, beach seine and spearing. By using trammel nets at the entrance to Landing Bay, we succeeded in capturing a considerable number of scarids and sparids, such as *Callyodon marshalli*, *Xanothon bipallidus*, *Hipposcarus* sp. and *Acanthopagrus bifasciatus* also appearing in the census area. The local fishermen spear for food various fishes associated with corals such as *Epinephelus summana*, *Cephalopholis argus*, *Pomacanthus asfur*, *Chaetodon larvatus*, *Heniochus acuminatus*, *Acanthurus sohal* and *Ctenochaetus strigosus*. *Manta ehrenbergi* is common in the area of Dahlak Archipelago being hooked occasionally by the local fishermen. Its flesh is used for food by the local population mostly after being dried in the sun.

Analysis of Fish Biomass

Weight of fishes collected:

Most of the fishes collected by poison were of small size, although a few medium-sized fish were also obtained by this method. Since the census area was not closed off by nets or natural formations, the majority of the medium and large sized fishes escaped the area and were not collected during the poisoning operation. Although the total number of individuals collected was fairly high (1016), their total weight was only 3.6 kg.

Weight of fishes only visually counted:

The calculated total weight of the fishes that were seen but not, later on, collected in the census area, is 132.4 kg. The data used in the calculations for the individual species of significant weight is presented in Table II.

Total weight of fishes in the census area:

The total weight of the fishes present in the area of investigation during the beginning of April, 1962 is established as 136.0 kg. This value represents the standing crop of fishes in this area. As mentioned earlier the marine area covered by our investigation was 3,300 square meters at low tide and 4,400 at high tide. The mean 3,850 square meters is taken as a basis for estimating the standing crop per unit of area. Thus we may calculate the total weight of fishes per square meter as 0.035 kg.

Following BROCK (1954) we can divide the fishes of the census area in: 1. resident species, 2. wandering schooling species, 3. solitary wanderers. Division of this kind is not always easy to make since some fishes change habits seasonally or with age. According to our data the residents species formed the greatest number of species (100) and individuals (1,551). However, their weight amounted only to 20.5 kg. Wandering schooling fishes were represented by 27 species of at least 648 individuals. They belonged to the following species: *Chanos chanos*, *Strongylura crocodila* *Hemiramphus* sp., *Crenimugil* sp., *Mugil* sp., *Caranx auroguttatus*, *Caranx* sp. a, *Caranx* sp. b, *Siganus rivulatus*, *Lutianus russelli*, *Caesio coerulaureus*, *Lethrinus harak*, *L. mahsenoides*, *Acanthopagrus bifasciatus*, *Chaetodon larvatus*, *Heniochus acuminatus*, *Acanthurus gaham*, *A. sohal*, *Ctenochaetus strigosus*, *Zebrasoma veliferum*, *Z. xanthurum*, *Bolbometopon muricatus*, *Callyodon ghobban*, *C. marshalli*, *C. niger*, *Hipposcarus harid*, *Xanothon bipallidus*. Their weight formed the bulk of the total fish biomass (116 kg or 85%*). Almost all of the wandering schooling fishes are commercially exploited by fishermen of the Dahlak Archipelago (see p. 21). *Manta ehrenbergi*, seen on one occasion in the census area, is predominantly a solitary wanderer though small groups of 4–6 specimens were observed in the Dahlak Archipelago by the authors.

Because of inadequacy of our technique both the total number of fishes and the total weight are minimum estimates. The weight of the standing crop of fishes,

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*In case the large manta with its estimated 100kg weight (see p. 20) it is taken into consideration that the biomass of wandering schooling species is reduced to 49% of the total fish biomass.

TABLE II

DATA USED IN THE CALCULATION OF THE TOTAL WEIGHT OF FISHES OBSERVED BUT NOT COLLECTED IN THE CENSUS AREA[1]

No.[2]	Species	Coef-ficient[3]	No. of indi-viduals	Median[4] length (cm)	Weight[5] in grams	Total[6] weight
2	*Chanos chanos*	0.02040	1	80.0	10,445	10,445
5	*Gymnothorax hepaticus*	0.00168	1	100.0	1,680	1,680
8	*Hemiramphus* sp.	0.01014	1	20.0	81	81
14	*Crenimguil* sp.	0.02598	20	9.0	19	380
15	*Mugil* sp.	0.02295	40	16.0	94	3,760
16	*Caranx auroguttatus*	———	3	19.0	177	531
17	*Caranx* sp. a	0.02691	1	20.0	215	215
18	*Caranx* sp. b	0.02691	1	20.0	215	215
20	*Pseudupeneus barberinus*	0.02203	30	16.5	99	2,970
22	*Siganus rivulatus*	0.02513	20	12.5	49	980
23	*S. stellatus*	0.02086	1	15.0	70	70
24	*Cephalopholis argus*	0.03423	5	12.5	67	335
25	*Epinephelus areolatus*	0.03245	1	25.0	507	507
26	*E. summana*	0.03245	2	25.0	507	1,014
30	*Lutianus russelli*	0.01341	25	13.5	33	825
31	*Scolopsis ghanam*	0.02988	5	14.0	82	410
32	*Caesio caerulaureus*	0.02563	300	16.0	105	31,500
33	*Gerres* sp.	0.03132	20	9.0	23	460
34	*Lethrinus harak*	0.03014	5	20.0	241	1,205
35	*L. mahsenoides*	0.03014	2	20.0	241	482
36	*Acanthopagrus bifasciatus*	0.04642	1	20.0	371	371
44	*Anisochaetodon semilarvatus*	0.05443	1	15.0	184	184
45	*Chaetodon larvatus*	0.05443	19	13.0	120	2,280
46	*C. mesoleucas*	0.05443	3	13.0	120	360
47	*Heniochus acuminatus*	0.06204	2	15.0	205	410
48	*Pomacanthus asfur*	0.06843	2	13.0	150	300
49	*P. maculosus*	0.05627	2	25.0	879	1,758
50	*Acanthurus gaham*	0.03249	30	15.0	110	3,300
51	*A. sohal*	0.03249	50	16.0	133	6,650
52	*Ctenochaetus strigosus*	0.04555	20	15.0	154	3,080
53	*Zebrasoma veliferum*	0.04178	1	18.0	44	44
54	*Z. xanthurum*	0.03911	2	13.0	86	172
55	*Pervagor melanocephalus*	0.06104	5	10.0	61	305
56	*Balistapus assasi*	0.04422	4	18.0	258	1,032
57	*Arothron diadematus*	0.13011	2	20.0	1,040	2,080
59	*Ostracion cyanurus*	0.07661	6	8.0	39	234
61	*Abudefduf biocellatus*	0.02544	50	4.2	2	100
63	*A. saxatilis*	0.04708	100	6.2	11	1,100
64	*A. sexfasciatus*	0.04708	100	6.2	11	1,100
67	*Pomacentrus tripunctatus*	0.04557	80	4.5	4	320
93–95	*Ecsenius* sp.	0.00661	27	6.5	2	54
102–104	*Salarias* sp..	———[7]	50	8.0	4	200
111	*Cheilinus trilobatus*	0.04471	1	12.0	77	77
112	*Duymeria* sp.	0.04340	1	21.0	402	402
114	*Halichoeres scapularis*	0.01599	10	4.5	1	10
117	*Stethojulis axillaris*	0.02836	2	9.0	21	42
121	*Bolbometopon muricatus*	0.04345	1	80.0	22,230	22,230
122	*Callyodon ghobban*	0.02977	1	24.0	411	411
123	*C. marshalli*	0.03388	20	21.5	314	6,280
124	*C. niger*	0.03388	3	30.0	915	2,745
125	*Hipposcarus harid*	0.02977	20	22.5	339	6,780
126	*Xanothon bipallidus*	0.03803	50	17.5	204	10,200

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[1] Exclusive of the single large manta and the relatively insignificant weights involved in Nos. 3, 11, 40, 62, 65, 66, 72, 74, 75, 83, 86, 98–101, 113, 115, 116, 118, 120 of Table I.

[2] Corresponds with number in Table I.

[3] Based on calculation; see text p. 19.

[4] Based on size range given in Table I.

[5] For individual of median length.

[6] Number of individuals × weight of individual of medium length.

[7] Since specimens of the size class in question were actually collected at the census site, the weight indicated here was derived from collected material.

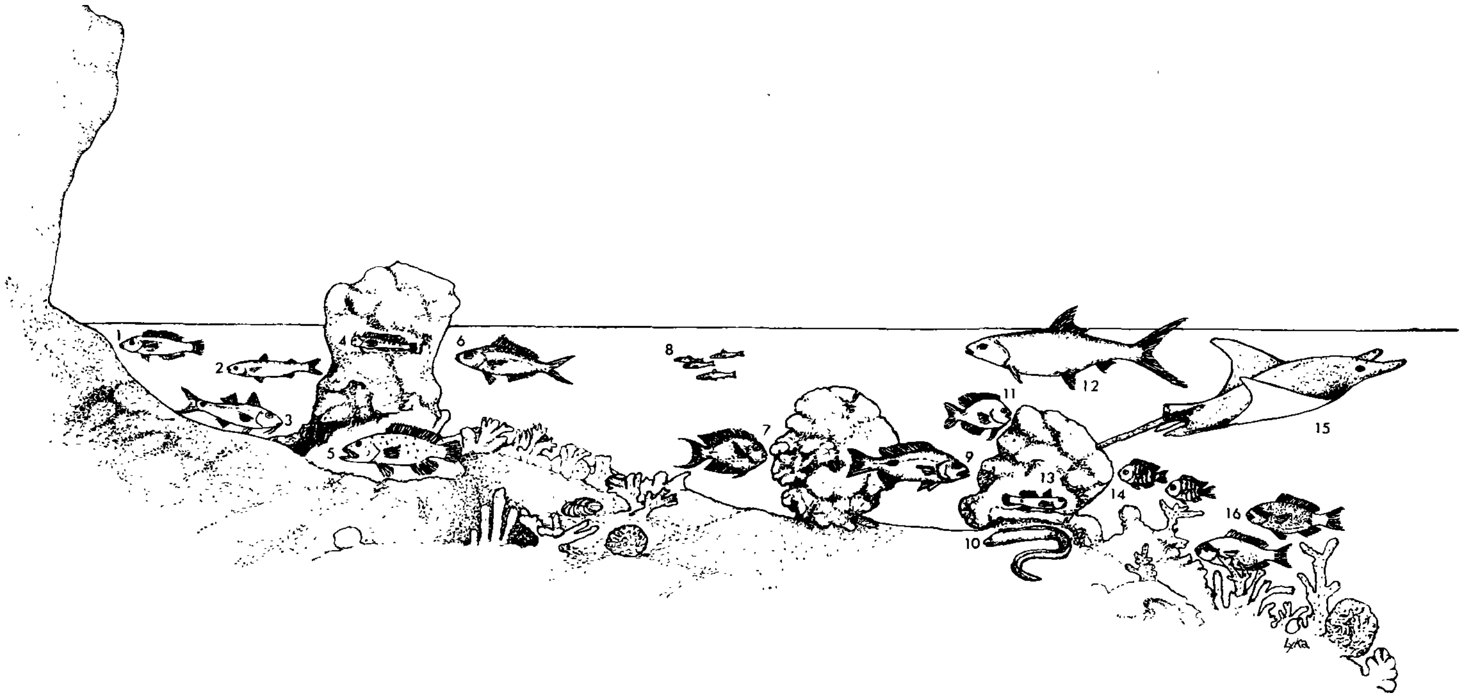

Fig. 4. Diagrammatic section through the census area with some of the typical fishes indicated (size proportion distorted for convenience). 1 – *Halichoeres scapularis*; 2 – *Mugil* sp.; 3 – *Pseudupeneus barberinus*; 4 – *Ecsenius frontalis*; 5 – *Cephalopholis argus*; 6 – *Caesio caerulaureus*; 7 – *Ctenochaetus strigosus*; 8 – *Spratelloides delicatulus*; 9 – *Lutianus russelli*; 10 – *Siderea geometrica*; 11 – *Pomacentrus tripunctatus*; 12 – *Chanos chanos*; 13 – *Eviota prasinus*; 14 – *Abudefduf sexfasciatus*; 15 – *Manta ehrenbergi*; 16 – *Xanothon bipallidus*.

obtained in similar but more extensive studies by Bardach (1959) for coral reefs in Bermuda waters amounted to 0.049 kg per square meter. Much higher values were obtained by Randall (1963) for the natural reefs of the Virgin Islands (0.160 kg per square meter). Randall, however, selected an area particularly abundant with fishes and used surrounding nets in order to prevent fishes poisoned by rotenone from escaping the area. In the Dahlak Archipelago we saw many areas with considerably more abundant fish life but for practical reasons these areas were inconvenient for this study.

Acknowledgements

We wish to thank the members of the ISRSE as the entire team aided this project directly or indirectly, especially Otto Oren, Salvator Uziel, Zvi Wolberg and Zvi Yaron for their help in making the collection with rotenone. We are grateful to Dr. Ruth Lotan for help in the identification of the blennies, to Dr. W. Klausewitz in that of the Scorpaenidae, and to Mrs. Lyka Zismann for help in preparing the figures.

Summary

The fish population in an area of about 4,000 square meters along the northwest coast of Entedebir Island in the Dahlak Archipelago, was studied by divers. Visual counts were taken during a period of 6 days of diving observations totalling 15 man hours spent in the water. At the end of this period a fish collection was made with rotenone poison. It is estimated that 128 species totalling a minimum of 2,200 individuals (not counting larvae) represented a biomass of 136.5 kg.

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ISRAEL SOUTH RED SEA EXPEDITION, 1962, REPORTS
No. 31

COPEPODS OF SOME LAND-LOCKED BASINS ON THE ISLANDS OF ENTEDEBIR AND NOCRA (DAHLAK ARCHIPELAGO, RED SEA)*

by

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Besides the rich Copepoda material collected during the Israel South Red Sea Expedition (March–April, 1962) in the littoral zone and in shallow depths of the Dahlak Archipelago, Copepoda have also been collected from five land-locked water bodies on the islands of Entedebir and Nocra.

There exist no water courses on the two islands. Like the majority of the islands of the archipelago, Entedebir and Nocra are formed of neogenic coral reef (Nir, in prep.). On Entedebir in particular there exists no freshwater body at all: of the rainwater only very little accumulates in the sediments of the valleys. Either because of layers of salt or through contact with sea water which penetrates along rock fissures, that water becomes brackish. On Nocra, an island much larger than Entedebir, accumulated rain water obviously forms a sufficiently large phreatic layer, providing by means of a few wells, lightly brackish drinkwater.

The material of the present note originated from the following five water bodies (see map).

1. *Devil's Crack on Entedebir.*

ISRSE E62/1721; 12.3.62. ISRSE E62/1831; 3.4.62.

This is formed by a series of open, but shaded pools at the bottom of a deep fissure near the north-eastern corner of the island, about 200m from the shore. The system of interconnected pools which undoubtedly have a subterranean connection with the sea, is the subject of special study (Steinitz, in preparation). According to this study, the water of the pools with a maximal water depth of about 90 cm has a slightly reduced salinity of about $36^0/_{00}$, a fairly constant, low temperature of 24.5–25.0°C, and exhibits tidal fluctuations 10–20 cm lower than those of the sea and delayed by nearly one hour as compared with the sea tides. The bottom of the basins is muddy. Since the contact with the sea is indirect, it may be suggested that during the rainy period (Steinitz's measurements were taken in March, i.e. after the rainy period) the salinity in the pool decreases to brackish levels. In addition, the low and stable temperatures, the protection against direct sunshine and the contact with subter-

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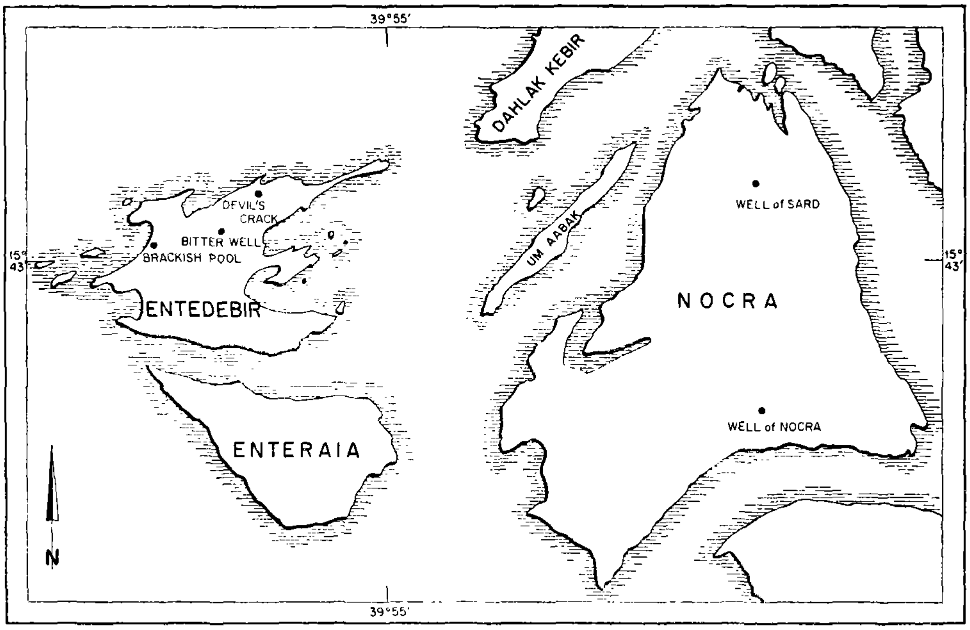
Received: April 1965. Revision of m.s., March 1967 (not involving species descriptions. Ed.).

* Aided by contract No. 62258-3335 between the U.S. Office of Naval Research, Department of the Navy, and Tel-Aviv University.



Map of collection localities

ranean water complete the set of peculiar milieu-conditions which make Devil's Crack a highly interesting biotope.

The most striking animal living in the pools is the blind red prawn *Antecaridina lauensis* (EDMONDSON), a species found in similar conditions on islands in different parts of the Indopacific realm (HOLTHUIS, 1963). The other fauna, as far as a superficial analysis indicates, is of marine character: the marine hemipter *Halobates* sp., syllid polychetes, one specimen of a sipunculoid, two species of Ostracoda, one of which belongs to the marine genus *Bairdia* M'COY (preliminary identification by Mrs. R. LERNER-SEGGEV), and probably two species of Nematoda. The water of the pools is densely covered by filamentous bluegreen algae and Diatomea.

The copepod fauna is very rich and highly specific: it contains four species of harpacticoids, all new to science, and a new calanoid species. The description of these species and the discussion of their taxonomic relationship form the subject of the special section of this note. The dominant species are the calanoid *Pseudocyclops steinitzi* n.sp. and the harpacticoid *Typhlamphiascus latifurca* n.sp. *Nitocra affinis stygia* n.ssp. follows in frequency. *Cletocamptus xenuus* n.sp. is represented by two specimens only and *Schizoperoides expeditionis* n.g.n.sp. by a single specimen. As to their ecological grouping, *P. steinitzi* and *T. latifurca* belong to genera dwelling on the muddy bottoms of offshore waters (to this group belongs also the ostracod *Bairdia*); *Nitocra affinis stygia* belongs to a species known from an Italian marine cave and from interstitial and brackish waters; *C. xenuus* and *S. expeditionis* belong or are related to genera well known from brackish waters all over the world.

2. *The "Bitter Well" on Entedebir.*

ISRSE E62/1736; 12.3.62.

The well is a small accumulation of water, subterraneanously connected with a phreatic layer. It is at the end of a valley which leads to the western shore at a distance of about 600m (see map, and Stock and Nijssen, 1965). We have no precise data of the saline content of the water of this well; it tasted slightly salty and bitter, but the goats wandering freely on the uninhabited island used to drink it. Stock and Nijssen (1965) described from here the new subterranean amphipod *Eriopisa longiramus*. Other faunal elements we found, have an obvious fresh-water character: oribatids, larvae of Chironomidae, Limnobiidae, water Coleoptera, Oligochaeta and Nematoda. The copepods are represented by a harpacticoid, *Nitocra spinipes orientalis* Sewell, known from Lake Chilka in India and the Suez Canal.

3. *A small brackish pool in Abiad Bay, Entedebir.*

ISRSE E62/1757; 18.3. 62. ISRSE E62/1765; 20.3.66.

Situated a few tens of metres from the shore, at the opening of the valley in which the Bitter Well is located. Several species of copepods were found: one specimen of the cosmopolitan cyclopoid *Eucyclops serrulatus* Fischer, numerous specimens of the harpacticoid *Horsiella elishevae* n.sp., a single male of *Nitocra spinipes orientalis*, a male of *Amphiascus* sp., and one specimen of an indeterminable tetragonicepsid harpacticoid.

4. *The well of Sard on the island of Nocra.*

ISRSE E62/1751; 16.3.62.

This well nourishes a freshwater pool about 1.5 km south of the northern end of the island. The well supplies drinking water to the police station of Sard. The pool, which has a diameter of about 15 m, is well built and deep and according to the police chief, Ali Sheikh Osman Hadj Ali, was built by the "Turks" (i.e. during the Egyptian rule, at least 80–90 years ago). The pool of Sard has a rich freshwater fauna consisting of Ostracoda, Cyclopoida, Oligochaeta, Chironomidae, Corixidae. Numerous ephippia indicate the seasonal presence of Cladocera.

The Ostracoda form one of the most important faunal elements in the pool and are represented by *Cypridopsis newtoni* Brady et Robertson (identified by Mrs. R. Lerner-Seggev). This species is considered by Bronstein (1947) to be an indicator of oligohaline conditions, and is spread over all of Europe, Central Asia and North Africa, but found also on the island of Aldabra (western Indian Ocean). The finding of *C. newtoni* in the southern Red Sea could well mean that this ostracod is carried by southwards migrating birds. The cyclopoid found in large numbers in the pool of Sard is *Thermocyclops* aff. *decipiens* Kiefer, a form morphologically close to a species belonging to the "Artenkreis" of *T. hyalinus* Rehberg.

5. *The well of the village of Nocra.*

ISRSE E62/1750; 16.3.62.

Slightly north-east of the village and a few hundred metres from the southern shore of the island. The well is highly polluted with dung and rubbish, but supplies drinking water to the small village. The fauna of the well poses a problem which we are unfortunately unable to solve: against a background of freshwater fauna consisting of Nematoda, Oligochaeta, larvae of Chironomida (with very large anal tubuli indicating brackish conditions), Oribatei, a macrothricid cladoceran, and again *Cypridopsis newtoni* and *Thermocylops* cf. *decipiens* — we found surprisingly, several marine harpacticoids: *Parastenhelia spinosa* FISCHER, *Amphiascopsis cinctus* (CLAUS), *Orthopsyllus linearis* CLAUS, and *Dactylopodia* sp. as well as several Tanaidacea.

We have a strong suspicion that the marine elements are impurities which accidentally reached either the well or our sample. The presence of a dried *Lucifer* in our sample strongly supports this view. Whether the impurities result from pearl-oyster rinsing, the cleaning of fishing gear by the inhabitants, or whether they are remnants of a previous sample in our net—is impossible to establish post factum. At any rate, all these marine harpacticoids are characteristic of the littoral algal growth of the open sea.

SPECIAL SECTION

The following species are described and discussed in this section:

Calanoida

- *Pseudocyclops steinitzi* n.sp.

Harpacticoida

- *Horsiella elishevae* n. sp.
- *Typhlamphiascus latifurca* n. sp.
- *Schizoperoides expeditionis* n.g.,n. sp.
- *Nitocra spinipes orientalis* SEWELL
- *Nitocra affinis stygia* n.ssp.
- *Cletocamptus xenuus* n.sp.

Cyclopoida

- *Thermocyclops* cf. *decipiens* KIEFER

Pseudocyclops steinitzi n. sp. (figs. 1–5).

Numerous females and males in Devil's Crack, Entedebir, (Dahlak Archipelago).

Syntypes: HUJ. COP 43 (E62/1721; 1831), in the collection of the Department of Zoology, The Hebrew University of Jerusalem.

FEMALE. Dimensions 0.66–0.70 mm. The habitus is typical of the genus. First

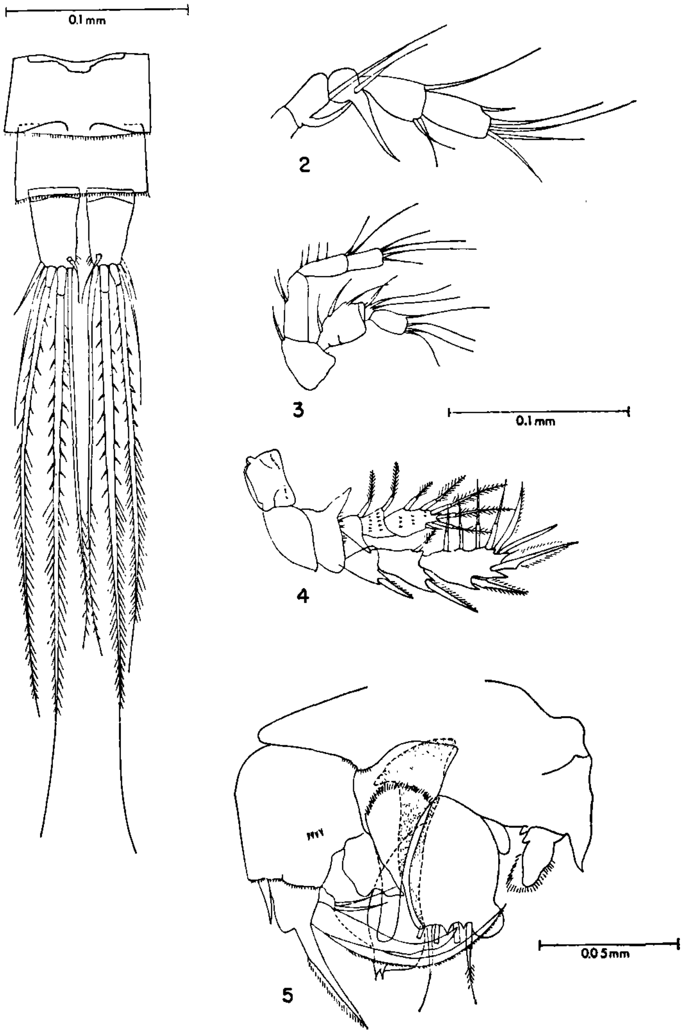


Plate I. *Pseudocyclops steinitzi* n. sp. 1. Furca and last abdominal segments. 2. Last segments of female antennula. 3. Antenna. 4. Female PV. 5. Male PV.

thoracic segment fused to cephalon. Rostrum an equilateral triangle. Furcal branches slighly more than twice as long as large. The two median apical setae proximally with stout spinulae; distal part with usual pennation.

Antennula 17-jointed. Antenna with three-jointed endopodite and three-jointed exopodite. Exopodite of mandibula bi-articulated, endopodite indistinctly divided. Pars molaris of maxillula with 7 denticles; exopodite uni-articulated, endopodite bi-articulated. Maxilla with 4 endites. Maxilliped typical of the genus.

	Armature of swimming legs	
	Exopodite	Endopodite
PI	1.1.322	1.2.321
PII	1.1.422	1.2.422
PIII	1.1.522	1.2.422
PIV	1.1.522	1.2.322

PV has both branches bi-articulated. Connecting plate between the two legs with slightly concave edge. Exopodite characterized by the lack of setae on basal joint; last joint bears a total of 8 setae and spines. Endopodite with inner edge of basal joint produced in a long spur; last joint with six setae.

Male. Dimensions 0.59–0.62 mm. Clasping antennae of the right side 17-jointed. Ante-penúltimate joint has a long spur-like processus similar to that of *P. rubrocinctus* Bowman et Gonzales. 14th joint with spine-like basal outgrowth. No dimorphism neither in armature of abdominal segments nor in form of armature of furcal setae.

The highly complicated structure of the PV shows several characteristics. Exopodite of right leg bears three long and strong spines, the innermost with 2 setae on its base. Right endopodite an unarmed plate with twice emarginated distal edge. Left exopodite fused to the incompletely delimited second basipodite. Endopodite is a broad rectangular plate with a rounded bulge on outer distal corner; distal edge with 5 setae. To the endopodite are attached 3 membranous plates: one ellipsoidal, with a bifide tip, one resembling a hammer of a clockwork and a third one somewhat similar to the second but with coarsely serrated distal margin.

Discussion. *Pseudocyclops steinitzi* is the most frequent copepod of Devil's Crack. It moves slowly among the filamentous algae of the pools. At the time of collecting (March 1962) we did not find ovigerous females.

Pseudocyclops is a genus of peculiar, bottom-dwelling calanoids, apparently of world wide distribution. They live close to the bottom or among algal vegetation, slowly sliding and swimming above the substrate (see Noodt, 1958, and Bowman et Gonzales, 1961). Owing to this peculiar way of life and habitat, this genus has been neglected not only by calanoid specialists, but also by other workers who studied the bottom-dwelling harpacticoids and cyclopoids.

Of the 14 species currently known, 6 are reported from the indopacific region: *Pseudocyclops simplex* Sewell and *P. latisetosus* Sewell (Indian plankton), *P. umbraticus* Giesbrecht (Ismailia, Suez Canal), *P. latus* Gurney (Ismailia, Suez Canal), *P. reductus* Nicholls (Ghardaqa, Red Sea), *P. gohari* Noodt (Ghardaqa, Red Sea), *P. australis* Nicholls (South Australia) and *P. pacificus* Vervoort (Ifaluk Atoll, Carolines).

The main differences between the species of this genus are found in the structure of the male and female PV. The armature of the swimming legs seems to be very constant throughout the genus, the number of antennal joints is variable, but the existence of incomplete articulations, such as in our species, seems to indicate that these differences are not constant.

Of two of the indopacific species (*P. reductus and P. australis*) the males are unknown. *P. gohari* has a peculiar primitive PV in the male and a very pronounced dimorphism of the abdomen and of the furcal branches. *P. umbraticus* has a reduced female PV endopodite. The differences as compared with *P. latens* are considerable, chiefly in the structure of the male PV and the furcal branches.

The nearest relative of *P. steinitzi* is *P. rubrocincta* BOWMAN et GONZALEZ from Puerto Rico, where this species lives among algal filaments growing on *Thalassia*, together with three other species of the genus. The most striking resemblance between the two species is the structure of the male PV, this highly complicated and specific limb: the basic structural pattern is identical in both species, the differences being found only in the shape and size of the various appendices. Additional differences exist in the fusion of the first thoracic segment to the cephalon, the length of the furcal branches, the number of antennular segments (but see above!), and the presence of a spine on the 14th joint of the male antennula in *P. steinitzi.*

Horsiella elishevae n. sp. (fig. 6–12).

Several females in brackish pool, Abiad Bay on Entedebir, Dahlak Archipelago.

Syntypes: HUJ. COP 46 (E62/1757; 1765; 18.3. and 20.3.1962, respectively) in the collection of the Department of Zoology, The Hebrew University of Jerusalem.

FEMALE. Dimensions 0.70 mm. The body has the typical shape of the genus. Rostrum quite prominent, with rounded tip. First thoracic segment fused to the cephalon. Genital segment dorsally divided and with two chitinous trabeculae on the ventral side. Genital field as in fig. 6. Operculum smooth, furcal branches about twice longer than broad. Only one apical seta well developed.

Antennula six-jointed; first joint very broad, with peculiar chitinous trabeculae near the distal end, and a false suture. Antennal exopodite uni-articulated, with two equally developed setae.

	Armature of legs	
	Exopodite	Endopodite
PI	0.0.022	1.011
PII	0.0.022	1.121
PIII	0.0.022	0.121
PIV	0.0.022	0.121

PI and PII endopodites have dorsally directed setae on their first joints. PV forms a unique arcuated plate with 3 setae on each side.

DISCUSSION. The outstanding feature of *Horsiella elishevae* is the unreduced antennal exopodite, a character found only in the related genus *Leptocaris* T. SCOTT. The

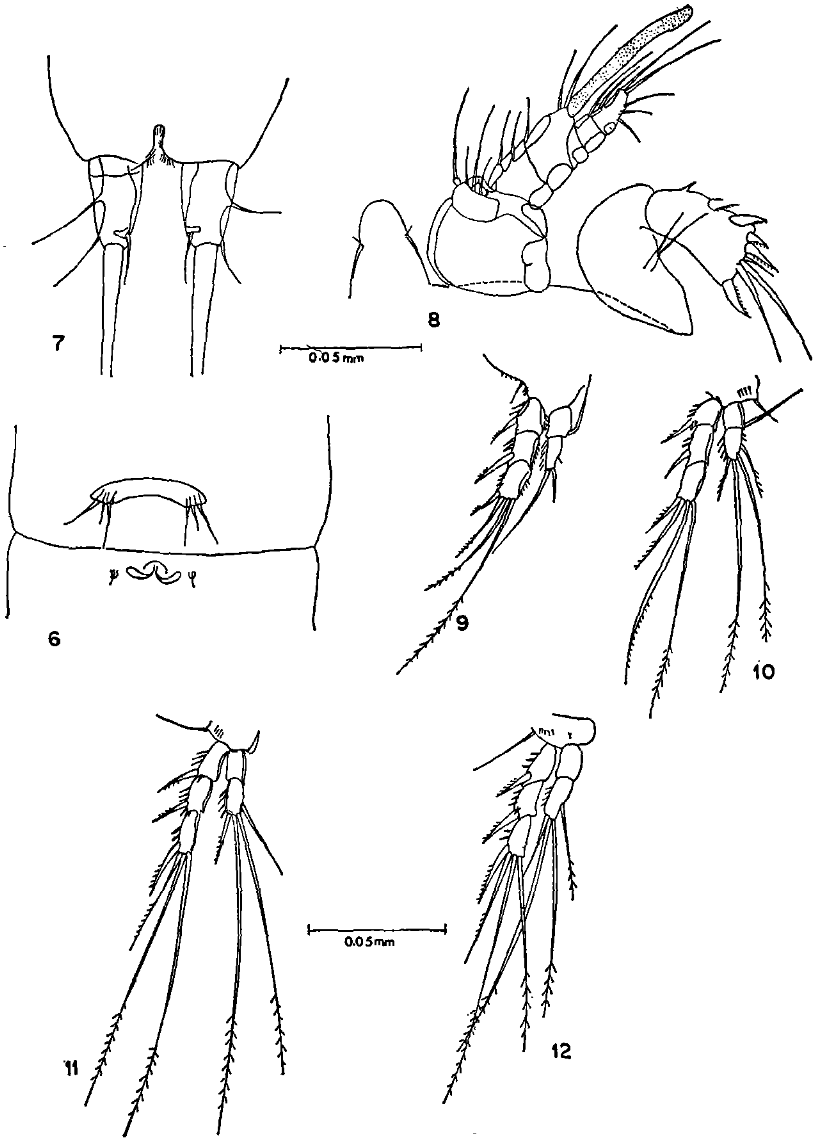


Plate II. *Horsiella elishevae* n. sp. 6. Female PV and genital area. 7. Furca. 8. Rostrum, antennula and antenna. 9. PI. 10. PII. 11. PIII. 12. PIV.

armature formula of the swimming legs is a peculiar combination of those known in other species, and perhaps chiefly in those of *H. gurneyi* Nicholls and *H. ignava* Noodt. An aberrant inner seta on the first endopodite joint of PII is known only in *H. trisetosa* Kunz and *H. ignava*. The only indopacific species reported till now is *H. gurneyi* from Ghardaqa, a species from which *H. elishevae* differs considerably in the structure of AI, AII, mandible and PV.

H. elishevae is the eighth species of this genus, which includes two wide-spread species of oligohaline and even brackish waters: *H. breicornis* (DOUWE) and *H. trisetosa* KUNZ.

Typhlamphiascus latifurca n.sp. (figs. 13–17).

Many specimens in Devil's Crack on Entedebir, Dahlak Archipelago. Syntypes: HUJ. COP 47 (E62/1721; 1831; 12.3 and 3.4.1962, respectively) in the collection of the Department of Zoology, The Hebrew University of Jerusalem.

Since this species belongs to the Artenkreis of *Typhlamphiascus confusus* T. SCOTT, we refrain from giving a detailed description of the new species, emphasizing only the characters which are peculiar of it.

Dimensions: ♀ 0.74–0.76 mm; ♂ 0.59–0.68 mm.

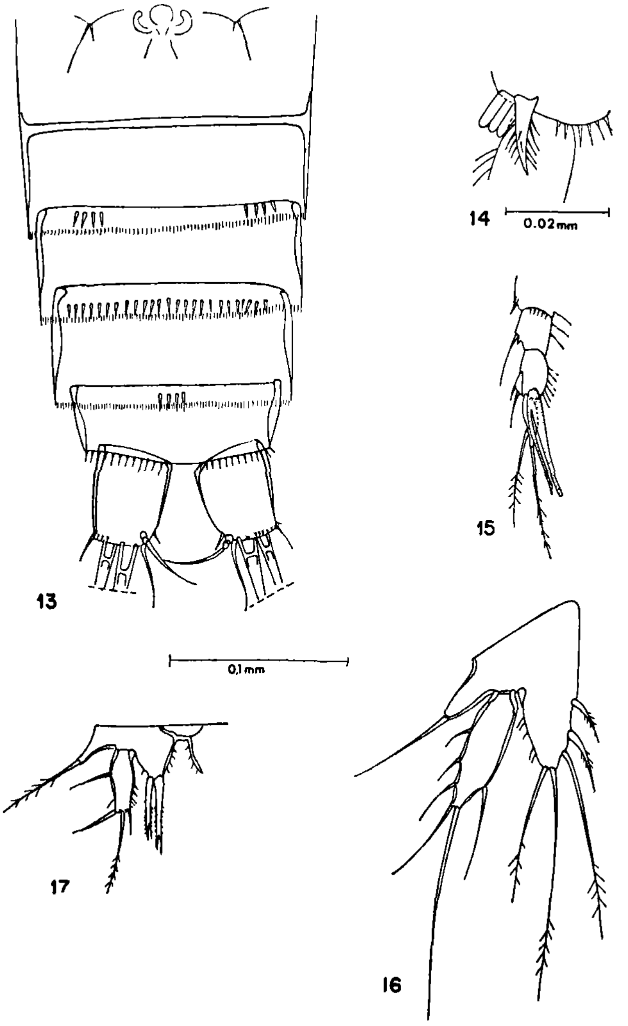


Plate III. *Typhlamphiascus latifurca* n. sp. 13. Abdomen and furca of female, ventral view. 14. Dimorphic basipodite of male PI. 15. Dimorphic PII endopodite of the male. 16. PV of female. 17. PV of male.

TABLE I

VARIABILITY IN *Typhlamphiascus latifurca* n. sp.

Segment	Abdominal armature						Furca	PV Exopodite
	Ventral			Dorsal			Length/Width	Length/Width
	II	III	IV	I	II	III		
Female 1	?	28	6	4+4	5+5	5+5	1.26	2.6
Female 2	5+5	26	6	4+4	7+7	6+6	1.35	2.7
Female 3	4+4	28	4	4+4	5+5	5+5	1.26	2.7
Female 4	5+5	22	4	4+4	4+4	4+4	1.38	2.8
Female 5	5+5	22	5	4+4	4+4	4+5	?	2.7
Male 1	26	24	6	5+5	5+5	4+4	1.36	—
Male 2	30	22	6	4+4	5+5	5+5	1.34	—
Male 3	24	20	6	4+4	5+5	6+6	1.50	—

In an earlier publication (POR, 1963) we defined the species-group "*confusus*" within the genus *Typhlamphiascus*. The new species shows the two principal characters of this group: a genital segment divided both on the dorsal and the ventral sides, and a single inner seta on the last endopodite joint of the fourth leg.

Two features characterize the new species:

1) The excessively short and straight-rectangular furcal branches in which the length-width ratio is 1.26–1.50. This value is much below the minimum of 2.3 found in our comparative study of *Typhlamphiascus confusus* sensu latu (POR, op.cit.). Values as low as these are found only in *T. gracilis* POR (1963), which however, does not belong to the "*confusus*" group (see table of measurements).

2) The armature of the abdominal segments (see table). If compared with the corresponding formulae of *T. confusus*, the differences are clear, and it appears that the species is related to Levantine and Pontic specimens of *T. confusus gullmaricus*: only in the females of these specimens can we find a ventral armature also on the second abdominal segment. The ventral armature of segment 3 of our new species is exceptionally rich: 22–28 spinulae; in the Levant and Red-Sea specimens of *confusus gullmaricus* the maximum is 18; only in the Black-Sea specimen studied, did we find 23 spinulae. All three abdominal segments show dorsal triangular spinulae. Such a situation was so far found only in one specimen of *confusus gullmaricus* from the Israel Mediterranean coast. It is also worthwhile to underline that in *latifurca* there are 5–6 such dorsal triangular spines on each side, while in *confusus* the rule is 3, and 4 spines are an exception. The abdominal armature of the males shows nothing additional. It may be added however, that the presence of dorsal spines on three abdominal segments is known also in a male of *confusus gullmaricus* from the Red Sea.

Nothing specific is found in the structure of mouthparts and antennae. The female PV is identical with that of *T. confusus* and the same is true of the male PV and PII endopodite. The basipodite of the male PI bears three chitinous lamellae.

DISCUSSION. *Typhlamphiascus latifurca* has to be considered a good species on grounds of the two characters quoted above, which exceed the range of variability found in *T. confusus*, and on grounds of the remarkable uniformity of these characters and the peculiar habitat in which the species is found. It must be underlined once more, that *T. confusus gullmaricus* and *T. confusus erythraeicus* live in the deep waters around Entedebir (ISRSE No. E62/1795 and E62/1836). *T. gracilicaudatus* THOMPSON et A. SCOTT, which has been reported too from deep muds around Entedebir (POR, op.cit.) belongs to another species-group within the genus.

Thus far, representatives of the genus *Typhlamphiascus* LANG have been chiefly found on deep, sublittoral and bathyal bottoms. The finding of a new species in a subterranean biotope is therefore of interest.

Schizoperoides expeditionis n.g.n.sp. (figs. 18–27).

A single female in Devil's Crack, Entedebir, Dahlak Archipelago.

Holotype: HUJ. COP 48 (E62/1831; 3.4.1962) in the Collections of the Deparment of Zoology, The Hebrew University of Jerusalem.

FEMALE. Length 0.65 mm. Body broadened and clumsy, with prominent and rounded articulated rostrum. The whole surface of the body covered with hair. Ventral edge of all the segments, except the last, deeply serrulated. Serrulation of fourth abdominal segment, which covers, shield-like, the middle of the last segment, particularly deep. Dorsal edges of segments with thick row of spiny hairs. Operculum smooth. Above furcal branches a short lateral row of spinulae. Furcal branches slightly triangular, equilateral, with inflated inner edges.

Antennulae 8-jointed with aesthetask on the fourth joint. The two-jointed antenna with peculiar uni-articulated exopodite bearing one seta on the broadened prominent half, and two long and one short seta on the tapering distal end. Mandible with uni-ramous palpus. Maxillula with uni-articulated exo- and endopodites. Maxilla with 4 endites. Maxilliped of the usual type of the Diosaccidae.

PI with bi-articulate endopodite, first joint exceeding by far the exopodite. This branch has equal joints. Second exopodite joint bears no inner seta, the last with four (?). PII-PIII with tri-articulated, PIV with bi-articulated endopodites.

	Armature	
	Exopodite	Endopodite
PII	0.1.022	0.1.220
PIII	0.1.022	1.1.120
PIV	0.1.022	–.1.120

PV has fused branches. Exopodite part with five setae, the basiendopodite part with four. Genital field of the *Amphiascella* and *Schizopera* type.

DISCUSSION. The new genus is thus described on grounds of a single female since the male is not known. This specimen differs from all the other genera of the Diosaccidae — a family to which it undoubtedly belongs—to such an extent, that in our opinion no doubts exist against this decision. Its independent status is based on the following

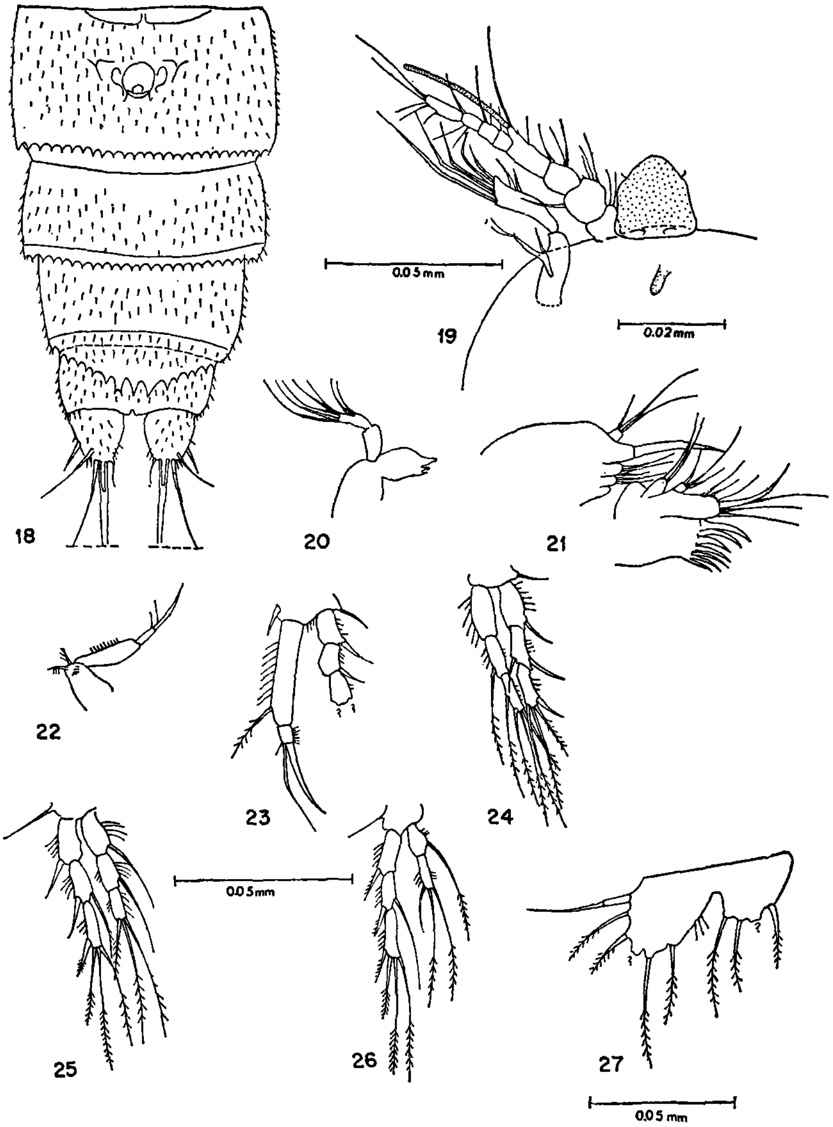


Plate IV. *Schizoperoides expeditionis* n. g. n. sp. 18. Abdomen, ventral view. 19. Rostrum, antennula and antenna. 20. Mandibula. 21. Maxillula and maxilla. 22. Maxilliped. 23. PI. 24. PII. 25. PIII. 26. PIV. 27. PV.

mean features: the shape of the segment edges, the antennal exopodite, the reduction of the PIV endopodite, and the fused PV. The relation to *Schizopera* is obvious from the reduced armature of the exopodite. Other details of the leg armature are also of the *Schizopera* type. The same is true of the genital field.

As known, *Schizopera* is the only genus of the Diosaccidae which is well represented in brackish and fresh waters. Occasionally, species of this genus are found in subterranean waters. *Schizoperoides* seems to be also related to *Schizopera* by its ecological preferences.

Nitocra affinis GURNEY ssp. *stygia* n.ssp. (figs. 28–32).

2 females and 3 males in Devil's Crack on Entedebir (Dahlak Archipelago). Syntypes: HUJ. COP 49 (E62/1721; 1831, 12.3. and 3.4.1962, respectively) in the

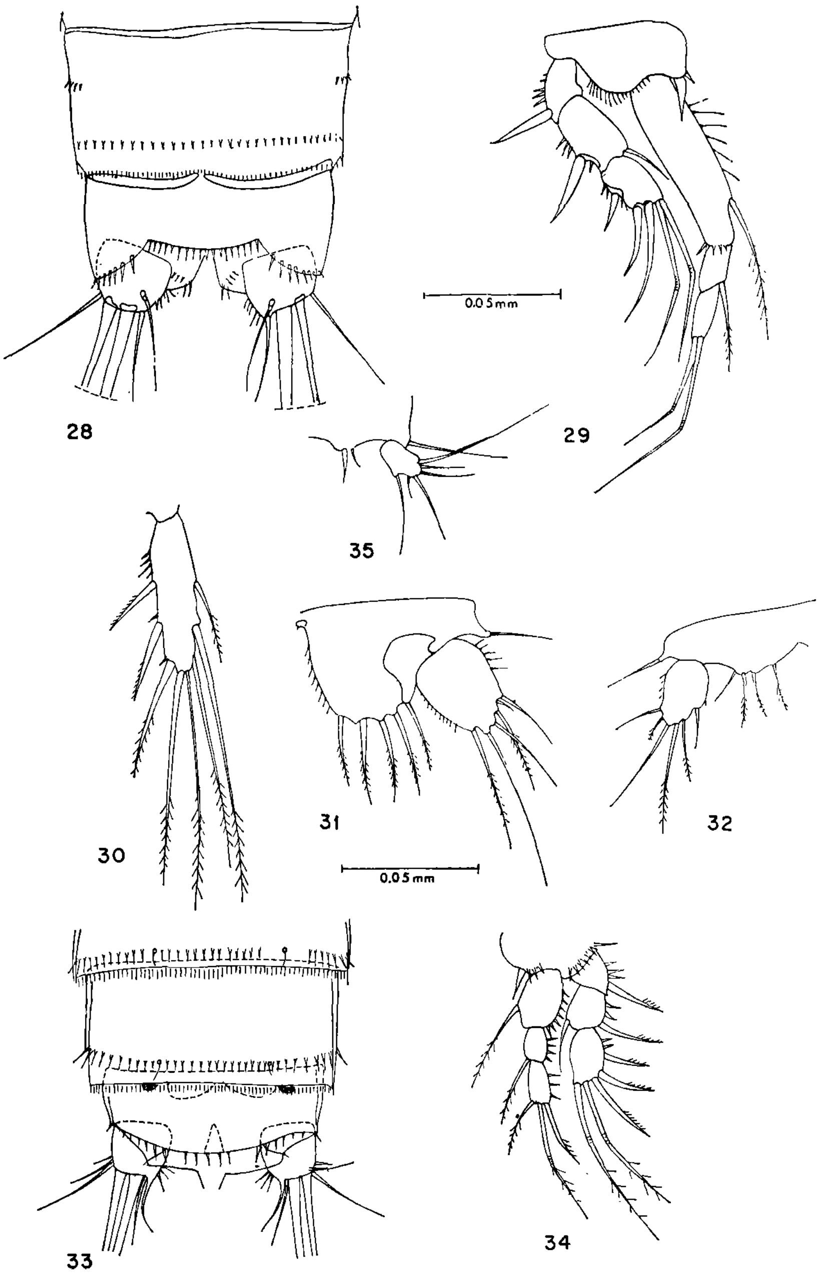


Plate V. *Nitocra affinis stygia* n. ssp. 28. Last abdominal segments and furca, dorsal view. 29. PI of female and modified spine of male. 30. Last joint of PIV exopodite. 31. Female PV. 32. Male PV. *Nitocra spinipes orientalis* SEWELL. 33. Last abdominal segments and furca, dorsal view. 34. PI of female. 35. PV of male.

collection of the Department of Zoology, The Hebrew University of Jerusalem.

Since our specimens clearly belong to *Nitocra affinis*, we join only a brief discussion of the distinctive characters present in the new subspecies.

The abdominal armature of the females shows a continuous dorso-ventral row of spinulae on segments III and IV. In the middle of every abdominal segment there are two short lateral groups of spinulae. It should be emphasized that in the males these medial spinulae form an almost complete dorsoventral row.

The internal spine of the basipodite of the male PI is modified—as normal in the genus—and unlike the specimens of VERVOORT (1964) in which there is no modified spine. The internal seta of the first endopodite joint is not longer and not more pennated than in the female.

The exopodite of PV in the female is rounded, nearly as long as broad, while in the typical *affinis* specimens it is about twice as long. There is a very obvious and large hyaline field on the basiendopodite which has not been reported in other *affinis* populations.

Finally ssp. *stygia* seems to be characterized by its large dimensions: 0.74–0.76 mm in the females, and 0.57–0.65 mm in the males. The maximal lengths reported in *affinis* are 0.63 mm in females, and 0.50 in males.

DISCUSSION. *Nitocra affinis* is a very widespread species, reported from Bermuda, Mangrove Lake (WILLEY, 1930), Port Taufiq, Suez Canal (GURNEY, 1927b), the cave of Castro Marina in Southern Italy (CHAPPUIS, 1938), Dalkey, Ireland (ROE, 1958), New Caledony (VERVOORT, 1964), and Ifaluk Atoll, Caroline Islands (VERVOORT, 1964). PETKOWSKY (1954) described a forma *rijekana* from Dubrovnik, Yugoslavia. VERVOORT (1964) admits the possibility that *Nitocra affinis* GURNEY includes several closely related species. If we compare the PV and the dimensions of our specimens with such geographically widely separated specimens as GURNEY's from the Suez Canal and VERVOORT's from the Pacific, the separate status of *stygia* becomes evident.

Another fact may be stressed: VERVOORT (1964) states that *affinis* is chiefly found in the interstitial water of sandy beaches. Our subspecies lives in open water within a cavernicolous biotope, like CHAPPUIS' specimens from Southern Italy.

Nitocra spinipes orientalis SEWELL (figs. 33–35).

The specimens found in the Bitter Well (E62/1736, 6 females) and the brackish pool in Abiad Bay (1 male), both on Entedebir, correspond to the descriptions of *orientalis* given by SEWELL (1924) and GURNEY (1927b). The spinulation of the abdomen and the armature of the male PV basiendopodites are characteristic of this subspecies.

Cletocamptus xenuus n.sp. (figs. 36–48).

One female and one male in Devil's Crack, Entedebir, Dahlak Archipelago.

Holotype and allotype: HUJ. COP 50, (E62/1831; 3.4.62), in the collection of the Department of Zoology, The Hebrew University of Jerusalem.

FEMALE. Length 0.48 mm. Rostrum squarish, articulated. The cephalothorax with chitinous trabeculum at base of antennulae. Edges of body segments smooth. Above the edges of abdominal segments II-IV scattered groups of spinulae, on ventral side. Genital segments divided dorso-laterally. Last abdominal segment with two round areas covered with chitinous dimples and spinulae in ventral anal outcut. Operculum smooth. Furcal branches quadratic, broader than long, with two rounded, chitinous areas near the base and with stout, blunt external apical spine. The external apical seta slightly inflated proximally.

Antennula six-jointed with aetshetask on third joint. First joint is very large, with peculiar denticulated upper margin. Two-jointed antenna with uni-articulated exopodite, bearing one apical seta. Mandibula and maxillula without exo- and endopodite. Maxilla with 3 endites.

PI-PIV with tri-articulated exo- and bi-articulated endopodites.

	Armature of legs	
	Exopodite	Endopodite
PI	0.0.211	1.020
PII	0.1.122	0.211
PIII	0.1.122	1.320
PIV	0.1.222	1.221

PV has a peculiar structure: the basi-endopodites are separated on the median line and exopodites are articulated. The basi-endopodites protrude only slightly and their armature is formed of 4 external, long setae, and 2 internal, stout and penicillated setae. The rounded exopodite bears 6 setae.

The genital field is shown in fig. 36.

MALE. Length 0.45 mm. Strongly modified antennula. Endopodite PIII tri-articulated, second joint produced in a slender, sinuous spine. PV forms a unique plate from which the exopoditic part, bearing 5 setae, does not protrude. Basi-endopoditic part bears only 3 setae, the two internal ones being penicillated like those of the female. There are hyaline fields above the external seta of the basipodite and between the exo- and basiendopoditic parts.

DISCUSSION. It has been very difficult to reach a decision on the inclusion of *Cletocamptus xenuus* in this genus. There are a considerable number of characters which would seem to necessitate the creation of a new genus. Experience has taught us however, that the limits of generic variability within the Cletodiidae and the notion of genus itself, have to be taken in a much wider sense than in any other harpacticoid family.

We have no doubts that our specimens belong to the *Cletocamptus-Rhizothrix-Nannopus* group within this heterogenous family and that they are closest to the first of these three genera. The armature of the exopodites and the structure of the male PIII endopodite of our animals are the principal charaters which they have in common with the other species of *Cletocamptus*. But the structure of the first an-

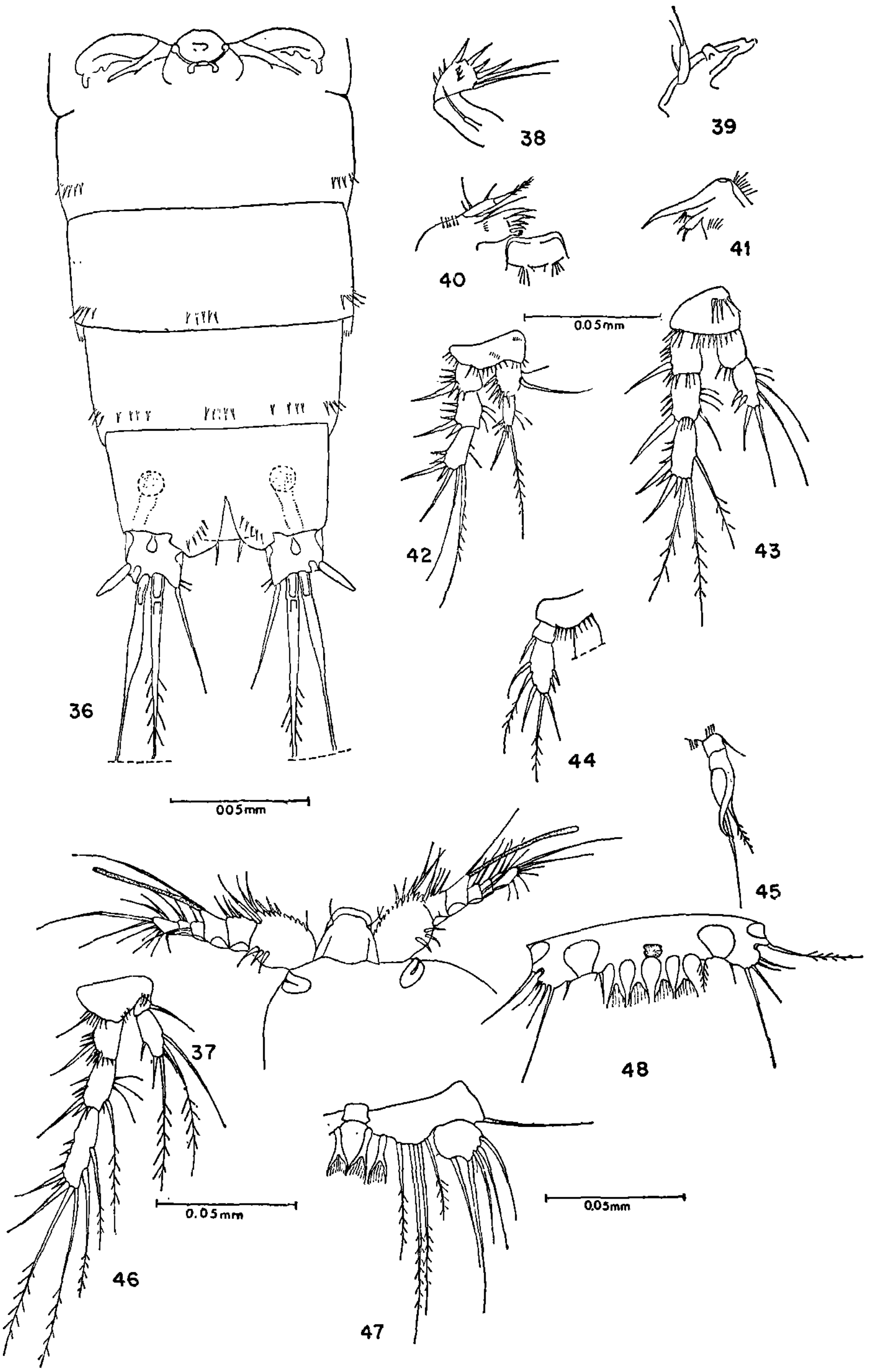


Plate VI. *Cletocamptus xenuus* n.sp. 36. Abdomen of female, ventral view. 37. Rostrum and antennulae of female. 38. Antenna. 39. Mandibula. 40. Maxillula and paragnathe. 41. Maxilla. 42. PI. 43. PII. 44. PIII endopodite of female. 45. PIII endopodite of male. 46. PIV. 47. PV of female. 48. PV of male.

tennular joint, the short furcal branches, the armature of the endopodites of the swimming legs and the structure of PV are highly peculiar.

It must also be underlined that our specimens live in an at least temporarily brackish biotope. *Cletocamptus* is known from all over the world from such saline, landlocked habitats.

Thermocyclops cf. *decipiens* KIEFER (figs. 49–52).

Numerous females (including ovigerous ones) and males in the wells of Sard and Nocra (Nocra, Dahlak Archipelago) (E62/1750; 16.3.1962)

We refrain from a complete description of this only cyclopoid of our collection, since the genus *Thermocyclops* KIEFER is widely known. As for the problem of the specific status of our specimens we refer to the morphological characters indicated as

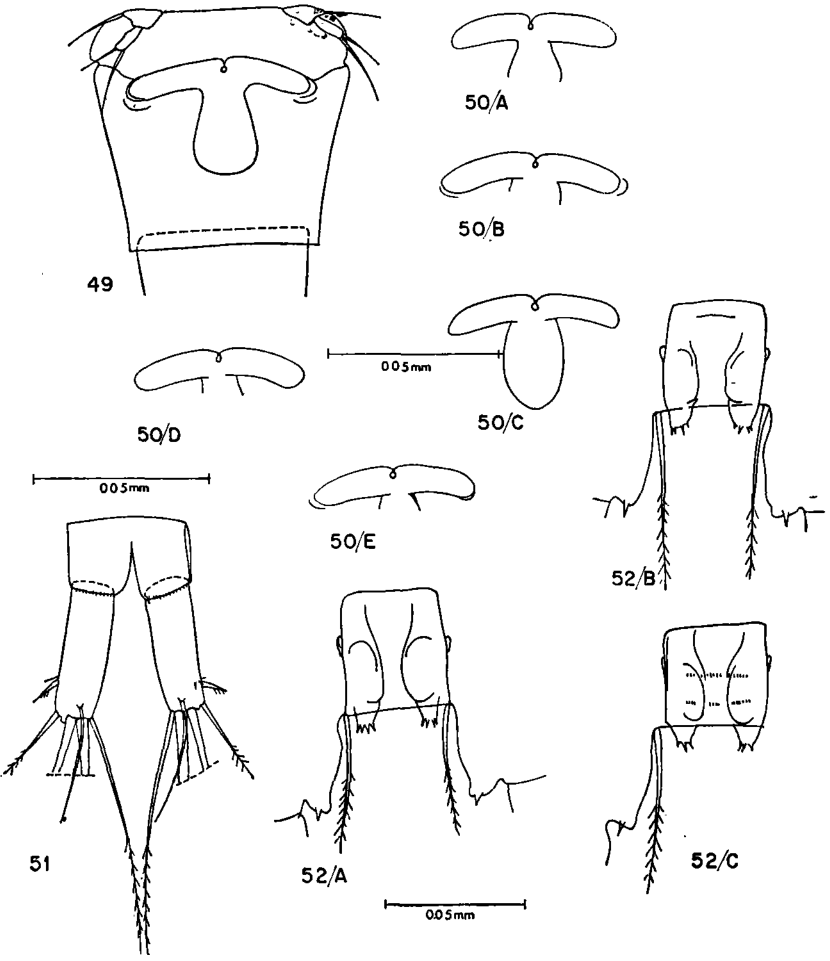


Plate VII. *Thermocyclops* cf. *decipiens* KIEFER. 49. PV and genital segment. 50. A–E. Shape of receptaculum seminis in different specimens. 51. Last abdominal segment and furca. 52. A–C. Connecting plate of PIV of several specimens.

essential by Kiefer (1937). Though Gurney (1932) proposes to attach no importance to minute differences, it seems that Kiefer is right in emphasizing the high degree of stability and specificity of these differences and their reliability as specific criteria. The population from the island of Nocra is remarkably uniform in all these characters.

Following the 5 morphological criteria proposed by Kiefer, we found that (1) the shape of the receptaculum seminis is constant and identical with that of *decipiens* Kiefer; (2) the furcal branches are much longer than in *decipiens* (length-width ratio 3.25–3.50 as against ± 2.70) and much longer than in *hyalinus* Rehberg (2.18–2.62) and resembling the long furcal branches of the African species *emini* (Mrazek); (3) the relative length of the external, internal and superficial furcal setae is shown in the table below. The length ratio between the inner and the outer apical seta is below 3/1 as in many African species of the genus—while in the two wide-spread species, *decipiens* and *hyalinus*, it is above 3/1; (4) the inner apical spine of the last PIV endopodite joint is shorter than the joint itself (shorter or equal in *hyalinus*, shorter in *decipiens*, longer in species like *macracanthus* Kiefer and *retroversus* Kiefer), the inner spine is 1.82–2.08 times longer than the external apical spine (± 1.60 times longer in *decipiens*, 1.75–2.15 times in *hyalinus*); (5) the chitinous bulges of the free edge of the connecting plate of the two PIV, are similar to those of *decipiens* and different from those of *hyalinus* and other African species.

Comparison between length of furcal setae in 10 specimens of *Thermocyclops* cf. *decipiens* Kiefer.

Specimen	External seta	Surface seta	Internal seta
1	25	28	64
2	22	26	59
3	22.5	25	62
4	24	25	61
4	24	25	61
5	22	26	61
6	20	26	60
7	21	26	62
8	21	26	59
9	23	26	62
10	23	26	61

On ground of the data presented above, and in according much more importance to characters (1) and (5) which are not strictly meristic, we consider our specimens to be closely related to *Thermocyclops decipiens* which is known from Eurasia and various stations in Africa. Our material, including figures and measurements, may serve for a future competent study of the variability within the genus *Thermocyclops* Kiefer, which should, however, be based on much more comparative material. Prof. F. Kiefer, to whom I am greatly indebted for his help, after having studied the specimens agreed with me that our individuals are indeed closely related to *T. decipiens*.

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Reprinted from *Trans. Roy. Soc. S. Afr.*. vol. 38, part I, 1968, p. 79-94

A REPORT ON SOME PELECYPODA DREDGED OFF THE NATAL AND MOÇAMBIQUE COASTS

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(With 1 text-fig. and Plates VI and VII)

SINOPSIS

Baggernet- en grypmonsters van die bodemfauna van die Natalse en Mosambiekse vastelandsbank is gedurende die Internasionale Indiese Oseaan-ekspedisie vir die Universiteit van Kaapstad se ekologiese ondersoek gekry. 52 Soorte Pelecypoda word berig as gevolg van dié en vorige ondersoek langs die Natalse kus. Drie nuwe spesies word deur Boshoff (1968) beskryf. Uit 'n kort ontleding van die verspreidingsaantekeninge omtrent Suidelike-Afrika van berigte Pelecypoda alleen, blyk dit asof die Natalse Pelecypod bodemfauna taamlik afsonderlik van dié van Suid-Afrika se suidkus is. Die Natalse fauna bevat 'n groter deel van endemiese soorte en 'n kleiner deel van tropiese soorte as die Mosambiekse fauna. Geen van die Mosambiekse en net 7% van die Natalse Pelecypoda verskyn langs die weskus van Suid-Afrika.

SUMMARY

Dredge and grab samples of the benthic fauna off Natal and Moçambique were obtained for the University of Cape Town ecological survey during the International Indian Ocean Expedition. 52 Species of Pelecypoda are reported as a result of this and some previous sampling off the Natal coast. Three new species of Pelecypoda are described in Boshoff (1968). From a brief analysis of the distribution records of only the reported species around southern Africa, it appears that the Natal benthic Pelecypod fauna is fairly distinct from that of the South African south coast. The Natal fauna contains a higher proportion of endemic species and a lower proportion of tropical species than the Moçambique fauna. None of the Moçambique Pelecypoda and only 7% of the Natal Pelecypoda extend to the West Coast of South Africa.

Introduction

This report forms part of the Ecological Survey of the marine fauna of southern Africa. The survey started with work on the sea-shore by Professor T. A. Stephenson and his co-workers and has been extended under Professor J. H. Day to include first the estuaries and more recently the benthos of the continental shelf. Since 1958 much sampling by dredges and grabs has been done, chiefly by the University of Cape Town's Research Vessel *John D. Gilchrist.* This survey has extended from Lüderitz in South West Africa to Natal on the east coast where only six dredgings had been obtained before 1964. Various systematic publications have so far resulted from this benthonic work but a synthesis of distribution patterns remains to be made.

The samples obtained for this Survey on Cruise 7 of R/V *Anton Bruun* have extended our knowledge of the fauna eastwards by giving a series of samples off Durban comparable to the transects sampled around the south and west coasts of southern Africa and they also represent our first benthonic samples off Moçambique. We thank the U.S. Program in Biology, International Indian Ocean Expedition for this material, housed at the University of Cape Town and for inviting one of us (J.G.F.) as Professor Day's representative on this cruise. We are indebted to the South African Council for Scientific and Industrial Research which has provided funds for this work and its publication. We wish to express our gratitude to Professor Day for all his advice and criticism.

Barnard (1964) gives full references to descriptions and records of most of the species mentioned in this report; for this reason his references for each species are not repeated except where they were found particularly useful or where they included figures.

Conchological distribution records are frequently misleading because dead shells may be carried well beyond the habitat of the live molluscs, therefore this survey has been confined to animals taken alive. Measurements of thickness given in the text are of both valves together.

STATION LISTS

Space does not permit that full collection data be given for each species. The Woods Hole Oceanographic Institution has issued a Cruise Report (vol. 1) containing the station data for Cruise 7 of *Anton Bruun.* The full data have been summarized in the station lists below. Under each species is the station number followed, in the case of grab samples, by the number of specimens in brackets. The grab sampled an area of 0·6m². The number of specimens from dredge samples, which are not quantitative, was not counted but each species is recorded as abundant (A), very common (V.C.), common (C), fairly common (F.C.) or merely present (P). The depth range of the stations at which the species is recorded is given.

The station numbers prefixed by the letters NAD were sampled prior to the International Indian Ocean Expedition by R/V *John D. Gilchrist* and R/V *Vema.* The station numbers not prefixed are those of Cruise 7 of *Anton Bruun.* When large Campbell Grab samples were obtained these samples were split into two halves and sorted separately. '½ kept' in the remarks column of the table refers to the fraction of the sample dealt with in this paper and kept by the University of Cape Town. The remaining fraction of the grab sample was sent to the Smithsonian Oceanographic Sorting Center, Washington, U.S.A.

In the case of dredge samples obtained by *Anton Bruun,* a sub-sample estimated as sufficient to be representative of the whole sample was kept and is reported in this paper and the remainder, if any, was sent to S.O.S.C., Washington.

Unless otherwise indicated in the remarks column, all stations are off the coast of Natal, South Africa.

Abbreviations

Sampling gear: D — dredge
G — Campbell Grab, sampling area 0·6 m².

Substratum: The following abbreviations are those used for British Admiralty Nautical Charts:
Cl. — clay
Crl. — coral
G. — gravel
M. — mud
R. — rock
S. — sand
Sh. — shell
St. — stones
c. — coarse
d. — dark
f. — fine
gn. — green
gy. — grey

STATION DATA

Station No.	Date	Position	Depth (metres)	Substratum	Sampling gear	Remarks
STATIONS SAMPLED BY R/V *Vema* AND R/V *John D. Gilchrist*						
NAD. 1	17.5.58	30°47′S/30°29′E	44	St	D	
NAD. 8	16.5.58	29°53′S/31°04′E	38	C1	D	
NAD. 9	23.4.58	29°46′S/31°17′E	110–130	?	D	
NAD. 17	12.8.58	29°58′S/31°02′E	49	?	D	
NAD. 24	13.7.59	29°50′S/31°04′E	20	S, M	D	
NAD. 26	13.7.59	29°53′S/31°06′E	71	M	D	
STATIONS SAMPLED ON CRUISE VII OF R/V *Anton Bruun*						
356–B	29.7.64	29°11′S/31°37′E	18	R	D	
356–C	29.7.64	29°10′S/31°40′E	33	d gn M	G	All kept
356–E	29.7.64	29°12′S/31°42′E	40	d gn S, M	G	½ kept
356–J	29.7.64	29°10′S/31°51′E	43	S	D	
358–C	30.7.64	29°21′S/31°58′E	370	gn S, M	D	
371–E	18.8.64	24°46′S/35°20′E	132	R, sh S	D	Moçambique
371–F	18.8.64	24°46′S/35°18′E	110	c S, R	D	”
372–C	19.8.64	24°46′S/34°50′E	22	sh S, R	D	”
372–G	19.8.64	24°63′S/34°56′E	55	f gy S, R	D	”
372–L	19.8.64	25°07′S/34°34′E	112	d s M	D	”
372–Q	22.8.64	25°57′S/33°02′E	42	Sh, R	D	”
373–B	22.8.64	26°00′S/33°05′E	135	R, Sh	D	”
381–A–C	30.8.64	33°13′S/43°51′E	38–46	Calcareous algae	D	Walters' Shoal
390–H	8.9.64	29°37′S/31°33′E	175–200	s M	D	
390–K	9.9.64	29°35′S/31°38′E	150	s M	G	½ kept
390–N	”	29°34′S/31°39′E	115	s M	G	½ kept
390–P	”	29°34′S/31°39′E	118	s M	D	
390–R	”	29°35′S/31°42′E	138	Gr, Crl	G	Poor sample, all kept
390–S	”	29°35′S/31°42′E	138	c S, Crl	D	
391–B	”	29°29′S/31°45′E	86	M	G	½ kept
391–C	”	29°29′S/31°45′E	86	M	D	
391–E	”	29°26′S/31°46′E	77	gn M	G	½ kept
391–F	”	29°26′S/31°46′E	77	gn M	D	
391–H	”	29°21′S/31°35,E	57	c M S, Sh	G	Small sample, ½ kept
391–J	”	29°31′S/31°35′E	57	M, S, Sh	D	
392–B	”	29°18′S/31°33′E	47	d M, debris	G	½ kept
392–C	”	29°18′S/31°33′E	45–47	d M, debris	D	
392–E	”	29°16′S/31°32′E	35	d M, debris	G	½ kept
392–F	10.9.64	29°16′S/31°32′E	35	d M, debris	G	½ kept
392–J	10.9.64	29°19′S/31°26′E	38	c S, Sh	G	Small sample, ½ kept
392–K	10.9.64	29°19′S/31°26′E	38	c S	D	

NUCULIDAE

Nucula fragilis Boshoff, 1968.

Nucula fragilis Boshoff, 1968: 95, pl. VIII, fig. a, text-fig. 1.

Records: 390–N (1), 390–P (P); depths: 115–118 m. Type specimens. Reported in Boshoff, 1968.

LEDIDAE

Leda lanceta Boshoff, 1968.

Leda lanceta Boshoff, 1968: 96, pl. VIII, figs. c, d.

Records: 358–C (1); depth: 370 m. Holotype. Reported in Boshoff, 1968.

Leda parceplicata Barnard, 1964.

Leda parceplicata Barnard, 1964*a*: 21, fig. 4b.

Records: 390–K (1), 390–R (1), 358–C (P); depths: 150–370 m.
L.: 10·25 mm, Alt. at umbo: 6·75 mm, Th: 4·0 mm.
Specimens in *stat. jun.*, L.: 2·5 mm, Alt.: 1·75 mm.

Leda gemmulata (Sow., 1904)

Plate VI *a*, *c*.

Nuculana gemmulata Sowerby, 1904: 6, pl. 6, fig. 9.
Leda gemmulata: Barnard, 1964: 366.

Records: 'Typical': 391–J (P), 392–J (3); depths: 38–57 m.
'Variant': NAD 9 (P), 390–H (P); depths: 110–200 m.

Measurement of specimens from 391–J, 392–J in mm:
Long: 20·0, 16·75, 14·75, 8·0
Alt.: 9·5, 7·5, 7·0, 4·0
Thick: 6·5, 5·5, 4·0, 2·5

Of 'variant specimens' from 390–H, NAD 9 in mm:
L.: 16·0, 15·0, 12·0
A.: 7·5, 7·5, 5·5
T.: 4·0, 4·5, 3·0

Remarks: *Leda gemmulata* (Sow.) seems to form a variant wherein a fifth posterior radial rib appears. Such variant valves have posterior shortening, e.g. when a random selection of 'typical' and 'variant' valves are compared, the proportion of the two tooth-bearing areas: $\frac{\text{anterior}}{\text{posterior}}$ = ·82 in 'typical' and ·52 in 'variant'. Also, valve length from resilium to either end: $\frac{\text{anterior}}{\text{posterior}}$ = ·75 in 'typical' and ·68 in 'variant'. Therefore, the variant seems to be posteriorly shortened. The concentric lirae of both show narrow intercostal lines over the anterior part of the valve widening as the posterior region is approached into spaces, with oblique lines crossing both rib and inter-rib spaces. The very occasional intercalation of a lira appears more frequently in the variant. The approach of the variant's lirae to the fifth rib shows an increased sinuosity with sublamellate tendency, so also do the lines in the inter-radial valleys. The usually almost spiky nodules on the radial ribs tend to be squamose in the variants. The sinuosity of the concentric lirae near the first radial is slight or absent in the 'typical' but becomes squamous in the variant with a preceding low part increasing the prominence of the fifth rib. All the variants show a denser concentric inter-rib lamellation and also more lamellation over the ribs themselves which appears to be a sign of scirrhosing pathology during nacreous deposition at early growth stages. Some specimens in the South African Museum show an accentuated juvenile edge lira indistinctly resembling a nepionic cap where pathology first caused a growth pause. We agree with Barnard who relegated the variants to *L. gemmulata* (Sow.).

ARCIDAE

Arca (*Scapharca*) *natalensis* Krss., 1848

Arca natalensis: Braga, 1952: 103, pl. 9, fig. 2.
Arca (*Scapharca*) *natalensis*: Barnard, 1964: 371.

Records: 392–C (F.C.), 392–B (1); depths: 45–47 m.

L.: 65 mm, Alt.: 50 mm, Th.: 45 mm. Smallest specimen, L.: 22 mm.

Arca (*Scapharca*) *africana* Sow., 1904

Arca africana Sowerby, 1904: 4, pl. 6, fig. 4.
Arca (*Scapharca*) *africana*: Barnard, 1964: 371.

Records: NAD 26 (P), 391–B (4 + 1 juv.), 391–F (P), 391–J (P), 391–C (A) depths: 61–86 m.

L.: 25 mm, Alt.: 16 mm, Th.: 15 mm. Smallest specimen, L.: 10 mm.

Arca (*Barbatia*) *obliquata* Gray, 1837

Arca (*Barbatia*) *obliquata*: Dautzenberg and Fischer, 1905: 191, Barnard, 1964: 373, fig. 2c.
Arca alfredensis Bartsch, 1915: 182, pl. 46, figs. 9, 10; Turton, 1932: 216.

Record: 372–C (P); depth: 22 m.

In stat. jun., L.: 1·75 mm., Alt.: 1·25 mm.

Remarks: Evidently not a purely 'littoral species', as Barnard, 1964, concluded.

Arca (*Barbatia*) *helblingii* Brug., 1789.

Plate VI*e*

Arca (*Barbatia*) *helblingii*: Barnard, 1964: 374.
Arca nivea (*Chemn.*) *var. velata*: Braga, 1952: 104, pl. 8, fig. 7.

Record: 372–G (P); depth: 55 m.

Remarks: Both specimens agree with specimens at South African Museum (Barnard, 1964: 374). The specimens do not agree with Braga's figure but appear very similar to his photograph of *A. decussata* (fig. 8) although his *A. nivea* var. *velata* is given as a synonym of *A. helblingii* by Barnard, 1964.

L.: 33 mm, Alt.: 20 mm, Th.: 15 mm.

Arca (*Barbatia*) *cafria* Bartsch, 1915

Arca cafria Bartsch, 1915: 183, pl. 38, figs. 1, 5.
Arca (*Barbatia*) *cafria*: Barnard, 1964: 375.
Cardita rufanensis Turton, 1932: 131, pl. 60, no. 1615 (= juv.).

Records: 356–B (P), 372–G (P); depths: 18–55 m.

L.: 7·0 mm, Alt.: 4·75 mm, Th.: 3·75 mm.

Arca (*Arcopsis*) *gibba* Krss., 1848

Plate VI *f*

Arca (*Arcopsis*) *gibba*: Barnard, 1964: 375.

Records: 371–E (P, juvs.), 371–F (P, juvs.) and 372–G (P); depths: 55–132 m. L.: 7·0 mm, Alt.: 5·0 mm, Th.: 4·3 mm.

LIMOPSIDAE

Limopsis anceps Thiele, 1931

Limopsis anceps Thiele, 1931: 184, pl. 6 (1), figs. 20, 20a, Barnard, 1964: 384, fig. 4b.

Record: 371–F (P); depth: 110 m.

Young specimen: L.: 7·0 mm, Alt.: 8·0 mm, Th.: 4·0 mm.

Limopsis natalis Barnard, 1964

Limopsis natalis Barnard, 1964: 382; 1964*a*: 23, fig. 4e, f.

Record: 371–F (P); depth: 110 m.

In *stat. jun.*: L.: 3·74 mm, Alt.: 4·0 mm, Th.: 2·0 mm.

Remarks: Slightly less sharp-angled hinge line than in Barnard's figure.

MYTILIDAE

Modiolus sirahensis Jouss., 1891

Modiolus sirahensis: Barnard, 1964: 393, fig. 6b.

Record: 392–C (F.C.); depth: 46 m.

L.: 48 mm, Alt.: (at highest part): 18 mm, Th.: 14 mm. Smallest specimen, L.: 30 mm.

Remarks: The specimens were attached to lumps of mud in which the byssus threads were embedded.

Modiolus philippinarum Hanley, 1844

Modiolus philippinarum: Barnard, 1964: 393, fig. 6a; Paes da Franca, 1960: 88, pl. 24, fig. 1.

Record: 372–Q (P); depth: 42 m.

L.: 4·0 mm.

Lithophaga (*Diberus*) *mucronata* (Phil., 1846)

Lithophaga (*Diberus*) *mucronata*: Soot-Ryen, 1964, *in litt.*; Boshoff, 1965, spec. no. 28.
Modiola mucronata: Krauss, 1848: 21, Sowerby, 1892: 64.
Lithodomus mucronata: Smith, 1903: 395.

Records: 372–Q (P), 371–F (P); depths: 42–110 m.

L.: 12 mm approximately.

Lithophaga (*Leiosolenus*) *nasuta* (Phil., 1846)

Lithophaga (*Leiosolenus*) *nasuta*: Soot-Ryen, 1964, *in litt.*; Barnard, 1964: 405; Boshoff, 1965, spec. no. 27.
Lithodomus lithophaga (*non* Linn.), Macnae and Kalk, 1958: 37, pl. 2, figs. 40, 41.
Lithophaga lithophaga (*non* Linn.), Paes da Franca, 1960: 88.

Record: 371–F (P); depth: 110 m.
L.: *circa* 12·0 mm. Specimens slightly crushed.

Lamya capensis (Krss., 1848)

Modiola capensis Krauss, 1848: 20, pl. 2, fig. 3.
Lamya capensis: Soot-Ryen, 1958: 341, fig. 1; Barnard, 1962: 183; 1964: 397, figs. 8e–g.

Records: 390–P (P) and 372–L (P); depths: 112–118 m.
L.: 16·5 mm, Alt.: at broadest 9·6 mm, Th.: 6·0 mm.

Remarks: In *stat. jun.* with the post ligamental crenulations typical of *Lamya* not yet showing. All features correspond to a specimen in the South African Museum, Cape Town, labelled in Dr. K. H. Barnard's handwriting as *Modiola capensis* Krss. while the other specimens were labelled *Lamya capensis* (Krss.), probably after publication of Soot-Ryen's work (1958), but this acrenulate adult he did not re-label. On page 398, Barnard states that crenulations in 'some large specimens' are feeble and obscure. We suspect that two species are represented and that *Modiolus capensis* may in future become the name of such acrenulate specimens. In the absence of more material and owing to the youth of the specimens in hand, we must retain them as *L. capensis* (Krss.), *pro tem.* Note that these specimens are not estuarine.

Lanistina cuneata (Gould, 1861)

Lanistina cuneata: Barnard, 1964: 401, fig. 9d.

Records: 356–B (P), 372–C (P), 391–J (P); depths: 18–57 m.
Lengths: 4–6 mm.

ISOGNOMONOTIDAE

Malleus anatinus (Gmelin, 1790)

Malleus anatinus: Barnard, 1964: 407.

Record: NAD 17 (P); depth: 49 m.

PECTINIDAE

Amussium texturatum Dautz. and Bavay, 1912

Plate VI*b*

Ammussium texturatum: Barnard, 1964: 432.

Record: 371–F (P); depth: 110 m.
L.: 6·0 mm, Alt.: 6·25 mm.

LIMIDAE

Lima lima (Linn., 1758)

Lima lima: Barnard, 1964: 439, fig. 16b, d.

Record: NAD 1 (P); depth: 44 m.

L.: 9 mm, Alt.: 10 mm.

OSTREIDAE

Crassostrea cucullata (Born, 1778)

Crassostrea cucullata: Barnard, 1964: 446; Korringa, 1957: 318.
Ostrea cucullata: Krauss, 1848: 30; Boshoff, 1965, spec. no. 59, pl. 12, fig. 2.

Record: 381–A–C (P); depth: 38–46 m. (This site is at Walters' Shoal in the Indian Ocean, 800 miles from the Natal Coast.)

Circa: 35 mm and 50 mm.

Pycnodonta hyotis (Linn., 1758)

Pycnodonta hyotis: Ranson, 1941: 86, figs. 1–6; Barnard, 1964: 448, fig. 17c.

Ostrea hyotis: Nicklés, 1950: 183, fig. 340.

Record: 372–G (P); depth: 55 m.

Circa: 45 mm.

CRASSATELLIDAE

Crassatella abrupta Sow., 1904

Plate VI*d*

Crassatella abrupta Sowerby, 1904: 10, pl. 6, fig. 15; Barnard, 1964: 456.

Records: NAD 9 (P), 390–S (C) and 390–R (5); depths: 110–138 m.

Size range: largest: L.: 24 mm, Alt.: 19 mm, Th.: 13 mm; smallest specimens: L.: 8 mm, Alt.: 7 mm, Th.: 4 mm.

Remarks: The larger specimens have a dark encrusting band about 4 mm wide obliquely crossing the line at which the concentric lirae disappear posteriorly. The concentric lirae disappear posteriorly on even the smallest shells in this collection (cf. Barnard, 1964).

UNGULINIDAE

Diplodonta (*Felania*) *agulhasensis* Jaeckel & Thiele, 1931

Diplodonta (*Felania*) *agulhasensis*: Barnard, 1964: 468, fig. 21b.

Record: 391–H (1); depth: 57 m.

L.: 8 mm, Alt.: 7·25 mm, Th.: 4·0 mm.

Thyasira unilateralis Brnrd., 1964

Thyasira unilateralis Barnard, 1964*a*: 24, fig. 5a.

Records: 391–C (P), 391–F (P), 390–K (1), 390–R (1); depths: 77–150 m.

L.: 10·0 mm, Alt.: 7·25 mm, Th.: 5·75 mm. Smallest specimen, L.: 5·5 mm.

LUCINIDAE

Phacoides capensis J. & T., 1931

Phacoides capensis Jaeckel & Thiele, 1931: 221, pl. 9 (4), fig. 92; Barnard, 1964: 473.
Fide Barnard, 1964: 472 in adoption of '*Phacoides*'.

Records: 392–B (13), 392–E (5), 392–F (4), 356–C (7); depths: 33–47 m.

L.: 4·75 mm, Alt.: 4·0 mm, Th.: 2·0 mm.

Phacoides aequalis J. & T., 1931

Phacoides aequalis Jaeckel & Thiele, 1931: 221, pl. 9 (4), fig. 93; Barnard, 1964: 474.

Record: 391–H (1); depth: 57 m.

L.: 6·75 mm, Alt.: 6·5 mm.

Loripes clausus (Phil., 1847)

Loripes clausus: Braga, 1952: 118, pl. 11, fig. 5; Macnae and Kalk, 1958: 41, fig. 23b; Barnard, 1964: 477.

Record: 390–H (P); depth: 175–200 m.

L.: 9·0 mm, Alt.: 8·5 mm, Th.: 4·75 mm.

ERYCINIDAE

Erycina subradiata (Gould, 1861)

Erycina subradiata: Barnard, 1964: 481.
Erycina alfredensis Bartsch, 1915: 197, pl. 43, figs. 7, 8.
Erycina rifaca Bartsch, 1915: 198, pl. 39, fig. 3, pl. 50, figs. 7, 8.

Record: 392–J (1); depth: 38 m.

L.: 3·75 mm, Alt.: 3·0 mm, Th.: 1·25 mm. Two gills bilaterally.

CHAMIDAE

Chama gryphoides Linn., 1758

Chama gryphoides: Barnard, 1964: 490.
Chama sp.: Paes da Franca, 1960: 93, pl. 25, fig. 3.

Records: 356–B (P), 372–G (P); depths: 18–55 m.

L., Alt. and Th.: *circa* 9·0 mm, *idem*: 13·5 mm.

CARDIIDAE

Cardium turtoni Sow., 1894

Cardium turtoni Sowerby, 1897: 25, pl. 7; Barnard, 1964: 492.

Record: NAD 17 (P); depth: 49 m.

L.: 13 mm, Th.: 9 mm.

Cardium gilchristi Sow., 1904

Cardium gilchristi Sowerby, 1904: 11, pl. 7, fig. 1; Barnard, 1964: 492.

Record: 371–F (P); depth: 110 m.

L.: 8·0 mm, Alt.: 9·0 mm, Th.: 6·0 mm. Slightly damaged.

Cardium asiaticum Brug., 1789

Cardium asiaticum: Braga, 1952: 109, pl. 9, fig. 8; Barnard, 1964: 493.

Records: 391–J (P), 391–H (1); depth: 57 m.

L.: 30 mm, Alt.: 29 mm, Th.: 21 mm. Smallest specimen L.: 19 mm.

PSAMMOBIIDAE

Solecurtus divaricatus (Lischke, 1869)

Solecurtus divaricatus: Hirase & Taki, 1954: pl. 48, fig. 2; Boshoff, 1965, spec. no. 131.

Record: 391–C (P); depth: 86 m.

L.: 17·75 mm, Alt. at umbo: 8·0 mm, Th.: 5·25 mm.

VENERIDAE

Venus (*Antigona*) *rugosa* Gmelin, 1790

Plate VII*b*

Venus rugosa: Sowerby, 1849–55: 728, pl. 160, figs. 185, 186; Boshoff, 1965, spec. no. 88.

Record: 372–Q (P juv.); depth: 42 m.

L.: 24 mm, Alt.: 21 mm, Th.: 15 mm.

Remarks: Subsmooth left valvular area just beginning to form posteriorly in this juvenile.

Venus arakana (Nevill, 1871)

Plate VII*a*

Venus arakana: Barnard, 1964: 497.

Records: NAD 17 (P), 356–E (1 juv.), 356–J (P), 391–J (P); depths: 40–57 m.

L.: 20 mm, Alt.: 14 mm, Th.: 9 mm. Smallest specimen, L.: 5 mm.

Venus (*Chione*) *marica* Linn., 1758

Venus (*Chione*) *marica*: Smith, 1885: 125, 126; Hirase & Taki, 1954: pl. 37, fig. 2; Boshoff, in press, spec. no. 93, pl. 11, fig. 4.
Chione marica: Lynge, 1909: 242 (146), pl. 5, figs. 1–4.

Records: 392–J (1), 373–B (P); depths: 38–135 m.

L.: 3·0 mm, Alt. 2 mm; L.: 18·0 mm, Alt.: 14·0 mm, Th.: 9·0 mm.

Remarks: Recently found and recorded from Inhaca. A specimen has been in the Natal Museum, Pietermaritzburg, for many years but has not been recorded in the literature of South African shells.

Pitaria manillae (Sow., 1851)

Pitaria manillae: Barnard, 1964: 503.

Records: NAD 8 (P), NAD 26 (P), 356–C (3), 356–J (1 juv.), 372–G (P), 390–N (1 juv.), 391–B (3 + 5 juvs.), 391–C (P juv.), 391–E (3 + 3 juvs.), 391–H (1), 392–C (P), 392–E (1), 392–F (1); depths: 33–115 m.

L.: 17 mm, Alt.: 15 mm, Th.: 10 mm. Smallest specimen, L.: 2·5 mm.

Remarks: A common species.

Dosinia lupinus (Linn., 1758)

Dosinia lupinus: Fischer-Piette and Delmas, 1967: 16.
Dosinia africana: (Gray): Barnard, 1964: 510.

Record: 391–E (1 juv.); depth: 77 m.

L.: 5·0 mm, Alt.: 4·5 mm, Th.: 2·0 mm.

Dosinia tumida (Gray, 1838)

Dosinia tumida: Fischer-Piette and Delmas, 1967: 37, pl. 8, figs. 12–17
Dosinia japonica (non Rve.), Paes da Franca, 1960: 96, pl. 27, fig. 2.
Dosinia pubescens: (Phil.): Barnard, 1964: 511.

Records: NAD 26 (P), 392–K (P); depths: 38–71 m.

L.: 21 mm, Alt.: 21 mm, Th.: 13 mm.

MACTRIDAE

Mactra glabrata Linn., 1767

Mactra glabrata: Barnard, 1964: 517.
Mactra adansoni var. *elongata* Turton, 1932: 255, pl. 69, no. 1804.

Records: NAD 24 (P) and 356–J (P); depths: 20–43 m.

L.: 16 mm, Alt.: 12 mm, Th.: 7 mm. Smallest specimen, L.: 5 mm.

Remarks: These specimens confirm the observation by Barnard (1964) that the Natal specimens of *M. glabrata* are smaller than those found further west in South African waters.

DONACIDAE

Donax (*Capsella*) *longissimus* J. & T., 1931

Donax (*Capsella*) *longissimus* Jaeckel & Thiele, 1931: 240, pl. 9 (4), fig. 116; Barnard, 1964: 531.

Record: 372–C (F.C.); depth: 22 m.

L.: 29 mm, Alt.: 13 mm, Th.: 7 mm.

SEMELIDAE

Theora alfredensis Bartsch, 1915

Plate VII*c*

Theora alfredensis Bartsch, 1915: 206, pl. 45, fig. 8, pl. 49, fig. 3; Barnard, 1964: 536.

Records: NAD 26 (P), 390–H (P), 390–N (10 + 2 juvs.), 390–P (F.C.), 390–R (1), 391–B (49), 391–C (P), 391–E (22), 391–H (1); depths: 57–200 m.

L.: 11 mm, Alt.: 7 mm, Th.: 3 mm, smallest specimen, L.: 4 mm.

Remarks: A common species.

TELLINIDAE

Specimens suspected of belonging to the genus *Tellina* are omitted as they are under review by Dr. Kenneth J. Boss of the Museum of Comparative Zoology, Harvard.

Macoma levior Sow., 1904

Tellina (*Macoma*) *levior* Sowerby, 1904: 13, pl. 7, fig. 6.
Macoma levior: Barnard, 1964: 584.

Records: 391–C (P), 391–B (2), 391–E (27 small), 391–H (2 small), 392–C (C), 392–B (10), 392–K (P), 356–C (15), 356–E (2 small); depths: 33–86 m.

L.: 18 mm, Alt.: 14 mm, Th.: 7 mm; smallest specimens, L.: 7 mm.

Remarks: A common species.

SOLENIDAE

Phaxas cultellus (Linn., 1758)

Phaxas cultellus: Gravely, 1941: 64, fig. 23a; Barnard, 1964: 554.

Record: 391–J (P); depth: 57 m.

L.: 43 mm, Alt.: 11 mm. (Also one valve: 63 × 16 mm.)

Siliqua polita (Wood, 1828)

Siliqua polita: Barnard, 1964: 554, fig. 32c.

Record: 356–J (P); depth: 43 m.

L.: 20 mm, Alt.: 7 mm.

POROMYIDAE

Poromya granosissima Sow., 1904

Plate VII*e*

Poromya granosissima Sowerby, 1904: 16, pl. 7, fig. 12; Barnard, 1964: 579.

Record: NAD 9 (P); depth: 110–130 m.

L.: 9 mm, Alt.: 7 mm, Th.: 5 mm. A single specimen recorded in Barnard, 1964.

LATERNULIDAE

Periploma fractura Boshoff, 1968

Periploma fractura Boshoff, 1968: 97, pl. VIII, fig. d, text-fig. 2.

Records: 390–P (P), 391–B (3), 391–C (P), 391–F (P); depths: 77–118 m.

Type specimens. Reported in Boshoff, 1968.

CUSPIDARIIDAE

Cuspidaria optima Sow., 1904

Cuspidaria optima Sowerby, 1904: 17, fig. 16; Barnard, 1964: 580.

Record: 391–C (P); depth: 86 m.

L.: 29 mm, Alt.: 16 mm, Th.: 11 mm.

Cuspidaria macrorhynchus Smith, 1895.

Plate VII*f*

Cuspidaria macrorhynchus Smith, 1895: 12, pl. 2, figs. 5, 5a (from Barnard, 1964: 581).

Record: 390–H (P); depth: 175–200 m.

L.: 22 mm, Alt.: 10 mm, Th.: 6 mm.

DISTRIBUTION

Figure 1 shows the distribution around the coast of southern Africa of the species of this report from depths of less than 200 m. Each line represents one species. The Moçambique area is here defined as being between 24° 00′ and 26° 59′ S and Natal between 27° 00′ and 31° 59′ S. When any species dealt with in this report has been recorded by the University of Cape Town Survey west of the Natal area and east of Cape Point (18° 30′ E) it is shown as extending to the south coast; similarly records to the west of Cape Point are indicated by extending the lines representing species through the west coast column.

Species have been assigned to three rough zoogeographical categories:

endemic: when the species has only been recorded from Africa, south of latitude 20° S.;

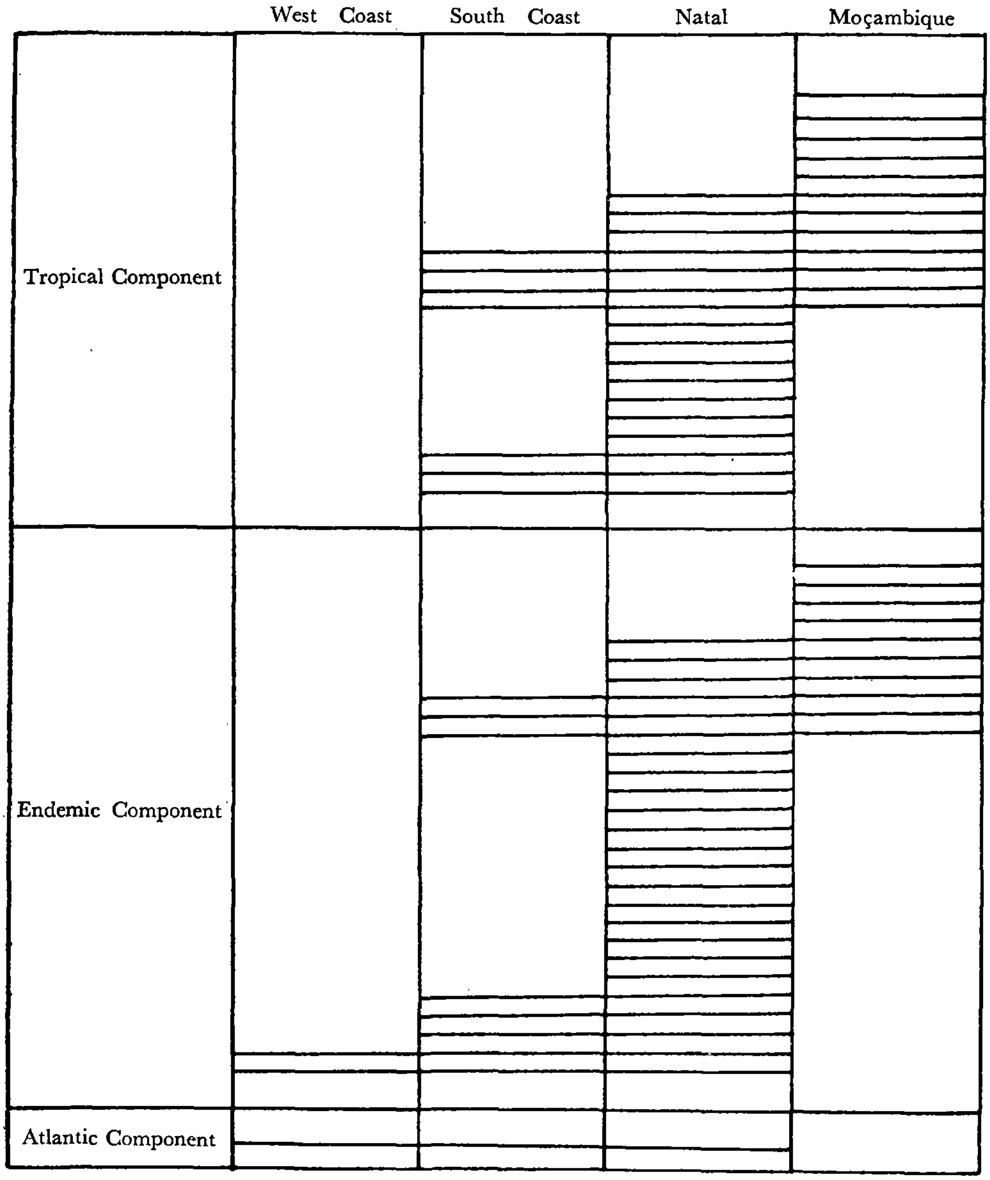

FIG. 1. Distribution to the south and west coasts of South Africa of Pelecypoda recorded in the text from Moçambique and Natal.

tropical:	when the species has been recorded outside southern African waters in the tropical Indo-West Pacific region or other tropical waters;
atlantic:	when the species has been recorded mainly from the Atlantic Ocean outside southern Africa.

The tropical component forms 55% of the Moçambique fauna. This component falls off to 40% of the fauna in the Natal area. The endemic component comprises 45% of the 22 Moçambique species and 57% of the 42 species in the Natal area. There is only one atlantic species which extends as far east as Natal, forming 3% of the Pelecypod fauna there. The diagram shows that none of the Moçambique species and only three of the Natal Pelecypoda (7% of the Natal fauna) extend to the west coast; of the three, one is an atlantic species and two are endemic. No tropical species extend to the cool west coast.

This indicates a change in the Pelecypod fauna from the warm waters of Moçambique to the more temperate south coast of South Africa. From these data Natal appears to have a rather distinct benthonic Pelecypod fauna; 48% of the species are not recorded elsewhere and only 31% of its species are shared with Moçambique. One should bear in mind that only 7 samples are from Moçambique and 29 from Natal so that further sampling off Moçambique may well show a greater similarity between the two areas. The Natal fauna is fairly distinct from that of the well-sampled south coast; this is shown by only 38% of the Natal species extending westwards to the south coast but it is beyond the scope of this report to deal properly with the zoogeography of southern African waters.

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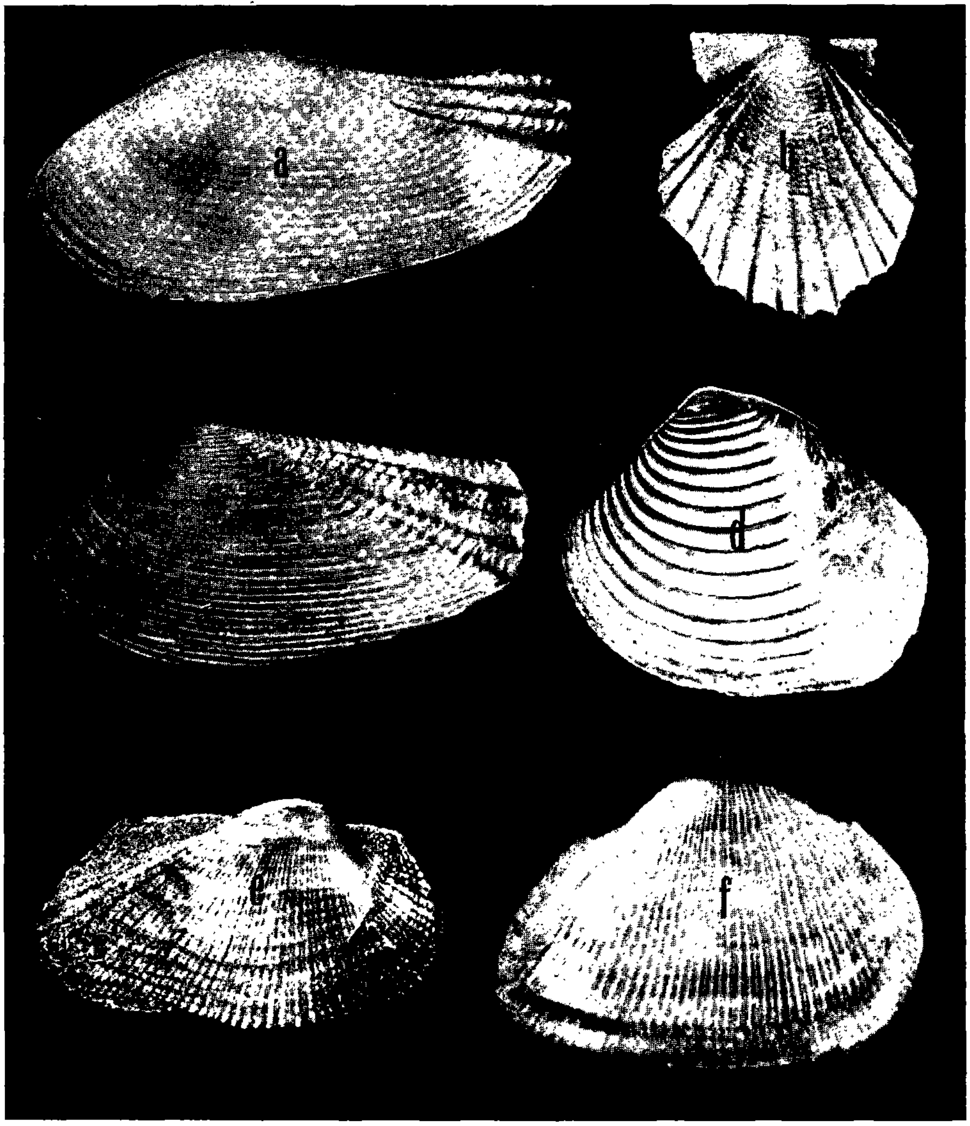
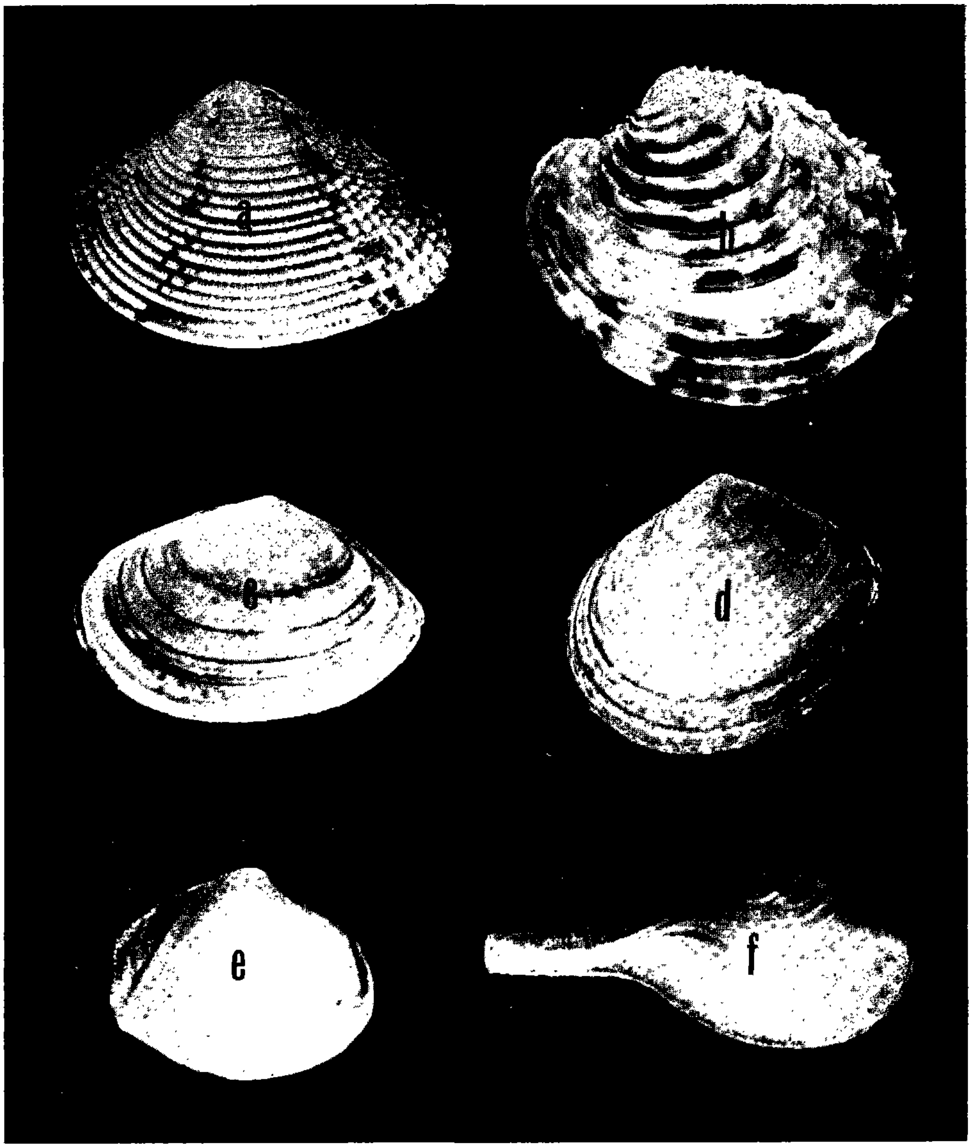
Plate VI



a. *Leda gemmulata*, 'typical' 4-ribbed form; b. *Amussium texturatum*; c. *Leda gemmulata*, 'variant 5-ribbed form; d. *Crassatella abrupta*; e. *Arca* (*Barbatia*) *helblingii*; f. *Arca* (*Arcopsis*) *gibba*.

Plate VII



a. *Venus arakana*; b. *Venus rugosa*; c. *Theora alfredensis*; d. *Macoma levior*; e. *Poromya granosissima*; f. *Cuspidaria macrorhynchus*.

Reprinted from *Rev. Zool. Bot. Afr.*, vol. 77, no. 3-4, 1968, p. 329-334.

Un Barychelide nouveau de Madagascar : *Atrophonysia intertidalis* gen. sp. nov.

(Aranea - Orthognatha)

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Le matériel qui est étudié ici a été récolté par la mission américaine dirigée par le Professeur A. G. HUMES de Boston, Mass., durant l'exécution de l' « U. S. Program in Biology of the International Indian Ocean Expedition » (A.I.O.I.). Nous tenons à exprimer nos très vifs remerciements à nos collègues américains, Monsieur le Professeur HUMES d'une part et le récolteur Monsieur JACK RUDLOE d'autre part, pour nous avoir fait parvenir ces très intéressantes Mygales.

Les deux exemplaires de Barychélides ont été récoltés en même temps que des Araignées marines appartenant à l'espèce *Desis crosslandi* POCOCK, 1903; le récolteur Monsieur JACK RUDLOE les a trouvés le 19 janvier 1964 dans la zone découverte à marée basse de la Pointe de la Fièvre, située à droite de l'embarcadère de la Station Océanographique O.R.S.T.O.M. de l'île de Nossi-bé (Madagascar). La localisation exacte indiquée par le récolteur est 13°24'23" Lat. Sud et 48°18'12" Long. Est. Le biotope est formé par des boues sablonneuses avec quelques nodules argileux. Aussi bien les *Desis crosslandi* que les deux Barychélides étaient à l'intérieur d'une retraite, formée par un terrier tapissé de soie. La présence d'Agelenidae du genre *Desis* indique clairement un habitat régulièrement submergé par les marées; c'est d'ailleurs pour rappeler ce singulier biotope que nous proposons le nom spécifique d'*intertidalis* n.sp.

Malheureusement aucun renseignement sur l'éthologie et le type des proies (fort vraisemblablement des Invertébrés marins) n'a pu être recueilli.

La famille des Barychelidae semble avoir des représentants qui ne craignent pas l'humectation, en effet le type du genre *Atrophothele* (*A. socotrana* Pocock, 1903) a été découvert à l'île de Socotra dans le lit d'un torrent temporairement asséché. La présence d'un Barychélide dans la zone de balancement des marées ne doit pas surprendre car actuellement deux autres représentants de la famille sont connus pour avoir des habitats marins. Le premier est *Idioctis littoralis* Abraham, 1924, découvert dans la région de Singapour; cette Araignée vit dans un terrier creusé dans les crevasses de l'écorce des palétuviers de la mangrove, juste au-dessous du niveau de pleine mer; conservée en captivité, cette Mygale a refusé toute nourriture autre que des Annélides Polychètes (H. C. Abraham, 1924). Le second est *Neodiplothele picta* Vellard, 1924 indiqué par C. F. de Mello-Leitao (1928) comme vivant au Brésil dans des cavités de rochers découverts très peu de temps à marée basse; ses abris sont encombrés de débris de Talitres et d'Isopodes marins dont il fait certainement sa nourriture. A ces deux Barychélides marins, il convient dorénavant d'adjoindre *Atrophonysia intertidalis* n. g., n. sp. de l'île de Nossi-bé, Madagascar.

Gen. **ATROPHONYSIA** nov.

Barychelinae. Chélicères sans protubérance, armées d'un rastellum puissant et d'une seule rangée de dents. Groupe oculaire situé sur une protubérance peu exprimée. Les yeux concentrés en groupe notablement plus large que long et plus large au niveau des PL qu'aux AL. La partie céphalique du céphalothorax surélevée et bien séparée. Fovea transversale, rectiligne. Les bords latéraux du céphalothorax démunis de soies spiniformes. Labium transversal, inerme. Lames maxillaires abondamment couvertes de pilosité longue et souple, à spiculation très réduite. Sternum fortement étiré en long mais la pointe distale ne s'engage pas entre les coxas IV qui restent strictement contigus; couvert de pilosité abondante et souple (pas spinuleuse comme chez tous les autres genres connus). Aucun coxa n'est pourvu de spicules. Pattes I et II épaissies, leurs tibias plus longs que les métatarses. Métatarses et tibias des pattes I et II portant ventralement des scopula très longs et denses sur toute leur longueur; ces scopula forment latéralement des franges épaisses et longues. Les scopula encore rudimentairement présents aux pattes III mais absents aux pattes IV. Fascicules ungueaux longs et épais mais les ongles restent dorsalement dégagés. Filières antérieures atrophiées, présentes sous forme de moignons. Filières postérieures à trois articles.

Espèce type:

Atrophonysia intertidalis n. sp.

Madagascar: île de Nossi-bé, dans la boue intertidale près du Pier de la Station Océanographique O.R.S.T.O.M., janvier 1964 (J. Rudloe). — ♀ holotype (MT 133.045) et ♀ juvénile paratype au Musée Royal de l'Afrique Centrale, Tervuren.

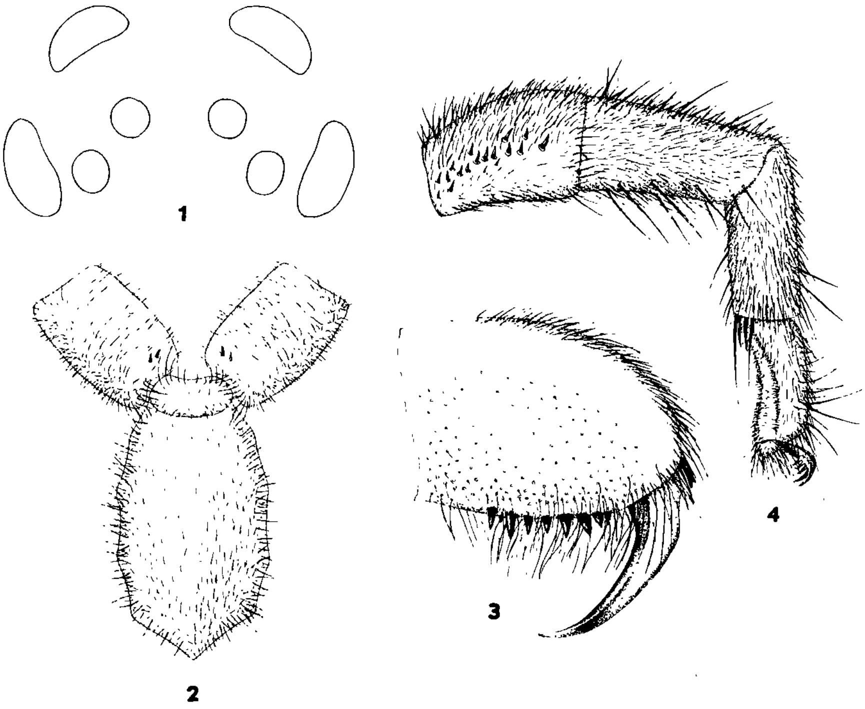

Fig. 1-4. — *Atrophonysia intertidalis* gen. sp. n. - 1. Groupe oculaire. - 2. L'ensemble sternum, labium et lames maxillaires. - 3. Chélicère, face intérieure. - 4. Patte III: patella, tibia, métatarse et tarse.

Entièrement ferrugineux sauf l'abdomen noirâtre. Face antérieure des chélicères à pilosité longue et dressée. Le rastellum composé de 9-10 épines (six chez le juvénile) strictement le long du bord inférieur et couvrant l'articulation des crochets. Dents chélicérales au nombre de huit (six chez le juvénile) dont la première est rudimentaire; au niveau des dents 7-8 se situent quatre denticules secondaires chez le type mais ce nombre devrait être individuellement variable. Yeux AL écartés par un peu plus que leur diamètre. Yeux AM situés au niveau du bord supérieur des PL et écartés par plus que leur diamètre. Yeux PL subégaux aux AL, leur écart est inférieur à leur diamètre. Céphalothorax étiré en long (Long. 3,9 mm, larg. 2,8 mm) avec le bord postérieur très peu incurvé et notablement rétréci; la pilosité est duveteuse et clairsemée sauf une dizaine de soies dressées entre les yeux et la fovea. Lames maxillaires avec deux spicules près du bord inférieur; elles sont uniformément couvertes de pilosité longue et très abondante. Labium plus de deux fois aussi large que long. Sternum étiré en longueur (long. 2,07 mm, larg. 1,30 mm). Pattes démunies de toute spinulation sauf les patellas III munies à la face antérieure d'une série de petites spinules. Les métatarses III et IV terminés par des soies spiniformes. Les ongles de tous les tarses portent 3-4 dents de peigne concentrées vers le milieu de l'ongle. Abdomen contracté par suite d'un dessèchement partiel du spécimen adulte, de ce fait la longueur du type devrait être inférieure à sa taille réelle. Longueur: 8,6 mm, hors chélicères.

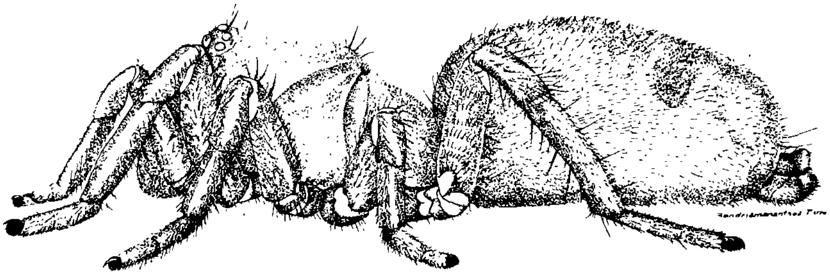

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Fig. 5. — *Atrophonysia intertidalis* gen. sp. n., Habitus.

Position taxonomique et affinités.

Dans le tableau générique des Barychelinae africains, publié par l'un de nous (*Rev. Zool. Bot. Afr.*, 74, 1966: 210), le genre *Atrophonysia* se situe près de *Cyphonisia* SIMON; la clé des genres doit être modifiée comme suit:

5 - Fovéa thoracique droite ou très légèrement récurvée. Métatarses et tibias I et II avec des scopula très serrés, formant des franges le long du bord intérieur 6

- Fovéa thoracique récurvée ou procurvée 7

6 - Métatarses et tibias I subégaux. Labium muni de quelques spinules. Sternum à pilosité très éparse et de nature spinuleuse. Ongles des tarses avec une petite dent au milieu. Filières supérieures normales .... *Cyphonisia* SIMON

- Tibias I plus longs que les métatarses I. Labium inerme. Sternum avec abondante pilosité longue et souple. Ongles des tarses munis de dents de peigne. Filières supérieures atrophiées ....
.... *Atrophonysia* nov.

7 - Les genres *Pisenor* SIMON et *Sipalolasma* SIMON suivant les critères fournis précédemment.

A l'intérieur de la sous-famille, ce nouveau genre constitue un nouvel échelon transitoire dans la régression du bulbe oculaire qui trouve son aboutissement complet dans le genre *Sason* SIMON. Cette régression progressive à travers les genres, allant depuis *Pisenor* SIMON et *Sipalolasma* SIMON, à bulbe oculaire saillant, jusque *Sason* SIMON, à bulbe oculaire nul, s'accompagne d'un étalement progressif en largeur du groupe oculaire. Le présent genre se situe à cet égard entre *Cyphonisia* SIMON, qui présente l'amorce de ces deux phénomènes concomitants, et *Sason*. Malgré l'existence de filières antérieures atrophiées qui pourraient à première vue rapprocher ce genre de *Atrophothele* POCOCK de Socotra, il semble se vérifier que des caractères de nature moins fonctionnelle classent *Atrophonysia* proche de *Cyphonisia*. *Atrophothele* possède en commun: outre l'atrophie des filières antérieures, la fovea droite et le groupe oculaire plus large que long mais il s'écarte par d'autres caractères très importants, à savoir: le groupe oculaire plus large à l'avant qu'aux yeux postérieurs, l'absence de rastellum, les lames maxillaires abondamment spinulées et les scopulas tarsaux des plus clairsemés. Tous ces caractères sont au contraire communs à *Cyphonisia* et *Atrophonysia*;

on peut y ajouter un caractère unique dans la famille; l'allongement du céphalothorax et du sternum. Dans toute la famille le sternum se présente sous une forme largement ovoïde, environ aussi long que large. A l'intérieur du genre *Cyphonisia* se manifeste chez quelques espèces une tendance à l'allongement et le phénomène est progressif (*soleata* THORELL, *obesa* SIMON, *annulata* BENOIT, *nesiotes* SIMON). Nous retrouvons le même caractère, plus nettement exprimé, chez *Atrophonysia*.

A moins que des découvertes ultérieures nous fassent connaître d'autres espèces dans les genres endémiques connus, il semble se confirmer que la faune des Barychelinae, tout au contraire des Diplothelinae, constitue à Madagascar un groupe aux allures de reliques. Les deux genres endémiques malgaches actuellement connus (*Zophoryctes* SIMON et *Atrophonysia* nov.) ainsi que le genre *Tigidia* SIMON, endémique de l'Ile Maurice, sont tous trois monotypiques et très différents des autres membres du groupe; le genre *Sason* est principalement lié à la péninsule indienne mais compte une espèce dans la « région malgache » au sens large: les îles Seychelles. Les considérations de l'un de nous (*Rev. Zool. Bot. Afr.*, 72, 1965: 27) sur cet état des choses restent parfaitement valables.

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ISRAEL SOUTH RED SEA EXPEDITION, 1962, REPORTS
No. 32

CHAETOGNATHES DE LA MER ROUGE*
(Archipel Dahlac)

PAR

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Le matériel étudié a été récolté au cours de l'expédition israélienne de 1962 dans le sud de la Mer Rouge, (OREN, 1962, 1964; STEINITZ, 1965). Les prélèvements de plancton effectués autour de l'archipel Dahlac nous ont aimablement été adressés par M. le Professeur B. KIMOR, de la Station de Recherches des Pêches maritimes d'Haifa.

Ces prélèvements ont été faits aux mois de mars et avril, soit en surface, soit en subsurface lors de pêches horizontales ou verticales (100–0m). La plupart ont eu lieu le matin entre 8 et 9h, quelques-uns la nuit (22h).

Sur une première série de prélèvements, disséminés dans les eaux avoisinant l'archipel, six (sur les stations n° 2–9–16–17) comportaient des Chaetognathes. Un certain nombre d'autres prélèvements positifs s'y sont ajoutés, les uns au nord ouest de l'île Nocra (n° 109–110–111–112–114), les autres au nord (n° 2202–2203) et au sud d'Entedebir (fig. 1). Les caractéristiques de l'ensemble de ces prélèvements au nombre de 15, sont réunies dans le tableau I.

On notera les valeurs fortes atteintes par la température (27 à 29°,5) et la salinité (37, 39 à 38,60 °/°°), ce qui laisse supposer la présence de Chaetognathes d'eau chaudes et tolérants au facteus halin.

Avant de faire l'inventaire des Chaetognathes récoltés lors de cette campagne, nous indiquerons quelles espèces étaient déjà connues en Mer Rouge. Elles sont au nombre de 9, citées par divers auteurs de récoltes échelonnées entre 1891 et 1957. Ce sont: *Sagitta inflata*, *S. hispida*, *S. regularis*, *S. serratodentata*, *S. pacifica*, *S. hexaptera*, *S. bipunctata*, *Krohnitta subtilis*, *Pterosagitta draco* (tabl. II).

Au cours de l'expédition de 1962, 2477 individus ont été recueillis. Ils comprennent 6 espèces: *Sagitta inflata*, *S. regularis*, *S. hispida*, *S. bedoti*, *S. robusta* et *Krohnitta pacifica*. Parmi elles, seules les 3 premières avaient déjà été signalées.

Leur abondance relative est très inégale, comme le montre leur pourcentage dans ces récoltes (tabl. II).

En raison de la faible bathymétrie de la zone prospectée (fonds entre 10 et 150 m) et du niveau superficiel de la plupart des pêches, ce sont toutes des formes néritiques ou semi-néritiques et de surface ou de subsurface. Il faut noter la fréquence des

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Received: June 1967.

* Aided by Contracts No. 62558–3335 between the U.S. Office of Naval Research, Department of the Navy, and Tel-Aviv University.

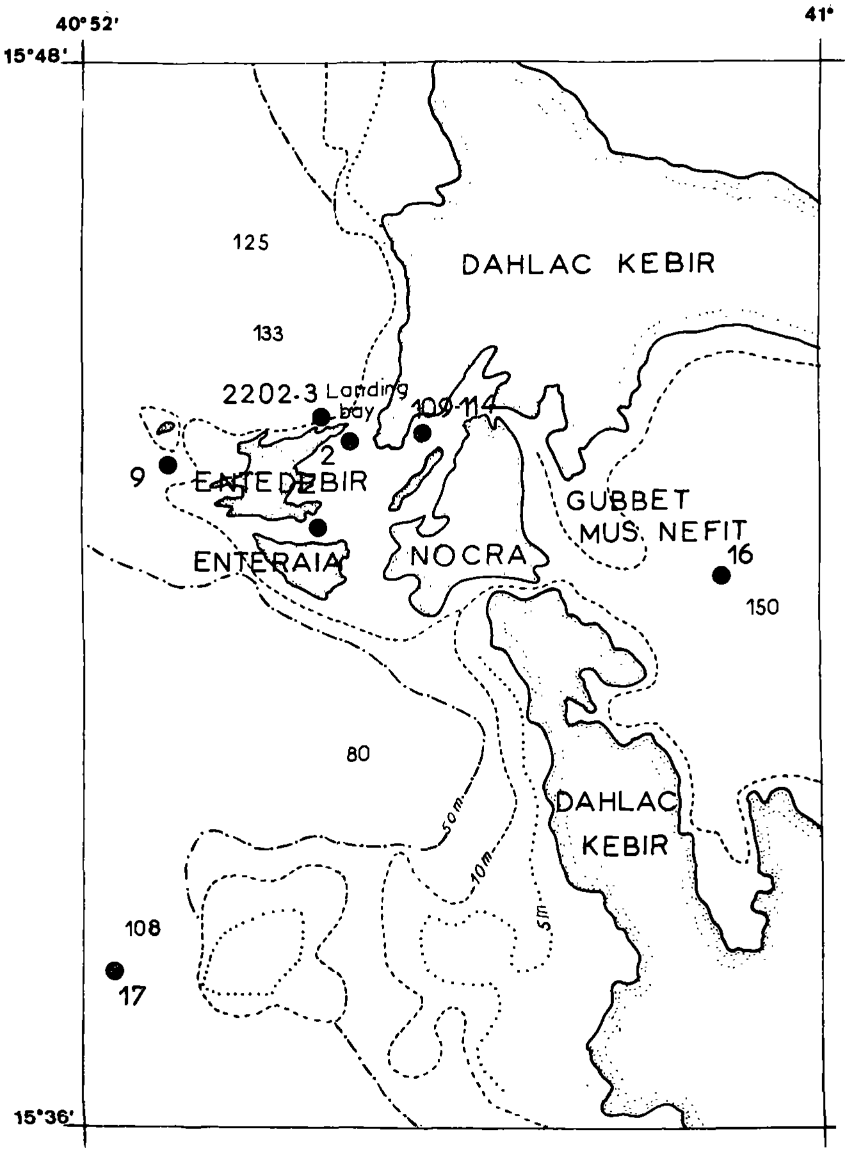

Fig. 1. Stations de pêches planctoniques, autour de l'archipel Dahlac, ayant rapporté des Chaetognathes. La bathymétrie a été sommairement indiquée.

spécimens de très petite taille et immatures, dont l'identification est particulièrement délicate.

Le tableau III donne, par station, la répartition des espèces, que nous allons successivement considérer. Sur le plan morphologique, nous dirons peu de choses, nous attachant seulement à faire ressortir les caractères locaux, s'il s'en trouve; nous avons cependant figuré pour chaque espèce l'aspect des yeux et, notamment, de la tache pigmentée, encore imparfaitement décrit pour plusieurs d'entre elles.

TABLEAU I

Caracteristiques des peches planctoniques comportant des Chaetognathes

Prélèvements n°	Latitude	Longitude	Date (1962)	Heure	Modalités des pêches	Niveau des mesures	T°	S°/°°	Densité
Station 2	15°43′15″	39°55′05″	8–IV			0m	28,78	38,33	24.634
1839						10	28,56	—	24.701
						15	28,57	38,08	24.552
Station 9	15°43′27″	39°53′10″	4–IV		surface	0m	28,83	38,26	24.634
1830–1829						13	27,70	38,21	24.920
Station 16	15°42′10″	39°59′15″	6–IV		verticale	0m	29,50	38,60	24.621
1834					(50m)				
1835					horizontale	50	27,00	38,60	25.450
Station 17	15°37′45″	39°52′30″				0m	27,41	37,39	24.418
1838						10	27,25	37,56	24.663
						25	27,12	38,21	25.115
109–110	Northern Nocra		12–III	8h–9h					
111–112	Channel								
114									
2202	Landing Bay		19–III	22h					
1837	Archipel Dahlac								
Plancton E—E Channel	Chenal entre Entedebir et Enteraia								

TABLEAU II

Chaetognathes signales en Mer Rouge de recoltes anterieures

Date des récoltes Région prospectée Navire	1891–93 Mer Rouge	1909 Mer Rouge “Pola”	1929–30 22°28′N–37°29′E “Snellius”	1947 Mer Rouge “Cherso”	1956–57 G. Eylath navire de la Station d’Haifa
AUTEUR	STEINHAUS	RITTER-ZAHONY	SCHILP	GHIRARDELLI	M.L. FURNESTIN
Sagitta inflata	2	+	5	126	244
S. hispida		+		30	
S. regularis		+			33
S. serratodentata	12	+	2		
S. pacifica					43
S. hexaptera		+	23	16	14
S. bipunctata	105			5	
Krohnitta subtilis					2
Pterosagitta draco				1	
Total	119	aucun chiffre précisé	30	178	336

TABLEAU III

REPARTITION DES CHAETOGNATHES PAR STATION ET POURCENTAGE PAR ESPECE POUR LA CAMPANGE DANS LES EAUX DE L'ARCHIPEL DAHLAC.

Stations	Prélèvements n°	*S. inflata*	*S. regularis*	*S. hispida*	*K. pacifica*	*S. bedoti*	*S. robusta*	Nb. total d'individus par station
2	1839	2		1				3
9	1829	36	2			3		731
	1830	642	33	11	1	3		
16	1834	91	5	3		1		116
	1835	7	9					
17	1838	2						2
Northern Nocra Channel	109	24						1065
	110	11						
	111	105		2	1			
	112	373		6	1			
	114	514	7	4	14	1	2	
Landing Bay	2202	2						543
	2203	20	360	124	37			
A. Dahlac	1837	5						5
Chenal Entedebir-Enteraia		10	1		1			12
Total par espèce		1844	417	151	55	8	2	Nb. total 2477
Pourcentage par espèce		74,46	16,83	6,09	2,22	0,32	0.08	

Sagitta inflata GRASSI, 1881

Morphologie

Sa taille varie entre 7 et 16 mm, ce qui est relativement faible pour une forme qui peut atteindre quelques centimètres.

Une série de mensurations et d'observations portant sur la longueur totale, celle des ovaires, le diamètre des oeufs et leur état de maturité permet d'indiquer que dans le secteur de Dahlac, *S. inflata* présente vraisemblablement 4 cycles de maturation: le premier chez des individus de 6 à 8 mm, le second entre 9 et 12 mm, le troisième entre 12 et 13 mm, le quatrième et dernier se prolongeant jusqu'à 15 et 16 mm.

Les ovaires dans le premier cycle sont courts, même à maturité; ils sont globuleux et remplis de petits oeufs dans les premiers stades, de gros oeufs dans les derniers; ils atteignent au plus le sommet des nageoires postérieures; tandis que chez les individus des cycles suivants, les ovaires mûrs sont plus longs et plus grêles; ils contiennent de même de petits oeufs dans les premiers stades et de gros oeufs, bien individualisés, dans les derniers; ils dépassent alors le sommet des nageoires postérieures et parfois même la base des nageoires antérieures (fig. 2).

Il semble que l'on puisse ramener aux premiers cycles de maturation la variété *minor* de *S. inflata* décrite en 1909 par RITTER-ZAHONY, avec une taille maximale de 12 mm, des ovaires, mûrs dès 8 mm de longeur totale, et ne dépassant pas le sommet

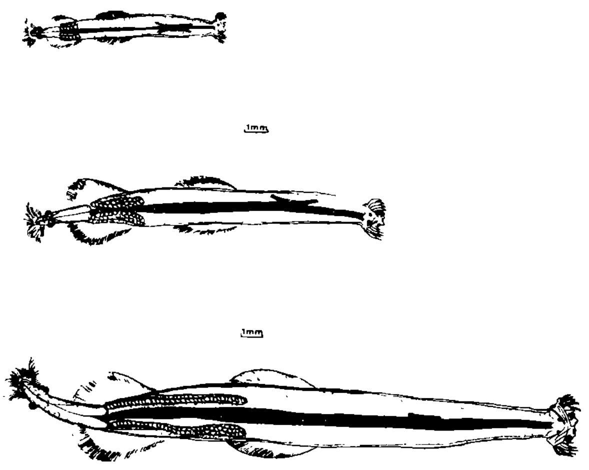

Fig. 2. *Sagitta inflata*. Spécimens mûrs des premier, deuxième et dernier cycles de maturation sexuelle. D'un cycle à l'autre, on note l'augmentation de taille (8,12 et 16 mm environ), la longeur croissante des ovaires, le nombre plus grand des oeufs.

des nageoires postérieures. De la même façon, on pourrait ramener aux cycles suivants sa variété *gardineri* décrite en 1902 par DONCASTER, avec une taille élevée pouvant aller jusqu'à 30 mm, des ovaires, mûrs seulement à partir de 16 mm de longueur totale, et arrivant à la base des nageorires antérieures.

On voit en effet que les principaux caractères qui étaient à l'origine de la distinction de ces formes, et qui reposent sur la taille des individus et celle des ovaires, sont les mêmes qui différencient les cycles sexuels successifs de l'espèce.

L'aspect extérieur de l'oeil de *S. inflata* a été reproduit sur la figure 6.

Répartition

Comme lors des pêches antérieures en Mer Rouge et dans le golfe d'Eylath, *S. inflata* est ici l'espèce la plus nombreuse. Thermophile, elle rencontre dans les régions situées entre 12° et 30° de latitude nord, un milieu favorable à son développement. Le prélèvement le plus riche correspond à une température de 28°83 en surface et 27°70 à 13 m de profondeur.

Quant aux salinités des eaux qui baignent les bancs Dahlac, elles sont assez fortes (37,39–38,60°/°°) pour les couches de surface, mais dans d'autres secteurs de la Mer Rouge, elles peuvent atteindre 40,5 à 41 °/°°. *S. inflata* supporte donc de très fortes salures, bien qu'on la mentionne en très grande abondance dans le golfe de Guinée où les teneurs sont relativement basses (35 °/°° environ).

Elle est présente ici sur toutes les stations, en proportions inégales cependant (fig. 3). La richesse de ces pêches côtières et superficielles s'accorde bien avec le caractère épiplanctonique reconnu à l'espèce.

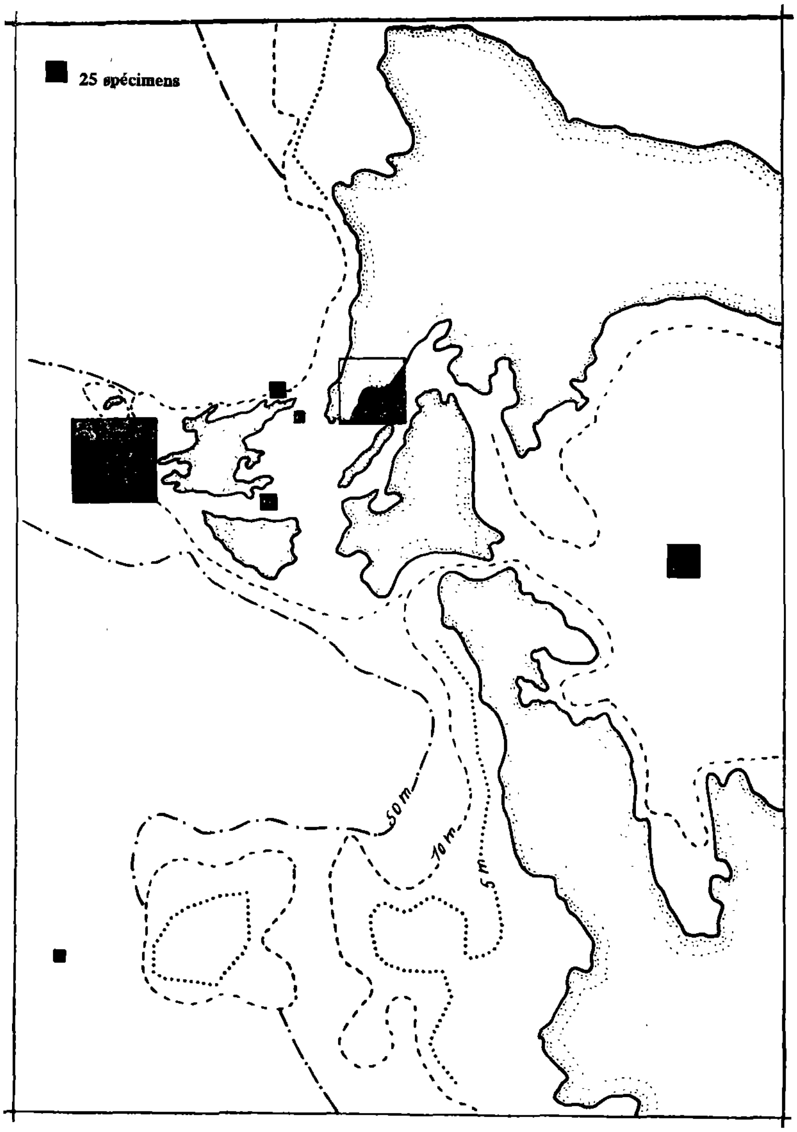

Fig. 3. Répartition de *Sagitta inflata* autour de l'archipel Dahlac (la carte est établie d'après le nombre moyen de spécimens par station).

Plus de la moitié des individus sont immatures, 30% environ ont des ébauches d'organes sexuels, le cinquième seulement est adulte. Jeunes et adultes fréquentent les mêmes zones car on les trouve ensemble aux mêmes stations.

Sagitta regularis Aida, 1897.

Nous avons précisé, sur une cinquantaine d'individus empruntés au prélèvement le plus riche (Landing Bay), les caractéristiques de l'espèce dans le secteur de Dahlac:

Longeur totale (mm)	Segment caudal % LT	Crochets	Dents antér.	Dents postér.	Stades de maturité sexuelle
3,7–6,0	29,6–26,8	6	4–6	8–12	I–II et III

La plupart des spécimens sont de très petite taille et immatures ou sexuellement peu développés. On a noté l'existence, au niveau du cou, d'une collerette que l'on distingue encore le long du tronc. La nageoire caudale est garnie de boutons épidermiques en houppes. Les vésicules séminales (fig. 4) s'observent dès 5 mm; légèrement élargies à la partie antérieure, elles vont en s'amincissant vers la nageoire caudale dont elles sont parfois séparées par un groupe de cellules sensorielles ciliées. Elles s'ouvrent latéralement. Les ovaires mûrs dépassent la base des nageoires antérieures. Les yeux sont gros et toujours bien visibles (fig. 5 et 6).

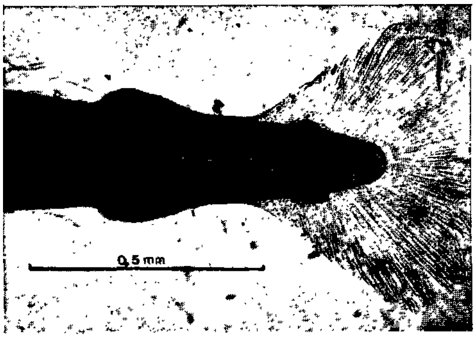

Fig. 4. *Sagitta regularis.* Segment caudal et vésicules séminales. La nageoire caudale porte deux boutons épidermiques antérieurs bien visibles et deux, postérieurs, moins nets.

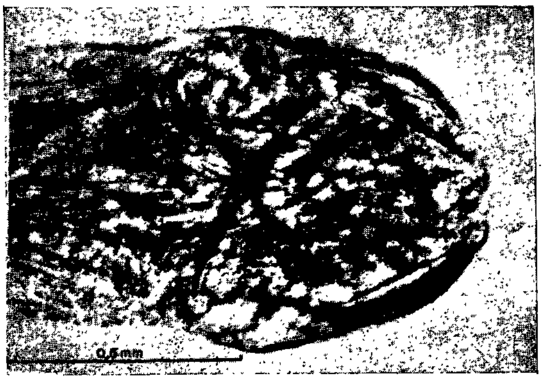

Fig. 5. ***Sagitta regularis.*** **Tête, face dorsale. On note la grande dimension des taches oculaires.**

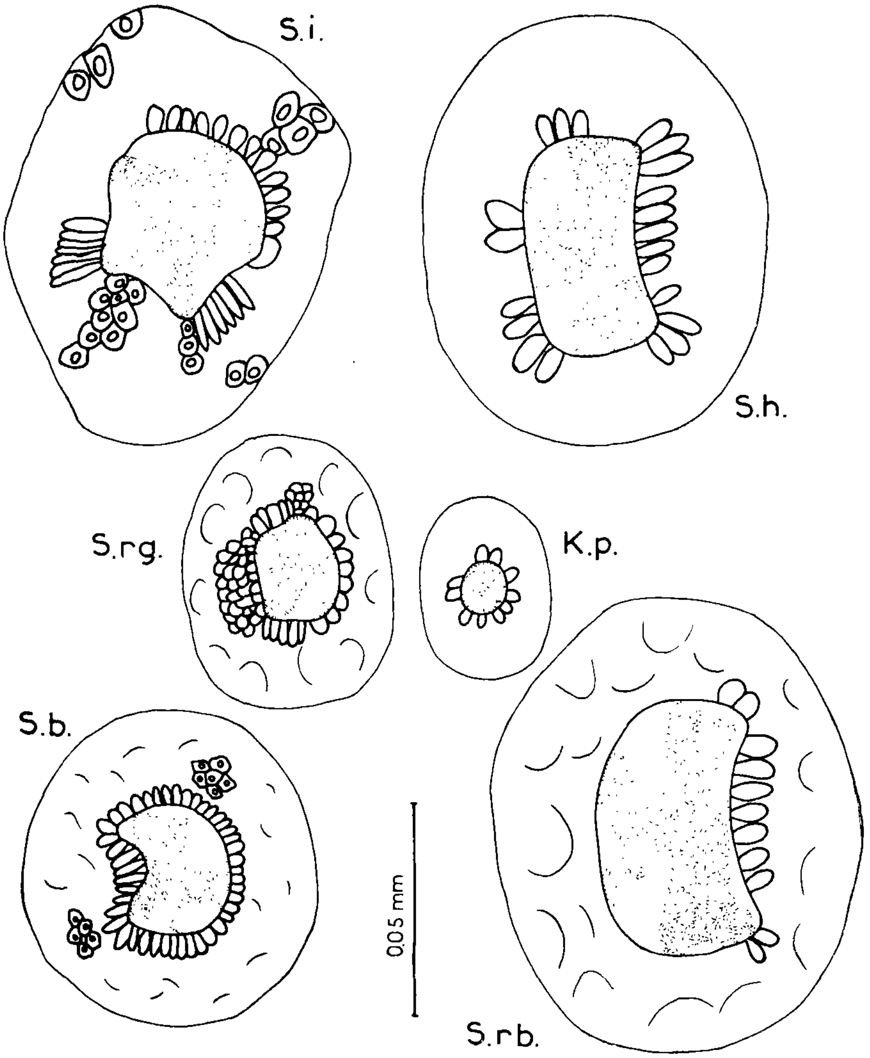

Fig. 6. Oeil gauche de *Sagitta inflata* (S.i.), *S. regularis* (S. rg.), *K. pacifica* (K.p.) et *S. bedoti* (S.b.); oeil droit de *S. hispida* (S.h.) et *S. robusta* (S. rb.).

On indiquera cependant que, contrairement aux descriptions classiques de l'espèce, la tête (fig. 5) n'est pas piriforme et que les dents postérieures sont en nombre relativement élevé.

Répartition

Déjà connue de la Mer Rouge et du golfe d'Eylath, *S. regularis* est bien représentée dans ces échantillons (près de 20%) mais très inégalement répartie (fig. 7), les prélèvements pouvant renfermer de un ou deux individus à plusieurs centaines. Le plus riche a été fait de nuit. La température des stations positives varie entre 27 et 29°5,

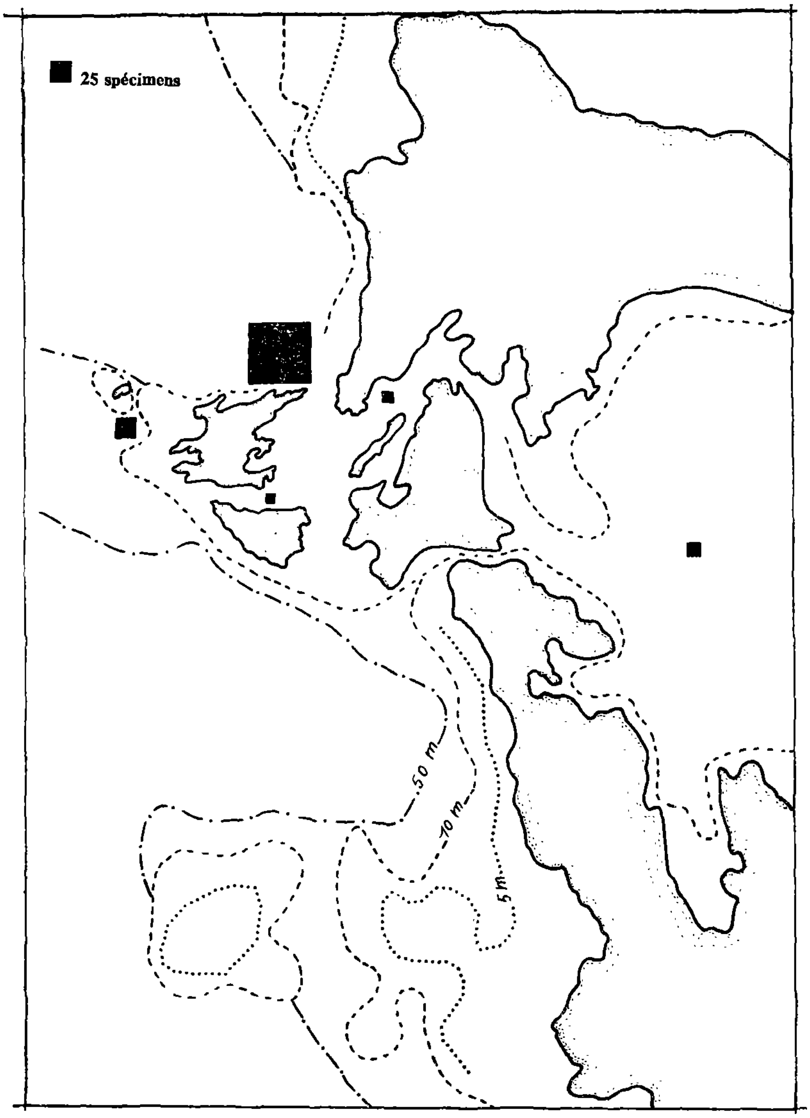

Fig. 7. Répartition de *Sagitta regularis* autour de l'archipel Dahlac (d'après le nombre moyen de spécimens par station).

la salinité entre 38,2 et 38,6 °/°°. *S. regularis*, forme thermophile, paraît être également halophile ou au moins euryhaline.

L'écologie de cette espèce est encore assez imprécise. Les trois stades de maturité sexuelle étant représentés dans ces prélèvements, on peut en déduire qu'elle effectue son cycle complet en eaux superficielles. Ce serait donc une espèce épiplanctonique. Il faut noter cependant que les immatures prédominent nettement (80 %); il n'y a que 13 % de jeunes et 7 % d'adultes.

En conclusion, *S. regularis*, bien que moins commune que *S. inflata* dans le secteur de Dahlac, semble trouver en eaux peu profondes, chaudes et à fortes salures, un milieu favorable à son maintien et à sa reproduction.

Sagitta hispida CONANT, 1895

Cette espèce est assez peu nombreuse dans le secteur de Dahlac (6% des récoltes).

Morphologie

Elle est sous sa forme la plus caractéristique, en "clou", la tête volumineuse débordant le tronc de part et d'autre du cou (fig. 8). La collerette est bien développée jusqu'au ganglion ventral et parsemée de nombreux boutons épidermiques. Comme pour les espèces précédentes, les yeux ont été figurés (fig. 6).

Fig. 8. *Sagitta hispida*. Tête, face ventrae, et partie antérieure du tronc. On remarque la collerette hérissée de soies sensorielles.

Les caractéristiques locales de *S. hispida* sont les suivantes:

Longueur totale (mm)	Segment caudal % LT	Crochets	Dents antér.	Dents postér.	Stades de maturité sexuelle
4,1–9,1	29,6–24,1	6–7	4–6	6–9	I et II

La petite taille des individus tient à leur état sexuel peu avancé; on peut supposer qu'ils dépasseraient largement 10 mm au stade III. La population comprend en effet 88% d'immatures et 12% d'individus approchant plus ou moins de la maturité sexuelle sans l'atteindre. L'absence d'adultes est probablement due au hasard des récoltes, car il est vraisemblable qu'ils vivent sur les mêmes lieux et aux mêmes niveaux approximatifs que le reste de la population.

Répartition

Sept prélèvements sur quinze renferment *S. hispida* qui a donc une répartition irrégulière dans l'archipel (fig. 9). Du reste, d'après les mentions antérieures, sa distribution semble inégale sur l'ensemble de la Mer Rouge (tabl. 2). Ceci tient peut-être aux salinités très fortes, car on sait qu'elle peuple surtout les zones relativement diluées (golfe de Guinée, par exemple). En revanche, espèce tropicale, ce ne peut être la température qui constitue pour elle le facteur limitant. C'est une forme épiplanctonique et néritique qu'il est normal de rencontrer dans des pêches telles que celles de cette campagne.

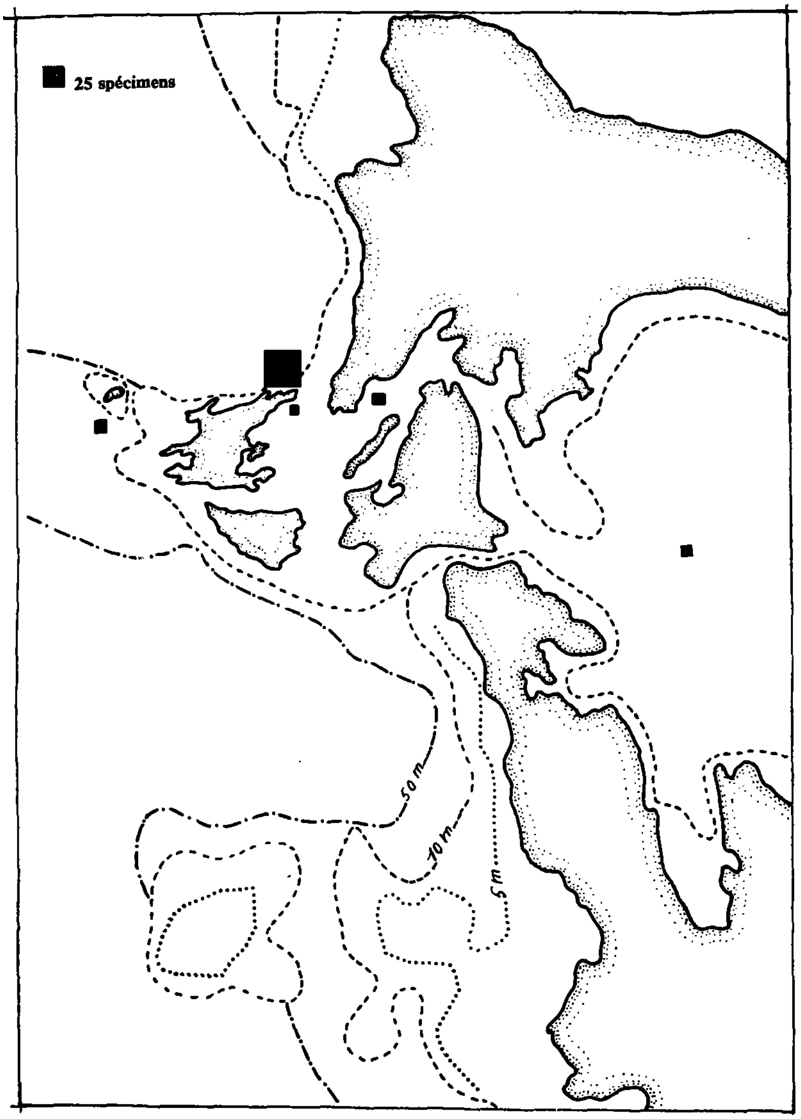

Fig. 9. Répartition de *Sagitta hispida* autour de l'archipel Dahlac (d'après le nombre moyen de spécimens par station).

Krohnitta pacifica AIDA, 1887.

K. pacifica est relativement rare (2% environ).

Morphologie

Ses caractéristiques peuvent être résumées ainsi:

Longeur totale (mm)	Segment caudal % LT	Crochets	Dents	Ovaires % LT	Stades de maturité sexuelle
4,0–6,5	34,7–29,1	7–9	11–13	16,2–22,5	II et III

Malgré ces dimensions restreintes, de nombreux spécimens sont mûrs. Les adultes représentent en effet 43,4% des récoltes et c'est la seule espèce dont la proportion d'individus mûrs soit plus forte que celle des immatures (20%).

L'allométrie négative affectant la croissance du segment caudal est caractérisée. Les ovaires mûrs dépassent nettement le bord antérieur des nageoires latérales. Les yeux ont été représentés (fig. 6). Ils sont relativement petits, très proches l'un de l'autre et en position très postérieure sur la tête; ils renferment une tache pigmentée circulaire.

Répartition

K. pacifica a été identifiée dans six récoltes dont deux seulement relativement riches, les autres ne comportant que des individus isolés (fig. 10). Peut-être les fonds sont-ils trop faibles autour de l'archipel pour convenir à une espèce, épiplanctonique certes, mais qui n'est pas absolument néritique. Quoi qu'il en soit, elle n'avait pas été signalée en Mer Rouge. Sa présence dans toute la partie nord-ouest de l'Océan Indien, et notamment dans le golfe d'Aden (CODACCIONI, 1965), suggère un transport par le détroit de Bab-El-Mandeb dans le sud de la Mer Rouge, bien que le nombre des captures (55 spécimens) puisse laisser supposer l'existence d'un petit peuplement local permanent.

Sagitta bedoti BERANEK, 1895.

Elle est rare dans le secteur de Dahlac: les prises ne totalisent que 8 spécimens (fig. 11). Malgré ce petit nombre, les trois stades de maturité sexuelle sont représentés.

Morphologie

Ses caractéristiques correspondent bien aux descriptions antérieures, notamment celle d'échantillons de l'Océan Indien et du golfe d'Aden (GHIRARDELLI, 1947).

Rappelons les principales, pour compléter le tableau des mensurations donné ci-après:

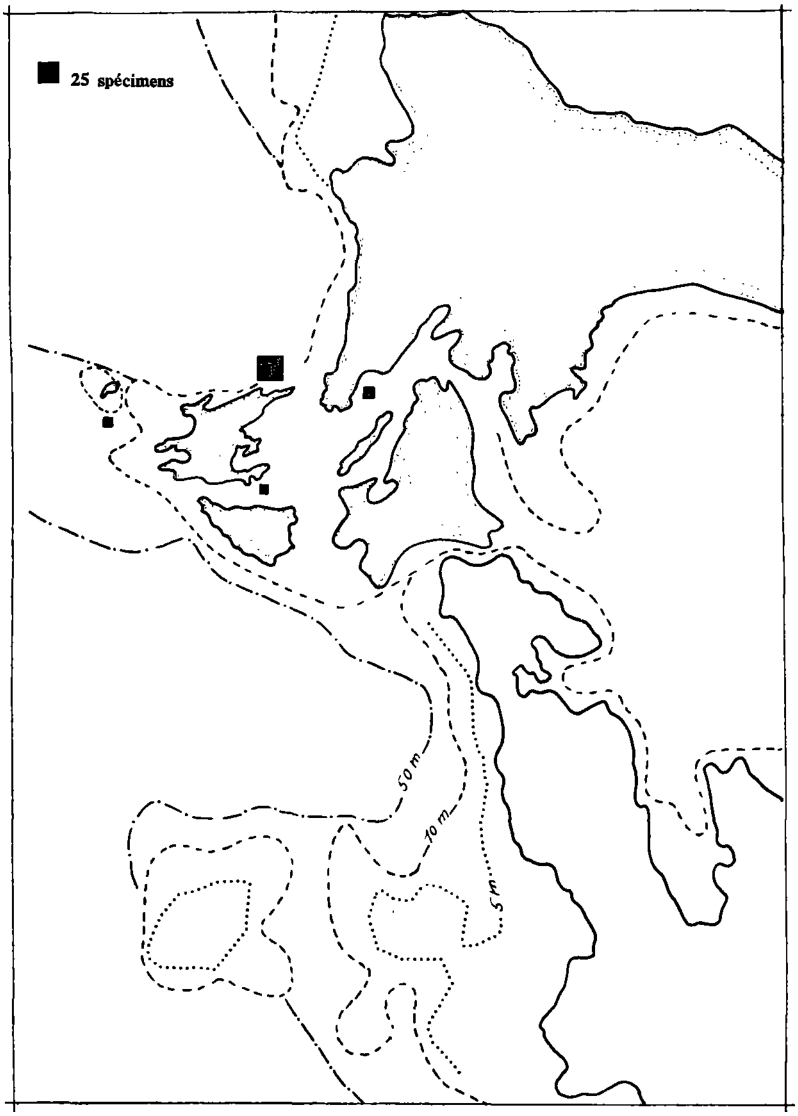

Fig. 10. Répartition de *Krohnitta pacifica* autour de l'archipel Dahlac (d'après le nombre moyen de spécimens par station).

Longueur totale (mm)	Segment caudal % LT	Crochets	Dents antér.	Dents postér.	Ovaires % LT	Stades de maturité sexuelle
6,4–8,5	24,4–22,5	6–7	8–12	12–26	4,5–7,6	II
					21,0	III

Le caractère le plus net est le nombre très élevé de dents, sutout celles de la rangée postérieure, pour une espèce de petite taille (fig. 12). Les diverticules intestinaux sont

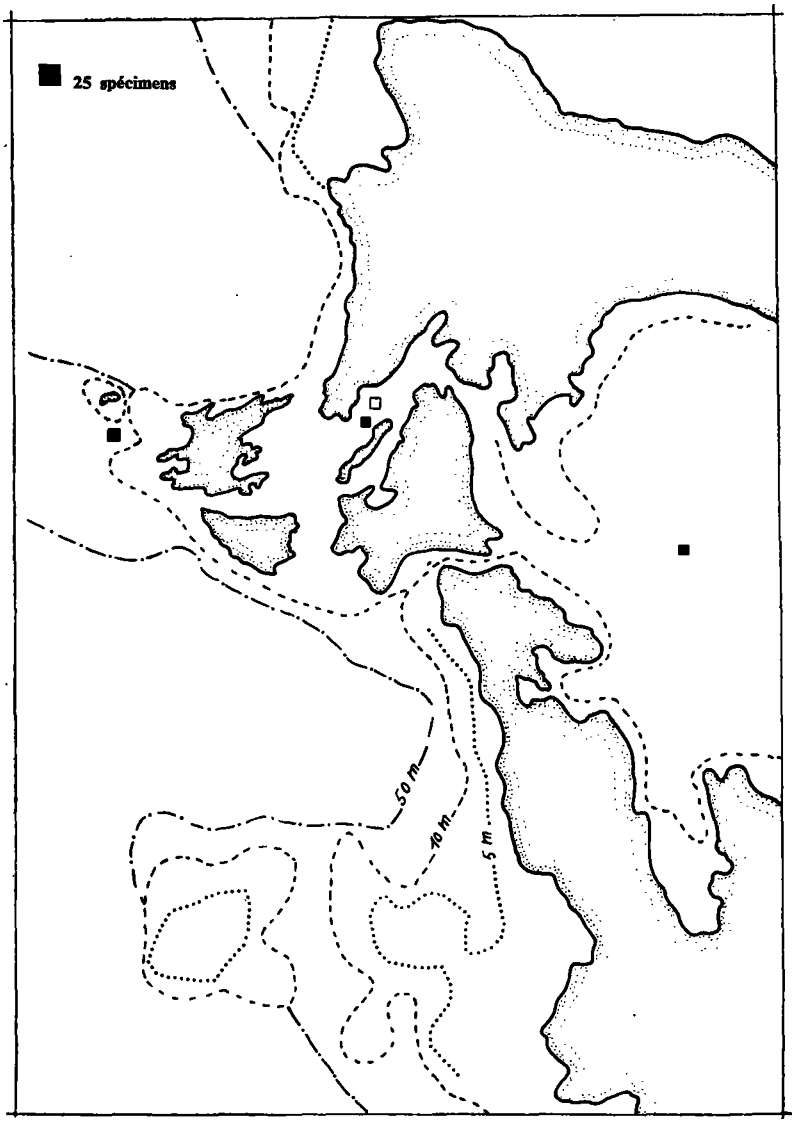

Fig. 11. Répartition de *Sagitta bedoti* (carrés noirs) et de *Sagitta robusta* (carrés blancs) autour de l'archipel Dahlac (d'après le nombre moyen de spécimens par station).

bien individualisés. L'oeil, avec une tache pigmentaire centrale incurvée en croissant, rappelle celui de *S. hispida* (fig. 6). Les ovaires, infléchis vers les parois du corps au niveau de la constriction caudale et contenant des oeufs de taille différente sur deux files, sont accompagnés par des réceptacles séminaux en cordons opaques. Les vésicules séminales, globuleuses mais sans tête différenciée, s'ouvrent latéralement. Très proches des nageoires postérieures, elles sont réunies à la caudale par un pont tégumentaire (fig. 13).

Fig. 12. *Sagitta bedoti.* Tête, face dorsale. Les dents postérieures, très nombreuses et très longues, rejoignent celles de la série antérieure, plus courtes et disposées en demi-cercle. L'oeil gauche est visible sous forme de la tache pigmentée incurvée en croissant.

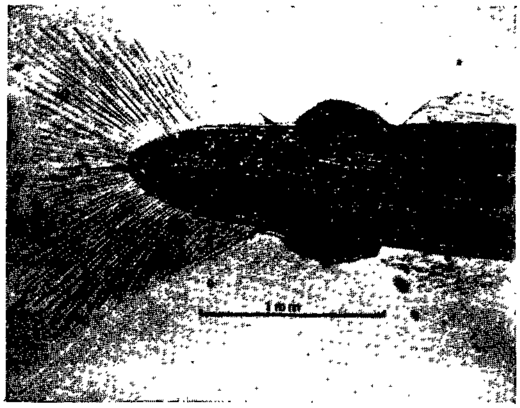

Fig. 13. *Sagitta bedoti.* Partie postérieure du segment caudal et vésicules séminales mûres.

Répartition

Rare dans l'archipel Dahlac, nous l'avons dit, *S. bedoti* doit l'être aussi sur l'ensemble de la Mer Rouge car elle n'y avait encore jamais été signalée. Or elle a été mentionnée à plusieurs reprises au voisinage (golfe d'Aden et côte des Somalies: GHIRARDELLI, 1947) et c'est un hôte habituel de l'Océan Indien. DONCASTER, par exemple, note sa grande abondance autour des îles Maldives et la tient pour une espèce caractéristique de l'Indo-Pacifique.

On peut donc la considérer comme un élément transporté assez sporadiquement de l'Océan Indien dans la partie méridionale de la Mer Rouge à travers le détroit de Bab-El-Mandeb. Après ec transport, elle se maintiendrait dans les secteurs néritiques, tel celui de Dahlac, conservant le caractère côtier qui lui est attribué dans les océans Pacifique et Indien où elle peuple généralement les zones de faible profondeur (TOKIOKA 1959, 1962).

Sagitta robusta Doncaster, 1902.

La présence de l'espèce dans ces prélèvements est réduite à deux individus (fig. 10) qui ont permis l'observation assez précise des particularités suivantes: la taille respective de ces sujets mûrs est de 11 et 13 mm. La collerette, relativement développée, est discernable du cou aux vésicules séminales; les nageoires postérieures comportent, au niveau des papilles génitales, une zone semi-elliptique dépourvue de rayons. Les ovaires, particulièrement longs, font 58 à 60% de la LT et atteignent la région du cou; les papilles génitales sont très saillantes; les vésicules séminales, renflées dans la partie antérieure, se prolongent en avant, le long des nageoires postérieures, par une bande tégumentaire étroite (fig. 14). Les yeux, volumineux, renferment une tache oculaire pigmentée subrectangulaire importante (fig. 6).

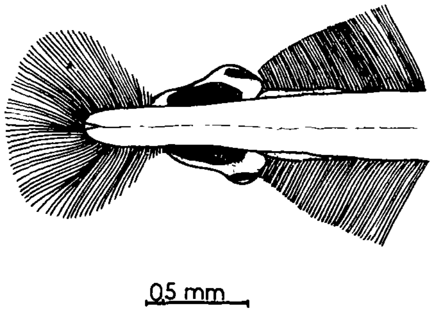

Fig. 14. *Sagitta robusta.* Segment caudal et vésicules séminales mûres.

Longueur totale (mm)	Segment caudal % LT	Crochets	Dents antér.	Dents postér.	Ovaires %LT	Stades de maturité sexuelle
11–13	29	6	6	8–10	58–60	III

Citée pour la première fois de la Mer Rouge, *S. robusta* paraît y être très rare, alors qu'elle est répandue dans le Pacifique et l'Océan Indien d'où elle a été décrite (îles Maldives). Elle se rencontre notamment dans tout le nord-ouest de cet océan, avec une abondance plus grande en Mer d'Arabie et dans le golfe d'Aden (Codaccioni, 1965). Comme pour *S. bedoti*, il semble vraisemblable d'admettre son transport en Mer Rouge à partir du peuplement de l'océan voisin.

⁂

Les pêches planctoniques effectuées en 1962 dans les eaux de l'archipel Dahlac ont rapporté un échantillonnage de Chaetognathes relativement abondant (près de 2500 spécimens) mais peu varié (6 espèces) dont l'étude a présenté un triple intérêt: celui d'établir l'inventaire et les proportions numériques des diverses espèces peuplant le secteur, celui de compléter les connaissances relatives au peuplement de Chaetognathes de la Mer Rouge, enfin celui de préciser les relations faunistiques entre cette dernière et l'Océan Indien.

Les résultats antérieurs ont été confirmés par la capture d'espèces comme *S. inflata*, *S. regularis* et *S. hispida*, déjà connues de la Mer Rouge et très largement représentées dans l'Océan Indien. *S. inflata* serait le plus commun des Chaetognathes épiplanctoniques de la Mer Rouge; *S. regularis* en serait également un élément caractéristique. Quant à *S. hispida*, sa pullulation serait empêchée en certains points par les teneurs en sel trop élevées.

Cependant, plusieurs espèces précédemment récoltées en Mer Rouge ne figurent pas dans les prélèvements étudiés: *S. bipunctata*, *S. serratodentata*, *S. pacifica*, *S. hexaptera*, *P. draco* et *K. subtilis*. Leur absence s'explique du reste par le caractère néritique des eaux entourant l'archipel. En effet, *S. bipunctata* appartient normalement à l'épiplancton du large, *S. serratodentata*, *S. pacifica*, *P. draco* et *K. subtilis* font partie du mésoplancton (couches de 200 à 500 m) et *S. hexaptera*, du bathyplancton (couches inférieures à 500 m). Il était donc peu probable qu'on les rencontre sur l'aire prospectée.

En revanche, nous avons montré la présence de trois Chaetognathes encore non mentionnés (*K. pacifica*, *S. bedoti* et *S. robusta*), portant à 12 le nombre d'espèces actuellement connues en Mer Rouge.

Pour les deux dernières au moins de ces formes nouvelles, typiquement indopacifiques et plusieurs fois signalées du golfe d'Aden, il semble que l'on puisse invoquer, à partir de l'Océan Indien, un transport plus ou moins sporadique et limité au sud de la Mer Rouge, dont l'irrégularité et la localisation expliqueraient à la fois la rareté de ces espèces et le fait qu'elles aient échappé jusqu'ici aux investigations. Le cas de *P. draco*, observée à raison d'un seul spécimen dans le détroit de Bab-el-Mandeb (GHIRARDELLI, 1947) mais en abondance dans le golfe d'Aden (CODACCIONI, 1965), serait analogue.

On peut donc considérer le peuplement de l'archipel Dahlac comme constitué par un petit nombre de formes néritiques et épiplanctoniques pérennes (*Sagitta inflata*, *S. regularis*, *S. hispida* et peut-être *K. pacifica*), sporadiquement enrichi par l'arrivée de transfuges issus du golfe d'Aden (*S. bedoti* et *S. robusta* notamment, sans doute aussi *P. draco*).

RÉSUMÉ

Le matériel étudié a été récolté au cours de l'expédition israélienne de 1962 dans le sud de la Mer Rouge, en mars et avril, en surface ou subsurface par pêches horizontales ou verticales (100-0m) entre 8 et 9 h le matin, ou la nuit pour quelques-unes.

Cette étude a permis d'établir l'inventaire et les proportions numériques des diverses espèces peuplant le secteur, de compléter la connaissance du peuplement de Chaetognathes de la Mer Rouge et de préciser les relations faunistiques de cette dernière avec l'océan Indien.

2477 Chaetognathes ont été déterminés. Ils comprennent 6 espèces: *Sahitta inflata*, *S. regularis* *S. hispida*, *S. bedoti*, *S. robusta*, *K. pacifica*.

Ce sont toutes des formes néritiques ou semi-néritiques et de surface ou de subsurface mais leur abondance relative est très inégale. *S. inflata* est largement dominante. Ce serait le plus commun des Chaetognathes de la Mer Rouge. *S. regularis* en serait aussi un élément caractéristique.

Trois des espèces sont pour la première fois signalées de la Mer Rouge: *K. pacifica*, *S. bedoti* et *S. robusta*. Les deux dernières, typiquement indo-pacifiques et déjà mentionnées du golfe d'Aden, sont vraisembleablement transportées plus ou moins sporadiquement dans le sud de la Mer Rouge. Il semble en être de même de *Pterosagitta draco* qu'on n'a encore citée que du détroit de Bab-El-Mandeb.

Au total, 12 espèces sont actuellement connues en Mer Rouge mais cinq, récoltées par d'autres auteurs, ne figurent pas dans ces collections: *S. bipunctata*, *S. serratodentata*, *S. pacifica*, *S. hexaptera* *K. subtilis*. Leur absence s'explique par le caractère néritique des eaux entourant l'archipel Dahlac.

SUMMARY

The material reported on in this paper was collected during the Israel South Red Sea Expedition, March–April 1962. The samples were taken in horizontal and vertical (100–0m) hauls, either in the morning at 8–9 h, or at night.

The present study establishes the species inventory of the investigated area as well as their part in the species composition. The material in hand supplements our knowledge of the Red Sea chaetognaths and helps formulating the faunistic interrelations between the latter and those of the Indian Ocean.

2477 chaetognaths specimens were identified, belonging to 6 species: *Sagitta inflata*, *S. regularis*, *S. hispida*, *S. bedoti*, *S. robusta*, and *Krohnitta pacifica*. All of them are neritic or semi-neritic forms and members of the surface and subsurface plankton; however, their relative abundance is strikingly different. *S. inflata* is, by and large dominant. It probably is the most common of the Red Sea species. *S. regularis* is as well a substantial Red Sea element.

The three species new to the Red Sea are *K. pacifica*, *S. bedoti* and *S. robusta*. The two latter species which are typically indo-pacific elements and have already been indicated for the Gulf of Aden, are probably more or less sporadically transported into the southern section of the Red Sea. This seems to be the case also regarding *Pterosagitta draco* which has so far been reported only from the Straits of Mandeb.

Altogether, 12 species of chaetognaths are known to occur in the Red Sea, but five of them, collected by other authors, are not included in the present collection: *Sagitta bipunctata*, *S. serratodentata*, *S. pacifica*, *S. hexaptera* and *Krohnitta subtilis*. Their absence is explained by the neritic nature of the seas which surround the Dahlak Archipelago.

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Reprinted from *Bull. Sea Fish. Res. Sta., Haifa*, no. 52, 1968, p. 21-55

ISRAEL SOUTH RED SEA EXPEDITION, 1962, REPORTS
No. 33

REPORT ON THE FISHERIES INVESTIGATIONS OF THE ISRAEL SOUTH RED SEA EXPEDITION, 1962*

by
A. BEN-TUVIA**
Sea Fishesies Research Station, Haifa

CONTENTS

INTRODUCTION

One of the purposes of the Israel South Red Sea Expedition (ISRSE) which took place during March and April of 1962 was to collect data on the fisheries resources of the Ethiopian coast.

The information gathered is incorporated with other data collected by the author, to form a preliminary account of the biology and distribution of commercial fishes and invertebrates in the Red Sea and the possibilities of their commercial exploitation. The present paper is based on an earlier report on the fisheries resources of the Red Sea published in Hebrew (BEN-TUVIA, 1963) which gave a brief survey. The material, in addition to that of the ISRSE, includes observations made in Eilat since 1949, some data from experimental fishing along the coast of Eritrea in 1957–1958 and those collected during a brief survey along the Sinai Peninsula in 1956. The collections of the Sea Fisheries Research Station, Haifa, the Hebrew University of Jerusalem, and Tel-Aviv University were available for study. These together form one of the largest collections of Red Sea Fishes and total approximately 600 species.

Some fisheries investigations have been made along the coasts of the countries bordering the Red Sea (SANTUCCI, 1934; BERTRAM, 1953; ANONYMOUS, 1954b; KRISTJONSSON, 1956; ANONYMOUS, 1958; BEN-TUVIA, 1958; ANONYMOUS, 1959; ANONYMOUS, 1962; BEN-YAMI, 1964, 1966). In general, however, the statistical and biological data are grossly inadequate for the assessment of the resources and additional studies are strongly recommended.

Received: March 1967

* Supported by contract No. 62258–3335 between the U.S. Office of Naval Research, Department of the Navy, and Tel-Aviv University.

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General Information on the Red Sea

The coasts of the Red Sea stretch from Eilat and Suez in the north to the Strait of Bab-el-Mandeb in the south, a distance of about 2,200 km (1,200 miles). It attains a maximum breadth of 352 km (190 miles) in the southern part near Massawa.

The fishing grounds can be divided into four areas, according to the type of fishing and the present state of exploitation.

1. Gulf of Eilat (Aqaba) — deep and completely unsuitable for trawling;
2. Gulf of Suez — rather shallow and with many banks suitable for trawling;
3. The northern section of the Red Sea proper — mostly deep and not good for trawling;
4. The central and southern Red Sea — fairly rich in fishes and with extensive banks for trawling.

It is unlikely that the primitive fishing methods at present used along the Red Sea coast can fully exploit local resources. The available material provides an estimate of the average total annual catch as approximately 39,380 metric tons of fishes (Table I).

TABLE I

The Estimated Average Annual Catch of Marine Fishes of the Countries Bordering the Red Sea

Country	Catch in tons	Sources of information
Ethiopia	14,000	Ben-Yami (1964)
Israel (Eilat)	200	Author's estimate
Jordan (Aqaba)	180	Anonymous (1966a)
Kamaran I.	500	Author's estimate
Saudi Arabia	5,000	Anonymous (1966b)
Sudan	300	Kristjonsson (1956)
UAR (Red Sea and Suez Canal)	16,700	Mietle (1966)
Yemen	2,500	Kerr (1966)
Total	39,380	

Sources of Data

Israeli fisheries research and some experimental fishing was started in Eilat in 1949 and this provided the preliminary information on the marine resources and possibilities of commercial exploitation in this area. Additional information was obtained during a survey along the coast of the Sinai Peninsula in the year of 1956 (Oren et al., 1956). In 1957 and 1958, experimental trawl fishing and biological investigations were carried out along the coast of Ethiopia. This was followed by the establishment of a successful trawl fishery. Much valuable material was collected on the biology and hydrography of the area during the ISRSE in the spring of 1962 (Oren, 1963).

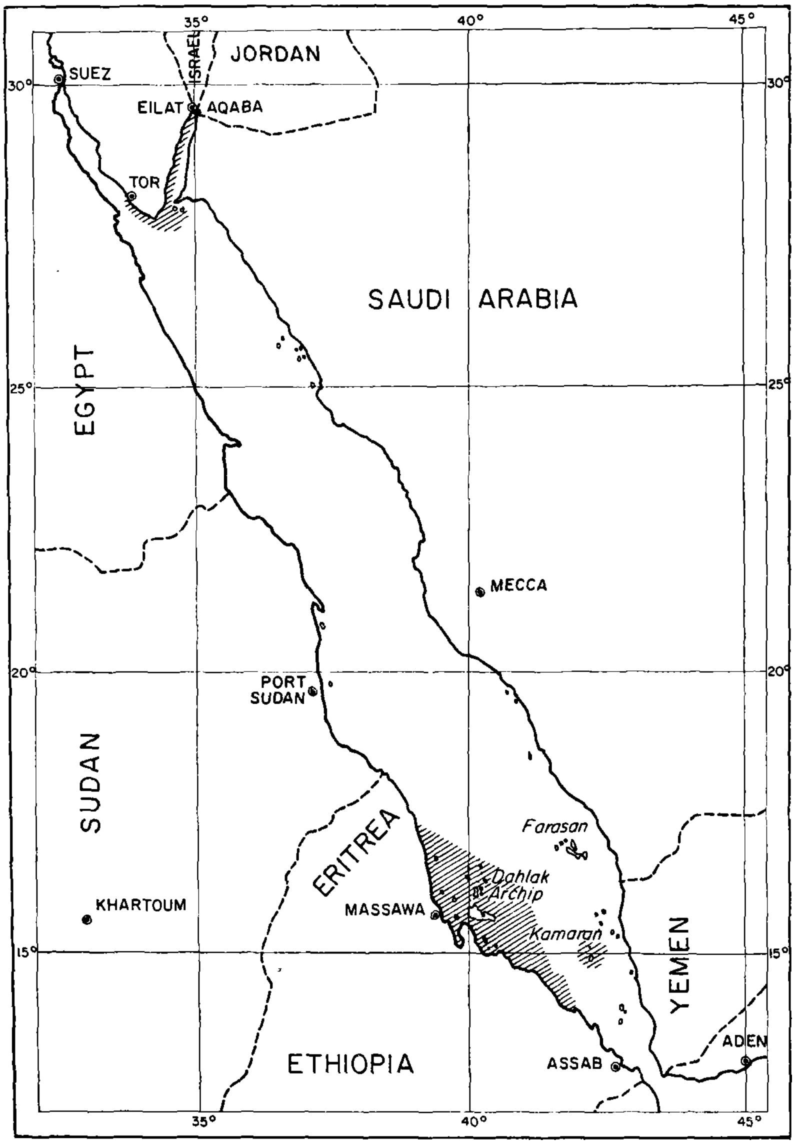

Fig. 1. Red Sea. The shaded areas were explored for living resources, by Israel teams.

Data on fish and fisheries resources were also collected at that time in the area of the Dahlak Archipelago and that of Massawa. The material was collected in the following ways:

1. Trolling gear, from a fibreglass boat, 4 meters long, propelled by an outboard motor of 15 h.p. — the trolling speed was usually about five knots. With this method, mostly large pelagic fishes were caught. Bottom fishes were occasionally caught in shallow waters 3–6 meters deep.
2. Small-meshed beach seine operated by two people used in shallow waters for collecting small fishes.
3. Trammel net set on two occasions only; it proved to be unsuitable for the rough ground of the area covered almost everywhere by small corals and stones which got entangled with the delicate webbing and prevented effective use of the net.
4. Underwater spearing.
5. Fishing by commercial boats: the Fishing Vessel *Stella* was engaged for a three-day trip in experimental purse seining for scombroids (the crew also did some commercial beach seining on this trip). Observation and material was also obtained during a one-day trip on a small trawler engaged in commercial fishing near Massawa.
6. "Pro-noxfish" poison used extensively in shallow coastal water.
7. Special survey of coastal fish community on Entedebir Island (CLARK et al., 1967)

Length measurements of specimens are standard lengths unless otherwise stated.

PELAGIC FISHERIES

No specialized fishing methods are at present in use for the capture of pelagic fishes in the Red Sea. They are mostly of a primitive character and confined to use of beach seines, gill-nets and hooks. The catch is composed almost totally of sardine and anchovy and amounts to about 10,000 tons per annum. Exploratory pelagic fishing was carried out by the Fisheries Department of Israel in the southern part of the Red Sea, during February and March 1962 (PORAT, 1962). The F/V *Stella* was engaged for this period to carry out the investigations. The author joined the group on one of their trips and frequently observed schools of jumping scombroids, particularly in the Zula Bay. On one occasion, 26 specimens of *Auxis thazard* and 2 specimens of *Euthynnus affinis* were captured.

From the various observations and studies made in this area, and particularly from the exploratory fishing carried out under the FAO/TA Project in 1964, (ANONYMOUS, 1967) there is a strong indication that a more extensive pelagic fishery could be developed. If the local stocks of *Thunnus*, *Auxis*, *Euthynnus*, *Scomber* and *Rastrelliger* were exploited, there should be a sufficient supply for a canning industry.

Various fishing gear and methods were tried by Israeli fishermen in the Red Sea but with limited results:

1. purse seine for scombroids,
2. trolling gear,

3. Japanese longlines,
4. beach seines,
5. gill nets,
6. fishing with artificial lights and purse seine.

The latter fishing method, commonly used in the Mediterranean for sardines and other small inshore-pelagic fish, seems to be ineffective in the Red Sea, as indicated by several attempts in Eilat and Massawa. Only small quantities of fish, mostly silversides (Atherinidae) were attracted by the lights. The important clupeoid fishes, such as *Sardinella sirm*, *Herklotsichthys* (*Harengula*) *punctata* and *Stolephorus heterolobum*, which are abundant in the southern Red Sea, do not appear near the lights in commercial quantities.

It is interesting to note that encouraging results with purse seining in association with light attraction have been obtained in the Zanzibar Channel (LOSSE, 1964).

TRAWL FISHERIES

Extensive data were collected during exploratory trawling trips along the coast of Ethiopia during the period of August 1957–May 1958 (ANONYMOUS, 1959), promoted by the Department of Fisheries, Ministry of Agriculture of the Government of Israel. The author participated in a number of these trips and collected a large quantity of material, mostly on the deck of the trawler, *Neghisti Saba*. As a result of this exploratory fishing, four modern trawlers began to work along the Ethiopian coast and their catch was sent to the Israel market through the port of Eilat. Their total annual catch for the period 1958–1965 is given in Table II, which is based on data taken from the statistical report "Israel Fisheries in Figures" of the Israeli Ministry of Agriculture, Department of Fisheries.

A considerable decrease in yearly catches can be noted for the period 1963–1965 as compared with 1961–1962. The explanation for it lies in the fact that up to the end of 1962 a special transport vessel subsidized by the Government of Israel was operating between Massawa and Eilat. This service was discontinued after 1962 and the trawlers transported their catches themselves, which resulted in a decrease of the number of fishing days. However, no pronounced decrease in catch per unit of effort was noticed during this period.

Some trawling has been carried on for the past fifteen years off the coast of Massawa by 3 to 4 small local trawlers. These supply small quantities of fish, crustaceans and molluscs to the local market, where the demand is mostly for flat fish, groupers, snappers and particularly for squids and shrimps.

These trawlers are old and use gear and nets of poor quality. It is not surprising that their catches are low, particularly since they have been fishing continuously on the same grounds in Harkiko Bay for many years. As not all the edible fishes are accepted on the local market, the profits are low.

The author joined one of these small trawlers in April 1962 and recorded the daily catch. The fishing started at 4.00 a.m. and continued until 4.00 p.m., one haul being made every four hours. The total commercial catch for the day consisted of two

TABLE II

Catches (in tons) of Israeli Trawlers in Ethiopian Waters

Year	Catch	Number of trawlers
1958	65.1	1
1959	55.4	1
1960*	180.0	3
1961*	930.0	3
1962	1,030.0	4
1963	562.5	4
1964	645.0	4
1965	686.7	4

* About 20% of the catch was obtained by hooks.

boxes of large shrimps, two boxes of squids, two boxes of flatfish (*Psettodes*) and four boxes of medium and large fishes. Other fishes, such as medium and small lizard fish and golden-threadfin, do not sell on the local market and are normally thrown out overboard. Including the non-commercial fishes, the total daily catch amounted to 30 boxes or 3.3 boxes (about 50 kg) per hour of trawling.

The catches of the newer trawlers operated by mixed Israeli and Ethiopian crews are much higher. According to the data collected by the author on the deck of the F/V *Neghisti Saba* during its exploratory fishing trip September–December 1957, the catch per unit of effort (hour of trawling) was 17.2 boxes (258 kg) of marketable fishes in the area south of Massawa and 17.3 boxes (260 kg) in the area north of Massawa. This catch per unit of effort was calculated after eliminating the unsuccessful hauls resulting from working on unfamiliar fishing grounds, where occasional rocks damaged the nets. On including the unsuccessful hauls, the catch per unit of effort amounted to 13.9 boxes (208 kg). The catch of this same vessel fishing on entirely commercial trips during the period June 1958–February 1959 averaged 19.1 boxes (287 kg) per unit of effort.

An Italian trawler, of a size and gear similar to that of the *Neghisti Saba* was engaged in exploratory fishing along the coast of Saudi Arabia during December 1952–March 1953 (Anonymous, 1954b) and obtained much lower catches: 11.5 boxes (172.6 kg) of commercial fishes per hour of trawling. Its largest landings were obtained near Kunfida, about 200 miles north of Massawa along the Saudi Arabia coast. Twelve hundred kg of fish were caught during two hours and 50 min. at 17–19 fathoms depth. North of Kunfida the catches were much lower, which may indicate that the northern part of the Red Sea is less productive than the southern part.

The comparatively large catches taken along the Ethiopian coast indicate the high productivity. They are mostly composed of small and middle size fishes of rather low commercial value. As shown in Table III, about half of the catch, 51.6%, consists of lizard fish (*Saurida tumbil*), and 31.3% of golden-threadfin (*Nemipterus japonicus*). Together they constitute almost 83% of the commercial trawl fishes. Other fishes of commercial importance were: goat fish (*Upeneus moluccensis*) and barracuda (*Sphyraena* sp.sp.). These catches resemble those taken in the eastern Mediterranean along the coast of Israel and Southern Anatolia which consist also largely of lizard fish (*Saurida undosquamis*) and pandora (*Pagellus erythrinus*), a fish resembling closely in form and size the golden-threadfin.

TABLE III

COMPOSITION OF THE CATCH OF THE F/V *Neghisti saba* DURING SEPTEMBER–DECEMBER 1957

	Lizard fish		Golden-threadfin		Goat fish barracuda		Other fishes		Total
	small	large	small	large			small	large	
Number of boxes	59	265	63	134	12	33	31	32	629
Percentage	9.3	42.3	10.0	21.3	1.9	5.3	4.9	5.0	100%

Table III shows that the total catch of commercial fishes during exploratory fishing in 1957 amounted to 629 boxes (15 kg/box) which is approximately equal to 9 metric tons. In addition to it, 70 boxes of elasmobranchs and small quantities of squids and crustaceans were caught.

During the years of 1960–1965, three to four trawlers with a mixed Israeli-Ethiopian crew operated in the southern Red Sea. The skippers of these boats complained that in 1962 the catch dropped considerably on the fishing grounds near Massawa, from Sheikh-El-Abu in the north to Umm-Es-Sarig in the south. During the spring and summer of 1962, most of the fishing vessels were working close to Shab Shakhs or even further south. It was assumed that intensive fishing in the vicinity of Massawa reduced the yield. In the autumn of the same year, the fishermen found the Massawa fishing grounds profitable again and resumed their work in those areas. This quick recovery suggests that natural factors, rather than over-fishing, played the major role in the temporary decrease of catches. Trawling grounds along the Ethiopian coast extend hundreds of miles to as far south as Assab or even further south, but fishing there presents additional difficulties such as a sea that is often rough, and the lack of harbour facilities. The fishing grounds in the vicinity of Massawa are, for the time being, very important and their resources should be investigated thoroughly, in order to prevent over-fishing. There is no doubt that the fishing grounds along the coast of Ethiopia are rich enough to support the present, or an increased, number of trawlers without danger of depletion of the resources. It is feasible to enlarge the trawler fleet. However, it would be preferable to employ large modern trawlers that could work on more distant grounds.

HOOK AND LINE FISHING

Experimental line fishing along the coast of Ethiopia was tried in 1960 with a small commercial F/V *Stella* (ARIAV, 1961). Encouraged by its success, the trawlers also spent some time during 1960–1961 fishing by hook-and-line. Red snapper (*Lutjanus gibbus*) formed the greater portion (57%) of the catch (Table IV), along with other lutjanids, serranids, lethrinids, carangids and pomadasyids. The mixed Ethiopian and

Israeli crews worked in the area of the Dahlak Archipelago at depths varying from 10 to 60 fathoms. Each fisherman used a single line with one or two hooks attached. The best fishing areas for hook-and-line were over rocks and corals. The catch varied greatly according to fishing grounds and season. Occasionally, each fisherman could land as much as 15 large fishes an hour (total weight 50–100 kg) but the average weight per catch was much lower. From the data for 1960 (Table V) the average catch per angler per hour was 14.52 kg. This calculation is based on the assumption that one box of large fish equals 20 kg.

The fishes caught by hook-and-line were sold in Israel but at low prices, as the red snapper is not considered a high quality fish. Thus one-and-a-half years after the initial enthusiasm, this fishery was discontinued in 1962 because of poor profits.

TABLE IV

CATCH COMPOSITION OF HOOK-AND-LINE FISHING, SEPTEMBER–DECEMBER 1960

Group of fishes		Number of boxes	%
Red snapper	(*Lutjanus gibbus*)	311	57.2
Groupers	(Serranidae)	92	16.9
Scavengers	(Lethrinidae)	85	15.6
Varia		56	10.3
total		544	100.0

TABLE V

HOOK AND LINE CATCHES, SEPTEMBER–DECEMBER 1960

Date	Number of fishermen	Hours	Catch in boxes
15. 9.60	7	4.5	35
18. 9.60	7	3.0	20
19. 9.60	7	2.0	17
22. 9.60	6	3.0	71
27. 9.60	6	2.5	71
12.10.60	8	6.5	24
13.10.60	8	14.5	57
14.10.60	8	2.0	3
17.10.60	8	6.5	37
18.10.60	8	14.5	46
16.12.60	7	9.0	25
18.12.60	6	6.0	40
19.12.60	6	12.0	20
21.12.60	8	14.0	68
22.12.60	8	4.0	10
Total	108	104	544
Average	7.2	6.93	36.27

INSHORE FISHERIES

Under this heading are included various fishing methods used in shallow inshore waters. Fishing with the beach seine used successfully in Eilat and in the southern Red Sea, is one of the common methods, as is fishing with gill-nets, trammel nets, cast nets and traps.

On March 22, 1962, the author was able to observe the use of a beach seine by the crew of the *Stella* on the eastern shore of the Zula Bay opposite the village Aliberate. The majority of the fishes were caught early in the night during the first haul; only a few were taken in the second haul. The total catch amounted to about 300 kg. Six fishermen were engaged in fishing and one haul lasted approximately one hour. The catch consisted of carangids, belonids, hemiramphids, mugilids, lutjanids, sphyraenids, pomadasyids, milk-fish (*Chanos chanos*) and *Monodactylus*.

According to the author's data and the information obtained from local fishermen, amount and composition of catch varies considerably. Hemiramphids and belonids occasionally form the major portion of the catch, and sometimes mackerels (*Scomber japonicus* and *Rastrelliger kanagurta*) are abundant.

COMMERCIAL FISHES

SCOMBRIDAE

This family includes several species of great importance as food fishes. Most of them are widely distributed throughout the Indo-Pacific and adjacent seas, and many of them are cosmopolitan.

The taxonomic nomenclature used in this paper is that of COLLETTE and GIBBS (1963).

Auxis thazard (LACÉPÈDE); frigate mackerel (Fig. 2a).

This fish is common in the Indo-Pacific including the Red Sea. In Eilat it forms the bulk of the catch, the main fishing season being April and May. No data are available on the catches of this species in other parts of the Red Sea but according to the author's estimate it contributes only small quantities to local fisheries. On the other hand, it is exploited as a commercial fish in India, the Philippines, Japan, Hawaii and other parts of the Indo-Pacific.

According to the experience of the ISRSE in spring 1962 and from earlier data from the same area of the Ethiopian coast it is evident that this fish is common in the southern Red Sea and could be exploited commercially.

No data are available on the spawning of this fish in the Red Sea. Fish caught in March 1962 near Massawa (Table VI) showed undeveloped gonads, very similar to those of specimens caught in Eilat during the spring months (March-May). Two ripening females observed off Massawa in September 1957 indicate that spawning takes place in summer as reported also from the Mediterranean (COLLIGNON, 1961) and the Hawaiian Islands (MATSUMOTO, 1958; STRASBURG, 1959). In the area of the Philippine Islands young fish were found in March-May (WADE, 1949) and larvae in January-March (WADE, 1951). It was pointed out by the same author that young fish

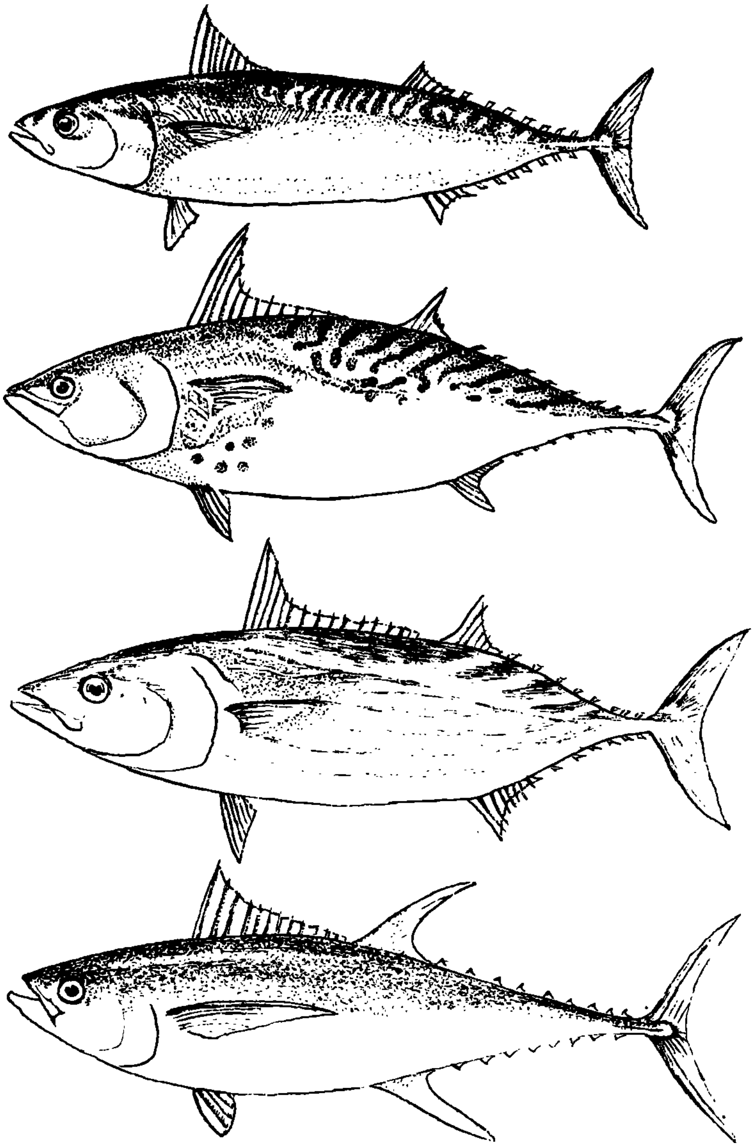

Fig. 2. Red Sea Scombroids. a. *Auxis thazard;* b. *Euthynnus affinis;* c. *Katsuwonus pelamis;* d. *Thunnus albacares.*

were found on the fish market from the end of November until May. On the Pacific coast of Central America young fish were found in March and May (MEAD, 1951; SCHAEFER and MARR, 1948). In the Gulf of Mexico many larvae were collected from March to August.

The length of fish caught in Zula Bay on 22 March 1962 are given in Table VI. Their sizes ranged between 33 and 39 cm with the modal value in the 35 cm size class.

TABLE VI

LENGTH, FREQUENCY, DISTRIBUTION OF *Auxis thazard* FROM ZULA BAY, MARCH 1962

Standard length (in cm)	Number
33	1
34	4
35	7
36	5
37	2
38	3
39	1
Total	23

Specimens from Eilat caught on May 21, 1962 were slightly smaller with the mode at 31 cm (Table VII). This fish usually appears in Eilat in large schools during March, April, May, and less frequently during June and the first part of July. It seems that only a small fraction of them are caught in Eilat by simple nets such as beach seine and gillnets used mostly to encircle a school of fish trapped in inshore waters.

TABLE VII

LENGTH, FREQUENCY, DISTRIBUTION OF *Auxis thazard* FROM EILAT, MAY 1962

Standard length (in cm)	Number
27	5
28	13
29	39
30	89
31	107
32	56
33	14
34	9
35	8
36	9
37	1
38	1
41	1
Total	352

Very little is known about the migration of frigate mackerel in the Red Sea. The fish apparently come to Eilat from the south, but because of lack of data it can only be assumed in a speculative way that the fish are born on the spawning grounds situated in the middle or southern parts of the Red Sea and in spring, with warming of the sea, they migrate northward, probably in search of food. As recent studies have shown (R. Landau, personal communication), those fish are predominantly less than one year old. It was also shown recently (R. Landau, personal communication) in a preliminary comparison of populations from Eilat and Massawa that no statistically significant differences exist in morphometric and meristic characteristics of fish from those two areas 1,500 km apart.

Euthynnus affinis (Cantor); little tuna (Fig. 2b).

This species, found in the West Pacific, Indian Ocean and the Red Sea, is caught in Eilat in small numbers during most of the year. It is commercially exploited in India, Japan the Philippines, Indonesia and along the coast of Arabia.

There are no proper records on little tuna catches in the Red Sea. According to the author's observations obtained in 1957 and 1962, the fish is abundant in the area of Massawa and it seems possible to exploit them commercially.

TABLE VIII

Records of *Euthynnus affinis* Caught in the Neighbourhood of Massawa

Date	Hour	Locality	Total length (in cm)	Gear
6.10.57	14.30	N15°23′; E40°12′	48.5	Trolling
3.12.57	11.30	N16°5′; E39°25′	—	Trolling
9.12.57	14.30	10 miles south of Massawa	40.0	Trolling
10.12.57	8.15	Shaab-Shakhs	60.0	Trolling
11.12.57	13.30	Curdumiat	60.0	Trolling
12.12.57	—	Umm Es Sharig		Trolling
21. 3.62	18.00	Zula Bay	44.0	Trolling
22. 3.62	—	Zula Bay	41.5	Purse seining
22. 3.62	—	Zula Bay	44.0	Purse seining

The material examined consisted of several specimens caught in the southern Red Sea by trolling during October–December 1957 and by trawling and purse seining in March 1962. Occasional records were also taken of fish caught in Eilat during the period 1954–1962. Their sizes in commercial catches vary usually between 30 and 40 cm.

Very little data is available on the spawning of little tuna in the Red Sea. A running male, 48.5 cm long, was caught 50 km south of Massawa on October 6, 1962. Specimens from Eilat caught in various seasons did not show ripe gonads. There is a possibility that little tuna does not spawn in the vicinity of Eilat, but this requires confirmation.

It was found by Wade (1950) that in the waters of the Philippines juvenile forms are present all the year round. Some biological observations on this species from the coast of East Africa are given by MORROW (1954), WILLIAMS (1963; 1964) and MERRETT and THORP (1965).

Katsuwonus pelamis (LINNAEUS); skipjack (Fig. 2c).

This circumtropical fish is known to be exploited commercially in Japan, the United States, Philippines, India, Australia and many other countries. Very little is known on the occurrence of skipjack in the Red Sea. One specimen 70 cm long was caught off Massawa by trolling on 11 September 1957. Small quantities of this fish are taken occasionally in Eilat; the author has the following records: 360 kg caught on 5 March 1954. Those fish were 58–71 cm long with the mode of 65 cm and weight of about 4 kg per fish. Seven tons of fish, 65–73 cm long and weighing about 5 kg per fish, caught on 5 November 1958; 22 tons of fish, 62–70 cm long caught on 4 January 1959; three tons of fish 60–70 cm long, caught on 14 April 1959. These records of occasional catches indicate that this fish is common in the Red Sea and can be exploited commercially.

No data are available on the biology of this fish in the Red Sea. A number of specimens of skipjack were reported by WILLIAMS (1956, and in press) from the coast of East Africa, who examined their gonads and stomach content. MATSUMOTO (1958) found juvenile forms in the Central Pacific Ocean during various months.

Thunnus albacares (LOWE); yellowfin tuna (Fig. 2d).

This commercially important fish is widely distributed through the Indo-Pacific. In several countries, particularly Japan and USA, there are big canning industries based on this fish. In the Gulf of Aden along the coast of Somali it forms the bulk of the local fishing industry (ANONYMOUS, 1954a).

Little is known of its occurrence in the Red Sea. Two specimens were caught off Massawa on 11 September 1957 by trolling. They were about 90 cm total length each. One of them, a male, was ripe with running milt. The other one, a female, did not have ripe gonads. The stomachs of these two fish contained scombroids, carangids, synodontids and holocentrids.

There are several records of occurrence of yellowfin at Eilat. On March 9, 1954, 11 fishes of 225 kg total weight (average weight per fish 20.45 kg) were caught in nets by commercial fishermen. Six fish were caught with Japanese longlines on 8–10 December 1958. They were 100–115 cm long and of a total weight of 100 kg (average weight per fish 16.67 kg). On May 21, 1962, a specimen of 105 cm length was caught together with a few others.

Thunnus tonggol (BLEEKER); longtailed tuna (Fig. 3e).

The distribution of this species covers most of the tropical and subtropical Indo-Pacific from California to the Red Sea. It is not as common as most of the other commercial species of scombroids and its part in world tuna fisheries is small. ANONYMOUS (1954a) reported its commercial exploitation from the coast of Somali. SERVENTY (1942) noted its commercial importance in Australian waters. The only specimen in

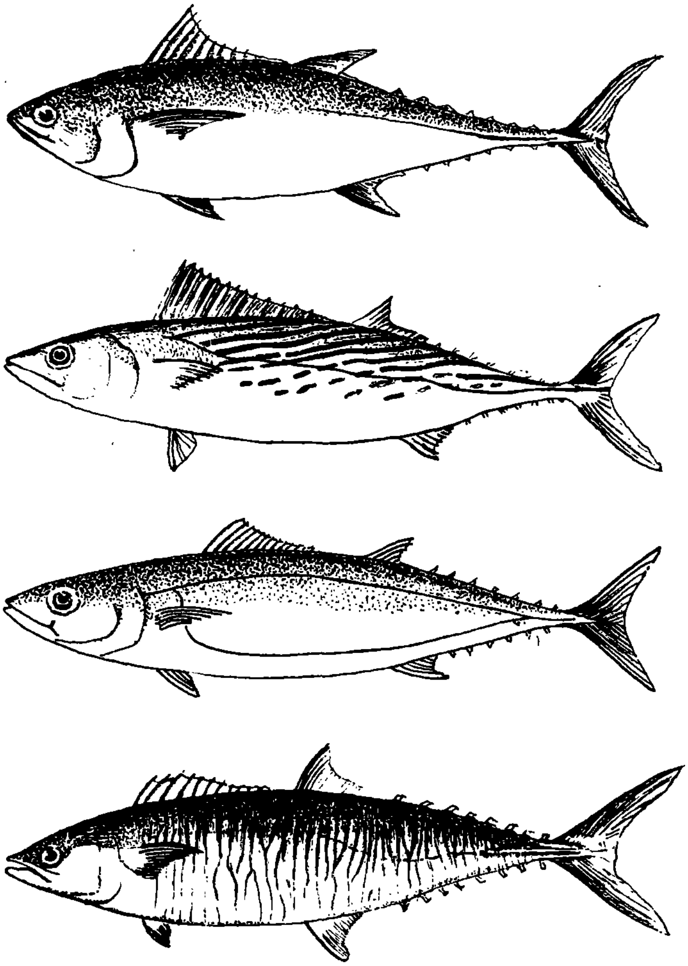

Fig. 3. Red Sea Scombroids. e. *Thunnus tongol;* f. *Sarda orientalis;* g. *Grammatorcynus bicarinatus;* h. *Scomberomorus commerson.*

our collection was caught by trolling near Curdumiat, coast of Ethiopia, on September 11, 1957. There are other records of this fish being hooked in commercial quantities along the Ethiopian coast. No data are available on its occurrence in Eilat.

Sarda orientalis (Bloch); bonito (Fig. 3f).

This species is widely distributed in the Indo-Pacific. No specimens are available from the area of Massawa, but since it is known from the Gulf of Aden (Anonymous 1954a) and from Eilat, there is reason to expect that schools of bonito are also present occasionally in the southern Red Sea. The only record from Eilat is five tons of bonito, 37–43 cm long, caught in May 1962.

No data are available on the spawning of this fish in the Red Sea. Klawe (1961) found that bonito in the eastern Pacific spawns in the summer months.

Grammatorcynus bicarinatus (RÜPPELL) (Fig. 3g).

This species is widely distributed throughout the Indo-Pacific but apparently nowhere in commercial quantities.

Two specimens were caught by trolling near Entedebir Island in March 1962. Two additional specimens were caught half a year earlier by Mr. M. BEN-YAMI, Fisheries Expert to the Government of Ethiopia, and preserved in the local collection of the Ethiopian Fisheries Department in Massawa. According to Mr. BEN-YAMI, those specimens were part of a small school spotted on the surface in the neighbourhood of Massawa.

Scomberomorus commerson (LACÉPÈDE); spanish mackerel; king-fish (Fig. 3h).

This is a common and important food fish in the Red Sea. Several specimens were caught by trolling in the Dahlak Archipelago during the ISRSE in March 1962. Also many specimens were caught during exploratory fishing in 1957–1958 along the Ethiopian coast. This fish is also common in Eilat, being hooked or captured in the stationary trap net. The size of spanish mackerels caught in the Red Sea does not usually exceed 100 cm.

Scomber japonicus (HOUTTUYN); mackerel.

There is apparently one circumtropical species which ranges through the Indo-Pacific and Atlantic Oceans, forming subspecies and local races in certain areas. This fish seems to be common in the Red Sea and several specimens have been collected in Ethiopia and in Eilat. Their lengths ranged between 25 and 40 cm. It has yet to be ascertained whether this fish appears in quantities which would justify commercial fishing operations.

Rastrelliger kanagurta (RUSSELL); rake-gilled mackerel; Indian mackerel.

Schools of these fishes were observed at Eilat and at Massawa. Several specimens, 20–30 cm long, from these two areas are preserved in the collection of the Sea Fisheries Research Station.

This fish is an important commercial fish in the Indo-Pacific.

CARANGIDAE

(Horse mackerels; jackfish; queenfish)

This family is represented by a large number of species of which the most important ones are listed below. They are caught along the coast of Ethiopia and in Eilat by gill-nets, trolling gear, hook-and-lines, beach seines and occasionally by trawl. Several specimens of carangid fishes were collected by "Pro-noxfish" poisoning in the southern Red Sea. Single specimens as well as schools of jackfish have been observed by the author while diving in the Red Sea.

Carangoides auroguttatus (VALENCIENNES).

This fish is very common in the area of the Dahlak Archipelago. It is easily recognised by the golden spots over its silverish body. Large fish, 30–60 cm long, were caught by ISRSE with trolling gear or through underwater spearing. Young specimens were collected by "Pro-noxfish" poisoning.

Caranx ignobilis (FORSKÅL).

Several specimens were caught with trolling gear by ISRSE in the area of the Dahlak Archipelago. Data on the following three specimens were recorded: (1) length 67 cm — weight 7.50 kg; (2) length 75 cm — weight 11.00 kg; (3) length 80 cm — weight 12.40 kg. Fish, 115 cm long, weighing 25 kg, were reported by WILLIAMS (1956) from East Africa. Additional data on its distribution and life-history from the same area is given by WILLIAMS (1956). According to the same author (personal communication) this fish attains a weight of 55 kg.

Caranx speciosus (FORSKÅL).

Several fish of 20–30 cm length were caught by beach seine in Zula Bay on March 22, 1962.

Megalaspis cordyla (LINNAEUS).

This fish is known as commercial fish in the Indo-Pacific. Several half-digested specimens were found in the stomach of a predatory bird, *Milvus migrans*, shot by ISRSE over Entedebir Island. Young specimens of *Megalaspis cordyla*, 10–20 cm long, were collected from trawl catches and beach seine catches in the area of Massawa, but no larger specimens were encountered. This fish attains a length of at least 50 cm.

Trachinotus blochii (LACÉPÈDE).

A common fish in the southern Red Sea. Many adults were caught in a commercial beach seine in Zula Bay. Juveniles, 4–9 cm long, were collected by ISRSE with experimental beach seine and "Pro-noxfish" poison in the Dahlak Archipelago.

Atule djeddaba (FORSKÅL).

Specimens of 15–25 cm were collected from trawl and beach seine catches in the southern Red Sea. This species has migrated through the Suez Canal into the eastern Mediterranean (BEN-TUVIA, 1966).

SERRANIDAE

(Groupers; sea perches; sea basses)

Large fishes which occasionally attain a size of two meters and weigh over 300 kg. They live mostly over a bottom covered with rocks and corals. Several species were collected by ISRSE with hook-and-line, "Pro-noxfish" poison and underwater spearing. Other specimens were collected on previous occasions from commercial catches taken in the Gulf of Aqaba and along the coast of Ethiopia.

Variola louti (FORSKÅL).

Several specimens, 20–30 cm long, were collected by ISRSE in the area of the Dahlak Archipelago. This fish is also common in Eilat and along the coast of Sinai. It attains a length of 60 cm.

Cephalopholis argus (SCHNEIDER).

Young fish belonging to this species are very common among corals in the southern Red Sea and hundreds of specimens, 10–30 cm long, were collected by ISRSE with fish poison. The large specimens caught occasionally by commercial fishing or underwater spearing were in the 30–50 cm size-range.

Epinephelus tauvina (FORSKÅL).

Fish of 40–70 cm are commonly taken with hook-and-line by commercial fishermen along the Ethiopian coast. One specimen, 250 cm long, of approximately 300 kg which apparently belongs to this species, was hooked in spring 1958 off the Ethiopian coast. According to WILLIAMS (1956) and MORGANS (1965) this fish is common along the coast of East Africa.

Epinephelus latifasciatus (TEMMINCK and SCHLEGEL).

This fish was recorded in 1959 from commercial hook-and-line fishing in Ethiopia·

Epinephelus summana (FORSKÅL).

A great number of fish of 20–40 cm were collected by ISRSE from rocks and corals of the Dahlak Archipelago.

Epinephelus areolatus (FORSKÅL).

These are caught occasionally by commercial fishermen in the southern Red Sea. Length 20–30 cm.

Epinephelus fasciatus (FORSKÅL).

One of the most common fishes in Eilat; specimens 20–30 cm long, are caught mostly by handlines. Seldom found in Ethiopia.

Plectropomus maculatus (BLOCH).

An important commercial fish taken by handlines along the coast of Ethiopia. It attains a length of 80 cm.

LUTJANIDAE

(Red snappers)

Lutjanus gibbus (FORSKÅL).

Important food fish in the area of the Dahlak Archipelago, caught mostly by handlines and occasionally by gillnets. Considerable quantities of this fish, 20–60 cm long, were caught by handlines by Israeli fishing boats with mixed Israeli and

Ethiopian crews in 1960–1961 and sold on Israeli markets (Table IV). Several specimens were handlined by ISRSE in waters less than 10 meters deep near Entedebir Island. On one occasion two young specimens were caught in a trammel net. Length (in cm) and weight (in kg) of two large specimens are given below:

Standard length	Total length	Weight
43.0	54.0	2.400
49.0	61.5	3.800

This fish belongs to one of the more important food fishes of the Indian Ocean (WHEELER and OMMANEY, 1953). Its taxonomy and occurrence along the East African coast has been recorded by TALBOT (1957).

Lutjanus janthinuropterus (BLEEKER).

Several specimens were collected from commercial catches taken by hook-and-line in Ethiopia and marketed in Israel. Their lengths were 20–45 cm. According to SMITH (1961) this species attains a length of 70 cm.

Lutjanus argentimaculatus (FORSKÅL).

Specimens of 25–75 cm were recorded and some of them collected from hook-and-line catches taken along the Ethiopian coast. According to SMITH (1961) it attains a length of 90 cm.

Lutjanus johni (BLOCH).

A very common fish in shallow coastal waters of Ethiopia. Many specimens, not exceeding 20 cm, were collected by ISRSE mostly with fish poison.

Lutjanus russellii (BLEEKER).

Schools of this fish were observed during a fish population survey in the neighbourhood of Entedebir Island (CLARK, et al., 1967). Several specimens of 12–16 cm were secured for the ISRSE collection.

LETHRINIDAE

(Pigface bream; scavengers)

Common fishes in the Indo-Pacific, including the Red Sea. Mostly small and medium-sized fishes which occasionally reach one meter in length.

Lethrinus mahsenoides (VALENCIENNES).

Common fish in the area of the Dahlak Archipelago. Two specimens, 22.0 and 23.5 cm long, were caught in a trammel net. Additional specimens were taken by commercial beach seine in Zula Bay, by underwater spearing and by poisoning with "Pro-noxfish". Their sizes varied between 12–25 cm. The same species is often caught by hooks in Eilat.

Lethrinus miniatus (SCHNEIDER).

Caught commercially by handline along the coast of Ethiopia, and marketed in Israel in the years 1960–1961. Observed lengths 35–60 cm. It may attain a length of a meter.

PLECTORHYNCHIDAE

(Sweetlips)

Gaterin gaterinus (FORSKÅL).

A very common fish in the area of the Dahlak Archipelago. Ten specimens were caught with trammel nets by ISRSE near Entedebir. Bottom living crustaceans were found in their stomachs.

TABLE IX

LENGTH AND WEIGHT OF 10 SPECIMENS OF *Gaterin gaterinus*

Standard length (in cm)	Total length (in cm)	Weight (ing)
19.0	23.5	160
20.0	25.5	220
21.0	26.5	250
21.5	27.3	280
21.5	27.2	300
22.0	28.2	320
22.0	28.3	350
23.0	28.8	400
24.0	29.5	420
24.5	30.5	450

ACANTHURIDAE

(Surgeon fish)

Fishes of this family are found chiefly over rocky and coral grounds. Most of them are not large enough or common enough to be of great commercial value. They are often caught by traps and underwater spearing in Eilat, along the coast of Ethiopia and in other parts of the Red Sea.

Acanthurus sohal (FORSKÅL).

This colourful fish is very common in the Dahlak Archipelago. Several specimens were collected by ISRSE, mostly after using fish poison near Cundabilu Island on March 25, 1962 (Table X). Additional specimens were collected near Um Aabak and Entedebir mainly by fish poisoning and occasionally by underwater spearing. Two specimens were caught in trammel nets near Entedebir. Ethiopian fishermen spear them for food or bait.

TABLE X

LENGTH AND WEIGHT OF *Acanthurus sohal* COLLECTED NEAR CUNDABILU ISLAND, DAHLAK ARCHIPELAGO

Standard length (in cm)	Weight (ing)
15.8	100
18.5	237
18.5	229
22.0	408
22.8	427
23.0	340
24.0	549
24.0	565
24.8	635
25.0	562
25.0	600
25.5	606
26.5	680
26.5	683

NEMIPTERIDAE

Bottom fishes of small or moderate size widely distributed throughout the Indo-Pacific. *Nemipterus japonicus* is very common on the trawling grounds of the southern Red Sea. Another species, *Nemipterus celebicus*, appears occasionally in small numbers in the catch.

Nemipterus japonicus (BLEEKER); golden-threadfin (Fig. 4).

This fish is very common on the fishing grounds of the Ethiopian coast. Data obtained during ISRSE from a fishing trip to Harkiko Bay on April 16, 1962 show that this species constitutes 20% of the commercial trawl fishes. Specimens of 4–18 cm were collected during this trip. The share of this fish in the trawl catch along the Ethiopian coast was estimated as 20–70%, depending on the fishing grounds and fishing seasons. The average for the period of September–December 1957 was 35%. Length measurements of *Nemipterus japonicus* were taken by the author on deck of

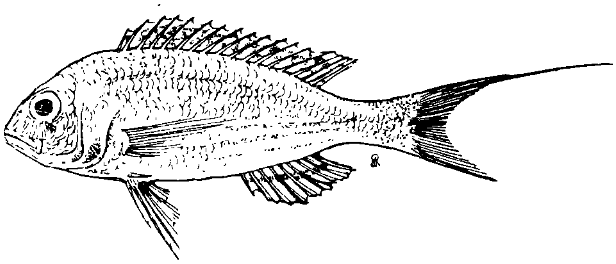

Fig. 5. *Nemipterus japonicus.*

F/V *Neghisti Saba* on November 21 and 23, and on December 4, 1957, in the area south of Massawa. Their lengths varied between 10–23 cm (Table XI). Two modes are visible: one in the 13 cm length group which probably corresponds to fish of 0-age group, and a second mode in the 17 cm length group which indicates perhaps one year old fish. An attempt to determine the growth rate of this species in the Gulf of Tonkin was made by CHUNG and DRUZHININ (1965).

TABLE XI

LENGTH, FREQUENCY, DISTRIBUTION OF *Nemipterus japonicus* FROM THE ETHIOPIAN COAST, TAKEN IN NOVEMBER–DECEMBER 1957

Total length (in cm)	Number
10	3
11	20
12	66
13	71
14	23
15	35
16	71
17	85
18	65
19	32
20	19
21	12
22	5
23	1
Total	508

MULLIDAE

(Red mullet; goat fish)

Small and medium sized bottom fishes. Their size does not usually exceed 30 cm. Several species of various degrees of commercial importance are known in the Red Sea.

Upeneus moluccensis (BLEEKER).

Appears in small quantities in trawl catches along the coast of Ethiopia. According to the author's records from the year 1957, it constituted 3.3% of the trawl catches. Length measurements from this period are given in Table XII. The fish were 10–16 cm long with a mode of 12.5 cm. Fish examined in the period September–December 1957 which were larger than 12 cm in total length had ripe gonads. Additional ripe specimens were found in the same area on April 16, 1962.

This species has apparently penetrated via the Suez Canal into the eastern Mediterranean and now forms one of the important commercial species on the trawling grounds of the United Arab Republic, Israel and southern Anatolia.

TABLE XII

LENGTH, FREQUENCY, DISTRIBUTION OF *Upeneus moluccensis* FROM THE ETHIOPIAN COAST TAKEN IN NOVEMBER–DECEMBER 1957

Total length (in cm)	Number
10.0	2
10.5	14
11.0	13
11.5	42
12.0	87
12.5	91
13.0	71
13.5	40
14.0	14
14.5	2
15.0	1
15.5	—
16.0	3
Total	380

Upeneus vittatus (FORSKÅL).

This species is caught occasionally in small quantities by trawl. Length 20–30 cm.

Upenus macronema ((LACÉPÈDE).

This fish is often caught in small numbers by gill-nets and traps in Eilat. A few specimens were also collected in the area of the Dahlak Archipelago. Length 20–30 cm.

Upeneus barberinus (LACÉPÈDE).

A common fish in the shallow inshore waters of the Dahlak Archipelago and Eilat where it is caught by gill-nets, beach seine and traps. Attains a length of 50 cm.

Mulloidichthys auriflamma (FORSKÅL).

Common on sandy patches of the coast of Eliat but rarely caught along the coast of Ethiopia. Length 20–35 cm.

SCARIDAE

(Parrot fishes)

Fishes of this family are found mostly near corals and rocks. Single specimens or small numbers were occasionally caught by gill-nets, traps and spearing. Several specimens were obtained during ISRSE by nets and "Pro-noxfish" poison.

It was noted that the local fishermen of Ethiopia spear them in considerable numbers as food or bait. Schools of these fishes were observed and counted in the area of special ecological study near the Entedebir Landing Bay. They were seen to feed on calcified algae which grow on the rough bottom and dead corals. Sexual dimorphism is strongly marked among scarids, chiefly by colours; often males and females were described as separate species. The species were identified by Dr. E. Clark.

Scarus harid (Forskål).

Eight specimens were caught in a trammel net by ISRSE. Lengths: 12.5–25.0 cm.

Scarus sordidus (Forskål).

Fifteen specimens, 12.5–22.5 cm long, were caught by ISRSE in a trammel net.

Scarus bipallidus (Smith).

Four specimens, 15.2–19.0 cm long, were caught in a trammel net.

Atherinidae

(Silversides)

Pranesus pinguis (Lacépède).

This fish is very common in the Red Sea. It has also migrated through the Suez Canal to the eastern Mediterranean. Schools composed of fishes, 7–10 cm long, were often encountered at Eilat, along the coast of Sinai and in the Dahlak Archipelago. It attains a length of 12 cm. Because of its small size this fish is not usually utilized for human consumption. Evidently it plays a considerable role in the food chain since it is heavily preyed upon by predatory fish.

Many specimens were collected in various parts of the Red Sea at night as the silverside is strongly attracted by artificial light. Mixed schools of *Pranesus* and *Herklotsichthys* were observed in the daytime near Harmil Island. A sample was obtained by a small beach seine on April 15, 1962 in Entedebir Island (Table XIII).

TABLE XIII

Length Frequency Distribution and Average Weight of *Pranesus pinguis* from Entedebir Island

Total length (in cm)	Number	Total weight (in g)	Average weight (in g)
7.0	2	5.6	2.8
7.5	2	9.2	4.6
8.0	2	12.0	6.0
8.5	6	37.3	6.2
9.0	24	167.9	7.0
9.5	65	536.7	8.3
10.0	55	479.9	8.7
10.5	34	345.1	11.5
11.0	2	25.4	12.7
Total	192	1619.1	8.4

MUGILIDAE

(Grey mullets)

Mugil waigiensis (QUOY and GAIMARD).

Common in the area of the Dahlak Archipelago and Massawa, being caught mostly by beach seine. Attains a length of 40 cm. This fish was seen on the fish markets of Massawa and Asmara. Grey mullets are cured and dried by the Ethiopian and Yemeni fishermen and sold on the local markets or exported to the neighbouring countries.

Crenimugil labiosus (VALENCIENNES).

Common in the southern and northern parts of the Red Sea. Many small specimens, 7–10 cm long, were collected in great numbers along the coast of Sinai, at Eilat and in the Dahlak Archipelago.

SPHYRAENIDAE

(Barracudas)

Large and medium-sized predators. Four species were encountered in the Red Sea, two of them in the upper layers of the sea while two others were taken mostly by trawl.

Sphyraena chrysotaenia (KLUNZINGER).

Common on the trawling grounds of Ethiopia, especially seems to be more abundant in the North Massawa Channel. According to the data recorded for the exploratory trawling of September–December 1957, this fish constituted 5% of the trawl catches. The same species has immigrated through the Suez Canal into the eastern Mediterranean where it is taken in commercial quantities by Israeli fishermen (BEN-TUVIA, 1966).

TABLE XIV

LENGTH, FREQUENCY, DISTRIBUTION OF *Sphyraena chrysotaenia* TAKEN OFF THE ETHIOPIAN COAST IN NOVEMBER–DECEMBER 1957

Total length (in cm)	Number
19.0	1
19.5	4
20.0	4
20.5	15
21.0	25
21.5	18
22.0	9
22.5	5
23.0	6
23.5	1
Total	88

Sphyraena jello (CUVIER).

This fish is caught in small quantities on the trawling grounds of Ethiopia. According to data obtained in 1957, it constituted 3% of the commercial trawl fishes. As shown in Table XV, this fish appeared in the catches in larger sizes than *Sphyraena chrysotaenia*.

TABLE XV

LENGTH, FREQUENCY, DISTRIBUTION OF *Sphyraena jello* TAKEN OFF THE ETHIOPIAN COAST IN NOVEMBER–DECEMBER 1957

Total length (in cm)	Number
22	2
23	2
24	6
25	23
26	11
27	6
28	3
Total	53

Sphyraena qenie (KLUNZINGER).

Sphyraena tessera from South Africa, described as new by SMITH (1956) is apparently identical with *S. qenie* KLUNZINGER, 1871, described from the Red Sea. Two specimens were taken by hook-and-line by ISRSE near Entedebir Island; the larger specimen was 86 cm long (100 cm total length) and weighed 3.70 kg, the smaller one was 78 cm (95 cm total length).

Sphyraena barracuda (WALBAUM).

This fish is of circumtropical range, being found in warm waters of the Atlantic, Pacific and Indian Oceans. According to DE SILVA (1963) it attains a length of two meters and a weight of 40 kg. Several specimens were hooked by ISRSE in the area of Entedebir Island. Their length varied between 70 to 85 cm and their weight between 4 to 6 kg.

SYNODONTIDAE

(Lizard fishes)

Four species of lizard fishes are found in the Red Sea: *Trachinocephalus myops* and *Synodus variegatus* are common in shallow, inshore waters of Eilat, Sinai and Ethiopia. *Saurida undosquamis* appears in small quantities on the trawling grounds of Ethiopia. All three of them are of little commercial importance. *Saurida tumbil* is the only one which is caught in large quantities by trawl.

Saurida tumbil (Bloch) (Fig. 5).

This fish constituted about 50% of the commercial fishes obtained on the trawling grounds of Ethiopia and marketed in Israel. Data collected during the exploratory fishing in 1957 and from commercial trawlers in later years shows that the proportion of this fish in the catch varies from one fishing ground to another between 20% and 70%.

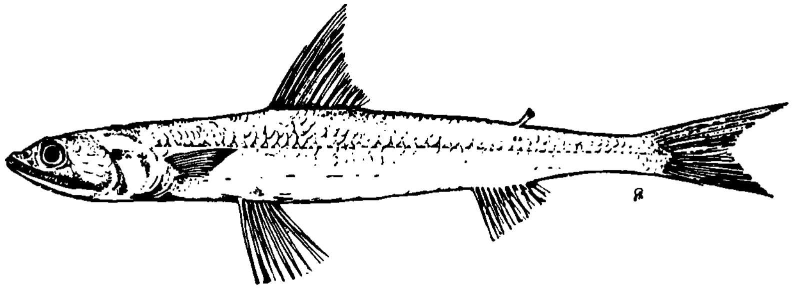

Fig. 5. *Saurida tumbil.*

Table XVI shows length measurements taken on the deck of F/V *Neghisti Saba* during the exploratory fishing along the coast of Ethiopia in 1957. The sizes ranged

TABLE XVI

Length Frequency Distribution of *Saurida tumbil* From the Coast of Ethiopia, November–December 1957

Total length (in cm)	Number	Total length (in cm)	Number
15.0	1	24.5	15
15.5	–	25.0	13
16.0	1	25.5	12
16.5	–	26.0	8
17.0	2	26.5	3
17.5	8	27.0	2
18.0	16	27.5	1
18.5	22	28.0	–
19.0	48	28.5	1
19.5	62	29.0	3
20.0	73	29.5	2
20.5	68	30.0	2
21.0	50	30.5	2
21.5	39	31.0	2
22.0	42	31.5	1
22.5	35	32.0	1
23.0	30	32.5	–
23.5	12	33.0	1
24.0	19	33.5	1
		34.0	1
Total			599

from 14.5 cm to 34.0 cm with two modes: one in the 20 cm size class and the other in that of 24 cm. The two modes indicate the presence of two distinct groups, probably the one- and the two-year age groups.

A considerable number of small fish was collected during a fishing trip on a trawler to Harkiko Bay near Massawa on April 16, 1962 (Table XVII).

TABLE XVII

LENGTH, FREQUENCY OF YOUNG *Saurida tumbil* CAUGHT NEAR MASSAWA IN APRIL 1962

Total length (in cm)	Number	Total length (in cm)	Number
3.0	1	9.0	6
3.5	-	9.5	4
4.0	3	10.0	4
4.5	7	10.5	6
5.0	12	11.0	8
5.5	11	11.5	-
6.0	11	12.0	-
6.5	10	12.5	-
7.0	14	13.0	2
7.5	13	13.5	1
8.0	8	14.0	-
8.5	6	14.5	1
Total			128

CHANIDAE

Chanos chanos (FORSKÅL); (milkfish).

This fish is common in the tropical waters of the Indo-Pacific and in several countries of South East Asia as for example Indonesia, Malaysia, India and the Philippines. It is not only fished in the sea but also grown in ponds of salt or brackish water. The milkfish is evidently common in the Red Sea. Several specimens were observed swimming in the sea near Entedebir Island, close to the surface, with their dorsal fins projecting from the water, and feeding on planktonic organisms. According to SMITH (1961) they attain a length of two meters.

Two large specimens were collected from commercial beach seine catches in Zula Bay. They were part of a small school which was encircled by the beach seine but escaped by jumping over the cork line. Schools of milkfish were also observed in Eilat.

CLUPEIDAE

(Sardines)

Herklotsichthys punctata (RÜPPELL).

This is the most common clupeoid in Ethiopian waters. Its size seldom exceeds 13 cm. Schools of this fish are caught in the southern Red Sea mostly by beach seine, often mixed with the engraulid *Stolephorus heterolobus*. Both of them are used for fish meal production which is centered in Massawa. The catch taken in various localities along the coast of Ethiopia is spread on the ground near the place of capture, dried in the sun and then sent to the factories in Massawa for final processing. Heaps of half dried sardines and anchovies called locally "uassif", were observed on several islands in the Dahlak Archipelago. Additional quantities were seen in the fish meal factories in Massawa.

A very large and dense school of *Herklotsichthys punctata* was observed near Harmil Island on March 29, 1962. Together with a small school of *Pranesus pinguis* they filled up a shallow bay of about 500 square meters. They were not driven out by the disturbance caused by persons swimming amidst the school. Some quantities of these fish were caught by a small experimental beach seine. Measurements and weights of a sub-sample drawn from this catch are given in Table XVIII.

TABLE XVIII

LENGTH MEASUREMENTS AND WEIGHTS OF *Herklotsichthys punctata* TAKEN NEAR HARMIL ISLAND ON MARCH 29, 1962

Total length (in cm)	Number	Total weight (ing)	Average weight (ing)
7.0	8	32	4.0
7.5	65	287	4.4
8.0	67	358	5.3
8.5	35	227	6.5
9.0	18	138	7.7
9.5	5	45	9.0
10.0	1	10	10.0
Total	199	1097	5.5

Another sample of this fish was taken in Goliath Bay (Entedebir Island) on March 23, 1962. They were of similar size.

Herklotsichthys punctata appears in the southern Red Sea in great quantities. Its commercial importance would increase greatly if this little fish could be used for canning or for human consumption in general.

The taxonomic status of this species was clarified by WHITEHEAD (1964).

ENGRAULIDAE

(Anchovies)

Two species of engraulids called locally "uassif", are common in the area of the Dahlak Archipelago, namely *Stolephorus heterolobus* (RÜPPELL) and *Thrissocles baelama* (FORSKÅL). These small fish that seldom exceed the size of 8 cm are used for production of fish meal. They are caught in large numbers by beach seines, and together with sardines are dried and sent to the fish meal factories in Massawa. Nothing is known on the biology of these fishes, which are of considerable importance to the local fish meal industry. Before the industry can be developed any further some basic information on the available stocks and their migrations should be acquired.

SELACHII

(Sharks)

Sharks are common in the southern Red Sea and in Eilat, and are to some extent commercially exploited. In the area of the Dahlak Archipelago the local fishermen dry shark meat and use it as food during fishing trips or sea voyages. Some years ago there was also an export of dried shark fins to China, which apparently ceased in recent years.

CARCHARHINIDAE

Carcharhinus melanopterus (QUOY and GAIMARD).

Several specimens were observed in the shallow waters of Entedebir and Cundabilu during the ISRSE in the spring of 1962. Their sizes varied between 50 and 160 cm (total lengths). One female, 76 cm long (100 cm in total length), weighing 8.20 kg, was captured by trammel net near Entedebir.

Carcharhinus dussumieri (MÜLLER and HENLE).

One male, 100 cm long (130 cm total length), weighing 16 kg, was caught by trammel net near Entedebir.

Carcharhinus limbatus (MÜLLER and HENLE).

Several specimens were obtained from trawlers working in Ethiopian waters. This species is widely distributed in the Indo-Pacific.

SPHYRNIDAE

(Hammerhead sharks)

Sphyrna mokarran (RÜPPELL).

One dried specimen about 150 cm long was found on Dahlak Island during the ISRSE in spring 1962. An additional specimen, 40 cm long, was captured by trawl in Harkiko Bay. Several specimens were also collected from Eilat and along the Sinai Peninsula in the years 1949–1957, which indicates that this species is common in the Red Sea.

BATOIDEA

(Rays and skates)

A considerable number of species of batoid fishes are known from the Red Sea. They are of little commercial importance.

DASYATIDAE

Taeniura lymma (FORSKÅL).

Common fish, easily recognized by the characteristic blue spots over the back of the disc. Three specimens were caught by trammel net at the entrance to Landing Bay on Entedebir. Lengths of discs were measured and respective weights recorded.

Length of disc in mm	Weight in g
210	620
230	700
230	720

Six additional specimens were caught at the entrance to Padina Bay; the length of their discs varied between 260–300 mm and their weight between 1.00–1.50 kg. Their stomach contents were composed of bottom living invertebrates.

MOBULIDAE

(Manta rays)

Manta ehrenbergi (MÜLLER and HENLE).

This giant fish was often seen in the Dahlak area during the ISRSE, in spring 1962. Most of them were approximately two meters or more across the disc. The same species also occurs occasionally in Eilat.

COMMERCIAL INVERTEBRATES

CRUSTACEA

Several edible crustaceans were collected from the coast of Ethiopia during the ISRSE and on earlier occasions. They were identified by Dr. L. HOLTHUIS of the Natural History Museum of Leiden, who participated in the ISRSE.

PENAEIDAE

(Shrimps; prawns)

Many specimens of penaeids were collected by the ISRSE from trawlers working in Harkiko Bay. Their presence has also been recorded on many occasions in the catches of trawlers operating in Ethiopian waters, usually in larger quantities at night than during the day. So far no extensive shrimp resources have been found in these waters, and it is assumed that they do not appear in sufficient concentrations to justify large scale fishing operations.

Six species, listed below, were collected in the southern Red Sea by the ISRSE. The first four of them are know to be of commercial value —

Penaeus semisulcatus DE HAAN

Penaeus japonicus BATE

Penaeus latisulcatus KISHINOUYE

Metapenaeus monoceros (Fabricius)

Metapenaeus stebbingi Nobili

Trachypenaeus curvirostris (Stimpson).

Three of these species, namely *P. japonicus*, *P. semisulcatus* and *M. monoceros*, are known also from the Mediterranean coast of Israel (Holthuis and Gottlieb, 1958).

Scyllaridae

Thenus orientalis (Lund) (Fig. 6).

This species is often caught together with demersal fishes by trawlers working along the Ethiopian coast. Small quantities are also collected in shallow waters by local divers. The total catch from all sources seems to be small and does not exceed a few tons per year. *Thenus orientalis* is marketed in Massawa and Asmara and occasionally is also brought in small quantities to Israel. Its size seldom exceeds 20 cm total length. No data are available on its distribution and life history.

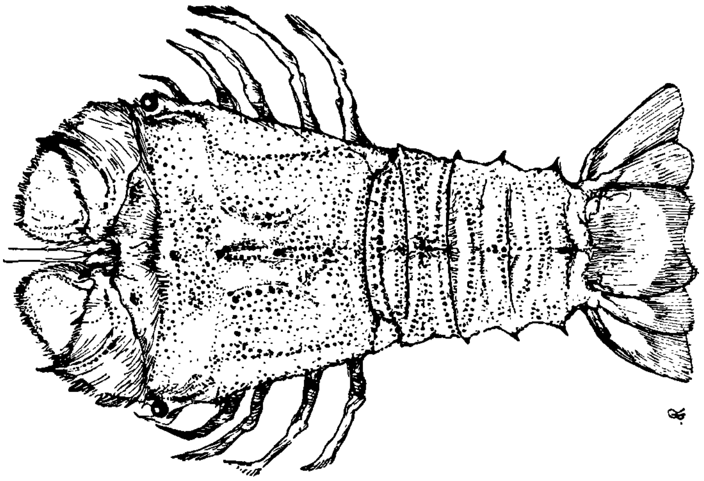

Fig. 6. *Thenus orientalis.*

Palinuridae

(Spiny lobsters)

Panulirus penicillatus (Olivier).

Several specimens were speared in crevices and shallow caves of Harmil Island in a depth of 2–4 m. Their carapace length was 120–140 mm. This lobster is known from vast areas of the Indo-Pacific.

anulirus ornatus (Fabricius).

A few specimens were collected by the ISRSE near Massawa and Entedebir Island.

Panulirus versicolor (LATREILLE).

A few specimens were collected by the ISRSE in the area of the Dahlak Archipelago.

PORTUNIDAE

(Crabs)

Portunus pelagicus (LINNAEUS).

This crab is common on the Ethiopian trawling grounds and many specimens were collected from cod-end of trawlers. It is also common in the eastern Mediterranean where it appeared in great numbers shortly after the opening of the Suez Canal.

Portunus sanguinolentus (HERBST).

Many specimens were collected from the cod-end of trawlers working in Ethiopian waters.

Scylla serrata (FORSKÅL).

This species is known to occur in the Red Sea but was not collected by the ISRSE. It is of commercial importance in many countries bordering the Indian Ocean and the Western Pacific.

Charybdis feriata (LINNAEUS).

This species occurs in the Red Sea but was not collected by the ISRSE. It is also known from the Indian Ocean and western Pacific.

STOMATOPODA

SQUILLIDAE

Squilla massawensis (KOSSMAN).

This species, caught by trawlers, often appears on the fish markets of Massawa and Asmara.

MOLLUSCA

They are of considerable importance for the local fishing industries of the Red Sea. From ancient times, this area was known for its pearl divers (TRESSLER and LEMON, 1951). Pearl oysters are taken in large quantities and their shells are exported for the button industry and ornaments. The meat is mostly eaten locally. About 200 tons of pearl oysters are taken yearly in Ethiopian waters. According to BEN-YAMI (1964) about 134 tons were landed in Massawa in 1961–1962. Their value was estimated at $30,000.

BIVALVIA

Margaritifera margaritifera erythroeensis (LINNAEUS); Red Sea pearl oyster; locally "bilbil".

The islands of the Dahlak Archipelago are known as one of the centers of the pearl oyster fishery, taken mainly for mother of pearl and meat. The size of commercial shells is 10–15 cm, rarely reaching 20 cm. The low prices obtained in recent years for shells caused a decrease in their export from Ethiopian waters. A small number of pearls from Ethiopia found their market in Aden. According to Ben-Yami (personal information) their total catch for 1962 was sold for $1,600. Considerable quantities of pearl oysters are being recently cultivated in Sudan (Reed, 1964). According to Anonymous (1962), 200–300 tons of commercial shells (*Trochus* and *Margaritifera*) are being taken yearly in Sudanese waters from natural beds.

Gastropoda

Trochus dentatus (Forskål).

Shells of this common mollusc are collected in large quantities and exported for the button industry. A considerable decrease was noted in the export of this product in recent years.

Cephalopoda

Small quantities of squids and octopusses taken by trawlers and by divers, are sold on the markets of Massawa and Asmara. The material collected by the ISRSE has not, as yet, been identified and analysed. A systematic review of cephalopods collected from Eilat and Sinai has been given by Adam (1960).

Acknowledgements

The author wishes to thank Dr. H. Steinitz of the Hebrew University of Jerusalem, Mr. O. H. Oren, Director of the Sea Fisheries Research Station, Haifa, and Dr. E. Clark, Director of the Cape Haze Marine Laboratory, Sarasota, for their assistance in collecting data, Dr. L. Holthuis of the Natural History Museum, Leiden, for the list of commercial Crustacea, and Dr. F. Williams, of the Scripps Institution of Oceanography, La Jolla, for commenting on the manuscript.

SUMMARY

The data collected during the Israel South Red Sea Expedition, March-April 1962, are considered together with data obtained from fishery research activities at Eilat and on the coast of Ethiopia. The available information on the fishery resources of the Red Sea is being reviewed and incorporated in the present evaluation. It has been estimated that the total catch from the Red Sea including the Gulf of Eilat and the Gulf of Suez, amounts to about 40,000 metric tons per year.

The pelagic fishes apparently constitute the main potential resource. At present *Herklotsichthys punctata* and *Stolephorus heterolobum* are caught in considerable quantities for fish meal production in Massawa. *Scomberomorus commerson* is one of the more important commercial fishes. Small quantities of *Thunnus tonggol*, *Thunnus albacares*, *Katsuwonus pelamis*, *Euthynnus affinis*, *Auxis thazard* and *Scomber japonicus* are caught occasionally in various regions of the sea, but according to the author's estimate the stocks are greatly underexploited.

Demersal fishes are abundant in the meridional and southern parts of the Red Sea and to a lesser extent, in the Gulf of Suez. The average catch per unit of effort of a 60 ton trawler working along the Ethiopian coast amounted to about 280 kg per hour. The lizard fish (*Saurida tumbil*) constituted 51.6% and the golden threadfin (*Nemipterus japonicus*) 31.3% of the catch. In general, the trawl fishes are of small size and of low economic value.

Red snapper (*Lutjanus gibbus*) is abundant on rocky grounds. It is caught by hook and line together with small quantities of other lutjanids, serranids, lethrinids, carangids and pomadasyids. A great variety of families such as carangids, belonids, hemiramphids, mugilids, lutjanids, sphyraenids, pomadasyids, milk-fish (*Chanos chanos*) and *Monodactylus*, are represented in the catch of beach seines.

Of considerable importance are some molluscs (*Margaritifera margaritifera erythroeensis* and *Trochus dentatus*) exploited mostly for their shells. Spiny lobsters and prawns are present in small quantities. *Thenus orientalis* is frequently taken by trawl.

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Reprinted from *Bull. Sea Fish. Res. Sta., Haifa*, no. 51, 1968, p. 3-5

CONTRIBUTION TO THE KNOWLEDGE OF THE RED SEA

No. 39

SUR LA PRÉSENCE D'HOLOTHURIES DIVERSES ET, EN PARTICULIER, DE L'HOLOTHURIE APODE *PROTANKYRA AUTOPISTA* MARENZELLER, EN MER ROUGE*.

par
Gustave Cherbonnier
Muséum national d'Histoire naturelle, Paris

Le Dr. Fishelson a récolté à Eilat une espèce souvent discutée: *Protankyra utopista* (Marenzeller), n'ayant jamais été trouvée, jusqu'ici, que sur les côtes japonaises.

Protankyra autopista (Marenzeller)

(Fig. a–w)

Synonymie. Synapta autopista Marenzeller, 1881, p. 223, pl. IV, fig. 3; Lampert, 1885, p. 222; Theel, 1885, p. 32; Britten, 1907, p. 149.

Protankyra autopista Oestergren, 1898, p. 117; H. L. Clark, 1907, p. 103, pl. V, fig. 31; Ohshima, 1913, p. 505, fig. 6; Ohshima, 1914, p. 472; Heding, 1928, p. 264, fig. 49, 1–6.

Origine. Eilat, golfe d'Aqaba, no. N.S. 1124, N.S. 1126, N.S. 1128, dans des blocs de corail reposant sur la vase, profondeur 15 mètres, Dr. L. Fishelson, récolteur, le 31.1.1965.

Tous les animaux se sont fragmentés en plusieurs morceaux gris rosés, très plissés transversalement, ayant respectivement 10, 24, 30, 32, 43, 45, 50, 58 et 80 mm de long. Seul, ce dernier exemplaire possède une extrémité céphalique, et encore n'est-elle sans doute pas intacte; en effet, je n'ai dénombré que six tentacules au lieu des douze que cette espèce possède normalement; ils ont environ 3 mm de long, portent une paire de digitations de chaque côté et, sur leur face ventrale, deux séries longitudinales de quatre cryptes sensorielles (x). La couronne calcaire, assez peu calcifiée, est très petite et composée de 12 pièces; les radiales, à sommet arrondi, sont largement perforées, les interradiales, pointues au sommet, portent une sculpture triangulaire (y). Il y a une très longue vésicule de Poli et un seul et court canal hydrophore terminé par un madréporite digitiforme peu calcifié. Les muscles longitudinaux sont larges et très épais. Tous les morceaux examinés avaient un gros intestin droit, ne formant

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Received: October 1966.

* Supported by Contract No. 62558–3335 between the U.S. Office of Naval Research, Department of the Navy, and Tel-Aviv University.

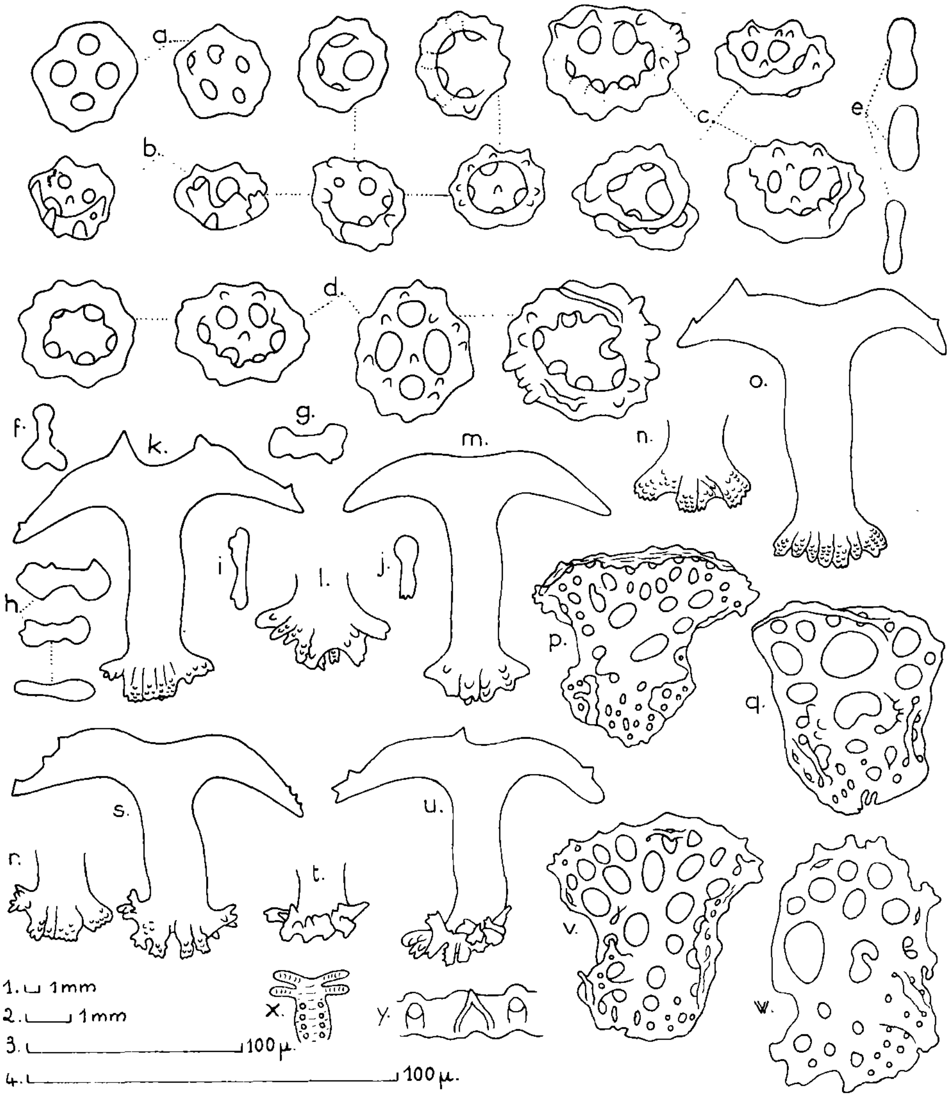

Fig. a-w

pas boucle. Je n ai constaté la présence d'aucune urne ciliée, aussi bien sur la paroi du corps que sur les mésentères, pas plus que je n'ai pu découvrir de gonades.

SPICULES. Les ancres sont larges et courtes, à bras presque droits, lisses (m), armés seulement de dents irrégulières à chaque extrémité (s) ou portant, en plus, une ou deux fortes dents près du milieu du sommet (k, o, u); la base de la manivelle est fractionnée en 4 à 8 pièces situées dans le même plan et armées d'aspérités fines à assez fortes (k, l, m, n, o, r), ou porte de fortes trabécules buissonneuses (t, u). Les plaques anchorales sont courtes, de forme irrégulière, percées de trous de diverses grandeurs; certaines, sans doute en voie de formation, sont presque lisses (w);

la plupart ont le sommet recourbé en bourrelet (p), cette courbure pouvant se limiter à une ou plusieurs trabécules (q) ou se trouver sur un des côtés de la plaque; la surface des plaques porte souvent quelques apophyses plus ou moins développées, mais il n'existe jamais de pont véritable.

Il y a également, dans le tégument, de petits corpuscules allant de la plaque lisse à 4–5 trous (a) à la vraie corbeille à périphérie lisse ou irrégulièrement armée de dents simples, bifides ou trifides (b); certaines atteignent une taille deux à trois fois plus forte que les corbeilles précédentes et prennent parfois une forme très irrégulière (c, d).

Rapports et différences. Comme le souligne Heding, c'est avec *P. molesta* (Semper) dont le type provient de Bohol. (Archipel des Philippines), que *Protankyra autopista* présente le plus d'affinités; mais elle en diffère nettement par la forme de la couronne calcaire, des ancres et des plaques anchorales, ainsi que par celle des corbeilles. Il ne aurait s'agir non plus, comme le suggère H. L. Clark, de *Protankyra bidentata* Woodward et Barret, également des mers japonaises, espèce bien différente à tous les points de vue. *Protankyra autopista* est une bonne espèce dont la présence, en mer Rouge, élargit considérablement l'aire de répartition.

Au cours d'une expédition en mer Rouge effectuée en octobre 1965, sur les côtes de l'Erythrée, dans un secteur compris entre 15 à 16°N et 40 à 41°E, les Dr. Fishelson, Lewinsohn et Neumann ont récolté, par des profondeurs de 2 à 35 mètres, un petit lot d'Holothuries dont ils ont bien voulu me confier l'étude. Les huit espèces qu'il contenait étaient déjà connues de la mer Rouge et n'appellent aucun commentaire spécial. Ce sont: *Actinopyga bannwarthi* Panning, *Halodeima atra* (Jaeger), *Halodeima flavomaculata* (Semper), *Halodeima edulis* (Lesson), *Holothuria pardalis* Selenka, *Holothuria impatiens* Forskal, *Holothuria arenicola* Semper, *Holuthuria vagabunda* Selenka et *Euapta godeffroyi* (Semper).

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Reprinted from *Bull. Sea Fish. Res. Sta., Haifa*, no. 51, 1968, p. 6-30

CONTRIBUTIONS TO THE KNOWLEDGE OF THE RED SEA
No. 40

FISHES FROM EILAT (RED SEA)

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INTRODUCTION

The knowledge of the fauna of the Red Sea becomes more and more important in connection with the study of the living world in the Eastern Mediterranean basin. In order to reach a better understanding of the present relations between the Indo-Pacific and the Mediterranean faunas, it is urgent to promote new investigations on the Erythraean animals of different groups, considering them from all points of view. Systematic, zoogeographical and biological studies are needed, because in many cases we easily realize how unsatisfactory is the information which we possess at present.

Marine biologists from the Mediterranean countries are well aware of all this; therefore, a course on tropical marine biology, sponsored by M.A.M.B.O. (Mediterranean Association for Marine Biology and Oceanology) and the Hebrew University of Jerusalem was held in Jerusalem and in Eilat from December 24th, 1965 to January 4th, 1966. The fauna and flora of the Red Sea were essentially considered.

Having been invited to lecture on fishes, I had a very welcome opportunity of observing and collecting a number of species. As something is to be added to our present knowledge of the ichthyofauna of the gulf of Eilat, a list is given in the present paper with a series of notes, partly assembled in the field. I was afforded the possibility of staying in Eilat a few more days after the end of the teaching activities, so that a fairly good idea of the general features of the local fauna has been obtained, improving and greatly enlarging the first impressions that I had during a short visit there, in September 1965.

This paper deals with a series of fishes from Eilat: 66 species, belonging to 33 families. Many of them were observed on the reefs by diving by day and by night; some were captured, some — of large size — were simply noticed without possibility of proper identification: this was the case with several green parrotfishes (*Scarus*), with two Lutjanids or Sparoids, with a *Lethrinus* and a big *Epinephelus*. A series of species was obtained with a seine on the beach at the northern end of the gulf. All of them have been preserved. Other fishes were seen in the Aquarium of the Museum, at Eilat; a last group consists of preserved specimens (dried or in formol) obtained from this institution, as already said. All the material that I brought from Eilat is now in the Museum of Natural History, Genova (MSNG). The large collection belonging to the latter contains many other fishes from the Red Sea (chiefly from

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Received: March 1966.

Massawa and the Dahlak Islands); they have often been very useful in the present study, affording the possibility of interesting comparisons.

For each species, one or a few essential bibliographical references are given here, mostly of recent papers. Length measurements are always standard.

The Gulf of Eilat (Gulf of Aqaba) is situated at the northern end of the Red Sea, between the Sinai Peninsula and the Arabian coast. Its position is about 29°N, 35°E. The hydrographical features have been described by OREN (1962). Let us simply point out that this gulf is smaller than the Gulf of Suez, but deeper (1830 m in the middle), the salinity is 40–41 ‰, the mean surface temperatures are 20°C (February) and 27°C (August—September). Near the town, just at the innermost point of the gulf, there is a beach; in front of it, the bottom is partly sandy, partly covered with *Halophila*. This grass forms rather extensive beds. Along the western coast, about 6 km south of Eilat, reefs are developed in shallow water; beyond them, the bottom rapidly sinks towards the depths. On these reefs, a rich fauna is found, with a typically Indo-Pacific composition. The corals are *Acropora*, *Pocillopora*, *Stylophora*, *Porites*, *Coeloria*, *Favia*, *Millepora*, etc.; among them, sandy areas are scattered here and there. In order to preserve at least a part of this wonderful marine life, a "coral reserve"—where collecting is forbidden—has been established by the State of Israel.

As a result of recent work that Israel students are carrying on at Eilat, several papers on fishes have already been published. BEN-TUVIA and STEINITZ (1952) and STEINITZ and BEN-TUVIA (1955) listed a series of species, and FISHELSON (1964; 1965) reported on the collection made during the "Manihine" Expedition to the Gulf of Aqaba. Among the recent works on the ichthyofauna of the Red Sea as a whole, those by KLAUSEWITZ (1958–1965) are outstanding; this author also wrote (1964a) a history of the researches accomplished in this region, with a complete review of the literature. FOWLER's book on the fishes of the Red Sea and Southern Arabia (1956) will remain restricted to vol. I; it is to be regretted that the loss of so eminent an ichthyologist has put a stop to this publication that was expected to be useful notwithstanding some evident failures of the available part. As far as the near Indian Ocean is concerned, a valuable series of taxonomic papers dealing with a number of families has been published by J.L.B. SMITH in recent years; many species from the Red Sea are included with descriptions and figures. At present, tropical marine fishes seem to draw the attention of many ichthyologists so that more and more faunistic and systematic studies are being made with important results; several papers, which have been employed during my study of the fishes from Eilat, are quoted with the other bibliographic references in the following pages.

GENERAL PART

The species considered in this paper are treated in systematic order in the main part. However, it may also be interesting to have them etho-ecologically arranged; those seen in the Eilat Museum or in the Aquarium there, but not observed in nature, are omitted.

1. CORAL REEFS

a) Free swimming: *Fistularia petimba, Cephalopholis miniatus, Variola louti, Caesio lunaris, Diplodus noct, Chaetodon austriacus, Ch. chrysurus, Ch. fasciatus, Gonochaetodon larvatus, Pomacanthus imperator, Pomacentrus sulphureus, Dascyllus trimaculatus, D. marginatus, Abudefduf saxatilis, Gomphosus caeruleus, Coris aygula, Thalassoma purpureum, Acanthurus nigrofuscus, Zebrasoma xanthurum, Pterois volitans* (at sunset and night), *P. radiata* (id.), *Sufflamen albicaudatus, Ostracion cyanurus, Canthigaster margaritatus.*

b) Keeping in the shadow, under masses of corals: *Myripristis murdjan*, *Cheilodipterus lineatus*, *Anthias squamipinnis*, *Pempheris mangula*.

c) Hidden in branched corals: *Echidna grisea*, *Dascyllus aruanus*.

d) Associated with large actinians: *Amphiprion bicinctus*.

e) Associated with large fishes: *Labroides dimidiatus*.

f) On the bottom in sandy areas: *Parupeneus macronema*, *Parapercis hexophthalma*.

2. ROCK POOLS ON THE SHORE: *Istiblennius rivulatus*.

3. SANDY BOTTOM AND HALOPHILA BEDS IN FRONT OF THE NORTHERN BEACH: *Synodus variegatus*, *Trachinocephalus myops*, *Pranesus pinguis*, *Allanetta afra*, *Mugil oligolepis* (?), *Diplodus noct*, *Mulloidichthys flavolineatus*, *Upeneus tragula*, *Gerres oyena*, *Scomberoides sancti-petri*, *Hemipteronotus pentadactylus*, *Siganus rivulatus*, *Dendrochirus brachypterus*, *Amblyrhynchotes hypselogeneion*.

As expected, I noticed quite different faunas on the reefs on the one, and near the northern beach on the other hand. *Diplodus noct* was the only species found in both habitats. However, it should be emphasized that these are nothing more than my own observations, accomplished during a rather short period. More extensive field work may have had different results: numerous species might have been added to every one of the groups mentioned above. Thus, further subdivision of the etho-ecological grouping would probably have been necessary.

At present, the study of the fishes living in the Red Sea goes on along three main directions. Firstly, it is necessary to collect more extensive material in order to discover new or hitherto unreported species; it seems that our species list of this fauna is far from being complete. Small forms as gobioids, blennioids, clingfishes, etc. deserve to be particularly looked for. Several species require a better understanding of their systematic position. Secondly, the life histories of these fishes are so poorly known that biological investigations must be planned regarding the various habitats; very interesting results have recently been obtained by several students as KLAUSEWITZ and FISHELSON. Thirdly, there are the problems connected with speciation and evolution: the study of populations of different parts of the Red Sea and comparison with related forms living in other Indo-Pacific areas, will surely be rewarding. In the following pages, some notes concerning these trends of research will be briefly reported in the hope that they will suggest stimulating lines of research to future students.

In conclusion I should like to emphasize how attractive and exciting it is to deal with the fishes from the Red Sea, not by way of dead old museum specimens, but through direct experience with living creatures observed in their natural surrounding.

Systematic Part

CARCHARHINIDAE

Galeocerdo cuvieri (LE SUEUR)

FOWLER, 1956, p. 17, f. 4.

Skin and teeth of medium sized specimen (Museum of Eilat).

MOBULIDAE

Manta birostris ehrenbergi (MÜLL. HENLE)

TORTONESE, 1954a, p. 18, f. 5.

A skin in the Museum of Eilat. As I stated earlier (1954a), this species is probably to be considered as polytypic, and the form living in the Red Sea deserves the name here employed.

SYNODIDAE

Synodus variegatus (LAC.)

NORMAN, 1935, p. 106.

A single specimen (length 125 mm) was captured near the north beach, on sandy bottom. In life, the colour on the upper parts was yellowish brown, with six dark brown bands across the back, the first one between the eyes. It would be interesting to know if also in the Red Sea there are two different colour phases (red and green, the latter living in shallower water) as observed in Japan and Hawaii. As the real identity of "*Cobitis japonica* HOUTTUYN" remains doubtful, the name *variegatus* is the correct one for this lizard fish.

Trachinocephalus myops (SCHN.)

NORMAN, 1935, p. 122, f. 13.

Several specimens (140–180 mm) were found in the same habitat as the preceding species. *T. myops* appears to be much more abundant. In life, the colour is very bright, with horizontal blue and yellow stripes.

MURAENIDAE

Echidna grisea (LAC.)

TORTONESE, 1936, p. 166, fig. 2. (*E. geometrica*); 1955, p. 52 (*id.*). MARSHALL, 1952, p. 223, fig. 1 (*Gymnothorax geometricus*). SMITH, 1962, p. 441, pl.61 C (*Siderea grisea*). KLAUSEWITZ, 1964, p. 125, fig. 2.

I saw one of these morays half hidden among the corals, very near to the shore, and two others in the Aquarium of Eilat. As pointed out by myself and by KLAUSEWITZ, this species is rightly referred to the genus *Echidna*. FOWLER (1956) wrongly considers *Gymnothorax geometricus* (RÜPP.) (=*E. grisea*) as a synonym of *G. flavimarginatus* (RÜPP.).

Echidna nebulosa (AHL)

SMITH, 1962, p. 423, pl. 60 F.

A fine specimen seen in the Aquarium of Eilat.

9

HEMIRHAMPHIDAE

Hyporhamphus dussumieri (VAL.)

WEBER-BEAUFORT, 1922, p. 155 (*Hemirhamphus dussumieri*). WOODS-SCHULTZ 1953, p. 172, fig. 34 b. FOWLER, 1956, p. 145, fig. 75 (*Hyporhamphus gambarur*).

One specimen, found dead on the beach.

Length 225 mm, depth 21, width 19, head 76, eye 10.5, beak 38. Body about as wide as deep, flattened on back. Upper jaw keeled, a little broader than long. Praeorbital shorter than eye. 27 lower gill rakers. 48 scales in axial lateral series. Dorsal (rays 2/12) and anal (2/11 ?) with a few scales on their anterior part. Origin of dorsal a little in front of that of anal. Caudal well forked, its middle rays subequal to eye. Base of ventrals equidistant from base of caudal and base of pectorals, the latter being twice the diameter of eye. Scales on back with a broad dusky edge which is wider on those of the caudal region. Two black parallel lines on the back, one on each side of the median series of scales; they end at the dorsal fin. A silvery lateral stripe, wider behind. Tip of beak red. Fins grey, ventrals and anal paler; tip of front lobe of dorsal blackish.

It is doubtful if the name *gambarur*, created by LACÉPÈDE, has a definite meaning and is to be applied to this species; it seems rather that different Hemirhamphidae from the Indo-Pacific and the Atlantic regions were originally confused under the name "Esoce Gambarur". Therefore, I prefer—as on former occasions—to keep the name *dussumieri*.

This is one of the more widespread hemirhamphidae, being known as far as the central Pacific. It was also recorded from the Eastern Mediterranean, but its immigration there is still uncertain.

FISTULARIIDAE

Fistularia petimba LAC.

FOWLER, 1956, p. 194.

Common on the reefs, where rather large pipefish were observed. They used to stay often immobile, in horizontal position.

CENTRISCIDAE

Centriscus scutatus L.

BLEGVAD, 1944, p. 81. FOWLER, 1956, p. 196.

Several small specimens (50–55 mm) in the Aquarium of Eilat. As far as I know, only RÜPPELL and KLUNZINGER reported the existence of this strange fish in the Red Sea.

SYNGNATHIDAE

Yozia bicoarctata (BLKR) (Fig. 1 A)

WEBER-BEAUFORT, 1922, p. 101, fig. 42. SMITH, 1963, p. 532, fig. 10, pl. 80 A.

A dried specimen (male) obtained from the Museum of Eilat. Length 316 mm;

preanal length 104; head 29; preocular length 17.5; eye 3.5. Rings 24 + 59. Trunk heptagonal, tail tetragonal. Snout long and slender, scarcely compressed, about twice the postocular part of head; its dorsal keel almost obsolete, lateral keel more evident, ending below the eye. Operculum swollen, with many radiating lines and with a faint, oblique keel on its upper part. Occiput rough and somewhat prominent. Interorbital equal to vertical diameter of eye. Rings with fine transverse lines and smooth borders. Superior and inferior ridges of trunk and tail discontinuous; median ridges of trunk and inferior ridges of tail continuous. Dorsal (27 rays) a little longer than snout; it occupies 3 + 2 1/2 rings; base not elevated. 4 anal rays, 16 pectorals. Pectoral as long as eye diameter. Caudal very small. Brood-pouch on 16 rings, on the anterior part of tail.

Colour (dried condition): brown, with a dark vertical band on each ring; two parallel series of black spots on the lower side of snout.

This specimen is in good agreement with the quoted descriptions and is interesting because *Y. bicoarctata* was not previously reported from Eilat. The species is very widespread in the Indo-Pacific region, as it reaches Durban and Japan. Fowler (1956) did not mention it among the syngnathids of the Red Sea. However, it was recorded by Dollfus and Petit (1938), who described *Y. bicoarctata erythraeensis*, after a single specimen (339 mm) with 32 dorsal rays (27–29 is the usual number), collected in the bay of Suez. According to Smith, this subspecific separation is not acceptable until more data are obtained; it is also not supported by the specimen from Eilat.

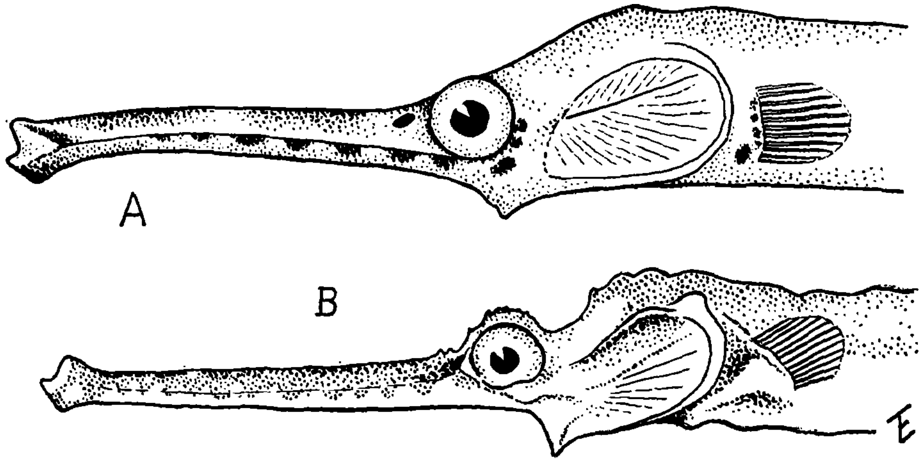

Fig. 1 A. Head of *Yozia bicoarctata* (Blkr). Eilat.
B. Head of *Phanerotokeus macrorhynchus* (Bamber), Eilat.

Phanerotokeus macrorhynchus (Bamber) (Fig. 1 B)

Bamber, 1915, p. 480, pl. 46 fig. 4 (*Halicampus m.*). Fowler, 1956, p. 204, fig. 109 (*Halicampoides m.*).—Smith, 1963, p. 530, pl. 76 H.

A dried specimen (female) obtained from the Museum of Eilat. Length 153 mm; preanal length 80; head 32; preocular length 20; eye 3; dorsal base 7. Rings 14 + 27.

Snout long and narrow, about 2.5 the postocular part of head, little compressed, without dorsal keel. Head rather narrower than trunk. Interorbital strongly concave, the supraorbital ridges being very prominent, spiny. Upper profile of head concave behind the eye, then raised and sinuous, strongly keeled from above the operculum to above the pectorals. Operculum with some radiating lines on its lower part and an oblique keel on its upper part. Trunk and tail a little wider than high. Two low, more or less distinct spines on the posterior border of each ring of trunk, one on each ring of tail. Prominent ridges; upper and lower ridges of trunk and tail discontinuous; median ridges of trunk and tail continuous. Cutaneous appendages totally absent Dorsal (18 rays) on 1 + 2 1/2 rings, its base elevated; pectorals (18 rays) with very swollen base. Caudal as long as the operculum.

Colour (dried condition): snout brown with white spots. Well evident bright red colour left on the upper postocular part of head. Four wide brown bands across trunk, seven on the tail; interspaces narrower and yellowish. Ventral side yellowish white, without spots.

This fish also deserves a peculiar mention, as it represents an endemic species of the Red Sea, of which—according to SMITH—only four specimens are known; they are from Suez, where the type was collected, and from Ghardaqa. The original description is extremely short.

Hippocampus hystrix KAUP

FOWLER-STEINITZ, 1956, p. 274. SMITH, 1963, p. 518, pl. 76 C. KLAUSEWITZ, 1964b, p. 127, f. 4.

A dried specimen was received from the Museum of Eilat. The species is also widely distributed in the Indian and Pacific oceans.

HOLOCENTRIDAE

Holocentrus diadema LAC.

FOWLER, 1956, p. 216.

One specimen obtained from the Museum of Eilat.

Myripristis murdjan (FORSSK.)

FOWLER, 1956, p. 212, f. 112.

Groups of these fishes are common on the reefs, always in shadowy situations under great masses of corals.

ATHERINIDAE

Pranesus pinguis (LAC.) (Fig. 2 A)

FOWLER-STEINITZ, 1956, p. 273. SMITH, 1965, p. 608, pl. 99, 100 A–C.

Atherinid fishes were found very abundant at Eilat, near the beach at the north end of the gulf; they used to leap out of the water in good numbers, not far from the shore. The collected specimens belong to two well distinct species, one of them—that appeared to be less numerous—being *P. pinguis*, already recorded from this locality (FOWLER-STEINITZ, loc. cit.).

Length 73–100 mm, depth 5–5.5, head 3.8; diameter of eye equal to postorbital or a little greater; width of head 7.3 in standard length (larger specimens), 6.5–6.75 (smaller specimens); width of silvery stripe about equal to snout; anal soft rays 13–14; black blotch on distal part of pectoral fins present (more evident in larger specimens).

As features of "*Atherina pinguis* LAC." and "*A. forskalii* RÜPP."—mentioned by KLUNZINGER (1884)—clearly coexist, the identity of these species is confirmed. According to the recent investigations by SMITH, the nominate subspecies is found in the Indian ocean and has 13–17 soft anal rays (average 14 or more); two subspecies replace it in the Red sea:

P. pinguis forsskali (RÜPP.): body depth 4.5–4.9 in standard length.

P. pinguis rueppelli SMITH: body depth 5–5.5.

Both have 12–15 soft anal rays (average less than 13). Using the available material, partly collected in Eilat (and described above) and partly preserved in the Museum of Genoa, I have tried to refer it to these different forms.

a) Massawa, Red Sea (MSNG 13925): five specimens: length 72–85 mm, depth 4.5–5, 13 anal soft rays.

b) Is. Du Rahakan, Red Sea (MSNG 7895), one specimen: length 85 mm, depth 5.2, 14 anal soft rays.

c) Sarawak, Borneo (MSNG 23302), nine specimens: length 75–85 mm, depth 4.5, 11–13 anal soft rays.

Checking also the other characters, it does not seem possible to recognize two or three subspecies in this series, as expected. This should, however not be taken as outright rejection of the assumption of a polytypic condition: my material is too scanty for drawing definite conclusions. I would simply suggest that in its wide area, *P. pinguis* is represented by populations more or less different in body proportions and meristic characters, as is very frequently the case among fishes, and that perhaps we are not yet in a position for grouping such populations into larger geographic entities (subspecies). For these reasons, I prefer at present to call simply *pinguis* the *Pranesus* from Eilat, without giving them a subspecific name. Finally, it is doubtful—on theoretical grounds—that two different subspecies (*P.p. forsskali* and *P.p. rueppelli*) actually coexist in one and the same region (Red Sea); it would be necessary to show that they are in some way geographically or at least ecologically separated.

Allanetta afra (PETERS) (Fig. 2B)

SMITH, 1965, p. 621, pl. 98 C.

Many specimens were collected together with those of the preceding species. All of them have the same size (80–85 mm); the shoals seem therefore to be of one age group. Depth 6–6.4; head 4–4.4. This species was found more abundant than *A. pinguis*; also during the "Calypso" Expedition many more *A. afra* than *A. fors-*

skali (=*P. pinguis*) were captured (ROUX-ESTÈVE and FOURMANOIR, 1954). This silverside is easily recognized for its slenderer body and for two characters separating the genus *Allanetta* from *Pranesus*: maxillary bone not extended under the eye (the mouth is smaller) and mandible with a posterior elevation on each side within the mouth. According to SMITH, *Hypoatherina gobio* KLUNZ. —quoted by MARSHALL (1952) from the Gulf of Aqaba— is the same species.

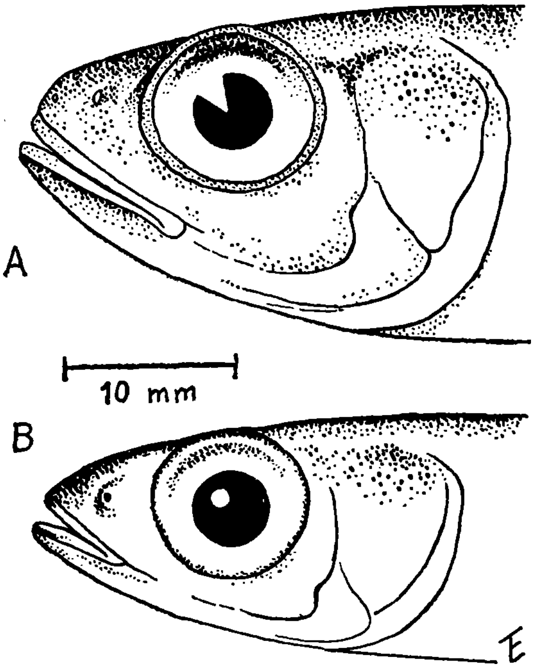

Fig. 2 A. Head of *Pranesus pinguis* (LAC.). Eilat.
B. Head of *Allanetta afra* (PETERS). Eilat.

Some records of "*Atherina*" *afra* in the literature are probably wrong. I briefly described under this name (TORTONESE, 1941) two specimens from Mogadiscio (Somaliland; MSNG 37731) of small size (20–29 mm). They have now been re-examined and the correction of the previous identification is interesting. Both fishes are *Atherion africanus* SMITH (1965), an atherinid with minute spinules on its head; vomerine and palatine teeth cannot be detected and owing to the imperfect preservation the count of the scales is approximate (about 40 on a lateral series). This species was recently described after material from Zululand, Delagoa Bay and the Island of Mozambique; it is evidently widespread all along the East African coast. The spinules on the head may be easily overlooked in the young individuals.

MUGILIDAE

Mugil oligolepis BLKR.

WEBER-BEAUFORT, 1922, p. 245.

On sandy bottom in front of the north beach a young grey mullet was caught.

Length 87 mm, head equal to depth, both 4 in length. Eye 3.75 in head, almost 2 in interorbital; the latter is nearly flat, equal to postorbital part of head. Very narrow ocular lid. Snout equal to eye. Lips not enlarged. Preorbital not bent downwards, its inferior border denticulated, not emarginate. Maxillary visible when the mouth is closed. Mandible with a single symphysial knob. Scales about 30 in longitudinal series, 10 in transverse series, about 17 predorsal. Origin of first dorsal nearer to the caudal base than to the snout. Origin of anal (rays 3/9) in front of origin of second dorsal (rays 1/9): both fins are scaled. Height of caudal peduncle equal to postorbital part of head. Caudal well emarginate. Pectorals much shorter than head, without axillary scale. Ventrals with axillary scale, about as long as half of the fin. Fins grey; ventrals white.

Two species of *Mugil* have been hitherto reported from Eilat: *M. labiosus* VAL. and *M. crenilabis* FORSSK. The present specimen can not be referred to either species; on the other hand, its features do not correspond to those of other common species found in the Red Sea (*M. tade* FORSSK., *M. seheli* FORSSK., *M. vaigiensis* QUOY-GAIM.). With some doubt, I identify it as *M. oligolepis*, not yet known from that sea; this grey mullet is found in the Indian Ocean (Seychelles, South Africa, India) and eastward until the Philippines.

APOGONIDAE

Cheilodipterus lineatus LAC.

LACHNER, 1953, p. 482, pl. 43 C. KLAUSEWITZ, 1959a, p. 258, f. 10.

Several specimens of large size were seen on the reef, always in the shadow and often staying motionless near the corals. The white and brown vertical bands on the caudal peduncle were very conspicuous.

SERRANIDAE

Cephalopholis miniatus (FORSSK.)

SCHULTZ, 1953, p. 369, pl. 31 C.

A single specimen, with the common bright colours (red with blue dots), was noticed half-hidden among the corals. Another individual was seen in the Eilat Aquarium.

Variola louti (FORSSK.)

SCHULTZ, 1953, p. 361, pl. 28.

A fairly big specimen was repeatedly seen near the base of the corals on the outer side of the reef, always in about the same place, which suggests rather sedentary habits.

Anthias squamipinnis (PETERS)

SMITH, 1961, p. 362, pl. 34 B,C,E.

Very common on the reef, in groups; always found in the shadow. Males, recognizable by their darker, purplish colour, appeared to be less numerous.

Grammistes sexlineatus (Thunb.)

Schultz, 1953, p. 385, pl. 32 A.
A fine specimen was seen in the Aquarium of Eilat.

Therapon jarbua (Forssk.)

Blegvad, 1944, p. 87. Marshall, 1952, p. 228.
One specimen was received from the Museum of Eilat.

PEMPHERIDAE

Pempheris mangula Cuv. (Fig. 3)

Fowler, 1931, p. 55.
Large shoals of these fishes are common at Eilat, concentrating during the day in the dark places on the reefs, where thay may be seen actively moving, sometimes mixed with *Anthias*. The percoids of the genus *Pempheris* have often been confused and there are many disagreements among the ichthyologists who dealt with them. Therefore, some difficulties arose in giving to the population of Eilat the appropriate name.

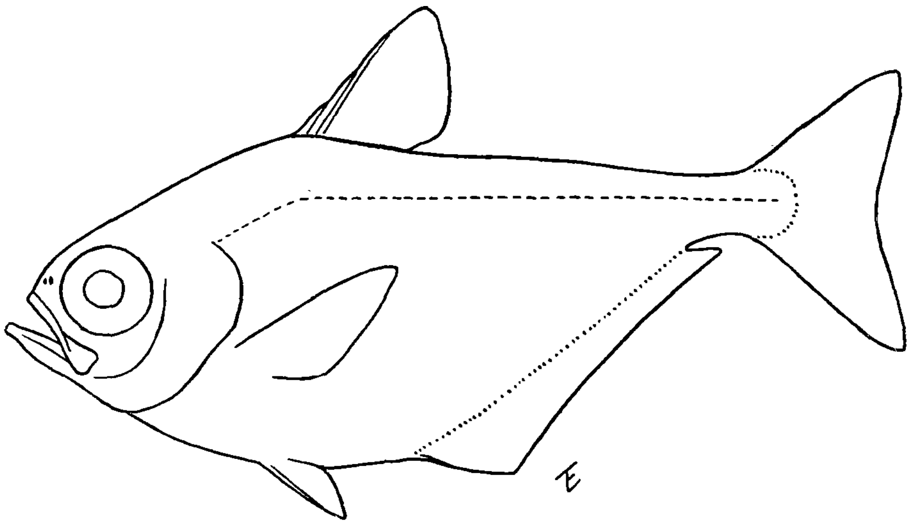

Fig. 3. *Pempheris mangula* Cuv. Massawa.

The first record of *Pempheris* from the Red Sea was Rüppell's (1835:*P. mangula*, Mohila), the second Klunzinger's (1871, 1884:*P. mangula*, Koseir). Kossman and Raüber (1877) described *P. rhomboidea* from an untold locality and proposed a new name (*P. erythraea*) for "*P.mangula*" of Klunzinger. Much later and simultaneously (1952) Marshall dubiously considered as *P. moluca* 25 juvenile specimens from Faraun Island (Gulf of Aqaba) and Ben Tuvia-Steinitz identified as *P. mangula* some specimens from Eilat. As far as I know, there are no other records in the literature.

Comparatively recent descriptions of the species of *Pempheris* are those of Fowler (1931) and Weber-Beaufort (1936); the latter authors did not include the Red Sea in the habitat of any species, but Fowler quoted as living in that sea only *P. mangula.* This species is not considered by Weber and Beaufort; according to them the name *mangula* was wrongly applied to different species. Fowler, on the contrary, gave a description of *P. mangula* that fits perfectly with the following specimens available to me.

a) Massawa, Red Sea (MSNG 13640), one specimen. Length 103 mm, depth 47, head 31, eye 14. Interorbital about 2/3 of eye, snout 2.5. Head as high as long. Rostro-frontal line slightly concave behind the eye. Maxillary ending below the center of the eye. Mandible projecting. Teeth small, villiform, in bands on jaws, on vomer and palatines. 17 lower gill rakers. Scales mainly cycloid, often with irregular border, about 50 in lateral line, which extends on the caudal fin. Distance of dorsal fin from point of snout less than height of body. Dorsal rays V.9, anal III.36. Dorsal tip blackish. Anal with evident dark base and with dark anterior tip. Caudal with somewhat dusky border. No black blotch on the base of pectorals.

b) Ras Dumeirah, Assab, Red Sea (MSNG 16228), one specimen. Length 100 mm, depth 50, head 31, eye 13. Anal rays 3/38. Similar to the preceeding fish in all other features.

c) Eilat, Red Sea (HUJF 3534), two specimens. Length 92–98 mm, depth 40, head 30–32, eye 12–13. 19 lower gill rakers. Anal rays 3/38. A well marked dark band all along the base of the anal fin. Owing to the much more recent capture, the original colour —rather dark brown— is better preserved.

The fishes from these three localities are very similar; no remarkable differences can be detected in two others from Amboina, Moluccas (MSNG 13639; length 63–83 mm). All of them are here referred to *P. mangula,* interpreting this species according to Fowler (loc.cit.). This being the species found in Eilat, the determination made by Ben Tuvia-Steinitz is confirmed. The figure given by Bleeker (1877, pl. 383 f.2) does not show the black tip of the dorsal, but is otherwise good. The synonymy *rhomboidea-mangula,* suggested by Fowler, appears to be exact.

Is *P. mangula* the only species living in the Red Sea? Probably not, as shown by the following material.

a) Is. Dahlak, Red Sea (MSNG 40311), one specimen. Length 94 mm, depth 40, head 25, eye 12. 16 lower gill rakers. Dorsal rays V.9, anal III.42. Dorsal black tipped, anal with a narrow dusky border.

b) Red Sea, locality unknown (HUJF 3535), 3 specimens. Length 117–130 mm, depth 49–55, head 33–36, eye 13–17. Head as high as long. Rostro-frontal line convex. Teeth small. 22 lower gill rakers. Scales cycloid, about 55 on lateral line. Distance of origin of the dorsal fin from point of snout less than depth of body. Dorsal rays 6/9, anal 3/40 (approximately). Dorsal tip blackish. Anal with well marked black border; caudal border also darker. No black blotch at the base of pectorals.

The former specimen of this group is rather similar to those mentioned before; the others are more different, chiefly for their more elongated body and for this reason are more fully described here. All agree in having a higher number of anal rays and a dark border on this same fin. Such characters are found in *P. vanicolensis* Cuv. Therefore, I think that this is the second species present in the Red Sea. It seems that the ratio length/depth of the body and the number of gill rakers are rather variable; my material is however too scarce for a satisfactory definition and comparison of these two pempherids, which perhaps were confused by KLUNZINGER. On this occasion, I simply assemble a few notes that may be useful to future workers in a detailed study which requires abundant and desirably fresh material. At present, nothing can be said about the distribution and frequency of *P. mangula* and *P. vanicolensis* in the Red Sea.

The following concluding remarks on *P. moluca* Cuv. are in order. According to FOWLER, this is a synonym of *P. macrolepidotus* (SCHN.); according to WEBER and BEAUFORT, it is applied to a valid species, recognizable for its stronger dentition, with anterior lower teeth partly directed outwards and visible from below. Such a character can not be found in any of my specimens.

LUTJANIDAE

Caesio lunaris Cuv.

WEBER-BEAUFORT, 1936, p. 299.

Large shoals were observed near the reef. These fishes show a bright blue colour and black tips on their caudal fin.

SPARIDAE

Diplodus noct (VAL.)

MARSHALL, 1952, p. 233.

This sparoid which according to MARSHALL, is endemic in the Red Sea, is very common at Eilat. Big specimens were found on the reefs, smaller ones on the *Halophila* beds.

MULLIDAE

Mulloidichthys flavolineatus (LAC.)

BLEGVAD, 1944, p. 133, pl. VII fig. 1 (*M. auriflamma*).

Abundant at the north end of the gulf, on sandy bottom and *Halophila* beds. NIELSEN and KLAUSEWITZ (1965) recently pointed out that the name *auriflamma* FORSSKÅL cannot be used for this species, because the type specimen (Univ. Zool. Mus. Copenhagen) is a *Parupeneus*.

Upeneus tragula RICH.

BLEGVAD, 1944, p. 135, pl. VII fig. 3. LACHNER, 1954, p. 522, pl. 14 C.

Good numbers were captured together with the preceeding species.

Parupeneus macronema (LAC.)

SMITH, 1950, p. 229, fig. 565.

Fishes belonging to this conspicuous member of the mullid family are very common on the sandy areas between the corals; they stay near the bottom, vividly moving their barbels. Only large specimens were seen, usually in groups of 3–4. They have a well marked black lateral band; the caudal region is bright yellow with a black spot. The closely related *P. barberinus* (LAC.) is probably also present.

LEIOGNATHIDAE

Gerres oyena (FORSSK.)

BLEGVAD, 1944, p. 115.

This is a common species on sandy bottoms and on *Halophila* beds.

CARANGIDAE

Scomberoides sancti-petri CUV.

BLEGVAD, 1944, p. 102 (*Chorinemus sancti-petri*).

Three young specimens were collected near the beach at the north end of the gulf. Maximum depth 3,75 in standard length (55–62 mm), equal to head length. Snout pointed, maxillary ending below middle of eye. Anterior tip of second dorsal fin and tip of each caudal lobe darker grey. Two specimens show undefined dark blotches on the upper part of the body sides, not extending beyond the lateral line.

CHAETODONTIDAE

Chaetodon austriacus (RÜPP.)

FRASER-BRUNNER, 1951, p. 45, pl. 11 fig. 2. BASCHIERI SALVADORI, 1954, p. 88, pl. I, fig. 1, II, fig. 1.

Very common on the reef, usually in pairs. This species has often been confused with *C. trifasciatus* M. PARK, a closely related *Chaetodon* living in the Indian and Pacific oceans.

Chaetodon chrysurus paucifasciatus AHL

FRASER-BRUNNER, 1951, p. 45, pl. II, fig. 4. BASCHIERI SALVADORI, 1954, p. 91, pl.II, fig. 4.

This pretty fish appears to be frequent, but less abundant than the preceding species; it was also commonly seen in pairs.

Chaetodon fasciatus FORSSK.

BASCHIERI SALVADORI, 1954, p. 93, pl. III f. 2, IV f. 2.

Rarely observed as isolated specimens near the outer border of the reef. Like *C. austriacus* and *C. chrysurus paucifasciatus*, this is an endemic form of the Red Sea.

Gonochaetodon larvatus (CUV.)

TORTONESE, 1936, p. 185 (*Chaetodon triangulum larvatus*). FRASER-BRUNNER, 1951, p. 44, pl. I, fig. 2. BASCHIERI SALVADORI, 1954, p. 95, pl. V fig. 1, VI, fig. 4.

Although common in the Red Sea, this fish was but rarely seen near Eilat. As I wrote many years ago (loc.cit.), it was usually assigned to other forms, considering the complex as a single species. FRASER-BRUNNER pointed out the differences, adding that *G. larvatus* is probably peculiar of the Aden-Zanzibar area. The existence in the Red Sea of fishes like the one from Aden painted by that author is, however, sure, as clearly demonstrated by my own observations on the reefs of Eilat, by the specimens from Massawa which I studied in 1936, by those photographed by BASCHIERI SALVADORI and by one (length 63 mm) from Dissei I. (Dahlak) preserved in the Museum of Genoa (MSNG 7901). Comparing the latter with a *G. baronessa* (CUV.) from the Bay of Geelwink, New Guinea (MSNG 38277; length 80 mm), I find that FRASER-BRUNNER is right in separating the eastern from the western *Gonochaetodon* according to the colour pattern, the number of scales and the length of the shout. This does not mean, of course, that further investigations are not needed for a better understanding of the forms assembled in this genus.

Heniochus acuminatus (L.)

BASCHIERI SALVADORI, 1954, p. 97, pl. V, fig. 2; VI fig. 2.

This easily recognizable chaetodontid was seen in the Eilat Aquarium and I was told by divers that it is often noticed near the northern beach; I never saw it on the reefs.

Pomacanthus imperator (BLOCH)

FRASER-BRUNNER, 1933, p. 556, pl. I.—BASCHERI SALVADORI, 1954, p. 98, pl. VI, f. 3; VII, fig. 1.

Isolated specimens of this magnificent fish were seldom observed on the reef. All of them showed the pattern of the adult condition.

POMACENTRIDAE

Pomacentrus sulfureus KLUNZ.

BASCHIERI SALVADORI, 1955, p. 63, pl. IV, fig. 3. SMITH, 1960, p. 345, pl. 28 C.

This bright yellow pomacentrid, with a black spot on the base of its pectoral fins, is one of the commonest fishes at Eilat; it swims abundantly among the corals. BASCHIERI SALVADORI found it scarce in the northern Red Sea. That author described (1955) *P. albicaudatus*; many specimens that I saw at Eilat possibly belonged to that species, but none was collected, so I cannot be sure of their identity. Another species which, unfortunately, I failed to collect is probably *P. tripunctatus* CUV., already reported from Eilat (BEN-TUVIA and STEINITZ, 1952).

Amphiprion bicinctus RÜPP.

BASCHIERI SALVADORI, 1955, p. 59, pl. I, fig. 2–3. FISHELSON, 1965, p. 3, fig. 1–7.

Very common. Each pair of specimens is invariably associated with one of the large actinians (*Stoichactis*) living among the corals.

Dascyllus aruanus (L.)

Baschieri Salvadori, 1959, p. 60, pl. II, fig. 1. Smith, 1960, p. 327, pl. 32 E.
Frequent, in small groups, always in the branched corals.

Dascyllus trimaculatus (Rüpp.)

Fowler-Steinitz, 1956, p. 277. Smith, 1960, p. 328, pl. 32 C,F.
Isolated, adult specimens were often seen on the reefs.

Dascyllus marginatus (Rüpp.)

Beaufort, 1940, p. 465, f. 54. Marshall, 1952, p. 237, f. 2. Baschieri Salvadori, 1955, p. 59, pl. I f. 4. Smith, 1960, p. 328, pl. 32 H.

According to personal observations, this species is the most abundant *Dascyllus* at Eilat. Groups of individuals, often of different size, live on the reefs and swim near the corals, not hiding as *D. aruanus* usually does.

It is interesting to examine the relationship of this pomacentrid and *D. reticulatus* (Rich.), a closely related form living in the Indo-Pacific region outside the Red Sea. They have been considered as synonyms (Beaufort, 1940), subspecies (Marshall, 1952) or species (Smith, 1960; Woods and Schultz, 1960). According to Marshall there are the following differences:

D. marginatus. Vertical brown bands absent. Spinous dorsal fin with black border; soft dorsal with black anterior border. Anal fin black anteriorly. Pectoral rays usually 18–19. Longest soft dorsal ray usually 23.8 % of standard length.

D. reticulatus. Two vertical brown bands. Spinous dorsal fin almost wholly black; soft dorsal without black anterior border. Anal fin largely black. Pectoral rays usually 20–21. Longest soft dorsal ray usually 21 % of standard length.

Marshall concluded that a single polytypic species exists, with a western representative (*D. marginatus marginatus*) found in the Red Sea, and an eastern one (*D. marginatus reticulatus*); he observed and figured intermediate specimens from Aden. I have tried to check this situation studying the available material. Owing to the generally worn condition of the soft dorsal rays, their length has not been considered.

a) Massawa, Red Sea (MSNG 12892), 10 specimens. Length 30–54 mm. Spinous dorsal largely black; this conspicuous band narrows behind, continuing with the black border of the soft dorsal fin. Anal black on its anterior half. Pectoral rays 17–19.

b) Massawa, Red Sea (MSNG 36899), 14 specimens. Length 26–50 mm. Colour faded, but probably as above. Pectoral rays 18–19.

c) Dilemmi I., Dahlak, Red Sea (MSNG 40249), 24 specimens. Length 20–47 mm. Colour as in N.12892, but anal less black. Pectoral rays 17–19.

d) Sarawak, Borneo (MSNG 23306), 175 specimens. Length 17–42 mm. Colour as above, but no black border can be detected on the soft dorsal fin. Pectoral rays 17–20, usually 18–19.

The fishes from the Red Sea differ from the one figured by MARSHALL because the black colour is rather more extended on the anal and, chiefly, on the spinous dorsal fin. 18 seems to be the more frequent number of pectoral rays. The series from Borneo was identified as *Tetradachmum reticulatum* by VINCIGUERRA (1926), who however, wrote that "there are no traces of dark bands on the body". For the reason indicated above, the length of the soft dorsal rays has not been measured; it seems that they are not shorter than in the specimens from the Red Sea.

I refer all the material at hand to *D. marginatus*, which appears to be widespread in the Indo-Pacific region at least until Borneo. SMITH's statement ("*marginatus* RÜPPELL, 1828, does not appear to occur beyond, or barely beyond the Red Sea") cannot be accepted. No specimens of *D. reticulatus* are available to me. The coexistence in large areas of *D. marginatus* and *reticulatus* would support the view that they are specifically different, not merely subspecific entities. I have to add that in BLEEKER's figure (1877, pl. 409, fig. 3) of *T. reticulatum* there are no dark bands and no black on the anal fin. Also, BEAUFORT's figure has no bands on the body (according to this author they disappear with age); the anal fin shows a black border all along. It seems that both these authors pictured *D. marginatus* rather than *D. reticulatus*.

Abudefduf saxatilis (L.)

BASCHIERI SALVADORI, 1955, p. 64, pl. V, fig. 1. SMITH, 1960, p. 332, pl. 29 B.

Like other recent ichthyologists I have avoided a trinominal. According to BEAUFORT (1940), the population of the Red Sea would be *A. saxatilis vaigiensis* (QUOY-GAIM.), being included in the subspecies which in the Indo-Pacific replaces the nominate form living in the Atlantic. Material from both areas is available in the Museum of Genoa: Indo-Pacific (Red Sea, Somaliland, New Guinea, Aru I.) and Atlantic (Cabo Verde I., Florida, Colombia).

Leaving apart the body proportions as the specimens have too different sizes, I tried to check the difference in the fifth brown vertical band; it is said to be confined to the caudal peduncle in the Indo-Pacific specimens, but extending to the soft dorsal fin in the Atlantic ones. I notice variations in this feature, so that I cannot confirm a difference which may, however, become statistically significant if more specimens would be examined. I have a fish from Massawa (MSNG 40310), 113 mm long, in which the mentioned band is well extended to the dorsal fin. The characters of the two populations must be thoroughly analyzed before subspecific units can be clearly defined.

According to FISHELSON (1964), this pomacentrid is more solitary and more erratic when adult; however, I frequently observed groups of 5–10 fully grown individuals swimming on the reefs.

LABRIDAE

Gomphosus caeruleus klunzingeri KLAUS.

KLAUSEWITZ, 1962, p. 12, pl. I, fig. 3–4.

Two single representatives of this labrid were seen on the reef. Both showed the dark blue colour ("blauschwarz") peculiar of males. The author quoted above described the differences between the Red Sea population and the nominate form found in the Indian ocean.

Labroides dimidiatus (Val.)

Randall, 1958, p. 329, fig. 1.

A specimen was captured at night (but not preserved) while freely swimming near the shore in front of the reef. Two others were seen associated with *Coris* and acting as cleaners.

Coris aygula Lac.

Smith, 1950, p. 292, pl. 101, fig. 806 (*C. angulata*).

This species is quite common at Eilat on the reef. However, only large specimens were seen, always solitary. Their forehead was well prominent, the colour showed remarkable variations, being sometimes very dark, almost black —but with a pale, more or less distinct vertical band across the anterior half of the body— and sometimes clear greenish. This is one of the largest labrids, as it may become more than a meter long.

Thalassoma purpureum (Forssk.)

Smith, 1950, p. 287, pl. 53, fig. 779.

Wrasses of small or medium size, frequently seen on the reefs, were so similar to the colored figure just mentioned that I suppose they belong to this well known Red Sea species.

Hemipteronotus pentadactylus (L.)

Smith, 1950, p. 293, p. 160 f. 812.

One specimen (length 145 mm) was caught near the north beach, on the *Halophila* bed. It would be very difficult to give a satisfactory description of the delicate colours of this fish (clear blue, pink, yellow); they rapidly disappear after death.

MUGILOIDIDAE

Parapercis hexophthalma (Cuv.)

Cantwell, 1964, p. 268, f. 1 J, 3 J, 9 B.

This species is rather common in sandy areas between the corals. The fishes were always seen resting on the bottom. The general colour was quite clear, so that the large black spot on the caudal fin was particularly evident.

BLENNIIDAE

Istiblennius rivulatus (Rüpp.)

Klausewitz, 1964b, p. 135, f. 11.

One specimen (length 72 mm) was collected at night along the shore, in a small rock pool. This blennioid —often confused with its close relative *I.edentulus* (SCHN.)— is probably endemic in the Red Sea.

SIGANIDAE

Siganus rivulatus (FORSSK.)

BEN-TUVIA, 1964, p. 5, f. 1.

This is a very common fish along the northern shore, on sand and *Halophila* ground. It is well known as an immigrant in the Eastern Mediterranean, where it is now found in great numbers. Both in Eilat and in Beirut I observed how quickly *S. rivulatus* changes its colour, becoming dark or pale, heavily spotted or almost plain.

ACANTHURIDAE

Acanthurus nigrofuscus (FORSSK.)

RANDALL, 1956, p. 190, f. 2 h; pl. 1.

Shoals of this surgeon fish are common on the reefs.

Zebrasoma xanthurum (BLYTH)

RANDALL, 1955, p. 402, f. 1 c, 5.

This brightly coloured species is very common, isolated or in small groups which usually stay close to the corals.

SCORPAENIDAE

Scorpaena erythraea CUV.

FOWLER-STEINITZ, 1956, p. 281.

A single specimen was captured near the reef. Length 87 mm, depth 30, head 32, eye 6. Maxillary reaching opposite front of eye. Lower jaw protruding. Eye 1.5 in snout, about equal to interorbital width. Both jaws with bands of villiform teeth. No palatine teeth. Interorbital deeply concave. Nasal spine sharp. Many cutaneous appendages scattered on head, trunk and fins; the larger are lobate. Supraocular tentacle long and flattened, with lobes. Scales finely ctenoid, 50 on lateral line; breast, axillary region and belly scaleless. Dorsal rays XI.I.9, anal III.5, pectoral 1.4.12 (4 branched). Life colour; brownish grey, with darker and blackish spots and blotches, a vertical band between soft dorsal and anal, breast and belly white, a dark blotch on the upper anterior part of soft dorsal, two dark grey bands on caudal, one at the base of the fin and the other, wider, behind the middle.

This species was described after a specimen from the Red Sea. The above mentioned authors had one from Eilat (70 mm long) which seems to be conspecific with mine. SMITH (1957) considers *S. erythraea* as a fish of uncertain identity; in any case, it does not belong to the genus *Scorpaena* as understood by this ichthyologist, because it lacks palatine teeth and has four divided rays in the pectoral fins. As a whole, *S. erythraea* appears to be a little known scorpaenoid.

Dendrochirus brachypterus (Cuv.)

Klausewitz, 1957, p. 320.

Two specimens were caught near the north beach.

Pterois volitans (L.)

Klausewitz, 1957, p. 322.

This well known fish is frequent on the reef, where during the day it is hidden among the corals, coming out at sunset. It is always solitary.

Pterois radiata Cuv.

Klausewitz, 1957, p. 320–321, 1958, p. 48.

A single specimen, not preserved, was captured at night near the shore in front of the reef.

Inimicus filamentosus (Cuv.)

Smith, 1958, p. 176, pl. 8 C.

According to the quoted author, this scorpaenid is rare and known from Zanzibar, Mauritius and Réunion. Two fine specimens were seen in the Eilat Aquarium.

PEGASIDAE

Pegasus draconis (L.)

Fowler, 1956, p. 191.

A dried specimen, 49 mm long, was obtained from the Museum of Eilat.

BALISTIDAE

Sufflamen albicaudatus (Rüpp.)

Clark-Gohar, 1953, p. 25, f. 3, pl. I f. 2.

This balistoid is common on the reefs, always solitary. In the Indian Ocean it is replaced by *S. chrysopterus* (Bl. Schn.), which lacks the white caudal band that is more or less evident in *S. albicaudatus.*

OSTRACIONIDAE

Ostracion cubicus L.

Clark-Gohar, 1953, p. 50, pl. II f. 3, IV f. 2. Tortonese, 1954b, p.82 (*O. tubercalatus*). Le Danois, 1961, p. 280, f. 36.

Trunk fishes have been known for a very long time, but the systematics of those living in the Red Sea is still in part obscure. According to Le Danois, *O. cyanurus* Rüpp. and *O. argus* Rüpp. "tombent en synonymie avec *O. cubicus*": however, no explanations are given for supporting this statement. The often used name *tuberculatus* L. has page priority, but –as pointed out by Le Danois– it was applied to the young stage of a species that might be either *O. cubicus* or *O. nasus*. Two dried specimens were received from the Eilat Museum. Both are young (length 33 and 93 mm) and show rather few clear spots with continuous encircling rings; on the belly of the smaller specimen the spots are solid black.

Ostracion cyanurus RÜPP.

CLARK-GOHAR, 1953, p. 51, pl. III f. 1 a–d.

I consider as belonging to this form a small, dried fish (female, 77 mm long; Museum of Eilat) and a larger one, bright blue, seen among the corals.

Tetrosomus gibbosus (L.)

CLARK-GOHAR, 1953, p. 52, pl. I f. 3. *Rhinesomus gibbosus* LE DANOIS, 1961, p. 288, f. 41–42 (*Ostracion gibbosus*). TORTONESE, 1966, p. 82.*

This is an easily recognizable fish, of which two dried specimens (length 90–150 mm) were obtained from the Museum.

CANTHIGASTERIDAE

Canthigaster margaritatus (RÜPP.)

CLARK-GOHAR, 1953, p. 63, pl. III f. 2. LE DANOIS, 1961, p. 319, f. 57 (*C. striolatus*).

This pretty fish, not rare on the reefs, was collected among the corals rather near to the shore. As many names were given to it, the synonymy is quite extensive. LE DANOIS revived *striolatus* QUOY-GAIM. (1824), ignoring the earlier *compressus* PROCÉ (1822) which however is included in her list of synonyms. As the descriptions of *striolatus* and *compressus* are not available to me and a reliable conclusion on the nomenclatorial problem can therefore not be reached, I prefer to keep RÜPPELL's well known name. For a century, that is after BLEEKER, *striolatus* has never been used. It is interesting to point out that according to LE DANOIS, the family Canthigasteridae has closer affinities with the Ostracionidae than with the Tetraodontidae. The latter were frequently understood as a very comprehensive group, including also *Canthigaster*.

LAGOCEPHALIDAE

Amblyrhynchotes hypselogeneion (BLKR)

CLARK-GOHAR, 1953, p. 57, f. 18.

Many specimens, 60–80 mm long, were captured on sandy and *Halophila* bottom; some very young were seen swimming close to the shore. When handled, these fishes moved their jaws emitting a peculiar sound.

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* Addition to m. s., June 1967 (Edit.)

TETRAODONTIDAE

Arothron hispidus perspicillaris (RÜPP.)

CLARK-GOHAR, 1953, p. 61, pl. III f. 3 (*A. hispidus*). KLAUSEWITZ, 1964b, p. 140, f. 18. Two fine adult specimens were seen in the Eilat Aquarium. As well shown by KLAUSEWITZ, this subspecies replaces in the Red Sea the nominate form living in the Indian and Pacific oceans. In *A. hispidus perspicillaris* the white spots are smaller, more numerous and extended also on the caudal fin, as confirmed by specimens at hand from Massawa (MSNG 12400).

ACKNOWLEDGEMENTS

It is a pleasure to express my best thanks to Drs. F. D. POR and H. STEINITZ, of the Zoological Department (The Hebrew University), who helped me all along with great enthusiasm and kindness, and to their assistants; I feel particularly obliged to Mrs. RUTH SEGGEV, Mr. YAIR ACHITUV and Mr. AVRAM WERECHSOHN. I wish also to thank Mr. DAVID FRIDMAN, director of the Maritime Museum (Eilat), who gladly cooperated, gave of his unique experience, and kindly presented several interesting specimens.

SUMMARY

66 fish species were observed at Eilat and identified; they belong to 33 families. Many of them were seen on the reefs, others were obtained from the sandy bottom and *Halophila* flats at the north end of the gulf; still others were examined in the public Aquarium of Eilat. Of particular interest is the reef fauna. There are numerous Pomacentrids, *Pempheris*, *Anthias*, *Chaetodon*, Plectognaths, etc. Morays were scarce. *Pterois volitans* appeared only at sunset and during the night. Near the sandy shore *Trachinocephalus*, *Siganus* and *Amblyrhynchotes* were numerous.

Systematic and biogeographical remarks: Two Syngnathids (*Yozia bicoarctata* and *Phanerotokeus macrorhynchus*) were not previously reported from this area. It is confirmed that *Pranesus pinguis* (Atherinidae) is a synonym of *Atherina forskali;* the specimens in hand are provisionally referred to the nominal form. Another Atherinid (*Allanetta afra*) was found more abundant. Two Pomacentrids were particularly considered: *Dascyllus marginatus* which appears to be widespread in the Indopacific region at least until Borneo, and *Abudefduf saxtilis;* two forms of the latter, living in the Indopacific and the Atlantic respectively, are known, but their separation is doubtful. The systematic position of some fishes living near Eilat, like *Pempheris* and *Scorpoena*, is not completely clear and further studies are needed.

RIASSUNTO

66 specie, appartenenti a 33 famiglie sono state osservate e identificate nella regione di Eilat. Molte di esse furono vedute tra le formazioni madreporiche, altre furono ottenute sui fondi di sabbia e *Halophila* all' estremità settentrionale del golfo ed altre ancora furono esaminate nell Acquario pubblico di Eilat. La fauna dei fondi a madrepore ha un interesse particolare; vi sono molti Pomacentridi, *Pempheris*, *Anthias*, *Chaetodon*, Plettognati, ecc. Le Murene sono scarse. *Ptereis volitans* appare solo al tramonto e durante la notte. Presso la riva sabbiosa sono numerosi *Tracinocephalus*, *Siganus* e *Amblyrhynchotes*.

Rilievi sistematici e biogeografici: Due Singnatidi (*Yozia bicoarctata* e *Phanerotokeus macrorhynchus*) non erano stati precedentemente segnalati in questa zona. Viene confermato che *Pranesus pinguis* (Aterinidi) è sinonimo di *Atherina forskali;* tutti gli individui sono per ora attribuiti alla forma nominale. Un altro Aterinide (*Allanetta afra*) fu rinvenuto in maggiore abbondanza. Due Pomacen-

tridi vennero particolarmente considerati: *Dascyllus marginatus* — che nella regione Indopacifica sembra essere diffuso almeno fino a Borneo — e *Abudefduf saxitilis;* di quest'ultimo sono note due forme — viventi nell'Indopacifico e nell'Atlantico — ma la loro separazione è dubbia. La posizione sistematica di alcuni pesci viventi presso Eilat, come *Pempheris* e *Scorpaena,* non è del tutto chiara e occurrono ulteriori studi.

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CONTRIBUTIONS TO THE KNOWLEDGE OF THE RED SEA
No. 41

OBSERVATIONS ON THE DISTRIBUTION AND BEHAVIOUR OF PELAGIC SCHOOLING FISH IN THE SOUTHERN RED SEA

by

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INTRODUCTION

Reports on the presence of schools of pelagic fish in the South Red Sea increased in frequency and reliability with the establishment of regular commercial off shore trawling based at Massawa. Surveys carried out in 1961–1963 on board the R.F.V. *Berbira*, a research boat of the Ethiopian Fisheries Section, confirmed these reports (BEN-YAMI, 1964). As early as 1957–1958, during the first trawling survey carried out on board the M.F.V. *Negisti Saba* (ANONYMOUS, 1959; PORATH, 1962), pelagic fish were observed and taken on trolling lines, the catch including such schooling fish as little tuna *Euthynnus affinis* (CANTOR), longtail tuna *Thunnus tonggol* (BLEEKER), and Spanish mackerel *Scomberomorus commersoni* (LACÉPÈDE). The Massawa trawlers and the *Berbera* operating in both Massawa channels, between Massawa and Dahlak and off the Dankalian shores, often hooked on their trolling lines various pelagic fishes, of which the most common were the above mentioned species, as well as barracudas (*Sphyraena* spp.), jackfish (*Caranx* spp.), and queenfish, *Chorinemus lysan* (FORSK.). Schools of the latter two species are often caught by local fishermen fishing with beach seines in shallow waters. Another schooling fish occurring in the catches of beach seines, is the milkfish, *Chanos chanos* (FORSK.).

The consistent reports on the abundance of pelagic fish in the South Red Sea brought the Israeli and the Ethiopian fisheries administrations to the decision to undertake pelagic fishing surveys in Ethiopian waters. The preliminary survey was carried out in February-March 1962, by a team headed by Mr. Z. PORATH (PORATH, 1962). In 1964, the Israeli Department of Fisheries reconditioned a 22 m trawler, *Negus Solomon*, for purse-seining, and equipped her with the gear necessary for explorations on a more extended scale. During this stage, observations were made by Mr. Z. PORATH in April and May, and by the author in June and in July.

Both surveys were carried out by the Israel Department of Fisheries in coordination with the Imperial Ethiopian Government (Department of Marine). Mr. J. KASEROFF, a FAO EPTA expert, was assigned by the FAO Fishing Gear Section to assist in the 1964 survey.

The objects of the surveys were:

1. to assess, the prospects for extended purse-seining in Ethiopian waters;

2. to train a crew of Ethiopian fishermen in the technique of purse-seining operation;

3. to determine the sort of gear and vessel suitable for commercial purse-seining in this area;

4. to observe and record the behaviour and movements of schools of pelagic fish, and to work out a suitable fishing tactic; to determine the most suitable fishing season, and to study the distribution of schooling fish in the surveyed area;

5. to estimate the qualitative and quantitative composition of the prospective catches.

The present paper reports on surveys carried out in 1962 and 1964, and deals mostly with items 4 and 5; it includes the observations and conclusions of Mr. Z. PORATH. Observations made by the author in 1965 are summarized.

FISHING CRAFT USED IN THE SURVEYS

The 1962 survey was carried out on board M.F.V. *Stella,* a typical Israel-made sardine purse-seiner (BEJERANO, 1960). She had the following features: length, o.a. — 11 m; engine — Diesel 40 HP; speed — 6.5–7 knots; deck equipment — seine winch and a purse-davit amidships, fore-mast with an outrigger for heaving the purse-rings and brailing the catch. An auxiliary row-boat was used in the purse-seining operations. The *Stella* was hired for the purpose of the exploratory fishing from her Massawa owners, Messrs. *Yotvath Red Sea Development (Ethiopia) Ltd.*

The *Negus Solomon,* a Medditerranean type steel trawler of Israeli construction, was hired from the same owners for the 1964 stage. She is a stern-trawler of 22 m l.o.a. powered by a 150 HP Caterpillar Diesel engine and developing 7.5–8 knots. To rig the *Negus Solomon* for purse-seining, the gallows and stern-roller were dismantled and a purse-davit was installed at the port side, amidships, slightly forwards of the trawl-winch, from which a purse-line was guided to the davit by means of specially installed snatch-blocks. The main derrick was re-rigged, to adapt it for heaving the purse rings, hauling the net and brailing the catch.

A rowing work-boat was used as an auxiliary when making a set. Manned by two men, this boat was connected by a short tow to the bunt end line of the purse-seine. When setting, the boat remained at the bunt end, and at the completion of the encircling operation, her crew would pass the bunt line and the purse-line ends on board the *Negus Solomon.* The *Berbira* and her crew, of the Ethiopian Marine Department, also participated.

THE PURSE-SEINE NET

A rather short (300 m) purse-seine, made of a 50 mm stretch mesh, 210/18 to 210/24 twine, green nylon netting, was used during the 1962 stage. The stretch depth of the net was 50 m (27.4 fathoms). It was satisfactorily used in the Mediterranean in purse-seining for small schools of little tuna. For the 1964 survey this same net was lengthened by a section of 50 mm stretch mesh netting, 165 m long, consisting partly of

210/21 nylon and the rest of polyethylene of equivalent strength, and at the wing end of the net a 150 m section of 84 mm stretch mesh white 210/9 nylon netting. A strip of 120 mm stretch mesh 210/27 green nylon netting, 6.4 m (3½ fathom) deep, was added to the depth of the net, between the leadline and the main body.

The net was assembled in the Californian manner, under the supervision of Mr. KASEROFF. The netting was not tapered and presented a rectangle with its outer meshes gathered and connected to large-meshed end pieces, the outer edges of which were gathered to an iron ring at each end of the seine. The netting was stapled to the kuralon corkline with a hanging coefficient of 0.90 and to the iron chain, which served for a leadline with 0.81 coefficient. The purse-line was a 12 mm dia., 6 × 19 steel wire-rope and the floats on the cork-line were of plastic and of natural cork.

In the course of our work, the white 210/9 twine netting proved to be too weak and was removed from the net. Thus, during most of the 1964 survey, the purse-seine had 465 m (254 fathom) net length and 419 m (229 fathom) corkline length. The reason for using several types of netting, some of them unsuitable (too thin nylon and polyethylene), was that a proper mackerel-bonito netting was not available in Israel during the preparation of the net.

OTHER FISHING GEAR

For the 1964 survey a tuna gillnet made of Japanese oval-sectioned monofilament No. 12, was assembled as follows: 100 m stretch length of 90 mm stretch mesh; 150 m stretch length of 110 mm stretch mesh and 150 m stretch length of 140 mm stretch mesh. Depth of all sections is 20 m stretch, and the netting is hung on both, cork-and leadline, with a coefficient of 0.70, which brings the whole net to an overall length (rope length) of 280 m, (153 fathom).

In 1964, also a floating longline of 180 hooks was constructed of kuralon main line with nylon monofilament snoods. The hooks were of various sizes to catch small tuna, sharks, etc.

Trolling lines and handlines were employed at various times during both the 1962 and 1964 surveys, and a beach-seine during the first survey only.

HANDLING THE GEAR

Purse-seining from the *Stella* was carried out in the manner employed in Mediterranean sardine fishing. While the purse-line was hauled by means of a seine winch and the rings weighed and taken on board from an outrigger overhanging the port working side of the boat, the net itself was hauled manually without any mechanical assistance.

The procedure on board the *Negus Solomon* was similar to that employed by American West Coast purse-seiners, except for the absence of a turn-table and power-block. The net was, nevertheless, hauled mechanically, bight by bight, from a stern derrick by means of two gypsy-head operated whips.

The longline and the gillnet were set from *Negus Solomon* stern. The longline was hauled from the stern over a gypsy head of the trawl-winch and the gillnet was hauled manually. Tin and glass buoys of different shapes and designs were used to hold the floating gear (lines, gillnet), their fishing depth being controlled by the length of the buoy-lines

RESULTS OF THE 1962 SURVEY

During the period from February 4 to March 6, 1962, a total of eight purse-seine sets were made, the details of which are given in Table I. The number of sets was limited by weather conditions and by the relative scarcity of schools suitable for surrounding by the small purse-seine. Most of the schools observed were in inshore waters between Ras Gedem and Ras Harb, 8 miles SE and 11 miles NNW, respectively, of Massawa. In addition to that area, the *Stella* team also surveyed the Bay of Zula, the area in the northern and western parts of the Dahlak Archipelago, the North Massawa Channel up to Harat Isl., the South Massawa Channel and the Howakil Bay. Two sets were empty including one made in the Bay of Howakil where the net suffered damage due to unfavourable bottom conditions.

TABLE I

PURSE-SEINE SETS AND RESULTS—1962 SURVEY

Date	*Sector*	*Results*
4.2	Off Massawa Harbour (C)	70 little tuna or frigate mackerel (about 100 kg) and 4 sharks.
5.2	Off Ras Harb (C)	5 sharks. The tunnids escaped the net.
14.2	Off Ras Harb (C)	6 little tunas and one yellowfin or longtail tuna.
19.2	Howakil Bay (F)	Net torn. All fish escaped.
23.2	Off Ras Harb (C)	400 little tunas (over 1/2 ton).
23.2	Off Ras Harb (C)	All fish escaped.
24.2	Off Ras Harb (C)	5 yellowfin or longtail tuna, and 1 shark.
25.2	Harkiko Bay (C)	4 unidentified tunnids.

According to observations made during this period, schools were relatively small and difficult to surround. They were less sensitive to the presence of the boat and the setting of the net during the early hours of the morning, when schools appear as slow moving dark spots, just below the surface. Only seldom does a fish from such a school break the surface. Apparently, the fish start feeding soon after sunrise, for then many jumping fish can be seen and the schools, accompanied by flocks of marine birds, move rapidly in various directions. Such schools could not be successfully fished by the *Stella* with her small purse-seine. In all sets except one, that of February 23, a fairly high number of fish managed to escape the net during the operation. Some schools were seen in inshore waters where the coral bottom does not allow the setting of purse-seines.

The species caught by the *Stella* were not, in most cases, authoritativelly identified. It seems, however, that the smaller fish, 38–45 cm in length, were mostly little tuna (*Euthynnus affinis*), while the larger, about 70 cm long fish were longtail tuna (*Thunnus* *tonggol*). Some of the younger specimens of the latter species might have been erroneously identified as yellowfin *Thunnus albacares* (BONNATERRE) (BEN-YAMI, 1964).

Throughout this period many fish were caught by the *Stella* with trolling lines. They were similar in size to those caught by the purse-seine and were probably the same species.

RESULTS OF THE 1964 SURVEY

Fig. 1 is a chart of the main part of the area explored during this survey by the *Negus Solomon* as well as the places where schools of pelagic fish were spotted. The area is divided into sectors, as follows:

A — Difnein Island area;
B — Harat Island area (North Massawa Channel);
C — Massawa area:
D — West Dahlak area;
E — Zula Bay;
F — South Massawa Channel and Howakil Bay;
G — Dahlak Reef area;
H — South East Islands area;
J — Shab Shakhs area. This sector appears in part only, on Fig. 1;
S — South area. This sector does not appear at all on Fig. 1. It covers the whole region between Sector J and the Assab area. It was not really surveyed, but the *Negus Solomon* crossed it four times — twice on the way to Assab and back, and twice on the way to the Bay of Edd and back. This area, when surveyed, might be further subdivided for better discrimination of fishing conditions;
W — Assab area. Under this heading are discussed direct approaches to Assab Assab Bay and the region of Ras Luma. This sector requires as well further investigation; it does not appear on Fig. 1.

The distribution of the schools sighted in sectors A–J can best be seen from the chart. Each numeral on the chart refers to the period of spotting a school which appeared to contain scombrids, carangids or milkfish (*Chanos chanos*) of commercial size, but which was not necessarily in a condition suitable for purse-seine setting. Attempts were made to surround only some of these schools. For example, wherever the numeral 3 appears on the chart, it indicates that at that spot a school or schools of pelagic fish were observed between May 16 and 31.

Fig. 2 offers a comparison of the number of sightings of such schools in the different sectors.

In most areas, (C, D, E, G, H and W), schools of tuna and other pelagic fish abounded during the survey. Two sectors seemed to be especially rich in schooling life, namely the sectors G (Dahlak Reef area) and H (South East Islands area). During the period between May 16 and July 5, most of the schools observed comprised

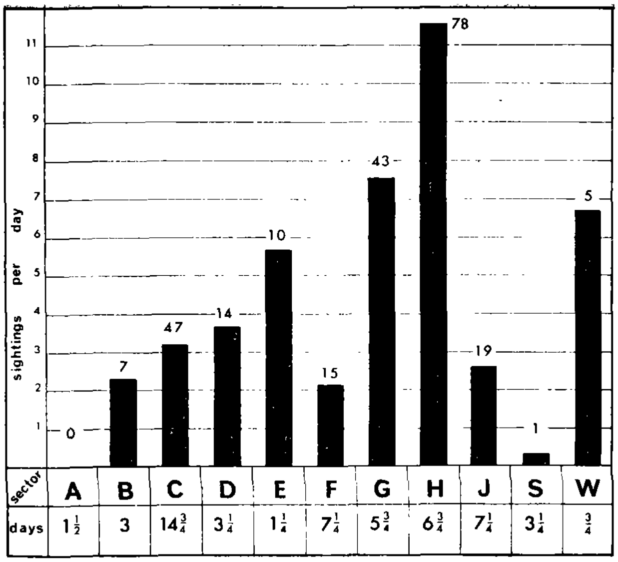

Fig. 2. Number of fish schools sightings per day by sectors.

mainly feeding and jumping fish. They were most frequent between and around the islands (sector H), between Shumma Islands and the Great Dahlak Iland, and between the latter and the Dahlak Reef (Sector G). In addition to the larger scombrids, schools of Indian mackerel, *Rastrelliger kanagurta* (RUSSELL), were observed throughout June and July, and schools of queen fish (*Chorinemus lysan*) in April and May, both in the area of the Dahlak Islands and in the inshore area of the continental coast. Whales were observed off Seil Amber (sector G) and in the adjoining waters of sectors F and H, in July, 1964.

PURSE-SEINING. Altogether, 35 sets of the purse-seine were made. In three sets the net was seriously damaged and in two of them, probably many of the surrounded fish escaped through the ripped netting. Fish were hauled from 13 sets, but only from eight of them in close to commercial quantities (150–800 kg). Apparently schools much larger than that were located and surrounded; however, in each instance the majority of fish managed to escape, either between the seiner and the auxiliary boat, just before the surrounding could be completed, or under the leadline, before the net could be pursed, especially when the fishing was done over depths greater than that of the seine.

On June 13, 1964, a school of little tuna chased by the *Negus Solomon* was intercepted by a school of longtail tuna swimming on opposite course. This meeting arrested the forward motion of both schools. They intermingled and started swimming in a whirlpool formation. At that moment the net was set and the whole concentration successfully surrounded over a depth of 70 fath. The catch, however, consisted of 300 kg of little tuna only, for all the longtail escaped under the leadline.

Table II contains details of the thirteen sets which were not totally empty.

TABLE II

PURSE-SEINE SETS AND RESULTS—1964 SURVEY

Date	Sector	Results
24.4	Bay of Edd (S)	150 kg queenfish (*Chorinemus lysan*).
25.4	Off Shab Shakhs (J)	500 kg longtail (*Thunnus tonggol*), 80 sharks (unidentified). Set on fish concentrated around trash-fish thrown overboard by a trawler. Considerable catch lost due to severely torn net.
15.5	Off Shab Shakhs (J)	5 Indian mackerel (*Rastrelliger kanagurta*) and 2 unidentified sharks. A small fast swimming fish escaped the net.
20.5	Off Ras Amas (C), close to shore	Few Spanish mackerel (*Scomberomorus commersoni*). A large school of unidentified fish escaped.
21.5	Hargigo Bay (C)	400 kg milkfish (*Chanos chanos*), 64 individuals.
22.5	Hargigo Bay (C)	800 kg milkfish.
27.5	Bu-*l*-hissar Isl. (H)	400 kg little tuna (*Euthynnus affinis*).
28.5	Aucan Isl. (H)	500 kg little tuna, 2 kg apiece. Probably only a fraction of the surrounded school was caught.
1.6	Hargigo Bay (C)	Few tuna and Spanish mackerel, and one hammerhead shark. A school of milkfish escaped.
6.6	Off Massawa (C)	150 kg of little tuna.
13.6	Off Ras Kumbit (G), 60 fath.	A school containing 300 kg of little tuna remained in the net while a school of longtail escaped downwards.
22.6	Off Dur Gaam Isl. (D), 70 fath.	50 kg (60 individuals) little tuna and frigate mackerel *Auxis thazard* (LACÉPÈDE). It was a small breezing school; probably all caught.
24.6	Off Mashilaga Isl. (H), 14 fath.	15 kg little tuna, Spanish mackerel, frigate mackerel and queenfish. Net torn. A considerable amount of fish escaped through the ripped net.

TROLLING. Most of the schools observed, especially during June-July, were feeding on fast-moving schools of tiny, unidentified fish. From the second half of June, tunas ceased to bite trolling jigs and no tuna whatsoever was hooked. Also, no schools of tuna were successfully surrounded at this time by the purse-seine. In respect to *Scomberomorus commersoni* and Carangidae, trolling was excellent in April and May, but gave poor results later on.

HANDLINING FOR TUNA. At the end of April and in the first half of May, good catches of little tuna and longtail tuna were taken by trawlers off Shab Shakhs, (sector J), with handlines using dead trash-fish as bait to bring the tuna into feeding frenzy. Older fish predominated in this catch: *E. affinis* were mostly age IV and about three kg (50–60 cm standard length) while *T. tonggol* were all between 70–80 cm standard length, about 6 kg, and probably age III or over (BEN-TUVIA and LANDAU, 1964; LANDAU, 1965). This type of fishing in the same area and season was described elsewhere (BEN-YAMI, 1964). It seems that conditions favourable for tuna handlining are an annual occurrence, but do not last long. The tuna concentrations around trawlers are accompanied by great numbers of sharks, which constitute a considerable part of the hooked fish.

MONOFILAMENT GILLNET. In total, 9 daytime sets were carried out, following one of several tactics: setting the net in an area in which a number of schools of tuna are swimming, setting around schools, and setting through a school. No commercial catches were made, the tuna apparently being able to avoid the net, probably due to the high transparency of the sea water during the whole survey period. Also, the net was too short to assure a complete surrounding of a tuna school. Altogether, 23 sharks, 2 longtail tuna, 4 little tuna, 3 barracudas, (*Spyraena* sp.), one wolf-herring (*Chirocentrus* sp.) and a few Indian mackerel (*Rastrelliter kanagurta*) were caught in the monofilament gillnet.

The high phosphorescence in the water, especially obvious in dark nights, enabled us to spot and surround pelagic fish schools at night. Two sets were made and in both, schools of Indian mackerel were successfully surrounded. The fish, however, were too small to be gilled in the netting and simply passed through the wide open mesh, leaving entangled individuals here and there. The passage of the mackerels through the netting could be easily observed, for both the net and the fish were shining in the water. Altogether one box of Indian mackerel and six barracuda were caught. It seems that there are always some barracuda preying on schools of Indian mackerel, for in each set on a school of the latter fish, one or more barracudas were caught. No tuna schools were located in the dark.

Since Indian mackerel behave calmly at night, they may be successfully fished with a purse-seine of suitable mesh-size.

LONGLINE. A longline was set twice in the surface layer in sector H, although due to the curvature of the main line between buoys, some of the hooks reached the bottom. The first set was made in daytime, in the midst of a concentration of schools of tuna, but no fish were caught. The second set made at night in the same area, resulted in a catch of five sharks and a very big grouper. The longline was severely damaged and some of the hooks were lost.

FURTHER OBSERVATIONS

In October 1965, during the South Red Sea Expedition of Tel-Aviv University, the author again searched for pelagic fish in secfors C, D, F, G and H, but observed only a few schools of tuna. One young longtail tuna was fished by troll line out of a school feeding on sardines; no more tuna were hooked. The remaining troll catches during this Expedition consisted of a few Spanish mackerel only.

Many schools of sardines were seen near the surface, or detected in midwater by means of an echosounder, in areas F, G and H. Whales were again spotted in sector G at this time. Further details on the fishery investigations of this expedition will be published elsewhere (BEN-YAMI, in preparation).

DISCUSSION

Except for the observations presented here and those reported previously (BEN-YAMI, 1964), there are no data available on distribution, behaviour and composition of schools of scombroid and other large pelagic fish in the South Red Sea. There is some

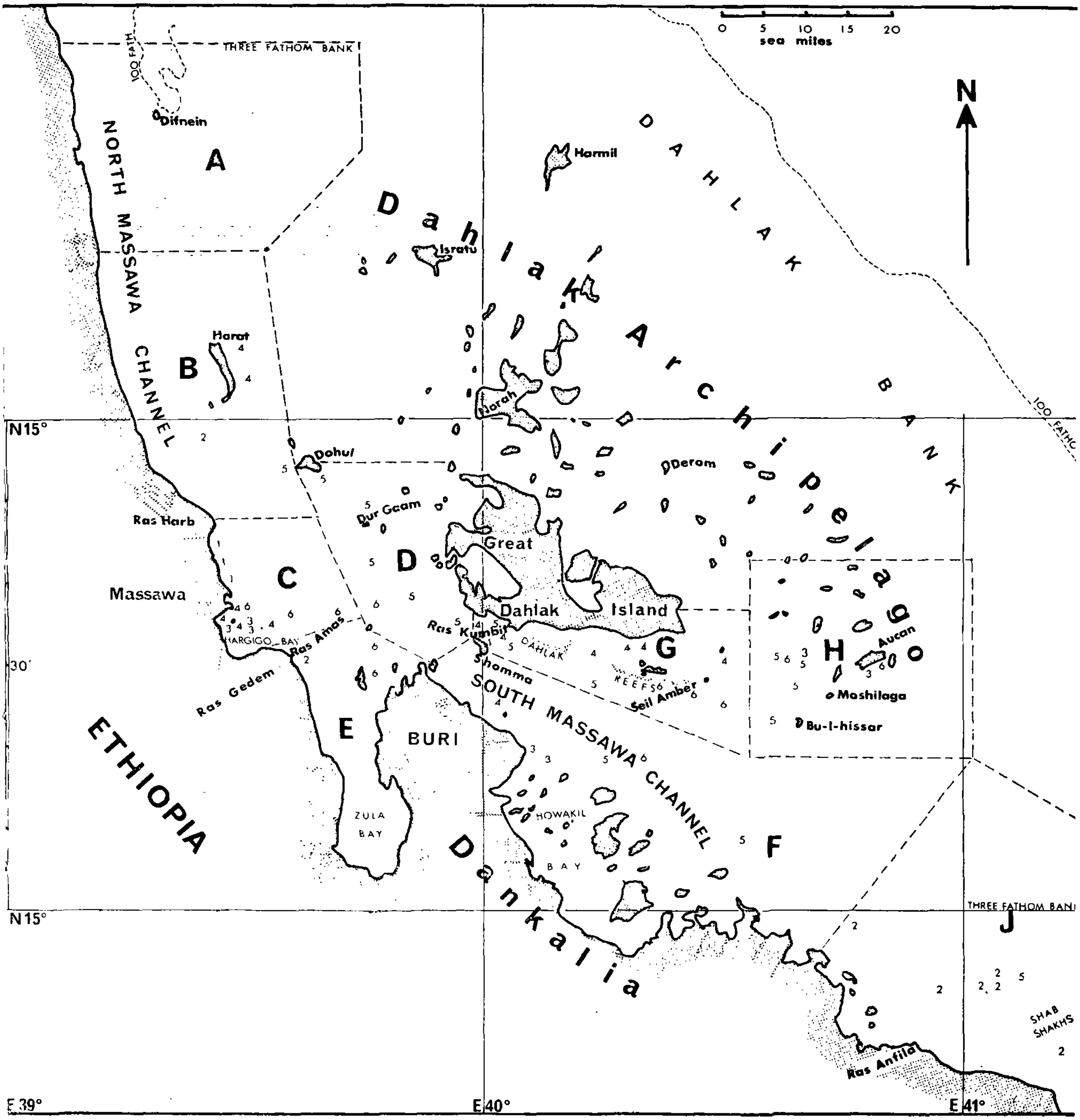

Fig. 1. Main part of the explored area. Numerals on the map indicate schools spotted in the following periods: 1—April 19-30; 2—May 1-15; 3—May 16-31; 4—June 1-15; 5—June 16-30; 6—July 1-5.

information on composition of catch in respect to species, size and age (BEN-TUVIA 1963; BEN-TUVIA and LANDAU, 1964; LANDAU, 1965). Hydrographic data are more extensive but still inadequate for a general picture of the conditions affecting distribution of pelagic fish in time and space. Therefore, no conclusions or definite recommendations in respect to commercial fishing can be offered, but in the following discussion an attempt is made to correlate existing knowledge.

SEASON. In offshore waters, where purse-seining is possible, schools of scombroid fish are more abundant from April to July than at other times of the year. Inshore, tunas are more common during the cooler months, as observed by the local fishermen beach-seining for inshore migrating schools of sardine and anchovy. Tuna species have a stronger tendency to form dense surface schools in summer, which may be attributed to a difference in the character of their prey: small, fast-moving schools of various bait in summer, and large, slow and very dense inshore concentrations of sardine and anchovy in winter.

From a comparison of troll and hand-line samples taken in April and May to troll and purse-seine samples from June and July, it appears that the size of *E. affinis* in surface waters declines in the course of the season (LANDAU, personal communication).

DISTRIBUTION. Geographical differences in abundance may to some extent be judged from the frequency at which schools were seen during the 1964 survey. Out of 54¾ survey days (100%), there were 32½ days (59%) when more than 3 schools were sighted, and 14½ days (27%) when over 5 sightings per day were recorded. The 1964 survey seems to indicate that sectors G and H were the most abounding in schools. for while they took only 23% of the survey time, over 50% of sightings were recorded there. Such notes on geographical distribution must, however, be read with due reserve, for a single vessel could be only at one place at a time. Thus, nothing is known, for instance, on the presence of schools in sector A, except for the first half of June 1964, or in sector B after June 15, (see Fig. 2), etc.

Species

The catches obtained, as well as observations made during this and other surveys, suggest that species can be listed in the following order, in respect to the abundance of schools in the surveyed area: 1. little tuna (most frequent); 2. longtail tuna; 3. Indian mackerel; 4. queenfish; 5. frigate mackerel. The frequently met schools of milkfish belong to a different category as they seem to form rather local, inshore populations along certain sections of the shores. The probability of occurrence of schools of double-lined mackerel, *Gramatorcynnus bicarinatus* (QUOI and GAIMARD), and of torpedo-jack, *Megalaspis cordyla* (L.) was indicated by the author elsewhere (BEN YAMI, 1964); it should be noted here that individuals of these species are known to accompany schools of various tuna, but have not by themselves been reported to form concentrations of commercial size (SILAS, 1963; WILLIAMS, 1963). No schools of Spanish mackerel or of barracuda were seen, although these species were frequently caught by trolling lines.

Size of schools

From size of catches and direct observations it appears that schools are comparatively small, mostly below 1–2 tons. The high degree of water transparency may mislead even an experienced observer if he is accustomed to estimate the total amount of fish in a school by multiplying the number of fish actually seen on or near the surface by a large figure. In the South Red Sea this figure should be kept low, for sometimes the visible fish comprise the bulk of the school.

Feeding habits

During the whole purse-seine season, most of the schools spotted were feeding intensively on schools of small, easily frightened fish. Some little tuna were caught with stomachs full of 3–4 cm long scombrids. The tuna observed offshore in October 1965, were evidently preying upon small dispersed schools of sardines. In winter the tuna follow shoreward dense concentrations of migrating sardines and anchovy. Thus, apparently, tuna feed in the South Red Sea the whole or almost the whole year round.

It seems that during the time that tuna were biting trolling jigs they were also easier to approach and surround. Good trolling was from April until June, when it deteriorated and remained poor through July. Poor trolling was also recorded for October, 1965. This reluctance to bite coincided with abundance of schools of small fish in the area. The general impression was that the more natural food was available for the tunas the worse was the trolling. Similar views are expressed by SUYEHIRO (1938) in regard to skipjack.

Behaviour as related to hydrography

Tuna displayed an extraordinary ability to escape the purse-seine net. Most schools acted wildly when approached, moving in all directions, both downward and horizontally. Some schools started these rapid movements at the time the net was being set. It would seem from this behaviour that there was a lack of thermal barriers to restrain their movements. During the set of June 13th, described earlier, when a mixed concentration of longtail and little tuna was surrounded, each species behaved differently. All little tuna were caught, while the longtail evidently escaped under the leadline. Unfortunately, no hydrographic data were collected along with the exploratory fishing, to corroborate the suggestion that the behaviour of these two species is differently affected by thermocline conditions.

The hydrographic data available to the author (ANONYMOUS, 1949; ANONYMOUS, 1966; FRIEDMAN, 1960; LUKSCH, 1901; NEUMANN and DENSMORE, 1959; NEUMANN and MCGILL, 1961; OREN, 1964; PICOTTI, 1930; SEYMOUR SEWELL, 1935–36; VERCELLI, 1930) indicate that there is no significant thermocline from November to April. During April the surface water layer starts heating up and in May a thermocline begins to develop at depth between 20 and 50 m. In June the thermocline is still mild, — a drop of about 4°C within 25 m of depths (Fig. 3), but by September it is more pronounced, — a drop of about 5–8° C within 20 m of depth, and it is situated in the

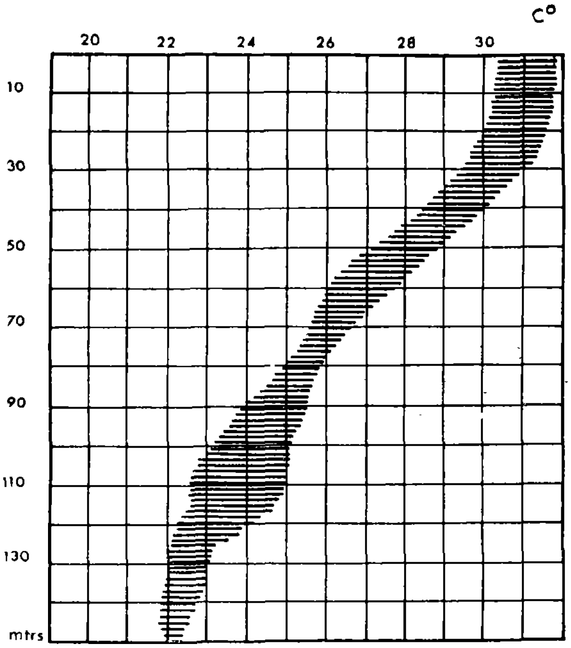

Fig. 3. Range of temperatures. South Red Sea (13°–17°N). June, 1934. Data compiled from SEYMOUR SEWELL, 1935–36.

depth range of 30–50 m (Fig. 4). Apparently, the thermocline descends in October to below 60 m (Fig 5) and disappears in November. During July and August the thermocline conditions in the surveyed area are intermediate to those of June and September, (ANONYMOUS, 1966).

There is an obvious similarity between thermocline conditions in the upper water layers of the South Red Sea and the Gulf of Aden, although during the summer months an inverse thermocline with an increase of up to 5°C at depths of 80 metres and more occurs in the South Red Sea and, particularly, in the waters adjacent to the straits of Bab el Mandeb (loc. cit.). Lately, the success of USSR purse-seining operations in the Gulf of Aden during the summer months of 1963 has been reported in the fisheries press (ANONYMOUS, 1964; HINDS, 1964), while the scarcity of tuna in surface water during winter was noted during the 1965 survey in the same area, carried out by the French tuna clipper *Tutina* using live bait and pole-and-line technique (PERCIER, personal communication). Also in winter, excellent longline catches of yellowfin were reported. All these results suggest the influence of the thermocline on the availability of tuna in the upper water layers of the Gulf of Aden.

The question of whether or not an analogous situation exists in the South Red Sea with its still warmer waters remains to be answered by further investigations. In summer the upper water layers in the surveyed area are 31.0–32.3°C offshore and still warmer in inshore sheltered zones where the temperature approaches that of the human body (ANONYMOUS, 1949; BEN-YAMI, 1964; AR, personal communication).

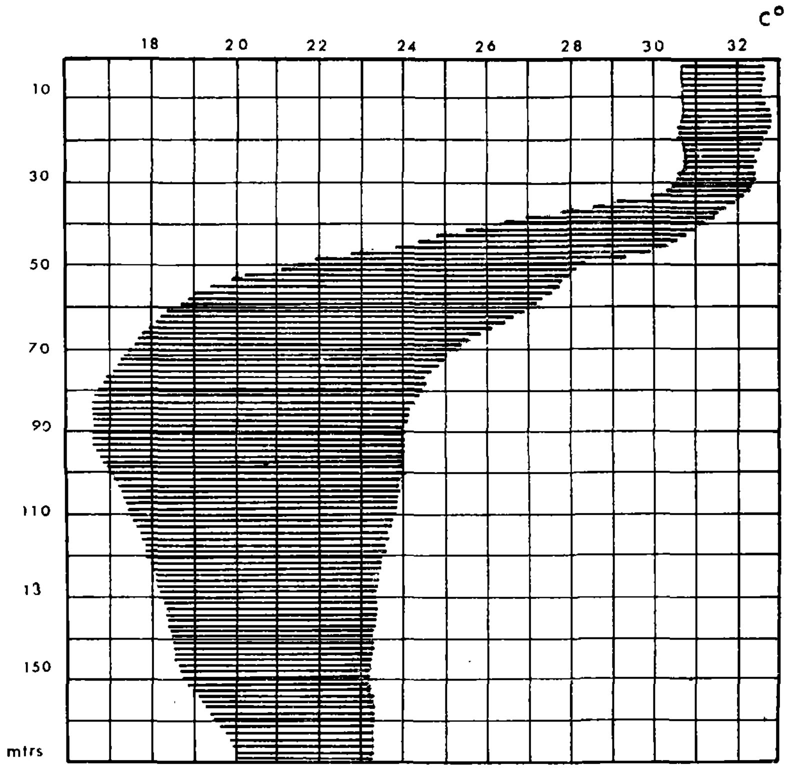

Fig. 4. Range of temperatures. South Red Sea (13°–17°N). September. Data compiled from ANONYMOUS, 1949; FRIEDMAN, 1960; LUKSCH, 1901; PICOTTI, 1930; SEYMOUR SEWELL 1935–36; VERCELLI, 1930.

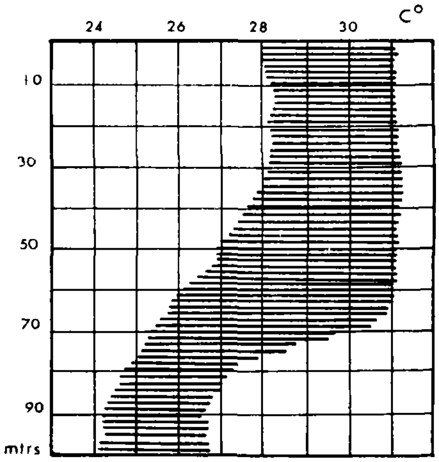

Fig. 5. Range of temperatures. South Red Sea (13°–17°N). October. Data compiled from ANONYMOUS, 1949; AR, personal communication; FRIEDMAN, 1960; LUKSCH, 1901; PICOTTI, 1930; SEYMOUR SEWELL, 1935–36; VERCELLI, 1930.

TABLE III

SURFACE TEMPERATURES IN THE SOUTH RED SEA (13°–17°N)

	Temperature in °C.		
Month	Minimum	Modal range	Maximum
January	24.2	24.7–25.5	27.4
February	24.7	24.8–25.6	26.3*
March	24.5	25.4–26.2	27.4**
April	25.8	26.2–27.4	27.4
May	27.8	28.4–29.4	29.4
June	30.1	30.5–31.0	31.6
July	30.0	30.3–31.4	32.0
August	30.4	31.1–31.6	32.3
September	30.5	31.6–32.2	32.2
October	28.1	29.8–31.0	31.0
November	26.5***	27.1–28.0	30.0
December	24.9	24.9–26.2	28.3

* 29°C approx. was recorded once, in 1924, west of the Dahlak Archipelago (PICOTTI, 1930; VERCELLI, 1930).

** 28.6°C to 29.6°C were measured at the end of April in the western inshore waters of the Dahlak Archipelago (OREN, 1964).

*** 23.4°C, 24.1°C and 25.5°C are recorded for the end of November 1897, in the southern part of the area (LUKSCH, 1901).

Table III summarizes according to the month, the surface temperature data for the Red Sea between the latitudes of 13 and 17°N. Since the data are relatively scarce and conditions are not uniform throughout the area to which they refer, means could not be calculated. The sources are: ANONYMOUS, 1949; FRIEDMAN, 1960; LUKSCH, 1901; NEUMANN and DENSMORE, 1959; NEUMANN and MCGILL, 1961; OREN, 1964; PICOTTI, 1930; SEYMOUR SEWELL, 1935–36; VERCELLI, 1930; these include results of seven expeditions and a summary of thousands of observations taken by commercial vessels (ANONYMOUS, 1949).

It can be surmised that the tuna observed and fished in the Red Sea during the summer of 1964, were living in water of higher temperature range than that recorded for any other area where little tuna and frigate mackerel abound (HELA and LAEVASTU, 1961; KIKAWA, 1963; LAEVASTU and ROSA, 1963; UCHIDA, 1963; WILLIAMS, 1963) and also, probably, beyond the temperature range for areas where longtail tuna is well-known (see JONES, 1963). On the other hand, summer temperatures below the thermocline in the South Red Sea, — 25 to 28°C, are within the known range for the distribution of all three tuna species (ibid). As yellowfin very often occurs in this temperature range (28 to 25°C) at depths between 50 and 100 m, and because yellowfin is abundant in the Gulf of Aden, there is some chance that this valuable fish may be found in the South Red Sea by longlines reaching below the thermocline.

CONCLUSIONS AND RECOMMENDATIONS

The greater part of the tuna stock available to purse-seine in the South Red Sea is made up of smaller species of lesser value because of their dark meat, little tuna and frigate mackeral. However, longtail is also plentiful; it resembles yellowfin in appearance and canning quality, but does not reach such a great size and is not the object of a specific fishery in other areas. Yellowfin has been reported from the South Red Sea, but is apparently not present in commercial concentrations in surface waters.

The purse-seine season will probably be limited to the months of May to August. More experimental fishing must be carried out, especially during this period, as the area has not been extensively explored.

Because schools are generally small, a seiner, in order to pay her way, should carry out many sets, rather than scout for large concentrations. Thus, a power-block will be necessary.

The fish being so sensitive to the gear, it is necessary to use very long and deep nets to encircle the school before it detects the danger. It seems that a purse-seine for the Southern Red Sea should be at least 650–700 m long (corkline length) and 78–85 m deep (stretched). The speed of the seiner—employed in tuna fishing should be at least 9–10 knots.

Some inshore methods of tuna fishing as well as night purse-seining for Indian mackerel ought to be considered.

In purse-seining off the West African coast, the French use live bait to keep the fish concentrated at the surface in the centre of the encircled area. This method may be experimentally applied during spring and summer in the South Red Sea.

Ethiopian fishermen quickly learned the deck work involved with purse-seining, so that there is no problem as far as the manning of a seiner is concerned, provided that experienced skipper, engineer and tuna scout (mastman) are available.

ACKNOWLEDGEMENTS

Valuable assistance has been given to the survey teams by the officers and employees of the Ethiopian Marine Department, and by the skippers and fishermen of "Yotvath" and "Yonah" Companies. The author wishes to thank Mr. J. Kasseroff, FAO tuna fishing expert, for his excellent guidance, and the FAO Fishing Gear Station for providing his services. The author is greatly indebted to Mrs. R. Landau and to Dr. H. Steinitz for checking the manuscript. Last but not least, thanks, are extended to Mr. Z. Porath, who lead the 1962 survey and the first part of the 1964 survey and whose observations, impressions and conclusions are also included in this paper.

SUMMARY

Schools of pelagic fish of commercial significance (Scombridae, Carangidae, Chanidae) were located and fished during two fishing surveys carried out in 1962 and 1964 in the Ethiopian waters of the southern Red Sea. The schools were relatively small, fast-swimming and sensitive to the presence of fishing boats and gear. The behaviour of the schools was observed and its relation to the hydrographic and feeding conditions is discussed in the report.

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Reprinted from *Proc. Biol. Soc. Wash.*, vol. 81, 1968, p. 179-190

LECANURIUS KOSSMANNIANUS, A NEW CYCLOPOID COPEPOD PARASITIC IN HOLOTHURIANS IN MADAGASCAR

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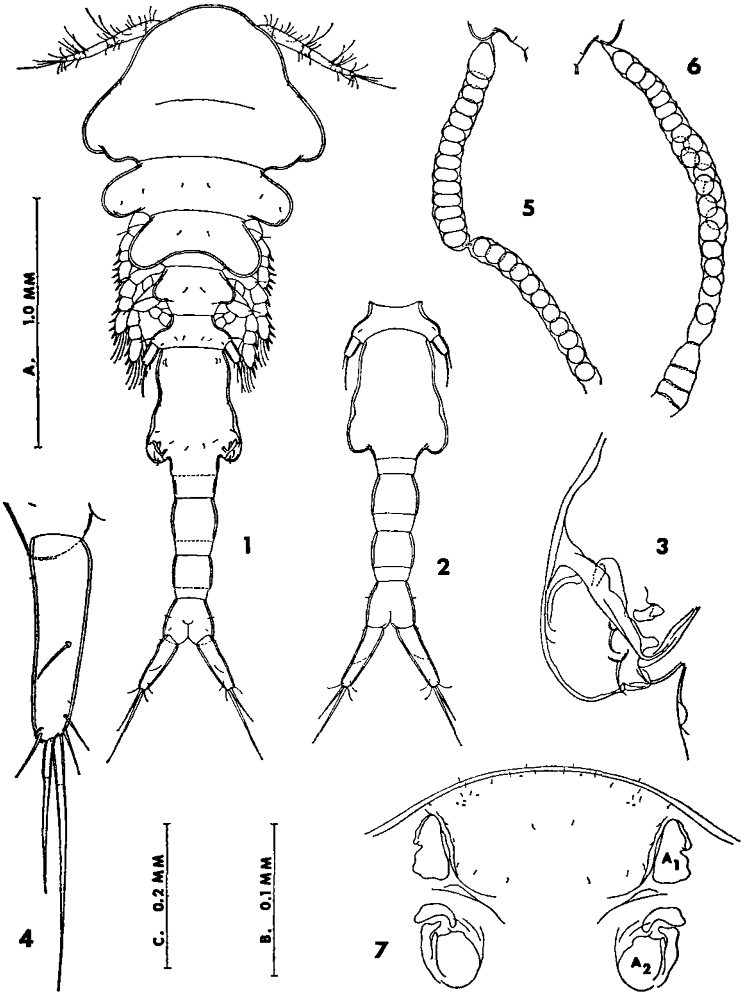
The lichomolgid copepod *Lecanurius intestinalis* Kossmann, 1877, was found by Semper at Bohol in the Philippine Archipelago in the intestine of the holothurian *Actinopyga lecanora* (Jaeger). The name of this host was given by Kossmann as *Müllleria lecanura* Jäger. His generic name *Lecanurius* was evidently based upon an incorrect spelling of the specific name. Another species of *Lecanurius*, found in *Actinopyga lecanora* and *A. miliaris* (Quoy and Gaimard) in northwestern Madagascar, is described below.

The specimens were obtained by slitting the ventral body wall of freshly collected holothurians while holding each over a pail of weakly alcoholized sea water and thus saving the fluid escaping from the body cavity. The entire holothurian was then rinsed in this water. The contents of the pail were subsequently strained through a fine net (after first removing coarse fragments of viscera) and the copepods picked from the sediment. Unfortunately, since the intestines of the holothurians often broke, the exact location of the copepods, whether in the body cavity or in the intestine, is not known.

All collections were made by the author, that in 1960 during an expedition sponsored by the Academy of Natural Sciences of Philadelphia and those in 1967 during field work aided by a grant (GB-5838) from the National Science Foundation. This grant has also supported the study of the specimens.

All figures have been drawn with the aid of a camera lucida. The letter after the explanation of each figure refers to the scale at which it was drawn. The abbreviations used are:



FIGURES 1–7. *Lecanurius kossmannianus* new species, female. 1, body, dorsal (A); 2, urosome, ventral (A); 3, area of attachment of egg sac, dorsal (B); 4, caudal ramus, dorsal (C); 5, right egg sac, incomplete, ventral (A); 6, left egg sac, incomplete, ventral (A); 7, rostral area, ventral (C).

A_1 = first antenna, A_2 = second antenna, MXPD = maxilliped, and P_1–P_4 = leg 1–leg 4. The measurements of the length of the body have been made from specimens in lactic acid and do not include the setae on the caudal rami.

I thank Dr. Elisabeth Deichmann of the Museum of Comparative Zoology, Harvard University, for the identifications of the holothurians.

FAMILY LICHOMOLGIDAE KOSSMANN, 1877

GENUS *LECANURIUS* KOSSMANN, 1877

Lecanurius kossmannianus new species

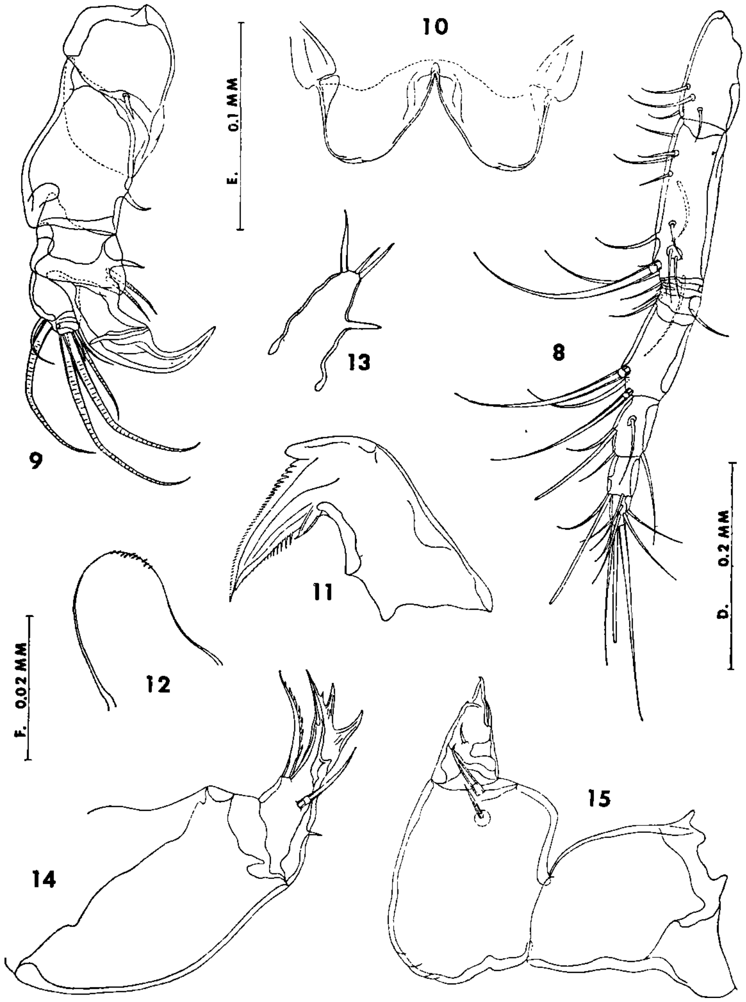
(Figs. 1–32)

Type material: 4 ♀♀ and 3 ♂♂ from 2 *Actinopyga lecanora* (Jaeger) in 1 m under coral, east of Ambariotelo, a small island almost between Nosy Komba and Nosy Bé, Madagascar. Collected July 20, 1967. Holotype ♀, allotype, and 5 paratypes (3 ♀♀, 2 ♂♂) deposited in the United States National Museum.

Other specimens: From *Actinopyga lecanora:* 1 ♀ and 1 ♂ from 2 hosts, in 1 m, Pte. Ambarionaomby, Nosy Komba, near Nosy Bé, June 8, 1967; 2 ♂♂ from 3 hosts, in 1 m, same locality, July 6, 1967; 2 ♀♀ from 1 host, in 3 m, Andjiabe, on the southern shore of Nosy Komba, July 8, 1967; 1 ♀ and 1 ♂ from 3 hosts, in 1 m, Nosy N'Tangam, near Nosy Bé, July 21, 1967; and 1 ♀ from 3 hosts, in 1 m, Ankify, on the mainland of Madagascar opposite Nosy Komba, July 22, 1967. From *Actinopyga miliaris* (Quoy & Gaimard): 1 ♀ from 25 hosts, in 1 m, among the "sea grass" *Cymodocea,* Ambatoloaka, Nosy Bé, May 28, 1967; 1 ♀ and 2 ♂♂ from 70 hosts, same locality, June 1, 1967; 1 ♀ and 2 ♂♂ from 60 hosts, same locality, June 15, 1967; and 1 ♂ from 50 hosts, in 1 m, Antsamantsara, north of Madirokely, Nosy Bé, Oct. 31, 1960.

Female: Body (Fig. 1) elongated and flattened dorsoventrally, with a broad and somewhat triangular cephalosome. Length 2.64 mm (2.40–2.77 mm) and greatest width (at the level of the segment of leg 1) 0.97 mm (0.88–1.01 mm), based on 8 specimens. Margin of the head indented on both sides. Segment of leg 1 very weakly separated from the head, the separation indicated only by an indistinct and incomplete transverse dorsal line. Tergal areas of segments of legs 1–4 becoming progressively narrower posteriorly, their epimera rounded as indicated in the figure. Ratio of length to width of the prosome 1.30 : 1.

Segment of leg 5 (Fig. 2) 165 μ × 352 μ. Between this segment and the genital segment no ventral intersegmental sclerite. Genital segment (Figs. 1 and 2) elongated, in dorsal view indented laterally near the junction of its anterior two-thirds, expanded posteriorly to form two lateral lobes, and then abruptly constricted in its posterior third (where there is ventrally a transverse line). Greatest length of the genital



FIGURES 8–15. *Lecanurius kossmannianus* new species, female. 8, first antenna, ventral (D); 9, second antenna, anterior (B); 10, labrum, ventral (E); 11, mandible, posterior (E); 12, paragnath, ventral (F); 13, first maxilla, posterior (E); 14, second maxilla, posterior (E); 15, maxilliped, antero-inner (E).

segment 540 μ, greatest width 396 μ, width in its anterior third 300 μ, and width at the level of the lateral indentations 280 μ. Areas of attachment of the egg sacs situated dorsally and posteriorly on the lateral lobes, each area (Fig. 3) bearing two naked setae 18 and 21 μ in length. Three postgenital segments 220 μ × 198 μ, 198 μ × 176 μ, and 188 μ × 180 μ from anterior to posterior. First and second of these segments with a transverse line ventrally. Anal segment with a row of minute spinules along its posteroventral margin on each side, and bearing a pair of relatively large dorsolateral setules.

Caudal ramus (Fig. 4) elongated, about 4 times longer than wide, tapering slightly distally, its greatest length 265 μ, its greatest width near its base 83 μ, and its width near middle 65 μ. Mid-dorsal seta (corresponding to the outer lateral seta in other lichomolgids) 63 μ long, distal dorsal setae 58 μ, outermost terminal seta 68 μ, innermost terminal seta 64 μ, and the two long median terminal setae 211 μ (outer) and 330 μ (inner). All setae naked. A minute lateral spinule 6 μ long on the outer proximal area of the ramus, and the distal outer corner of the ramus with a dorsal group of small spiniform processes and a marginal row of minute spinules.

Dorsal surface of prosome and urosome with a few small hairs as in Fig. 1. Urosome longer than the prosome, the ratio being 1 : 1.20.

Egg sacs in the single ovigerous female collected very long and slender, but incomplete. Eggs in the right egg sac (Fig. 5) in a linear series, the distalmost egg 78 μ in diameter. This incomplete egg sac 1.5 mm long. Eggs in the left sac (Fig. 6) partly linear and partly in two rows.

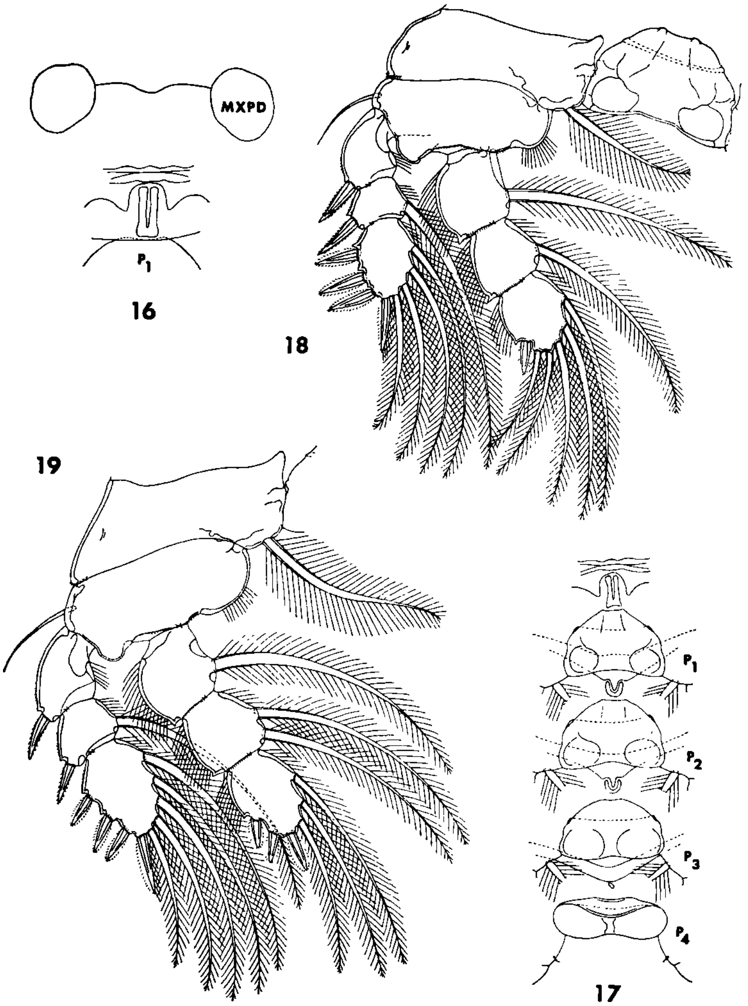
Rostral area (Fig. 7) not well defined posteroventrally.

First antenna (Fig. 8) 7-segmented, 470 μ in length, with a sclerite on the ventral side of the third segment suggesting an intercalary segment. A slight flexure in the first antenna at the level of the third segment. Lengths of the segments (measured along their posterior nonsetiferous margins): 42 μ (99μ along the anterior edge), 138 μ, 36 μ, 78 μ, 52 μ, 38 μ, and 29 μ respectively. Formula for the armature: 4, 13, 6, 3, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete, as in many other lichomolgids. All setae naked.

Second antenna (Fig. 9) 4-segmented, 237 μ long, including the claw. Armature: 1, 1, 3 + claw, and 7. Second segment 109 μ along its outer edge. Claw 109 μ along its axis. Last segment with five of the seven setae arising from a small distal lobe.

Labrum (Fig. 10) with two posteroventral lobes.

Mandible (Fig. 11) having at the base of the pectinate blade a blunt process on the convex side and a pointed process on the concave side. Paragnath (Fig. 12) a small lobe with a few small spinules, located close to the inner side of the base of the first maxilla. First maxilla (Fig. 13) with three terminal setae and a subterminal hyaline seta. Second maxilla (Fig. 14) 2-segmented. First segment unarmed. Second segment having on its outer (ventral) margin a small proximal hyaline seta, on its posterior surface a naked seta jointed basally, on its inner (dorsal)



FIGURES 16–19. *Lecanurius kossmannianus* new species, female. 16, area between maxillipeds and first pair of legs, ventral (D); 17, midsternal areas of legs 1–4, with intercoxal plates pushed somewhat posteriorly, ventral (C); 18, leg 1, anterior (D); 19, leg 2, anterior (D).

margin a seta with hyaline serrations along its distal edge, and terminating in a short lash bearing two long teeth arising from a hyaline expansion followed by a small hyaline tooth. Maxilliped (Fig. 15) 3-segmented. First segment unarmed. Second segment rather tumid in outline and bearing two naked setae. Third segment with two naked setae and terminating in a spiniform process with a slightly recurved tip.

Area between the maxillipeds and the first pair of legs (Fig. 16) not protuberant; a sclerotized line between the bases of the maxillipeds. Ventral sclerite of the segments of legs 1 and 2 projected posteriorly in a median pointed process, which is surrounded by a small semilunar sclerite (Fig. 17). Ventral sclerite of leg 3 without this pointed process and only a trace of the semilunar sclerite present. Ventral sclerite of leg 4 not evident and the semilunar sclerite absent.

Legs 1–4 (Figs. 18, 19, 20, and 22) with 3-segmented rami. Armature as follows (Roman numerals indicating spines, Arabic numerals setae):

P_1	protopod	0–1	1–0	exp	I–0	I–1	III,I,4
				end	0–1	0–1	I,5
P_2	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,II,3
P_3	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,III,2
P_4	protopod	0–1	1–0	exp	I–0	I–1	II,I,5
				end	0–1	0–1	I,I,1,1,1

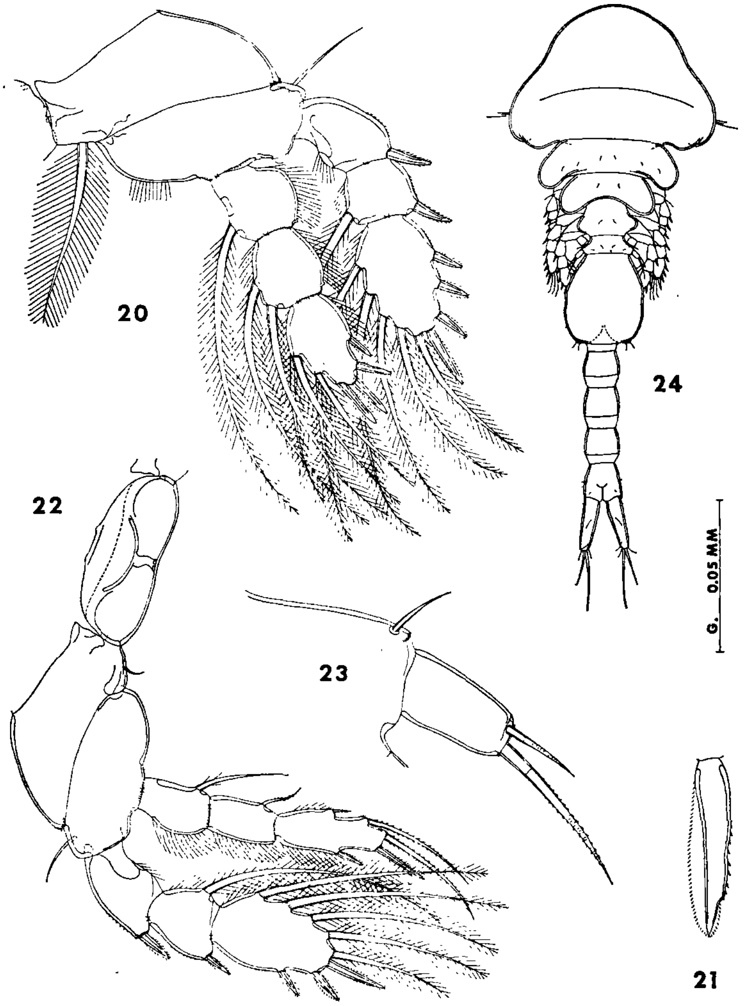
Inner seta on the coxa of legs 1–3 long and plumose but in leg 4 short (24 μ) and naked. Inner margin of the basis in leg 4 naked, but in legs 1–3 bearing a row of hairs. Two proximal outer spines on the exopods of legs 1–3 with prominent spinules; remaining spines fringed with fine spinules. Distalmost spine of the exopod of leg 3 (Fig. 21) and leg 4 with the inner margin bearing short spinules and with a short distal fringe. Endopod of leg 4 nearly equal in length to the exopod. First segment 68 μ × 44 μ, with a slightly haired inner distal seta 88 μ long. Second segment 68 μ × 39 μ, with a shorter inner distal very minutely barbed seta 39 μ. Third segment 101 μ × 42 μ, bearing five elements from outer to inner: a fringed spine 26 μ, a terminal fringed spine 56 μ, a terminal barbed seta 112 μ, a subterminal barbed seta 91 μ, and a minutely barbed seta 13 μ. Inner margin of the second segment naked, but this margin of the third segment with a few hairs.

Leg 5 (Fig. 23) with a relatively small subrectangular free segment 78 μ × 42 μ in greatest dimensions (about 1.86 times longer than wide), bearing two terminal setae, the outer 55 μ and naked, the inner 106 μ and finely barbed. Segment without ornamentation except for a terminal row of minute spinules. Seta on the body near the free segment 44 μ and naked, with a row of small spinules between it and the free segment.

Leg 6 probably represented by the two setae near the attachment of each egg sac (see Fig. 3).

Color in life in transmitted light opaque and slightly brownish, eye red, intestine brown, eggs light tan.

Male: Body (Fig. 24) resembling in general form that of the female. Length 1.97 mm (1.92–2.08 mm) and greatest width 0.79 mm (0.75–



FIGURES 20–23. *Lecanurius kossmannianus* new species, female. 20, leg 3, anterior (D); 21, distalmost spine on exopod of leg 3, anterior (G); 22, leg 4, anterior (D); 23, leg 5, dorsal (B).

FIGURE 24. *Lecanurius kossmannianus* new species, male. 24, body, dorsal (A).

0.81 mm), based on 7 specimens. Ratio of length to width of the prosome 1.13 : 1.

Segment of leg 5 (Fig. 25) 86 μ × 208 μ. No ventral intersegmental sclerite. Genital segment (Fig. 25) only a little longer than wide, 341 μ × 335 μ. (In males where the genital segment does not contain formed spermatophores the segment is somewhat longer, as in Fig. 24, where the dimensions are 363 μ × 308 μ.) Four postgenital segments 133 μ × 156 μ, 151 μ × 153 μ, 127 μ × 140 μ, and 135 μ × 151 μ from anterior to posterior.

Caudal ramus (Fig. 25) similar in form to that of the female but relatively a little shorter, 198 μ × 58 μ, or 3.4 times longer than wide.

Dorsal surface of the body ornamented with hairs as in the female. Urosome longer than the prosome, the ratio being 1 : 1.52.

Rostral area, first antenna, second antenna, labrum, mandible, paragnath, first maxilla, and second maxilla like those of the female. Maxilliped (Figs. 26 and 27) 4-segmented, assuming that the proximal part of the claw represents a fourth segment. First segment unarmed. Second segment with two short naked setae and two groups of two or three short stout spines. Third segment small and unarmed. Claw 242 μ along its axis (including the terminal lamella), with a spiniform prominence (keeled on its posterior surface) on its concave margin, and bearing two very unequal naked setae proximally.

Exopods of legs 1–3 and both rami of leg 4 segmented and armed as in the female. Endopods of legs 1–3 with the same arrangement of spines and setae as in the female, but showing sexual dimorphism. (Spine and setal formula of the male is thus similar to that of the female, taking into account the fusion of the second and third segments of the endopods in legs 1 and 2.) Endopod of leg 1 (Fig. 29) 2-segmented, with the last two segments fused, but the original articulation still indicated by an outer marginal spiniform process and a transverse row of spinules. Endopod of leg 2 (Fig. 30) 2-segmented, with the original articulation between the last two segments indicated as in leg 1. Endopod of leg 3 with the four spines on the last segment somewhat different in length from those in the female; these spines from proximal to distal in the male 10 μ, 11 μ, 17 μ, and 23 μ, in the female 27 μ, 33 μ, 44 μ, and 55 μ.

Leg 5 (Fig. 31) resembling that of the female, but the free segment smaller, 42 μ × 21 μ (about twice as long as wide), its two terminal setae 39 μ (outer) and 83 μ (inner).

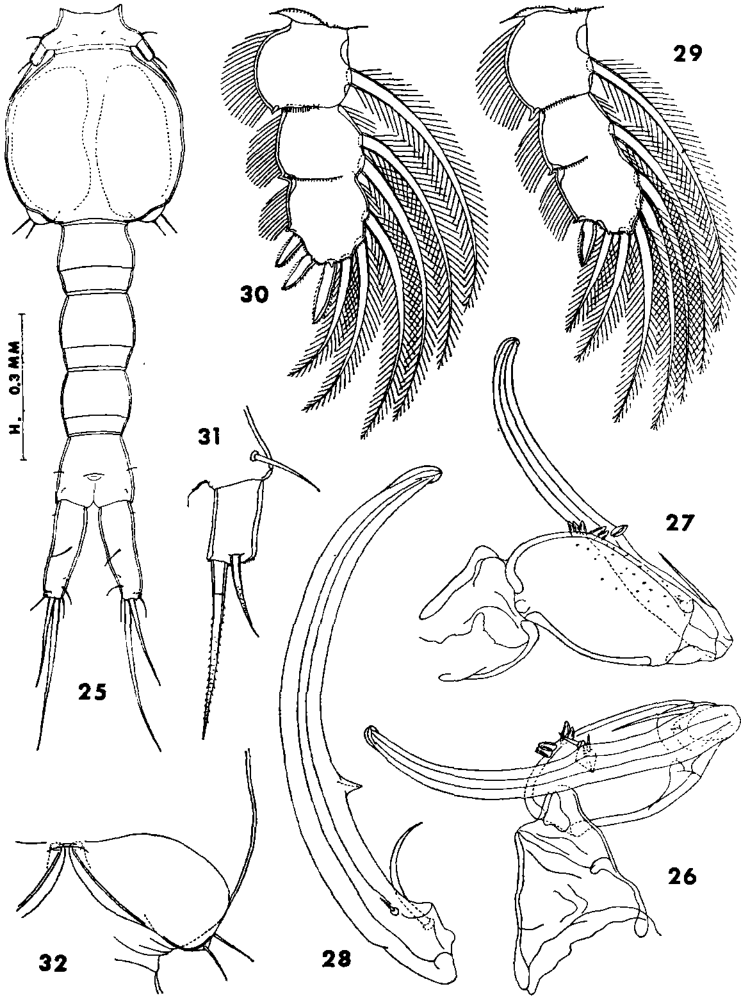
Leg 6 (Fig. 32) a posteroventral flap on the genital segment bearing two slender naked setae 36 μ and 44 μ in length.

Spermatophore not observed.

Color in life similar to that of the female.

(This species is named for Dr. Robby Kossmann, who first described the genus *Lecanurius.*)

Comparison with Lecanurius intestinalis *Kossmann:* There are several features whereby *L. kossmannianus* appears to be distinct from *L. intes-*



Figures 25–32. *Lecanurius kossmannianus* new species, male. 25, urosome, dorsal (H); 26, maxilliped, antero-inner (B); 27, maxilliped, postero-outer (B); 28, claw of maxilliped, anterior (E); 29, endopod of leg 1, anterior (B); 30, endopod of leg 2, anterior (B); 31, leg 5, dorsal (E); 32, leg 6, ventral (D).

tinalis. However, since Kossmann's specimen was evidently a male (judging from his figure of the maxilliped), only males can be compared. In *L. kossmannianus* the length of the body of the male is greater (1.97 mm) than in *L. intestinalis* (1.46 mm), the cephalosome is laterally indented (but approximately semicircular in *L. intestinalis*), the genital segment is a little longer than wide or its length is nearly equal to its width (but twice as wide as long in Kossmann's figure of *L. intestinalis*), the claw of the maxilliped has one pointed prominence (but two blunt protuberances in *L. intestinalis*), and the free segment of leg 5 is 42 μ long (but 130 μ in *L. intestinalis*).

The armature of legs 1 and 4 of *L. kossmannianus* differs in certain respects from that of *L. intestinalis.* Kossmann mentioned two setae on the inner side of the second segment of the endopod of leg 1, but in the Madagascan species there is only one such seta. (Perhaps this is a *lapsus* by Kossmann, since the presence of two setae on the inner side of this segment would be indeed remarkable in a lichomolgid copepod.) In the exopod of leg 4 of Kossmann's species the outer spines on the first two segments are absent; on the endopod the inner element on the first segment is absent, that on the second segment is a spine rather than a seta, and the elements on the last segment are 3 spines and 2 setae (in his text) or 3 spines and 3 setae (in his figure).

The males of both *L. intestinalis* and *L. kossmannianus* show striking similarities in their general body form, and in the nature of the second antenna, mandible, and second maxilla.

Relationship of Lecanurius *to* Scambicornus: The genus *Lecanurius* shows certain characters which are similar to those of *Scambicornus* Heegaard, 1944 (= *Preherrmannella* Sewell, 1949), a genus of which many species live externally on holothurians. Stock (1964) has already suggested that the two genera are related, noting the similarity in the second antennae (the third segment with a large claw) and in the armature (5 elements) of the third segment of the endopod of leg 4. In addition, both genera have a bladelike mandible, without a long lash, and both have 2-segmented endopods in legs 1 and 2 of the male.

There are, however, important differences between *Lecanurius* and *Scambicornus.* In *Lecanurius* the body is elongated, with a much broadened cephalosome, while in *Scambicornus* the form of the body is more typically lichomolgid. In *Lecanurius* the egg sacs (as far as known) are very long and the eggs are in a more or less linear series, rather than sacciform with massed eggs as in *Scambicornus.* In *Lecanurius* the mandible bears processes at both sides of the base of the blade, rather than a single process (on the concave side) or none as in *Scambicornus.* In *Lecanurius* the lash of the second maxilla is short and bears only a few large teeth, whereas in *Scambicornus* it is longer and has a row of several teeth. In *Lecanurius* the five elements on the last segment of the endopod of leg 4 consist of both spines and setae, but in *Scambicornus* these elements are spines. *Lecanurius* lives inside the holothurians, while *Scambicornus* lives on the outside of these hosts.

In view of these differences it seems best to retain Kossmann's genus *Lecanurius* for *L. intestinalis* and *L. kossmannianus.* If in the future species intermediate between the two genera (in respect to the several differences listed above) are discovered, *Lecanurius* might be considered as a senior synonym of *Scambicornus.* This position is untenable now, however, in the present state of knowledge of these genera.

Hosts of Lecanurius: Both *L. intestinalis* and *L. kossmannianus* live in members of the genus *Actinopyga.* In fact, both of these copepods are known from the same species of host, *A. lecanora,* though in widely separated regions,—*L. intestinalis* in the Philippines, and *L. kossmannianus* in Madagascar. The new species occurs also in *Actinopyga miliaris* in Madagascar, although apparently less commonly than in *A. lecanora.* Sixteen specimens were recovered from 14 *A. lecanora,* but only 8 from 205 *A. miliaris.*

A single copepodid of what is possibly a *Lecanurius* was found in another holothurian, *Synapta maculata* (Chamisso and Eysenhardt), at Ambariobe, near Nosy Bé, October 6, 1963 (during field work of the U. S. Program in Biology, a part of the International Indian Ocean Expedition). The immaturity of this specimen made it impossible to determine the genus with certainty, but some of its features suggest Kossmann's *Lecanurius.*

Associated with both hosts of *L. kossmannianus* there is a species of *Scambicornus, S. campanulipes* (Humes and Cressey, 1961), which lives on the exterior of *A. lecanora* and *A. miliaris* in Madagascar (Humes, 1967).

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Reprinted from *Sarsia*, no. 34, 1968, p. 285-298

SITUATION HYDROLOGIQUE ET DISTRIBUTION DU ZOOPLANCTON DANS LE N.W. DE LA MER D'ARABIE

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ABSTRACT

THE HYDROLOGICAL SITUATION AND THE DISTRIBUTION OF ZOOPLANKTON IN THE NW OF THE ARABIAN SEA

An attempt is made in this paper to explain the distribution of zooplankton in the Arabian Sea. The most important influence on the hydrographical conditions of the area is the exchange of water between the Persian Gulf and the Arabian Sea. Zooplankton was observed to be transported in this exchange. At the same time high productivity due to the influence of Persian Gulf water and upwelling in the Arabian Sea would explain the development of zooplankton in this region.

INTRODUCTION

Pendant très longtemps l'ocean Indien et en particulier la mer d'Arabie n'ont pas été prospectés et on ne disposait jusqu'ici que de données peu nombreuses concernant l'hydrologie et la distribution du plancton de cette région. L'Expédition Internationale de l'Océan Indien permit d'entreprendre des recherches et de combler quelques lacunes dans de nombreux domaines. Dans ce travail, nous avons essayé d'expliquer la distribution du zooplancton de la mer d'Arabie du N.W., par la situation hydrologique, qui est influencée par les échanges de masses d'eau entre le golfe Persique et les régions voisines.

ETUDE DE LA SITUATION HYDROLOGIQUE

On peut observer au niveau du détroit d'Hormuz, à la sortie du golfe Persique, un phénomène analogue à celui qui se produit en Méditerranée par exemple, au niveau du détroit de Gibraltar: soit une sortie d'eau en profondeur de la mer la plus salée vers la moins salée et une entrée en surface de sens inverse.

Nous avons dans le golfe Persique, situé sous un climat aride, une forte évaporation qui entraine une augmentation de la salinité. En outre nous pouvons noter que les débouchés des grands fleuves ont peu d'influence sur la salinité (pendant la période étudiée). Il résulte de cette salinité élevée une augmentation de la densité qui produit une convection verticale et permet un écoulement par gravité vers la sortie de ce golfe. Cette eau sortant du golfe Persique va s'enfoncer, étant donné qu'à immersion égale, l'eau du golfe d'Oman est moins dense. Cette eau va s'étendre en profondeur jusqu'à ce quelle rencontre une eau de densité équivalente. Pour compenser cette perte d'eau du golfe Persique il se produit un courant d'entrée en surface.

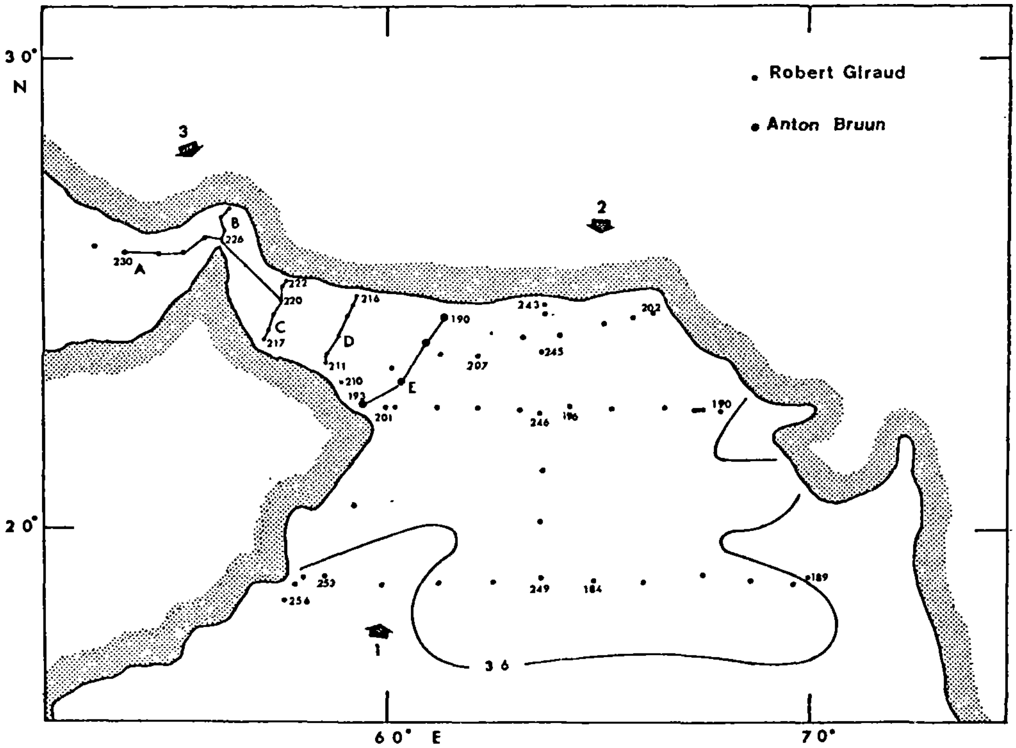

Fig. 1. Carte de la mer d'Arabie, du golfe d'Oman et d'une partie du golfe Persique avec représentation des stations de la campagne du navire *Ct Robert Giraud* 1961 et d'une radiale de l'*Anton Bruun* (1963).—Les flèches indiquent les 3 directions des prises de vues de la maquette reproduites sur la fig. 7.—L'isohaline de 36‰ en surface a été tracée d'aprés les données du *Méteor*, de l'*Anton Bruun* et du *Ct Robert Giraud.*

Pour expliquer ce phénomène nous avons utilisé les données des stations figurées sur la carte suivante (Fig. 1). Sur cette carte nous avons présenté l'ensemble des coupes qui nous ont permis de connaitre la situation hydrologique des golfes Persique et d'Oman.

La coupe A (Fig. 2) est longitudinale. Elle est située en grande partie dans le golfe Persique et n'intéresse qu'une station médiane du golfe d'Oman, peu éloignée du détroit d'Hormuz. Les autres radiales B, C, D, E (Fig. 2 et 3) sont transversales; la coupe B se trouve située au niveau du détroit d'Hormuz, les autres coupes C, D, E sont localisées dans le golfe d'Oman. La coupe C étant la plus proche du golfe Persique, la coupe E, la plus éloignée se trouve située à l'entrée du golfe d'Oman. La coupe A comporte 6 stations au total, 5 dans le golfe Persique, dont une au niveau du détroit d'Hormuz, et, enfin, une dernière station dans le golfe d'Oman.

Dans le golfe Persique, nous pouvons observer sur cette coupe longitudinale, deux gradients horizontaux différents de salinité: l'un en surface, l'autre en profondeur. L'eau du golfe d'Oman qui pénètre dans le golfe Persique va voir sa salinité augmenter, en partie par les eaux sous-jacentes plus salées qui s'écoulent en sens inverse, mais surtout par une forte évaporation. De ce fait nous pouvons observer une augmentation de la salinité de 36.6‰ au niveau du détroit d'Hormuz jusqu'à 41.35‰ dans le nord du golfe Persique. En profondeur le gradient est beaucoup moins élevé puisque nous avons une salinité maximale de 41.62‰ dans la partie N.W. du golfe et 38.4‰ au niveau du détroit.

A l'entrée du golfe Persique, nous pouvons également noter que la salinité présente un fort gradient vertical puisqu'elle passe de 36.6‰ en surface à 38.4‰ au fond et pour une profondeur de 70 m environ. Ce gradient reste élevé tant que l'influence des eaux du golfe d'Oman qui s'écoulent en surface dans le golfe Persique se fait sentir. A l'extrémité nord du golfe par contre, nous avons des eaux dont la salinité présente un très faible gradient puisqu'elle varie de 41.35‰ en surface à 41.62‰ près du fond.

La coupe A montre donc très nettement la superposition de deux masses d'eaux, l'une relativement peu salée (36.6‰) qui pénètre dans le golfe Persique pour compenser la perte d'eau due à l'écoulement sur le fond en sens inverse.

Sur la même figure, la station 220 située dans le golfe d'Oman à environ 120 milles du détroit d'Hormuz, permet de constater la présence de l'eau du golfe Persique qui s'est enfoncée et se trouve alors localisée entre 180 et 250 m. La salinité qui est proche de 37‰ a fortement diminué du fait du mélange entre les eaux qui sortent et celles du golfe d'Oman. Nous signalerons toutefois que nous sommes ici en bordure de la zone d'écoulement intense, comme nous pourrons le constater sur la coupe transversale C.

Les coupes transversales B, C, D (Fig. 2) et E (Fig. 3) nous permettent d'avoir un certain nombre de renseignements sur la profondeur et la zone d'écoulement la plus intense, ainsi que sur le degré de mélange entre les eaux du golfe Persique et celles du golfe d'Oman. Ainsi sur la coupe B nous pouvons voir que cette eau s'écoule dans la partie sud du détroit d'Hormuz. Une station située plus au sud, au niveau des plus grands fonds (150 m) nous aurait trés certainement permis de constater une zone d'écoulement plus épaisse. Sur les coupes C, D, E, nous pouvons observer l'enfoncement de la nappe d'eau qui se localise entre 130 et 400 m, avec un noyau plus salé entre 200 et 300 m.

L'ecoulement des eaux du golfe Persique s'effectue en grande partie le long de la côte sud ouest du golfe d'Oman avec toutefois un étalement de cette nappe vers le nord. Nous avons en effet des eaux beaucoup plus salées sur la côte sud que sur la côte nord: les salinités atteignent des valeurs supérieures à 37.8‰ à station 217 (la plus méridionale de la coupe C) alors qu'à la station 221 (plus au nord) les salinitées sont proches de 37‰. Il y a donc une diminution de la salinité en bordure de la zone d'écoulement intense. On doit très certainement rechercher la cause de cette dernière dans la force de Coriolis puisque les eaux

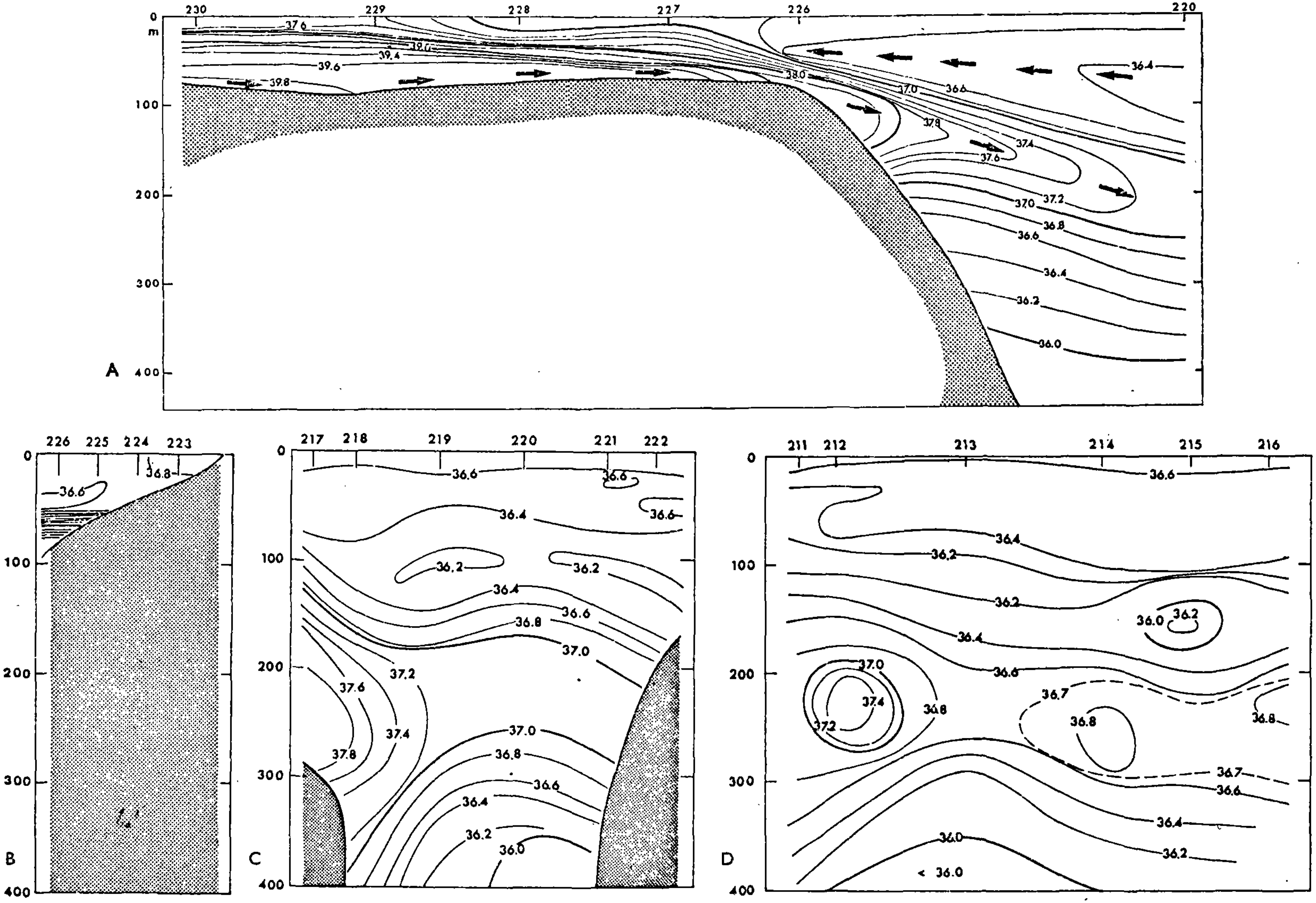

Fig. 2. Représentation de la salinité dans le golfe Persique et le golfe d'Oman sur la coupe longitudinale A. Les isohalines n'ont pas toutes été représentées entre 38‰ et 39‰ en raison du fort gradient (Profondeur indiquée en mètres). — Représentation de la salinité sur les coupes transversales B, C, D. La côte d'Arabie est toujours située à gauche des coupes. Sur la coupe B, située au niveau du détroit d'Hormuz, le fort gradient de salinité indique l'eau de sortie du golfe Persique (salinité maximale 38.8‰).

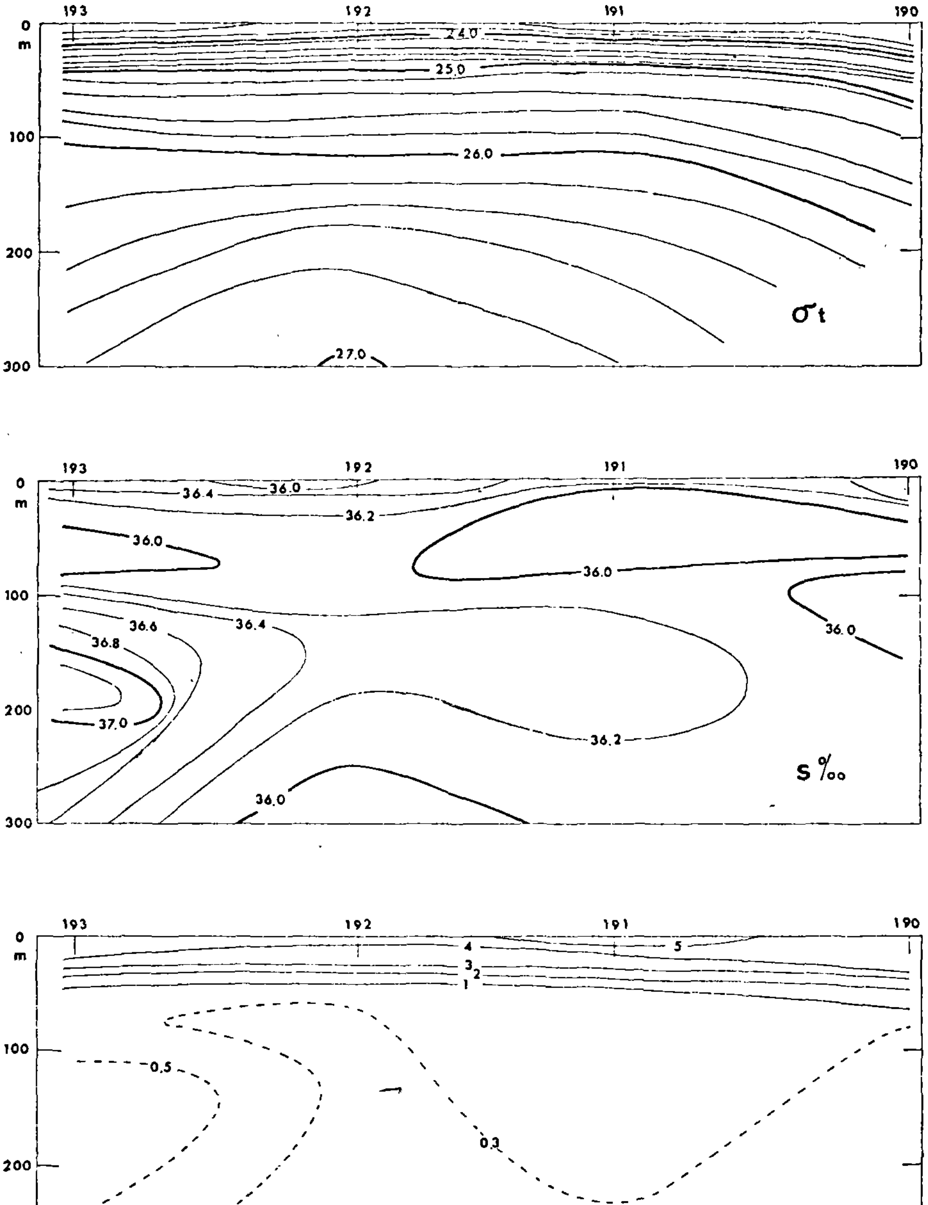

Fig. 3. Coupe transversale E représentant σ_t, la salinité, et l'oxygène à l'extrémité du Golfe d'Oman

qui s'écoulent en profondeur dans le golfe d'Oman demeurent collées au littoral d'Arabie, soit à droite d'un observateur regardant dans le sens d'écoulement des eaux.

Le déplacement vers le sud-est de cette masse d'eau va entrainer une diminution progressive de la salinité. Nous pouvons constater qu'au fur et à mesure que l'eau séloigne du détroit d'Hormuz, la salinité maximale de cette couche passe de 38‰ sur la coupe B, à 37.8‰ sur la coupe C, à 37.4‰ sur la coupe D et enfin à 37.2‰ sur la coupe E située à la sortie du golfe d'Oman. Cette eau va continuer à s'étendre dans la mer d'Arabie vers le sud-est; nous avons pu encore la repérer à une station située à environ 300 milles du golfe d'Oman.

Pour compenser cette sortie d'eau du golfe Persique en profondeur, il existe une courant de surface qui suit un trajet inverse. La salinité de l'eau du golfe d'Oman qui pénètre dans le golfe Persique va augmenter progressivement: elle passera assez rapidement de 36.6‰ à l'entrée du golfe à 37‰ puis à 38‰ peu après la station 230. Parallèlement à cette augmentation de la salinité nous pouvons noter une diminution de la température qui passe de 27°C à l'entrée puis à 25°C au fur et à mesure que les eaux se dirigent vers le fond du golfe.

En conclusion, nous pouvons dire que les eaux issues de la mer d'Arabie et du golfe d'Oman qui pénètrent en surface dans le golfe Persique, effectuent un circuit. Elles vont voir leurs caractéristiques hydrologiques se modifier au cours de leur passage dans ce golfe Persique (augmentation de la salinité, diminution de la température); elles sortent ensuite, puis s'étaleront en profondeur entre 120 et 400 m dans le golfe d'Oman et, encore bien individualisées, déboucheront dans la partie septentrionale de la mer d'Arabie où leur influence se fera sentir très nettement. En effet dans cette région nous avons pu constater la présence d'une masse d'eau, dont la salinité était supérieure à 36‰; elle se trouvait localisée entre 300 m et la surface dans la partie la plus occidentale de la mer d'Arabie du N.W. et allait en s'amenuisant vers l'Est.

ETUDE BIOLOGIQUE

Remarques

Dans cette étude biologique nous avons essayé de montrer l'influence des courants sur la distribution et l'abondance du plancton. Nous envisagerons, tout d'abord les effets, sur le zooplancton, du courant de surface qui pénètre dans le golfe Persique, puis nous essaierons de voir l'influence du courant de sortie au niveau de la mer d'Arabie du N.W.

Ces deux masses d'eaux s'écoulant en sens inverse vont transporter des organismes planctoniques, qui devront pour survivre s'adapter à leur nouveau milieu. Les organismes qui pénètrent dans le golfe Persique auront à faire face à une sursalure et à une diminution de la température, alors que ceux qui en sortent, doivent supporter une dessalure ainsi qu'une diminution de l'intensité lumineuse, due à l'enfoncement des eaux du golfe Persique dans le golfe d'Oman. Il se peut que les organismes remontent dans les eaux plus superficielles, dans ce cas ils devront s'adapter aux variations particulièrement importantes de la salinité et température, ce qui exige d'eux d'être, à la fois très eurythermes et très euryhalins

L'étude de quelques groupes zooplanctoniques de cette région ne fut entreprise qu'à partir des prélèvements effectués par l'aviso *Ct Robert Giraud.* Ces récoltes n'ont que très rarement dépassé la profondeur de 100 m; de ce fait nous avons que peu de renseignements sur les organismes qui peuvent passer du golfe Persique dans le golfe d'Oman. Par contre cette couche d'eau des 100 premiers métres correspond tout particulièrement aux eaux qui pénètrent dans le golfe Persique. Il faut noter toutefois que seules les espèces épiplanctoniques pourront être transportées vers le golfe Persique du fait de la faible profondeur au niveau du détroit d'Hormuz, mais aussi du courant de sortie qui s'écoule en sens inverse, sur le fond.

L'influence des eaux du golfe d'Oman sur la repartition du zooplancton

Trois groupes zooplanctoniques ont été étudiés: les Mollusques pélagiques (FRONTIER 1963b), les Appendiculaires (FENAUX 1964), les Ostracodes pélagiques (LEVEAU 1968).

Ces trois auteurs ont constaté, pour chacun des groupes étudiés, une diminution progressive du nombre d'espèces, de la mer d'Arabie vers le golfe Persique.

Pour les Ostracodes, nous avons trouvé 17 espèces dans la mer d'Arabie, 6 dans le golfe d'Oman et seulement 2 dans le golfe Persique. Il faut noter que les deux espèces qui persistent dans le golfe Persique sont celles qui sont les plus superficielles et qui de ce fait peuvent être entrainées par le courant de surface. Ces deux espèces: *Cypridina chierchiae* et *Euconchoecia aculeata* sont très répandues dans tout le nord de l'Océan Indien (Fig. 4).

Pour les Mollusques pélagiques, FRONTIER (1963b) a noté la présence de huit espèces, qui sont par ordre de fréquence *Creseis virgula*, *Cavolinia* sp., *Desmopterus papilio*, *Limacina inflata*, *Creseis acicula*, *Hyalocylix striata*, *Corolla* sp. et *Clionina longicauda.*

Comme pour les Ostracodes, nous trouvons quelques espèces très euryhalines qui ont pu s'adapter aux eaux sursalées du golfe Persique; ce sont *Creseis virgula*, *Cavolinia* sp., *Desmopterus papilio*, qui ont été recueillies en de nombreuses stations. Il faut noter que ce sont les espèces les plus fréquemment capturées au cours de l'expédition du *Ct Robert Giraud*, puisque *Creseis virgula* a été récoltée à 75 stations sur 80 prospectées, *Cavolinia* sp. à 54, *Desmopterus papilio* à 65 stations. Nous signalerons toutefois que *Creseis acicula*, bien que deuxième dans l'ordre de fréquence des espèces (66 stations) ne fut capturée qu'a l'entrée du golfe Persique, au niveau du détroit d'Hormuz, là où les eaux de surface présentent encore des salinités voisines de 36‰. Les salinités supérieures seraient donc un obstacle à

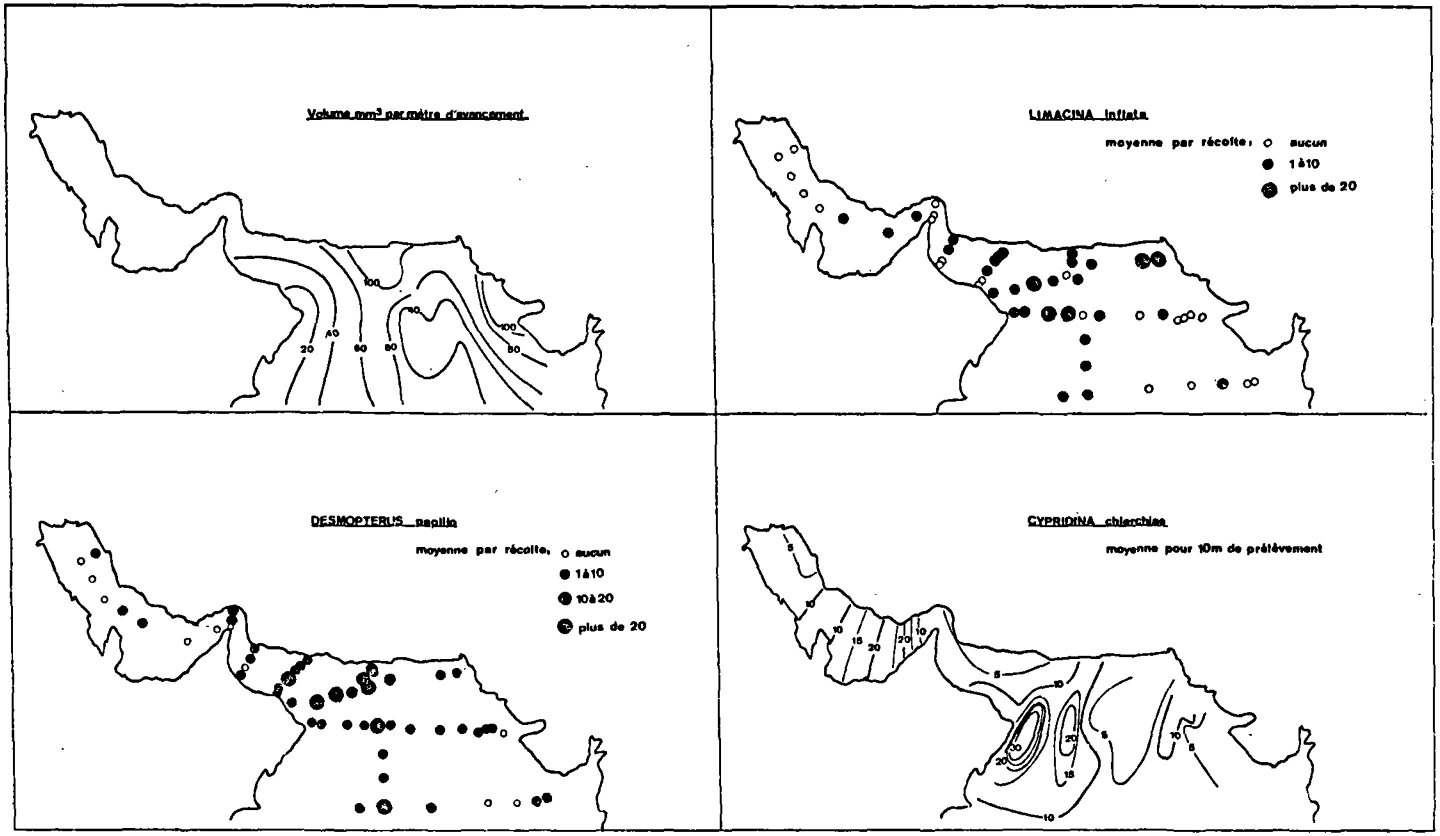

Fig. 4. Distribution des volumes planctoniques et de 3 espèces zooplanctoniques.

son entrée. En outre cette espèce est localisée plus profondément que *Creseis virgula*; de ce fait deux "barrières" semblent s'opposer à son entrée dans le golfe Persique: tout d'abord le courant de sortie qui s'écoule au fond mais aussi la faible profondeur du golfe.

Trois autres espèces ne dépasseront pas le niveau du détroit d'Hormuz; il s'agit d'*Hyalocylix*, de *Corolla* sp. et de *Clionina longicaudata*. Bien qu'entrainées par le courant de surface vers le golfe Persique, ces espèces n'ont pas été retrouvées aux stations situées proches de l'entrée du golfe. Il se peut donc qu'il y ait une forte mortalité due à une sursalure, à moins que les espèces s'enfonçant plus profondément soient repoussées par le courant de sortie vers le golfe d'Oman. Parmi les Mollusques recueillis dans le Golfe Persique, *Limacina inflata* semble pouvoir survivre jusqu'à un certain seuil de salinité. En effet nous la retrouvons pour la dernière fois en une station dont les eaux ont une salinité proche de 39‰. Elle disparait ensuite totalement au fond du golfe Persique où la salinité atteint des valeurs voisines de 41‰.

Pour les Appendiculaires, Fenaux (1964) a constaté également une diminution progressive du nombre d'espèces depuis la mer d'Arabie jusque dans le golfe Persique; en effet il en a recueilli 19 dans la mer d'Arabie, 12 dans le golfe d'Oman et seulement 6 dans le golfe Persique. Sur ces 6 espèces, deux (*Oikopleura longicauda* et *O. rufescens*) ont été capturées dans presque toutes les stations du golfe Persique, ce sont par ailleurs les espèces les plus fréquentes récoltées au cours de la campagne du *Ct Robert Giraud* puisque, sur les 80 stations prospectées, la première espèce a été trouvée dans 76, la deuxième dans 60 stations. Enfin quatre autres espèces ont été trouvées, deux dans la partie septentrionale du golfe, il s'agit de *O. formica* et *O. fusiformis*, et deux autres au niveau de détroit d'Hormuz: *Megalocercus huxleyi* et *Stegosoma magnum*.

En conclusion, nous pouvons dire que, pour les trois groupes zooplanctoniques étudiés, quelques espèces arrivent à se maintenir dans tout le golfe Persique. Ce sont dans tous les cas les espèces les plus abondantes et les plus fréquentes, recueillies au cours de la campagne du *Ct Robert Giraud* dans tout le N.W. de l'Océan Indien. En outre ces espèces sont florissantes du fait très certainement d'une concurrence moins grande.

Pour ces trois groupes zooplanctoniques, nous n'avons trouvé aucune espèce endémique du golfe Persique; au contraire, toutes les espèces que nous avons pu recueillir sont celles dont la répartition géographique est la plus large. Il doit donc s'agir d'espèces très résistantes aux variations de températures et de salinité. Nous pensons donc que les eaux du golfe d'Oman et de la mer d'Arabie enrichissent en plancton de par leur entrée de façon continue, les eaux du golfe Persique, la survie des espèces ne se maintenant que jusqu'à un certain seuil limite de résistance propre à chacune d'elles. Ceci permettrait d'expliquer la diminution progressive du nombre d'espèces, dans le golfe Persique, du sud vers le nord.

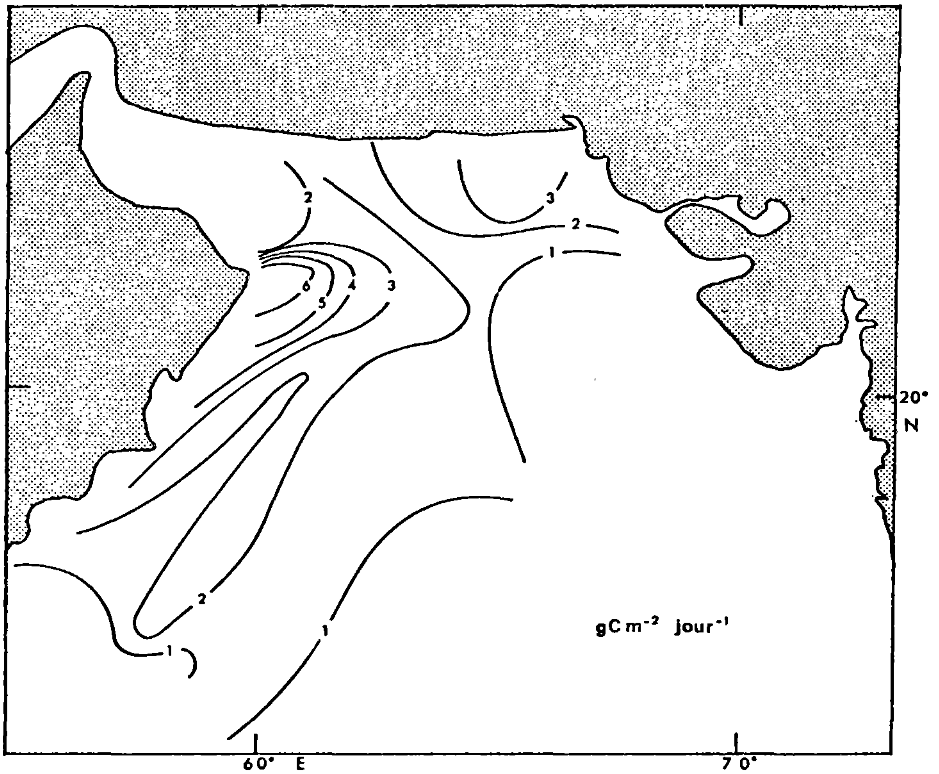

Fig. 5. Carte de la productivité primaire d'aprés les données de Ryther et al. 1966.

Influence des eaux du golfe Persique dans la mer d'Arabie

En général on a constaté une forte concentration planctonique dans la mer d'Arabie du N.W., ainsi qu'une productivité primaire importante (Ryther et al. 1966). La figure 5 nous montre deux régions où la productivité est particulièrement intense; ce sont: l'extrèmité sud du golfe d'Oman en bordure de la mer d'Arabie où nous avons une productivité primaire atteignant par endroit 6 gC/m^{-2} jour^{-1}, et la zone située au nord de la mer d'Arabie, le long du littoral du Pakistan où elle atteint 3 gC/m^{-2} jour^{-1}.

Parmi les groupes zooplanctoniques que nous avons signalé précédemment, nous nous sommes interessés plus particulièrement aux espèces les plus superficielles qui présentent un développement intense dans la mer d'Arabie du N.W. Nous pouvons noter (Fig. 4) que leur distribution horizontale semble calquée sur les zones à forte productivité primaire et sur celles à volumes planctoniques importants (Fig. 5).

Les conditions physico-chimiques conduisant à une forte productivité dans la mer d'Arabie du N.W. ont été données par Ryther & Menzel (1965). L'origine

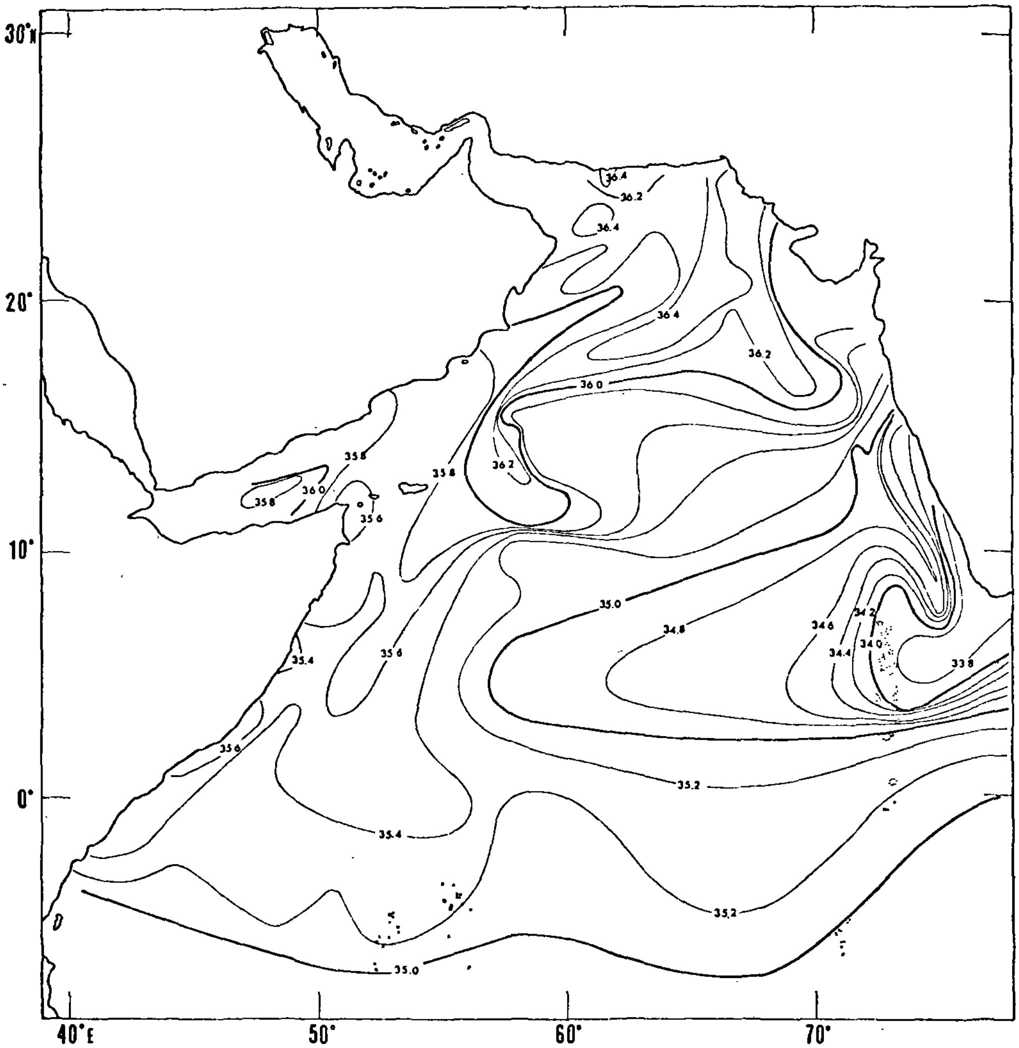

Fig. 6. Carte de la salinité dans l'horizon de 15 m pendant la mousson de N.E.

principale de cette zone riche est sans nul doute due à l'abondance des nitrates et des phosphates, dans la couche euphotique ou proche de celle-ci. Il se pose alors le problème de l'origine de cette masse d'eau ainsi que celui des phénomènes qui permettent la remontée de ces éléments nutritifs dans la couche superficielle.

Nous aborderons ici le problème de l'origine de cette masse d'eau. Les différentes coupes hydrologiques que nous avons pu faire dans le golfe d'Oman et dans la mer d'Arabie jusqu'à la profondeur de 400 m nous amènent à penser que cette eau provient du golfe Persique. Une carte de la salinité à 15 m, ainsi qu'une maquette donnant une représentation spatiale de la situation hydrologique

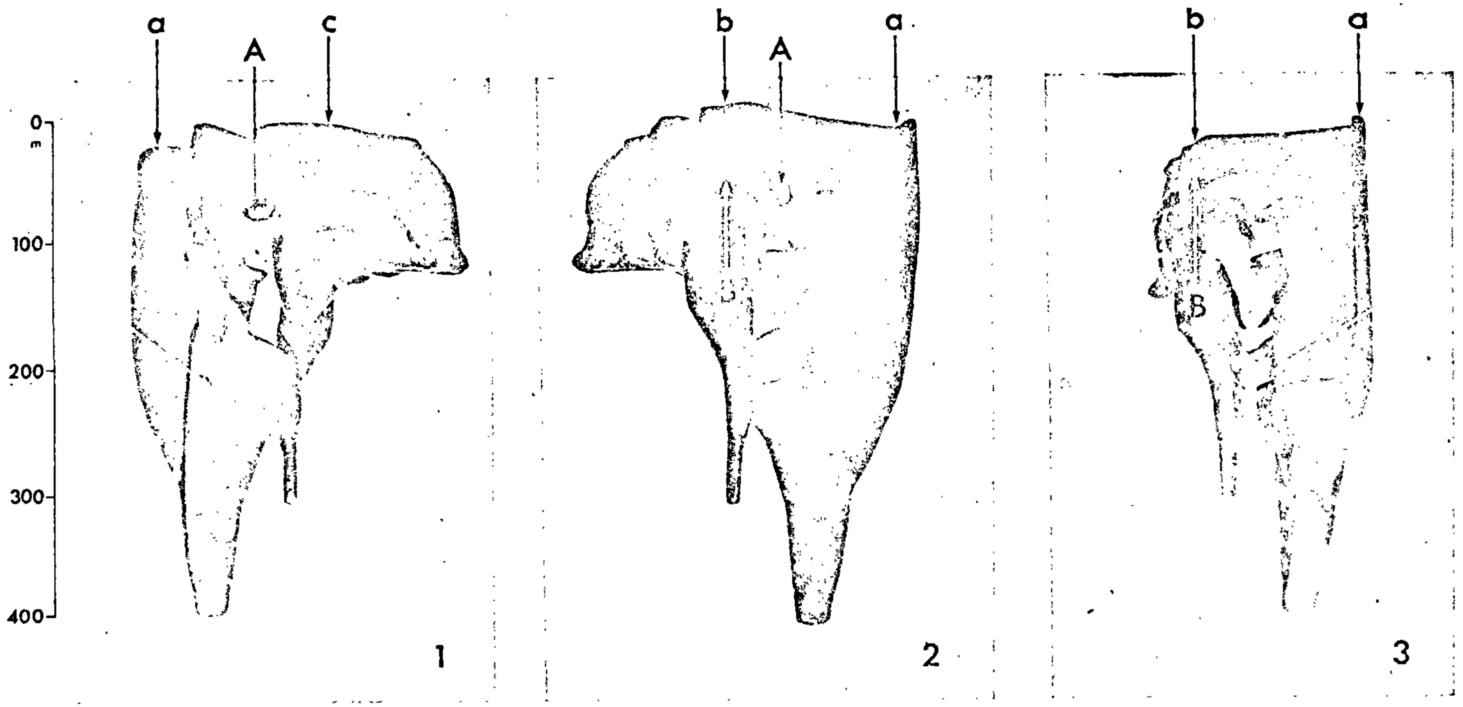

Fig. 7. Vues de la maquette donnant une représentation spatiale des masses d'eau dont les salinités sont supérieures ou égales à 36‰ dans le golfe d'Oman et la mer d'Arabie du N.W., jusqu'à la profondeur de 400 m.

1, 2, 3. Photographies de la maquette prises sous des angles différents notés avec des flèches 1, 2, 3 sur la figure 1. a) Eau du golfe d'Oman. b) Eau de la mer d'Arabie, région de la côte du Pakistan. c) Limite sud-est de la masse d'eau de salinité supérieure ou égale à 36‰ dans la mer d'Arabie. A) Zone à salinité inférieure à 36‰, localisée entre 75 et 100 m qui correspond au courant Sud-Nord signalé par Ryther et al. (1966). B) Correspond au "pilier" localisé le long de la côte du Pakistan qui semble dénoter la présence d'un "upwelling". Les flèches blanches indiquent la direction du mouvement et de l'ecoulement de l'eau.

de cette région du golfe d'Oman et de la mer d'Arabie, nous permettent de confirmer en partie notre hypothèse sur l'origine de cette masse d'eau.

La carte des salinités (Fig. 6) pour une profondeur de 15 m montre que toute la région du N.W. de la mer d'Arabie présente une salinité supérieure à 36‰. En outre, l'isohaline 36‰ présente une expansion vers le sud analogue à celles observées sur les fig. 4 et 5 concernant la productivité primaire et les volumes planctoniques. La maquette (Fig. 7) représente les eaux dont les salinités sont égales ou supérieures à 36‰ dans la mer d'Arabie du N.W. et le golfe d'Oman. Dans le golfe d'Oman nous pouvons observer que l'isohaline de 36‰ s'enfonce progressivement depuis le détroit d'Hormuz jusqu'à la sortie du golfe. Dans la mer d'Arabie, nous retrouvons l'expansion vers le sud de l'isohaline 36‰ déjà observée sur la carte.

Nous remarquerons également la présence d'une zone à salinité moins élevée, localisée entre 50 m et 75 m (partie A de la maquette fig. 7) correspondant au courant Sud-Nord, signalé dans cette région par RYTHER et al. (1966).

Sur la côte du Pakistan, nous avons trouvé une masse d'eau bien individualisée, en forme de "pilier" (partie B de la maquette fig. 7) qui doit correspondre à un upwelling. Ceci permettrait d'expliquer la forte productivité primaire observée par RYTHER et al. (1966) dans cette région.

L'isohaline de 36‰, bien que choisie arbitrairement, nous a permis d'individualiser une masse d'eau qui s'étend du golfe Persique au golfe d'Oman et à toute la région du N.W. de la mer d'Arabie, de la surface jusqu'à la profondeur maximale de 400 m. Cette masse d'eau dont la salinité est élevée est sans nul doute influencée par les eaux de sortie du golfe Persique, très salées, qui occupent des niveaux identiques et en outre se dirigent vers l'est.

En conclusion, nous pensons que les échanges de masses d'eaux entre le golfe Persique et la mer d'Arabie ont une influence sur la distribution horizontale des organismes zooplanctoniques. En outre, ils permettent l'enrichissement en éléments nutritifs du N.W. de la mer d'Arabie où se produit un développement intense de la flore et de la faune.

RÉSUMÉ

Dans ce travail nous avons essayé d'expliquer la répartition de quelques groupes zooplanctoniques dans la mer d'Arabie et le golfe Persique. L'influence la plus importante en ce qui concerne la distribution du zooplancton de cette région reste très certainement celle des échanges d'eaux en surface et en profondeur entre le golfe Persique d'une part et la mer d'Arabie d'autre part. Nous avons observé un appauvrissement progressif en espèces d'est en ouest, dû à l'augmentation de la salinité mais aussi aux faibles profondeurs du golfe Persique. En outre nous avons noté une forte productivité primaire et secondaire dans la

mer d'Arabie, dues à la présence d'un upwelling le long de la côte du Pakistan mais surtout à l'influence de l'eau du golfe Persique dans tout le N.W. de l'océan Indien.

REMERCIEMENTS

Nous tenons à remercier Monsieur le Directeur du "Data Center" de Washington qui nous a envoyé gracieusement les données des différentes campagnes ayant eu lieu dans l'Océan Indien. M.M. les Dr. Menzel et Dr. Ménaché, respectivement chefs de mission de l'*Anton Bruun* et de l'aviso *Ct Robert Giraud*, nous ont accordé la permission d'utiliser les résultats des campagnes, nous leur exprimons notre profonde recõnnaissance.

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Reprinted from *Limnol. Oceanogr.*, vol. 13, no. 4, 1968, p. 656-664

THE CHARACTERISTICS AND DISTRIBUTION OF MARINE BACTERIA ISOLATED FROM THE INDIAN OCEAN[1]

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ABSTRACT

During the eighth cruise of the RV *Anton Bruun* in the Indian Ocean, bacteria were collected from water, mud, fish, shark, and one island. The marine samples were collected from depths ranging from 100 to 3,050 m. A total of 127 isolates was classified to genus and the physiological response of the cultures to 17 diagnostic tests was related to their source. The physiological test response of the isolates, regardless of genus, was more highly correlated with the source of the cultures than were the genera as such.

INTRODUCTION

Reports of systematic collections of bacteria from marine environments have been comparatively few. ZoBell and Upham (1944) characterized 60 such species. Wood (1952) reported comprehensively on bacterial genera of the marine environment of eastern Australia. Kriss (1963) listed the genera isolated from several expeditions. Recently Leifson et al. (1964) investigated motility in marine bacteria and Pfister and Burkholder (1965) collected data from antarctic and Puerto Rican waters. Marine bacteria are predominantly Gram negative and motile, and occur in low concentrations in water and higher ones in bottom sediments. MacLeod (1965) reviewed evidence that marine bacteria are unique in their ability to survive and grow in the sea.

Liston (1960), Colwell (1962), and Colwell and Liston (1962) have reported on the bacterial flora associated with marine fish. Liston (1957) has suggested that the normal intestinal flora of marine fish is predominately of the genus *Vibrio.* We are aware of only one paper (Wood 1952) reporting the bacterial intestinal flora of elasmobranchs. Davies and Campbell (1962) found hemolytic *Paracolons* on the teeth of sharks examined.

During the eighth cruise of the RV *Anton Bruun* in the Indian Ocean a collection of bacteria was made, limited in that all samples were from 100 m or deeper, only one basic type of peptone-seawater medium was used, and specimens were incubated in the broth medium at 10C prior to plating, thus consisting only of types favored by these conditions. However, it is possible to compare the bacterial flora from the five environments from which cultures were obtained. The intestinal contents of 17 fish and five shark were cultured. The fish were selected for their relatively deep natural habitat. A total of 127 isolates was examined. Their source was distributed as follows: water 31, bottom muds 20, fish intestine 51 (27 aboard ship, 24 after storage), shark intestine 15, land 10.

MATERIALS AND METHODS

Collection of specimens

Thirty-ml water samples were collected from Nansen bottles after initial flushing and 10 ml of concentrated medium added. Aged seawater was used for all media aboard ship. The cultures were incubated at 10C and subsequent isolations made within 48 hr at both 10 and 20C. Isolates were lettered or numbered serially; those with designations above 8C were isolated from material brought home. Bottom muds were collected with sterile vials from the inner portion of a snapper immediately after its return to shipboard; some of the mud was then inoculated into sterile me-

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[1] This work was supported by the Arizona State University Research Committee and Ciba Pharmaceutical Co. The collection cruise of the RV *Anton Bruun* was supported by the National Science Foundation.

[2] Trainee on U.S. Public Health Grant No. TI-A-1259.

TABLE 1. *Differential generic characteristics*

Genus	Gram stain	Spores	Pigment	Flagella	Hugh-Leifson glucose	Pteridine 0/129 sensitivity	Luminescence
Bacillus	+	+	±	Peritrichous	No growth	–	–
Brevibacterium	+	–	±	Peritrichous	No growth	±	–
Corynebacterium	+	–	–	Variable	No growth	–	–
Pseudomonas	–	–	–	Polar	Oxidative	–	–
Xanthomonas	–	–	+	Polar	Oxidative	–	–
Achromobacter	–	–	–	Variable	Fermentative	–	–
Flavobacterium	–	–	+	Variable	Fermentative	–	–
Alcaligenes	–	–	–	Variable	Negative	–	–
Vibrio	–	–	–	Polar	Fermentative	+	±
Spirillum	–	–	–	Bipolar	No growth	–	–
Photobacterium	–	–	–	Variable	Fermentative	–	+
Hyphomicrobium	*	–	–	Polar	Fermentative	–	–

* Characterized by pleomorphic cells and budding.

dium and incubated at 10C. Isolations were subsequently made from the mud suspensions at both 10 and 20C. The maximum water temperature at the surface during this cruise was 24C and isolates were never exposed to a temperature over this for more than 1 hr. All isolates were transported as pure cultures from the ship's refrigerator to a refrigerator in Tempe, Arizona, in 44 hr. During this period no temperature control was possible.

Determination of genera

All cultures were Gram stained, examined microscopically, and a series of biochemical tests was made by standard bacteriological methods (Pelcazar 1957) using artificial seawater (Aquarium Systems Inc.). Glucose metabolism was determined by the method of Hugh and Leifson (1953). Cultures were tested for chitin utilization, H_2S production, and cellulose digestion by the method of Skerman (1959). Growth on the chitin plate was considered positive for chitin utilization as a carbon source although these positive strains failed to digest chitin in a liquid medium. Table 1 shows key characteristics used for distinguishing genera. All cultures were tested for their ability to grow in nutrient broth without seawater; only those belonging to the Gram positive genera *Brevibacterium*, *Corynebacterium*, and *Bacillus* would grow in this medium. Flagella were stained by the method of Rhodes (1958). Pteridine 0/129 was kindly supplied by Allen and Hanburys' Ltd. and used as a saturated solution on filter

TABLE 2. *Composition of media used*

Components*	Medium designation					
	M2	M2G	M2F	M3	M5	M6
Peptone (g)	5	5	5	—	5	5
Yeast extract (g)	0.5	0.5	0.5	—	1	0.5
Glucose (g)	—	10.0	—	—	5	—
$FePO_4$ (g)	—	—	0.1	—	—	0.1
Fish extract† (ml)	—	—	—	100	10	—
Shark blood (ml)	—	—	—	—	—	50‡
Seawater (ml)	1,000	1,000	1,000	900	1,000	1,000

* Nobel agar (Difco) was added to the above media in a 1.5% concentration for solid media.
† Prepared by autoclaving cut fish in seawater.
‡ Autoclaved and added to medium.

TABLE 3. *Distribution of various genera of bacteria in water and bottom samples by depth range*

Depth (m) and hydrographic ranges*	Genera		
	Water	Bottom	
200–500 4 stations			
Temp 8.7–12.1C	*Achromobacter*	1 station	*Pseudomonas*
O_2 3.8–4.4 ml/liter	*Vibrio* (4)†		*Achromobacter*
PO_4-P 1.0–1.6 µg atoms/liter	*Photobacterium*		*Vibrio* (2)
NO_3-N 14.3–22.5 µg atoms/liter	*Flavobacterium*		*Hyphomicrobium*
NO_2-N 0.02–0.09 µg atoms/liter	*Alcaligenes* (2)		
SiO_3-Si 9.4–18.5 µg atoms/liter	*Corynebacterium* (3)		
600–975 5 stations			
Temp 5.5–8.6C	*Flavobacterium* (3)	1 station	*Pseudomonas*
O_2 2.5–3.9 ml/liter	*Achromobacter*		*Vibrio*
PO_4-P 1.6–2.4 µg atoms/liter	*Photobacterium*		*Flavobacterium*
NO_3-N 21.6–26.6 µg atoms/liter	*Pseudomonas* (2)		
NO_2-N 0.01–0.04 µg atoms/liter	*Brevibacterium*		
SiO_3-Si 23–69.1 µg atoms/liter	*Vibrio* (2)		
1,000–1,470 5 stations			
Temp 2.6–6.2C	*Alcaligenes* (3)	2 stations	*Pseudomonas* (2)
O_2 2.1–3.4 ml/liter	*Pseudomonas* (2)		*Vibrio*
PO_4-P 2.3–2.7 µg atoms/liter	*Spirillum* (2)		*Flavobacterium*
NO_3-N 32.3–33.0 µg atoms/liter			
NO_2-N 0.02–0.16 µg atoms/liter			
SiO_3-Si 65.5–87.0 µg atoms/liter			
1,600–3,050 4 stations			
Temp 1.7–3.6C	*Achromobacter* (2)	9 stations	*Pseudomonas*
O_2 2.9–4.9 ml/liter	*Flavobacterium*	2 stations	*Bacillus*
PO_4-P 1.9–2.5 µg atoms/liter	*Pseudomonas*	negative	*Brevibacterium* (4)
NO_3-N 26.8–34.8 µg atoms/liter	*Alcaligenes* (2)		*Achromobacter*
NO_2-N 0.02–0.11 µg atoms/liter	*Vibrio* (2)		*Flavobacterium*
SiO_3-Si 75–123 µg atoms/liter	*Spirillum* (2)		
	Corynebacterium		
	Bacillus (3)		

* From Final Cruise Report *Anton Bruun* cruises 7, 8, 9, v. 2. October 1965, Woods Hole Oceanographic Institution.
† Number of individual strains each genus.

paper disks to test for bacteriostatic action according to the method of Collier, Campbell, and Fitzgerald (1950). Commercial antibiotics disks (BBL) were used for the other antibiotic sensitivity tests.

Media

The media used are shown in Table 2. The M2 medium was used routinely, with or without glucose or ferric phosphate. Later subculture of all strains on M2 medium showed no specific requirement for either glucose or iron. The change from aged seawater to artificial seawater did not appear to affect growth of the strains.

Isolation technique for fish and shark

Sections of fish intestine were removed aseptically within 15 min after the fish were collected and placed in liquid M2 medium at 10C; streak plates were made on M2 and M3 media incubated at both 10 and 20C. The 10 intestines collected near the end of the cruise were overlaid with M2 agar and streak cultures made from them later at Tempe. The shark were

TABLE 4. *Genera of bacteria found in water samples from different depths along Nansen bottle line*

Sample water (increasing relative depth)	Station							
	398	399	400	404	405	407	410	411
1	*Photobacterium* *Corynebacterium*	*Achromobacter* *Flavobacterium* *Vibrio*	*Brevibacterium* *Pseudomonas*	*Flavobacterium*	*Bacillus*	*Pseudomonas*	*Vibrio*	*Flavobacterium* *Vibrio*
2	*Flavobacterium*	*Vibrio* (luminescent)	*Alcaligenes*	*Alcaligenes* *Pseudomonas*	*Vibrio* *Achromobacter* *Flavobacterium* *Pseudomonas*	*Pseudomonas* No. 2*	*Spirillum*	*Spirillum*
3			*Alcaligenes* No. 2		*Alcaligenes* *Bacillus* No. 2 *Corynebacterium*	*Alcaligenes* *Bacillus*	*Achromobacter*	*Vibrio*
4							*Spirillum* No. 2	*Spirillum* No. 2
Bottom	*Flavobacterium* No. 2 *Pseudomonas* *Vibrio*	*Vibrio* No. 2 *Alcaligenes*	*Pseudomonas* (same) *Vibrio*	*Pseudomonas* (same) *Vibrio*	*Brevibacterium*	*Achromobacter* *Bacillus*	*Pseudomonas*	*Alcaligenes*

* Strain different biochemically from strain of same genus isolated at the same station.

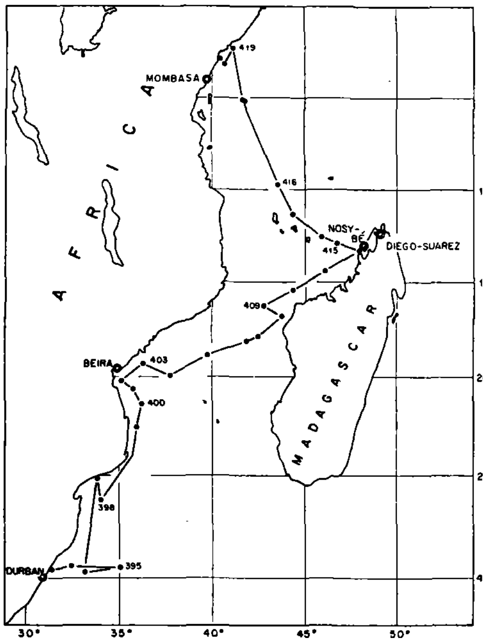

FIG. 1. Stations at which specimens were obtained during the eighth cruise of the RV *Anton Bruun*.

opened on the ship's deck after surface treatment of the skin with alcohol. A section of the intestine was removed aseptically and put into a sterile vial. M5 or M6 liquid medium was added to the vial and streak plates subsequently made from this on M2 and M6 media.

Shark were identified aboard ship by Dr. S. Springer. The fish from which isolations were made were tagged and subsequently identified by Dr. L. Knapp.

The cruise track of the RV *Anton Bruun* and location of stations are shown in Fig. 1. Chesterfield Island is located approximately 56 km off the coast of Madagascar at 16° 21′ S lat, 43° 59′ E long.

RESULTS AND DISCUSSION

Water and bottom mud bacteria

A comparison of genera obtained from water and mud at four different depth ranges is shown in Table 3. While *Pseudomonas*, *Flavobacterium* and *Vibrio* were found in almost all samples, *Spirillum* and

TABLE 5. *Bacterial intestinal flora isolated from fish aboard ship*

Fish	Media and isolation temp (°C)		
	M2 20	M3 20	M2 10
Chaunax fimbriatus	*Vibrio* R*	*Vibrio* 10	*Vibrio* Y *Vibrio* Z
Chloropthalmus sp.	*Achromobacter* Q	*Achromobacter* 1R	*Vibrio* W
Macrouridae sp. No. 1	*Vibrio* 1E	*Alcaligenes* 2W	Not done
Selachophidium guentheri	*Vibrio* 1B *Bacillus* 1C *Photobacterium* 1D	*Achromobacter* 1T *Vibrio* 1U	Not done
Coloconger raniceps	*Achromobacter* 2D *Achromobacter* 2E	*Alcaligenes* 1Y	Culture lost
Macrouridae sp. No. 2	*Vibrio* 2C *Photobacterium* 2B	*Alcaligenes* 1Z	*Vibrio* 2S *Photobacterium* 2T *Vibrio* 3L
Argyrops filamentosus	*Achromobacter* 3I	Not done	*Pseudomonas* 3M
Opisthoproctus soleatus	*Pseudomonas* 4J	Not done	*Vibrio* 5R

* Strain designation.

Photobacterium were found only in water samples. Gram positive genera were primarily found in deep samples and four of the five *Brevibacterium* isolates were from the deepest muds. None of the cultures attacked cellulose or chitin.

The problem of contamination when Nansen bottles are used for collecting specimens has been debated (Kriss 1962; Kriss, Lebedeva, and Tsiban 1966). To check this, the genera collected from different depths at the same station were compared relative to their position on the collecting line along with the bottom samples obtained at the same station from the snapper (Table 4). Where two or

TABLE 6. *Bacterial intestinal flora isolated from fish after storage*

Fish	Isolation temp (Aerobic)		Anaerobic isolation
	20C	10C	25C
Sternoptyx diaphana	*Flavobacter* 8J*	*Vibrio* 8C	*Micrococcus* 9E
Melamphaidae	*Flavobacter* 8S	*Achromobacter* 8X	Not done
Cyclothone sp.	*Vibrio* 8T	None found	Not done
Pseudomonacanthus sp.	*Achromobacter* 8P	*Achromobacter* 8F	*Achromobacter* 9C *Vibrio* 9F
Antigonia rubescens	*Achromobacter* 8L	*Achromobacter* 8E	Not done
Scorpaena sp.	*Achromobacter* 8O	*Achromobacter* 8H	Not done
Polyipnus sp.	*Achromobacter* 8N	*Achromobacter* 8I	*Xanthomonas* 9A *Micrococcus* 9B
Malthopsis sp.	*Achromobacter* 8Q	*Achromobacter* 8D	*Alcaligenes* 9D
Cynoglossus (Trulla) sp.	*Vibrio* 8M	*Achromobacter* 8G	No growth
Macrouridae sp. No. 3	Culture lost	*Achromobacter* 8U	No growth

* Strain designation.

Table 7. *Bacterial flora of shark intestine*

Shark species	Bacterial strain 20C	10C
Halaelurus hispidus	None found	None found
Carcharinus albomarginatus	*Bacillus* 4R* *Bacillus* 5V *Corynebacterium* 4G	Not done
Carcharinus longimanus	*Bacillus* 6P *Bacillus* 6G *Bacillus* 6H *Bacillus* 6I	*Vibrio* 7O
Carcharinus spallanzini	*Alcaligenes* 7M	None found
Rhizoprionodon acutus	*Bacillus* 5A *Bacillus* 5B *Bacillus* 5C *Bacillus* 5D	*Xanthomonas* 6S *Spirillum* 6T

* Strain designation.

more isolates of the same genus were obtained at the same station their biochemical characteristics were compared; if they were similar this might indicate cross contamination. Only in two cases of nine tested (*Pseudomonas* at Stas. 400, 404) were similar strains found. Most isolates from one station were of different genera. Every bottle on the line was not examined and the minimum distance between bottles was 200 m, often more at the deeper stations.

Fish and shark isolates

Tables 5, 6, and 7 show the bacterial flora isolated from fish and shark. The lack of pigmented and Gram positive strains in the fish population is evident. None of the Gram negative cultures isolated grew in nutrient broth without seawater. All genera except the single *Bacillus* had monotrichous polar or subpolar flagellation. Three of the *Vibrios* isolated on the ship (R, 2D, 5R) showed beta hemolysis on a blood agar medium containing 3% NaCl. Eight *Achromobacter* strains (8F, 8G, 8H, 8I, 8N, 8O, 8P, 8Q) isolated after storage showed similar hemolysis, as did the *Vibrio* 8M. The lack of sensitivity to pteridine 0/129 accounted for the high incidence of *Achromobacter* in the isolations made from the stored fish intestine. However, the morphology of this group was also considerably more uniform than the *Vibrio* isolates. Chitinoclastic activity was found in all of the stored cultures but in none of those freshly isolated.

Anaerobic streak cultures were made on M2 agar from six of the fish intestines brought home (Table 6). No strict anaerobes were found. Two identical Gram negative micrococci were isolated from the two Sternoptychidae (*Sternoptyx* and *Polyipnus*).

Attempts were continually made for over a month to isolate bacteria from a suspension of *Halaelurus* intestinal contents maintained at 10C in M2 medium. All attempts failed. The three Gram negative bacteria isolated from other shark were obtained at an incubation temperature of 10C. At 20C, and only at 20C, *Bacillus* was isolated. The characteristics of all of these *Bacillus* isolates were similar and diagnostic for *Bacillus firmis*. Since at least two days intervened between any two individual shark isolations and no Gram negative bacilli were regularly isolated as they were with fish, the possibility of general cross contamination is low. Assuming the *Bacillus* to be a contaminant, three of the shark intestines were sterile. Alternatively,

TABLE 8. *Isolates from Chesterfield Island*

Source	Genera
Mud	*Flavobacterium* 5E* *Corynebacterium* 5F *Corynebacterium* 5G *Micrococcus* 5H *Bacillus* 5I *Brevibacterium* 5J *Brevibacterium* 6V
Beach sand	*Alcaligenes* 5M *Flavobacterium* 5F *Micrococcus* 6A

* Strain designation.

the similarity of the *Bacillus* strains isolated from three of the five shark examined may indicate a common bacterial flora for shark.

TABLE 9. *Temperature characteristics of 10C isolates*

Source	Genus	Growth temp (°C)				
		–6	10	18	30	37
Water	*Vibrio*	+	+	+	+	–
	Vibrio (3)*	+	+	+	+	+
	Vibrio	+	+	+	–	–
	Spirillum (3)	+	+	+	–	–
	Pseudomonas	–	+	+	–	–
	Alcaligenes	+	+	+	+	–
	Alcaligenes	–	+	+	+	–
	Brevibacterium	+	+	+	+	+
	Photobacterium	+	+	+	+	–
	Achromobacter	+	+	+	–	–
	Achromobacter	+	+	+	+	+
	Flavobacter (2)	+	+	+	–	–
Fish	*Vibrio*	+	+	+	+	+
	Vibrio	+	+	+	–	–
	Vibrio	–	+	+	+	+
	Vibrio	+	+	+	+	–
	Pseudomonas	+	+	+	+	+
Shark	*Vibrio*	+	+	+	+	+
	Spirillum	+	+	+	+	–
	Pseudomonas	+	+	+	+	+
Bottom	*Vibrio*	–	+	+	–	–
	Vibrio (2)	+	+	+	+	+
	Hyphomicrobium	+	+	+	–	–
	Pseudomonas	–	+	+	+	–
	Pseudomonas	+	+	+	+	+
	Flavobacterium	+	+	+	+	+
	Brevibacterium	+	+	+	+	+

* Number of strains.

TABLE 10. *Penicillin sensitivity* of Gram negative genera*

Genus	Total No. of strains tested	No. of sensitive strains	% sensitive
Pseudomonas	16	4	25
Vibrio	40	12	30
Achromobacter	29	11	37
Alcaligenes	23	9	39
Flavobacterium	11	4	36
Photobacterium	7	3	43
Total	126	43	34

* Two units of penicillin.

Chesterfield Island isolates

Table 8 shows the source of isolates made from this island. The preponderance of Gram positive and pigmented bacteria is obvious. This island is submerged during storms and only three crevices in the single rock formation on the island contained mud; thus the island may be considered a transition zone from sea to land.

Psychrophiles

At the laboratory, all of the isolates made at 10C were immediately subcultured at 10C and characterized. All would grow without yeast extract in a 0.5% peptone, artificial seawater medium. The large majority grew well at 30C and also at –6C (Table 9). It is apparent that in spite of the attempt to select strict psychro-

TABLE 11. *Distribution of pigmented bacteria*

Source	No.	Genus
Bottom	6	*Brevibacterium*
	3	*Flavobacterium*
	1	*Xanthomonas*
Water	5	*Flavobacterium*
	1	*Brevibacterium*
Fish (immediate isolation)	0	
Fish (after storage)	2	*Flavobacterium*
	1	*Xanthomonas*
Shark	1	*Flavobacterium*
Chesterfield Island	2	*Brevibacterium*
	2	*Flavobacterium*
	1	*Bacillus*
	1	*Micrococcus*

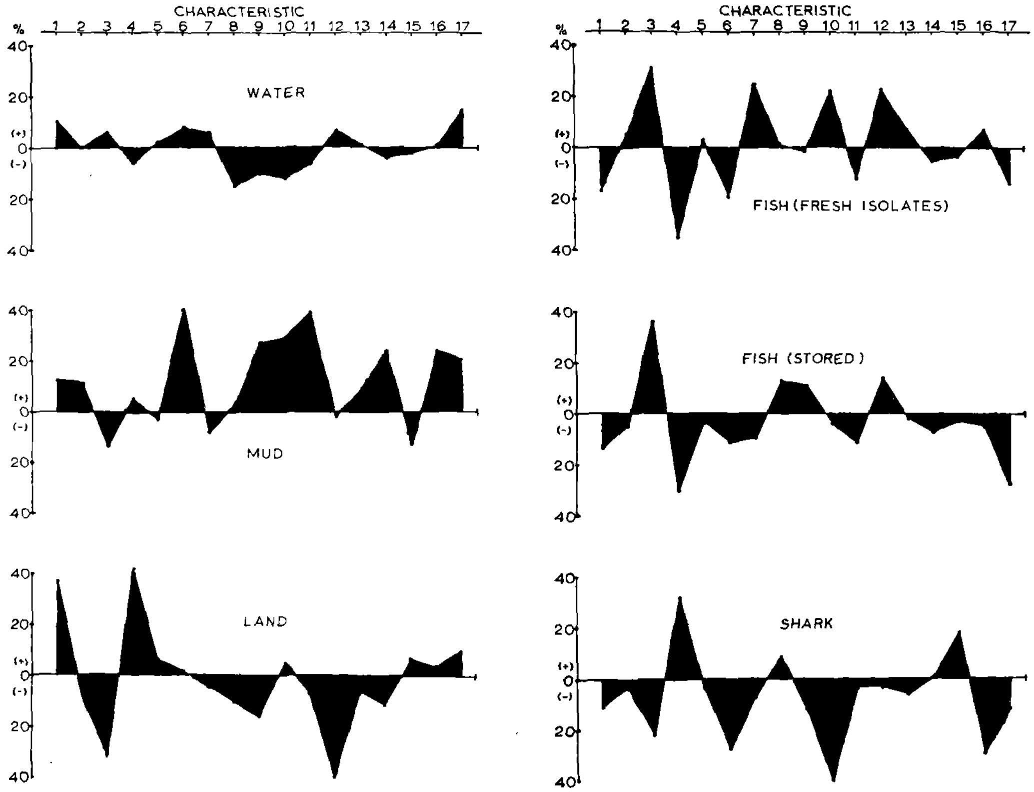

FIG. 2. Deviation of physiological characteristics of isolates from those of collection as a whole, as a function of isolation source. *Legend:* 1, *pigment;* 2, *oxidative glucose metabolism;* 3, *fermentative* glucose metabolism; 4, alkaline glucose; 5, cellulose digestion; 6, chitin utilization; 7, lactose fermentation; 8, starch hydrolysis; 9, gelatin liquifaction; 10, H_2S production; 11, casein hydrolysis; 12, nitrate reduction; 13, indol production; 14, urease production; 15, catalase production; 16, oxidase production; 17, motility.

philes, all were capable of growth at 18C and many at higher temperatures. Of the Gram positive genera present, only *Brevibacterium* was isolated at 10C and it was also capable of growth at 37C.

Antibiotic sensitivity

Over 90% of the cultures were resistant to streptomycin and sensitive to chloromycetin. Shewan, Hodgkiss, and Liston (1954) reported *Achromobacter* to be uniquely sensitive to penicillin. Our results (Table 10) do not confirm this.

Pigment

Table 11 shows the distribution of pigmented bacteria. Sixteen of the 26 cultures came from mud or land and the lack of pigmented strains from fish intestine when isolated prior to storage is noteworthy.

Physiological diagnostic tests and source of bacteria

The percentage of cultures from each of the five sources giving positive results on each of 17 physiological diagnostic tests was calculated. The percentage of positive results for each area was then compared to the percentage of positives for the entire collection (Fig. 2). The fish samples were divided into two groups—those freshly isolated aboard ship and those isolated from the intestines brought home.

It is apparent that except for the two fish groups there is no correlation between areas that would suggest a physiological response from each group of bacteria unique to its source of isolation. As might be expected, the water isolates, although only 25% of the collection, show the closest correlation to the entire collection, while those isolated from land show the greatest deviation. Wood (1952) has reported the flora of shark to be more closely related to that of muds than to that of seawater; this is confirmed only weakly here. The two collections from fish are interesting in that their deviation from the entire collection is in general the same, differing only in intensity of response. The minor difference is explainable as a function of two months' storage of the intestines, and this similarity tends to confirm the differences found between the ecological areas as a real phenomenon.

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Reprinted from *Proc. Biol. Soc. Wash.*, vol. 81, 1968, p. 635-691

CYCLOPOID COPEPODS OF THE GENUS *LICHOMOLGUS* ASSOCIATED WITH OCTOCORALS OF THE FAMILY ALCYONIIDAE IN MADAGASCAR

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Three species of *Lichomolgus* are already known to be associated with octocorals of the family Alcyoniidae in Madagascar. These are *L. decorus* Humes and Frost, 1964, from *Cladiella laciniosa* (Tixier-Durivault), *L. squamiger* Humes and Frost, 1964, from *Sinularia polydactyla* (Ehrenberg), and *L. protentus* Humes and Frost, 1964, from *Sarcophyton globosum* Tixier-Durivault. The last named host was listed by Humes and Frost (1964) as *Sarcophyton* sp., but has since been described as new by Tixier-Durivault (1966). This paper concerns seven new species of *Lichomolgus*, two species which are redescribed, and a new host record for *L. squamiger*, all washed from various species of Alcyoniidae in the region of Nosy Bé in northwestern Madagascar.

All collections were made by A. G. Humes, those in 1960 during an expedition sponsored by the Academy of Natural Sciences of Philadelphia, and those in 1963–64 as part of the U.S. Program in Biology of the International Indian Ocean Expedition.

The study of the specimens has been aided by a grant (GB-5838) from the National Science Foundation of the United States.

All figures have been drawn with the aid of a camera lucida. The letter after the explanation of each figure refers to the scale at which it was drawn. The abbreviations used are: A_1 = first antenna, A_2 = second antenna, MXPD = maxilliped, and P_1 = leg 1.

All descriptions are based on type material. The measurements of the length of the body have been made in all cases from specimens in lactic acid and do not include the setae on the caudal rami. The lengths of the segments of the first antenna have been measured along their posterior nonsetiferous margins.

We are indebted to Mme. A. Tixier-Durivault of the Muséum National d'Histoire Naturelle, Paris, for the identifications of the octocorals collected in 1960, and to Dr. J. Verseveldt, Zwolle, The Netherlands, for the determinations of those collected in 1963–64. We thank Dr. John O. Corliss of the University of Illinois for the identification of the suctorian attached to *L. singularipes.*

The new copepods described in this paper comprise the following:

1) *Lichomolgus cristatus* new species
   from *Sinularia leptoclados* (Ehrenberg).
2) *Lichomolgus adelphus* new species
   from *Sinularia whiteleggei* Lüttschwager, *S. pedunculata* Tixier-Durivault, and *S. polydactyla* (Ehrenberg).
3) *Lichomolgus hetaericus* new species
   from *Cladiella pachyclados* (Klunzinger) and *C. krempfi* Hickson.
4) *Lichomolgus insolens* new species
   from *Lobophytum crassum* Marenzeller.
5) *Lichomolgus spathophorus* new species
   from *Sarcophyton glaucum* (Quoy and Gaimard).
6) *Lichomolgus incisus* new species
   from *Sarcophyton ehrenbergi* Marenzeller.
7) *Lichomolgus singularipes* new species
   from *Parerythropodium rubiginosum* Verseveldt.

Of the following two species, females are redescribed and males described for the first time:

1) *Lichomolgus dentipes* Thompson and A. Scott, 1903
   from *Sinularia humesi* Verseveldt.
2) *Lichomolgus foxi* Gurney, 1927
   from *Cladiella krempfi* Hickson, *C. laciniosa*

(Tixier-Durivault), and *C. pachyclados* (Klunzinger).

The following is a new host record:

1) *Lichomolgus squamiger* Humes and Frost, 1964
from *Sinularia whiteleggei* Lüttschwager.

FAMILY LICHOMOLGIDAE KOSSMANN, 1877

GENUS *LICHOMOLGUS* THORELL, 1859[1]

Lichomolgus dentipes Thompson and A. Scott, 1903

Figures 1–28

This species was established on the basis of one female found in washings of dredged invertebrates in Ceylon. It has not been reported again, and the original specimen is presumably lost along with the rest of the Andrew Scott collection (see Humes and Ho, 1967, p. 209). The male has been unknown until now.

Both sexes of *L. dentipes* (87♀♀ and 145♂♂) were washed from one colony of *Sinularia humesi* Verseveldt, collected in 2 m, off Ampombilava, Nosy Bé, Madagascar, 26 September 1964. One hundred and fifty-six specimens (54♀♀, 102♂♂) have been deposited in the United States National Museum; 35 specimens (15♀♀, 20♂♂) in the Zoölogisch Museum, Amsterdam; and the remaining specimens in the collection of A. G. Humes.

Female: Body (fig. 1) with rather broad prosome. Length 0.94 mm (0.91–0.95 mm) and greatest width 0.57 mm (0.56–0.58 mm), based on 10 specimens. Ratio of length to width of prosome 1.14 : 1. Segments of legs 1–3 with irregularly serrate hyaline lateral margins. Segment of leg 4 narrow and mostly concealed beneath dorsum of preceding segment; terminating posteriorly on each side in a hyaline spiniform process.

Segment of leg 5 (fig. 2) 78 μ × 187 μ. Genital segment wider than long, 100 μ × 148 μ, in dorsal view rounded laterally and abruptly constricted in its posterior fifth. Areas of attachment of egg sacs situated dorsolaterally on posterior part of expanded region. Each area (fig. 3) bearing two naked spiniform setae 7 μ and 11 μ long, with a recurved sclerotized pointed process between them. Three postgenital segments 39 μ × 78 μ, 31 μ × 73 μ, and 65 μ × 70 μ, from anterior to posterior.

Caudal ramus (fig. 4) slightly longer than wide, its greatest dimen-

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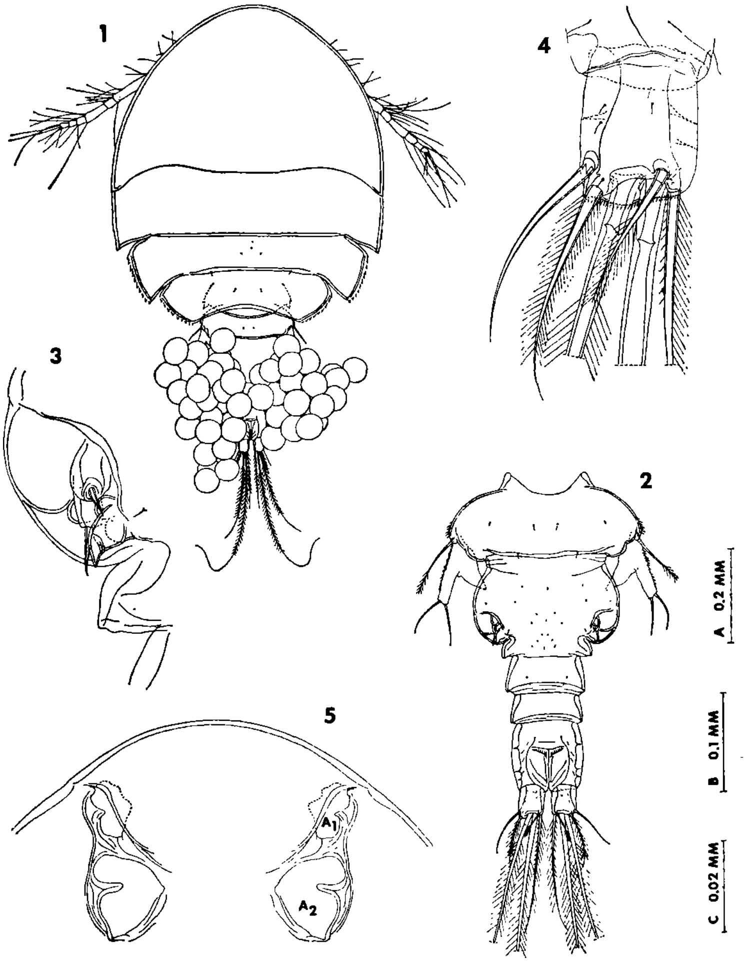
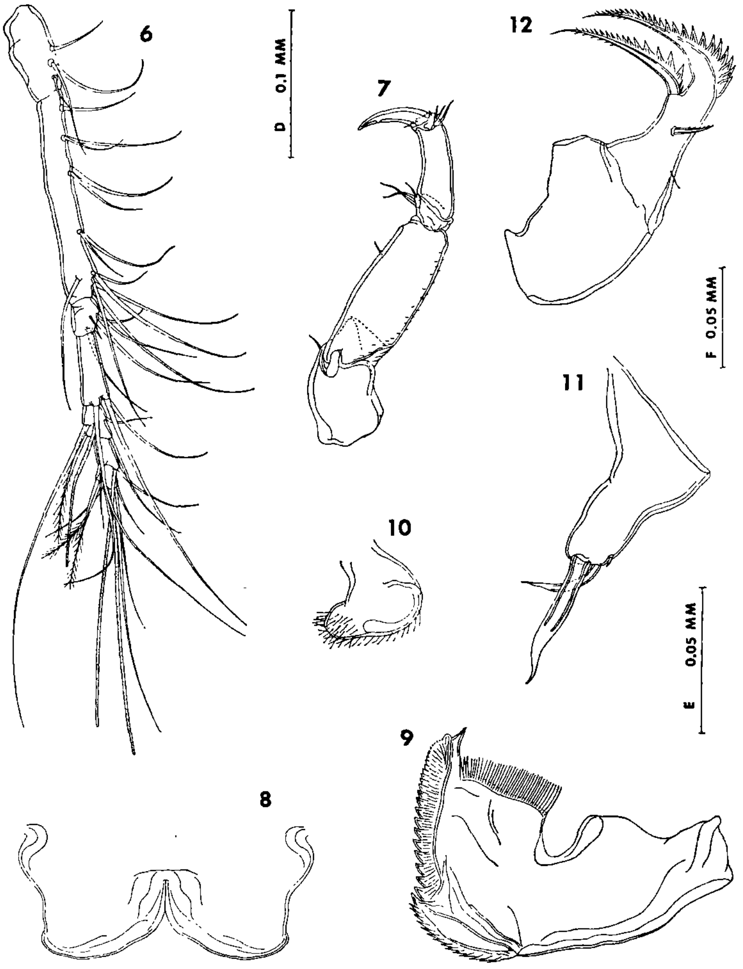
[1] The year of publication of Thorell's genus has been cited by some authors as 1859, by others as 1860. The source of this confusion lies in the fact that Thorell published *Lichomolgus* as a new generic name in two different papers (1859, p. 340, and 1860, p. 64). Although the title page of Arg. 16 of the Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar for 1859 bears the year 1860, the actual year of publication for *Lichomolgus* appears to be 1859, since the last page of no. 8 (in which Thorell's paper appears) bears that year.



FIGS. 1–5. *Lichomolgus dentipes* Thompson and A. Scott, 1903, female: 1, body, dorsal (A); 2, urosome, dorsal (B); 3, area of attachment of egg sac, dorsal (C); 4, caudal ramus, dorsal (C); 5, rostral area, ventral (B).

sions being 33 μ × 26 μ. Outer lateral seta 50 μ, pedicellate dorsal seta 40 μ, outermost distal seta 55 μ, innermost distal seta 109 μ, and the two long median terminal setae 220 μ (outer) and 360 μ (inner) and both inserted between dorsal (unornamented) and ventral (with marginal row of spinules) flaps. All these setae with lateral hairs except outer lateral seta which is naked.



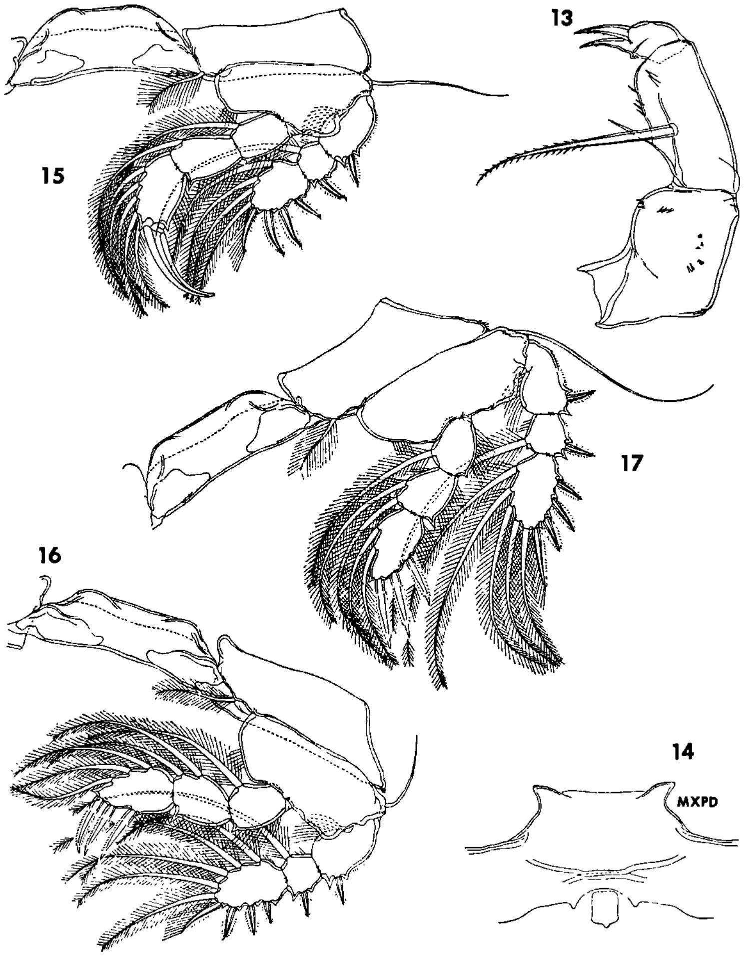
Figs. 6–12. *Lichomolgus dentipes* Thompson and A. Scott, 1903, female: 6, first antenna, ventral (D); 7, second antenna, anterior (inner) (D); 8, labrum, ventral (E); 9, mandible, posterior (C); 10, paragnath, ventral (C); 11, first maxilla, posterior (C); 12, second maxilla, posterior (E).

Ratio of length of prosome to that of urosome 2.24 : 1.

Egg sacs incomplete on females examined. Each egg about 55 μ in diameter.

Rostral area (fig. 5) without well defined posterior margin.

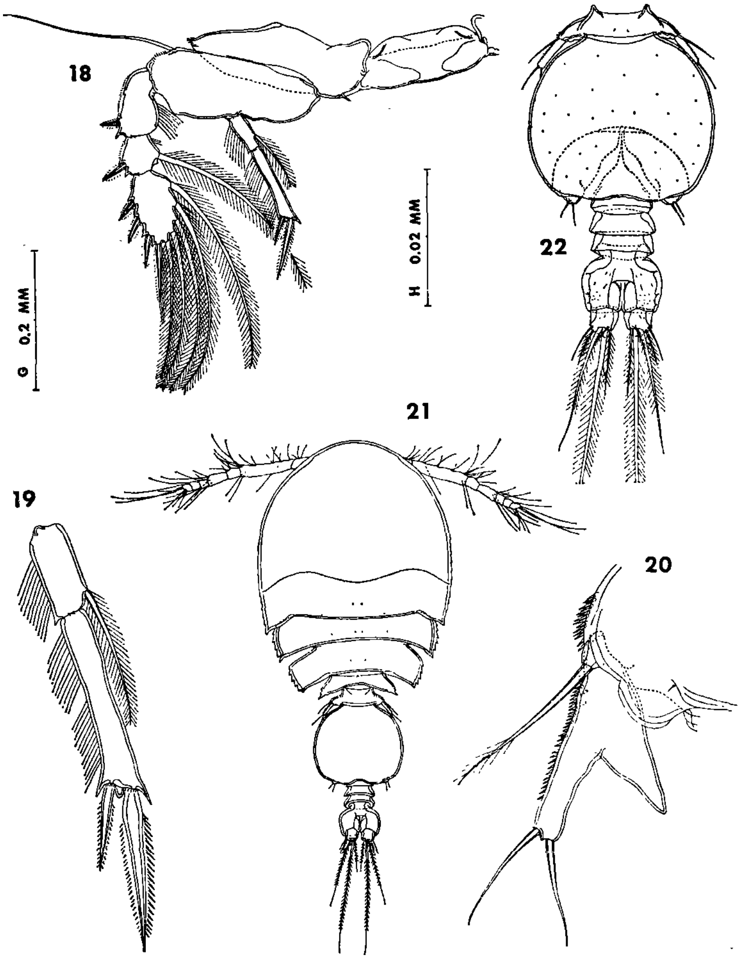
First antenna (fig. 6) 7-segmented, 326 μ long. Lengths of segments:



FIGS. 13–17. *Lichomolgus dentipes* Thompson and A. Scott, 1903, female: 13, maxilliped, posterior (E); 14, area between maxillipeds and first pair of legs, ventral (D); 15, leg 1 and intercoxal plate, anterior (F); 16, leg 2 and intercoxal plate, anterior (F); 17, leg 3 and intercoxal plate, anterior (F).

30 μ (58 μ along anterior margin), 138 μ, 21 μ, 50 μ, 23 μ, 19 μ, and 17 μ respectively. Formula for armature: 4, 13, 6, 3, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete.

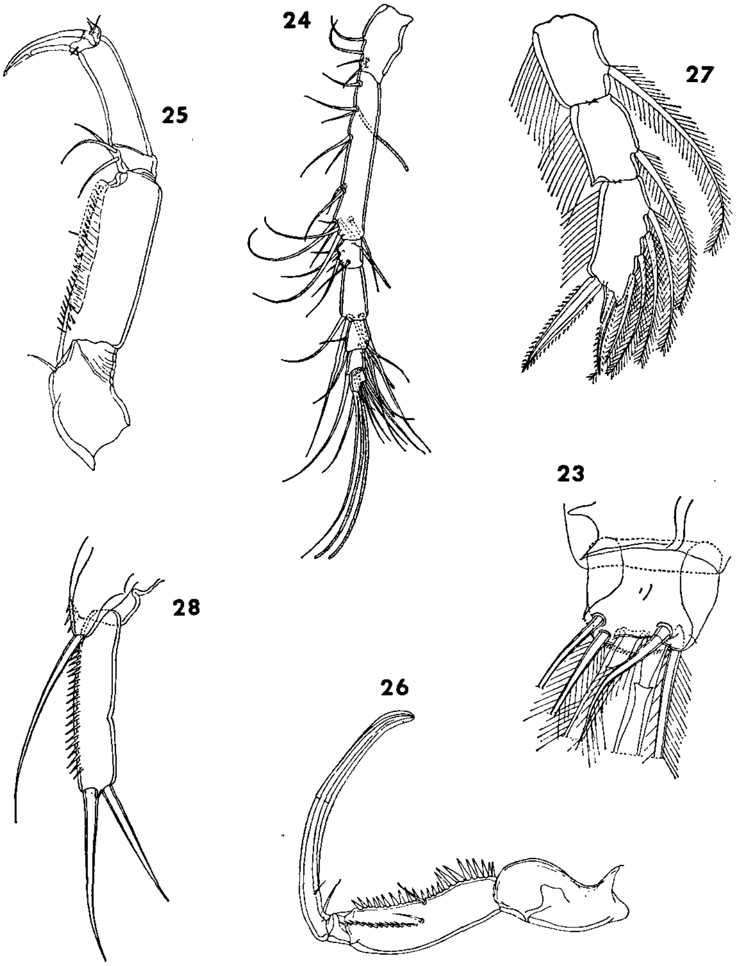
Second antenna (fig. 7) 4-segmented, last segment moderately elongated, 71 μ along its outer edge, 40 μ along its inner edge, bearing



FIGS. 18–22. *Lichomolgus dentipes* Thompson and A. Scott, 1903, female: 18, leg 4 and intercoxal plate, anterior (F); 19, endopod of leg 4, anterior (C); 20, leg 5, dorsal (E). Male: 21, body, dorsal (G); 22, urosome, dorsal (D).

distally five small hyaline elements and a single claw 44 μ along its greatest axis.

Labrum (fig. 8) with two broad posteroventral lobes. Mandible (fig. 9) with flagellum very reduced, and represented only by a small pointed process. Paragnath (fig. 10) a small hairy lobe. First maxilla



Figs. 23–28. *Lichomolgus dentipes* Thompson and A. Scott, 1903, male: 23, caudal ramus, dorsal (H); 24, first antenna, dorsal (F); 25, second antenna, posterior (outer) (E); 26, maxilliped, outer (F); 27, endopod of leg 1, anterior (C); 28, leg 5, dorsal (H).

(fig. 11) with two long unequal naked terminal elements and a small subterminal one. Second maxilla (fig. 12) 2-segmented. Maxilliped (fig. 13) 3-segmented, the second segment with two very unequal setae, and the third with two terminal spiniform elements (one lacking a distinct articulation) and a small seta. Area between maxillipeds and first pair of legs (fig. 14) not protuberant.

Legs 1–4 (figs. 15–18) with trimerous rami except for 2-segmented endopod of leg 4. Armature of legs as follows (Roman numerals = spines, Arabic numerals = setae):

P_1	protopod	0–1	1–0	exp	I–0	I–1	III,I,4
				end	0–1	0–1	I,5
P_2	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,II,3
P_3	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,II,2
P_4	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	II	

Inner seta on coxa of leg 4 very short (6 μ), blunt, and naked. Outer seta on basis of legs 3 and 4 unusually long (up to 90 μ). Terminal spine on last segment of endopod of leg 1 a little longer than the segment, naked, and recurved. Endopod of leg 4 (fig. 19) slender, first segment 22 μ × 9 μ, with inner distal seta 33 μ, second segment 47 μ long (including processes) and 7 μ wide at middle, with the two terminal spines 18 μ (outer) and 36 μ (inner). Hairs along outer margin of second segment arranged in two rows.

Leg 5 (fig. 20) with free segment 74 μ long, its proximal area extended obliquely and inwardly to form a very large toothlike process. Oblique length from outer base of segment to tip of process 67 μ. Two terminal naked setae 34 μ and 37 μ. Row of spinules along outer edge of segment.

Leg 6 probably represented by the two spiniform setae near areas of attachment of each egg sac (see fig. 3).

Color in life in transmitted light translucid, eye red, egg sacs light gray.

Male: Body (fig. 21) with prosome less broadened than in the female. Length 0.58 mm (0.56–0.60 mm) and greatest width 0.28 mm (0.26–0.30 mm), based on 10 specimens. Ratio of length to width of prosome 1.27 : 1.

Segment of leg 5 (fig. 22) 21 μ × 81 μ. Genital segment rounded in dorsal view, 122 μ × 133 μ, with a small constricted area posteriorly. First postgenital segment 15 μ × 46 μ, second 14 μ × 41 μ. Third and fourth postgenital segments fused, third probably represented by the anterior constricted part, 11 μ × 35 μ, and fourth being the much broadened posterior region, 39 μ × 55 μ.

Caudal ramus (fig. 23) about as long as wide, 17 μ × 19 μ.

Ratio of length of prosome to that of urosome 1.6 : 1.

Rostral area like that of female. First antenna (fig. 24) similar to that of female, but two aesthetes added on second segment, and one on third, so that the formula is 4, 13 + 2 aesthetes, 6, 3 + 1 aesthete, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. Second antenna (fig. 25) resembling that of female, but inner surface of second segment with a row of spinules and a raised membranous lamella.

Labrum, mandible, paragnath, first maxilla, and second maxilla like those of female. Maxilliped (fig. 26) slender and 4-segmented (assuming that the proximal part of claw represents a fourth segment). Claw 124 μ long (measured along its axis). Area between maxillipeds and first pair of legs like that in female.

Legs 1–4 segmented as in female and with same spine and setal formula except for endopod of leg 1 (fig. 27), which has arrangement of 0–1; 0–1; I,I,4. Last segment of endopod of leg 1 bearing two terminal barbed spines, with a slender process between them. Endopod of leg 4 as in female.

Leg 5 (fig. 28) with a slender free segment 27 μ × 6 μ, lacking the large toothlike process seen in the female. Two terminal setae 24 μ and 22 μ.

Leg 6 (see fig. 22) a posterolateral flap on ventral surface of genital segment bearing two naked setae 17 μ and 22 μ long.

Spermatophore not observed.

Color in life like that of female.

Remarks: The brief original description of the female of *L. dentipes* by Thompson and A. Scott (1903, p. 281, pl. XVI, figs. 27–30), based on one female, fits almost exactly the specimens from *Sinularia*. Although it is impossible to compare them with the single Ceylonese female (which no longer exists), the specimens from Madagascar appear to be identical with *L. dentipes*. Probably Thompson and A. Scott's specimen, obtained in washings of dredged invertebrates, actually came from an octocoral, perhaps even *Sinularia*.

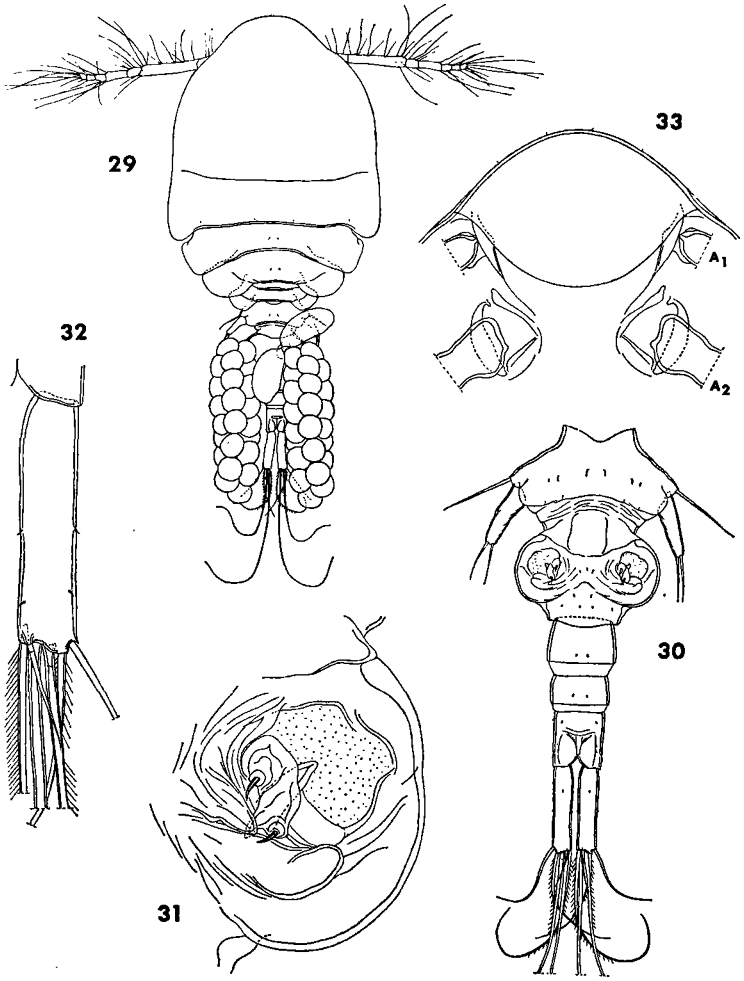
Lichomolgus cristatus new species

Figures 29–50

Type material: 57 ♀ ♀ and 10 copepodids from one colony of *Sinularia leptoclados* (Ehrenberg), in 1 m, west of Pte. Mahatsinjo, Nosy Bé, Madagascar, collected 2 November 1960. Holotype and 45 paratypes deposited in the United States National Museum and the remaining paratypes in the collection of A. G. Humes.

Female: Body (fig. 29) with moderately broadened prosome, the sides of the cephalosome more or less parallel instead of rounded. Length 1.00 mm (0.95–1.10 mm) and greatest width 0.48 mm (0.45–0.50 mm), based on 10 specimens. Ratio of length to width of prosome 1.37 : 1. Segment of leg 1 separated dorsally from head by a transverse furrow. Epimeral areas of segments of legs 1–4 rounded posteriorly as in figure.

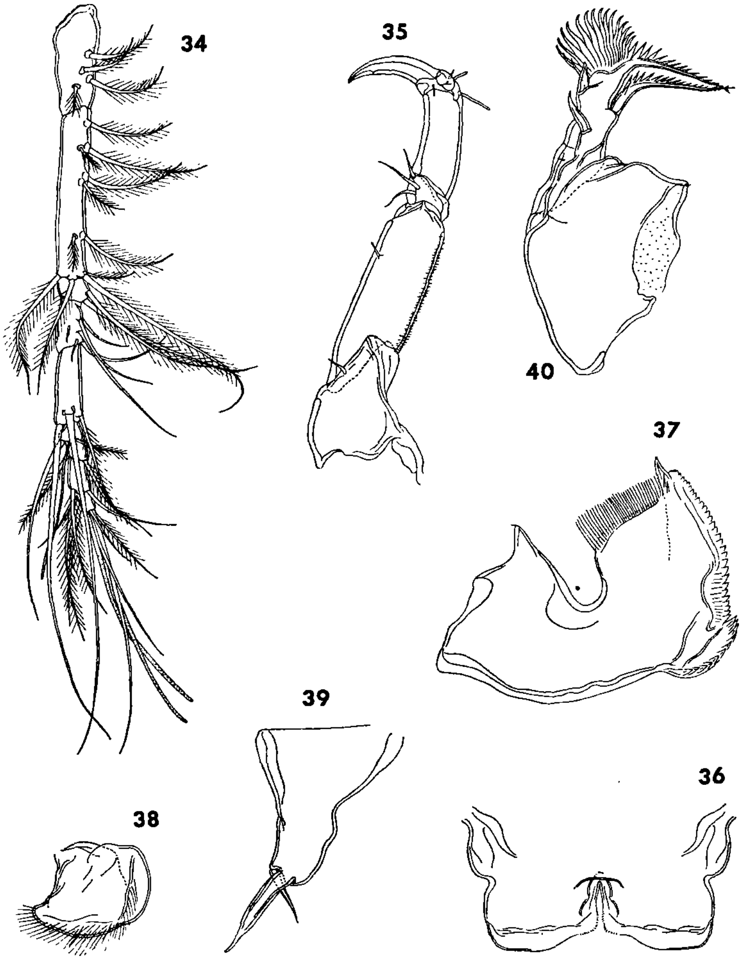
Segment of leg 5 (fig. 30) 96 μ × 166 μ. Ventrally between this segment and genital segment a weak intersegmental sclerite. Genital segment shorter than wide, 94 μ × 146 μ, in dorsal view rounded on either side and constricted posteriorly. Areas of attachment of egg sacs situated dorsally in midregion of segment. Each area (fig. 31) bearing two small naked setae 6 μ long. Three postgenital segments



FIGS. 29–33. *Lichomolgus cristatus*, new species, female: 29, body, dorsal (A); 30, urosome, dorsal (B); 31, area of attachment of egg sac, dorsal (C); 32, caudal ramus, dorsal (E); 33, rostral area, ventral (B).

57 μ × 70 μ, 36 μ × 60 μ, and 60 μ × 50 μ, from anterior to posterior.

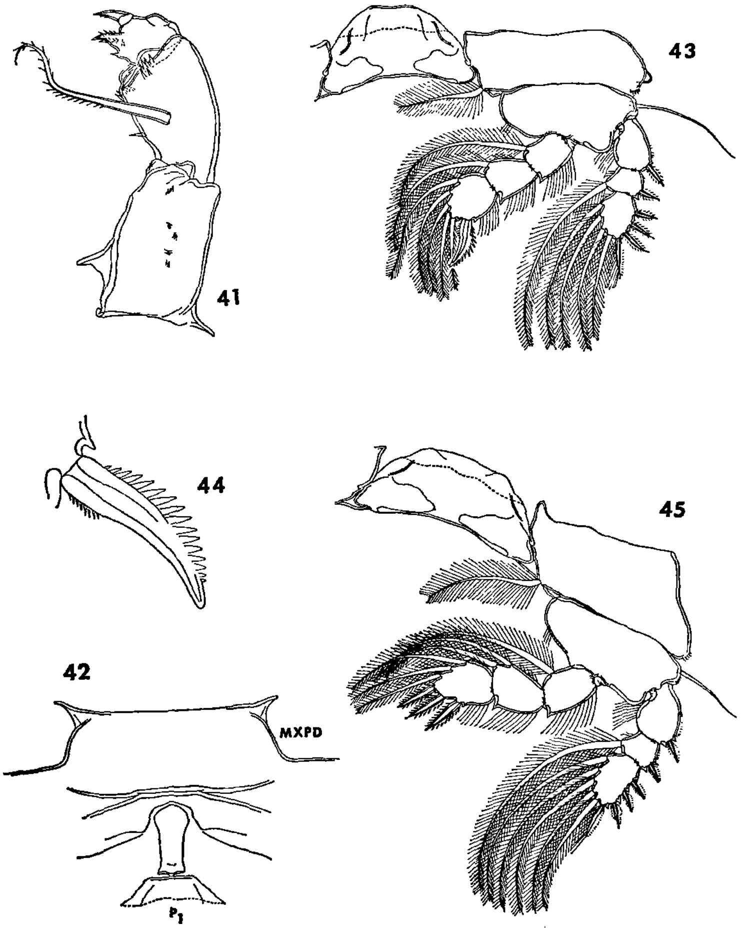
Caudal ramus (fig. 32) about 4.5 times longer than wide, its greatest dimensions being 89 μ × 20 μ. Outer lateral seta 80 μ long and naked, pedicellate dorsal seta 38 μ and naked, outermost distal seta 112 μ with lateral hairs proximally, innermost distal seta 156 μ with hairs along inner margin, and the two long median terminal setae 325 μ (outer)



FIGS. 34–40. *Lichomolgus cristatus,* new species, female: 34, first antenna, anteroventral (D); 35, second antenna, posterior (outer) (F); 36, labrum, ventral (E); 37, mandible, posterior (C); 38, paragnath, ventral (C); 39, first maxilla, posterior (C); 40, second maxilla, posterior (E).

with a few spinules on outer margin and 400 μ (inner) without spinules. A few surficial spinules on ramus.

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 1.7 : 1.

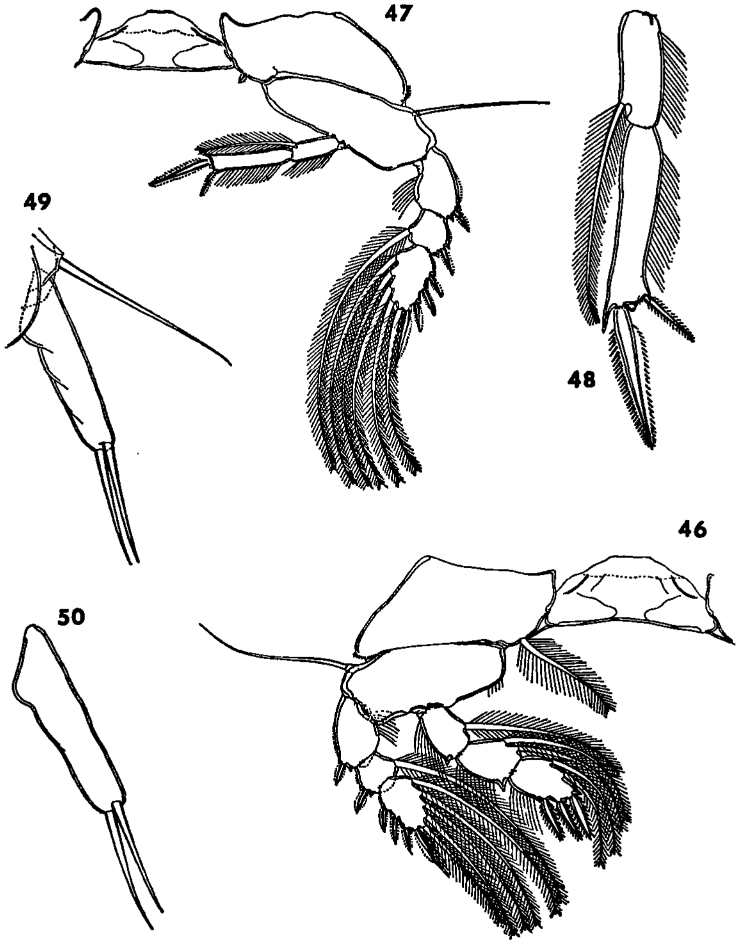


FIGS. 41–45. *Lichomolgus cristatus*, new species, female: 41, maxilliped, posterior (E); 42, area between maxillipeds and first pair of legs, ventral (F); 43, leg 1 and intercoxal plate, anterior (F); 44, spine on last segment of endopod of leg 1, anterior (H); 45, leg 2 and intercoxal plate, anterior (F).

Egg sac (fig. 29) elongated, 380 μ × 100 μ, reaching beyond caudal rami, with each egg about 50 μ in diameter.

Rostral area (fig. 33) with an extremely delicate broadly rounded posteroventral margin.

First antenna (fig. 34) 7-segmented, 342 μ in length. Lengths of segments: 55 μ (68 μ along anterior margin), 130 μ, 33 μ, 47 μ, 25 μ,



FIGS. 46–50. *Lichomolgus cristatus*, new species, female: 46, leg 3 and intercoxal plate, anterior (F); 47, leg 4 and intercoxal plate, anterior (F); 48, endopod of leg 4, anterior (C); 49, leg 5, dorsal (E); 50, free segment of leg 5, dorsal (E).

21 μ, and 18 μ respectively. Formula for armature as in *L. dentipes*. Many setae haired as in figure.

Second antenna (fig. 35) 4-segmented, with last segment moderately elongated, 70 μ along its outer edge, 42 μ along its inner edge, and 19 μ wide at middle. First segment with a small inner seta, second with a similar seta and outer surficial spinules, third with three setae, and fourth with six elements: five small hyaline elements and a terminal recurved claw 46 μ along its greatest axis. All setae naked.

Labrum (fig. 36) with two broad and rather truncated posteroventral lobes.

Mandible (fig. 37) with very reduced flagellum and resembling closely that of *L. dentipes.* Paragnath (fig. 38) a small hairy lobe. First maxilla (fig. 39) 1-segmented, with two unequal terminal elements. Second maxilla (fig. 40) 2-segmented, large first segment unarmed, second segment with a very small setule near its proximal outer margin, a naked seta on its posterior surface, an outer distal spine as long as the lash and prominently barbed along one edge, and the segment produced distally to form a lash bearing along its inner edge a proximal spine, followed by a row of unusually long rather hyaline setae, and then a graduated row of smaller spinules. Maxilliped (fig. 41) 3-segmented, first segment with a few small spinules, second with a few spinules and two very unequal setae (the short seta naked, the long one with barbules distally), and third with two terminal spiniform barbed elements (the inner one without a distinct articulation) and a minute setiform process.

Area between maxillipeds and first pair of legs (fig. 42) not protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 43, 45–47) segmented as in *L. dentipes,* and having same spine and setal formula. Inner seta on coxa of legs 1–3 long and plumose, but in leg 4 very short (8 μ) and finely barbed. Inner margin of basis in legs 1–3 with row of hairs, but this margin naked in leg 4. Outer seta on basis unusually long in legs 3 and 4. Spine on last segment of endopod of leg 1 (fig. 44) somewhat recurved with prominent spinules on outer margin and a proximal fringe of much smaller spinules on inner margin. Endopod of leg 4 (fig. 48) slender, first segment 25 μ × 9 μ with its inner distal feathered seta 45 μ, second segment 48 μ long (including processes) and 8.5 μ wide at middle, its two terminal unequal barbed spines being 15 μ (outer) and 34 μ (inner), the latter more strongly barbed along inner side than outer side. Row of long hairs along outer margins of both segments.

Leg 5 (fig. 49) with elongated free segment, 68 μ long, 17 μ wide at the slight proximal inner expansion (fig. 50), 12 μ wide at midregion. Two terminal naked setae 40 μ and 42 μ. Naked seta on body near insertion of free segment 60 μ.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 31).

Color in life in transmitted light translucid, eye red, egg sacs gray.

Male: Unknown.

Etymology: The specific name *cristatus,* from Latin = crested, refers to the crest of unusually long setae on the proximal part of the terminal lash of the second maxilla.

Comparison with related species: The crest of long setae on the terminal lash of the second maxilla sets this species apart from all other known species in the genus. In some respects *L. cristatus* resembles *L. dentipes*, for example, the second antenna, labrum, mandible, maxilliped, and endopod of leg 4.

Since the male of *L. cristatus* is unknown, comparisons with *L. aegyptius* Gurney, 1927, and *L. vagans* Gurney, 1927, of which only males are known, cannot be made directly. In *L. aegyptius*, however, the male has three claws and two setae on the end of the second antenna, the caudal ramus is very short (nearly as broad as long), and the slender mandible has a long flagellum. In *L. vagans* the male has two claws on the second antenna, the caudal ramus is only a little longer than wide, and the formula for the third segment of the exopod of leg 4 is II,I,5. It would appear very unlikely, therefore, that the new species could be the same as either of Gurney's species.

Lichomolgus adelphus new species
Figures 51–66

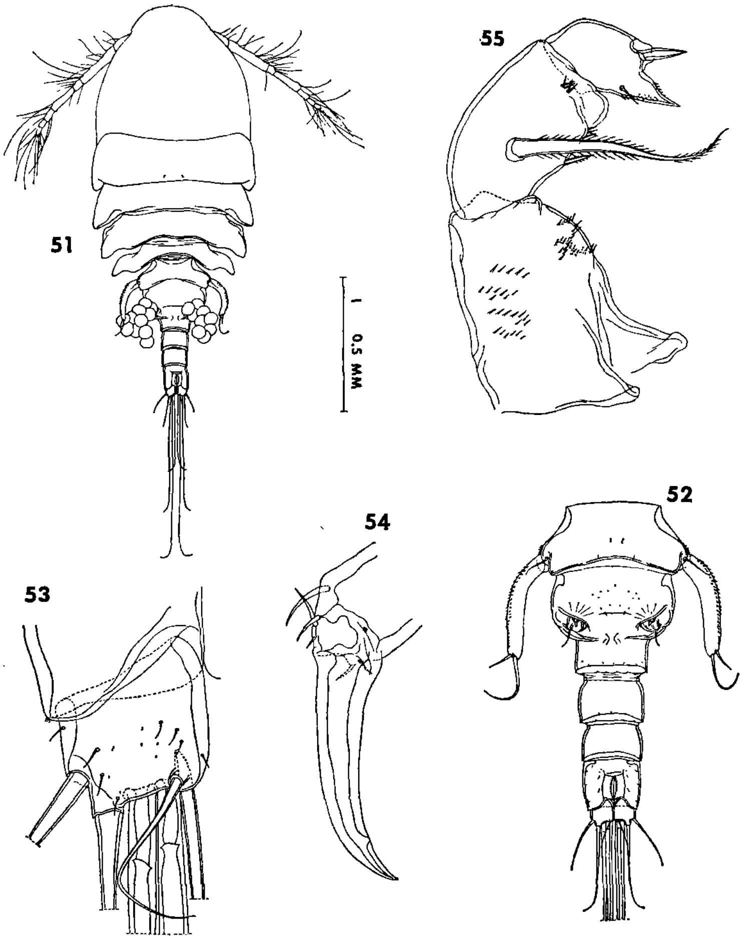
Type material: 51♀♀, 34♂♂, and 11 copepodids from one colony of *Sinularia whiteleggei* Lüttschwager, in 2 m, Antsamantsara, northwest of Madirokely, Nosy Bé, Madagascar, collected 31 October 1960. Holotype ♀, allotype, and 62 paratypes (37♀♀, 25♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Other material: 5♀♀, 11♂♂, and 4 copepodids from one colony of *Sinularia pedunculata* Tixier-Durivault, in 3 m, Pte. Ambarionaomby, Nosy Komba, near Nosy Bé, 3 October 1960; and 10♀♀, 9♂♂, and 4 copepodids from one colony of *Sinularia polydactyla* (Ehrenberg), in 15 m, Tany Kely, a small island south of Nosy Bé, 30 August 1964.

Female: Body (fig. 51) resembling that of *L. squamiger* Humes and Frost, 1964. Length 1.29 mm (1.26–1.37 mm) and greatest width 0.55 mm (0.51–0.59 mm), based on 10 specimens. Ratio of length to width of prosome 1.58 : 1. Epimeral areas of segments of legs 1–4 somewhat more angulate posteriorly than in *L. squamiger.*

Segment of leg 5 (fig. 52) 101 $\mu \times 229\ \mu$. Ventrally between this segment and genital segment no intersegmental sclerite. Genital segment 153 μ long, in dorsal view expanded in anterior part (width 187 μ) and constricted with parallel sides posteriorly (width 109 μ). Areas of attachment of egg sacs situated dorsolaterally near middle of segment. Each area with two very unequal naked elements, as in *L. squamiger.* Three postgenital segments 73 $\mu \times 99\ \mu$, 57 $\mu \times 91\ \mu$, and 78 $\mu \times 88\ \mu$, from anterior to posterior.

Caudal ramus (fig. 53) about as long as wide, 35 $\mu \times 23\ \mu$ in greatest dimensions. Outer lateral seta 77 μ, pedicellate dorsal seta 50 μ, outer most distal seta 121 μ, innermost distal seta 300 μ, and the two long median terminal setae 470 μ (outer) and 685 μ (inner), both inserted between slight unornamented dorsal and ventral flaps. All



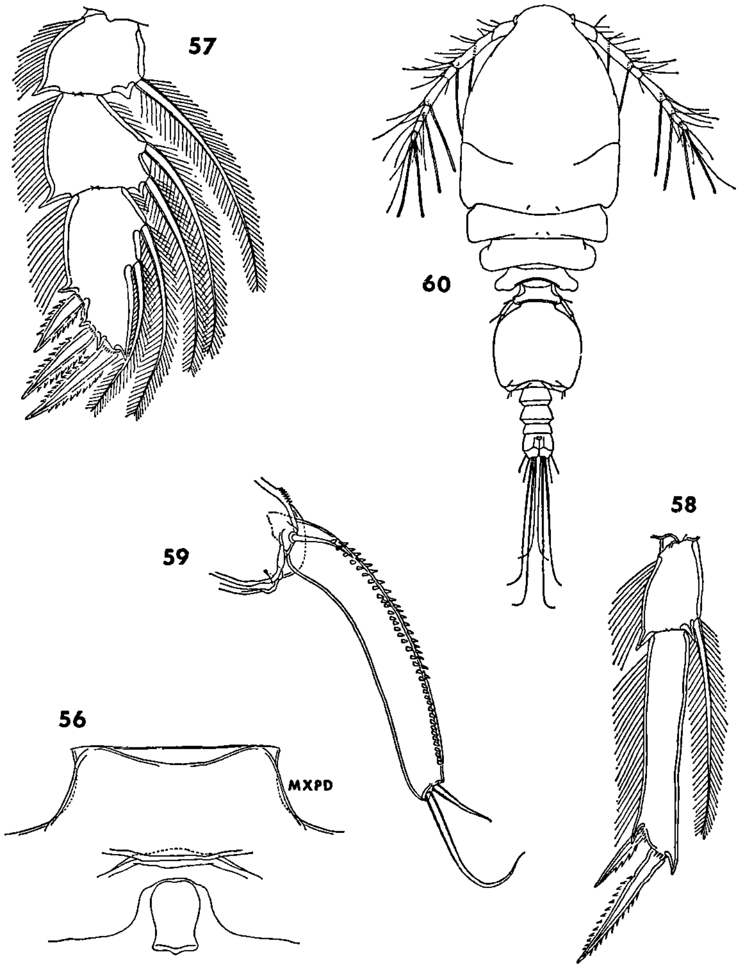
FIGS. 51–55. *Lichomolgus adelphus*, new species, female: 51, body, dorsal (I); 52, urosome, dorsal (G); 53, caudal ramus, dorsal (C); 54, tip of second antenna, anterior (inner) (C); 55, maxilliped, postero-inner (E).

setae naked. A few surficial small setules and refractile points on ramus.

Dorsal surface of prosome and urosome with a few short hairs. Ratio of length of prosome to that of urosome 1.85 : 1.

Form of egg sac unknown, since all ovigerous females collected had broken sacs. Each egg about 52 μ in diameter.

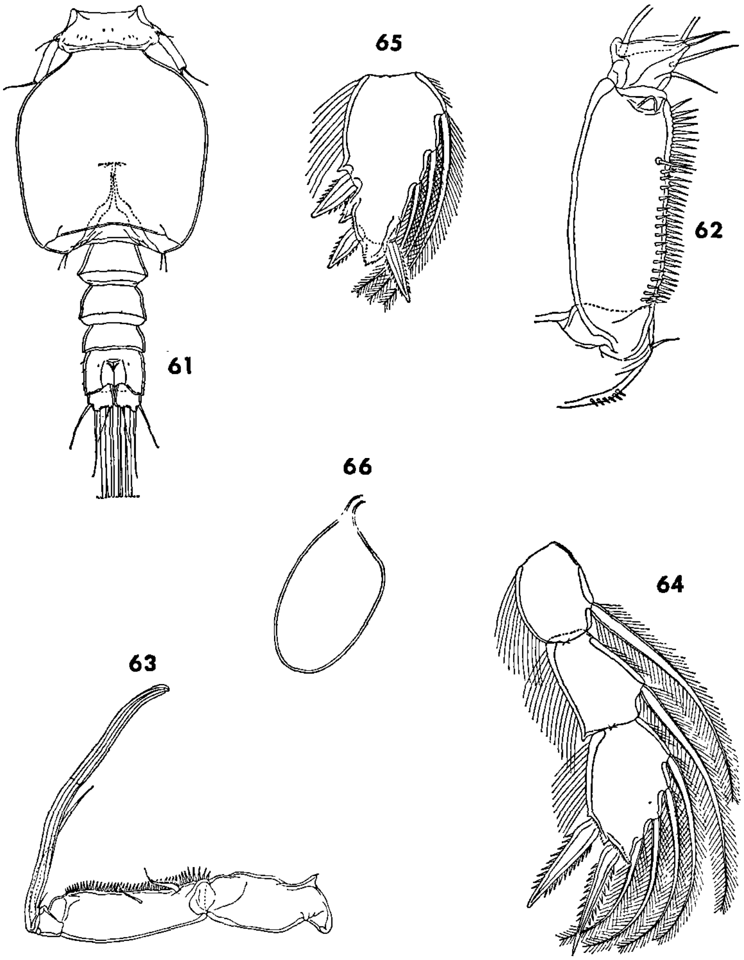
Rostral area as in *L. squamiger*.



FIGS. 56–60. *Lichomolgus adelphus*, new species, female: 56, area between maxillipeds and first pair of legs, ventral (D); 57, endopod of leg 3, anterior (F); 58, endopod of leg 4, anterior (F); 59, leg 5, dorsal (F). Male: 60, body, dorsal (A).

First antenna similar to that of *L. squamiger*. Lengths of segments: 55 μ (88 μ along anterior edge), 143 μ, 44 μ, 104 μ, 47 μ, 36 μ, and 31 μ respectively. Formula for armature as in *L. squamiger* (and also like *L. dentipes*, given above).

Second antenna resembling that of *L. squamiger*, but inner distal edge of first segment a little more swollen. Fourth segment 104 μ along



FIGS. 61–66. *Lichomolgus adelphus*, new species, male: 61, urosome, dorsal (B); 62, second segment of second antenna, anterior (inner) (E); 63, maxilliped, outer (B); 64, endopod of leg 1, anterior (E); 65, last segment of endopod of leg 2, anterior (E); 66, spermatophore, empty and attached to female, dorsal (B).

outer side, 66 μ along inner side, and 21 μ wide; bearing distally six small hyaline elements (as in *L. squamiger*, though only three such elements indicated in Humes and Frost's figure 174) and a terminal claw 52 μ long (fig. 54).

Labrum, mandible, paragnath, first maxilla, and second maxilla as in *L. squamiger*. Maxilliped (fig. 55) closely resembling that of *L. squamiger* with only minor differences in ornamentation and with third segment bearing in addition to the two large terminal elements a small seta (present also in *L. squamiger*, but not shown in Humes and Frost's figure 180).

Area between maxillipeds and first pair of legs (fig. 56) slightly protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 segmented as in *L. squamiger* and with the same spine and setal formula (also same as in *L. dentipes*, given above). Legs 1 and 2 like those of *L. squamiger*. Leg 3 with exopod like that of *L. squamiger*, but last segment of endopod (fig. 57) relatively shorter and of a slightly different form than in that species. Leg 4 also with exopod similar to that of *L. squamiger*; endopod (fig. 58) with first segment 47 μ long (not including processes) and 30 μ wide, with inner distal seta 107 μ, second segment 125 μ long (including processes), 19 μ wide at midregion, with only two terminal spiniform processes instead of three as in *L. squamiger*. Two terminal spines of endopod 40 μ (outer) and 69 μ (inner).

Leg 5 (fig. 59) with free segment elongated, slender, and bowed, 195 μ × 26 μ, distinctly longer and more slender than in *L. squamiger*. Convex surface with two rows of scalelike spines along proximal half merging to a single row in distal half. Two terminal naked setae 36 μ (outer) and 73 μ (inner). Seta on body near insertion of free segment 39 μ and naked.

Leg 6 as in *L. squamiger*.

Color in life in transmitted light translucid, with orange globules in prosome, eye red.

Male: Body (fig. 60) resembling that of *L. squamiger*. Length 0.98 mm (0.95–0.99 mm) and greatest width 0.34 mm (0.33–0.35 mm), based on 10 specimens. Ratio of length to width of prosome 1.77 : 1.

Segment of leg 5 (fig. 61) 52 μ × 112 μ. No ventral intersegmental sclerite. Genital segment a little longer than wide, 200 μ × 185 μ, similar in form to that of *L. squamiger*. Four postgenital segments 36 μ × 71 μ, 39 μ × 70 μ, 27 μ × 62 μ, and 36 μ × 60 μ, from anterior to posterior.

Caudal ramus similar to that of female, but a little wider than long, 22 μ × 26 μ.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 1.58 : 1.

Rostral area as in *L. squamiger*, with two lateral anterior processes more prominent than in female, as in that species.

First antenna like that of *L. squamiger*, with same formula for armature (also same as for *L. dentipes*, given above). Second antenna as in *L. squamiger*, but lacking the obtuse spines seen in that species and having two rows of slender spines along inner surface of second segment (fig. 62).

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 63) very long and slender (about 600 μ including claw when extended). Second segment with a single inner row of spines; two inner setae as in *L. squamiger*, the proximal one with a fringe of spinules along its proximal edge as in that species. Claw 297 μ along its axis, longer than in *L. squamiger.* Area between maxillipeds and first pair of legs as in *L. squamiger.*

Legs 1–4 segmented as in female, and the spine and setal formula as in that sex except for last segment of endopod of leg 1 (fig. 64) which is I,I,4 (as in *L. squamiger*). Sexual dimorphism also in last segment of endopod of leg 2 (fig. 65), where spines and spiniform processes are very different from those of *L. squamiger.* Legs 3 and 4 resembling those of *L. squamiger.*

Leg 5 (see fig. 61) similar to that of *L. squamiger,* free segment being $50\ \mu \times 9\ \mu$. Leg 6 as in *L. squamiger.*

Spermatophore (fig. 66), attached to female and empty, $151\ \mu \times 86\ \mu$, not including neck.

Color in life as in female.

Etymology: The specific name *adelphus*, from Greek ἀδελφός = sisterly or brotherly, alludes to the close relationship of this species to *L. squamiger.*

Comparison with related species: Like *L. squamiger*, the new species is close to *L. spinipes* (Sewell, 1949), known only from a single female (now lost) found in weed-washings in the Nicobar Islands. However, like *L. squamiger*, *L. adelphus* is distinct from *L. spinipes.* The distinctions are largely the same as those mentioned by Humes and Frost (1964, pp. 147–148) in comparing *L. squamiger* with *L. spinipes.*

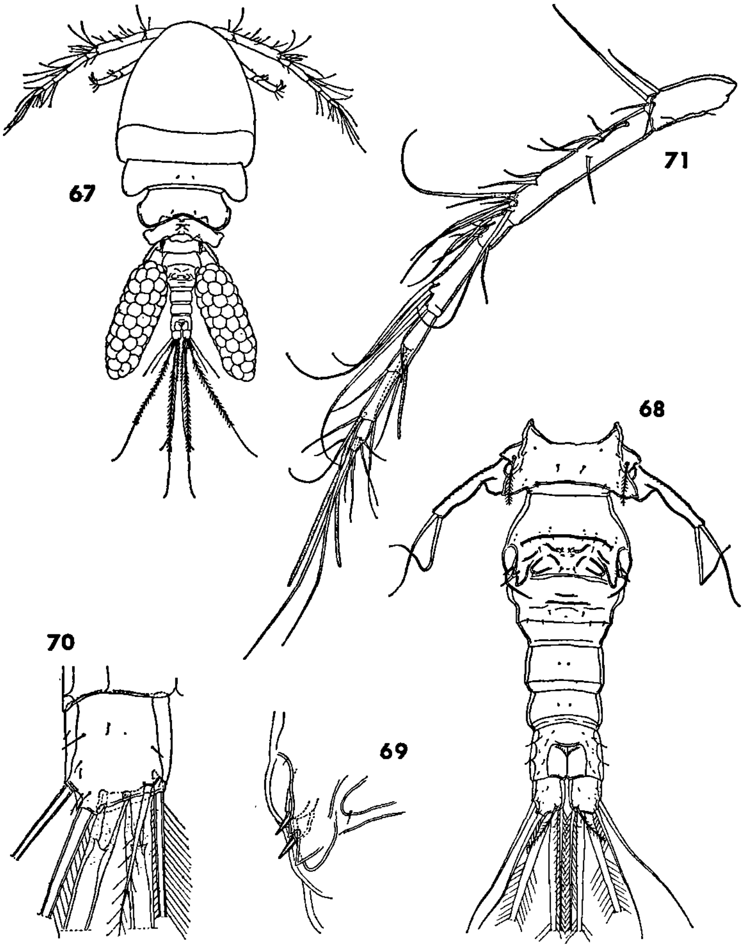
Several characters may be used to distinguish *L. adelphus* from *L. squamiger:* the form of the last segment of the endopod of leg 3 in the female, the presence of only two terminal spiniform processes on the endopod of leg 4 in both sexes, the more elongated slender bowed free segment of leg 5 in the female, the absence of obtuse spines on the second antenna of the male, and the sexual dimorphism in the last segment of the endopod of leg 2 in the male.

Lichomolgus foxi Gurney, 1927

Figures 67–88

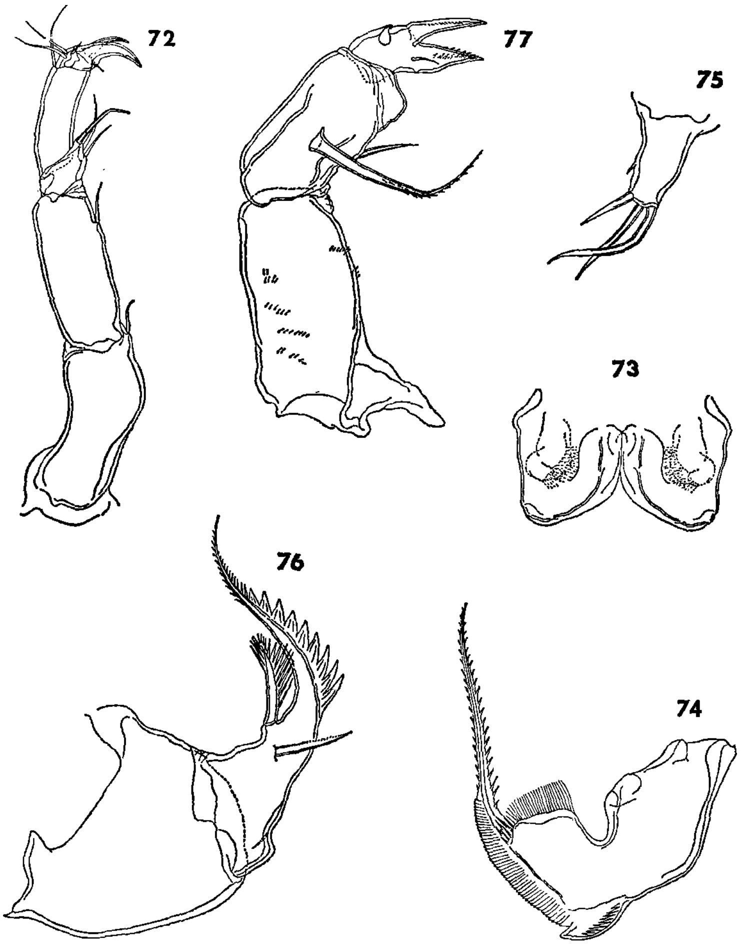
Gurney described this species on the basis of one female taken at Port Taufiq in the Suez Canal. This specimen was supposed to have been deposited in the British Museum (Natural History), but upon examination of the vial in the museum's collection labeled "*Lichomolgus foxi* n. sp." we have found only a fragment of an unknown lichomolgid and a specimen of *Corycaeus.* Thus the type specimen appears to have been misplaced or lost. The male has been unknown until now.

In Madagascar the first author collected specimens referable to *L. foxi* as follows: 196 ♀♀, 212 ♂♂, and 74 copepodids from several colonies



FIGS. 67–71. *Lichomolgus foxi* Gurney, 1927, female: 67, body, dorsal (I); 68, urosome, dorsal (B); 69, area of attachment of egg sac, dorsal (E); 70, caudal ramus, dorsal (E); 71, first antenna, dorsal (B).

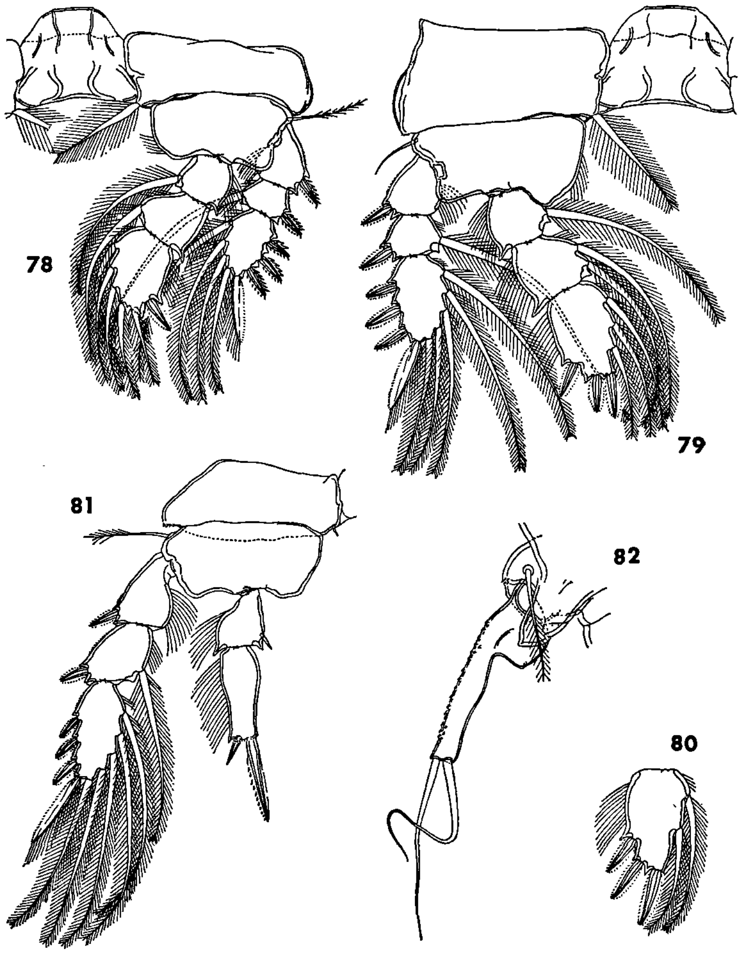
of *Cladiella krempfi* Hickson, in 1 m, west of Pte. de Tafondro, Nosy Bé, 5 December 1963 (specimens deposited in the United States National Museum, the Zoölogisch Museum, Amsterdam, and the British Museum (Natural History)); 25♀♀, 19♂♂, and 7 copepodids from one colony of *Cladiella laciniosa* (Tixier-Durivault), in 1 m, Nosy Kisimany, a small island 27 km southwest of Nosy Bé near the mainland of Madagascar, 4 October 1960 (specimens in the U.S.N.M.); and 20♀♀



FIGS. 72–77. *Lichomolgus foxi*, Gurney, 1927, female: 72, second antenna, anterior (inner) (D); 73, labrum, with paragnaths in dashed lines, ventral (F); 74, mandible, posterior (E); 75, first maxilla, anterior (E); 76, second maxilla, posterior (E); 77, maxilliped, posterior (E).

and 9 ♂ ♂ from one colony of *Cladiella pachyclados* (Klunzinger), in 1 m, Ambariotelo, a small island almost between Nosy Bé and Nosy Komba, 15 May 1964 (specimens in the U.S.N.M.).

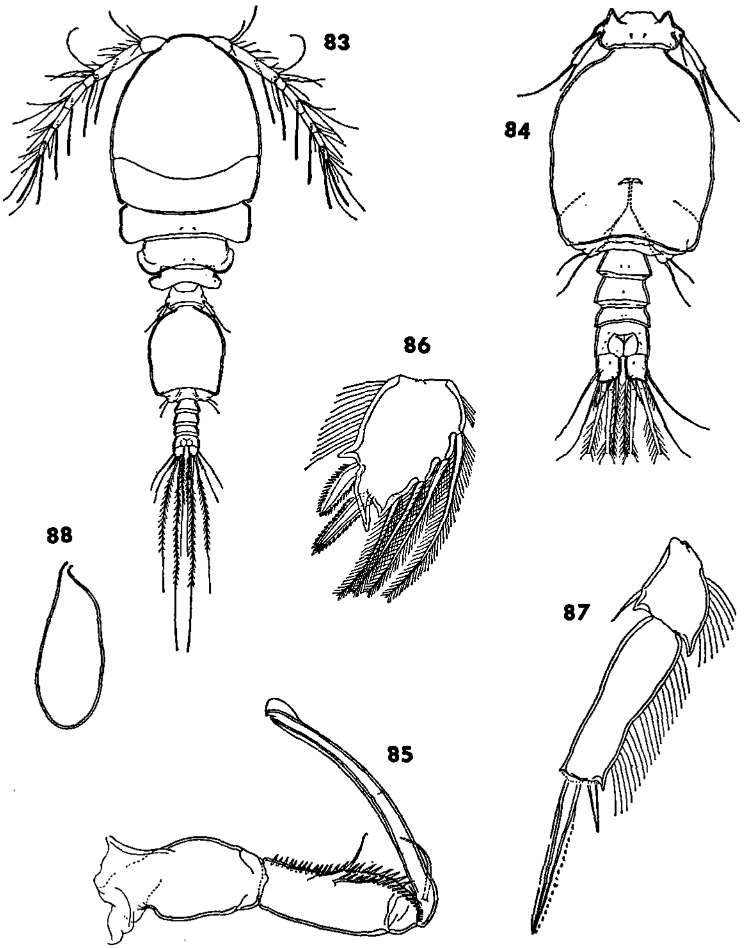
Female: Body (fig. 67) with slender prosome. Length 1.16 mm (1.04–1.27 mm) and greatest width 0.51 mm (0.49–0.54 mm), based on 10 specimens. Ratio of length to width of prosome 1.57 : 1. Segment



FIGS. 78–82. *Lichomolgus foxi* Gurney, 1927, female: 78, leg 1 and intercoxal plate, anterior (D); 79, leg 2 and intercoxal plate, anterior (D); 80, last segment of endopod of leg 3, anterior (D); 81, leg 4, anterior (D); 82, leg 5, dorsal (F).

of leg 1 separated dorsally and laterally from head by a transverse furrow. Epimeral areas of segments of legs 1–4 as in figure.

Segment of leg 5 (fig. 68) 80 μ × 143 μ. Between this segment and genital segment a short ventral intersegmental sclerite. Genital segment 156 μ × 135 μ, only a little longer than wide, and not greatly expanded laterally in dorsal view. Areas of attachment of egg sacs located



FIGS. 83–88. *Lichomolgus foxi* Gurney, 1927, male: 83, body, dorsal (A); 84, urosome, dorsal (B); 85, maxilliped, outer (D); 86, last segment of endopod of leg 1, anterior (E); 87, endopod of leg 4, anterior (E); 88, spermatophore, empty and attached to female, dorsal (G).

dorsolaterally in middle of segment. Each area (fig. 69) bearing two small naked setae 10 μ and 12 μ long, partially covered in dorsal view by sclerotized processes. Region between two areas of attachment with sclerotized lines and setules as indicated in figure. Three postgenital segments 52 μ × 86 μ, 36 μ × 78 μ, and 52 μ × 78 μ, from anterior to posterior.

Caudal ramus (fig. 70) about as long as wide, 43 μ × 37 μ in greatest dimensions. Outer lateral seta 180 μ and naked, pedicellate dorsal seta 46 μ and lightly feathered, outermost distal seta 195 μ with hairs on proximal inner side, innermost distal seta 350 μ with hairs on both sides proximally, and the two long median terminal setae 600 μ (outer) and 790 μ (inner), both with coarse spinules on both sides except near bases and both inserted between unornamented dorsal and ventral flaps.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 2.1 : 1.

Egg sac (fig. 67) elongated, 420 μ × 140 μ, reaching well beyond caudal rami. Each egg about 46 μ in diameter.

Rostral area resembling that of *L. cristatus*.

First antenna (fig. 71) 7-segmented, 563 μ long. Lengths of segments: 55 μ (91 μ along anterior edge), 179 μ, 36 μ, 91 μ, 73 μ, 55 μ, and 38 μ respectively. Formula for armature as in three previous species. All setae naked.

Second antenna (fig. 72) 4-segmented. Longest seta on third segment characteristically bent. Last segment moderately elongated, 88 μ along its outer edge, 59 μ along its inner edge, and 23 μ wide, bearing distally two short and three rather long setae and two unequal terminal claws, the stouter claw 46 μ along its axis, the more slender claw 33 μ.

Labrum (fig. 73) with two somewhat obtusely pointed posteroventral lobes. Mandible (fig. 74) with basal region distal to constriction bearing on its convex margin a distally directed pointed scalelike process ornamented with a row of spinules, followed by a serrated fringe, and on its concave margin a row of slender spinules joining a group of somewhat stouter spinules near base of flagellum; flagellum elongated with lateral spinules. Paragnath (fig. 73) a small hairy lobe. First maxilla (fig. 75) with three long terminal naked setae and a minute subterminal seta. Second maxilla (fig. 76) 2-segmented, first segment unarmed, second with a small setule on proximal inner margin, a surficial posterior seta finely barbed along one edge, an outer distal spine with prominent spinules mostly along one edge, and the segment produced distally to form a lash with dentiform spines proximally and fine bilateral spinulation distally. Maxilliped (fig. 77) 3-segmented, armed as in *L. dentipes*, though details of form and ornamentation somewhat different.

Area between maxillipeds and first pair of legs similar to that in *L. cristatus*, but slightly protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 78–81) segmented as in three previous species and with same spine and setal formula. Inner seta on coxa of legs 1–3 long and plumose, but in leg 4 very short (8 μ) and naked. Inner margin of basis with row of hairs in legs 1–3, but naked in leg 4. Outer spines of exopod of leg 1 with strong spinules along proximal edges. Endopod of leg 4 shorter than exopod. First segment 37 μ × 32 μ (not including processes) with inner distal naked seta very short (11 μ) and turned anteriorly (so that in casual examination it might appear to be absent). Second segment 65 μ × 26 μ (greatest width) bearing two terminal very unequal spines, outer 23 μ and naked, inner 61 μ with an outer finely barbed fringe and a narrow inner lamella. Both segments with outer margins haired, and second segment with a row of fine spinules near insertions of terminal spines.

Leg 5 (fig. 82) with elongated free segment, 101 μ in length, its proximal area expanded inwardly (width here 33 μ) but distal two-thirds of segment slender (15 μ at widest point). Segment bearing two naked terminal setae 94 μ and 99 μ and short spinules along its outer margin. Seta on body near insertion of free segment 45 μ and feathered. Expansion of free segment partially covered in dorsal view by a posterolateral extension of dorsum of body segment.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 69).

Color in life in transmitted light translucid to slightly opaque, eye red, egg sacs gray.

Male: Body (fig. 83) similar in general shape to female. Length 0.93 mm (0.88–0.96 mm) and greatest width 0.32 mm (0.31–0.33 mm), based on 10 specimens. Ratio of length to width of prosome 1.66 : 1.

Segment of leg 5 (fig. 84) 42 μ × 91 μ. No ventral intersegmental sclerite. Genital segment longer than wide, 211 μ × 172 μ, its lateral borders in dorsal view slightly irregular. Four postgenital segments 32 μ × 57 μ, 28 μ × 56 μ, 20 μ × 56 μ, and 29 μ × 56 μ, from anterior to posterior.

Caudal ramus similar to that of female, but smaller, 26 μ × 24 μ.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 1.46 : 1.

Rostral area as in female.

First antenna similar to that of female, but with two aesthetes added on second segment and one on fourth segment, so that formula is same as for *L. dentipes* and *L. adelphus*. Second antenna resembling that of female, but with small spinules added on inner surface of first, second, and fourth segments.

Labrum, mandible, paragnath, first maxilla, and second maxilla like those of female. Maxilliped (fig. 85) resembling in general form and armature that of *L. dentipes*. Claw 185 μ along its axis (including terminal lamella).

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, and spine and setal formula as in that sex except for last segment of endopod of leg 1 (fig. 86) which is I,I,4. No sexual dimorphism in legs 2 or 3. Endopod of leg 4 (fig. 87) closely resembling that of female.

Leg 5 (see fig. 84) with slender free segment 41 μ × 8 μ, without a proximal expansion. Outer margin with fewer spinules than in female. Two terminal naked setae 31 μ (inner) and 63 μ (outer).

Leg 6 (see fig. 84) a posterolateral flap on ventral surface of genital segment bearing two naked setae 30 μ and 39 μ long.

Spermatophore (fig. 88), attached to female and empty, elongated, 220 μ × 90 μ (not including neck).

Color in life as in female.

Remarks: As nearly as can be determined, the specimens from *Cladiella* in Madagascar represent the species described by Gurney (1927) as *L. foxi*. In Gurney's description, based upon a single female, several significant points of similarity with the Madagascan specimens may be noted: the body shape and size, the proportional lengths of the segments of the first antenna, the bent seta on the third segment and the two unequal claws on the last segment of the second antenna, the strong spinules on the proximal edges of the outer spines of the exopod of leg 1, and the form of the caudal ramus.

There are two rather perplexing apparent differences. Gurney stated that the first segment of the endopod of leg 4 had no seta, but added that "it may have been broken off." In his figure 113E he showed two small spiniform processes at the region where the seta would normally be. In the Madagascan females the very small seta at this point is often directed anteriorly and could easily be overlooked when the leg is examined on a slide in flat view. We think it probable that one of Gurney's spiniform processes may represent this seta, since it would be very unusual in *Lichomolgus* for two spiniform processes to be present here. The length of the second segment of the endopod in leg 4 is relatively shorter and the two terminal spines are less unequal in Gurney's figure than in the Madagascan females. However, such small differences may be attributable to the technique of drawing.

Leg 5 as shown in Gurney's figure 113G in general resembles that in the Madagascan specimens, but shows an inner proximal expansion of somewhat different form, the terminal setae are relatively shorter, and the outer margin is said to be hairy. The form of the expansion in his figure does not appear to be significantly different from that in the Madagascan females, since the variation could be introduced by the angle at which the leg was drawn. The terminal setae in the Madagascan females are very delicate distally and those shown in Gurney's figure may not represent their entire length. The "hairy" nature of the outer margin may simply be an interpretation of the rather small spinules seen here in the Madagascan material.

Admittedly we are interpreting these features in relation to what we know of the females from Madagascar, but in the absence of types or other specimens we have come to the conclusion that the apparent differences in the endopod of leg 4 and in leg 5 are probably not significant, and that our specimens from *Cladiella* actually represent *L. foxi*.

Lichomolgus hetaericus new species

Figures 89–106

Type material: 74♀♀, 18♂♂, and 1 copepodid from one colony of *Cladiella pachyclados* (Klunzinger), in 1 m, Ambariotelo, a small island almost between Nosy Komba and Nosy Bé, Madagascar, collected 15 May 1964. Holotype ♀, allotype, and 62 paratypes (50♀♀, 12♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Other material: 9♀♀ from several colonies of *Cladiella krempfi* Hickson, in 1 m, west of Pte. de Tafondro, Nosy Bé, 5 December 1963.

Female: Body (fig. 89) with moderately broadened prosome. Length 0.84 mm (0.78–0.89 mm) and greatest width 0.42 mm (0.40–0.45 mm), based on 10 specimens. Ratio of length to width of prosome 1.27 : 1. Segment of leg 1 separated dorsally and laterally from head by a transverse furrow. Epimeral areas of segments of legs 1–4 as in figure.

Segment of leg 5 (fig. 90) 62 μ × 109 μ. No ventral intersegmental sclerite. Genital segment (fig. 90) about as long as wide, 107 μ × 112 μ, in dorsal view moderately expanded laterally. Areas of attachment of egg sacs situated laterally near middle of segment. Each area (fig. 91) bearing two small naked spiniform setae 6 μ and 4.5 μ long, and partly covered dorsally by a flap of dorsum of genital segment. Three postgenital segments 34 μ × 62 μ, 26 μ × 60 μ, and 29 μ × 57 μ, from anterior to posterior.

Caudal ramus (fig. 92) nearly quadrate, 22 μ × 23 μ in greatest dimensions. Outer lateral seta 133 μ and naked, dorsal pedicellate seta 80 μ and apparently naked, outermost distal seta 79 μ and naked, innermost distal seta 143 μ and haired proximally, and the two long median terminal setae 395 μ (outer) and 495 μ (inner), both with lateral spinules except near bases and inserted between dorsal and ventral unornamented flaps.

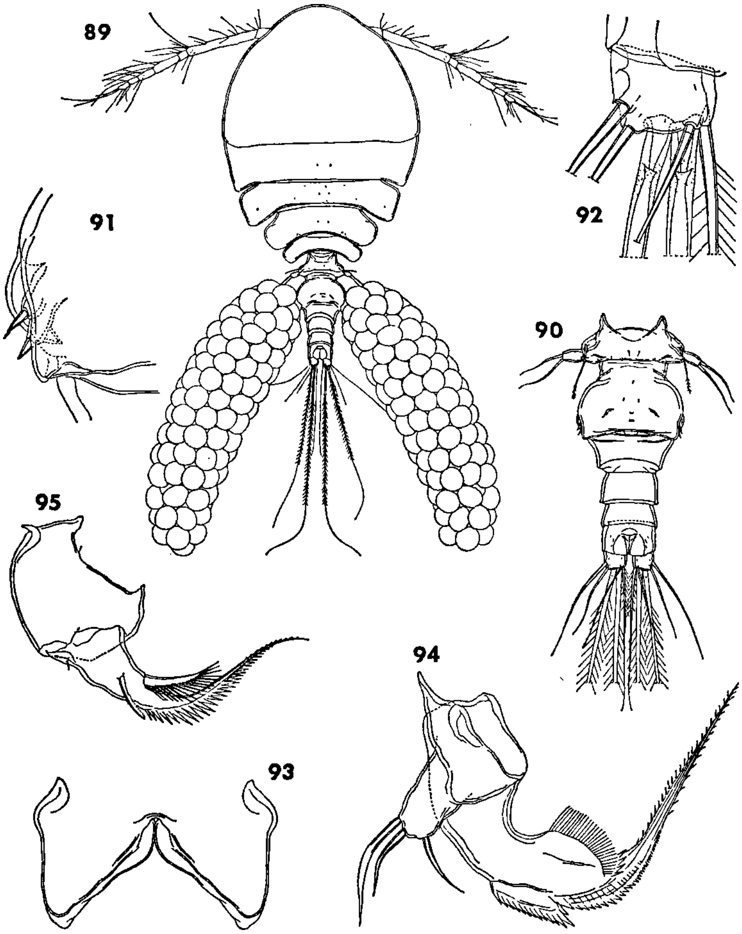
Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 2.15 : 1.

Egg sac (fig. 89) elongated, 660 μ × 187 μ, nearly three times length of urosome. Each egg about 49 μ in diameter.

Rostral area as in *L. cristatus.*

First antenna similar to that of *L. foxi.* Lengths of segments: 34 μ (68 μ along anterior margin), 151 μ, 26 μ, 65 μ, 47 μ, 32 μ, and 29 μ respectively. All setae naked. Second antenna also resembling that of *L. foxi,* with seta on third segment bent as in that species. Last segment 75 μ along outer side, 47 μ along inner side, and 17 μ wide at middle. Stouter claw 36 μ, more slender claw 29 μ.

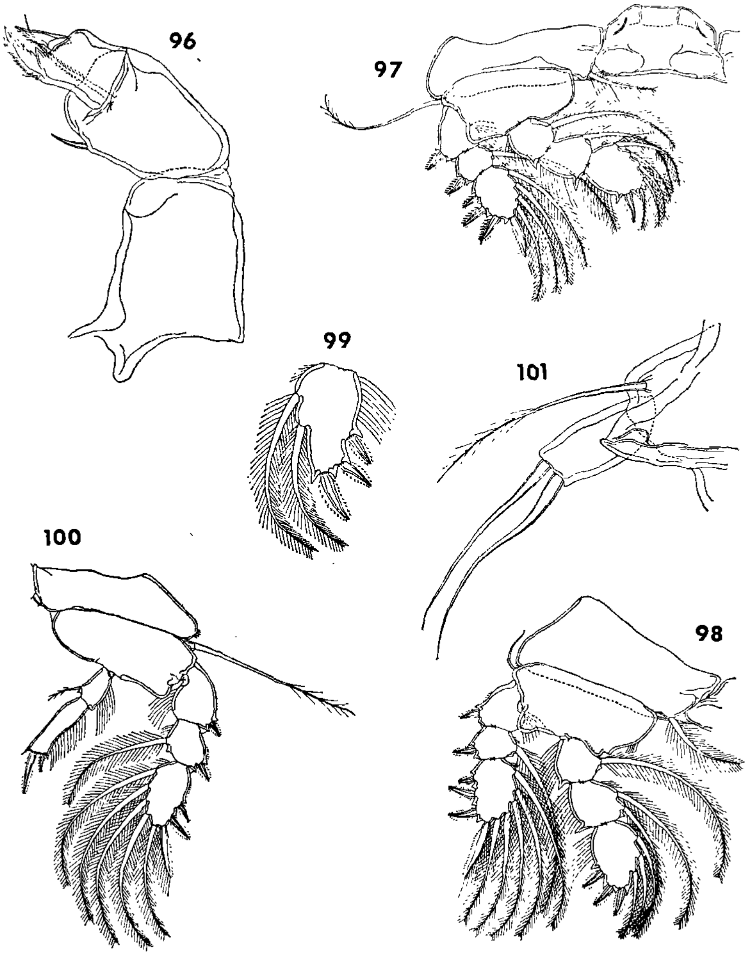
Labrum (fig. 93) with two rather pointed posteroventral lobes. Mandible (fig. 94) resembling that of *L. foxi,* but distal end of scalelike process on convex margin of basal region ornamented with spinules. Paragnath and first maxilla (fig. 94) similar to those in *L. foxi.* Second maxilla (fig. 95) resembling that of *L. foxi,* but proximal



FIGS. 89–95. *Lichomolgus hetaericus*, new species, female: 89, body, dorsal (A); 90, urosome, dorsal (B); 91, area of attachment of egg sac, dorsal (C); 92, caudal ramus, dorsal (C); 93, labrum, ventral (E); 94, mandible and first maxilla, posterior (C); 95, second maxilla, posterior (E).

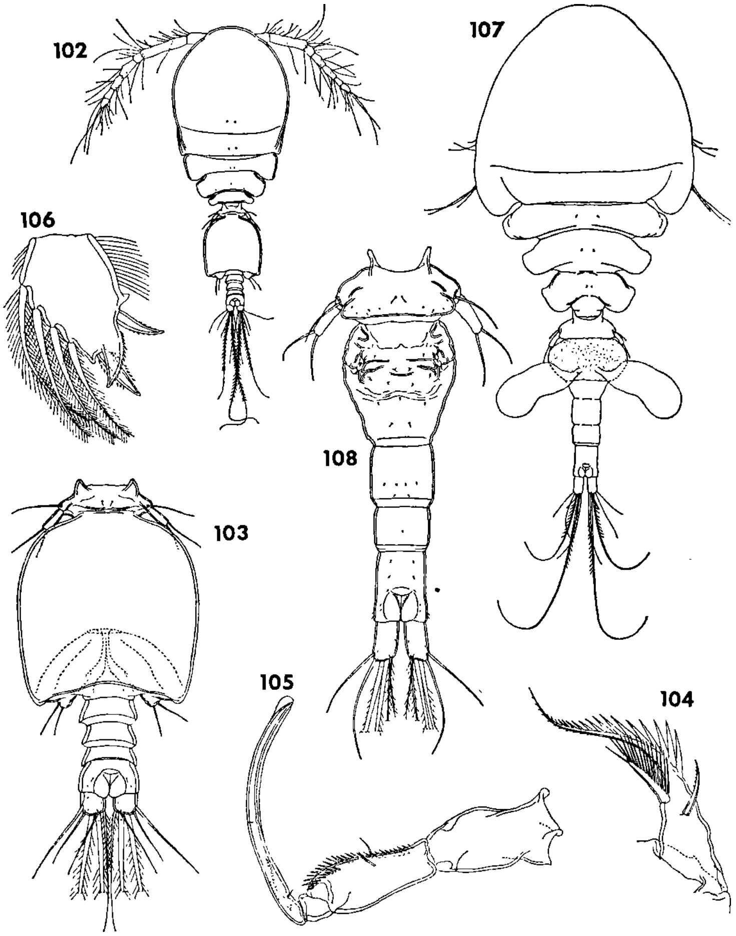
spines on lash more slender. Maxilliped (fig. 96) similar to that of *L. foxi*, but first segment without ornamentation, long seta on second segment relatively shorter, and a spiniform process between two large terminal elements.

Area between maxillipeds and first pair of legs not protuberant and similar to that in *L. cristatus*.



FIGS. 96–101. *Lichomolgus hetaericus*, new species, female: 96, maxilliped, anterior (C); 97, leg 1 and intercoxal plate, anterior (F); 98, leg 2, anterior (F); 99, last segment of endopod of leg 3, anterior (E); 100, leg 4, anterior (F); 101, leg 5, dorsal (C).

Legs 1–4 (figs. 97–100) segmented as in four previous species, with same spine and setal formula except for last segment of exopod of leg 4 which is II,I,5. Inner seta on coxa long and plumose in legs 1–3, but extremely minute (3 μ) and naked in leg 4. Outer seta on basis long (70 μ) in legs 1, 3, and 4. Inner margin of basis in leg 4 naked. Proximal outer spine on third segment of exopod in legs 1–3 distinctly



Figs. 102–108. *Lichomolgus hetaericus*, new species, male: 102, body, dorsal (A); 103, urosome, dorsal (D); 104, second maxilla, posterior (C); 105, maxilliped, outer (F); 106, last segment of endopod of leg 1, anterior (C). *Lichomolgus insolens*, new species, female: 107, body, dorsal (A); 108, urosome, dorsal (B).

shorter than distal spines. Endopod of leg 4 (fig. 100) rather slender, shorter than exopod. First segment 22 μ × 12 μ, with its inner distal seta 20 μ and very lightly feathered. Second segment 44 μ × 11 μ (including processes and width taken at widest point), two terminal fringed spines 11 μ (outer) and 23 μ (inner). Hairs along outer margins of both segments and minute spinules near insertions of terminal spines.

Leg 5 (fig. 101) with small unornamented free segment 27 μ × 12 μ, its two terminal naked setae 46 μ (outer) and 55 μ (inner). Seta on body near free segment 50 μ and lightly feathered.

Leg 6 probably represented by the two small setae near areas of attachment of each egg sac (see fig. 91).

Color in life as in *L. foxi.*

Male: Body (fig. 102) with prosome more slender than in female. Length 0.62 mm (0.59–0.66 mm) and greatest width 0.25 mm (0.24–0.27 mm), based on 10 specimens. Ratio of length to width of prosome 1.53 : 1.

Segment of leg 5 (fig. 103) 26 μ × 65 μ. No ventral intersegmental sclerite. Genital segment about as long as wide, 139 μ × 130 μ, its lateral borders in dorsal view only slightly rounded. Four postgenital segments 18 μ × 41 μ, 17 μ × 40 μ, 13 μ × 40 μ, and 19 μ × 43 μ, from anterior to posterior.

Caudal ramus resembling that of female, but smaller, 19 μ × 18 μ.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 1.62 : 1.

Rostral area as in female. First antenna like that of female, but two aesthetes added on second segment and one on fourth segment, so that formula is same as in *L. dentipes, L. adelphus,* and *L. foxi.* Second antenna similar to that of female, but, as in *L. foxi,* a few small spinules added on inner surface of segments 1, 2, and 4.

Labrum, mandible, paragnath, and first maxilla like those of female. Second maxilla similar to that of female but proximal spines on lash coarser and longer (fig. 104). Maxilliped (fig. 105) resembling that of *L. foxi,* but claw (122 μ) shorter.

Area between maxillipeds and first pair of legs like that of female.

Legs 1–4 segmented as in female, with same spine and setal formula, except for last segment of endopod of leg 1 (fig. 106) which has arrangement of I,I,4. Proximal outer spine on third segment of exopod in legs 1–3 short as in female. Legs 2 and 3 as in female, without sexual dimorphism.

Leg 5 (see fig. 103) with small unornamented free segment 17 μ × 7 μ, its two terminal setae 28 μ (outer) and 20 μ (inner). Seta on body near free segment 33 μ. All setae naked.

Leg 6 (see fig. 103) a posterolateral flap on ventral surface of genital segment bearing two naked setae 24 μ and 26 μ long.

Spermatophore not observed.

Color in life like that of female.

Etymology: The specific name *hetaericus,* from Greek ἐταιρικός = comradely or sociable, alludes to the occurrence of this species along with *L. foxi* on the same colonies of octocorals.

Comparison with related species: L. hetaericus may be distinguished from all other known species of *Lichomolgus* by the combination of the following characters: the nearly quadrate caudal ramus, the second antenna with two short terminal claws, the mandible with a relatively long flagellum and without a strong tooth on its basal part, leg 1 showing sexual dimorphism (I,I,4) in the male, legs 1–3 with the proximal outer spine on the third segment of the exopod reduced, the formula for the third segment of the exopod of leg 4 as II,I,5, and the free segment of leg 5 in the female with a length to width ratio of 2.3 : 1 and lacking a proximal expansion or surficial ornamentation.

Two species of *Lichomolgus* described from southeastern India by Ummerkutty (1962) might at first glance be confused with *L. hetaericus*, but differ from the new species in significant details. In *L. brevifurcatus* Ummerkutty, 1962, the female is 1.6 mm in length and the male 1.5 mm; the genital segment of the female is "barrel-like and does not become narrowed in the posterior half"; and the proximal outer spine on the third segment of the exopod in the swimming legs is not reduced. In *L. indicus* Ummerkutty, 1962, the female is 1.05 mm and the male 1.00 mm; there are only two postgenital segments in the female and three in the male; there is no sexual dimorphism in leg 1; and the endopod of leg 4 differs from that of *L. hetaericus* in details of shape and armature. *L. indicus* shows a reduction (as in the new species) of the proximal outer spine on the third segment of the exopod of leg 1 (Ummerkutty's Pl. XII, fig. 9) and leg 2 (his Pl. XIII, fig. 2).

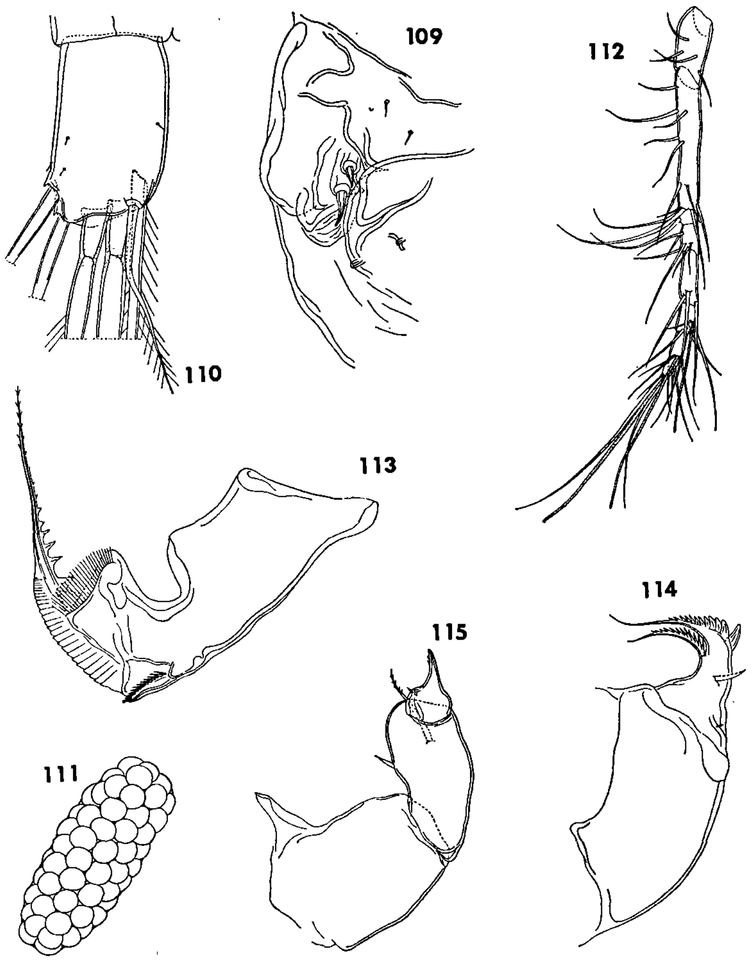
Lichomolgus insolens new species
Figures 107–127

Type material: 18♀♀, 16♂♂, and 17 copepodids from one colony of *Lobophytum crassum* Marenzeller, in 1 m, opposite Ambariotsimaramara, a small island on the southern coast of Nosy Bé, Madagascar, collected 12 June 1964. Holotype ♀, allotype, and 23 paratypes (12♀♀, 11♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Other material (from *Lobophytum crassum*): 16♀♀, 15♂♂, and 4 copepodids, from one colony, in 10 cm, Ambafaho, Nosy Bé, 25 September 1964; and 12♀♀, 16♂♂, and 6 copepodids, from one colony, in 1 m, Nosy N'Tangam, near Nosy Bé, 5 September 1963.

Female: Body (fig. 107) rather weakly sclerotized and with broadened prosome. Anterior border of head with a minute median notch. Length 1.11 mm (1.06–1.19 mm) and greatest width 0.52 mm (0.48–0.58 mm), based on 10 specimens. Ratio of length to width of prosome 1.40 : 1. Segment of leg 1 separated from head by a weak dorsal furrow. Epimeral areas of segments of swimming legs formed as in figure.

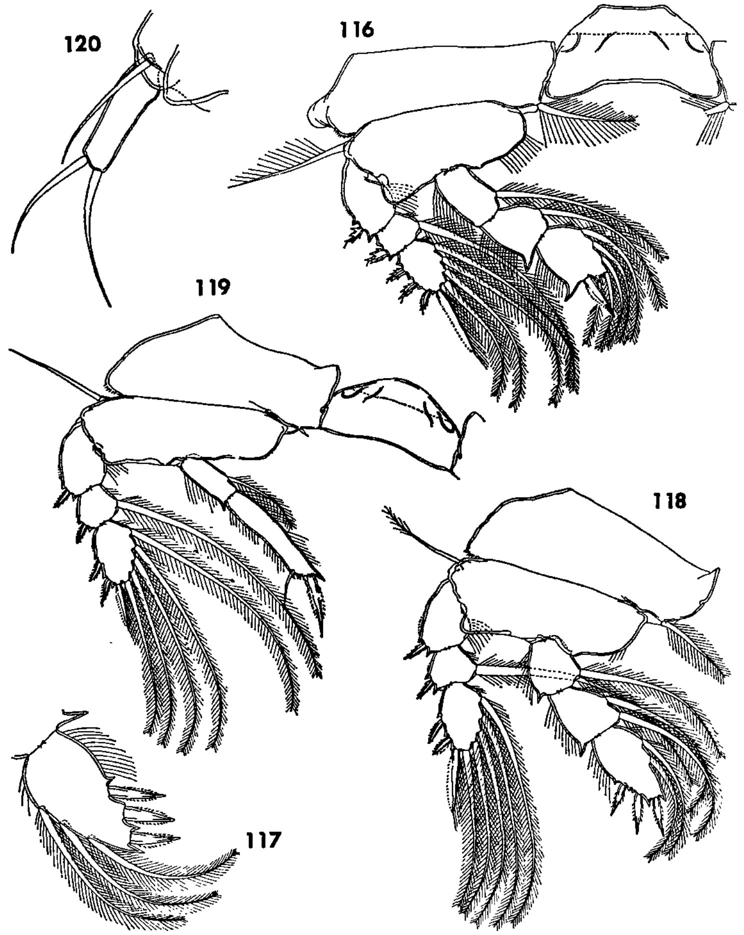
Segment of leg 5 (fig. 108) 78 μ × 138 μ. Between this segment and genital segment a weak intersegmental sclerite ventrally. Genital segment (fig. 108) longer than wide, 153 μ × 121 μ, broadest in its anterior half and tapering gradually posteriorly. Areas of attachment



Figs. 109–115. *Lichomolgus insolens*, new species, female: 109, area of attachment of egg sac, dorsal (F); 110, caudal ramus, dorsal (C); 111, egg sac, ventral (A); 112, first antenna, dorsal (B); 113, mandible, posterior (C); 114, second maxilla, posterior (E); 115, maxilliped, anterior (E).

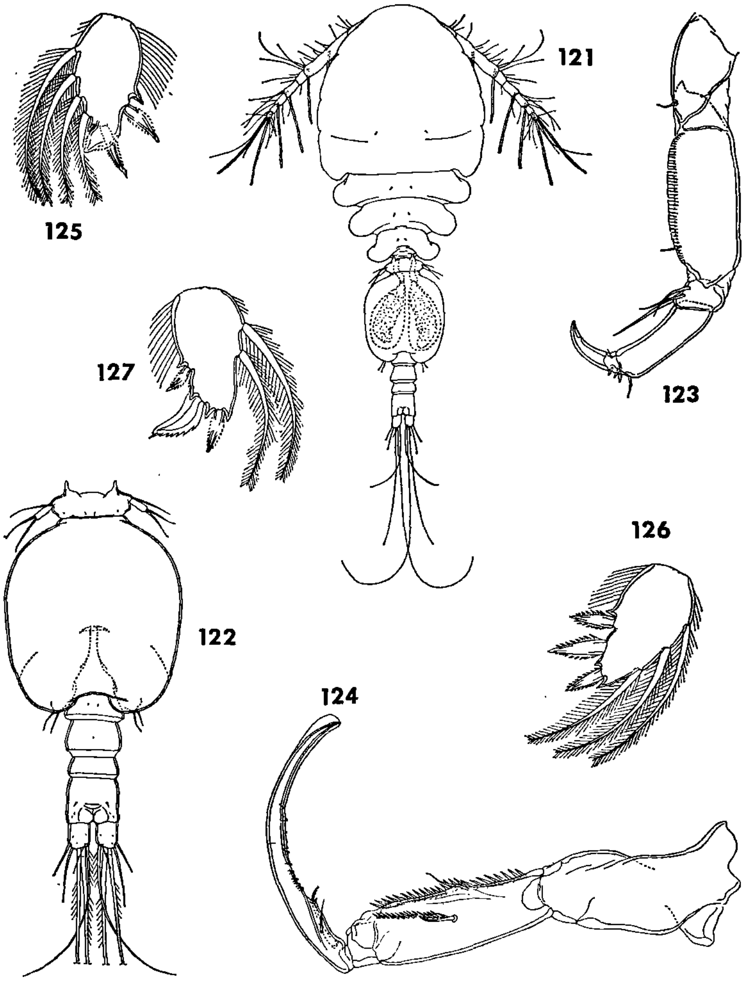
of egg sacs situated dorsolaterally at level of junction of anterior two thirds of segment. Each area (fig. 109) with two small spiniform naked setae 5 μ and 8 μ in length. Three postgenital segments 68 μ ×70 μ, 47 μ × 62 μ, and 74 μ × 55 μ, from anterior to posterior.

Caudal ramus (fig. 110) nearly twice as long as wide, 43 μ × 23 μ



FIGS. 116–120. *Lichomolgus insolens*, new species, female: 116, leg 1 and intercoxal plate, anterior (F); 117, last segment of endopod of leg 2, anterior (E); 118, leg 3, anterior (F); 119, leg 4 and intercoxal plate, anterior (F); 120, leg 5, dorsal (E).

in greatest dimensions. Outer lateral seta 70 μ and naked, dorsal pedicellate seta 38 μ and lightly feathered, outermost distal seta 104 μ and naked, innermost distal seta 203 μ and haired proximally, and the two long median terminal setae 290 μ (outer) with a few outer spinules and 430 μ (inner) with a few inner spinules, both inserted between the usual dorsal (unornamented) and ventral (with a short row of spinules) flaps.



FIGS. 121–127. *Lichomolgus insolens*, new species, male: 121, body, dorsal (A); 122, urosome, dorsal (B); 123, second antenna, posterior (outer) (F); 124, maxilliped, outer (F); 125, last segment of endopod of leg 1, anterior (E); 126, last segment of endopod of leg 2, anterior (E); 127, last segment of endopod of leg 3, anterior (E).

Dorsal surface of prosome and urosome with a few hairs. Ratio of length of prosome to that of urosome 1.64 : 1.

Egg sac (fig. 111) elongated, 462 μ × 176 μ, reaching well beyond ends of caudal rami. Each egg about 47 μ in diameter.

Rostral area as in *L. protentus.*

First antenna (fig. 112) 350 μ long and resembling that of previous species, with the same formula for armature. Lengths of segments: 50 μ (57 μ along anterior edge), 135 μ, 32 μ, 50 μ, 30 μ, 28 μ, and 19 μ respectively. All setae naked.

Second antenna similar to that of *L. protentus.* Last segment 48 μ along its inner side, 66 μ along its outer side, and 20 μ wide. Claw 39 μ along its axis.

Labrum as in *L. protentus.* Mandible (fig. 113) with basal region distal to constriction bearing on its convex edge a small sclerotized process followed by a scalelike process with spinules and then by a serrated fringe, and on its concave margin a row of long slender setules and at base of lash a toothlike prominence (on anterior surface); lash elongated with spiny concave margin proximally and barbed distally. Paragnath and first maxilla as in *L. protentus.* Second maxilla (fig. 114) resembling in major respects that of *L. protentus,* but first toothlike spine at base of lash larger and not in line with others. Maxilliped (fig. 115) much like that of *L. protentus,* but lesser of two terminal elements smaller than in that species, so that with casual observation there may appear to be only one large terminal element.

Area between maxillipeds and first pair of legs generally like that of *L. protentus,* but not protuberant; a line between bases of maxillipeds.

Legs 1–4 (figs. 116–119) segmented as in previous species, but spine and setal formula differing as follows:

P_1	protopod	0–1	1–0	exp	I–0	I–1	III,I,4
				end	0–1	0–1	I,5
P_2	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,II,3
P_3	protopod	0–1	1–0	exp	I–0	I–1	II,I,5
				end	0–1	0–2	I,II,2
P_4	protopod	0–1	1–0	exp	I–0	I–1	II,I,5
				end	0–1	1,I	

Outer margin of coxa of leg 1 with a prominent protrusion. Inner seta on coxa in legs 1–3 long and plumose, but in leg 4 only 6 μ long and naked. Inner margin of basis of leg 4 naked except for a minute sensillum. Outer spines on exopod of leg 1 with coarse spinulation as in *L. protentus.* Third segment of exopod of leg 3 with only two outer spines (fig. 118) as in leg 4. Endopod of leg 4 (fig. 119) slender and a little longer than exopod. First segment 32 μ × 13 μ, with inner distal plumose seta 44 μ. Second segment 68 μ × 13 μ (including terminal processes), bearing distally an outer naked seta 25 μ and an inner fringed spine 35 μ, and resembling the endopod of *L. protentus.*

Leg 5 (fig. 120) with unornamented free segment about 3.6 times longer than wide, 43 μ × 12 μ, with width at very slight inner proximal expansion 14 μ; bearing two terminal naked setae 40 μ (outer) and 53 μ (inner). Seta on body near free segment 50 μ and naked.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 109).

Color in life in transmitted light translucid, prosome sometimes finely speckled with reddish orange, intestine brown, eye red, ovary opaque gray, egg sacs gray or speckled with reddish orange.

Male: Body (fig. 121) with prosome less broadened than in female. Anterior border of head smooth, without median notch. Length 0.89 mm (0.84–0.91 mm) and greatest width 0.33 mm (0.29–0.34 mm), based on 10 specimens. Ratio of length to width of prosome 1.49 : 1. Segment of leg 1 incompletely separated from head. Lateral borders of cephalosome showing a few slight indentations.

Segment of leg 5 (fig. 122) 38 μ × 74 μ. No ventral intersegmental sclerite. Genital segment longer than wide, 192 μ × 164 μ. Four postgenital segments 31 μ × 48 μ, 31 μ × 47 μ, 21 μ × 44 μ, and 36 μ × 45 μ, from anterior to posterior.

Caudal ramus similar to that of female, but smaller, 30 μ × 19 μ.

Surfaces of prosome and urosome with a few small hairs as in female. Ratio of length of prosome to that of urosome 1.46 : 1.

Rostral area as in female.

First antenna as in female, but two aesthetes added on second segment and one on third segment, so that formula is same as for males of previous species and of *L. protentus*. Second antenna (fig. 123) like that of female, but second segment with a long striated inner membranous lamella.

Labrum, mandible, paragnath, first maxilla, and second maxilla resembling those of female. Maxilliped (fig. 124) slender, as in *L. protentus*. Claw 126 μ along its axis, with a series of obtuse hyaline knobs on its concave surface.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with same spine and setal formula as in that sex except for last segment of endopod of leg 1 which has arrangement of I,I,4 (fig. 125). Sexual dimorphism seen also in endopods of legs 2 and 3. Last segment of endopod of leg 2 (fig. 126) with three spines shorter and broader than in female, with first two having coarser spinulation. (In female lengths of these spines from proximal to distal are 18 μ, 17 μ, and 17 μ; in male 13 μ, 14 μ, and 12 μ). Last segment of endopod of leg 3 (fig. 127) with middle spine modified (compare with fig. 118). Endopod of leg 4 as in female.

Leg 5 (see fig. 122) with small unornamented free segment, 20 μ × 7 μ, without a proximal expansion. Two terminal naked setae 28 μ and 31 μ, and naked seta on body near free segment 35 μ.

Leg 6 (see fig. 122) a posterolateral flap on ventral surface of genital segment bearing two naked setae about 23 μ long.

Spermatophore (see fig. 107), attached to female, elongated and somewhat irregular, 177 μ × 86 μ (not including neck).

Color in life in transmitted light more translucid than in female, eye red.

Etymology: The specific name *insolens*, from Latin = contrary to custom, refers to the unusual formula of II,I,5 for the last segment of the exopod of leg 3 in this species.

Comparison with related species: L. insolens appears to be closely related to *L. protentus*, a species associated with *Sarcophyton* in Madagascar. In both there are striking similarities in the mandible, the maxilliped of the female, the nature of the outer spines on the exopod of leg 1, and the armature of the endopod of leg 4. The new species differs from *L. protentus*, however, in several important features: its smaller size, the proportions of the genital segment in the female, details of the mouthparts, the presence of only two outer spines on the last segment of the exopod of leg 3, the unornamented leg 5 in the female, the membranous lamella on the second segment of the second antenna in the male, and the series of hyaline knobs on the claw of the maxilliped of the male.

Like *L. protentus, L. insolens* seems to approach *L. robustus* Thompson and A. Scott, 1903, described from one female found in washings of dredged invertebrates in Ceylon. However, in *L. robustus* the formula for the last segment of the exopod of leg 4 is III,I,5, and the two terminal elements on the endopod of this leg appear to be different (T. and S., Pl. XVI, fig. 20).

Although interspecific variation in the number of outer spines on the last segment of the exopod of leg 4 occurs in *Lichomolgus* (the formula for the segment being either III,I,5 or II,I,5), it is unusual that the corresponding segment of leg 3 should show a reduction from III,I,5 to II,I,5, as is the case in the new species. Another species, *L. curtiramus* Bocquet and Stock, 1962, shows a similar armature on the third segment of leg 3.

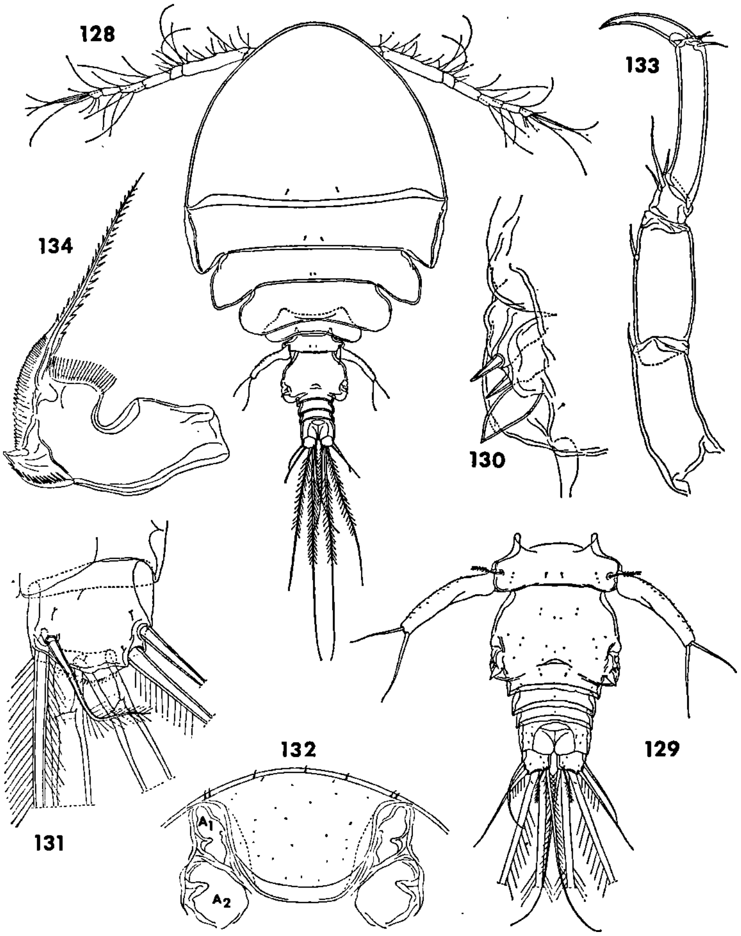
Lichomolgus spathophorus new species

Figures 128–147

Type material: 13♀♀ and 17♂♂ from two colonies of *Sarcophyton glaucum* (Quoy and Gaimard), in 0.5 m, Tany Kely, a small island south of Nosy Bé, Madagascar, collected 23 June 1963. Holotype ♀, allotype, and 18 paratypes (7♀♀, 11♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

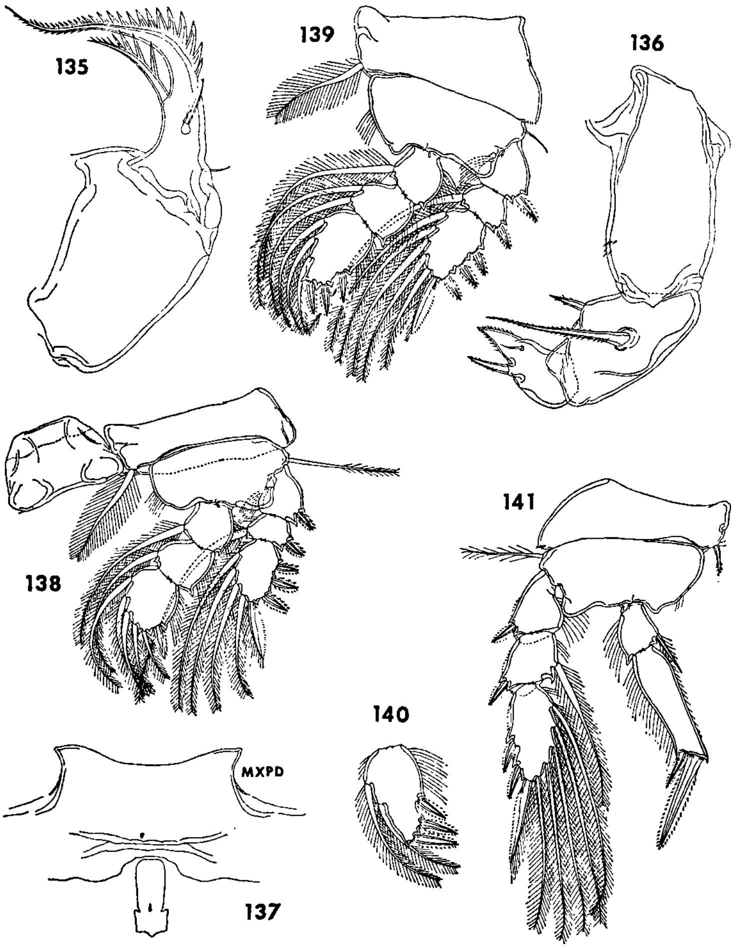
Female: Body (fig. 128) with expanded prosome. Length 0.98 mm (0.95–1.04 mm) and greatest width 0.59 mm (0.57–0.61 mm), based on 10 specimens. Ratio of length to width of prosome 1.17 : 1. Segment of leg 1 distinctly separated from head. Epimeral areas of segments of legs 1–4 as in figure.

Segment of leg 5 (fig. 129) 60 μ × 146 μ. Between this segment and genital segment a short ventral intersegmental sclerite. Genital



Figs. 128–134. *Lichomolgus spathophorus*, new species, female: 128, body, dorsal (A); 129, urosome, dorsal (B); 130, area of attachment of egg sac, dorsal (C); 131, caudal ramus, dorsal (C); 132, rostral area, ventral (B); 133, second antenna, posterior (outer) (D); 134, mandible, posterior (E).

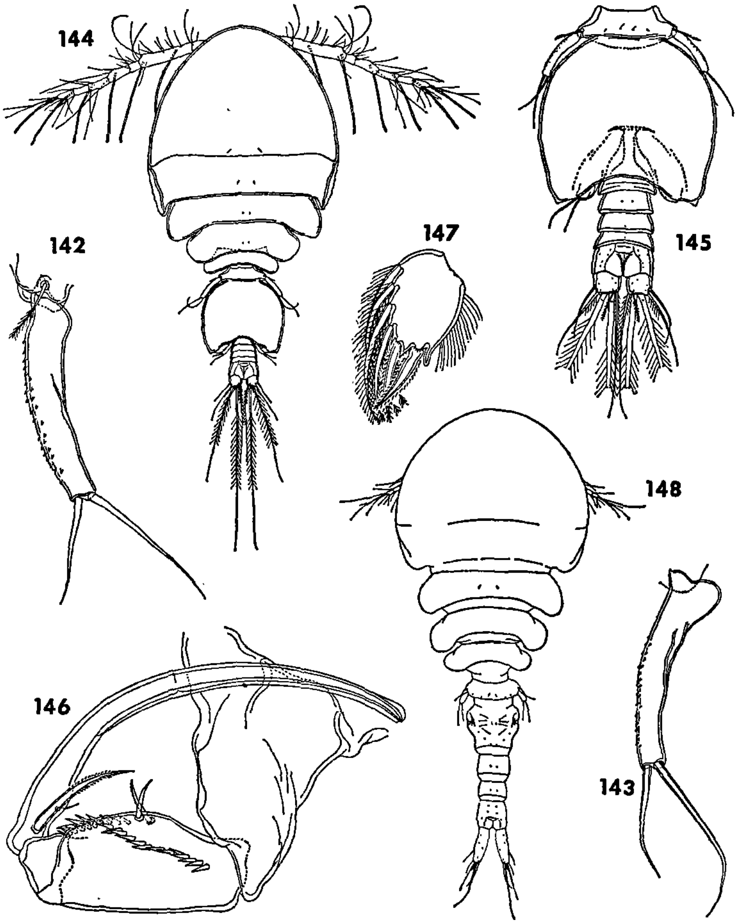
segment (fig. 129) 117 μ × 140 μ, wider than long, a little broadened in its anterior four-fifths in dorsal view, but abruptly narrowed in its posterior fifth. Areas of attachment of egg sacs located almost laterally in posterior half of segment. Each area (fig. 130) with two naked spiniform setae 10 μ and 8 μ long and a large pointed bladelike process.



FIGS. 135–141. *Lichomolgus spathophorus*, new species, female: 135, second maxilla, posterior (E); 136, maxilliped, posterior (E); 137, area between maxillipeds and first pair of legs, ventral (D); 138, leg 1 and intercoxal plate, anterior (D); 139, leg 2, anterior (D); 140, last segment of endopod of leg 3, anterior (D); 141, leg 4, anterior (D).

Three postgenital segments 26 μ × 89 μ, 21 μ × 83 μ, and 31 μ × 78 μ, from anterior to posterior.

Caudal ramus (fig. 131) quadrate, 30 μ × 30 μ in greatest dimensions. Outer lateral seta 44 μ and naked, pedicellate dorsal seta 45 μ and feathered, outermost distal seta 104 μ with proximal inner spinules,



Figs. 142–148. *Lichomolgus spathophorus*, new species, female: 142, leg 5, dorsal (F); 143, leg 5, dorsal (F). Male: 144, body, dorsal (A); 145, urosome, dorsal (B); 146, maxilliped, inner (E); 147, last segment of endopod of leg 1, anterior (E). *Lichomolgus incisus*, new species, female: 148, body, dorsal (A).

innermost distal seta 180 μ with spinules along both sides proximally, and the two long median terminal setae 375 μ (outer) with spinules on inner midregion only or along both sides and 500 μ (inner) with spinules along both sides proximally. Both terminal setae inserted between dorsal (unornamented) and ventral (with a marginal row of spinules) flaps.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 2.58 : 1.

Egg sacs broken in all ovigerous females seen, but apparently elongated and containing many small eggs.

Rostral area (fig. 132) with broadly rounded posteroventral margin.

First antenna similar to that of *L. foxi*. Lengths of segments: 35 μ (71 μ along anterior margin), 143 μ, 23 μ, 64 μ, 55 μ, 39 μ, and 27 μ respectively. All setae naked. Armature as in *L. foxi*.

Second antenna (fig. 133) 4-segmented and slender. Last segment elongated, 122 μ along its outer edge, 94 μ along its inner edge, and 18 μ wide, bearing distally five small hyaline elements and a claw 58 μ along its axis. All setae naked.

Labrum resembling that of *L. foxi*. Mandible (fig. 134) much like that of *L. foxi*, but with scalelike process on convex basal region more acutely pointed. Paragnath and first maxilla as in *L. foxi*. Second maxilla (fig. 135) 2-segmented, and armed as in figure. Maxilliped (fig. 136) 3-segmented, with armature resembling in general that of *L. foxi*.

Area between maxillipeds and first pair of legs (fig. 137) not protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 138–141) segmented as in previous species, with spine and setal formula as in *L. hetaericus*. Inner seta on coxa of legs 1–3 long and plumose, but in leg 4 short (18 μ), somewhat spiniform, and finely barbed. Inner distal corner of coxa of leg 1 slightly protuberant. Inner margin of basis of legs 1–4 with hairs. Outer spines on exopod of leg 1 with coarse spinulation along proximal margins. Endopod of leg 4 (fig. 141) a little shorter than exopod. First segment 33 μ × 25 μ (without processes), its inner distal seta relatively short (37 μ) and somewhat spiniform, with hairs proximally but naked distally. Second segment 85 μ long (including processes), 23 μ in greatest width, and 17 μ in least width. Two unequal terminal spines 26 μ (outer) with a delicate fringe and 54 μ (inner) with a coarsely serrated hyaline fringe. Hairs along outer margins of both segments and short hairs on inner margin of second segment. A row of minute spinules near insertions of terminal spines.

Leg 5 (fig. 142) with elongated free segment, 122 μ × 20 μ, having a slight proximal inner expansion, where width is 22 μ. Outer convex surface with numerous small spines. Two naked terminal setae 57 μ (outer) and 81 μ (inner). Plumose seta on body near free segment 38 μ. Apparent variation in size of proximal expansion, some females showing free segment of leg 5 as in fig. 143, where dimensions of segment are 112 μ × 16 μ, and width at expansion 27 μ. Other females showing expansion intermediate in size between those in figs. 142 and 143.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 130).

Color in life in transmitted light slightly amber, eye red, egg sacs opaque gray.

Male: Body (fig. 144) with prosome expanded nearly as in female. Length 0.79 mm (0.72–0.86 mm) and greatest width 0.39 mm (0.33–0.44 mm), based on 10 specimens. Ratio of length to width of prosome 1.26 : 1.

Segment of leg 5 (fig. 145) 33 μ × 105 μ. A very short ventral intersegmental sclerite. Genital segment 174 μ × 187 μ. Four postgenital segments 22 μ × 60 μ, 22 μ × 64 μ, 18 μ × 64 μ, and 29 μ × 66 μ, from anterior to posterior.

Caudal ramus as in female, 25 μ × 24 μ.

Surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 2.0 : 1.

Rostral area as in female. First antenna similar to that of *L. foxi*, with three aesthetes added as in that species. Second antenna as in female, but with small spinules on inner surfaces of first, second, and fourth segments.

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 146) moderately stout and armed as in previous species, with a long claw 151 μ along its axis.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female and with same spine and setal formula, except for last segment of endopod of leg 1 (fig. 147) which has the arrangement of I,I,4. Legs 2–4 as in female.

Leg 5 (see fig. 145) with free segment 62 μ × 8 μ, without a proximal expansion, and with extremely small spinules on outer surface. Two terminal naked setae 58 μ and 33 μ. Seta on body near free segment 33 μ.

Leg 6 (see fig. 145) a posterolateral flap on ventral surface of genital segment bearing two naked setae 50 μ long.

Spermatophore not observed.

Color in life similar to that of female.

Etymology: The specific name *spathophorus*, from Greek σπάθη = a broad blade and φορέω = to carry, refers to the bladelike process on the area of attachment of each egg sac.

Comparison with related species: L. spathophorus may be distinguished from all but two species of *Lichomolgus* on the basis of a combination of three features: the single short claw on the second antenna, the formula of II,I,5 for the third segment of the exopod of leg 4, and the short quadrate caudal ramus. The remaining two species have other characters that show them to be distinct from *L. spathophorus*. *L. anomalus* A. Scott, 1909, differs in having the endopod of leg 1 in the male geniculate between the second and third segments, the third segment being elongated (about 3 : 1 in A. Scott's Pl. LXVII, fig. 14). *L. elegans* Thompson and A. Scott, 1903, of which the male is unknown, is larger (female 1.5 mm), has a less expanded prosome, and the genital segment has different proportions and shape than in the new species.

Lichomolgus incisus new species

Figures 148–167

Type material: 24♀♀, 10♂♂, and 3 copepodids from one colony of *Sarcophyton ehrenbergi* Marenzeller, in 0.5 m, Andilana, Nosy Bé, collected 9 August 1963. Holotype ♀, allotype, and 24 paratypes (19♀♀, 5♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Female: Body (fig. 148) with expanded and relatively short cephalosome, its anterior border broadly rounded in dorsal view. Length 1.03 mm (0.90–1.08 mm) and greatest width 0.42 mm (0.40–0.43 mm), based on 10 specimens. Ratio of length to width of prosome 1.41 : 1. Segment of leg 1 separated from head by an incomplete dorsal transverse furrow. Epimeral areas of legs 1–4 rounded.

Segment of leg 5 (fig. 149) 52 μ × 117 μ. Between this segment and genital segment a short ventral intersegmental sclerite. Genital segment (fig. 149) only a little wider than long, 114 μ × 121 μ. Areas of attachment of egg sacs situated dorsolaterally in anterior half of segment. Each area (fig. 150) bearing two minute naked setae about 4 μ long. Three postgenital segments 52 μ × 68 μ, 44 μ × 63 μ, and 56 μ × 61 μ, from anterior to posterior.

Caudal ramus (fig. 151) elongated, 77 μ long, 24 μ wide near base, and 19 μ wide distally. Setae relatively short. Outer lateral seta 35 μ, dorsal pedicellate seta 28 μ, outermost distal seta 33 μ, innermost distal seta 82 μ, and the two long median terminal setae 105 μ (outer) and 150 μ (inner), both inserted between unornamented dorsal and ventral flaps. All setae naked.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 1.42 : 1.

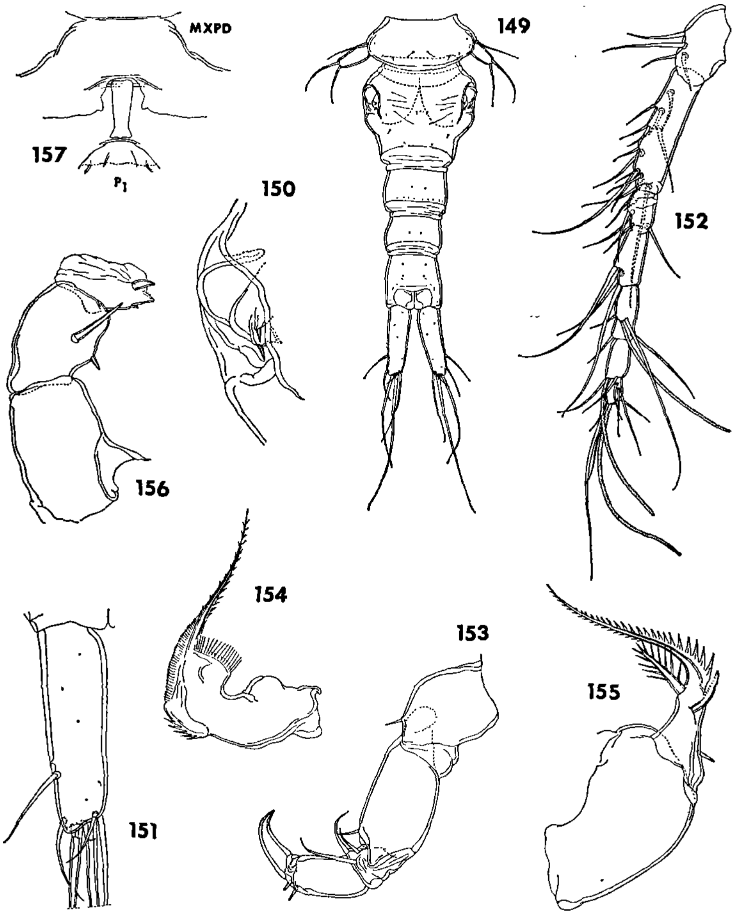
Egg sac in one ovigerous female elongated, 450 μ × 175 μ, reaching just beyond ends of caudal rami and containing many eggs about 52 μ in diameter.

Rostral area as in *L. cristatus*.

First antenna (fig. 152) 7-segmented, but relatively short (232 μ). Armature as in all previous species. Lengths of segments: 25 μ (41 μ along anterior margin), 61 μ, 21 μ, 31 μ, 30 μ, 21 μ, and 17 μ respectively. All setae naked.

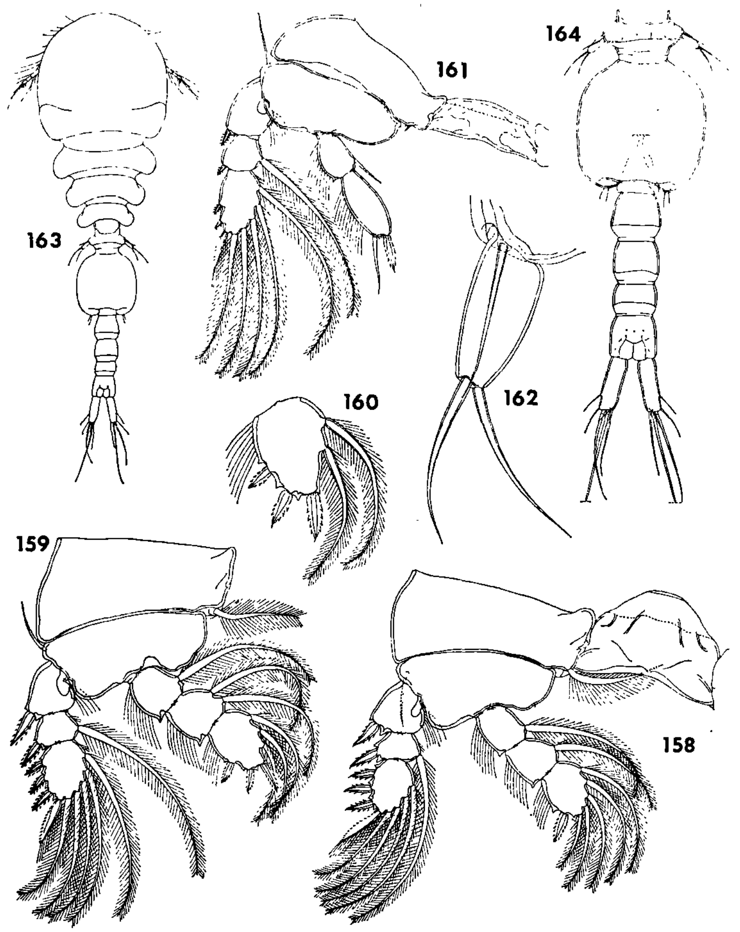
Second antenna (fig. 153) 4-segmented. Last segment relatively short, 46 μ along its outer edge, 31 μ along its inner edge, and 19 μ wide, bearing distally four small hyaline elements and a terminal claw 33 μ along its axis. All setae naked.

Labrum as in *L. foxi*. Mandible (fig. 154) resembling that of *L. spathophorus*, but scalelike process on convex side of basal region not pointed distally. Paragnath and first maxilla as in *L. protentus*. Second



FIGS. 149–157. *Lichomolgus incisus*, new species, female: 149, urosome, dorsal (B); 150, area of attachment of egg sac, dorsal (C); 151, caudal ramus, dorsal (E); 152, first antenna, ventral (F); 153, second antenna, posterior (outer) (F); 154, mandible, posterior (E); 155, second maxilla, posterior (E); 156, maxilliped, posterior (E); 157, area between maxillipeds and first pair of legs, ventral (D).

maxilla (fig. 155) resembling that of *L. spathophorus*. Maxilliped (fig. 156) 3-segmented. Second segment with two unequal naked setae, the longer seta only about four times the length of the other. Third segment with the usual two terminal spiniform elements (one without an articulation) and a small subterminal seta; outer side of segment swollen and membranous.



FIGS. 158–164. *Lichomolgus incisus*, new species, female: 158, leg 1 and intercoxal plate, anterior (F); 159, leg 2, anterior (F); 160, last segment of endopod of leg 3, anterior (E); 161, leg 4 and intercoxal plate, anterior (F); 162, leg 5, dorsal (C). Male: 163, body, dorsal (A); 164, urosome, dorsal (B).

Area between maxillipeds and first pair of legs (fig. 157) not protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 158–161) segmented as in previous species, with spine and setal formula as follows:

P_1	protopod	0–1	1–0	exp	I–0	I–1	III,I,4
				end	0–1	0–1	I,5

P_2	protopod	0–1	1–0	exp	I–0	I–1	III,I,5	
				end	0–1	0–2	I,II,3	
P_3	protopod	0–1	1–0	exp	I–0	I–1	II,I,5	(or III,I,5)
				end	0–1	0–2	I,II,2	
P_4	protopod	0–1	1–0	exp	I–0	I–1	II,I,5	
				end	0–1	1,I		

Inner seta on coxa of legs 1–3 long and plumose, but in leg 4 short (5 μ) and naked. Inner margin of basis of legs 1–4 without row of hairs, though a minute setule (sensillum ?) may be present. Third segment of exopod of leg 3 with II,I,5 or III,I,5 (on either or both legs of same individual), though most frequently II,I,5 (in 7 of 8 legs in 4 females). Endopod of leg 4 (fig. 161) shorter than exopod. First segment 25 μ × 17 μ, with inner distal seta short (19 μ) and naked. Second segment 39 μ × 17 μ, its two terminal elements being an outer naked seta 29 μ and an inner barbed spine 18 μ. Both segments with hairs along outer margins and second segment with a row of spinules near insertions of terminal elements.

Leg 5 (fig. 162) with small free segment 34 μ × 15 μ, tapering slightly distally, without proximal expansion and unornamented. Two terminal setae 38 μ (outer) and 42 μ (inner). Seta on body near insertion of free segment 36 μ. All setae naked.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 150).

Color in life in transmitted light translucid except for slightly opaque cephalosome, eye red, egg sacs opaque gray.

Male: Body (fig. 163) resembling in general form that of female. Length 0.90 mm (0.86–0.92 mm) and greatest width 0.29 mm (0.29–0.30 mm), based on 10 specimens. Ratio of length to width of prosome 1.69 : 1.

Segment of leg 5 (fig. 164) 44 μ × 88 μ. No ventral intersegmental sclerite. Genital segment 156 μ × 146 μ, subquadrate in dorsal view. Four postgenital segments 44 μ × 55 μ, 44 μ × 49 μ, 34 μ × 47 μ, and 49 μ × 49 μ, from anterior to posterior.

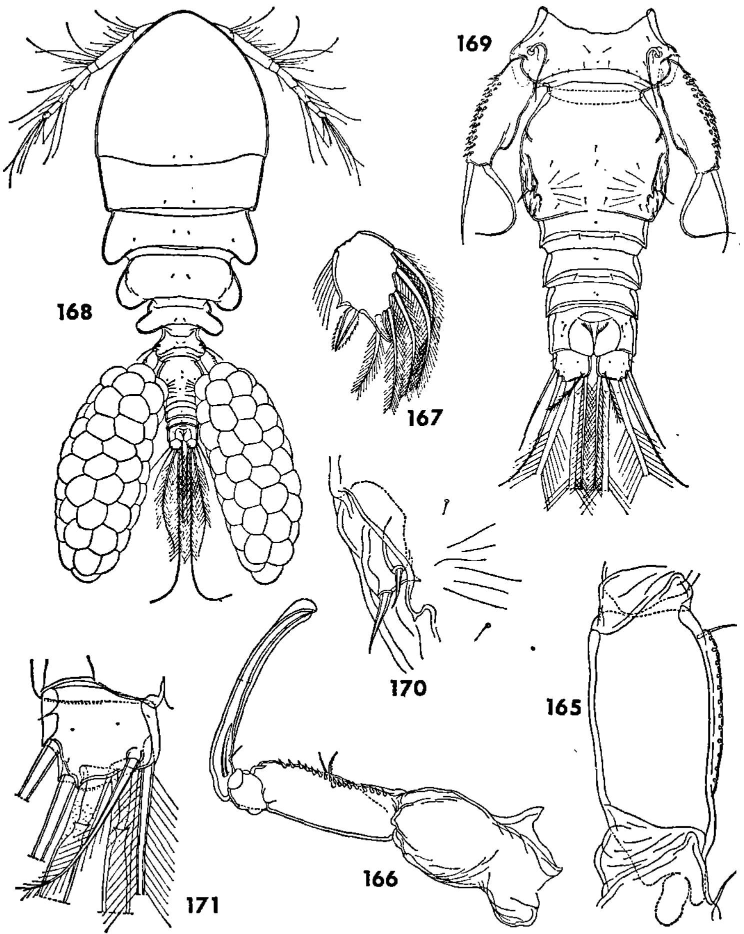
Caudal ramus as in female, but slightly shorter, 68 μ × 19 μ.

Surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 1.12 : 1.

Rostral area as in female. First antenna similar to that of female but three aesthetes added, so that formula is same as for males of previous species. Second antenna resembling that of female but second segment (fig. 165) bearing a notched lamella along inner surface.

Labrum, mandible, paragnath, first maxilla, and second maxilla like those of female. Maxilliped (fig. 166) with only one row of spines along inner surface of second segment; claw relatively short, 115 μ along its axis (including terminal lamella), and not strongly recurved.

Area between maxillipeds and first pair of legs as in female.



FIGS. 165–171. *Lichomolgus incisus*, new species, male: 165, second segment of second antenna, posterior (outer) (C); 166, maxilliped, inner (F); 167, last segment of endopod of leg 1, anterior (E). *Lichomolgus singularipes*, new species, female: 168, body, dorsal (A); 169, urosome, dorsal (D); 170, area of attachment of egg sac, dorsal (C); 171, caudal ramus, dorsal (C).

Legs 1–4 segmented as in female and with same spine and setal formula. Sexual dimorphism showing in last segment of endopod of leg 1 (fig. 167), where terminal spiniform process is much longer than in female. Last segment of endopods of legs 2 and 3 also with longer terminal processes than in female.

Leg 5 (see fig. 164) with free segment 24 μ × 8 μ, unornamented, its two terminal setae 25 μ and 35 μ. Seta on body near free segment 25 μ. All setae naked.

Leg 6 (see fig. 164) a posterolateral flap on ventral surface of genital segment bearing two naked setae 22 μ and 24 μ.

Spermatophore not observed.

Color in life similar to that of female, but cephalosome more translucid.

Etymology: The specific name *incisus*, from Latin = cut into or notched, alludes to the notched lamella on the second segment of the second antenna of the male.

Comparison with related species: Two features of *L. incisus* may be used as recognition characters,—the swollen and membranous outer side of the last segment of the maxilliped in the female and the notched lamella along the inner surface of the second segment of the second antenna of the male. These occur in no other known species of *Lichomolgus*.

The new species has several features which suggest a relationship to *L. insolens*. Both species have a reduction in the number of outer spines on the third segment of the exopod of leg 3, the terminal armature of the endopod of leg 4 consisting of a spine and a seta, and a lamella or membrane along the inner surface of the second segment of the second antenna of the male.

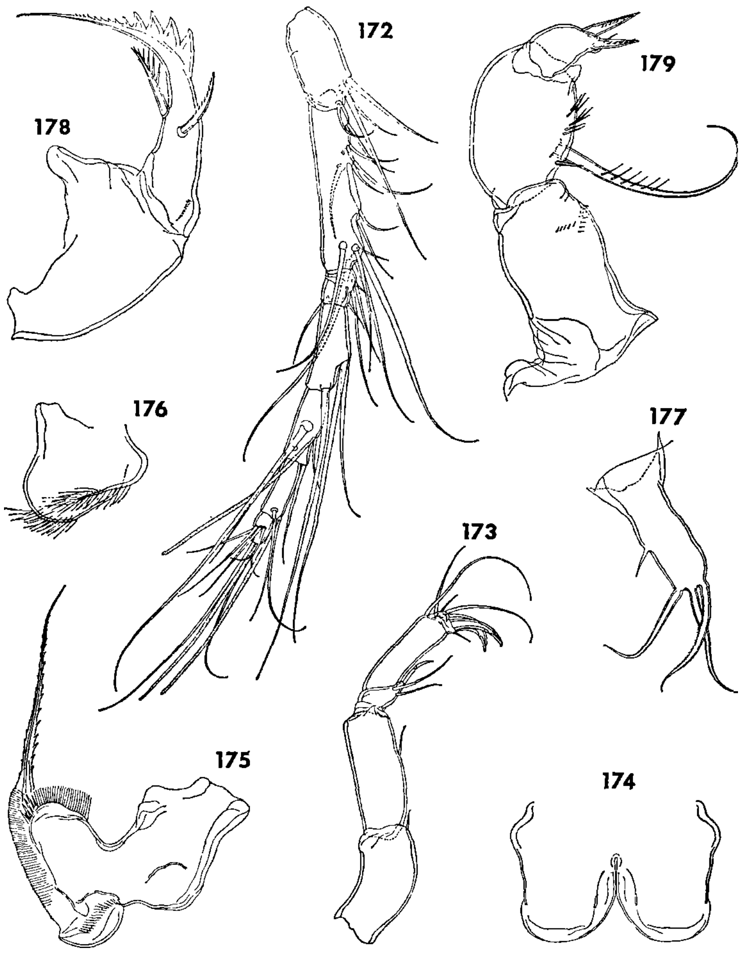
Lichomolgus singularipes new species

Figures 168–187

Type material: 40 ♀ ♀ from several encrusting colonies of *Parerythropodium rubiginosum* Verseveldt, in 2 m, Ambariobe, a small island almost between Nosy Komba and Nosy Bé, Madagascar, collected 4 October 1964. Holotype and 30 paratypes deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

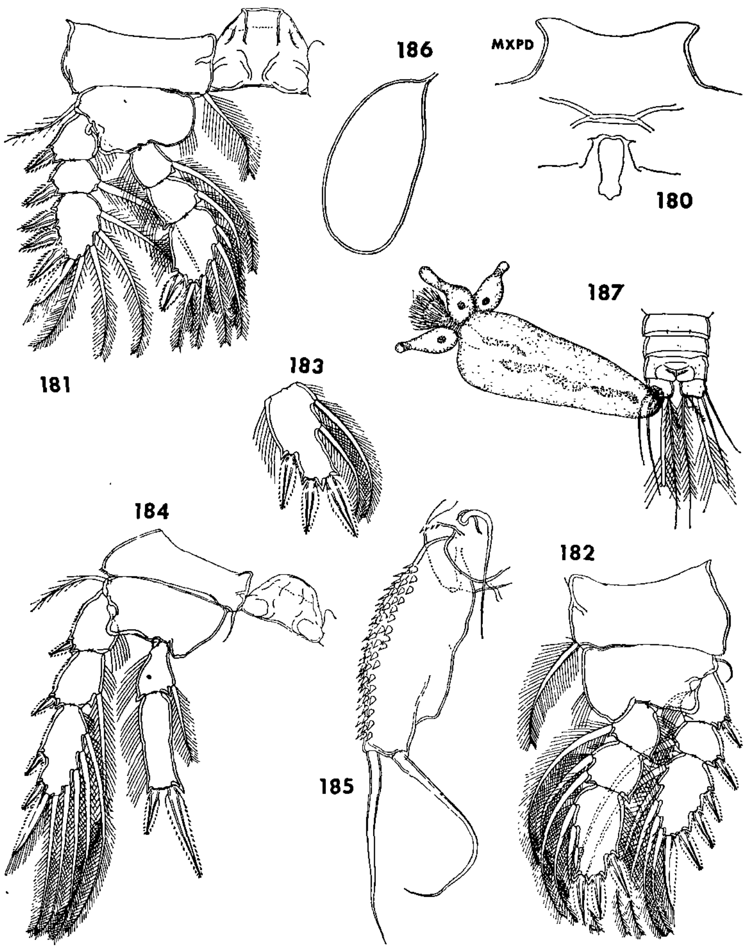
Female: Body (fig. 168) with rather slender prosome. Length 0.95 mm (0.88–1.01 mm) and greatest width 0.40 mm (0.39–0.42 mm), based on 10 specimens. Ratio of length to width of prosome 1.86 : 1. Segment of leg 1 separated from head by a dorsal transverse furrow. Epimeral areas of segments of legs 1–4 rounded.

Segment of leg 5 (fig. 169) 57 μ × 120 μ. Between this segment and genital segment a very short ventral intersegmental sclerite. Genital segment a little longer than wide, 120 μ × 107 μ, in dorsal view not greatly expanded, with its posterior eighth set off by transverse dorsal ridges and at first glance suggesting a postgenital segment. Areas of attachment of egg sacs situated dorsolaterally just posterior to middle of segment. Each area (fig. 170) with two spiniform naked setae 11 μ and 17 μ long. Three postgenital segments 26 μ × 68 μ, 21 μ × 63 μ, and 29 μ × 61 μ, from anterior to posterior.



Figs. 172–179. *Lichomolgus singularipes*, new species, female: 172, first antenna, ventral (D); 173, second antenna, posterior (outer) (D); 174, labrum, ventral (F); 175, mandible, posterior (E); 176, paragnath, posterior (C); 177, first maxilla, posterior (E); 178, second maxilla, posterior (E); 179, maxilliped, anterior (E).

Caudal ramus (fig. 171) quadrate, 24 μ × 25 μ in greatest dimensions. Outer lateral seta 83 μ and naked, dorsal pedicellate seta 40 μ and feathered, outermost distal seta 95 μ and naked, innermost distal seta 161 μ with proximal spinules, and the two long median terminal setae 275 μ (outer) and 360 μ (inner) with strong spinules except near tips,



FIGS. 180–187. *Lichomolgus singularipes*, new species, female: 180, area between maxillipeds and first pair of legs, ventral (D); 181, leg 1 and intercoxal plate, anterior (D); 182, leg 2, anterior (D); 183, last segment of endopod of leg 3, anterior (D); 184, leg 4 and intercoxal plate, anterior (D); 185, leg 5, dorsal (E); 186, spermatophore, empty and attached to female, dorsal (D); 187, *Ophryodendron* sp., attached to caudal ramus, dorsal (B).

both inserted between dorsal (unornamented) and ventral (with a marginal row of very small spinules) flaps.

Dorsal surface of prosome and urosome with a few small hairs. Ratio of length of prosome to that of urosome 2.62 : 1.

Egg sac (fig. 168) elongated, 500 μ × 200 μ, reaching almost to tips of ramal setae, containing numerous (fewer than in previous species) moderately large eggs about 60 μ in diameter.

Rostral area as in *L. spathophorus.*

First antenna (fig. 172) 7-segmented and armed as in all previous species. Setae naked and rather long. Lengths of segments: 33 μ (61 μ along anterior margin), 115 μ, 22 μ, 61 μ, 51 μ, 40 μ, and 23 μ respectively.

Second antenna (fig. 173) 4-segmented. Last segment 80 μ along its outer edge, 53 μ along its inner edge, and 20 μ wide, bearing distally five hyaline setae (three of them long) and two unequal terminal claws, the stouter claw 36 μ along its axis, the more slender claw 43 μ. All setae naked.

Labrum (fig. 174) with two moderately elongated lobes. Mandible (fig. 175) similar to that of *L. foxi.* Paragnath (fig. 176) a small hairy lobe. First maxilla (fig. 177) with three terminal elements and one subterminal. Second maxilla (fig. 178) with lash bearing several large proximal teeth, followed by a row of small spines; tip of lash naked. Maxilliped (fig. 179) resembling in general form that of *L. commodus* Humes, 1964, with two setae on second segment extremely unequal, the shorter seta naked, the longer one with a row of 6–9 long erect spinules. Last segment with two rather slender spiniform terminal elements and a small seta. Ornamentation on first two segments of maxilliped as in figure.

Area between maxillipeds and first pair of legs (fig. 180) not protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 181–184) segmented as in previous species, with spine and setal formula as in *L. hetaericus* and *L. spathophorus* (the formula for last segment of exopod of leg 4 being II,I,5). Inner seta on coxa of legs 1–3 long and plumose, but in leg 4 shorter (23 μ) and naked. Inner margin of basis of legs 1–3 with row of hairs, but in leg 4 naked. Outer seta on basis of leg 2 shorter than in other legs and naked. Endopod of leg 4 (fig. 184) shorter than exopod. First segment 33 μ × 26 μ (not including processes), its inner distal feathered seta 50 μ. Second segment 70 μ × 21 μ (length including processes and width taken at middle), its two unequal terminal barbed spines 32 μ (outer) and 67 μ (inner). Both segments with hairs along outer margins and second segment with a row of spinules near insertions of terminal spines.

Leg 5 (fig. 185) with rather broad free segment, 81 μ × 34 μ in greatest dimensions, its outer surface with scalelike spines and its inner margin abruptly expanded a short distance from distal end of segment, the contour of margin from this point to base of segment being irregular as in figure. Two terminal naked setae 68 μ (outer) and 82 μ (inner). Seta on body near insertion of free segment 44 μ and naked. A row of small spines near this seta.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 170).

Spermatophore (fig. 186), attached to female and empty, elongated, 125 $\mu \times 60$ μ (not including neck).

Color in life in transmitted light slightly opaque, eye red, ovary gray, egg sacs gray.

Male: Unknown.

Etymology: The specific name *singularipes*, from Latin *singularis* = remarkable, extraordinary, and *pes* = foot, refers to the unusual form of leg 5.

Comparison with related species: L. singularipes may be distinguished by the form of leg 5 from all other species in the genus having similarly a quadrate caudal ramus, two short claws on the second antenna, and the formula II,I,5 on the last segment of the exopod of leg 4. The maxilliped of the new species resembles that of *L. commodus* Humes, 1964, but leg 5 in the latter is very different (ratio about 4 : 1 with a slight proximal inner expansion).

L. singularipes cannot be directly compared with *L. vagans* Gurney, 1927, and *L. aegyptius* Gurney, 1927, of which only males are known. In *L. vagans* the length of the male is 1.07 mm, the second antenna is unusually long and slender, and the caudal ramus is a little longer than wide. In the male of *L. aegyptius* the second antenna has terminally three claws and two setae and the form of the mandible (Gurney's fig. 112D) is distinctly different from that in *L. singularipes.* It is very unlikely, therefore, that the new species could be the same as either of Gurney's species.

Epibiotic protozoan on L. singularipes: Thirteen of the 40 females collected (33 per cent) had large suctorians, identified by Dr. John O. Corliss as *Ophryodendron* sp., attached to the caudal ramus. These epibionts were not specially stained, but observed only incidentally in dissections in lactic acid. The greatest dimensions of the specimen drawn (fig. 187), which shows three buds, were 275 $\mu \times 78$ μ, the length being almost one-third that of the copepod.

The suctorians were attached always to the dorsal surface of the caudal rami, and there was never more than one on each ramus. They were distributed on the 13 females as follows: 8 copepods had one on the right caudal ramus, 4 copepods had one on the left ramus, and one copepod had two suctorians, one on each ramus.

Since only female copepods were collected, it is not known whether male copepods also bear these suctorians.

Lichomolgus squamiger Humes and Frost, 1964

This species has been previously recorded from *Sinularia polydactyla* (Ehrenberg) at Nosy Bé, Madagascar (Humes and Frost, 1964).

New host record: From *Sinularia whiteleggei* Lüttschwager: 36 ♀ ♀, 24 ♂ ♂, and 19 copepodids from one colony, in 2 m, Pte. Lokobe, Nosy Bé, 16 August 1960.

Two minor additions should be made to the original description by Humes and Frost. In their figure 174 of the second antenna of the female, there are six small hyaline elements near the terminal claw, and in their figure 180 of the maxilliped of the female there is a small seta on the last segment in addition to the two terminal elements. These features have been verified by studying a paratype of *L. squamiger*.

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Reprinted from *Proc. Biol. Soc. Wash.*, vol. 81, 1968, p. 693-750

CYCLOPOID COPEPODS OF THE GENUS *LICHOMOLGUS* ASSOCIATED WITH OCTOCORALS OF THE FAMILIES XENIIDAE, NIDALIIDAE, AND TELESTIDAE IN MADAGASCAR

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In two previous papers (Humes and Ho, 1968b and 1968c) several new species of *Lichomolgus* were described, all associated with octocorals of the families Nephtheidae and Alcyoniidae in the region of Nosy Bé, in northwestern Madagascar. This paper deals with seven new species associated with the alcyonacean families Xeniidae (*Anthelia, Heteroxenia,* and *Xenia*) and Nidaliidae (*Siphonogorgia*) and with the telestacean family Telestidae (*Telesto* and *Coelogorgia*) from the same geographical area.

All collections were made by A. G. Humes, those in 1960 during an expedition sponsored by the Academy of Natural Sciences of Philadelphia, and those in 1963–64 as part of the U. S. Program in Biology of the International Indian Ocean Expedition.

The study of the specimens has been aided by a grant (GB-5838) from the National Science Foundation of the United States.

All figures have been drawn with the aid of a camera lucida. The letter after the explanation of each figure refers to the scale at which it was drawn. The abbreviations used are: A_1 = first antenna, A_2 = second antenna, MXPD = maxilliped, and P_1 = leg 1.

All descriptions are based on type material. The measurements of the length of the body have been made in all cases from specimens in lactic acid and do not include the setae on the caudal rami. The lengths of the segments of the first antennae have been measured along their posterior nonsetiferous margins.

We are indebted to Mme. A. Tixier-Durivault of the Muséum National d'Histoire Naturelle, Paris, for the identifications of the octocorals collected in 1960, and to Dr. J. Verseveldt, Zwolle, The Netherlands, for the determinations of those collected in 1963–64.

The new copepods described below are as follows:

1. *Lichomolgus verseveldti* new species
   from *Heteroxenia elisabethae* Kölliker.
2. *Lichomolgus triquetrus* new species
   from *Anthelia gracilis* (May).
3. *Lichomolgus glabripes* new species
   from *Xenia umbellata* Lamarck.
4. *Lichomolgus longispinifer* new species
   from *Siphonogorgia pendula* Studer.
5. *Lichomolgus hians* new species
   from *Siphonogorgia pendula* Studer.
6. *Lichomolgus telestophilus* new species
   from *Telesto arborea* Wright and Studer.
7. *Lichomolgus clavatus* new species
   from *Coelogorgia palmosa* Milne Edwards and Haime.

FAMILY LICHOMOLGIDAE KOSSMANN, 1877

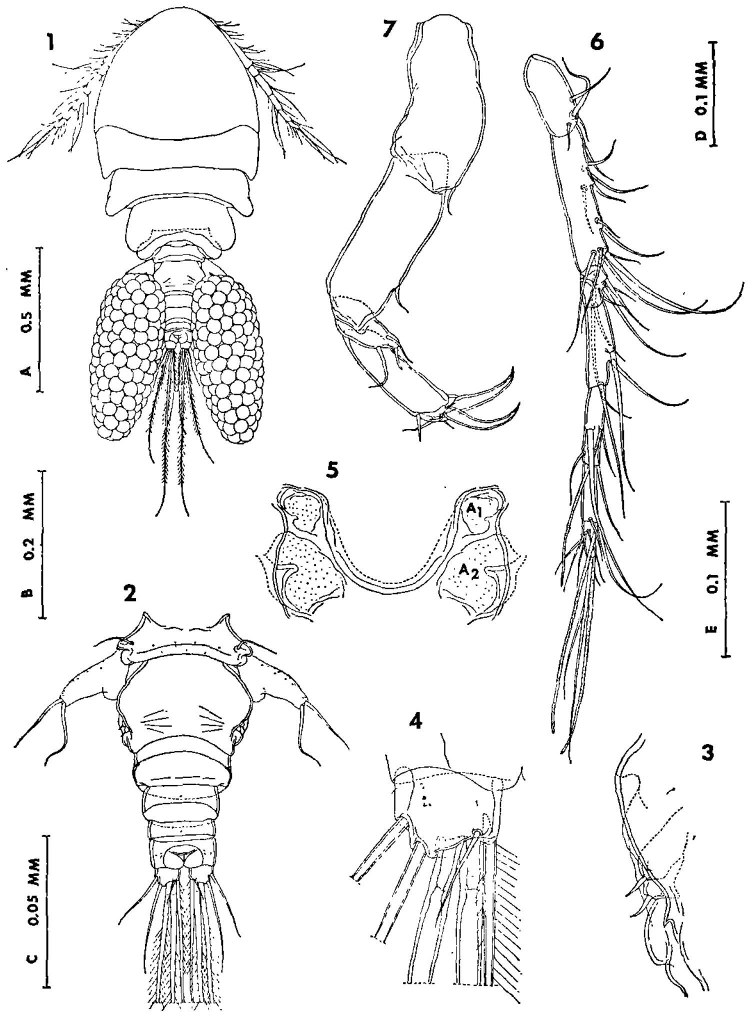
Genus *Lichomolgus* Thorell, 1859

Lichomolgus verseveldti new species

Figures 1–26

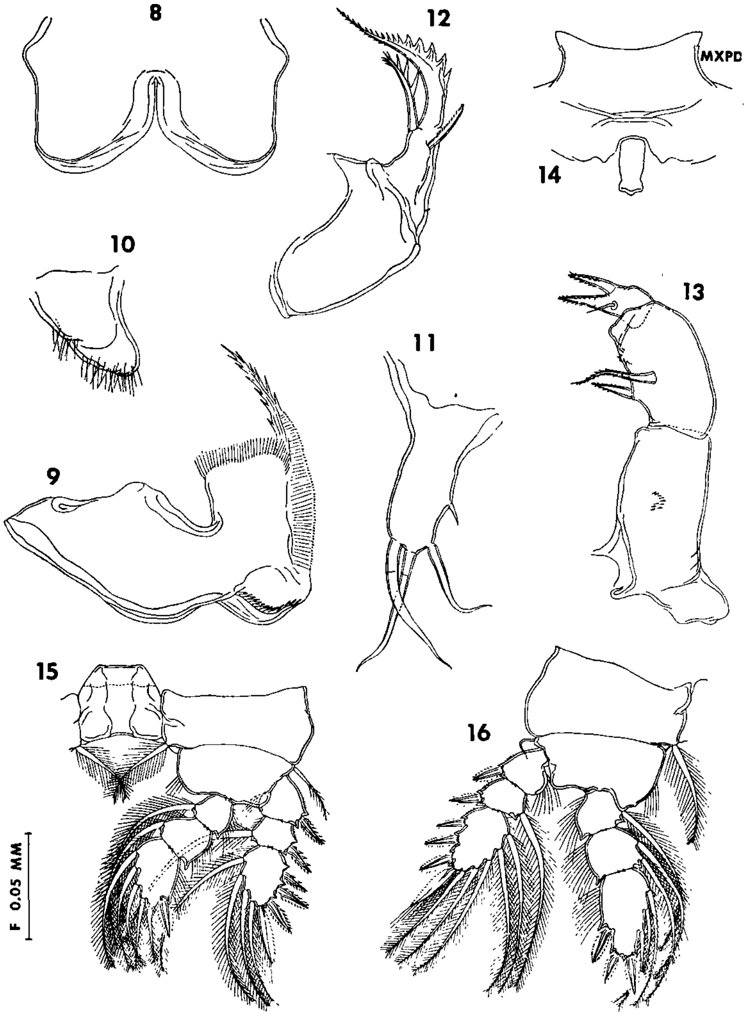
Type material: 92 ♀♀, 25 ♂♂, and 7 copepodids from colonies of *Heteroxenia elisabethae* Kölliker, in 1 m, Pte. Lokobe, Nosy Bé, Madagascar, collected 13 August 1960. Holotype ♀, allotype, and 81 paratypes (65 ♀♀, 16 ♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Other specimens (all from *Heteroxenia elisabethae*): 16 ♀♀, 4 ♂♂, and 3 copepodids, in 1 m, Pte. Lokobe, 12 August 1960; 14 ♀♀, 1 copepodid, in 1 m, Pte. Lokobe, 1 November 1960; and 40 ♀♀, 25 ♂♂, and 3 copepodids, in 1 m, Pte. Ambarionaomby, Nosy Komba, near Nosy Bé, 27 September 1964.

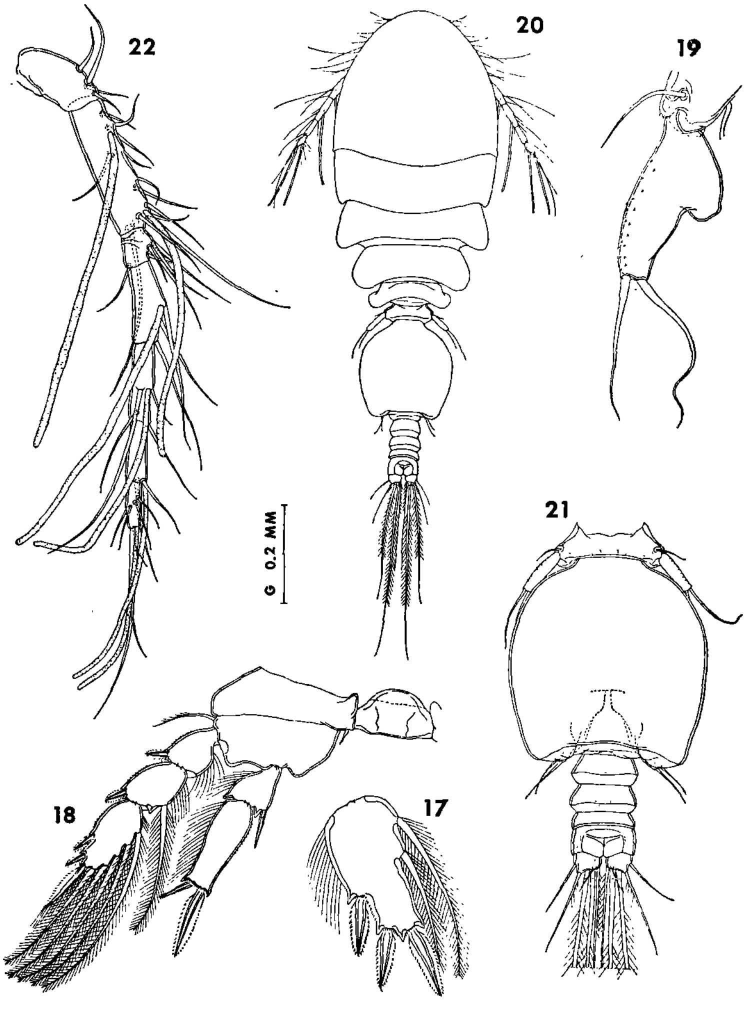


FIGS. 1–7. *Lichomolgus verseveldti*, new species, female: 1, body dorsal (A); 2, urosome, dorsal (B); 3, area of attachment of egg sac, dorsal (C); 4, caudal ramus, dorsal (C); 5, rostral area, ventral (D); 6, first antenna, ventral (D); 7, second antenna, posterior (outer) (E).

Female: Body (fig. 1) with prosome not unusually broadened. Length 1.20 mm (1.12–1.25 mm) and greatest width 0.54 mm (0.51–0.58 mm), based on 10 specimens. Ratio of length to width of prosome 1.47 : 1. Segment of leg 1 distinctly separated from head dorsally by a



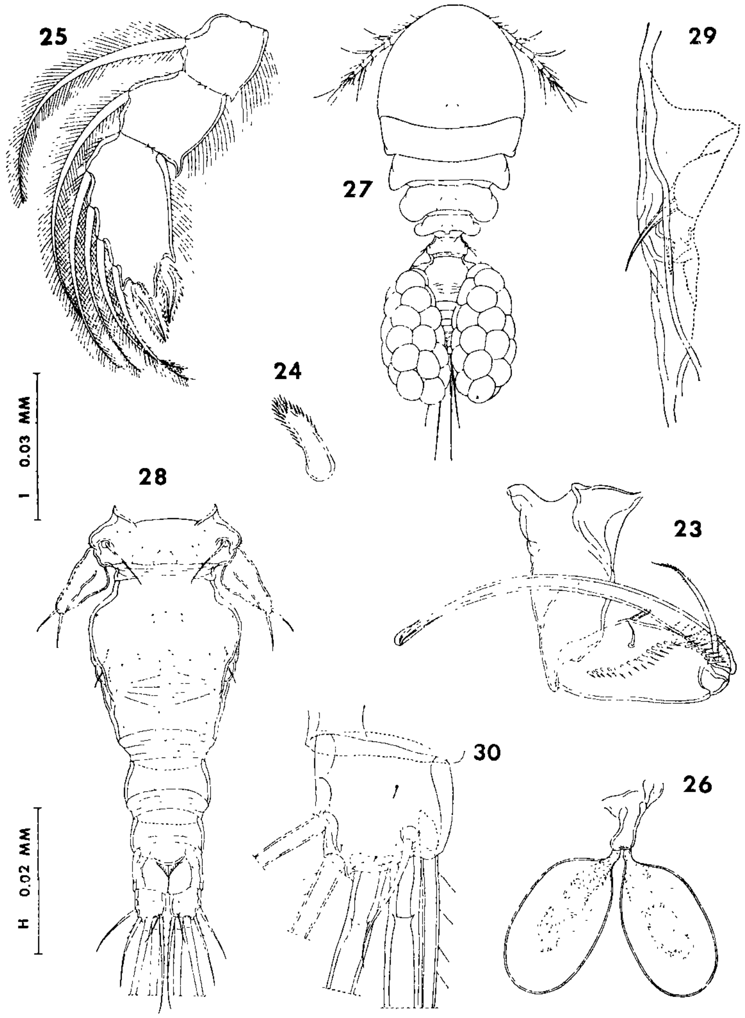
Figs. 8–16. *Lichomolgus verseveldti*, new species, female: 8, labrum, ventral (F); 9, mandible, posterior (C); 10, paragnath, ventral (C); 11, first maxilla, posterior (C); 12, second maxilla, posterior (F); 13, maxilliped, posterior (F); 14, area between maxillipeds and first pair of legs, ventral (D); 15, leg 1 and intercoxal plate, anterior (D); 16, leg 2, anterior (D).



Figs. 17–22. *Lichomolgus verseveldti*, new species, female: 17, third segment of endopod of leg 3, anterior (E); 18, leg 4 and intercoxal plate, anterior (D); 19, leg 5, dorsal (E). Male: 20, body, dorsal (G); 21, urosome, dorsal (D); 22, first antenna, ventral (E).

transverse furrow. Epimeral areas of segments of legs 1–4 as shown in figure.

Segment of leg 5 (fig. 2) 68 μ × 187 μ. Between this segment and genital segment a slight ventral intersegmental sclerite. Genital segment



FIGS. 23–30. *Lichomolgus verseveldti*, new species, male: 23, maxilliped, inner (F); 24, outer element on second segment of maxilliped, posterior (H); 25, endopod of leg 1, anterior (C); 26, spermatophores, attached to genital segment of female, lateroventral (B). *Lichomolgus triquetrus*, new species, female: 27, body, dorsal (A); 28, urosome, dorsal (D); 29, area of attachment of egg sac, dorsal (I); 30, caudal ramus, dorsal (I).

only slightly longer than wide, 200 μ × 190 μ, widest in its anterior half and narrowed posteriorly, where the dorsal surface has two transverse lines simulating a segment but the ventral surface is smooth. Areas of attachment of egg sacs lateral in position just behind widest portion of segment. Each area (fig. 3) bearing two naked setae about 12 μ long. Three postgenital segments 55 μ × 101 μ, 34 μ × 91 μ, and 40 μ × 90 μ, from anterior to posterior.

Caudal ramus (fig. 4) slightly wider than long, 31 μ × 34 μ in greatest dimensions. Outer lateral seta 86 μ long and naked, pedicellate dorsal seta 33 μ and naked, outermost distal seta 130 μ and naked, innermost distal seta 260 μ with lateral spinules (mostly along inner edge), and the two long median terminal setae 495 μ (outer) and 620 μ (inner), both with strong lateral spinules and both inserted between unornamented dorsal and ventral flaps. A minute setule on proximal outer margin of ramus.

Dorsal surface of prosome without hairs; surface of urosome with only a few hairs and refractile points. Ratio of length of prosome to that of urosome 2.25 : 1.

Egg sac (fig. 1) elongated, 570 μ × 230 μ, with many eggs, each about 50 μ in diameter.

Rostral area (fig. 5) with a well defined broadly rounded posteroventral margin.

First antenna (fig. 6) 7-segmented, 495 μ long. Lengths of segments: 50 μ (77 μ along anterior margin), 138 μ, 35 μ, 78 μ, 74 μ, 56 μ, and 37 μ respectively. Formula for armature: 4, 13, 6, 3, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. All setae naked.

Second antenna (fig. 7) 4-segmented, last segment moderately elongated, 90 μ along its outer edge, 57 μ along its inner edge, 23 μ wide, bearing distally five small hyaline elements and two slightly unequal claws 55 μ and 46 μ in length. Distalmost of three setae on third segment with a blunt tip. All setae naked.

Labrum (fig. 8) with two posteroventral lobes. Mandible (fig. 9) with basal region distal to constriction showing on its convex margin a scalelike protrusion ornamented with a row of spinules, followed by a serrated fringe, and on its concave margin a row of slender spinules. Flagellum rather short and coarsely barbed. Paragnath (fig. 10) a small hairy lobe. First maxilla (fig. 11) with three long terminal and one short subterminal setae, all naked. Second maxilla (fig. 12) 2-segmented. First segment unarmed, second with a minute setule on its proximal outer (ventral) surface, a surficial posterior seta finely barbed along one edge, an inner (dorsal) distal spine with several large spinules along its distal edge, and the segment produced distally to form a lash with strong teeth along one edge proximally, grading into fine bilateral spinulation distally. Maxilliped (fig. 13) 3-segmented. First segment with a small posterior patch of spinules, second with an inner patch of spinules and two barbed setae, and third with a small naked seta and two terminal barbed spiniform elements, one without a distinct articulation.

Area between maxillipeds and first pair of legs (fig. 14) not protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 15–18) with trimerous rami except for endopod of leg 4 which is 2-segmented. Armature as follows (Roman numerals = spines, Arabic numerals = setae):

P_1	protopod	0–1	1–0	exp	I–0	I–1	III,I,4
				end	0–1	0–1	I,5
P_2	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,II,3
P_3	protopod	0–1	1–0	exp	I–0	I–1	III,I,5
				end	0–1	0–2	I,II,2
P_4	protopod	0–1	1–0	exp	I–0	I–1	II,I,5
				end	0–I	II	

Inner seta on coxa of legs 1–3 long and plumose, but in leg 4 short (17 μ) and naked. Outer margin of coxa of leg 1 showing a slight protrusion. Outer seta on basis short and naked in leg 2, longer and with lateral hairs in other legs. Inner margin of basis with row of hairs in legs 1–3, but naked in leg 4. Three middle spines on exopod of leg 1 with spinules along their proximal edges much stronger than in legs 2–4. Endopod of leg 4 (fig. 18) a little shorter than exopod. First segment 50 μ × 40 μ (including spiniform processes), with its inner distal element a slender naked spine 36 μ long. Second segment 97 μ (including processes) × 38 μ (greatest width), its two unequal terminal spines 34 μ (outer), with a slight distal fringe, and 72 μ (inner), with a prominent fringe. Both segments with outer margins haired, and second segment with a row of minute spinules on proximal inner margin and another row near insertions of terminal spines.

Leg 5 (fig. 19) with rather broad free segment, 122 μ long, with its proximal area expanded inwardly, width here being 55 μ. Segment bearing two terminal naked setae 91 μ (outer) and 114 μ (inner) and ornamented with small spinules on its outer surface. Seta on body near base of free segment 66 μ and naked; a few small spinules near its insertion.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 3).

Color in life in transmitted light opaque to translucid, eye red, ovary gray, egg sacs gray.

Male: Body (fig. 20) with prosome a little more slender than in female. Length 0.90 mm (0.86–0.94 mm) and greatest width 0.35 mm (0.33–0.36 mm), based on 10 specimens. Ratio of length to width of prosome 1.79 : 1.

Segment of leg 5 (fig. 21) 33 μ × 106 μ. No ventral intersegmental sclerite. Genital segment about as long as wide, 203 μ × 195 μ. Four postgenital segments 25 μ ×64 μ, 22 μ × 64 μ, 17 μ × 62 μ, and 24 μ × 63 μ, from anterior to posterior.

Caudal ramus much like that of female, 21 μ × 25 μ, with a few inner proximal hairs on outermost distal seta.

Dorsal surface of prosome smooth; surface of urosome with a few small hairs as in figure. Ratio of length of prosome to that of urosome 1.62 : 1.

Rostral area as in female.

First antenna (fig. 22) resembling that of female, but with two aesthetes added on second segment and one on fourth segment, so that formula is 4, 13 + 2 aesthetes, 6, 3 + 1 aesthete, 4 + 1 aesthete, 2 + 1 aesthete, and 7 + 1 aesthete. Second antenna like that of female, but with small spinules added on inner surface of first, second, and fourth segments.

Labrum, mandible, paragnath, first maxilla, and second maxilla like those of female. Maxilliped (fig. 23) 4-segmented, assuming that proximal part of claw represents a fourth segment. First segment unarmed. Second segment with two setae, one slender and naked, the other (fig. 24) stout, spiniform, obtusely tipped, and spinulose; and with two rows of moderately long spines. Third segment short and unarmed. Claw slender, 168 μ along its axis including terminal lamella, with a suggestion of division midway along its length, and bearing two proximal setae, that on inner surface long with a finely barbed tip, the other on concave margin short and naked.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with spine and setal formula as in that sex except for last segment of endopod of leg 1 (fig. 25) which is I,I,4. This endopod slightly geniculate. No sexual dimorphism in legs 2 or 3. Endopod of leg 4 as in female.

Leg 5 (fig. 21) with slender free segment 42 μ × 11 μ, without a proximal expansion. Outer surface with a few minute spinules. Two terminal naked setae 30 μ (inner) and 77 μ (outer). Seta on body near free segment 30 μ and naked.

Leg 6 (fig. 21) a posterolateral flap on ventral surface of genital segment bearing two naked setae 66 μ and 50 μ long.

Spermatophore (fig. 26), attached to female in pairs, elongated, 210 μ × 117 μ, not including neck.

Color in life as in female.

Etymology: This species is named for Dr. J. Verseveldt, who has identified many octocorals which were the hosts for copepods.

Comparison with related species: There are 40 species of *Lichomolgus* which, like *L. verseveldti*, have two claws on the second antenna and the formula II,I,5 for the third segment of the exopod of leg 4. Thirty-five of these have a seta (usually feathered) on the first segment of the endopod of leg 4, thus differing from the new species. In none of these is the proximal inner expansion (when present) of leg 5 like that in

L. verseveldti. L. securiger Humes, 1964, an associate of the nudibranch *Doris mabilla* Abraham in Madagascar, has a fifth leg somewhat resembling that of the new species, but differs in having a long flagellum on the mandible, spinules rather than strong teeth on the lash of the second maxilla, two extremely unequal setae on the second segment of the maxilliped of the female, a feathered seta on the first segment of the endopod of leg 4, relatively short aesthetes on the first antenna of the male, and the free segment of leg 5 in the male being about 2 : 1 instead of about 4 : 1 as in the new species.

The remaining five species in the genus (which similarly have two claws on the second antenna and the formula II,I,5 on the last segment of the exopod of leg 4) have a spine (rather than a seta) on the first segment of the endopod of leg 4, as in the new species. These species, the first five described by Humes and Ho (1968b), associated with nephtheid octocorals in Madagascar, may be distinguished from *L. verseveldti* by the combination of two characters,—the longer claws on the second antenna in both sexes and the form of leg 5 in the female.

Lichomolgus triquetrus new species

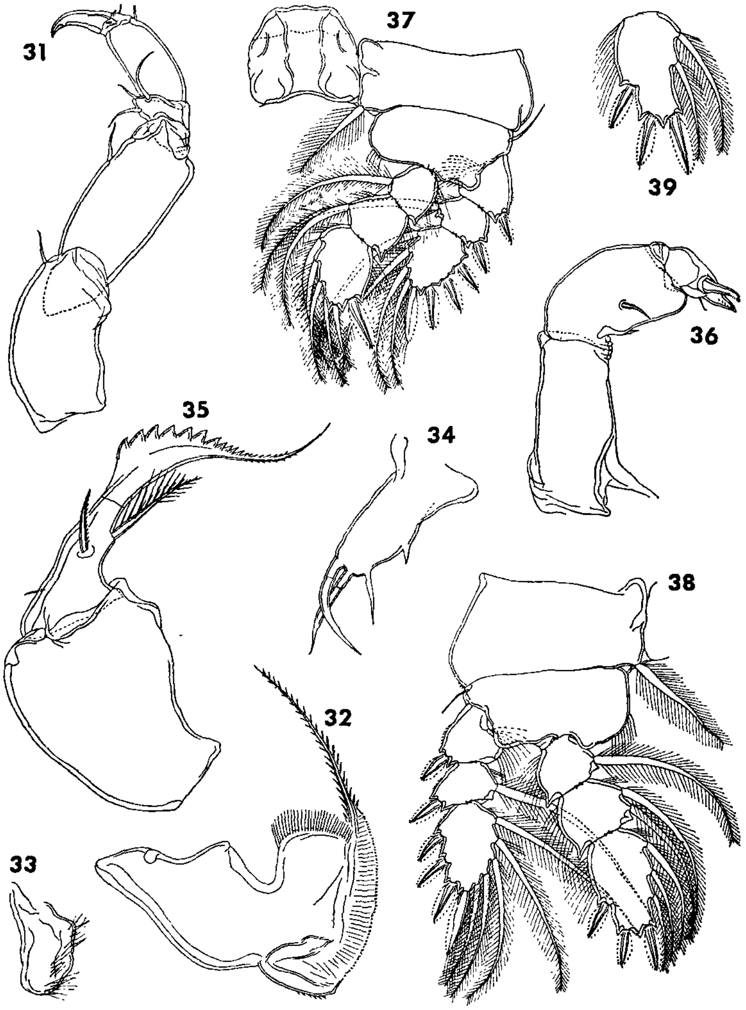
Figures 27–48

Type material: 74♀♀, 27♂♂, and 10 copepodids from *Anthelia gracilis* (May), on stems of *Cymodocea* in 0.5 m, Antsakoabe, Nosy Bé, Madagascar, collected 12 July 1964. Holotype ♀, allotype, and 75 paratypes (55♀♀, 20♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

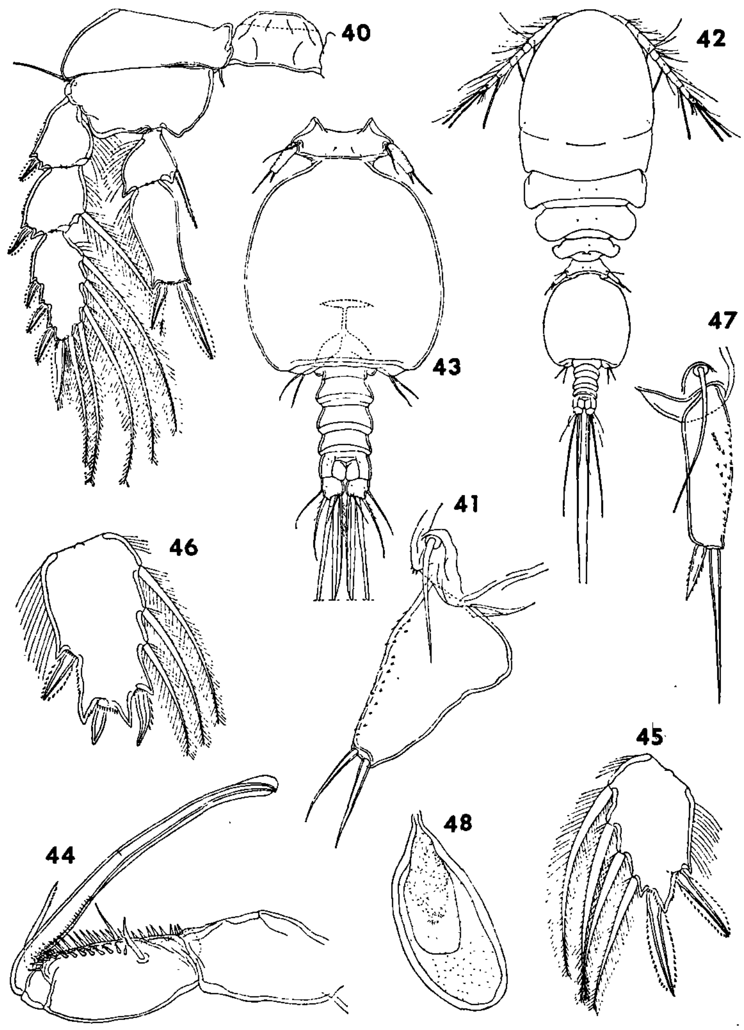
Female: Body (fig. 27) resembling that of *L. verseveldti.* Length 1.12 mm (1.01–1.23 mm) and greatest width 0.45 mm (0.42–0.47 mm), based on 10 specimens. Ratio of length to width of prosome 1.58 : 1. Segment of leg 1 separated from head by a dorsal furrow. Epimeral areas of segments of legs 1–4 as in figure.

Segment of leg 5 (fig. 28) 64 μ × 148 μ. Between this segment and genital segment a very slight ventral intersegmental sclerite. Genital segment a little longer than wide, 166 μ × 143 μ, in dorsal view broadest in its anterior third and tapering gradually posteriorly. Areas of attachment of egg sacs situated laterally near middle of segment. Each area (fig. 29) with two naked unequal setae, the longer one 21 μ and attenuated, the shorter one 10 μ with a rather blunt tip. Three postgenital segments 50 μ × 80 μ, 33 μ × 69 μ, and 39 μ × 66 μ, from anterior to posterior.

Caudal ramus (fig. 30) quadrate, 30 μ × 28 μ in greatest dimensions. Outer lateral seta 52 μ and naked, pedicellate dorsal seta 25 μ and naked, outermost distal seta 68 μ with only a few proximal outer spinules, innermost distal seta 115 μ with inner spinules, and the two long median terminal setae 240 μ (outer) and 385 μ (inner), both naked and both inserted between unornamented dorsal and ventral flaps.



FIGS. 31–39. *Lichomolgus triquetrus*, new species, female: 31, second antenna, posterior (outer) (F); 32, mandible, posterior (C); 33, paragnath, ventral (C); 34, first maxilla, anterior (C); 35, second maxilla, posterior (C); 36, maxilliped, posterior (F); 37, leg 1 and intercoxal plate, anterior (E); 38, leg 2, anterior (E); 39, third segment of endopod of leg 3, anterior (E).



Figs. 40–48. *Lichomolgus triquetrus*, new species, female: 40, leg 4 and intercoxal plate, anterior (E); 41, leg 5, dorso-inner (C). Male: 42, body, dorsal (G); 43, urosome, dorsal (D); 44, maxilliped, outer (F); 45, third segment of endopod of leg 1, anterior (C); 46, third segment of endopod of leg 2, anterior (C); 47, leg 5, dorsal (I); 48, spermatophore, as seen inside genital segment of male, dorsal (D).

Dorsal surface of prosome and urosome with a few hairs. Ratio of length of prosome to that of urosome 1.94 : 1.

Egg sac (fig. 27) elongated, 473 μ × 204 μ, reaching well beyond caudal rami and containing about 22–26 moderately large eggs, each approximately 68 μ in diameter.

Rostral area as in *L. verseveldti.*

First antenna also like that of *L. verseveldti,* with same formula for armature. Lengths of segments: 23 μ (57 μ along anterior margin), 112 μ, 22 μ, 49 μ, 46 μ, 35 μ, and 22 μ respectively. All setae naked. Second antenna (fig. 31) 4-segmented, last segment not greatly elongated, 58 μ along its outer edge, 40 μ along its inner edge, 23 μ wide, bearing distally six small hyaline elements and a single relatively short claw 31 μ along its axis. All setae naked.

Labrum as in *L. verseveldti.* Mandible (fig. 32) with fewer spinules on protrusion of convex margin of basal part distal to constriction and with flagellum longer than in *L. verseveldti.* Paragnath (fig. 33) a small hairy lobe. First maxilla (fig. 34) with four elements as in *L. verseveldti.* Second maxilla (fig. 35) in general like that of *L. verseveldti,* but with inner distal spine of second segment with three rows of slender spinules. Maxilliped (fig. 36) lacking patches of spinules on first and second segments and the two setae on second segment naked and smaller than in *L. verseveldti.*

Area between maxillipeds and first pair of legs as in *L. verseveldti,* but slightly protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 37–40) segmented as in *L. verseveldti,* and with same spine and setal formula except for leg 4 where exopod is I–0; I–1; III,I,5 and endopod is 0–1; II. Inner seta on coxa of leg 4 short (15 μ) and naked, instead of long and plumose as in legs 1–3. Outer seta on basis short in leg 2, as in *L. verseveldti,* and inner margin of basis naked in leg 4 as in that species. Endopod of leg 4 (fig. 40) shorter than exopod. First segment 40 μ × 39 μ (including spiniform processes), with inner distal element a seta 38 μ long which is lightly feathered in some specimens and apparently naked in others. Second segment 70 μ × 33 μ in greatest dimensions including processes, its two unequal terminal fringed spines 35 μ (outer) and 54 μ (inner). Both segments with outer margins haired and second segment with a row of minute spinules near insertions of terminal spines.

Leg 5 (fig. 41) with rather triangular free segment, 63 μ × 39 μ in greatest dimensions, bearing two relatively short terminal naked setae 29 μ (outer) and 31 μ (inner). Small spinules on outer surface of segment. Seta on body near base of segment 44 μ and naked, a few small spinules near its insertion.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 29).

Color in life in transmitted light translucid except for fine reddish brown speckling, eye red, ovary gray, egg sacs greenish gray.

Male: Body (fig. 42) similar in general form to that of female, but prosome a little more slender. Length 0.89 mm (0.85–0.96 mm) and greatest width 0.29 mm (0.28–0.30 mm), based on 10 specimens. Ratio of length to width of prosome 1.85 : 1.

Segment of leg 5 (fig. 43) 41 μ × 98 μ. No ventral intersegmental sclerite. Genital segment about as long as wide, 205 μ × 195 μ. Four postgenital segments 31 μ × 58 μ, 25 μ × 55 μ, 23 μ × 52 μ, and 25 μ × 50 μ, from anterior to posterior.

Caudal ramus similar to that of female, but smaller, 23 μ × 22 μ.

Dorsal surface of prosome and urosome with a few hairs. Ratio of length of prosome to that of urosome 1.58 : 1.

Rostral area as in female.

First antenna as in *L. verseveldti*, with three aesthetes added as in that species. Second antenna as in female, without sexual dimorphism.

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 44) with two setae on second segment attenuated, one of them with small spinules along one edge, the other naked. Claw 168 μ along its axis including terminal lamella, with its outer proximal surface faintly striated. Otherwise maxilliped similar to that of *L. verseveldti*.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with spine and setal formula as in that sex except for last segment of endopod of leg 1 (fig. 45) which is I,I,4. (One male showed the formula I,5 on both first legs, but the usual condition is I,I,4.) Last segment of endopod of leg 2 (fig. 46) with same formula as in female, but two terminal spines modified. Legs 3 and 4 as in female.

Leg 5 (fig. 47) with an elongated and somewhat rectangular free segment, 33 μ × 10 μ with nearly parallel sides. Two terminal elements very unequal, the outer one a naked seta 31 μ long, the inner one a delicately barbed spine 12 μ. (In the same male mentioned above which showed the abnormal armature of the last segment of the endopod of leg 1, the fifth leg had the unusual condition of two nearly equal naked setae, as in the female.) Outer surface of segment with small spinules. Seta on body near free segment 30 μ and naked.

Leg 6 (see fig. 43) a posterolateral flap on ventral surface of genital segment bearing two naked setae about 33 μ long.

Spermatophore (fig. 48), seen only inside genital segment of male, elongated with an unusually thick wall.

Color in life as in female.

Etymology: The specific name *triquetrus*, from Latin = three-cornered, triangular, refers to the rather triangular form of the free segment of leg 5 in the female.

Comparison with related species: In six species of *Lichomolgus* the second antenna bears terminally a single claw and a few small hyaline elements and the formula for the last segment of the exopod of leg 4 is III,I,5, as in the new species. All of these differ from *L. triquetrus*, however, in significant respects. In *L. dentipes* Thompson and A. Scott, 1903, there is a large toothlike process on leg 5 of the female. (This species has been redescribed by Humes and Ho, 1968c.) In *L. protentus* Humes and Frost, 1964, the caudal ramus of the female is twice as long as wide, and the formula for the endopod of leg 4 is 0–1; 1,I. In *L. spinipes* (Sewell, 1949) leg 5 of the female is long and curved, and the formula for the endopod of leg 4 is 0–1; 1,I. In *L. squamiger* Humes and Frost, 1964, the areas of attachment of the egg sacs are dorsolateral, the endopod of leg 4 is a little longer than the exopod, and leg 5 in the female is elongated with broad scalelike spines. In the two remaining species, *L. cristatus* and *L. adelphus*, both described by Humes and Ho (1968c), leg 5 in the female is elongated, at least five times longer than wide.

In *L. elegans* Thompson and A. Scott, 1903, the second antenna of the female has a single claw as in the new species. The armature of the exopod of leg 4 is undescribed. (The male is unknown.) This Ceylonese species differs from *L. triquetrus* in the genital segment having "a wedge-shaped notch near the centre on each side," in the second segment of the first antenna being relatively longer, and in the inner distal seta on the first segment of the endopod of leg 4 being longer and more conspicuously feathered.

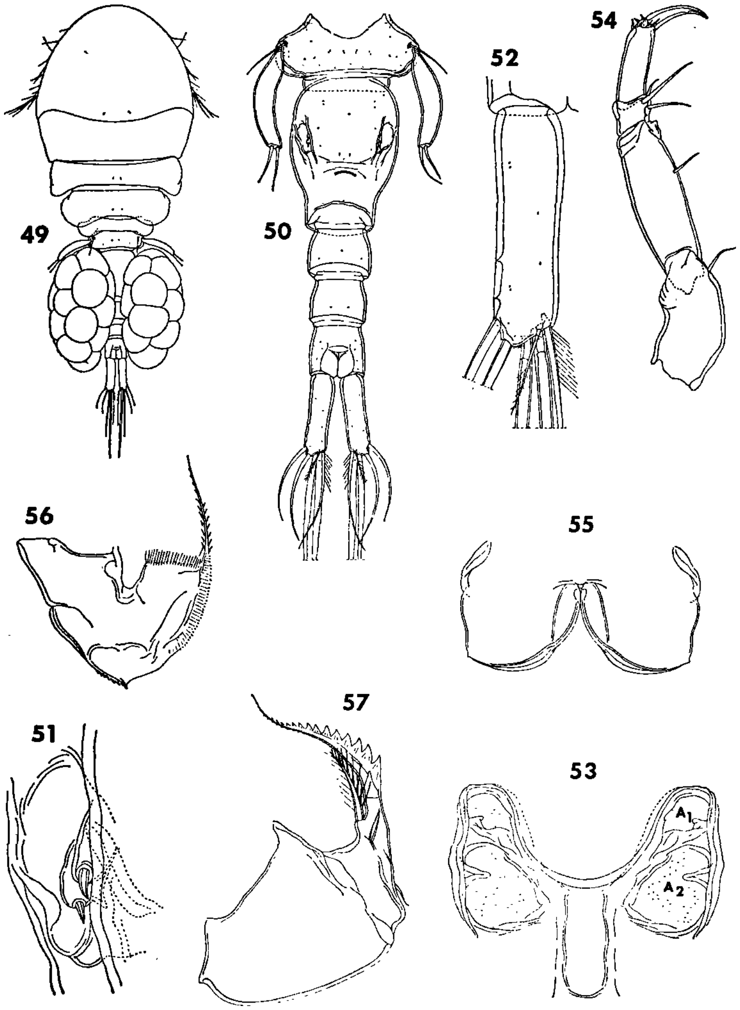
Lichomolgus glabripes new species
Figures 49–68

Type material: 53♀♀, 37♂♂, and 33 copepodids from *Xenia umbellata* Lamarck, in 1 m, Andilana, Nosy Bé, Madagascar, collected 9 August 1963. Holotype ♀, allotype and 69 paratypes (40♀♀, 29♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

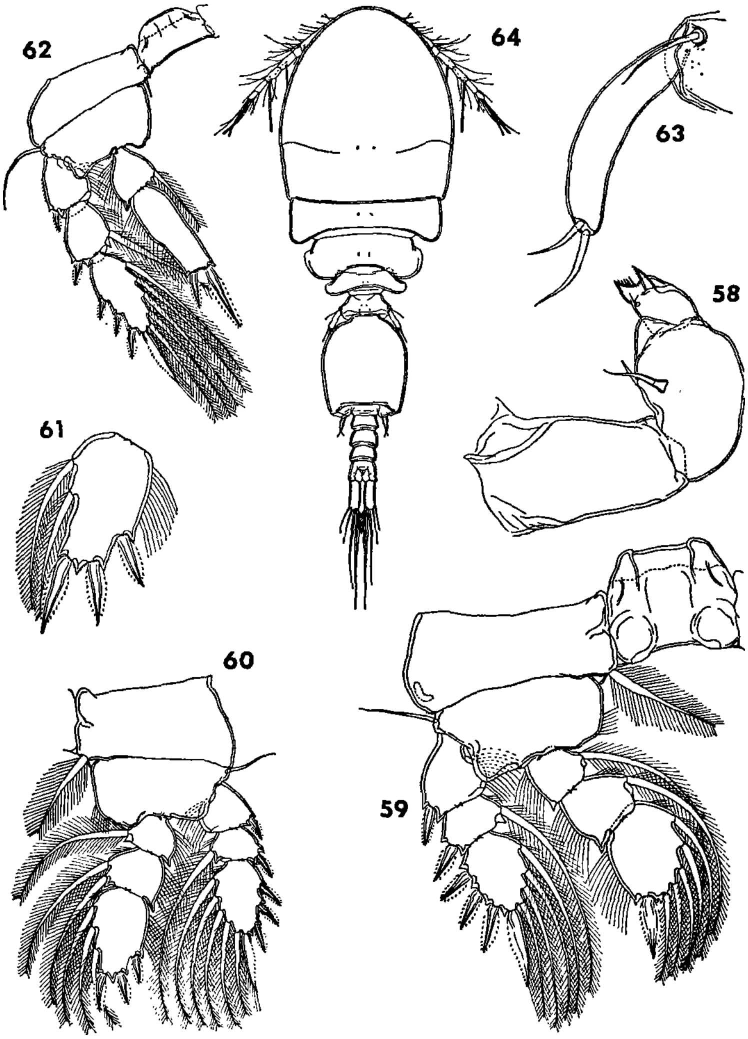
Female: Body (fig. 49) with a moderately slender prosome. Length 1.33 mm (1.26–1.42 mm) and greatest width 0.53 mm (0.51–0.55 mm), based on 10 specimens. Ratio of length to width of prosome 1.46 : 1. Segment of leg 1 separated from head by a dorsal furrow. Epimeral areas of segments of legs 1–4 as in figure.

Segment of leg 5 (fig. 50) 99 μ × 200 μ. Between this segment and genital segment a short ventral intersegmental sclerite. Genital segment longer than wide, 200 μ × 151 μ in greatest dimensions, its posterior part in dorsal view somewhat constricted (99 μ wide). Areas of attachment of egg sacs located dorsolaterally just anterior to middle of segment. Each area (fig. 51) with two short naked spiniform setae 7 μ and 4.5 μ long. Three postgenital segments 75 μ × 87 μ, 62 μ × 78 μ, and 70 μ × 78 μ, from anterior to posterior.

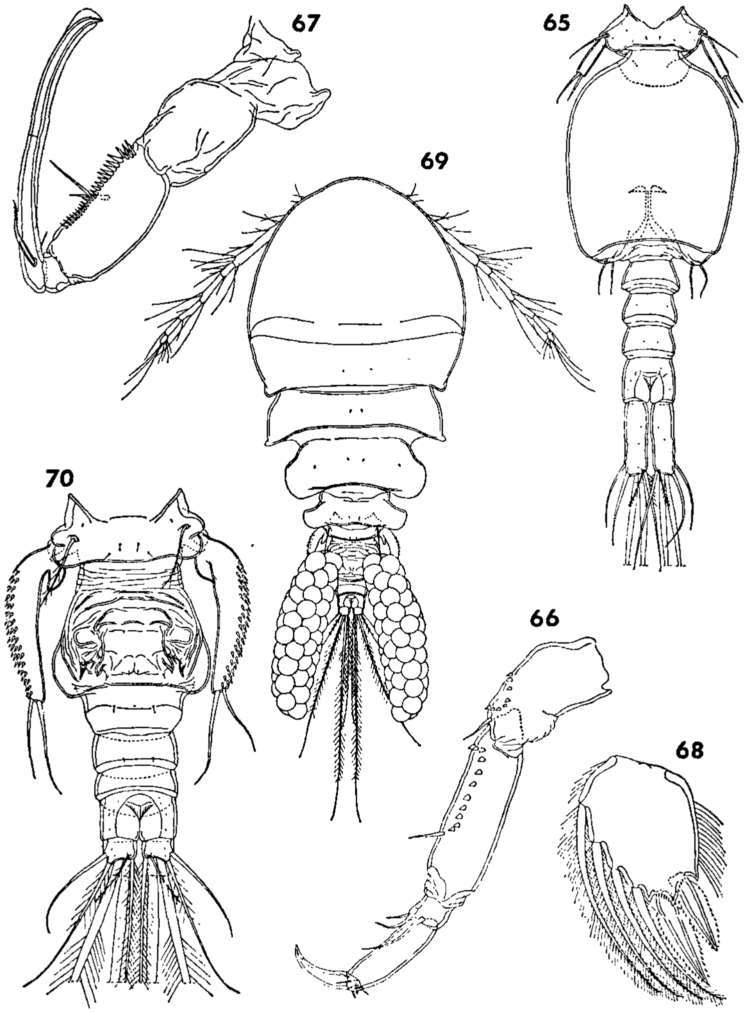
Caudal ramus (fig. 52) elongated, 110 μ × 32 μ, or 3.4 times longer than wide. Outer lateral seta 112 μ and naked, pedicellate dorsal seta 33 μ and lightly feathered, outermost distal seta 120 μ and naked, inner-



FIGS. 49–57. *Lichomolgus glabripes*, new species, female: 49, body, dorsal (A); 50, urosome, dorsal (B); 51, area of attachment of egg sac, dorsal (I); 52, caudal ramus, dorsal (F); 53, rostral area, ventral (E); 54, second antenna, posterior (outer) (E); 55, labrum, ventral (F); 56, mandible, posterior (F); 57, second maxilla, posterior (F).



FIGS. 58–64. *Lichomolgus glabripes*, new species, female: 58, maxilliped, posterior (F); 59, leg 1 and intercoxal plate, anterior (E); 60, leg 2, anterior (D); 61, third segment of endopod of leg 3, anterior (E); 62, leg 4 and intercoxal plate, anterior (D); 63, leg 5, dorsal (E). Male: 64, body, dorsal (G).



FIGS. 65–70. *Lichomolgus glabripes*, new species, male: 65, urosome, dorsal (D); 66, second antenna, posterior (outer) (F); 67, maxilliped, inner (E); 68, third segment of endopod of leg 1, anterior (C). *Lichomolgus longispinifer*, new species, female: 69, body, dorsal (G); 70, urosome, dorsal (E).

most distal seta 130 μ with prominent inner proximal hairs, and the two long median terminal setae 200 μ (outer) and 263 μ (inner), both naked and inserted between an unornamented dorsal flap and a ventral flap with a marginal row of minute spinules.

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 1.42 : 1.

Egg sac (fig. 49) elongated oval, 396 μ × 220 μ, reaching just beyond anal segment and containing about 15–17 eggs, each approximately 105 μ in diameter.

Rostral area (fig. 53) with broadly rounded posteroventral margin.

First antenna 340 μ long, with segmentation and armature as in *L. verseveldti* and *L. triquetrus*. Lengths of segments: 25 μ (55 μ along anterior edge), 105 μ, 28 μ, 46 μ, 47 μ, 35 μ, and 24 μ respectively. All setae naked. Second antenna (fig. 54) 4-segmented and slender, last segment 61 μ along its outer edge, 44 μ along its inner edge, 18 μ wide, bearing distally six small hyaline elements and a single short claw 40 μ along its axis. All setae naked.

Labrum (fig. 55) with two broad and outwardly angular lobes. Mandible (fig. 56), paragnath, first maxilla, second maxilla (fig. 57), and maxilliped (fig. 58) resembling in major respects those of *L. triquetrus*.

Area between maxillipeds and first pair of legs as in *L. verseveldti*; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 59–62) segmented as in the two previous species, with spine and setal formula as in *L. triquetrus* (exopod of leg 4 being I–0; I–1; III,I,5). Coxa of leg 1 with a sclerotized boss on outer posterior surface. Inner seta on coxa of leg 4 short (20 μ) and naked, instead of long and plumose as in legs 1–3. Inner margin of basis of leg 4 naked, but haired in legs 1–3. Endopod of leg 4 shorter than exopod. First segment 51 μ × 43 μ (including spiniform processes), with inner distal feathered seta 66 μ long. Second segment 98 μ × 38 μ in greatest dimensions (including processes), its two unequal terminal fringed spines 37 μ (outer) and 64 μ (inner). Both segments with outer margins haired and second segment with a terminal row of minute spinules.

Leg 5 (fig. 63) with a long bowed free segment 135 μ × 31 μ in greatest dimensions, without fine ornamentation. Two terminal naked setae 44 μ (outer) and 60 μ (inner). Seta on body near free segment 58 μ and naked. (In ovigerous females leg 5 is held erect so that its curvature fits around the ends of the egg sacs.)

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 51).

Color in life in transmitted light opaque to transparent, eye red, egg sacs gray.

Male: Body (fig. 64) resembling that of female. Length 1.04 mm (1.00–1.07 mm) and greatest width 0.35 mm (0.34–0.35 mm), based on 10 specimens. Ratio of length to width of prosome 1.67 : 1.

Segment of leg 5 (fig. 65) 47 μ × 107 μ. No ventral intersegmental sclerite. Genital segment longer than wide, 205 μ × 169 μ. Four postgenital segments 36 μ × 60 μ, 39 μ × 55 μ, 31 μ × 52 μ, and 43 μ × 53 μ, from anterior to posterior.

Caudal ramus similar to that of female, but relatively shorter, 73 μ × 23 μ, or 3.17 : 1.

Dorsal surface of prosome and urosome with only a few hairs. Ratio of length of prosome to that of urosome 1.33 : 1.

Rostral area as in female.

First antenna as in female, but with three aesthetes added as in the two previous species. Second antenna (fig. 66) like that of female, but with scalelike spines added on first two segments, those on first segment arranged in an arc.

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 67) slender. Second segment bearing a row of spines and two moderately long naked setae. Claw not greatly recurved, 189 μ along its axis including terminal lamella.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with spine and setal formula as in that sex except for last segment of endopod of leg 1 (fig. 68) which is I,I,4. Legs 2–4 as in female, without sexual dimorphism.

Leg 5 (fig. 65) with an elongated straight unornamented free segment, 44 μ × 11 μ, its two naked terminal setae 30 μ and 33 μ. Naked seta on body near free segment 40 μ.

Leg 6 (fig. 65) a posterolateral flap on ventral surface of genital segment bearing two naked setae 40 μ and 36 μ long.

Spermatophore not observed.

Color in life as in female.

Etymology: The specific name *glabripes*, from Latin *glaber* = without hairs, bald, and *pes* = foot, alludes to the absence of fine ornamentation on leg 5.

Comparison with related species: In seven species of *Lichomolgus* the second antenna bears terminally a single claw and a few small hyaline elements and the formula for the last segment of the exopod of leg 4 is III,I,5, as in *L. glabripes*. Each of these species may, however, be readily differentiated from *L. glabripes*. In *L. dentipes* Thompson and A. Scott, 1903, the free segment of leg 5 in the female has a large toothlike process. In *L. protentus* Humes and Frost, 1964, the armature of the endopod of leg 4 is 0–1; I,I. In *L. spinipes* (Sewell, 1949) the caudal ramus is wider than long, and the fourth endopod is 0–1; I,I. In *L. squamiger* Humes and Frost, 1964, the caudal ramus is 1 : 1, and leg 5 of the female bears scales. In *L. cristatus* Humes and Ho, 1968c, the genital segment of the female is wider than long, the mandible has a very short flagellum, and the lash of the second maxilla has a crest of long spinules. In *L. adelphus* Humes and Ho, 1968c, the caudal ramus is about 1 : 1, the genital segment of the female is wider than long, and leg 5 of the female has scalelike spines. In *L. triquetrus*, described above, the caudal ramus is about 1 : 1, and the free segment of leg 5 is triangular and ornamented with small spines.

L. elegans Thompson and A. Scott, 1903, of which only the female is known, has a single claw on the second antenna. The armature of the exopod of leg 4 is undescribed. However, this Ceylonese species differs from *L. glabripes* in having the caudal ramus about as broad as long, and in the presence of "a wedge-shaped notch near the centre on each side" of the genital segment.

Lichomolgus longispinifer new species
Figures 69–89

Type material: 83♀♀, 28♂♂, and several copepodids from one colony of *Siphonogorgia pendula* Studer, in 10–12 m, south of Andjiabe, Nosy Komba, near Nosy Bé, Madagascar, collected 30 July 1964. Holotype ♀, allotype, and 80 paratypes (60♀♀, 20♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Other specimens: 39♀♀, 47♂♂, and several copepodids from one colony of *Siphonogorgia pendula*, in 20 m, Banc de Dzamandzar, near Nosy Bé, 16 September 1964.

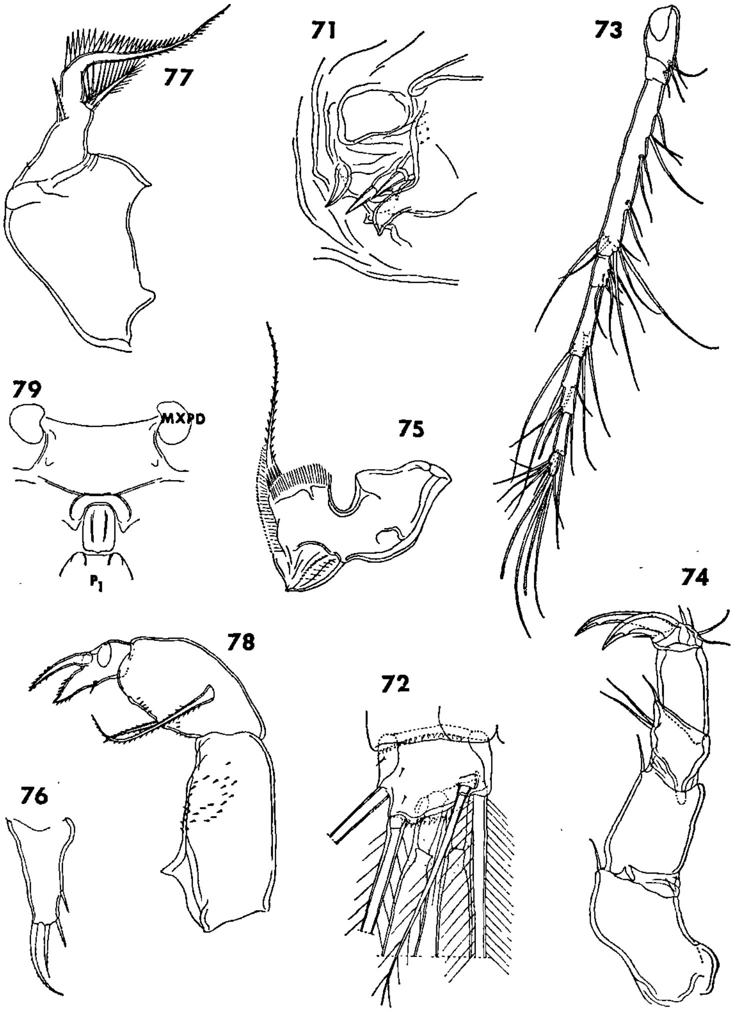
Female: Body (fig. 69) with prosome not much broadened; urosome relatively short. Length 0.88 mm (0.84–0.90 mm) and greatest width 0.43 mm (0.40–0.44 mm), based on 10 specimens. Ratio of length to width of prosome 1.60 : 1. Segment of leg 1 well separated from head dorsally. Epimeral areas of segments of legs 1 and 2 rather angular posteriorly, those of segments of legs 3 and 4 rounded.

Segment of leg 5 (fig. 70) 47 μ × 101 μ. Between this segment and genital segment no ventral intersegmental sclerite. Genital segment about as long as wide, 104 μ × 101 μ, in dorsal view gradually broadened from anterior to posterior, then rather abruptly constricted in its posterior fourth. Areas of attachment of egg sacs dorsal in position near midregion of segment. Each area (fig. 71) bearing two naked setae 11 μ and 9 μ long and two pointed processes. Three postgenital segments 26 μ × 56 μ, 21 μ × 52 μ, and 28 μ × 51 μ, from anterior to posterior.

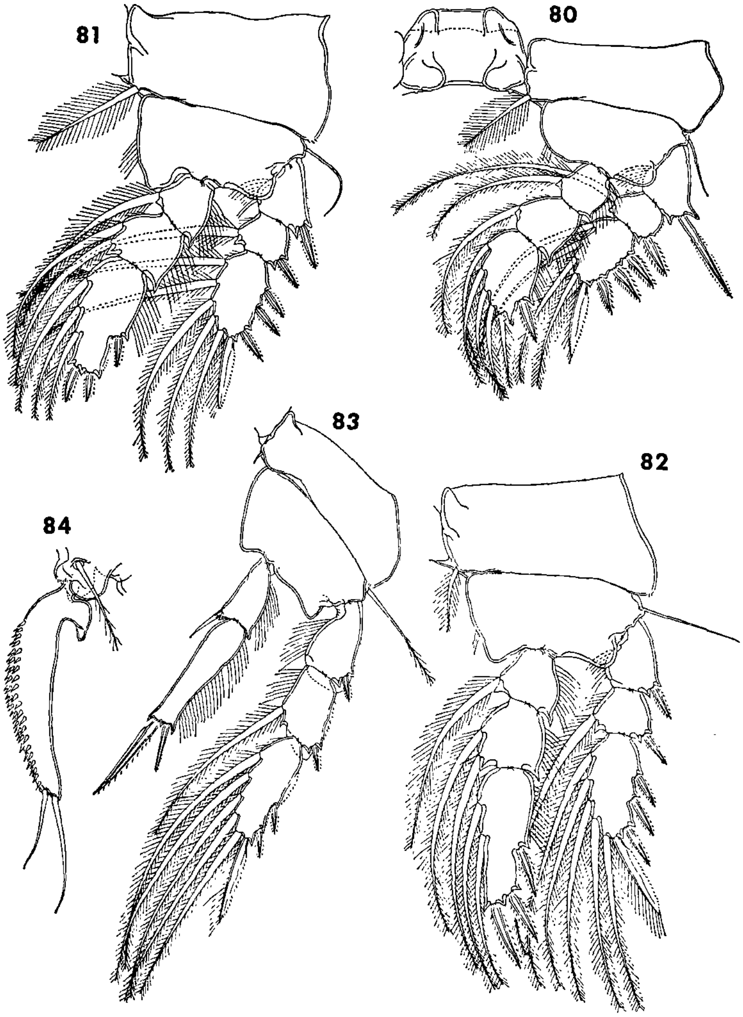
Caudal ramus (fig. 72) a little wider than long, 20 μ × 22 μ in greatest dimensions. Outer lateral seta 77 μ and naked, pedicellate dorsal seta 66 μ and lightly feathered, outermost distal seta 105 μ with lateral hairs proximally, innermost distal seta 143 μ and similarly haired, and the two long median terminal setae 440 μ (outer) and 495 μ (inner), both strongly haired along their midregions and both inserted between an unornamented dorsal flap and a ventral flap with a marginal row of minute spinules.

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 3.33 : 1.

Egg sac (fig. 69) slender and elongated, 363 μ × 101 μ, reaching far



Figs. 71–79. *Lichomolgus longispinifer*, new species, female: 71, area of attachment of egg sac, dorsal (I); 72, caudal ramus, dorsal (I); 73, first antenna, dorsal (D); 74, second antenna, anterior (inner) (F); 75, mandible, posterior (C); 76, first maxilla, posterior (C); 77, second maxilla, posterior (C); 78, maxilliped, posterior (C); 79, area between maxillipeds and first pair of legs, ventral (E).

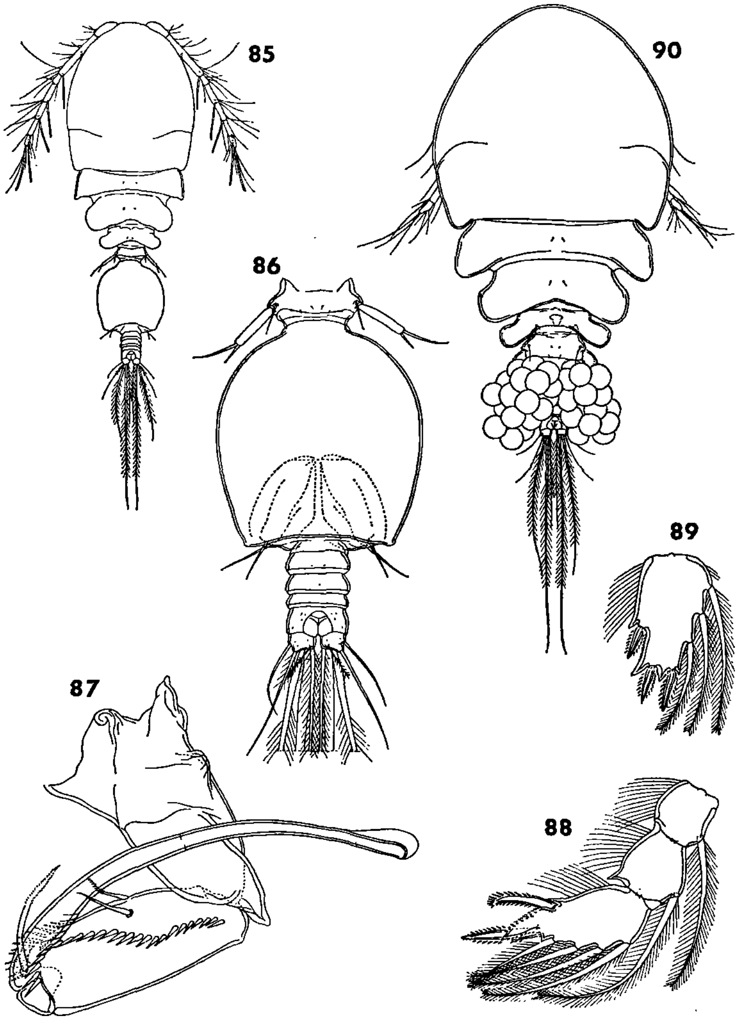


FIGS. 80–84. *Lichomolgus longispinifer*, new species, female: 80, leg 1 and intercoxal plate, anterior (F); 81, leg 2, anterior (F); 82, leg 3, anterior (F); 83, leg 4, anterior (F); 84, leg 5, dorsal (F).

beyond caudal rami and containing many eggs, each about 47 μ in diameter.

Rostral area similar to that in *L. verseveldti* and *L. triquetrus*.

First antenna (fig. 73) long and slender, 437 μ in length, with segmentation and armature as in the three previous species. Lengths of



FIGS. 85–90. *Lichomolgus longispinifer*, new species, male: 85, body, dorsal (G); 86, urosome, dorsal (E); 87, maxilliped, postero-inner (C); 88, endopod of leg 1, anterior (C); 89, third segment of endopod of leg 2, anterior (C). *Lichomolgus hians*, new species, female: 90, body, dorsal (G).

segments: 42 μ (65 μ along anterior edge), 164 μ, 27 μ, 68 μ, 55 μ, 37 μ, and 21 μ respectively. All setae naked. Second antenna (fig. 74) 4-segmented, last segment 55 μ along its outer edge, 28 μ along its inner edge, 23 μ wide, bearing distally five short hyaline elements and two short terminal claws, one stout and 39 μ along its axis, the other more slender and 44 μ. All setae naked.

Labrum resembling that of *L. verseveldti.* Mandible (fig. 75) with basal region strongly constricted, the scalelike protrusion on convex side distal to constriction pointed and ornamented with a row of minute spinules. Paragnath as in *L. verseveldti.* First maxilla (fig. 76) with four setae. Second maxilla (fig. 77) similar to that in *L. triquetrus* and *L. glabripes,* but with slender spines instead of strong teeth along terminal lash. Maxilliped (fig. 78) resembling that of *L. verseveldti* but differing in details of ornamentation.

Area between maxillipeds and first pair of legs (fig. 79) slightly protuberant; a sclerotized line between bases of maxillipeds.

Legs 1–4 (figs. 80–83) segmented as in all previous species and with spine and setal formula as in *L. verseveldti.* Inner seta on coxa of leg 4 short (7 μ) and naked. Inner margin of basis of leg 4 naked. First segment of exopod of leg 1 with outer spine unusually long, 44 μ, a little more than twice length of spine on second segment (21 μ). Spinulose fringe on this long spine narrower and more delicate than on more distal spines. Spine on first segment of exopod of leg 2 only slightly longer than others; proximal spine on third segment of this exopod slightly shorter than adjacent spines; lengths of the five outer spines on exopod being 25 μ, 20 μ, 18 μ, 20 μ, and 18 μ, from proximal to distal. Endopod of leg 4 shorter than exopod. First segment 37 μ × 17 μ (including spiniform processes), with a short naked inner distal spinelike element 18 μ long. Second segment 66 μ × 17 μ in greatest dimensions (including processes), its two unequal terminal spines 22 μ (outer) and weakly barbed distally, and 50 μ (inner) with an outer spinulose fringe and an inner narrow smooth lamella. Both segments with outer margins haired and second segment with a terminal row of minute spinules.

Leg 5 (fig. 84) resembling in general form that of *L. cuneipes* Humes and Ho, 1968b. Free segment elongated, 106 μ in greatest length and 21 μ wide near middle. Proximal inner expansion (smaller than in *L. cuneipes*) in the form of a bent thumb. Two terminal naked setae 39 μ (outer) and 56 μ (inner). Outer surface of segment with short spines. Seta on body near free segment 44 μ and lightly feathered.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 71).

Color in life in transmitted light faintly rose or lavender, sometimes translucid, eye red, egg sacs light gray.

Male: Body (fig. 85) with prosome more slender than in female. Length 0.67 mm (0.64–0.70 mm) and greatest width 0.24 mm (0.23–

0.28 mm), based on 10 specimens. Ratio of length to width of prosome 1.76 : 1.

Segment of leg 5 (fig. 86) 34 μ × 59 μ. No ventral intersegmental sclerite. Genital segment 148 μ × 130 μ, only a little longer than wide. Four postgenital segments 15 μ × 44 μ, 15 μ × 44 μ, 11 μ × 42 μ, and 17 μ × 44 μ, from anterior to posterior.

Caudal ramus similar to that of female, 15.5 μ × 19 μ.

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 1.89 : 1.

Rostral area as in female. First antenna like that of female, but with three aesthetes added as in the three previous species. Second antenna similar to that of female, but bearing a few short spinules along inner surface of second and fourth segments.

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 87) resembling in general form that of *L. cuneipes* and *L. gentilis* Humes and Ho, 1968b. Claw 142 μ along its axis including terminal lamella.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with same spine and setal formula except for last segment of endopod of leg 1 (fig. 88) which is I,I,4. Leg 2 showing slight sexual dimorphism, with outer terminal spiniform process on third segment of endopod larger than in female and turned outwardly (fig. 89). Legs 3 and 4 as in female, without sexual dimorphism.

Leg 5 (fig. 86) with free segment straight and elongated, 32 μ × 6 μ, without ornamentation. Two terminal naked setae 29 μ and 14 μ, and seta on body near free segment 20 μ.

Leg 6 (fig. 86) a posterolateral flap on ventral surface of genital segment bearing two naked setae 39 μ and 30 μ.

Spermatophore not observed.

Color in life in transmitted light translucid, eye red.

Etymology: The specific name *longispinifer*, from Latin = bearing a long spine, refers to the unusually long spine on the first segment of the exopod of leg 1.

Comparison with related species: The new species appears to be unique in the genus in having an unusually long outer spine on the first segment of the exopod of leg 1. It may be further separated from all but two species of *Lichomolgus* on the basis of a combination of the following four characters: the second antenna with two short claws, the formula for the last segment of the exopod of leg 4 being II,I,5, the endopod of leg 4 being 0–I; II, and the caudal ramus being nearly quadrate, a little wider than long. The two species which share these features with *L. longispinifer* are *L. cuneipes* Humes and Ho, 1968b, and *L. verseveldti*, described above. In *L. verseveldti*, however, the form of the fifth leg and genital segment in the female is very different and the lash of the second maxilla bears stout teeth rather than slender spines. The new species seems closely related to *L. cuneipes* (associated with the octocoral *Stereonephthya acaulis* Verseveldt in Madagascar). In *L. cuneipes*, however, all ramal setae are naked, the teeth on the lash of the second maxilla are partly slender and partly stout, the genital segment of the female has a different form, and the fifth leg of the male bears fine ornamentation.

Lichomolgus hians new species

Figures 90–108

Type material: 238 ♀♀, 37 ♂♂, and several copepodids from one colony of *Siphonogorgia pendula* Studer, in 10–12 m, south of Andjiabe, on the southern shore of Nosy Komba, near Nosy Bé, Madagascar, collected 30 July 1964. Holotype ♀, allotype, and 225 paratypes (200 ♀♀, 25 ♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

Other specimens (also from *Siphonogorgia pendula*): 78 ♀♀, 112 ♂♂, and several copepodids from one colony, in 20 m, Banc de Dzamandzar, near Nosy Bé, 16 September 1964.

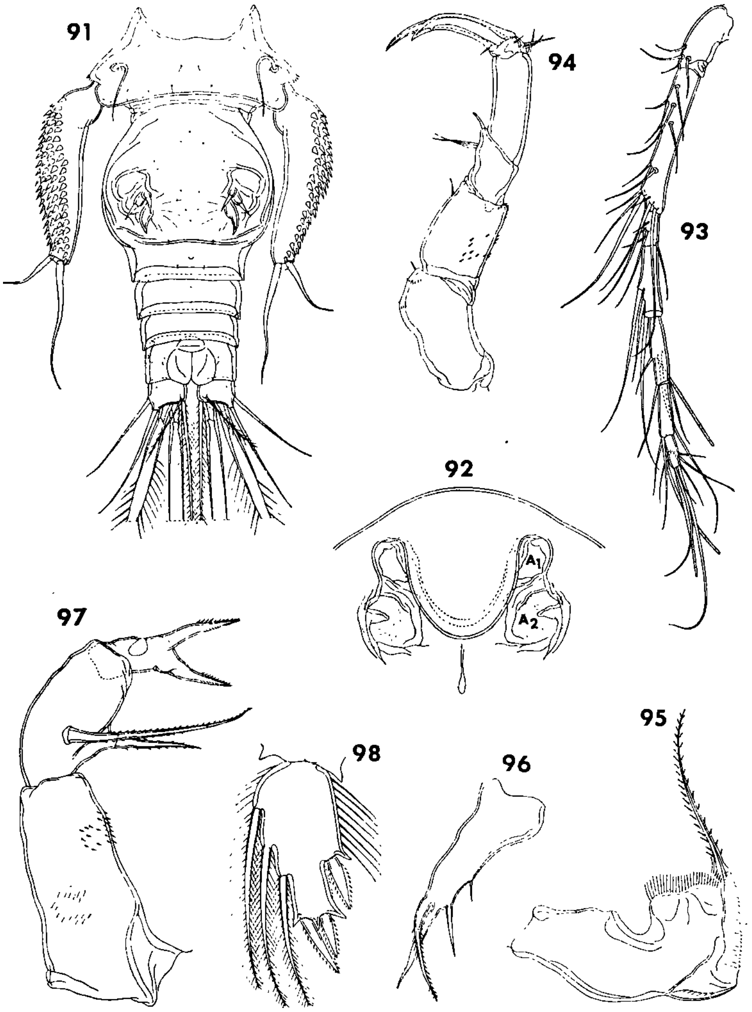
Female: Body (fig. 90) with moderately broadened prosome. Length 0.93 mm (0.86–1.03 mm) and greatest width 0.49 mm (0.46–0.51 mm), based on 10 specimens. Ratio of length to width of prosome 1.37 : 1. Segment of leg 1 separated incompletely from head. Epimeral areas of segments of legs 1–4 as in figure.

Segment of leg 5 (fig. 91) 65 μ × 131 μ. Between this segment and genital segment a slight ventral intersegmental sclerite. Genital segment 112 μ × 109 μ, about as long as wide, and resembling that of *L. varirostratus* Humes and Ho, 1968b. Areas of attachment of egg sacs situated dorsally near middle of segment. Each area bearing two naked setae 10 μ and 11 μ long and a prominent unguiform process. Three postgenital segments 29 μ × 67 μ, 24 μ × 60 μ, and 26 μ × 57 μ, from anterior to posterior.

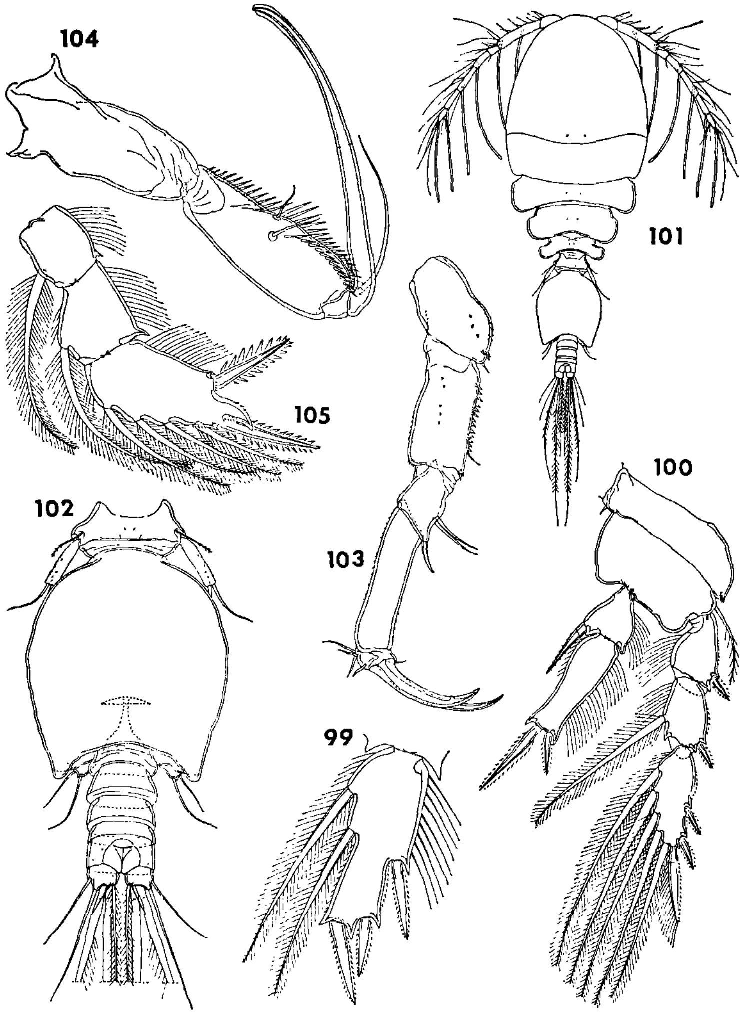
Caudal ramus (fig. 91) quadrate, 23 μ × 24 μ in greatest dimensions. Outer lateral seta 66 μ long and naked, pedicellate dorsal seta 50 μ and lightly feathered, outermost distal seta 110 μ and naked, innermost distal seta 200 μ with hairs along both sides of its proximal half, and the two long median terminal setae 308 μ (outer) and 440 μ (inner), both with strong lateral spinules (stronger than in *L. longispinifer*) except in distal third, and both inserted between an unornamented dorsal flap and a ventral flap with a marginal row of minute spinules. A minute spinule on proximal outer margin of ramus.

Dorsal surface of prosome and urosome with very few hairs. A small crescentic sclerotization in tergum of segment of leg 4. Ratio of length of prosome to that of urosome 3.23 : 1.

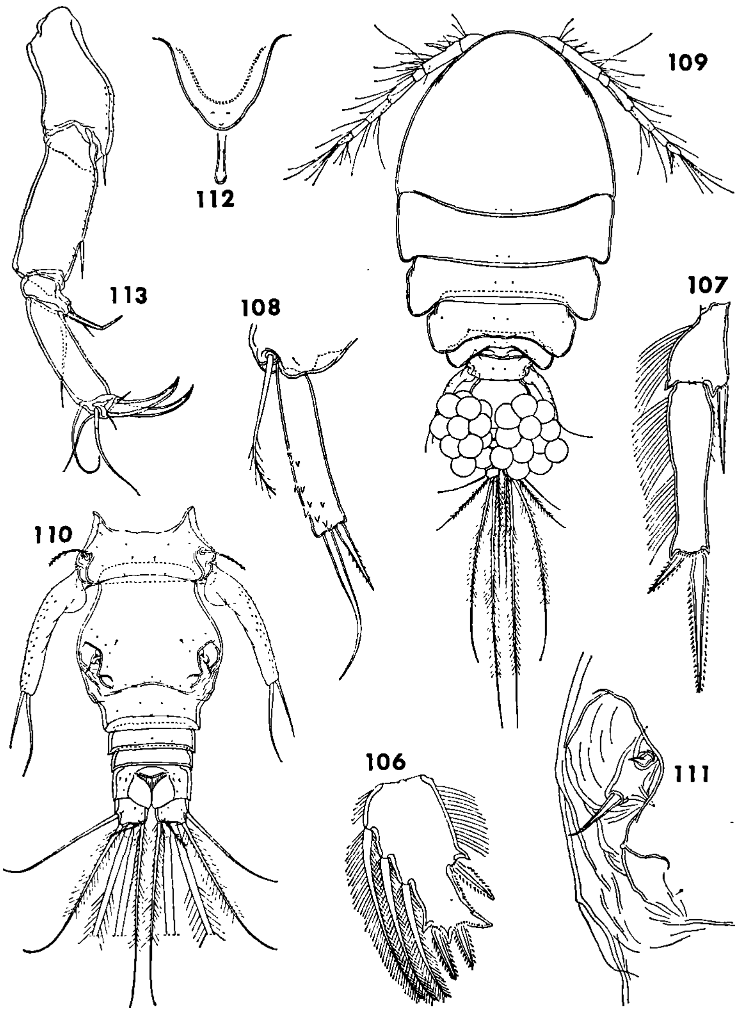
Egg sac seen complete in only one female, where it measured 495 μ × 165 μ, reaching almost to ends of ramal setae, and containing many



FIGS. 91–98. *Lichomolgus hians*, new species, female: 91, urosome, dorsal (E); 92, rostral area, ventral (D); 93, first antenna, dorsal (D); 94, second antenna, anterior (inner) (E); 95, mandible, posterior (C); 96, first maxilla, posterior (C); 97, maxilliped, postero-inner (C); 98, third segment of endopod of leg 2, anterior (F).



FIGS. 99–105. *Lichomolgus hians*, new species, female: 99, third segment of endopod of leg 3, anterior (F); 100, leg 4, anterior (E); Male: 101, body, dorsal (G); 102, urosome, dorsal (E); 103, second antenna, anterior (inner) (F); 104, maxilliped, outer (F); 105, endopod of leg 1, anterior (C).



FIGS. 106–113. *Lichomolgus hians*, new species, male: 106, third segment of endopod of leg 2, anterior (C); 107, endopod of leg 4, anterior (C); 108, leg 5, dorsal (I). *Lichomolgus telestophilus*, new species, female: 109, body, dorsal (G); 110, urosome, dorsal (D); 111, area of attachment of egg sac, dorsal (I); 112, rostral area, ventral (D); 113, second antenna, anterior (inner) (E).

eggs about 52 μ in diameter. Egg sacs in other ovigerous females incomplete, as in figure 90.

Rostral area (fig. 92) raised ventrally, with a well defined posteroventral border.

First antenna (fig. 93) 7-segmented, 441 μ long, and slender. Lengths of segments: 40 μ (69 μ along anterior margin), 133 μ, 31 μ, 68 μ, 62 μ, 48 μ, and 30 μ respectively. Formula for armature as in the four previous species. All setae naked.

Second antenna (fig. 94) 4-segmented, last segment 86 μ along its outer edge, 50 μ along its inner edge, 24 μ wide, bearing distally five small hyaline elements and two moderately long unequal claws, the stouter one 65 μ along its axis, the more slender one 78 μ. Third segment with a spiniform seta and two longer slender setae. Groups of *small spinules on first and second segments. All setae naked.*

Labrum and paragnath as in *L. verseveldti.* Mandible (fig. 95) resembling that of *L. longispinifer.* First maxilla (fig. 96) slender with four elements as in the four previous species. Second maxilla as in *L. varirostratus.* Maxilliped (fig. 97) resembling in general form that of *L. longispinifer,* but the two terminal elements equal and widely divergent, suggesting open blades of scissors.

Area between maxillipeds and first pair of legs as in *L. verseveldti.*

Legs 1–4 segmented as in the four previous species, and spine and setal formula as in *L. verseveldti* and *L. longispinifer.* Inner seta on coxa of leg 4 short (7 μ) and naked. Inner margin of basis of leg 4 naked. Rami of leg 1 as in *L. varirostratus.* Rami of legs 2 and 3 also similar to those in *L. varirostratus,* but last segment of endopod slightly different (figs. 98, 99). Endopod of leg 4 (fig. 100) shorter than exopod. First segment 43 μ × 32 μ (including processes), with its distal inner finely barbed spine 44 μ long. Second segment 78 μ long (including spiniform processes), its greatest width 32 μ and least width 17.5 μ; its two unequal terminal spines 31 μ (outer) and 57 μ (inner), the fringe on the inner spine more coarsely spinulose on its outer than on its inner margin. Both segments with outer margins haired, second segment with a few weak hairs on proximal half of inner margin and with a terminal row of minute spinules.

Leg 5 (fig. 91) suggesting that of *L. varirostratus,* but differing in details of form and ornamentation. Free segment elongated, 117 μ × 26 μ in greatest dimensions. Outer surface of segment with many scalelike spines. Two terminal naked setae 41 μ (outer) and 69 μ (inner). Seta on body near free segment about 50 μ and naked.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 91).

Color in life in transmitted light translucid or slightly opaque, eye red, egg sacs light gray.

Male: Body (fig. 101) with prosome more slender than in female. Length 0.73 mm (0.70–0.78 mm) and greatest width 0.28 mm (0.27–

0.29 mm), based on 10 specimens. Ratio of length to width of prosome 1.70 : 1.

Segment of leg 1 (fig. 102) 39 μ × 75 μ. No ventral intersegmental sclerite. Genital segment 151 μ × 133 μ, only a little longer than wide, with its lateral margins sometimes slightly irregular. Four postgenital segments 25 μ × 48 μ, 18 μ × 46 μ, 11 μ × 45 μ, and 19 μ × 46 μ, from anterior to posterior.

Caudal ramus similar to that of female, 20 μ × 20 μ in greatest dimensions.

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 1.90 : 1.

Rostral area as in female. First antenna similar to that of female, but with three aesthetes added as in the four previous species. Second antenna (fig. 103) resembling that of female, but last segment relatively more elongated, its outer margin 82 μ, its inner margin 56 μ, and its width 17 μ, and both margins with minute spinules. Second segment with small spines along inner surface.

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 104) slender. Second segment with two naked setae and two rows of spinules. Claw 159 μ along its axis (including terminal lamella), only slightly recurved, its proximal inner surface faintly striated.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with same spine and setal formula except for last segment of endopod of leg 1 (fig. 105) which is I,I,4. Last segment of endopod of leg 2 (fig. 106) showing slight sexual dimorphism, with outer terminal process larger than in female, and bearing minute spinules. Leg 3 entirely as in female. Endopod of leg 4 (fig. 107) with second segment relatively more slender than in female. First segment 31 μ × 21 μ including processes, its spine 32 μ; second segment 60 μ long, 15.5 μ in greatest width, and 10 μ in least width, its two terminal spines 17 μ (outer) and 47 μ (inner).

Leg 5 (fig. 108) with free segment 35 μ × 8 μ, bearing two terminal setae, outer 34 μ and naked, inner 16 μ and finely barbed. Surface of segment with a few small spines. Seta on body near free segment 29 μ and lightly feathered.

Leg 6 (fig. 102) a posterolateral flap on ventral surface of genital segment bearing two slender setae 31 μ and 40 μ long.

Spermatophore not observed.

Color in life as in female.

Etymology: The specific name *hians*, from the Latin word *hio* = to stand open or gape, alludes to the two divergent terminal elements on the maxilliped of the female.

Comparison with related species: L. hians may be separated from all but seven species of *Lichomolgus* on the basis of a combination of four characters: the caudal ramus being about as long as wide, the second antenna having two terminal claws, the formula for the last segment of the exopod of leg 4 being II,I,5, and the formula for the endopod of leg 4 being 0–I; II. Of the remaining species *L. varirostratus* Humes and Ho, 1968b, *L. exilipes* Humes and Ho, 1968b, and *L. gentilis* Humes and Ho, 1968b, have the two claws on the second antenna about as long as or longer than the greatest length of the fourth segment (instead of distinctly shorter than this segment as in the new species), and the outer spine on the last segment of the endopod of leg 1 in the males of these species is differently formed. In *L. fissisetiger* Humes and Ho, 1968b, *L. cuneipes* Humes and Ho, 1968b, *L. verseveldti*, and *L. longispinifer* (both described above) the fifth leg of the female has a distinct proximal inner expansion.

Although in several respects *L. hians* resembles rather closely *L. varirostratus*, particularly in the form of the genital segment in the female, the mandible, the second maxilla, the maxilliped in the female, and legs 1–4, there are many differences between the two species. The distinctions include not only the two features mentioned above, but also (in *L. varirostratus*) the sexual dimorphism in the rostral area, the exact nature of leg 5 in both sexes, and the two unornamented long terminal setae on the caudal ramus.

Lichomolgus telestophilus new species

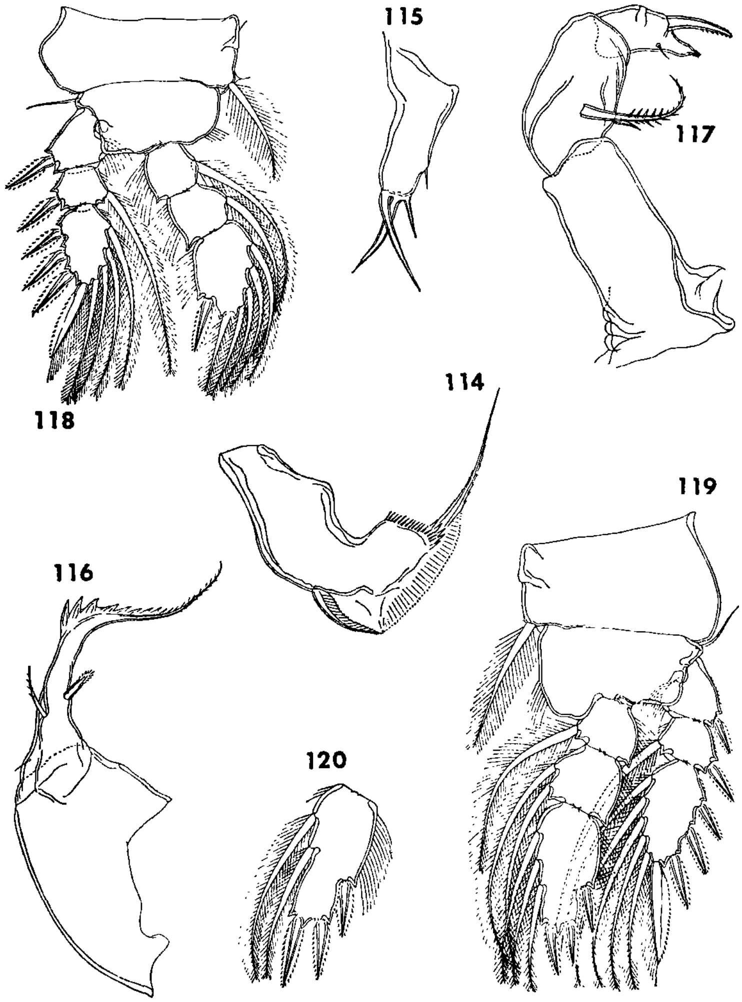
Figures 109–127

Type material: 13 ♀♀, 22 ♂♂, and 4 copepodids from one colony of *Telesto arborea* Wright and Studer, in 4 m, northeastern coast of Antany Mora, Isles Radama, Madagascar, 14°06′10″S, 47°45′10″E, collected 30 September 1964. Holotype ♀, allotype and 26 paratypes (9 ♀♀, 17 ♂♂) deposited in the United States National Museum, and the remaining paratypes in the collection of A. G. Humes.

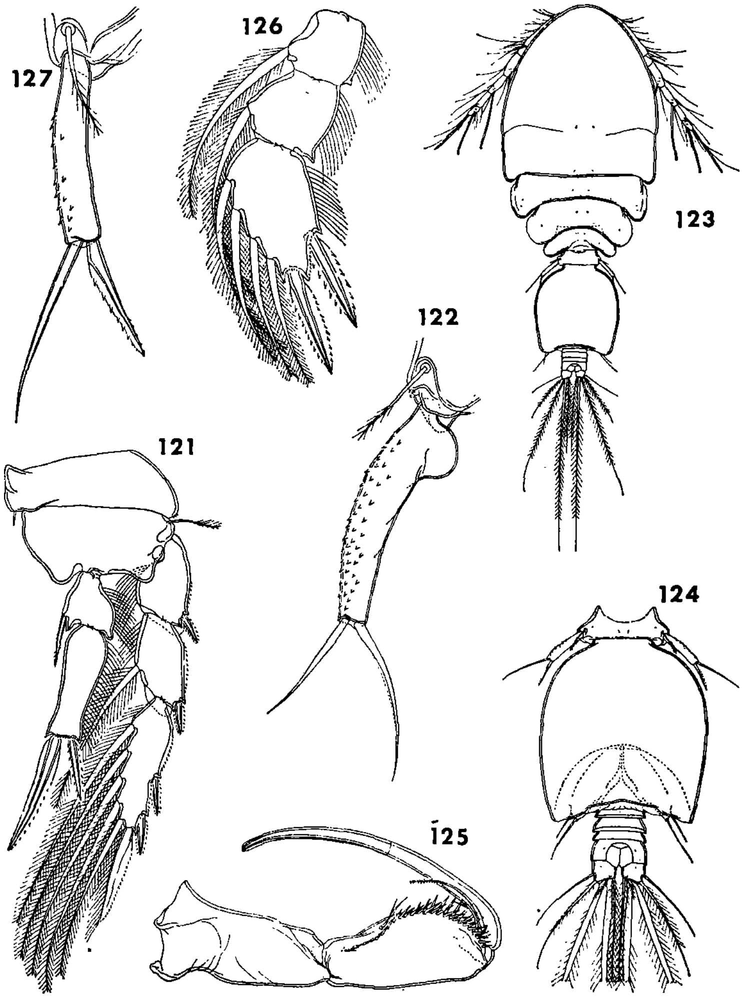
Female: Body (fig. 109) with moderately slender prosome. Length 0.91 mm (0.85–0.95 mm) and greatest width 0.46 mm (0.42–0.50 mm), based on 10 specimens. Ratio of length to width of prosome 1.49 : 1. Segment of leg 1 distinctly separated from head by a transverse furrow. Epimeral areas of segments of legs 1–4 more or less rounded posteriorly.

Segment of leg 5 (fig. 110) 68 μ × 133 μ. Between this segment and genital segment a weak ventral intersegmental sclerite. Genital segment 138 μ × 133 μ, about as long as wide and somewhat expanded laterally in its midregion. Areas of attachment of egg sacs located dorsolaterally near middle of segment. Each area (fig. 111) bearing two unequal naked setae 4 μ and 12 μ in length and a small spiniform process. Three postgenital segments 30 μ × 80 μ, 23 μ × 75 μ, and 33 μ × 72 μ, from anterior to posterior.

Caudal ramus (fig. 110) quadrate, 32 μ × 31 μ in greatest dimensions. Outer lateral seta 104 μ, pedicellate dorsal seta 36 μ, outermost distal seta 151 μ, innermost distal seta 221 μ, and the two long median terminal



FIGS. 114–120. *Lichomolgus telestophilus*, new species, female: 114, mandible, posterior (C); 115, first maxilla, posterior (C); 116, second maxilla, posterior (C); 117, maxilliped, posterior (C); 118, leg 1, anterior (E); 119, leg 2, anterior (E); 120, third segment of endopod of leg 3, anterior (E).



Figs. 121–127. *Lichomolgus telestophilus*, new species, female: 121, leg 4, anterior (E); 122, leg 5, dorsal (F). Male: 123, body, dorsal (G); 124, urosome, dorsal (D); 125, maxilliped, inner (F); 126, endopod of leg 1, anterior (C); 127, leg 5, dorsal (I).

setae 429 μ (outer) and 529 μ (inner), both inserted between an unornamented dorsal flap and a ventral flap with a marginal row of minute spinules. Ornamentation of these setae similar to that in *L. longispinifer.*

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 2.62 : 1.

Egg sacs incomplete on all females collected. Each egg about 43 μ in diameter.

Rostral area (fig. 112) slightly raised ventrally and broadly tongue-shaped.

First antenna 377 μ long, and resembling that of *L. verseveldti*. Lengths of segments: 23 μ (55 μ along anterior margin), 88 μ, 26 μ, 65 μ, 62 μ, 45 μ, and 36 μ respectively. All setae naked. Second antenna (fig. 113) 4-segmented, last segment elongated, 94 μ along its outer edge, 64 μ along its inner edge, and 21 μ wide, bearing distally five hyaline elements and two slightly unequal claws 57 μ and 53 μ in length. One of three setae on third segment angularly bent. All setae naked. Inner surfaces of all four segments with minute spinules.

Labrum as in *L. verseveldti* and *L. hians*. Mandible (fig. 114) rather like that of *L. hians*, but with shorter barbs on flagellum than in that species. Paragnath a small hairy lobe as in *L. verseveldti*. First maxilla (fig. 115) with four naked elements. Second maxilla (fig. 116) somewhat resembling that of *L. verseveldti*, but inner distal spine near base of lash rather blunt and finely barbed, instead of being attenuated and ornamented with large spinules as in that species. Maxilliped (fig. 117) with two setae on second segment very unequal, the larger seta with two rows of erect spinules in its midregion and more finely barbed distally, the smaller seta naked. Third segment with two unequal terminal barbed elements, one without an articulation.

Area between maxillipeds and first pair of legs as in *L. verseveldti*.

Legs 1–4 (figs. 118–121) segmented and armed with spines and setae as in *L. verseveldti*, *L. longispinifer*, and *L. hians*. Inner seta on coxa of leg 4 short (9 μ) and naked. Inner margin of basis of leg 4 naked. Rami of all four legs resembling in general aspects those of *L. fissisetiger* Humes and Ho, 1968b. Endopod of leg 4 (fig. 121) much shorter than exopod. First segment 42 μ × 34 μ (including processes), with its distal inner finely barbed spine 33 μ long and setiform. Second segment 77 μ long (including spiniform processes), its greatest width 33 μ and least width 19 μ; its two unequal terminal fringed spines 45 μ (outer) and 83 μ (inner). Both segments with outer margins haired and second segment with a terminal row of minute spinules.

Leg 5 (fig. 122) suggesting that of *L. fissisetiger*. Free segment elongated, 133 μ in length, width at expansion 42 μ, width distally 21 μ. Two terminal setae 50 μ (outer) and naked and 81 μ (inner) with a slight lamella along its midregion. Outer surface of free segment with many small spines. Seta on body near free segment 46 μ and lightly feathered.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 111).

Color in life in transmitted light slightly opaque, eye red.

Male: Body (fig. 123) resembling in general form that of female. Length 0.75 mm (0.72–0.79 mm) and greatest width 0.31 mm (0.29–0.31 mm), based on 10 specimens. Ratio of length to width of prosome 1.60 : 1.

Segment of leg 5 (fig. 124) 36 μ × 86 μ. No ventral intersegmental sclerite. Genital segment 174 μ × 161 μ, only a little longer than wide. Four postgenital segments 15.5 μ × 50 μ, 14 μ × 52 μ, 12 μ × 50 μ, and 20 μ × 53 μ, from anterior to posterior.

Caudal ramus similar to that of female, 24 μ × 23 μ in greatest dimensions.

Dorsal surface of prosome and urosome with very few hairs. Ratio of length of prosome to that of urosome 1.91 : 1.

Rostral area as in female. First antenna resembling that of female, but with three aesthetes added as in the five previous species. Second antenna similar to that of female but inner surficial spinules coarser that in that sex.

Labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 125) slender and resembling in most respects that of *L. hians*. Claw 130 μ along its axis including terminal lamella.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented as in female, with same spine and setal formula except for last segment of endopod of leg 1 (fig. 126) which is I,I,4. Legs 2–4 as in female, without sexual dimorphism.

Leg 5 (fig. 127) with free segment 38 μ × 8.5 μ, bearing two terminal elements, the outer setiform and naked, 48 μ long, the inner spiniform with an outer barbed fringe and a few inner barbules, 25 μ. Surface of segment with a few small spines. Seta on body near free segment 20 μ and lightly feathered.

Leg 6 (fig. 124) a posterolateral flap on ventral surface of genital segment bearing two slender naked setae 24 μ and 55 μ long.

Spermatophore not observed.

Color in life as in female.

Etymology: The specific name *telestophilus* is a combination of the generic name of the host and the Greek word φίλος = loving.

Comparison with related species: Only four species of *Lichomolgus* have, as in the new species, the following combination of characters: the second antenna with two short claws (shorter than the fourth segment), the third segment of the exopod of leg 4 with the formula II,I,5, the inner distal element on the first segment of the endopod of leg 4 a spine and not feathered, and the dimensions of the caudal ramus in the ratio of about 1 : 1. These are *L. cuneipes* Humes and Ho, 1968b, *L. verseveldti*, *L. longispinifer*, and *L. hians*. All four may be readily distinguished from *L. telestophilus*, however. The free segment of the fifth leg of *L. cuneipes* has a large wedge-shaped expansion. In *L. verseveldti* this segment is relatively short and broad. In *L. longispinifer* the outer spine on the first segment of the exopod of leg 1 is unusually long. In *L. hians* the two terminal elements on the maxilliped of the female are widely divergent and the two setae on the second segment of this appendage have a different size and ornamentation.

L. telestophilus might at first glance be confused with *L. botulosus* Stock and Kleeton, 1963, from octocorals in the Mediterranean, but the two species are easily separated by the nature of the lash on the second maxilla and the ornamentation of the inner distal element on the first segment of the endopod of leg 4.

Lichomolgus clavatus new species

Figures 128–148

Type material: 22♀♀, 19♂♂, and 1 copepodid from one colony of *Coelogorgia palmosa* Milne Edwards and Haime, in 2 m, near village of Ampasindava, northern end of Nosy Sakatia, near Nosy Bé, Madagascar, collected 8 October 1960. Holotype ♀ allotype, and 35 paratypes (19♀♀, 16♂♂) deposited in the United States National Museum, and the remaining paratypes (dissected) in the collection of A. G. Humes.

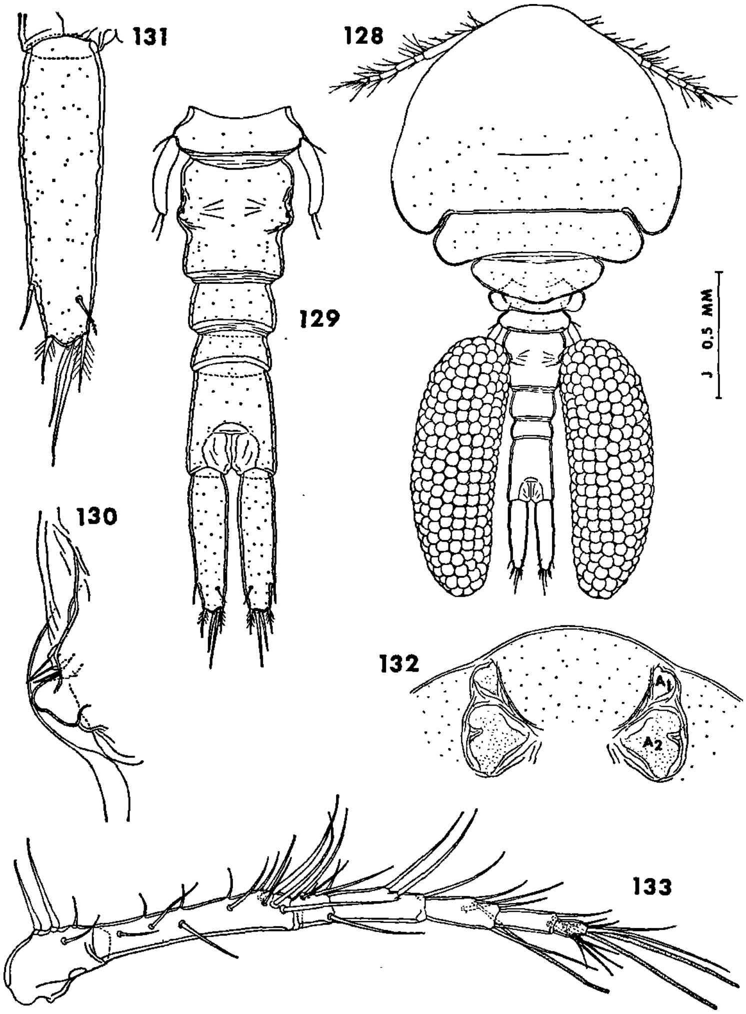
Other specimens (all from *Coelogorgia palmosa*): 3♀♀, 2♂♂, and 2 copepodids from one colony, in 1 m, Ambariobe, near Nosy Bé, 3 November 1960; and 1♂ from one colony, in 1 m, Ambariobe, 17 December 1963.

Female: Body (fig. 128) with broad prosome and slender urosome. Length 2.27 mm (2.19–2.37 mm) and greatest width 1.09 mm (1.01–1.16 mm), based on 10 specimens. Ratio of length to width of prosome 1.08 : 1. Segment of leg 1 almost completely fused with head. Epimeral areas of legs 1–4 as in figure; tergum of segment of leg 3 overlapping segment of leg 4.

Segment of leg 5 (fig. 129) 110 μ × 264 μ. Between this segment and genital segment no ventral intersegmental sclerite. Genital segment 242 μ long, in dorsal view not expanded laterally, its greatest width 238 μ and its least width in its posterior third 204 μ. Areas of attachment of egg sacs situated laterally in front of middle of segment. Each area (fig. 130) bearing two naked setae about 13 μ long. Three postgenital segments 112 μ × 177 μ, 78 μ × 164 μ, and 221 μ × 174 μ, from anterior to posterior.

Caudal ramus (fig. 131) elongated, 286 μ × 77 μ in greatest dimensions, or 3.7 times longer than wide. All setae relatively short. Outer lateral seta 42 μ and naked, pedicellate dorsal seta 39 μ and lightly feathered, outermost distal seta 47 μ with lateral hairs proximally, innermost distal seta 61 μ and haired, and the two median terminal setae 85 μ (outer) and 127 μ (inner), both naked and inserted between an unornamented dorsal flap and a ventral flap with a marginal row of minute spinules.

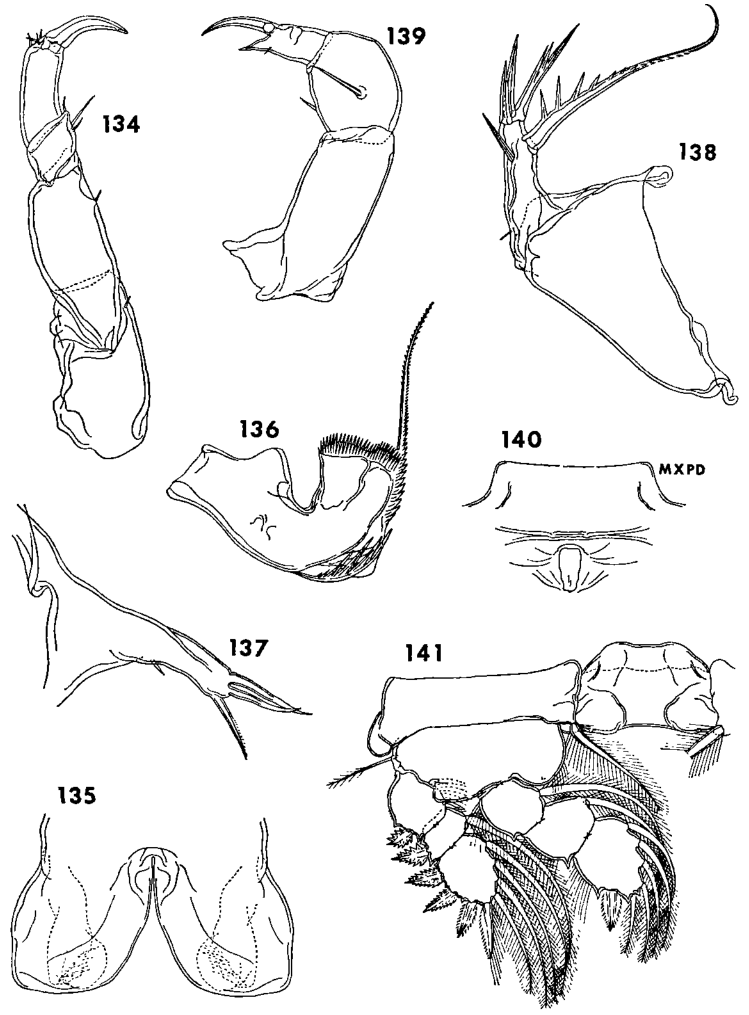
Dorsal surface of prosome and urosome with small refractile points. Ratio of length of prosome to that of urosome 1.18 : 1.



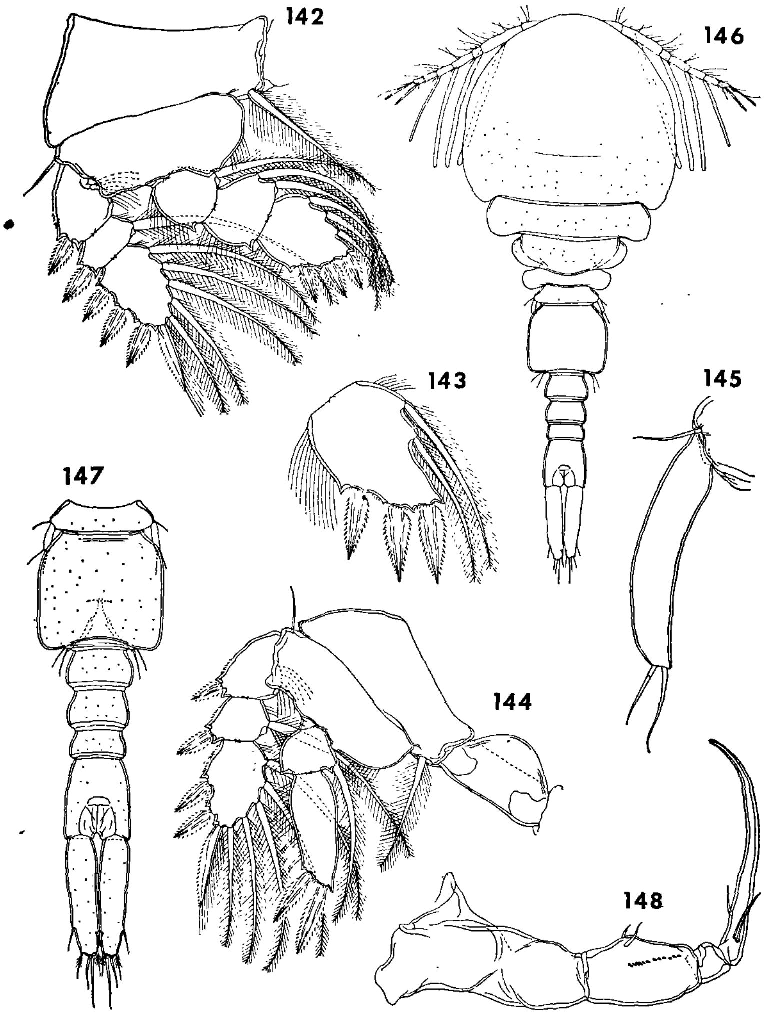
Figs. 128–133. *Lichomolgus clavatus*, new species, female: 128, body, dorsal (J); 129, urosome, dorsal (G); 130, area of attachment of egg sac, dorsal (C); 131, caudal ramus, dorsal (D); 132, rostral area, ventral (G); 133, first antenna, dorsal (D).

Egg sac (seen on only one female) elongated, 1090 μ × 340 μ, reaching to ends of ramal setae, and containing many eggs, each about 57 μ in diameter.

Rostral area (fig. 132) weakly developed.



FIGS. 134–141. *Lichomolgus clavatus*, new species, female: 134, second antenna, anterior (inner) (D); 135, labrum, with paragnaths indicated by dashed lines, ventral (E); 136, mandible, posterior (E); 137, first maxilla, anterior (C); 138, second maxilla, posterior (E); 139, maxilliped, posterior (E); 140, area between maxillipeds and first pair of legs, ventral (B); 141, leg 1 and intercoxal plate, anterior (D).



Figs. 142–148. *Lichomolgus clavatus*, new species, female: 142, leg 2, anterior (D); 143, third segment of endopod of leg 3, anterior (E); 144, leg 4 and intercoxal plate, anterior (D); 145, leg 5, dorsal (E). Male: 146, body, dorsal (A); 147, urosome, dorsal (G); 148, maxilliped, inner (E).

First antenna (fig. 133) 7-segmented, 554 μ long. Lengths of segments: 55 μ (97 μ along anterior margin), 180 μ, 39 μ, 85 μ, 64 μ, 57 μ, and 32 μ respectively. All setae naked. Second antenna (fig. 134) 4-segmented, last segment moderately elongated, 114 μ along its outer edge, 75 μ along its inner edge, and 33 μ wide, bearing distally six small hyaline elements and a claw 72 μ along its axis. All setae naked.

Labrum (fig. 135) rather deeply indented. Mandible (fig. 136) with basal region distal to constriction showing on its convex margin a scale-like sclerotization with a row of long blunt spinules, and on its concave margin a row of spinules interrupted by a sclerotization. Near base of flagellum a dentate fringe (not rather delicately serrated as in many other species). Flagellum elongated and finely barbed. Paragnath (fig. 135) a small hairy lobe. First maxilla (fig. 137) with three long terminal setae and a small subterminal element, the innermost terminal seta finely barbed along one edge. Second maxilla (fig. 138) with first segment unarmed. Second segment with a minute setule on its proximal outer (ventral) surface, a surficial naked seta, an unusually long inner (dorsal) seta bearing a row of erect spinules, and the segment terminating in a relatively short lash bearing two large spines near its base and two spikelike spinules along its midregion. Maxilliped (fig. 139) with two unequal naked setae on second segment; one of the terminal elements long and clawlike.

Area between maxillipeds and first pair of legs as in figure 140.

Legs 1–4 (figs. 141–144) segmented and armed as in *L. verseveldti*, *L. longispinifer*, *L. hians*, and *L. telestophilus*, except that formula for endopod of leg 4 is 0–1; II. Coxa of leg 1 with an outer protuberance. Inner seta on coxa of leg 4 long (112 μ) and feathered, instead of much reduced as in many other species. Inner margin of basis of all four legs with a row of hairs. Outer spines on exopod of leg 1 with unusually strong lateral spinules. Endopod of leg 4 (fig. 144) a little shorter than exopod. First segment 52 μ × 55 μ (including spinous processes), with its distal inner seta long (155 μ) and feathered. Second segment 122 μ × 45 μ (including processes), its tip obliquely truncated; its two terminal fringed spines 60 μ (outer) and 70 μ (inner) in one female, 66 μ and 68 μ in another. Both segments with outer margins haired and second segment with a terminal row of spinules.

Leg 5 (fig. 145) with an elongated unornamented free segment without a proximal inner expansion, 170 μ × 32 μ in greatest dimensions (ratio 5.3 : 1), its two terminal setae 40 μ (outer) and 55 μ (inner). Seta on body near free segment 40 μ. All three setae naked.

Leg 6 probably represented by the two setae near areas of attachment of each egg sac (see fig. 130).

Color in life in transmitted light slightly opaque to transparent, eye red, egg sacs opaque.

Male: Body (fig. 146) with prosome less expanded than in female. Length 1.74 mm (1.60–1.80 mm) and greatest width 0.64 mm (0.58–

0.70 mm), based on 10 specimens. Ratio of length to width of prosome 1.28 : 1.

Segment of leg 5 (fig. 147) 60 μ × 211 μ. No ventral intersegmental sclerite. Genital segment subquadrate, 244 μ × 252 μ. Four postgenital segments 86 μ × 133 μ, 83 μ × 125 μ, 55 μ × 114 μ, and 169 μ × 138 μ, from anterior to posterior.

Caudal ramus similar to that of female, 239 μ × 60 μ.

Dorsal surface of prosome and urosome with small refractile points as in female. Ratio of length of prosome to that of urosome 1 : 1.

Rostral area as in female. First antenna like that of female, but three long asethetes added (fig. 146) as in six previous species, proximalmost aesthete as long as entire first antenna. Second antenna, labrum, mandible, paragnath, first maxilla, and second maxilla as in female. Maxilliped (fig. 148) slender. Claw 140 μ along its axis.

Area between maxillipeds and first pair of legs as in female.

Legs 1–4 segmented and armed as in female. Leg 1 not showing sexual dimorphism.

Leg 5 (fig. 147) with free segment 62 μ × 14 μ, without ornamentation, its two terminal setae 38 μ and 43 μ. Seta on body near free segment 36 μ. All three setae naked.

Leg 6 (fig. 147) a posterolateral flap on ventral surface of genital segment bearing two naked setae 39 μ and 47 μ.

Spermatophore not observed.

Color in life as in female.

Etymology: The specific name *clavatus*, a Latin word meaning furnished with nails or spikes, alludes to the spikelike elements on the short lash of the second maxilla.

Comparison with related species: L. clavatus may be distinguished from all other species in the genus by the combination of the following features: the broad prosome and slender urosome, the moderately elongated caudal ramus (3.7 : 1 in the female) with relatively short setae, the second antenna with a single claw, the formula of II,I,5 on the last segment of the exopod of leg 4, a long feathered inner seta on the coxa and on the first segment of the endopod of leg 4, the elongated free segment of leg 5 (5.3 : 1 in the female), and the absence of sexual dimorphism in legs 1–4.

The new species is larger than most *Lichomolgus*. The females of only three other species reach or exceed a body length of 2 mm: *L. gigas* Thompson and A. Scott, 1903 (2 mm), *L. magnificus* Humes, 1964 (3.06 mm), and *L. pterophilus* Stock, 1962 (2.06 mm).

Three features of *L. clavatus* appear to be unique among the species in the genus, as far as they are known. These are: the long blunt spinules on the convex side of the mandible, the short lash with strong spikelike spines on the second maxilla, and the long feathered inner seta on the coxa of leg 4.

Remarks on *Lichomolgus* Associated With Octocorals

Almost one-third of the known species of *Lichomolgus* (34 out of 105) are associated with octocorals,—25 with Alcyonacea, 4 with Pennatulacea, 2 with Stolonifera, 2 with Telestacea, and 1 with Gorgonacea. It seems very probable that the small number of species reported from Gorgonacea reflects not the lack of preference of the copepods for these hosts but rather the very few observations as yet made on lichomolgids associated with them.

Among the species of *Lichomolgus* from octocorals there are several external anatomical features which are worthy of note. Only in this series of species does the endopod of leg 4 have the formula 0–1; 1,I (as in *L. protentus* Humes and Frost, 1964, *L. incisus* Humes and Ho, 1968c, and *L. insolens* Humes and Ho, 1968c). Nine of the species (*L. cuneipes* Humes and Ho, 1968b, *L. exilipes* Humes and Ho, 1968b, *L. fissisetiger* Humes and Ho, 1968b, *L. gentilis* Humes and Ho, 1968b, *L. hians*, *L. longispinifer*, *L. telestophilus*, *L. varirostratus* Humes and Ho, 1968b, and *L. verseveldti*) have this formula as 0–I; II, a condition not found in other *Lichomolgus*, except perhaps in *L. anomalus* A. Scott, 1909. (If Scott's fig. 15, pl. LXVII, is correct, the inner element on the first segment of the endopod of leg 4 is a spine. Such an armature suggests to us that *L. anomalus*, obtained from washings of dredged invertebrates from a depth of 1595 m, was actually associated with an octocoral.) In all 34 species the second antenna is 4-segmented. In five species (*L. aculeatus*, *L. exilipes*, *L. fissisetiger*, *L. gentilis*, and *L. varirostratus*, all described by Humes and Ho, 1968b), the two claws on the second antenna are very long (as long as or longer than the last segment). In two species (*L. cristatus* Humes and Ho, 1968c, and *L. dentipes* Thompson and A. Scott, 1903) the flagellum of the mandible is extremely short and reduced to a small pointed process. In three species (*L. conjunctus* Humes and Ho, 1967c, *L. decorus* Humes and Frost, 1964, and *L. organicus* Humes and Ho, 1967c, the convex margin of the mandible has a prominent toothlike process, replacing the scale-like spinulose area seen in other species.

Two features of these species, the number of claws on the second antenna and the formula for the last segment of the exopod of leg 4, vary without correlation. Hence they are useful in an artificial key, but probably do not indicate natural groups. Eleven species have one claw with the formula II,I,5 in four of them and III,I,5 in seven. Twenty-three species have two claws with II,I,5 in nineteen and III,I,5 in four.

In three species among those from octocorals, *L. trispinosus* Stock, 1959, *L. cristatus* Humes and Ho, 1968c, and *L. singularipes* Humes and Ho, 1968c, males are unknown. In the remaining 31 species sexual dimorphism in the formula for the endopod of leg 1 (I,5 in the female, I,I,4 in the male) occurs in all but four (*L. pteroidis* Della Valle, 1880, *L. pterophilus* Stock, 1962, *L. serratipes* Ummerkutty, 1962, and *L. clavatus*).

Characters especially useful in distinguishing the species of *Lichomolgus* associated with octocorals are: the number of claws on the second antenna and their length in relation to the last segment, the length of the flagellum and the nature of the convex margin of the mandible (whether a toothlike process or a spinulose scalelike crest), sexual dimorphism in the formula for the last segment of the endopod of leg 1, the formula for the last segment of the exopod and for the endopod of leg 4, the length to width ratio and the shape of the free segment of leg 5 in the female (presence or absence of a proximal inner expansion), and the length to width ratio and the nature of the armature of the caudal ramus.

KEYS TO THE 52 SPECIES OF *LICHOMOLGUS* KNOWN FROM THE REGION OF NOSY BÉ, MADAGASCAR

The following keys include those species not only from octocorals but from all other invertebrate hosts as well. The number of species now known from Madagascar comprises about half of the known species in the genus.

These artificial keys are intended only as aids in identification. In many instances it has been necessary to rely upon qualitative rather than quantitative characters for distinctions. Final determination of a species should be made by reference to the original description and figures, or to actual specimens, if available.

The copepod referred to by Humes and Cressey (1961) as *Lichomolgus oreastriphilus* (Kossmann, 1877), from asteroids at Nosy Bé, is in reality a *Stellicola* and therefore not included in the keys.

The host for *L. protentus* was cited in the original description by Humes and Frost (1964) as *Sarcophyton* sp., but has since been described as *S. globosum* n. sp. by Tixier-Durivault (1966).

Descriptions of several new species of octocorals listed as hosts may be found in the work of Verseveldt (1968).

FEMALES

1. Last segment of exopod of leg 4 with formula II,I,5 2
   Last segment of exopod of leg 4 with formula III,I,5 41
2. Second antenna with 1 claw 3
   Second antenna with 2 claws 20
3. A large sometimes toothlike process on convex margin of mandible 4
   Convex margin of mandible without such a process or at most with 2–4 small digitiform processes 6
4. A setiferous sphere on second segment of second maxilla (from corals, *Pavona angulata*, *P. danai*, *P. cactus*, and *P. ?venusta*) .... *L. actinophorus* Humes and Frost, 1964

Without such a sphere 5

5\. Free segment of leg 5 small, 34 μ × 13 μ, without proximal inner expansion (from coral, *Alveopora* sp.) .... *L. campulus* Humes and Ho, 1968a

Free segment of leg 5 larger, 90 μ × 22 μ, with a rounded proximal inner expansion (from coral, *Psammocora contigua*) .... *L. rhadinus* Humes and Ho, 1967a

6\. Convex margin of mandible with 2–4 small digitiform processes 7

Convex margin of mandible without such processes 10

7\. A prominent posteroventral lobe on first postgenital segment (from corals, *Acropora scherzeriana*, *A. cytherea*, and *Acropora* sp.) .... *L. lobophorus* Humes and Ho, 1968a

Without such a lobe 8

8\. Segments 3 and 4 of second antenna fused; free segment of leg 5 strongly arched (from coral, *Acropora palifera*) .... *L. arcuatipes* Humes and Ho, 1968a

Segments 3 and 4 of second antenna not fused; free segment of leg 5 not arched 9

9\. Free segment of leg 5 small, 36 μ × 17 μ, ratio about 2 : 1 (from corals, *Goniopora* sp. and *Porites* sp.) .... *L. digitatus* Humes and Ho, 1968a

Free segment of leg 5 elongated, 203 μ × 30 μ, ratio about 6.8 : 1 (from corals, *Porites* sp. cf. *P. andrewsi*, *P.* sp. cf. *P. nigrescens*, and *Porites* (s.g. *Synaraea*) sp.) .... *L. prolixipes* Humes and Ho, 1968a

10\. Formula for endopod of leg 4 = 0–1; 1,I 11

Formula for endopod of leg 4 = 0–1; II 12

11\. Seta on first segment of endopod of leg 4 naked; third segment of maxilliped with swollen membranous outer edge (from octocoral, *Sarcophyton ehrenbergi*) .... *L. incisus* Humes and Ho, 1968c

Seta on first segment of endopod of leg 4 feathered; third segment of maxilliped without swollen membranous outer edge (from octocoral, *Lobophytum crassum*) .... *L. insolens* Humes and Ho, 1968c

12\. Length exceeding 2 mm (2.19–2.37 mm); inner coxal seta long and feathered (from octocoral, *Coelogorgia palmosa*) .... *L. clavatus* Humes and Ho, above

Length distinctly less than 2 mm; inner coxal seta much reduced and either naked or at most with minute barbules 13

13\. Free segment of leg 5 minute, less than 25 μ long, and not reaching anterior border of genital segment 14

Free segment of leg 5 large, at least 80 μ in length, reaching beyond anterior border of genital segment 15

14\. Rostral area broadly rounded and slightly triangular; terminal setae on caudal ramus haired (from pelecypods, *Asaphis rugosa* and *Standella solanderi*) .... *L. asaphidis* Humes, 1959

Rostral area forming a long triangular beak; terminal setae on caudal ramus naked (from pelecypod, *Chama iostoma*) .... *L. chamarum* Humes, 1968

15\. Second antenna 3-segmented (third and fourth segments fused) 16

Second antenna 4-segmented 18

16\. Prosome broad, about as long as wide, with urosome flexed beneath it; outer spines on exopods of legs 2–4 with smooth lamellae (from corals, *Stylophora pistillata, S. mordax,* and *Acropora* sp.) .... *L. crassus* Humes and Ho, 1968a

Prosome not unusually broad, ratio about 1.3 : 1; urosome held posteriorly; outer spines on exopods of legs 2–4 with finely spinulose lamellae 17

17\. Caudal ramus with ratio 9.1 : 1 (from corals, *Stylophora pistillata, S. mordax,* and *Acropora* sp.) .... *L. geminus* Humes and Ho, 1968a

Caudal ramus with ratio 5 : 1 (from corals, *Seriatopora subseriata, S. octoptera,* and *Seriatopora* sp.) .... *L. compositus* Humes and Frost, 1964

18\. Caudal ramus as long as wide (from octocoral, *Sarcophyton glaucum*) .... *L. spathophorus* Humes and Ho, 1968c

Caudal ramus longer than wide 19

19\. Free segment of leg 5 with a proximal inner expansion (from sea anemone, *Rhodactis rhodostoma*) .... *L. simulans* Humes and Ho, 1967b

Free segment of leg 5 without a proximal inner expansion (from sea anemone, *Rhodactis rhodostoma*) .... *L. politus* Humes and Ho, 1967b

20\. Convex margin of mandible with a strong toothlike process 21

Convex margin of mandible without such a process 22

21\. Caudal ramus 36 μ × 24 μ (1.5 : 1); genital segment broadest near middle (from octocoral, *Tubipora musica*) .... *L. organicus* Humes and Ho, 1967c

Caudal ramus 28 μ × 23 μ (1.22 : 1); genital segment broadest more posteriorly (from octocoral, *Tubipora musica*) .... *L. conjunctus* Humes and Ho, 1967c

22\. Ratio of caudal ramus distinctly more than 1.5 : 1 23

Ratio of caudal ramus distinctly less than 1.5 : 1, often 1 : 1 or even wider than long 26

23\. Longer claw on second antenna longer than greatest length of fourth segment (from octocorals, *Nephthya aberrans, N. sphaerophora, N. tixierae, N. crassa,* and *Litophyton arboreum*) .... *L. aculeatus* Humes and Ho, 1968b.

Longer claw on second antenna shorter than greatest length of fourth segment 24

24\. Caudal ramus 3.3 : 1 (from octocorals, *Lemnalia* sp., *L. flava*, *L. elegans*, *L. amabilis*, *L. africana*, and *Paralemnalia thyrsoides*) .... *L. spinulifer* Humes and Frost, 1964

Caudal ramus about 1.7–1.8 : 1 25

25\. Free segment of leg 5 83 μ × 35 μ, without a proximal inner expansion (from sea anemones, *Stoichactis giganteum* and *Radianthus ritteri*) .... *L. cuspis* Humes, 1964

Free segment of leg 5 75 μ × 19 μ, with a proximal inner expansion where width is 31 μ (from zoantharians, *Palythoa tuberculosa* and *P. liscia*) .... *L. inaequalis* Humes and Ho, 1966

26\. Longer claw on second antenna about as long as or longer than greatest length of second segment 27

Longer claw on second antenna shorter than greatest length of second segment 30

27\. Two long terminal setae on caudal ramus naked; a prominent unguiform process (twice the length of the setae) on area of attachment of egg sac (from octocorals, *Dendronephthya mucronata*, *D. regia*, *D. stocki*, and *D. kollikeri*) .... *L. varirostratus* Humes and Ho, 1968b

Two long terminal setae on caudal ramus haired; without such a prominent unguiform process on area of attachment of egg sac ... 28

28\. Free segment of leg 5 with a weak proximal inner expansion; longer claw on second antenna distinctly longer than greatest length of fourth segment (143 μ to 130 μ) (from octocorals, *Dendronephythya mucronata*, *D. kollikeri*, *D. stocki*, *Stereonephthya acaulis*, and *S. papyracea*) .... *L. gentilis* Humes and Ho, 1968b

Free segment of leg 5 with a well developed proximal inner expansion; longer claw on second antenna about as long as greatest length of fourth segment 29

29\. Free segment of leg 5 148 μ long; lateral contour of genital segment in dorsal view rounded (from octocorals, *Stereonephthya acaulis*, *S. papyracea*, and *Lemnalia elegans*) .... *L. fissisetiger* Humes and Ho, 1968b

Free segment of leg 5 172 μ long; lateral contour of genital segment in dorsal view angular rather than rounded (from octocorals, *Dendronephthya mucronata*, *D. regia*, *D. stocki*, and *D. kollikeri*) .... *L. exilipes* Humes and Ho, 1968b

30\. Formula for endopod of leg 4 = 0–I; II 31

Formula for endopod of leg 4 = 0–1; II 35

31\. Free segment of leg 4 117 μ × 26 μ, without a proximal inner expansion (from octocoral, *Siphonogorgia pendula*) .... *L. hians* Humes and Ho, above

Free segment of leg 5 with a distinct proximal inner expansion .. 32

32\. Free segment of leg 5 with a broad rounded expansion 33
Free segment of leg 5 with a pointed expansion, directed distally .. 34

33\. Genital segment broadest near middle; free segment of leg 5 rather slender (from octocoral, *Telesto arborea*) .... *L. telestophilus* Humes and Ho, above
Genital segment broadest anterior to middle; free segment of leg 5 moderately broad (from octocoral, *Heteroxenia elisabethae*) .... *L. verseveldti* Humes and Ho, above

34\. Setae on caudal ramus naked; genital segment broadest near middle; spine on first segment of exopod of leg 1 of usual length (from octocoral, *Stereonephthya acaulis*) .... *L. cuneipes* Humes and Ho, 1968b
Setae on caudal ramus mostly haired; genital segment broadest posterior to middle; spine on first segment of exopod of leg 1 unusually long (from octocoral, *Siphonogorgia pendula*) .... *L. longispinifer* Humes and Ho, above

35\. Free segment of leg 5 small, less than 50 μ long 36
Free segment of leg 5 large, more than 80 μ long 37

36\. Proximalmost outer spine on third segment of exopod of legs 1–3 shorter than others; seta on first segment of endopod of leg 4 very lightly feathered; free segment of leg 5 27 μ × 12 μ (from octocorals, *Cladiella pachyclados* and *C. krempfi*) .... *L. hetaericus* Humes and Ho, 1968c
Proximalmost outer spine on third segment of exopod of legs 1–3 not shorter than others; seta on first segment of endopod of leg 4 conspicuously feathered; free segment of leg 5 49 μ × 20 μ (from nudibranch, *Phyllidia trilineata*) .... *L. venustus* Humes, 1959

37\. Caudal ramus a little longer than wide, ratio 1.3 : 1 (from nudibranch, *Trevelyana rubromaculata*) .... *L. sensilis* Humes, 1964
Caudal ramus about as long as wide or a little wider than long .. 38

38\. Free segment of leg 5 without a basal expansion 39
Free segment of leg 5 with a proximal inner expansion 40

39\. Free segment of leg 5 broad, 81 μ × 34 μ, with relatively large scalelike spines on outer surface (from octocoral, *Parerythropodium rubiginosum*) .... *L. singularipes* Humes and Ho, 1968c
Free segment of leg 5 slender, 98 μ × 22 μ, with small spines on outer surface (from nudibranch, *Phyllidia trilineata*) .... *L. patulus* Humes, 1959

40\. Expansion slight; outer surface of free segment of leg 5 with small spinules (from nudibranchs, *Hexabranchus orbicularis* and *Doridopsis ruber*) .... *L. commodus* Humes, 1964
Expansion large and rounded; outer surface of free segment of leg 5 smooth (from nudibranch, *Doris mabilla*) .... *L. securiger* Humes, 1964

41. Second antenna with 1 claw 42
Second antenna with 2 claws 48
42. Formula of endopod of leg 4 = 0–1; 1,I (from octocoral, *Sarcophyton globosum*) .... *L. protentus* Humes and Frost, 1964
Formula of endopod of leg 4 = 0–1; II 43
43. Caudal ramus distinctly longer than wide (at least 3.5 : 1) 44
Caudal ramus about as long as wide 45
44. Setae on first antenna haired; mandible with an extremely short flagellum; lash of second maxilla with a crest of long spinules (from octocoral, *Sinularia leptoclados*) .... *L. cristatus* Humes and Ho, 1968c
Setae on first antenna smooth; mandible with moderately long flagellum; without crest of long spinules on lash of second maxilla (from octocoral, *Xenia umbellata*) .... *L. glabripes* Humes and Ho, above
45. Free segment of leg 5 with an inner expansion 46
Free segment of leg 5 lacking an inner expansion 47
46. Inner expansion in the form of a large tooth (from octocoral, *Sinularia humesi*) .... *L. dentipes* Thompson and A. Scott, 1903
Inner expansion large, not well delimited, and giving a triangular appearance to the segment (from octocoral, *Anthelia gracilis*) .... *L. triquetrus* Humes and Ho, above
47. Free segment of leg 5 195 μ × 26 μ, with spines on outer surface arranged in two rows proximally and in one row distally (from octocorals, *Sinularia polydactyla*, *S. pedunculata*, and *S. whiteleggei*) .... *L. adelphus* Humes and Ho, 1968c
Free segment of leg 5 82 μ × 34 μ, with spines on outer surface not arranged in rows (from octocorals, *Sinularia polydactyla* and *S. whiteleggei*) .... *L. squamiger* Humes and Frost, 1964
48. Body length 3 mm; caudal ramus 7.8 : 1 (from sea anemone, *Stoichactis giganteum*) .... *L. magnificus* Humes, 1964
Body length less than 1.5 mm; caudal ramus 2 : 1 or less, in some even wider than long 49
49. Seta on first segment of endopod of leg 4 naked; mandible with a spiniform or toothlike process on convex margin 50
Seta on first segment of endopod of leg 4 feathered; mandible without a spiniform or toothlike process 51
50. Free segment of leg 5 short, 33 μ × 15 μ, with an inner expansion but unornamented (from octocoral, *Cladiella laciniosa*) .... *L. decorus* Humes and Frost, 1964
Free segment of leg 5 elongated, 101 μ × 15 μ, with an inner expansion and outer surface with spinules (from octocorals, *Cladiella krempfi*, *C. laciniosa*, and *C. pachyclados*) .... *L. foxi* Gurney, 1927
51. Inner surface of segment 2 of second antenna with small spines;

caudal ramus wider than long, 24 μ × 30 μ (from nudibranch, *Platydoris scaber*) .... *L. audens* Humes, 1959
Inner surface of segment 2 of second antenna smooth; caudal ramus longer than wide, 55 μ × 31 μ (from sea anemone, *Stoichactis giganteum*) .... *L. gemmatus* Humes, 1964

MALES

(The males of *L. cristatus* Humes and Ho, 1968c, and *L. singularipes* Humes and Ho, 1968c, are unknown, and hence are not included in the key.)

1. Last segment of exopod with formula II,I,5 2
   Last segment of exopod with formula III,I,5 40
2. Second antenna with 1 claw 3
   Second antenna with 2 claws 20
3. A large sometimes toothlike process on convex margin of mandible 4
   Convex margin of mandible without such a process or at most with 2–4 small digitiform processes 6
4. A setiferous sphere on segment 2 of second maxilla .... *L. actinophorus* Humes and Frost, 1964
   Without such a sphere 5
5. Last segment of endopod of leg 1 = I,I,4; free segment of leg 5 18 μ × 6 μ; caudal ramus 1.55 : 1 .... *L. rhadinus* Humes and Ho, 1967a
   Last segment of endopod of leg 1 = I,5, as in female; free segment of leg 5 15 μ × 9 μ; caudal ramus 3.2 : 1 .... *L. campulus* Humes and Ho, 1968a
6. Convex margin of mandible with 2–4 small digitiform processes 7
   Convex margin of mandible without such processes 10
7. A prominent posteroventral lobe on second postgenital segment .... *L. lobophorus* Humes and Ho, 1968a
   Without such a lobe 8
8. Segments 3 and 4 of second antenna fused; segment 2 of maxilliped with two rows of prominent spinules .... *L. arcuatipes* Humes and Ho, 1968a
   Segments 3 and 4 of second antenna not fused; segment 2 of maxilliped with only one row of prominent spinules 9
9. Caudal ramus 2 : 1 .... *L. prolixipes* Humes and Ho, 1968a
   Caudal ramus 4.3 : 1 .... *L. digitatus* Humes and Ho, 1968a
10. Formula for endopod of leg 4 = 0–1; I,I 11
    Formula for endopod of leg 4 = 0–1; II 12
11. Seta on first segment of endopod of leg 4 naked; inner margin of segment 2 of second antenna with a notched lamella; concave edge of claw of maxilliped smooth .... *L. incisus* Humes and Ho, 1968c

Seta of first segment of endopod of leg 4 feathered; inner margin of segment 2 of second antenna with a striated membrane; concave edge of claw of maxilliped with hyaline knobs .... *L. insolens* Humes and Ho, 1968c

12\. Length 1.74 mm (1.60–1.80 mm); inner coxal seta long and feathered .... *L. clavatus* Humes and Ho, above

Length not exceeding 1.55 mm; inner coxal seta much reduced and either naked or at most with minute barbules 13

13\. Last segment of endopod of leg 1 with formula I,5, as in female 14

Last segment of endopod of leg 1 with formula I,I,4 16

14\. Caudal ramus 4.4 : 1, its setae relatively long and naked .... *L. chamarum* Humes, 1968

Caudal ramus at least 5.13 : 1, its setae otherwise 15

15\. Two terminal setae on caudal ramus not broadened, ornamented with hairs; concave margin of claw of maxilliped smooth; free segment of leg 5 minute, 18 $\mu \times 12$ μ .... *L. asaphidis* Humes, 1959

Two terminal setae on caudal ramus naked and slightly broadened; concave margin of claw of maxilliped with hyaline dentation; free segment of leg 5 larger, 35 $\mu \times 10$ μ .... *L. crassus* Humes and Ho, 1968a

16\. Second antenna with third and fourth segments fused 17

Second antenna 4-segmented 18

17\. Outer of two terminal spines on last segment of endopod of second leg not modified .... *L. compositus* Humes and Frost, 1964

Outer of two terminal spines on last segment of endopod of second leg modified (truncated and broadened at tip) .... *L. geminus* Humes and Ho, 1968a

18\. Caudal ramus about as long as wide .... *L. spathophorus* Humes and Ho, 1968c

Caudal ramus distinctly longer than wide 19

19\. Length 1.33 mm (1.26–1.40 mm); caudal ramus 138 $\mu \times 36$ μ, ratio 3.8 : 1 .... *L. politus* Humes and Ho, 1967b

Length 0.96 mm (0.85–1.08 mm); caudal ramus 52 $\mu \times 34$ μ, ratio 1.5 : 1 .... *L. simulans* Humes and Ho, 1967b

20\. Convex margin of mandible with a strong toothlike process 21

Convex margin of mandible without such a process 22

21\. Caudal ramus 31 $\mu \times 21$ μ, ratio 1.48 : 1; free segment of leg 5 36 $\mu \times 9$ μ, ratio 4 : 1 .... *L. organicus* Humes and Ho, 1967c

Caudal ramus 25 $\mu \times 21$ μ, ratio 1.19 : 1; free segment of leg 5 28 $\mu \times 8$ μ, ratio 3.5 : 1 .... *L. conjunctus* Humes and Ho, 1967c

22\. Longer claw on second antenna about as long as or longer than greatest length of fourth segment 23

Longer claw on second antenna shorter than greatest length of fourth segment 27

23\. Caudal ramus 2 : 1; terminal spine on third segment of endopod of leg 1 concave with two rows of strong spinules .... *L. aculeatus* Humes and Ho, 1968b

Caudal ramus about 1 : 1; terminal spine on third segment of endopod of leg 1 otherwise 24

24. Rostral area pointed, not broadly rounded as in female; two terminal setae on caudal ramus naked; free segment of leg 5 33 μ × 9 μ, ratio 3.66 : 1 .... *L. varirostratus* Humes and Ho, 1968b

Rostral area rounded; two terminal setae on caudal ramus haired; free segment of leg 5 with ratio of 5–5.77 : 1 25

25. One of two setae on second segment of maxilliped terminating in several pointed spiniform elements; free segment of leg 5 with ratio of 5.77 : 1 .... *L. fissisetiger* Humes and Ho, 1968b

Both setae on second segment of maxilliped normally attenuated; free segment of leg 5 with ratio close to 5 : 1 (not more than 5.2 : 1) 26

26. Outer spine on last segment of endopod of leg 1 angularly bent; genital segment with lateral margins rounded posteriorly .... *L. exilipes* Humes and Ho, 1968b

Outer spine on last segment of endopod of leg 1 not strongly bent; genital segment with lateral margins angular posteriorly .... *L. gentilis* Humes and Ho, 1968b

27. Spine on first segment of exopod of leg 1 unusually long (about twice length of succeeding spines) .... *L. longispinifer* Humes and Ho, above

Spine on first segment of exopod of leg 1 of usual length 28

28. Setae on caudal ramus naked 29

Setae on caudal ramus haired 30

29. First segment of endopod of leg 4 with slightly barbed spine .... *L. cuneipes* Humes and Ho, 1968b

First segment of endopod of leg 4 with feathered seta .... *L. venustus* Humes, 1959

30. Endopod of leg 4 with formula 0–1; II, first segment with a feathered seta 31

Endopod of leg 4 with formula 0–I; II, first segment with a very finely barbed or naked spine 38

31. One of two setae on second segment of maxilliped strongly modified, with base swollen and spinose and distal part slender and naked .... *L. cuspis* Humes, 1964

Neither of two setae on second segment of maxilliped so modified 32

32. Second antenna like that of female, without ornamentation added .... *L. inaequalis* Humes and Ho, 1966

Second antenna with ornamentation on inner surface of second segment 33

33. This ornamentation consisting of hairs .... *L. commodus* Humes, 1964

This ornamentation consisting of spinules (in some cases knoblike) 34

34. Caudal ramus longer than wide 35

Caudal ramus with ratio close to 1 : 1, or wider than long 36

35. Caudal ramus 1.3 : 1; inner surface of segment 2 of second antenna with small knobs (spinules ?) .... *L. sensilis* Humes, 1964

Caudal ramus 2.44 : 1; inner surface of segment 2 of second antenna with strong spinules .... *L. spinulifer* Humes and Frost, 1964

36. Inner distal spine on segment 2 of second maxilla with spinules on one side; seta on first segment of endopod of leg 4 very lightly feathered .... *L. hetaericus* Humes and Ho, 1968c

Inner distal spine on segment 2 of second maxilla with spinules on both sides; seta on first segment of endopod of leg 4 well feathered 37

37. Free segment of leg 5 small, $20\ \mu \times 9\ \mu$, without fine ornamentation .... *L. securiger* Humes, 1964

Free segment of leg 5 larger, $87\ \mu \times 14\ \mu$, with small spinules on outer surface .... *L. patulus* Humes, 1959

38. Longer claw on second antenna about 80 per cent of greatest length of fourth segment; slight sexual dimorphism in third segment of endopod of leg 2 .... *L. hians* Humes and Ho, above

Longer claw on second antenna about 61 per cent of greatest length of fourth segment; without sexual dimorphism in third segment of endopod of leg 2 39

39. One of two setae on second segment of maxilliped with a blunt finely spinulose tip .... *L. verseveldti* Humes and Ho, above

Both setae on second segment of maxilliped attenuated and naked .... *L. telestophilus* Humes and Ho, above

40. Second antenna with 1 claw 41

Second antenna with 2 claws 46

41. Formula for endopod of leg 4 = 0–1; 1,I .... *L. protentus* Humes and Frost, 1964

Formula for endopod of leg 4 = 0–1; II 42

42. Mandible with extremely short flagellum; last postgenital segment much wider than preceding three .... *L. dentipes* Thompson and A. Scott, 1903

Mandible with long flagellum; last postgenital segment not noticeably wider than preceding segments 43

43. Segment 2 of second antenna with inner surface unornamented, as in female; seta on first segment of endopod of leg 4 naked .... *L. triquetrus* Humes and Ho, above

Segment 2 of second antenna with inner surface ornamented with spinules or spines; seta on first segment of endopod of leg 4 feathered 44

44. Segment 2 of second antenna with few scalelike spines on inner

surface .... *L. glabripes* Humes and Ho, above

Segment 2 of second antenna with many spinules on inner surface 45

45. Last segment of endopod of leg 2 with spiniform process between two terminal spines broadly triangular .... *L. adelphus* Humes and Ho, 1968c

Last segment of endopod of leg 2 with spiniform process between two terminal spines in the form of a bent thumb .... *L. squamiger* Humes and Frost, 1964

46. Body length 2.74 mm; caudal ramus 6.7 : 1 .... *L. magnificus* Humes, 1964

Body length not exceeding 1 mm; caudal ramus less than 2 : 1 47

47. Last segment of endopod of leg 1 with formula I,II,3; segment 2 of second antenna with refractile knobs on inner surface .... *L. gemmatus* Humes, 1964

Last segment of endopod of leg 1 with formula I,I,4; segment 2 of second antenna without refractile knobs on inner surface 48

48. Seta on first segment of endopod of leg 4 naked; genital segment longer than wide .... *L. foxi* Gurney, 1927

Seta on first segment of endopod of leg 4 feathered; genital segment not longer than wide 49

49. Segment 2 of second antenna with smooth inner surface, as in female; seta on first segment of endopod of leg 4 weakly feathered .... *L. decorus* Humes and Frost, 1964

Segment 2 of second antenna with spinules on inner surface; seta on first segment of endopod of leg 4 well feathered .... *L. audens* Humes, 1959

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Mémoire O.R.S.T.O.M. n° 31

DIATOMÉES PLANCTONIQUES DU CANAL DE MOZAMBIQUE ET DE L'ILE MAURICE

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ORSTOM
PARIS
1968

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Quelques conclusions :

RÉSUMÉ

Étude taxinomique portant sur 196 Diatomées, planctoniques ou tychoplanctoniques. Les récoltes, échelonnées sur vingt mois, proviennent de Nossi-Bé et de Tuléar (Madagascar), de la croisière n° 8 du R/V « Anton Bruun » (Expédition internationale dans l'océan Indien), et de l'île Maurice. Pour chaque taxon, la répartition dans l'océan Indien et dans l'océan mondial est esquissée. La composition biogéographique globale de l'inventaire est examinée en conclusion. Diverses innovations taxinomiques sont proposées : 1 espèce et 1 variété nouvelles, 3 nouvelles combinaisons et 3 nouveaux noms spécifiques.

Illustration : 1 carte, 45 figures et 44 microphotographies.

Bibliographie : 340 références.

ABSTRACT

A taxonomic study dealing with 196 planktonic or tychoplanktonic Diatoms. Samples spread over twenty months from Nossi-Bé and Tuléar (Madagascar), R/V « Anton Bruun » cruise n° 8 (International Indian Ocean Expedition), and Mauritius I. Distribution in the Indian ocean and in the world ocean is outlined for each taxon. Biogeographic composition of the whole list is considered in conclusion. Several taxonomic innovations are proposed: 1 new species, 1 new variety, 3 new combinations and 3 new specific names.

Illustration: 1 map, 45 figures and 44 microphotographs.

Bibliography: 340 references.

INTRODUCTION

TRAVAUX ANTÉRIEURS DANS L'OCÉAN INDIEN

L'océan Indien était considéré jusqu'à une date récente comme le plus mal connu des océans. Ce retard se trouvera probablement comblé lorsque tout le matériel et toutes les observations recueillis au cours de l'Expédition internationale auront été dépouillés et publiés. Cependant, la connaissance du phytoplancton, et plus particulièrement celle des Diatomées planctoniques, n'est actuellement dans cet océan ni plus ni moins avancée que dans les autres — si l'on excepte toutefois l'Atlantique nord et les mers adjacentes, qui constituent sous cet aspect comme dans bien d'autres domaines de l'Océanographie une région tout à fait privilégiée.

Les différents travaux de taxinomie traitant, exclusivement ou non, des Diatomées planctoniques dans l'océan Indien peuvent être classés, du point de vue méthodologique, sous trois rubriques : 1° les grandes expéditions océanographiques, 2° ce que l'on pourrait appeler les « collections particulières », 3° les monographies régionales. Un quatrième groupe doit être ajouté, qui englobe les trois précédents : celui des index récapitulatifs, groupe actuellement représenté par l'unique « check-list » de Wood (1963 *a*).

Les localisations de ces divers travaux sont reportées sur la carte I.

1° **Les grandes expéditions** : La légende de la carte en reproduit la liste, accompagnée des références bibliographiques correspondantes. N'ont pu être reportées ici les expéditions très récentes organisées au cours de l' « I.I.O.E. » (notamment diverses croisières soviétiques) dont le matériel est en cours d'exploitation. Reste par ailleurs à mentionner l'expédition de la « Gazelle » (1874-1876) qui a donné lieu au travail manuscrit de Janisch (1890), repris en grande partie dans l'atlas de Schmidt.

2° **Collections particulières** : On peut ainsi désigner les échantillons récoltés par des Diatomistes ou par des voyageurs bénévoles, et de provenance souvent imprécise. Ce groupe est historiquement le plus ancien : il remonte au début du siècle dernier, qui fut le siècle des « collectionneurs de Diatomées ». Les travaux de cette nature tiennent d'ordinaire le milieu pour secondaire, aussi les indications géographiques qui les accompagnent sont-elles parfois vagues, et les données hydrologiques exceptionnelles. Par ailleurs, les résultats acquis dans cette voie n'ont pas tous été publiés *in texto:* certains ont été divulgués sous forme d'exsiccata, d'autres ont donné lieu à des illustrations dans l'atlas de Schmidt, enfin de nombreuses observations étaient simplement échangées par les Diatomistes à titre de correspondance personnelle.

La transition avec le troisième groupe est progressive.

3° **Monographies régionales** : Ce sont les inventaires floristiques limités à une région donnée; ces travaux concernent le plus souvent les domaines littoral et néritique, car effectués dans le voisinage d'un laboratoire côtier. Certains d'entre eux, de date récente ou relativement récente, accompagnés de descriptions et figures, constituent des documents indispensables : Allen & Cupp, 1935 (mer de Java), Subrahmanyan, 1946 (côte orientale des Indes), Silva, 1956 *a* et 1960 (côtes du Mozambique), Taylor, 1967 (côtes d'Afrique du Sud).

Pour le canal de Mozambique lui-même, les trois groupes définis ci-dessus sont représentés comme suit :

1° Expédition du « Discovery II » (Hendey, 1937).

2° Récoltes provenant de Durban (Shadbolt, 1854), de Fort-Dauphin et de Nossi-Bé (Petit, 1902), de Zanzibar et de Dar-es-Salam (Amossé, 1924).

3° Monographies du phytoplancton de la côte du Mozambique (Silva, 1956 *a*, 1960) et de la région de Tuléar (Travers & Travers, 1965).

CARTE I

État actuel des recherches sur les Diatomées planctoniques dans l'océan Indien

Principales expéditions océanographiques :

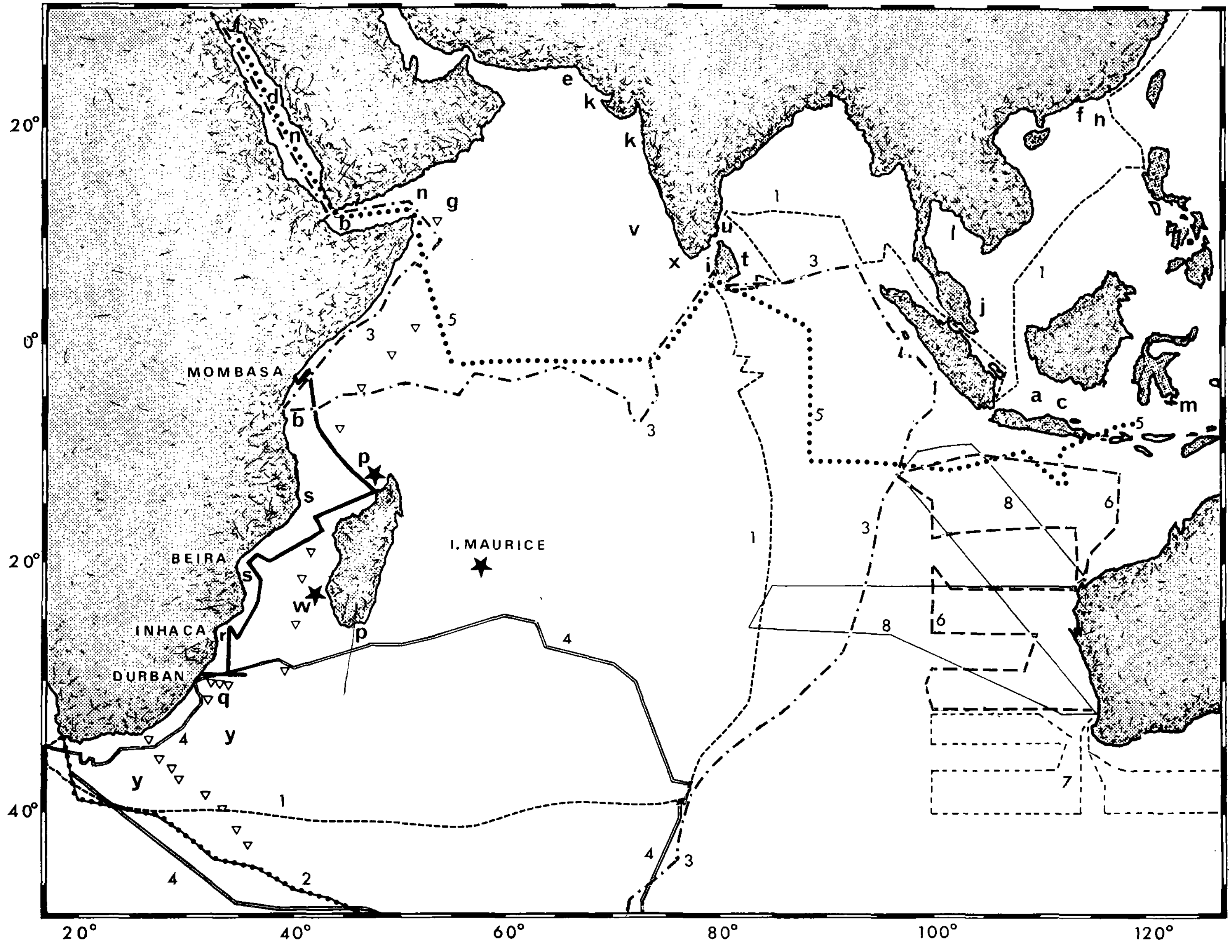
1 — « *Novara* » 1857-1859 : cf. Grunow (1867c).
2 — « *Challenger* » 1873-1874 : cf. Castracane (1886).
3 — « *Valdivia* » 1898-1899 : cf. Karsten (1907).
4 — « *Gauss* » 1902-1903 : cf. Heiden et Kolbe (1928).
5 — « *Albatross* » 1947-1948 : cf. Kolbe (1957).
6 — « *Diamantina* » 1959/I
7 — « *Diamantina* » 1960/I } cf. Wood (1962, 1963a).
8 — « *Diamantina* » 1960/III
triangles : « *Discovery II* » 1930-1935 : cf. Hendey (1937).

Principales « collections particulières » et monographies régionales :

a - Allen et Cupp (1935).
b - Amossé (1924).
c - Cleve (1873a).
d - Cleve (1900c).
e - Czapek (1909).
f - Greville (1865).
g - Kitton (1884).
h - Lauder (1864).
i - Leuduger-Fortmorel (1878).
j - Leuduger-Fortmorel (1892).
k - Misra (1956).
l - Ostenfeld (1903).
m - Ostenfeld (1915).
n - Ostenfeld et Schmidt (1901).
p - Petit (1902).
q - Shadbolt (1854).
r - Silva (1956a).
s - Silva (1960).
t - Skvortzow (1932e).
u - Subrahmanyan (1946).
v - Subrahmanyan (1958).
w - Travers (1965).
x - Venkataraman (1940, 1957, 1958).
y - Taylor (1967).

Récoltes personnelles :

En trait fort : croisière n° 8 du R/V « *Anton Bruun* » dans le canal de Mozambique, 1964: cf. Anonyme (1965).
Étoiles : Nossi-Bé et Tuléar (nord et sud de Madagascar), île Maurice.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RÉCOLTES PERSONNELLES[*]

Le matériel ici étudié provient soit de pêches horizontales ou verticales au filet fin (vide de maille : 50 µ env.), soit de prélèvements à différents niveaux réalisés au moyen d'échantillonneurs du type VAN DORN. Les récoltes étaient fixées au formol ou au lugol, ou, dans quelques cas, étudiées *in vivo*. Les stations se répartissent en quatre groupes :

— Nossi-Bé (Madagascar) : Prélèvements hebdomadaires dans la baie du Centre d'Océanographie, de février 1963 à juillet 1964. Les données écologiques et quantitatives relatives à cette série ont été récemment publiées (SOURNIA, 1968 a).

— Tuléar (Madagascar) : Prélèvements en surface, plus ou moins côtiers, en août et septembre 1964 (cf. SOURNIA, 1968 b).

— Croisière n° 8 du R/V « Anton Bruun » dans le canal de Mozambique, de septembre à novembre 1964 : le trajet en est reporté sur la carte I (voir aussi la liste des stations *in* ANONYME, 1965).

— J'inclus ici par commodité quelques pêches au filet de surface réalisées, en dehors du canal de Mozambique, à l'île Maurice en septembre 1964, et dont j'ai antérieurement publié (1966) un inventaire préliminaire.

MÉTHODES D'ÉTUDE

Microscopie : J'ai utilisé, selon les lieux de travail, un microscope inversé ZEISS (« microscope à plancton »), un microscope standard ZEISS, un photomicroscope LEITZ et, principalement, un photomicroscope ZEISS à contraste de phase. Ce dernier dispositif s'est révélé extrêmement utile dans l'examen de la structure et de l'ornementation de nombreuses espèces : on sait que les techniques classiques de la diatomologie font appel à des procédés plus ou moins drastiques (incinération ou lavage aux acides, montage dans un milieu réfringent) auxquels les formes planctoniques trop fragiles résistent rarement; l'avantage de l'observation en contraste de phase est de révéler assez fréquemment les détails nécessaires à l'identification, sur matériel brut — ou même vivant —, possédant encore, notamment, ses chromatophores.

Accessoirement, j'ai pratiqué l'observation à sec, l'incinération modérée, et le montage en milieu réfringent (monobromonaphtalène, ou Clearax).

Bibliographie[**] : Soulignons ici l'intérêt que présentent les divers « index » de Diatomées : principalement, ceux de DE-TONI (1891-1894), BOYER (1926-1927) et de MILLS[***] (1933-1935); ces catalogues, malheureusement rares dans les bibliothèques, permettent de retrouver quand il est nécessaire la bibliographie et l'iconographie complètes (sauf erreurs et omissions) d'une espèce donnée. Un grand travail également peu divulgué est l'atlas de SCHMIDT (1874-1958).

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[*] J'exprime ici toute ma reconnaissance aux divers Organismes qui m'ont permis de réaliser ce travail : l'Office de la recherche scientifique et technique outre-mer (O.R.S.T.O.M.) pour son accueil prolongé au Centre de Nossi-Bé; la Faculté des Sciences de Tananarive et la Station marine d'Endoume-Marseille pour les facilités de travail qui m'ont été accordées à la Station de Tuléar; la Woods Hole oceanographic Institution pour ma participation au programme américain à bord de l' « Anton Bruun »; enfin, le Centre national de la recherche scientifique (C.N.R.S.) et le Comité « Exploitation des océans » (COMEXO) qui ont bien voulu prendre en charge l'ensemble de mon séjour à Madagascar.

[**] La bibliothèque et les collections du Laboratoire de Cryptogamie du Muséum m'ont été librement ouvertes : j'en remercie vivement M. le Professeur R. HEIM, Directeur de ce Laboratoire, ainsi que M. le Dr P. BOURRELLY, Sous-Directeur, dont les conseils m'ont été si précieux.

[***] Dont VAN LANDINGHAM (1967) vient tout récemment d'entreprendre la remise à jour; voir note]p. 103.

Enfin, les collections d'exsiccata, telles que celles de CLEVE et MÖLLER (1877-1882) et de TEMPÈRE et PERAGALLO (1907), sont d'un intérêt inestimable; elles sont malheureusement plus rares encore, et relèvent d'ailleurs d'un usage à peu près disparu.

DISPOSITIONS PRATIQUES

La classification suivie ici est celle de HENDEY (1937, 1964), préférée à la classification binaire (Centriques et Pennées) de SCHÜTT (1896) développée par HEIDEN & KOLBE (1928), HUSTEDT (1930-1966), CUPP (1943), etc. Pour pallier les désagréments de cette rupture avec la tradition, j'ai reproduit en tête de ce travail la liste des familles et des genres traités (table des matières); les espèces elles-mêmes seront aisément retrouvées au moyen de l'index alphabétique.

Au sujet des règles de nomenclature, voir LANJOUW *et al.* (1966) : Code international de la nomenclature botanique. Par ailleurs, les rangs de variété et de forme sont ici entendus au sens de HENDEY (1964, p. 55).

Références : On s'est efforcé dans cette étude de mettre à jour ou compléter les ouvrages de base : GRAN (1905), HUSTEDT (1930-66), HENDEY (1937, 1964), CLEVE-EULER (1951-55). Aussi, sauf intérêt particulier, les références et synonymies indiquées par ces auteurs ne seront pas reproduites ici. D'autre part, à moins d'indication contraire (« *fide...* »), je ne cite aucun travail sans en avoir pris personnellement connaissance.

Descriptions et illustrations : Ne sont ici décrits et illustrés que seuls les taxons qui ne le sont pas dans les travaux de base mentionnés ci-dessus, sauf dans les cas où j'ai cru pouvoir apporter une précision nouvelle.

« **Océan Indien** » : Comme indiqué plus haut, on doit à WOOD (1963 *a*) un index bibliographique des Diatomées de cet océan. Comme toute entreprise de cette nature, celle-ci est entachée de diverses erreurs ou omissions que je me suis efforcé de rectifier ou de combler : les références *additives* seront données entre parenthèses à la fin de cette rubrique. Par ailleurs, la désignation « océan Indien » inclut ici, à la suite de WOOD *(ibid.)* et pour raison de commodité, la mer Rouge, les mers de l'Indonésie, et les parages de l'Antarctique.

Il convient peut-être enfin de rappeler quelques définitions de termes courants : L'*axe pervalvaire* passe par les centres des deux valves du frustule; l'*axe apical* joint les deux sommets d'une valve lorsque celle-ci est bipolaire; l'*axe transapical* est perpendiculaire au précédent dans le plan valvaire; la *vue valvaire* montre une valve « de face »; la *vue connective* montre la *ceinture* (formée par les *bandes connectives* des deux valves) et accessoirement, 1) les *manteaux valvaires*, prolongations marginales des valves dans un plan perpendiculaire à celles-ci, et 2) les *bandes intercalaires*, qui se développent entre la ceinture et les valves.

SYSTÉMATIQUE

Fam. COSCINODISCACEAE

Paralia sulcata (Ehrenberg) Cleve, 1873

Ehrenberg, 1838, p. 170, pl. 21, fig. 5 : « *Gallionella sulcata* ». Cleve, 1873b, p. 7. Gran, 1905, p. 14, fig. 5. Pavillard, 1925, p. 4, fig. 1. Hendey, 1958, p. 35, et 1964, p. 73, pl. 23, fig. 5.

= *Melosira sulcata* (Ehrenberg) Kützing

Hustedt, 1930, p. 276, fig. 118-119. Subrahmanyan, 1946, p. 86, fig. 1-2.
Saunders, 1965 (monographie).

Récoltes personnelles : Nossi-Bé.

Océan Indien : espèce fréquente dans la zone tropicale; Kerguelen. (Silva, 1956a, 1960; Kolbe, 1957).

Distribution mondiale : espèce littorale, tychoplanctonique, cosmopolite.

Selon Hendey (1958, 1964, *non* 1937), la structure particulière du manteau, ainsi que la striation des valves, justifient la position de cette espèce dans un genre distinct de *Melosira.*

(?) ***Melosira sphaerica*** Karsten, 1905

Karsten, 1905a, p. 70, pl. 1, fig. 2. Mangin, 1915, p. 68, fig. 47. Hendey, 1937, p. 234. Boden, 1950, p. 328, fig. 1.

? = *Hyalophysa delicatula* Cleve

Cleve, 1900a, p. 18, pl. 8, fig. 1-2.

Cellules isodiamétriques : axes pervalvaire et apical de longueurs voisines (50-65 µ). Cellules isolées ou formant de courtes chaînes (dans ce dernier cas, « par une petite quantité de mucilage » selon Mangin). Parois extrêmement délicates, sans structure ni ornementation visibles. Plusieurs petits chloroplastes discoïdes.

Espèce néritique antarctique?

Je rapporte sans certitude à cette espèce quelques spécimens récoltés à Nossi-Bé. La structure et l'ornementation du frustule étant inconnues, cette Diatomée demeure purement énigmatique : un rapprochement n'est pas même exclu avec la forme décrite par Cleve (Açores) et classée par cet auteur parmi les « *Cysteae* ».

Coscinodiscus excentricus Ehrenberg, 1840

EHRENBERG, 1840-1841, p. 146 (« *C. eccentricus* »), et 1854, pl. 18, fig. 32, pl. 21, fig. 6. HUSTEDT, 1930, p. 388, fig. 201. HASLE, 1960, p. 10. HENDEY, 1964, p. 80, pl. 24, fig. 7.

= *Brenneckella Lorenzenii*, *B. Kohlii* Lohmann = *Coscinodiscus sp.* Lecal-Schlauder

LOHMANN, 1912. LECAL-SCHLAUDER, 1949. (Au sujet de ces deux synonymes, voir GAARDER et HASLE, 1962.)

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; espèce courante dans les récoltes de l' « Anton Bruun ».

OCÉAN INDIEN : l'une des espèces les plus courantes du genre, rencontrée sous toutes les latitudes jusqu'aux eaux antarctiques. (KOLBE, 1957; SILVA, 1960; TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce cosmopolite très courante; euryhaline (estuaires).

Coscinodiscus lineatus Ehrenberg, 1839

EHRENBERG, 1839a, p. 129 et 1854, pl. 18, fig. 33, pl. 22, fig. 6, pl. 35B, fig. 16/3-17/7. HUSTEDT, 1930, p. 392, fig. 204. HASLE, 1960, p. 10. HENDEY, 1964, p. 76.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); Tuléar; île Maurice; espèce courante dans le canal de Mozambique, mais plus abondante dans les eaux océaniques.

OCÉAN INDIEN : espèce très courante, comme la précédente. (AMOSSÉ, 1924; HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : cosmopolite.

Coscinodiscus Normanii Gregory *in* Greville, 1859

GREVILLE, 1859a, p. 80, pl. 6, fig. 3. RATTRAY, 1890, p. 500. PERAGALLO, 1921, p. 81. CLEVE-EULER, 1951, p. 58, fig. 78. HENDEY, 1964, p. 80.

= *C. Rothii* var. *Normanii* (Gregory) Van Heurck

HUSTEDT, 1930, p. 402, fig. 213.

RÉCOLTES PERSONNELLES : Tuléar, et sud du canal de Mozambique.

OCÉAN INDIEN : très rare. Fort-Dauphin (Madagascar); golfe d'Aden; Zanzibar; sédiments dans la zone tropicale. (PETIT, 1902; AMOSSÉ, 1924; KOLBE, 1957).

DISTRIBUTION MONDIALE : Sporadique. Mers polaires; mer du Nord; côtes anglaises; mer d'Arafura; Californie. Espèce euryhaline. (Éventuellement signalée sous d'autres noms : *C. Rothii*, *C. fasciculatus*.)

Coscinodiscus marginatus Ehrenberg, 1843

EHRENBERG, 1843, p. 412 et 1854, pl. 18, fig. 44, pl. 33B, fig. 12/13, pl. 38B, fig. 22/8. HUSTEDT, 1930, p. 416, fig. 223. SUBRAHMANYAN, 1946, p. 96, fig. 41. HENDEY, 1964, p. 78, pl. 22, fig. 2.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce assez courante sous toutes les latitudes. (AMOSSÉ, 1924; HENDEY, 1937; SILVA, 1956a, 1960).

DISTRIBUTION MONDIALE : cosmopolite.

Coscinodiscus radiatus Ehrenberg, 1840

Pl. VII, fig. 50

EHRENBERG, 1840-1841, p. 148, pl. 3, fig. 1a-c, *vix* d. GRUNOW, 1884, p. 71, pl. 3, fig. 1-4, 7. GRAN, 1905, p. 31, fig. 31. HUSTEDT, 1930, p. 420, fig. 225. CLEVE-EULER, 1951, p. 65, fig. 97. HENDEY, 1964, p. 76, pl. 22, fig. 7.

= *Coscinodiscus neoradiatus* Cleve-Euler

CLEVE-EULER, 1951, p. 65, fig. 96.

RÉCOLTES PERSONNELLES : Nossi-Bé, et au large de Nossi-Bé; Tuléar.

OCÉAN INDIEN : espèce rencontrée sous toutes les latitudes, Antarctique inclus. (AMOSSÉ, 1924; HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : cosmopolite, probablement océanique.

Coscinodiscus nodulifer A. Schmidt, 1878

Pl. VII, fig. 47

SCHMIDT, 1878, pl. 59, fig. 20-23. HUSTEDT, 1930, p. 426, fig. 229. KOLBE, 1954, p. 9, 33, pl. 3, fig. 35-37. HENDEY, 1964, p. 77, pl. 22, fig. 10.

RÉCOLTES PERSONNELLES : centre du canal de Mozambique.

OCÉAN INDIEN : espèce largement répandue. Indonésie; côtes est et sud de l'Afrique; Tuléar; golfe d'Aden. (AMOSSÉ, 1924; KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce cosmopolite, cependant plus abondante entre les tropiques.

Sur les spécimens de grande taille, les alignements radiaires, ainsi que les alignements spiralés secondaires, apparaissent clairement (fig. 47).

Coscinodiscus africanus Janisch *ex* A. Schmidt, 1878

SCHMIDT, 1878, pl. 59, fig. 24-25. JANISCH, 1890, pl. 3, fig. 2 *(nomen nudum)*. HUSTEDT, 1930, p. 428, fig. 231. MANN, 1937, p. 37. KOLBE, 1954, p. 27; 1955, p. 168; 1957, p. 28. TAYLOR, 1967, pl. 88, fig. 3.

RÉCOLTES PERSONNELLES : côte du Mozambique.

OCÉAN INDIEN : ce *Coscinodiscus*, nouveau pour le canal de Mozambique, était antérieurement connu en diverses stations : golfe d'Aden; côtes d'Afrique du Sud; région sud-est de l'océan, et divers sondages inter-tropicaux. (KOLBE, TAYLOR, *ibid.*).

DISTRIBUTION MONDIALE : espèce probablement cosmopolite, mais peu commune. Probablement néritique. Antilles; Méditerranée; Nagasaki; Antarctique; île de l'Ascension; divers sondages dans le Pacifique équatorial et l'Atlantique équatorial et tempéré nord.

Coscinodiscus Thorii Pavillard, 1925

Pl. VII, fig. 49

PAVILLARD, 1925, p. 13, fig. 15. HUSTEDT, 1930, p. 433, fig. 236.

RÉCOLTES PERSONNELLES : rare (Nossi-Bé; Tuléar).

OCÉAN INDIEN : l'espèce est nouvelle pour cet océan.

DISTRIBUTION MONDIALE : de découverte relativement récente, cette espèce était jusqu'ici inconnue en dehors de la Méditerranée.

Coscinodiscus jonesianus (Greville) Ostenfeld, 1915

GREVILLE, 1862, p. 22, pl. 2, fig. 3 : « *Eupodiscus jonesianus* ». OSTENFELD, 1915, p. 13, fig. 7. HUSTEDT, 1930, p. 438, fig. 239. ALLEN et CUPP, 1935, p. 116, fig. 10. HENDEY, 1958, p. 37, et 1964, p. 79.

RÉCOLTES PERSONNELLES : Nossi-Bé; parages de Beira.

OCÉAN INDIEN : mer de Java et des Célèbes; îles Cocos; côtes des Indes; canal de Mozambique. (KOLBE, 1957; SILVA, 1960 : var. *aculeatus* Meister).

DISTRIBUTION MONDIALE : encore mal connue, probablement inter-tropicale. La variété *commutatus* (Grunow) Hustedt — absente de mes récoltes — a été rétablie au rang d'espèce par CLEVE-EULER (1951).

Coscinodiscus nobilis Grunow, 1879

Pl. VII, fig. 46

GRUNOW, 1879, p. 687, pl. 21, fig. 1. RATTRAY, 1890, p. 545. MANN, 1907, p. 255. ALLEN et CUPP, 1935, p. 118, fig. 13. CHIN, 1939b, p. 459.

= *C. concinnus* f. *nobilis* (Grunow) Cleve-Euler

CLEVE-EULER, 1951, p. 69, fig. 108 f.

= *Coscinodiscus cylindricus* Mangin

MANGIN, 1928, p. 379, fig. 7.

Valves convexes, aplaties au centre, de grande taille (diamètre : 250-540 µ). Bandes intercalaires bien développées, donnant au frustule l'aspect d'un tambour. Champ central des valves hyalin (rosette absente). Ornementation très fine : 6-10 aréoles en 10 µ, disposées au centre de la valve en lignes radiaires irrégulières, et vers la périphérie en un système hexagonal régulier; spinules marginaux peu développés, donnant chacun naissance à un rayon hyalin centripète; deux apicules marginaux peu saillants.

RÉCOLTES PERSONNELLES : Nossi-Bé (période estivale).

OCÉAN INDIEN : espèce seulement signalée dans les mers indonésiennes, et nouvelle pour la région étudiée. (Réf. *in* WOOD, 1963a : cf. « *C. concinnus* »).

DISTRIBUTION MONDIALE : océanique, essentiellement inter-tropicale. Hong-Kong; mer d'Arafura; golfe de Guinée; mer du Japon. Cette espèce est reportée par ailleurs en mer du Nord et dans la mer d'Okhotsk.

Cette espèce doit-elle être intégrée au *C. concinnus* W. Smith? C'est l'avis de SUBRAHMANYAN (1946) et de WOOD (1963a), qui toutefois ne justifient pas leur opinion. CLEVE-EULER *(ibid.)*, considérant l'absence de rosette centrale comme seul caractère distinctif du *C. nobilis*, fait de cette espèce une forme du *C. concinnus*.

Les deux espèces ayant été souvent confondues, leurs distributions géographiques respectives sont incertaines; *C. concinnus* semble psychrophile, *C. nobilis* thermophile.

Rappelons que HOLMES & REIMANN (1966) ont étudié expérimentalement *C. concinnus*, et montré l'existence chez cette Diatomée de trois phases morphologiques, dont l'une est assimilable au *C. Granii* — ce dernier nom devenant prioritaire.

Coscinodiscus centralis var. ***pacificus*** Gran et Angst, 1931

Pl. VII, fig. 51

GRAN et ANGST, 1931, p. 446, fig. 23. CUPP, 1943, p. 60, fig. 24, et pl. 2.
Non : Coscinodiscus pacificus Rattray.

RÉCOLTES PERSONNELLES : Nossi-Bé.

OCÉAN INDIEN : cette variété n'y a été jusqu'ici reportée que par MANGUIN (1954) : île Heard (sud-est des îles Kerguelen).

DISTRIBUTION MONDIALE : côte nord-ouest des U.S.A., jusqu'à l'Alaska. Ce *Coscinodiscus* est donc signalé ici pour la première fois sous une latitude tropicale.

Coscinodiscus asteromphalus Ehrenberg, 1844
Pl. VII, fig. 48

Ehrenberg, 1844a, p. 77, et 1854, pl. 18, fig. 45, *vix* pl. 33, fig. 15/7. Hustedt, 1930, p. 452, fig. 250-251. Cleve-Euler, 1951, p. 67, fig. 103. Hendey, 1964, p. 78, pl. 24, fig. 2.

Récoltes personnelles : très rare; seulement deux exemplaires, au large de Nossi-Bé.

Océan Indien : cette espèce, nouvelle pour le canal de Mozambique, est assez rare dans l'océan Indien; côtes des Indes; Indonésie; Antarctique. (Kolbe, 1957; Venkataraman, 1958).

Distribution mondiale : probablement cosmopolite. Rappelons que, comme divers *Coscinodiscus*, celui-ci a été morcelé par Grunow (1884) en un grand nombre de variétés, dont certaines constituent en fait des espèces autonomes; de cette taxinomie assez complexe, il résulte une incertitude sur la répartition géographique.

Coscinodiscus oculus-iridis Ehrenberg, 1840 var. *oculus-iridis*
Pl. VIII, fig. 55

Ehrenberg, 1840-41, p. 147, et 1854, pl. 18, fig. 42, pl. 19, fig. 2. Hustedt, 1930, p. 454, fig. 252. Cupp, 1943, p. 62, fig. 26, et pl. 3, fig. 2. Subrahmanyan, 1946, p. 101, fig. 66-68, 72. Hendey, 1964, p. 78, pl. 24, fig. 1.

= *C. oculus-iridis* var. *genuinus* Grunow

Grunow, 1884, p. 77. Cleve-Euler, 1951, p. 67, fig. 102 a-b.

Récoltes personnelles : Tuléar; au large du cap Saint-André.

Océan Indien : cette variété-type est assez courante. Indonésie; côtes des Indes; Ceylan; îles Cocos; golfe d'Aden; canal de Mozambique; Antarctique. (Amossé, 1921; Silva, 1956a, 1960; Kolbe, 1957; Travers, 1965).

Distribution mondiale : cosmopolite, océanique.

var. ***borealis*** (Bailey) Cleve, 1883
Pl. VIII, fig. 54

Bailey, 1856, p. 3 : « *Coscinodiscus borealis* ». Cleve, 1883, p. 488. Hustedt, 1930, p. 456, fig. 253. Subrahmanyan, 1946, p. 103, fig. 75. Cleve-Euler, 1951, p. 67, fig. 102 c.

Récoltes personnelles : centre du canal de Mozambique.

Océan Indien : cette variété n'a été signalée, en tant que telle, que sur la côte des Indes (Subrahmanyan); d'autres auteurs ont pu la mentionner sous le nom spécifique.

Distribution mondiale : difficile à distinguer de celle du type, d'où l'intérêt de désigner ce dernier sous le nom de variété-type.

Coscinodiscus gigas var. ***praetextus*** Janisch *ex* Hustedt, 1930
Pl. VIII, fig. 53

JANISCH, 1890, pl. 3, fig. 4 : « *Coscinodiscus praetextus* » *(nomen nudum)*. HUSTEDT, 1930, p. 457, fig. 255, 256 b. ALLEN et CUPP, 1935, p. 120, fig. 16. SUBRAHMANYAN, 1946, p. 103, fig. 69, 73, 76-78.

RÉCOLTES PERSONNELLES : Nossi-Bé (espèce estivale); au large de Beira et du cap Saint-André.

OCÉAN INDIEN : cette variété, nouvelle pour la région étudiée, est peu signalée par ailleurs : côtes des Indes; mer de Java; côtes d'Afrique du Sud. (TAYLOR, 1967).

DISTRIBUTION MONDIALE : une seule station, semble-t-il, à ajouter aux précédentes (mer de Chine : SPROSTON, 1949). L'espèce, par ailleurs (*C. gigas* var. *gigas*), est assez commune dans les mers chaudes et tempérées.

Coscinodiscus Janischii var. ***arafurensis*** Grunow, 1884
Pl. VIII, fig. 56

GRUNOW, 1884, p. 76. RATTRAY, 1890, p. 96. ALLEN et CUPP, 1935, p. 120, fig. 17.

= *Coscinodiscus arafurensis* O'Meara

Nomen nudum, in : JANISCH, 1890, pl. 4, fig. 3-5. *Vix* O'MEARA, 1877, p. 463.

? = *C. arafurensis* O'Meara var. *apud* Castracane

CASTRACANE, 1886, p. 153, pl. 2, fig. 4 (figure douteuse).

? = *Coscinodiscus Woodwardii* Eulenstein *pro parte*

SILVA, 1956a, p. 30, pl. 1, fig. 4. *Vix* SCHMIDT, 1878, pl. 61, fig. 2-3, *non* pl. 60, fig. 8, *nec* 1881, pl. 65, fig. 2. Voir aussi : MANN, 1907, p. 260.

Valves presque planes, seulement légèrement déprimées au centre. Zone centrale hyaline (rosette absente). Aréoles arrondies, disposées en lignes radiaires et en lignes spiralées; aréoles centrales plutôt ovales et plus petites; une rangée marginale d'aréoles très petites. Parois délicates, aspect général membraneux. Diamètre : 170-425 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; sporadique dans les récoltes de l' « Anton Bruun ».

OCÉAN INDIEN : Inhaca; Indonésie; golfe du Bengale. (SILVA, 1956a, 1960).

DISTRIBUTION MONDIALE : variété très peu connue en dehors de l'océan Indien (références incertaines). Atlantique (?).

Il n'existe pas de description originale du *C. Woodwardii* Eul., mais seulement un exsiccatum (1868) — que je n'ai pu examiner — assimilable selon HUSTEDT au *C. perforatus* Ehr. Dans son atlas, SCHMIDT donne plusieurs figures assez dissemblables qu'il identifie sans certitude au *C. Woodwardii.*

Coscinodiscus Karstenii, nom. nov.

Pl. VIII, fig. 52

= *Coscinodiscus incertus* Karsten, 1907

KARSTEN, 1907, p. 366, pl. 35, fig. 2. SILVA, 1952a, p. 586, pl. 1, fig. 3, et 1960, p. 13, pl. 1, fig. 7-8.

Non : Coscinodiscus incertus Leuduger-Fortmorel, 1898

LEUDUGER-FORTMOREL, 1898, p. 13, pl. 1, fig. 13.

Valves circulaires, convexes. Pas de rosette centrale différenciée, ni de zone centrale hyaline. Aréoles sub-hexagonales, de taille variable, plus petites au centre et sur les bords de la valve, disposées selon un réseau complexe et comme imparfait : rangées radiaires, rangées spiralées et rangées sub-radiaires fasciculées. Bord des valves strié radialement (15 stries en 10 μ). Chloroplastes peu nombreux, petits, discoïdes. Diamètre des valves : 32-95 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; côtes du Mozambique.

OCÉAN INDIEN : espèce très rarement signalée; au nord des îles Saint-Paul et Amsterdam (localité-type); Inhaca (SILVA, 1960).

DISTRIBUTION MONDIALE : une seule référence à ajouter (Guinée portugaise).

Le nom de *C. incertus* Karsten doit en effet être rejeté, comme homonyme postérieur de *C. incertus* Leud.-Fort. (cf. : LANJOUW *et al.*, 1966). Ajoutons qu'il n'existe aucune similitude entre les deux espèces, et qu'il n'est par ailleurs pas assuré que l'homonyme antérieur soit bien un *Coscinodiscus.*

Coscinodiscus reniformis Castracane, 1886

CASTRACANE, 1886, p. 160, pl. 12, fig. 12. RATTRAY, 1890, p. 548. MANN, 1925, p. 69, et 1937, p. 46. KOLBE, 1955, p. 170, pl. 1, fig. 4, et 1957, p. 31. WOOD, 1963b, p. 190, pl. 1, fig. 10. TAYLOR, 1967, p. 446, pl. 92, fig. 44.

= *Stoschia admirabilis* Janisch *(nomen nudum)*

JANISCH, 1890, pl. 1, fig. 1-5.

= *Stoschia mirabilis (nomen nudum)*

VAN HEURCK, 1885, légende pl. 128, fig. 6.

= *Stoschia (sp.)* Janisch *in* Van Heurck

VAN HEURCK, 1896, p. 537, fig. 283.

= *Stoschia reniformis* (Rattray) Heiden et Kolbe

HEIDEN et KOLBE, 1928, p. 476.

= *Coscinodiscus Stoschii* Witt *in* A. Schmidt

SCHMIDT, 1889, légende pl. 140, fig. 17.

RÉCOLTES PERSONNELLES : au large de Beira (très rare).

OCÉAN INDIEN : espèce nouvelle pour la région étudiée; connue par ailleurs aux Seychelles (sondage) et au sud de l'Afrique. (KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : ce *Coscinodiscus* « aberrant » est essentiellement connu dans l'Atlantique tropical, au large des côtes occidentales d'Afrique. Par ailleurs : Philippines; Antarctique.

Planktoniella sol (Wallich) Schütt, 1892

Pl. VIII, fig. 57

WALLICH, 1860, p. 38, pl. 2, fig. 1-2 : « *Coscinodiscus sol* ». SCHÜTT, 1892, p. 258, fig. 64. HUSTEDT 1930, p. 465, fig. 259. CUPP, 1943, p. 63, fig. 27. HASLE, 1960, p. 11, pl. 2, fig. 19-20. Pour le polymorphisme de cette espèce, voir aussi : KARSTEN, 1907, p. 369, pl. 39, fig. 1-11. SILVA, 1956b, p. 16, pl. 6, fig. 1-3, pl. 7, fig. 1-2, et pl. 8, fig. 1.

RÉCOLTES PERSONNELLES : Nossi-Bé (espèce plutôt estivale); Tuléar; île Maurice; fréquente et abondante dans tout le canal de Mozambique, mais seulement dans les prélèvements verticaux (« plancton d'ombre »).

OCÉAN INDIEN : espèce très courante jusqu'aux latitudes sub-antarctiques. (HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : exemple-type d'espèce tropicale (SMAYDA, 1958), rencontrée occasionnellement dans les eaux tempérées. Océanique, oligophotique.

Gossleriella tropica Schütt, 1892

Pl. X, fig. 69

SCHÜTT, 1892, p. 258, fig. 63. HUSTEDT, 1930, p. 500, fig. 280. HENDEY, 1937, p. 258, pl. 12, fig. 1. SUBRAHMANYAN, 1946, p. 107, fig. 86. TAYLOR, 1967, p. 449, pl. 88, fig. 4.

? Incl. « *G. tropica* Schütt 1893 (?) var. » *apud* Sproston

SPROSTON, 1949, p. 82, fig. 25.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); Tuléar; île Maurice; centre et nord du canal de Mozambique, dans les prélèvements verticaux seulement (« plancton d'ombre »).

OCÉAN INDIEN : côtes d'Afrique du Sud; parages de Magadascar; Indonésie; côtes des Indes. (HENDEY, 1937; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce océanique, inter-tropicale. Mers de Chine et du Japon; Méditerranée; Atlantique tropical.

Actinocyclus octonarius Ehrenberg, 1838 var. ***octonarius***

EHRENBERG, 1838, p. 172, pl. 21, fig. 7. HENDEY, 1937, p. 262, et 1964, p. 83, pl. 24, fig. 3. BODEN, 1950, p. 349, fig. 24.

= *Actinocyclus Ehrenbergii* Ralfs *in* Pritchard

HUSTEDT, 1930, p. 525, fig. 298, *et plur. auct.*

= *Actinocyclus Ehrenbergii* subsp. *genuinus* Cleve-Euler

CLEVE-EULER, 1951, p. 81, fig. 144 a.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : Ceylan; Indonésie; côtes des Indes; Zanzibar. (AMOSSÉ, 1924; KOLBE, 1957).

DISTRIBUTION MONDIALE : cosmopolite, néritique.

Roperia tessellata (Roper) Grunow *in* Van Heurck, 1885
Pl. IX, fig. 62

ROPER, 1858, p. 19, pl. 3, fig. 1 : « *Eupodiscus tesselatus* ». VAN HEURCK, 1885, pl. 118, fig. 6-7. HUSTEDT, 1930, p. 523, fig. 297.

= *Coscinodiscus* sp., *apud* Silva

SILVA, 1956a, p. 31, pl. 2, fig. 1, et 1956c, pl. 6, fig. 1.

RÉCOLTES PERSONNELLES : Tuléar; centre du canal de Mozambique; au large de Nossi-Bé.

OCÉAN INDIEN : espèce peu courante. Iles Célèbes; côtes du Mozambique; Zanzibar; côtes d'Afrique du Sud; Antarctique? (AMOSSÉ, 1924; SILVA, 1956, 1960; KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : assez sporadique. Côtes du Brésil et du Chili; Atlantique nord-ouest et mers adjacentes; Nagasaki; divers sondages dans le Pacifique tropical.

Au sujet de la variabilité de cette espèce, se reporter à MANN (1925, 1937), VOIGT (1949) et KOLBE (1954, 1955, 1957). Dans mes récoltes, *R. tessellata* présente un type morphologique constant (pl. IX, fig. 62).

Thalassiosira subtilis (Ostenfeld) Gran, 1900

OSTENFELD, 1899 : « *Podosira* (?) *subtilis* » (*fide* GRAN). GRAN, 1900, p. 117, et 1905, p. 19, fig. 14. HUSTEDT, 1930, p. 330, fig. 166. HENDEY, 1937, p. 239, et 1964, p. 86. CUPP, 1943, p. 49, fig. 13. BODEN, 1950, p. 337, fig. 9.

= *Coscinodiscus (Thalassiosira) Ostenfeldii* Cleve-Euler

CLEVE-EULER, 1951, p. 73, fig. 120 a.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce peu répandue. Mer d'Arabie; mer d'Arafura; côtes d'Afrique du Sud et du Mozambique; sud et sud-ouest de l'océan. (HENDEY, 1937; SILVA, 1956a, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : large répartition latitudinale, probablement cosmopolite. Atlantique nord et mers adjacentes; côtes occidentales des U.S.A. et de l'Amérique du Sud.

Skeletonema costatum (Greville) Cleve, 1878

GREVILLE, 1866, p. 77, pl. 8, fig. 3-6 : « *Melosira costata* ». CLEVE, 1878, p. 18. HUSTEDT, 1930, p. 311, fig. 149. HENDEY, 1964, p. 91, pl. 7, fig. 3. STEIDINGER, 1964 (monographie).

La graphie « *Sceletonema* » est erronée.

RÉCOLTES PERSONNELLES : Nossi-Bé (au début des deux grandes poussées annuelles); côtes d'Afrique du Sud.

OCÉAN INDIEN : espèce courante. Côtes des Indes et d'Australie; Indonésie; canal de Mozambique; Antarctique? (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce cosmopolite néritique, eurytherme et euryhaline. Souvent très prolifique.

Diatomée planctonique très commune, *S. costatum* constitue un matériel de choix pour les études expérimentales. Au sujet de sa biologie et de sa physiologie, voir CURL et MC LEOD (1961), BRAARUD (1962), HULBURT, (1963). etc.

Stephanopyxis palmeriana (Greville) Grunow, 1884

GREVILLE, 1865b, p. 2, pl. 1, fig. 9 : « *Cresswellia Palmeriana* ». GRUNOW, 1884, p. 90. GRAN et YENDO, 1914, p. 26. PAVILLARD, 1925, p. 5, fig. 3. HUSTEDT, 1930, p. 308, fig. 147. HENDEY, 1937, p. 208, 236. CUPP, 1943, p. 40, fig. 4. BODEN, 1950, p. 332, fig. 4. KOLBE, 1957, p. 42, pl. 1, fig. 6.

RÉCOLTES PERSONNELLES : Nossi-Bé; au large de la côte d'Afrique, de Durban à Beira.

OCÉAN INDIEN : Indonésie; côtes des Indes; îles Cocos; canal de Mozambique; Antarctique ? côtes d'Afrique du Sud. (SILVA, 1956a, 1960; KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : Méditerranée; Atlantique et Pacifique inter-tropicaux.

La confusion avec *Stephanopyxis turris* est probablement très fréquente. Des stades intermédiaires entre les deux espèces sont reportés par HENDEY et par BODEN *(loc. cit.)*, et l'un au moins des caractères morphologiques donnés comme distinctifs est sujet à controverse (constriction des manteaux valvaires). La question reste donc ouverte.

S. palmeriana différerait de *S. turris* (« *S. t.* ») par les caractères suivants :

Diamètre moyen des valves : 80 µ (*S. t.:* 40), les tailles extrêmes étant 20 et 150 µ (*S. t.:* 10-115). Manteaux valvaires relativement peu développés, l'axe pervalvaire étant de longueur inférieure ou égale au diamètre valvaire (*S. t.:* supérieure). Aréoles hexagonales, progressivement plus grandes et plus délicates à partir du bord des valves vers le centre (*S. t.:* aréoles de forme irrégulière, et de taille à peu près constante). Manteaux valvaires non comprimés au voisinage de la suture des valves (?). Répartition inter-tropicale (*S. t.* : tempérée).

La production de gamètes, d'auxospores et de spores de résistance a été étudiée expérimentalement par DREBES (1966) chez les deux espèces.

Fam. HEMIDISCACEAE

Hemidiscus cuneiformis Wallich, 1860

Pl. XIII, fig. 85

WALLICH, 1860, p. 42, pl. 2, fig. 3-4. HUSTEDT, 1930, p. 904, fig. 542. HENDEY, 1937, p. 264, et 1964, p. 94, pl. 22, fig. 9. SCHMIDT, 1940, pl. 435, fig. 1-6, pl. 436, fig. 1-9, pl. 437, fig. 1-2, et pl. 438, fig. 4-10. HART et CURRIE, 1960, p. 215.

Incl. : var. *gibba* (Bailey) Hustedt, var. *recta* (Castracane) Hustedt, var. *ventricosa* (Castracane) Hustedt, et var. *orbicularis* (Castracane) Hustedt : cf. HUSTEDT *(loc. cit.), et cet. auct.*

RÉCOLTES PERSONNELLES : Nossi-Bé; île Maurice; sporadiquement dans le centre et le nord du canal de Mozambique.

OCÉAN INDIEN : mer Rouge; Sumatra; mer d'Arabie; Tuléar; divers sondages dans la zone tropicale; côtes d'Afrique du Sud. (KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce océanique, cosmopolite mais plus répandue dans les mers chaudes.

Le développement inégal de la ceinture donne à cette Diatomée la forme d'un coin, d'où le nom d'*H. cuneiformis*; toutefois ce caractère n'est pas spécifique, mais générique.

Comme le note HENDEY (1937), le polymorphisme de cette espèce est considérable, et toutes les transitions sont observables entre les prétendues variétés.

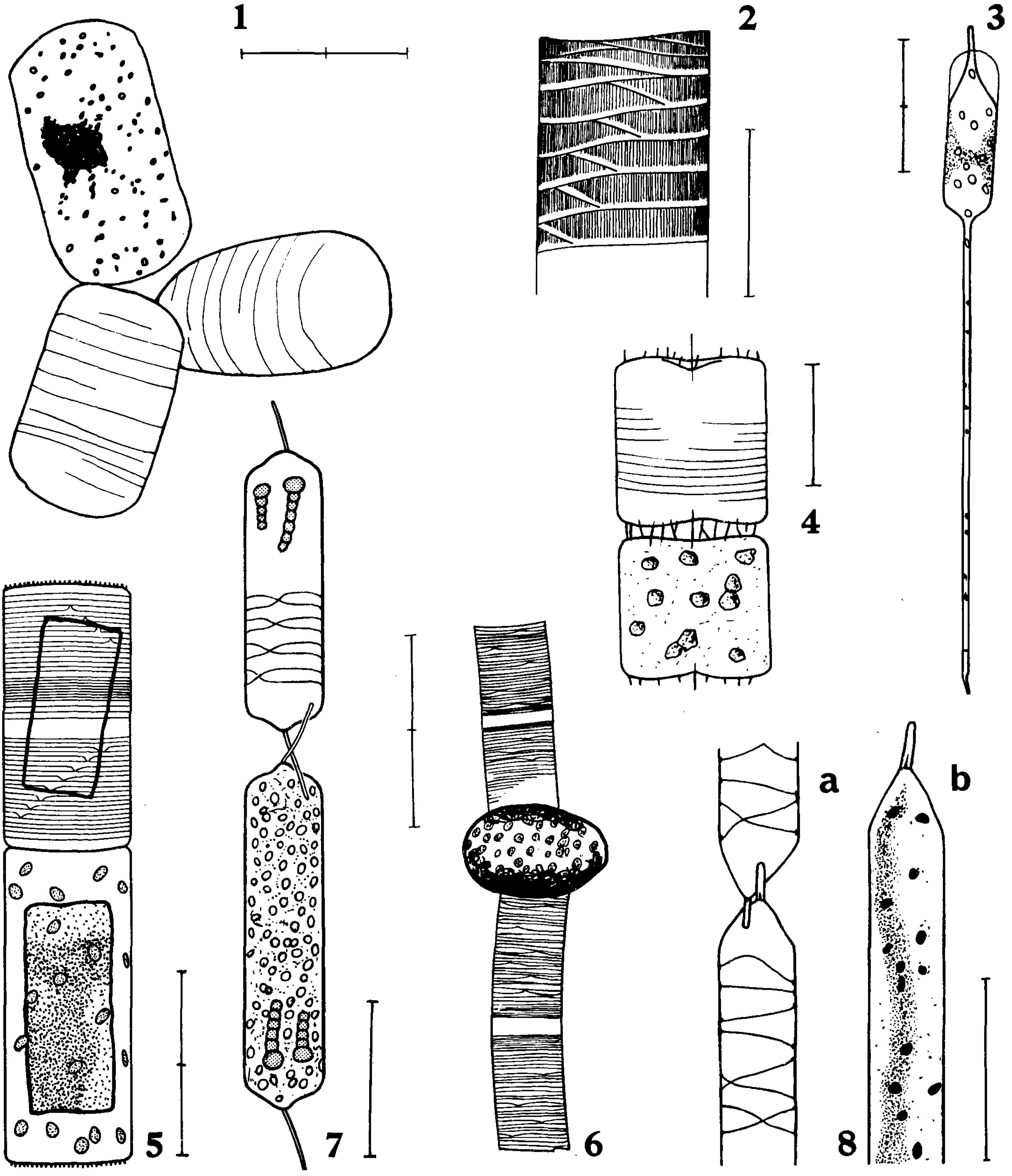
Hemidiscus hardmanianus (Greville) Mann, 1907

Pl. IV, fig. 31

GREVILLE, 1865a, p. 2, pl. 5, fig. 1-4 : « *Palmeria Hardmaniana* ». MANN, 1907, p. 316. ALLEN et CUPP, 1935, p. 152, fig. 91. SUBRAHMANYAN, 1946, p. 160, fig. 310-312, 314, 315. SCHMIDT, 1940, pl. 439, fig. 1-5. CURL, 1959, p. 287, fig. 17.

PLANCHE I : **1** — *Chrysanthemodiscus floriatus* Mann *emend.* Takano. **2** — *Dactyliosolen antarcticus* f. *laevis* (Karst.) Heid. et Kolbe. **3** — *Rhizosolenia alata* f. *gracillima* (Cl.) Gran : auxospore. **4** — *Schroederella delicatula* f. *Schroederi* (Bergon) n. comb. **5** — *Detonula moseleyana* (Castr.) Gran. **6** — *Guinardia flaccida* (Castr.) H. Per. : sporulation. **7** — *Rhizosolenia cylindrus* Cleve. **8** a, b — *R. obtusa* Hensen.

Échelle « simple » : 50 μ; échelle « double » : 100 μ.


1
2
3
4
5
7
6
a
b
8

= *Palmeria hardmaniana* Greville

GREVILLE, *ibid.* VAN HEURCK, 1896, p. 538, fig. 287. CLEVE, 1901, p. 22 et 56. OSTENFELD, 1903a, p. 4, fig. 1-2, et 1915, p. 16. SILVA, 1960, p. 19, pl. 8, fig. 4-6.

= *Euodia hardmaniana* (Greville) Schröder

SCHRÖDER, 1906, p. 341.

= *Euodia (Hemidiscus) capillaris* Brun

BRUN, 1891, p. 26, pl. 17, fig. 4.

Valves hémicycliques, de grande taille (diamètre de l'hémicycle : 370-530 μ), à ornementation très fine rappelant celle du *Coscinodiscus nobilis.* Ceinture très inégalement développée, donnant au frustule l'aspect d'un secteur sphérique (... ou d'un quartier d'orange). Parois très délicates.

RÉCOLTES PERSONNELLES : Nossi-Bé; au large du cap Saint-André.

OCÉAN INDIEN : mer Rouge; nord-ouest de l'océan; Indonésie; Madras; Inhaca. (KOLBE, 1957; SILVA, 1960).

DISTRIBUTION MONDIALE : espèce très rarement signalée en dehors de l'océan Indien et de l'Indonésie. Mers de Chine et du Japon; golfe du Mexique.

Fam. ACTINODISCACEAE

Actinoptychus senarius (Ehrenberg) Ehrenberg, 1843

EHRENBERG, 1838, p. 172, pl. 21, fig. 6 : « *Actinocyclus senarius* »; 1843, pl. 1/1, fig. 27. HENDEY, 1937, p. 271, et 1964, p. 95, pl. 23, fig. 1-2. BODEN, 1950, p. 351, fig. 26. HART et CURRIE, 1960, p. 215.

= *Actinoptychus undulatus* (Bailey) Ralfs

HUSTEDT, 1930, p. 475, fig. 264, *et plur. auct.*

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); île Maurice.

OCÉAN INDIEN : mer Rouge; Indonésie; golfe d'Aden; côtes des Indes; nord du canal de Mozambique; Afrique du Sud; Kerguelen; Antarctique. (AMOSSÉ, 1924; HENDEY, 1937; KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : néritique, cosmopolite.

Actinoptychus splendens (Shadbolt) Ralfs *in* Pritchard, 1861

Pl. IX, fig. 63

SHADBOLT, 1854, p. 16 : « *Actinosphaenia splendens* ». PRITCHARD, 1861, p. 840. HUSTEDT, 1930, p. 478, fig. 265. HENDEY, 1937, p. 272, et 1964, p. 95, pl. 22, fig. 1. BODEN, 1950, p. 351, fig. 27.

RÉCOLTES PERSONNELLES : Nossi-Bé; côte du Mozambique.

OCÉAN INDIEN : Tasmanie; Indonésie; Ceylan; Madagascar; Zanzibar; Inhaca; côtes d'Afrique du Sud. (SHADBOLT, 1854; AMOSSÉ, 1924; KOLBE, 1957; SILVA, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite, néritique.

Actinoptychus trilingulatus (Brightwell) Ralfs *in* Pritchard, 1861

Pl. VI, fig. 45

BRIGHTWELL, 1860, p. 93, pl. 5, fig. 2 : « *Actinocyclus trilingulatus* ». PRITCHARD, 1861, p. 840. SCHMIDT, 1874, pl. 1, fig. 20. BOYER, 1926, p. 66. SILVA, 1960, p. 16, pl. 5, fig. 3, et pl. 6, fig. 1.

Valves circulaires, très convexes, de grande taille (diamètre : 90-260 µ), divisées en six secteurs; espace central trilingulé. Chaque secteur porte une rangée marginale d'épines tronquées, en nombre variable. Ornementation très fine, constituée d'un réseau hexagonal comptant environ 15 ponctuations en 10 µ.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); côte du Mozambique.

OCÉAN INDIEN : Ceylan; Sumatra; Java; Aden; Zanzibar; Inhaca. (AMOSSÉ, 1924; SILVA, 1960).

DISTRIBUTION MONDIALE : une seule référence à ajouter aux précédentes, « Indes occidentales » (localité-type).

Asterolampra marylandica Ehrenberg, 1844

EHRENBERG, 1844a, p. 76, 1844b, pl. 1, fig. 10. HUSTEDT, 1930, p. 485, fig. 270-271. HENDEY, 1937, p. 268.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; nombreuses récoltes en domaine océanique (« Anton Bruun »).

OCÉAN INDIEN : espèce la plus répandue du genre; essentiellement tropicale. (HENDEY, 1937; SILVA, 1956a; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tempérées et, surtout, tropicales. Océanique.

Asterolampra Van-Heurckii Brun, 1891

BRUN, 1891, p. 10, pl. 14, fig. 1. HUSTEDT, 1930, p. 487, fig. 272. HENDEY, 1937, p. 268.

RÉCOLTES PERSONNELLES : extrêmement rare à Nossi-Bé, mais abondante au large dans les prélèvements de l' « Anton Bruun »; île Maurice.

OCÉAN INDIEN : seulement trois références. Au nord de l'archipel des Chagos (KARSTEN, 1907); au large du Kénya (HENDEY, 1937); Sumatra (KOLBE, 1957).

DISTRIBUTION MONDIALE : l'espèce semble inconnue en dehors de la Méditerranée (où elle fut découverte) et de l'océan Indien.

Asterolampra Grevillei (Wallich) Greville, 1860

WALLICH, 1860, p. 47, pl. 2, fig. 15 : « *Asteromphalus Grevillii* ». GREVILLE, 1860, p. 113, pl. 4, fig. 21. HUSTEDT, 1930, p. 489, fig. 274. HENDEY, 1937, p. 267.

RÉCOLTES PERSONNELLES : Nossi-Bé; île Maurice.

OCÉAN INDIEN : diverses stations tropicales et sub-tropicales. (TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce peu connue. Méditerranée; Atlantique tempéré.

Asteromphalus elegans Greville, 1859

Pl. IX, fig. 59

GREVILLE, 1859b, p. 161, pl. 7, fig. 6. PRITCHARD, 1861, p. 837, pl. 5, fig. 87. SCHMIDT, 1876, pl. 38, fig. 1-2. KARSTEN, 1907, p. 370, pl. 38, fig. 3 (?). HENDEY, 1937, p. 269. *Vix* SILVA, 1956b, p. 22, pl. 1, fig. 7. WOOD *et al.*, 1959, p. 215, pl. 16, fig. 23.

= *Asteromphalus Wyvillei* Castracane

CASTRACANE, 1886, p. 134, pl. 5, fig. 6. KARSTEN, 1907, p. 370, pl. 38, fig. 4. SUBRAHMANYAN, 1946, p. 106, fig. 87, et pl. 2, fig. 4.

= *Asteromphalus schroeterianus* Schröder

SCHRÖDER, 1906, p. 342, fig. 1.

Valves planes, circulaires ou sub-circulaires; diamètre : 70-230 μ. Champ hyalin médian en position centrale ou légèrement excentrique, occupant environ 1/3 du diamètre valvaire. Rayons en nombre très variable, de 12 à 29. Nervures centrales plus ou moins infléchies, ou ramifiées une ou plusieurs fois. Aréoles, dans chaque secteur extérieur, diminuant légèrement en taille vers la périphérie.

(Dans sa description originale, GREVILLE reconnaît n'avoir observé qu'un seul spécimen de cette espèce, qu'il suppose cependant très variable : ceci a été largement vérifié par la suite.)

RÉCOLTES PERSONNELLES : centre et nord du canal de Mozambique (rare).

OCÉAN INDIEN : espèce assez fréquente sous toutes les latitudes, Antarctique compris, mais nouvelle pour le canal de Mozambique. (KOLBE, 1957).

DISTRIBUTION MONDIALE : mers tropicales et sub-tropicales. Méditerranée; Californie; mers de Chine et du Japon; côtes du Chili; Pacifique tropical oriental.

Asteromphalus arachne (Brébisson) Ralfs *in* Pritchard, 1861
Pl. IX, fig. 60

BRÉBISSON, 1857, p. 296, pl. 3, fig. 1 : « *Spatangidium arachne* ». PRITCHARD, 1861, p. 837, pl. 5, fig. 66. HUSTEDT, 1930, p. 493, fig. 276.

RÉCOLTES PERSONNELLES : côte d'Afrique du Sud (rare).

OCÉAN INDIEN : espèce peu signalée, de distribution incertaine. Ceylan; « Océan Indien »; Tuléar; Antarctique?; au large de l'Afrique du Sud. (KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : également assez rare. Méditerranée; mer de Marmara; côtes d'Angola; côtes du Pérou; île de l'Ascension. Espèce probablement océanique.

Asteromphalus heptactis (Brébisson) Ralfs *in* Pritchard, 1861
Pl. IX, fig. 58

BRÉBISSON, 1857, p. 296, pl. 3, fig. 2 : « *Spatangidium heptactis* ». PRITCHARD, 1861, p. 838, pl. 8, fig. 21. HUSTEDT, 1930, p. 494, fig. 275, 277. HENDEY, 1937, p. 269, et 1964, p. 96, pl. 24, fig. 5. CUPP, 1943, p. 69, fig. 32.

RÉCOLTES PERSONNELLES : Nossi-Bé; côtes du Mozambique.

OCÉAN INDIEN : espèce rencontrée sous toutes les latitudes, plutôt littorale. (HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite. Océanique?

Asteromphalus flabellatus (Brébisson) Greville, 1859

BRÉBISSON, 1857, p. 297, pl. 3, fig. 3 : « *Spatangidium flabellatum* ». GREVILLE, 1859b, p. 160, pl. 7, fig. 4-5. SCHMIDT, 1876, pl. 38, fig. 10-12. HUSTEDT, 1930, p. 498, fig. 279.

? = *Asteromphalus cleveanus* Grunow

CLEVE, 1873a, p. 5. SCHMIDT, *ibid.*, fig. 13-14. RATTRAY, 1890, p. 662. OKAMURA, 1911, p. 3, pl. 8, fig. 2. SKVORTZOW, 1932d, p. 267, pl. 4, fig. 1. ALLEN et CUPP, 1935, p. 123, fig. 23. SUBRAHMANYAN, 1946, p. 106, fig. 84, 88. KOLBE, 1957, p. 24, pl. 1, fig. 3. WOOD, 1963b, p. 193, pl. 2, fig. 28.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar. Très rare.

OCÉAN INDIEN : Indonésie; côtes des Indes; canal de Mozambique; Afrique du Sud. (KOLBE, 1957; SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique, tempérée et surtout tropicale.

L'autonomie spécifique de *A. cleveanus* me semble douteuse. D'après la bibliographie et l'iconographie consultées, aucun caractère décisif ne permet de séparer les deux espèces — dont les aires de répartition semblent d'ailleurs identiques.

Asteromphalus roperianus (Greville) Ralfs *in* Pritchard, 1861

Pl. IX, fig. 61

Greville, 1860, p. 120, pl. 4, fig. 14 : « *Asterolampra Roperiana* ». Pritchard, 1861, p. 838. Schmidt, 1876, pl. 38, fig. 15. Karsten, 1905a, p. 90, pl. 8, fig. 8, et 1928, p. 222, fig. 242. Heiden et Kolbe, 1928, p. 506. Hendey, 1937, p. 270. Wood, 1960, p. 220?, *non* pl. 4, fig. 26.

= *A. roperianus* var. *atlanticus* Castracane

Castracane, 1886, p. 133, pl. 5, fig. 3.

Valve discoïde, légèrement convexe. Zone hyaline médiane en position centrale, son diamètre égal au 1/3 environ du diamètre valvaire. Rayons très généralement au nombre de sept, élargis et légèrement arrondis à leur extrémité, le septième (impair) beaucoup plus fin que les autres; suture médiane très nettement étranglée en face du septième rayon. Sept secteurs subégaux; aréolation bien marquée, selon un réseau hexagonal; aréoles plus grosses sur la ligne bordant chaque rayon. Diamètre des valves : 85-120 μ.

Récoltes personnelles : région de Nossi-Bé et des îles Comores.

Océan Indien : rare. Zanzibar; Antarctique. (Amossé, 1924; Kolbe, 1957).

Distribution mondiale : très sporadique. Diverses stations dans l'Atlantique; îles Galapagos; Antarctique.

« L'une des espèces les plus reconnaissables dans ce genre si variable » (Mann, 1937). Elle est cependant confondue par Wood (*ibid.*, et 1963a), et peut-être par d'autres auteurs, avec *A. robustus* Castr. Mentionnons également ici l'énigmatique Diatomée décrite par Wood (1959) : frustule composé d'une valve de *Coscinodiscus lineatus* et d'une valve d' « *A. roperianus* ».

Fam. BIDDULPHIACEAE

Biddulphia pulchella Gray, 1821

Gray, 1821 (I), p. 294. Hustedt, 1930, p. 832, fig. 490. Hendey, 1964, p. 101, pl. 25, fig. 1.

= *Biddulphia biddulphiana* (W. Smith) Boyer

Boyer, 1900, p. 694, et 1926, p. 121. Gran, 1905, p. 104, fig. 135. Okamura, 1911, p. 9, pl. 12, fig. 42. Lebour, 1930, p. 172, pl. 3, fig. 3. Cleve-Euler, 1951, p. 120, pl. 6, fig. 259 B.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; côte du Mozambique.

OCÉAN INDIEN : espèce courante sous les latitudes tropicales et tempérées. (AMOSSÉ, 1924; SILVA, 1956a; KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : mers tempérées et tropicales. Espèce littorale, tychoplanctonique.

Biddulphia tridens (Ehrenberg) Ehrenberg, 1840

Pl. V, fig. 33, et pl. XII, fig. 83

EHRENBERG, 1839a, p. 129 : « *Denticella tridens* »; 1840b, p. 205; 1854, pl. 18, fig. 52, pl. 19, fig. 21, et pl. 20, fig. 53 (« *B. tridentata* »). PRITCHARD, 1861, p. 848. BOYER, 1900, p. 695, et 1926, p. 121.

= *Biddulphia Tuomeyi* (Bailey) Roper

ROPER, 1859, p. 8, pl. 1, fig. 1-2. HUSTEDT, 1930, p. 834, fig. 491, *et plur. auct.*

= *B. Tuomeyi* var. *pacifica* Castracane

CASTRACANE, 1886, p. 106, pl. 30, fig. 6.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; parages de Durban et de Beira.

OCÉAN INDIEN : cette espèce est principalement connue dans la région du canal de Mozambique. Par ailleurs : côte nord-est des Indes; divers sondages entre les Seychelles et Socotra; Indonésie; Antarctique. (SHADBOLT, 1854; AMOSSÉ, 1924; SRINIVASAN, 1954; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tropicales et Méditerranée; beaucoup plus rare dans les mers tempérées.

L'épithète originelle d'EHRENBERG s'est révélée par la suite mal choisie, car le nombre de protubérances portées par les valves, s'il est généralement voisin de trois, est cependant très variable : de 1 à 11 (voir aussi DEFLANDRE, 1935). Ceci ne constitue nullement une raison pour adopter le binôme créé postérieurement par ROPER; cette seconde désignation a cependant été largement suivie, quoique non unanimement : BOYER, dans sa monographie (1900) puis dans son index (1926), et plus récemment WOOD (1963a), sont revenus au terme *originel.* Dans ces conditions, il semble justifié d'appliquer la loi de priorité, au bénéfice d'EHRENBERG.

J'ai principalement observé cette espèce sous la forme décrite par CASTRACANE *(loc. cit.)* sous le nom de *B. Tuomeyi* var. *pacifica :* une paire seulement de protubérances à peine marquées de part et d'autre de la protubérance centrale (fig. 83); plus rarement, sous la forme baptisée par SHADBOLT (1854) *Denticella simplex :* protubérance centrale unique; enfin, sous ce second aspect, *B. tridens* m'a montré à trois reprises, dans les récoltes de Tuléar, la formation de spores (?) par groupe de quatre dans chaque cellule (fig. 33).

Biddulphia mobiliensis (Bailey) Grunow *in* Van Heurck, 1885

BAILEY, 1851b, p. 40, pl. 2, fig. 34-35 : « *Zygoceros (Denticella?) mobiliensis* ». VAN HEURCK, 1885, pl. 101, fig. 4, *non* 5-6, *nec* pl. 103, fig. A. HUSTEDT, 1930, p. 840, fig. 495. SUBRAHMANYAN, 1946, p. 155, fig. 286-287, 291-296, 299, et pl. 2, fig. 1-2. HENDEY, 1964, p. 104, pl. 20, fig. 3.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; côte d'Afrique du Sud.

OCÉAN INDIEN : mer d'Arabie; côtes des Indes et d'Australie; golfe d'Aden; canal de Mozambique; Afrique du Sud; «océan Indien». (AMOSSÉ, 1924; SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce largement répandue dans les mers tempérées et tropicales.

Biddulphia sinensis Greville, 1866

GREVILLE, 1866, p. 81, pl. 9, fig. 16. HUSTEDT, 1930, p. 837, fig. 493. MÜLLER-MELCHERS, 1952, p. 1-14, pl. 1-5. HENDEY, 1964, p. 105, pl. 20, fig. 1.

Faut-il écrire *chinensis* ou *sinensis?* Le Code de la Nomenclature botanique (LANJOUW *et al.*, 1966) laisserait hésiter entre le respect de la graphie originale (GREVILLE, *loc. cit. :* « *chinensis* »), et celui des usages de la latinisation; cependant l'écriture *sinensis* a été presque universellement adoptée. Aussi, la raison de commodité — autre principe du Code — impose ici de considérer la graphie *chinensis* comme erronée.

RÉCOLTES PERSONNELLES : Nossi-Bé (période estivale); Tuléar; côte du Mozambique; cap Saint-André.

OCÉAN INDIEN : mer Rouge; mer d'Arabie; côtes des Indes; Indonésie; îles Cocos; canal de Mozambique; côtes d'Afrique du Sud. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tropicales et tempérées; espèce particulièrement euryhaline. (Au sujet de la biologie de cette espèce dans la mer du Nord, voir WIMPENNY, 1956.) Rappelons que, selon OSTENFELD (réf. *in* HUSTEDT, etc.), il s'agirait ici d'une espèce tropicale artificiellement introduite dans l'Atlantique Nord au début du siècle... Cette hypothèse est excessivement hasardeuse.

Biddulphia longicruris var. ***hyalina*** (Schröder) Cupp, 1943

SCHRÖDER, 1906, p. 353, fig. 21 : « *Biddulphia hyalina* ». CUPP, 1943, p. 157, fig. 111 B (1-3). BODEN, 1950, p. 396, fig. 80. AVARIA, 1965, p. 98, pl. 7, fig. 2.

= *Biddulphia hyalina* Schröder

SCHRÖDER, *ibid.* KRASSKE, 1941, p. 269, pl. 6, fig. 3-5.

= *Biddulphia extensa* Mann

MANN, 1907, p. 302, pl. 47, fig. 1-2. BOYER, 1926, p. 127.

RÉCOLTES PERSONNELLES : très rare. Quelques exemplaires seulement, récoltés au sud-est de Beira.

OCÉAN INDIEN : variété nouvelle pour cet océan; le type de l'espèce (à désigner sous le nom de *B. longicruris* Grev. var. *longicruris*) y est d'ailleurs rare.

DISTRIBUTION MONDIALE : jusqu'ici très rarement signalée. Côte occidentale des U.S.A., de la Californie à l'Alaska; côte occidentale d'Afrique du Sud; côte du Chili.

Biddulphia rhombus (Ehrenberg) W. Smith, 1856

EHRENBERG, 1839b, p. 156 : « *Zygoceros rhombus* »; 1840-41, p. 160, pl. 4, fig. 11. SMITH, 1856, p. 49, pl. 45, fig. 320, et pl. 61, fig. 320. HUSTEDT, 1930, p. 842, fig. 496-497.

RÉCOLTES PERSONNELLES : Tuléar.

OCÉAN INDIEN : rare. Ceylan; mer de Java; côtes des Indes; canal de Mozambique. (SILVA, 1956a, 1960).

DISTRIBUTION MONDIALE : espèce littorale, principalement tempérée.

Biddulphia aurita (Lyngbye) Brébisson, 1838

LYNGBYE, 1819, p. 182, pl. 62, fig. D : « *Diatoma auritum* ». BRÉBISSON, 1838, p. 12. HUSTEDT, 1930, p. 846, fig. 501. CUPP, 1943, p. 161, fig. 112 A (1-3). HENDEY, 1964, p. 103, pl. 24, fig. 6.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); parages de Durban.

OCÉAN INDIEN : Madagascar; côte du Mozambique; Afrique du Sud; côtes des Indes et d'Australie; îles Cocos; Indonésie; Antarctique. (KOLBE, 1957; SILVA, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce littorale, cosmopolite. Au sujet du polymorphisme, voir CUPP et HENDEY *(loc. cit.)*.

Biddulphia membranacea Cleve, 1878

CLEVE, 1878, p. 20, pl. 5, fig. 33. WOLLE, 1890, pl. 110, fig. 9-10. *Non* PERAGALLO, 1908, pl. 105, fig. 4-5.

= *Trigonium membranaceum* (Cleve) Mann

MANN, 1925, p. 170 (variété tripolaire?).

= *Biddulphia titiana* (Grunow) Grunow *in* Van Heurck, *pro parte*

HUSTEDT, 1930, p. 855, fig. 508. OKUNO, 1954, p. 172, fig. 1, 2 A, et pl. 1, fig. 1. MARGALEF, 1961a, p. 82, fig. 27 h. *Non :* GRUNOW *in* VAN HEURCK, 1881, pl. 95 bis, fig. 7-9 : « *B. ? (Janischia?) titiana* Grunow ».

Non : Cerataulus titianus Grunow

GRUNOW, 1863, p. 159, pl. 4, fig. 25.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); Tuléar; île Maurice.

OCÉAN INDIEN : espèce nouvelle pour le canal de Mozambique; seulement connue par ailleurs dans la région indonésienne (CLEVE, 1901).

DISTRIBUTION MONDIALE : espèce néritique des mers chaudes et tempérées, rare.

Le binôme *B. membranacea* de CLEVE doit prévaloir par simple priorité : non parce que le nom de *B. titiana* n'a pas été publié validement par VAN HEURCK (on pourrait alors décider qu'il a été ultérieurement validé par HUSTEDT), mais bien parce que ce nom et, plus encore, celui de *Cerataulus titianus* désignent une Diatomée d'identité douteuse, vraisemblablement distincte de *B. membranacea.*

Cette *Biddulphia,* ainsi que les deux suivantes, témoigne d'une évolution particulière au sein du genre ou de la famille : « simplification » du frustule, par suppression des appendices et réduction extrême des protubérances valvaires, et par allègement du squelette à l'état de membrane siliceuse. Il s'agit probablement là d'une adaptation à la vie pélagique, également observée, dans un genre voisin, chez *Triceratium pelagicum* (cf. p. 36).

Biddulphia azorica Pavillard, 1930
Pl. XI, fig. 74

PAVILLARD, 1930, p. 4, fig. 13 a-c, et 1931, p. 30, pl. 1, fig. 13 a-c.

Cellules solitaires ou appariées. Valves elliptiques (ellipse « arrondie », à foyers rapprochés), presque planes, sans apophyses, mais seulement légèrement renflées aux deux extrémités de l'axe apical. Manteaux valvaires bien développés, ceinture réduite. Parois fines et transparentes. Ornementation du manteau et du bord des valves : alvéoles sub-rectangulaires alignées suivant trois directions. Ornementation du centre des valves : à préciser. Chloroplastes arrondis, peu nombreux. Axe apical : 80-120 μ; axe transapical : 75-100 μ; axe pervalvaire : 55-80 μ.

RÉCOLTES PERSONNELLES : très rare. Seulement quelques spécimens récoltés à l'île Maurice.

OCÉAN INDIEN : espèce nouvelle pour cet océan.

DISTRIBUTION MONDIALE : *B. azorica* semble ne pas avoir été signalée depuis sa découverte originelle par PAVILLARD dans les parages des Açores; elle a cependant pu être confondue avec *B. membranacea.*

Cette espèce est très proche de *B. membranacea:* elle ne diffère de cette dernière que par le contour de la valve et les proportions relatives des manteaux valvaires et de la ceinture — et peut-être aussi par son ornementation, celle-ci n'étant qu'imparfaitement connue.

Biddulphia schroederiana Schussnig, 1915
Pl. IV, fig. 32

SCHUSSNIG, 1915, p. 396, fig. 12-13. PAVILLARD, 1931, p. 29, pl. 1, fig. 12.

= *Biddulphia pellucida* Castracane « *forma* », *apud* Schröder

SCHRÖDER, 1908, p. 619, fig. 3, 5.

Cellules solitaires (?). En vue connective, frustules sub-rectangulaires ou sub-trapézoïdaux, environ 2-3 fois plus « hauts » que « larges »; manteaux valvaires bien développés; surface des valves plane ou légèrement déprimée. En vue valvaire : valves elliptiques (ellipse très allongée), sans apophyses ni excroissances. Parois très délicates. Ornementation très fine, difficilement visible, constituée d'un réseau hexagonal de ponctuations. Chromatophores minuscules, très nombreux. Auxospores? (à ce sujet, cf. SCHUSSNIG). Axe apical : 70-130 μ; axe transapical : 30-40 μ; axe pervalvaire : 145-220 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); île Maurice.

OCÉAN INDIEN : espèce jusqu'ici seulement signalée à Tuléar (TRAVERS, 1965).

DISTRIBUTION MONDIALE : encore très incertaine. Adriatique; Açores et Gibraltar.

Hemiaulus Hauckii Grunow *in* Van Heurck, 1885

VAN HEURCK, 1885, pl. 103, fig. 10. HUSTEDT, 1930, p. 874, fig. 518. HENDEY, 1937, p. 285, pl. 12, fig. 14, et 1964, p. 106.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; sporadique et rare dans les prélèvements de l' « Anton Bruun ».

OCÉAN INDIEN : côtes des Indes et mer d'Arabie; « océan Indien »; canal de Mozambique; Afrique du Sud. (HENDEY, 1937; SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique, tempérée et tropicale.

Hemiaulus sinensis Greville, 1865
Pl. XI, fig. 75

GREVILLE, 1865a, p. 5, pl. 5, fig. 9 (« *H. chinensis* »). PAVILLARD, 1925, p. 57, fig. 101. HUSTEDT, 1930, p. 875, fig. 519. ALLEN et CUPP, 1935, p. 150, fig. 88. SUBRAHMANYAN, 1946, p. 159, fig. 307-309, 313. CROSBY et WOOD, 1958, p. 509, pl. 36, fig. 24 (?).

= *Hemiaulus Heibergii* Cleve

CLEVE, 1873a, p. 6, pl. 1, fig. 4. PERAGALLO, 1908, p. 392, pl. 94, fig. 3-5. OKAMURA, 1911, p. 10, pl. 13, fig. 50.

Au sujet de la graphie « *H. chinensis* », voir remarque concernant *Biddulphia sinensis*, p. 28.

RÉCOLTES PERSONNELLES : Nossi-Bé; île Maurice; parages de Beira; cap Saint-André; Mombasa.

OCÉAN INDIEN : espèce courante dans la zone tropicale. (KOLBE, 1957; SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tropicales et Méditerranée; principalement néritique.

Hemiaulus indicus Karsten, 1907

Pl. IV, fig. 29 a-b

Karsten, 1907, p. 394, pl. 46, fig. 4. Allen et Cupp, 1935, p. 151, fig. 89. Silva, 1956a, p. 42, pl. 5, fig. 7. Crosby et Wood, 1958, p. 510, pl. 36, fig. 26? (*non* 25).

Cellules isolées ou formant de courtes chaînes droites (de 2 à 6 individus). Valves circulaires ou elliptiques, régulièrement convexes, prolongées par deux apophyses bien développées; ces apophyses sont constituées de deux parties, l'une (basale) tubuliforme, l'autre (distale) aciculaire; la jonction entre cellules voisines s'effectue par le contact de ces terminaisons aciculaires. Foramen comprimé au centre (du fait de la convexité des valves), de hauteur inférieure à la hauteur pervalvaire des cellules. A la différence de *H. sinensis*, l'ornementation des parois n'est pas visible dans les conditions usuelles d'observation et reste à préciser.

Récoltes personnelles : Nossi-Bé; Tuléar; côte d'Afrique du Sud.

Océan Indien : espèce rarement signalée depuis sa découverte par Karsten. Côte occidentale de Sumatra; mer de Java; côte du Mozambique; «océan Indien». (Silva, 1956a, 1960).

Distribution mondiale : une seule référence (douteuse) à ajouter aux précédentes (côte orientale de l'Australie : Crosby et Wood).

Hemiaulus membranaceus Cleve, 1873

Pl. IV, fig. 28 a-b et 30 a-c

Cleve, 1873a, p. 6, pl. 1, fig. 5. Schmidt, env. 1889, pl. 142, fig. 13-15. Allen et Cupp, 1935, p. 151, fig. 90. Cupp, 1943, p. 170, fig. 120. Silva, 1952a, p. 592, pl. 4, fig. 9. Crosby et Wood, 1958, p. 510, pl. 36, fig. 25 (*non* 24). Curl, 1959, p. 291, fig. 40.

Espèce citée, sans description ni illustration, *in :* Grunow, 1884; Leuduger-Fortmorel, 1892; Cleve, 1901; Silva, 1956a, 1956c; Subrahmanyan, 1958; Takano, 1960; Travers, 1965.

= *Hemiaulus* sp., *apud* Silva

Silva, 1956a, p. 43, pl. 5, fig. 8.

= *Climacodium japonicum* Schröder

Schröder, 1906, p. 352, fig. 19.

= *Eucampia hemiauloides* Ostenfeld *in* Ostenfeld et J. Schmidt

Ostenfeld et Schmidt, 1901, p. 157, fig. 9.

= *Eucampia biconcava* (Cleve) Ostenfeld

Ostenfeld, 1903, p. 23. Skvortzow, 1931b, p. 97, pl. 2, fig. 9.

= *Climacodium biconcavum* Cleve, *pro parte*

Okamura, 1911, p. 8, pl. 11, fig. 35.

? Karsten, 1905b, p. 172, pl. 28, fig. 10.

??? Cleve, 1897a, p. 22, pl. 2, fig. 16-17. Gran, 1905, p. 100, fig. 130 (« d'après Cleve »). Lebour, 1930, p. 189, fig. 149 b (« d'après Cleve »). Cleve, 1900c et 1901. Subrahmanyan, 1958 : chez ces deux derniers auteurs, sans description ni figure.

Non : Hustedt, 1930, p. 777, fig. 454. Hendey, 1937, p. 287, pl. 12, fig. 13. Curl, 1959, p. 291, fig. 44. Avaria, 1965, p. 97, pl. 6, fig. 3.

Cellules formant des chaînes plutôt courtes (de 2 à 10 individus) ou, plus rarement, cellules isolées. Chaînes droites ou parfois tordues autour de l'axe pervalvaire. Cellules très polymorphes car de proportions très variables. Valves elliptiques, donnant aux chaînes un aspect général aplati mais non rubané (en section transapicale : cellules circulaires ou elliptiques). Valves plus ou moins concaves ou, plus rarement, planes. Sur chaque valve, deux apophyses courtes, plus ou moins pointues mais apparemment sans épine ni crochet (selon SCHMIDT : une *minuscule* épine). La jonction entre les cellules voisines est réalisée par l'adhésion des surfaces des apophyses, de façon telle que, en vue connective, les deux apophyses d'une même valve sont l'une « recouverte », l'autre « recouvrante ». Parois membraneuses; ornementation inconnue.

Les chaînes se présentent d'ordinaire, après montage entre lame et lamelle, dans le plan connectif-apical, et sous un aspect très variable : foramen plus ou moins développé, sub-elliptique ou sub-rectangulaire; cellules soit isodiamétriques, soit plus « hautes » que « larges » (axe pervalvaire allongé), soit plus larges que hautes (axe apical allongé).

RÉCOLTES PERSONNELLES : espèce très courante dans toute la région étudiée.

OCÉAN INDIEN : inter-tropicale, très courante sous ses divers synonymes. (HEIDEN et KOLBE, 1928; SILVA, 1956a, 1960; TRAVERS, 1965).

DISTRIBUTION MONDIALE : sporadique en dehors de l'océan Indien et des mers indonésiennes. Pacifique équatorial; mers de Chine et du Japon; golfe de Guinée; parages de Dakar; golfe du Mexique. Hypothétiquement (sous le nom de *Climacodium biconcavum*) : Atlantique tropical et Méditerranée.

Le *C. biconcavum* figuré par OKAMURA — une chaîne tordue montrant les cellules sous divers plans — doit vraisemblablement être rattaché à la présente espèce; il en serait de même du spécimen de KARSTEN. Par contre, la diagnose originale du *C. biconcavum* (CLEVE, 1897a), reprise par GRAN et par LEBOUR, s'applique à une chaîne rubanée qui se rapproche effectivement davantage du genre *Climacodium*. Enfin, au sujet de ce *C. biconcavum*, les descriptions plus récentes de HUSTEDT, de HENDEY et de CURL sont celles d'un véritable *Climacodium*, absent de mes récoltes.

Eucampia cornuta (Cleve) Grunow *in* Van Heurck, 1885

CLEVE, 1873a, p. 7, pl. 1, fig. 6 : « *Moelleria cornuta* ». VAN HEURCK, 1885, pl. 95 bis, fig. 5. HUSTEDT, 1930, p. 774, fig. 452. ALLEN et CUPP, 1935, p. 143, fig. 75. HENDEY, 1937, p. 286, pl. 12, fig. 10. SUBRAHMANYAN, 1946, p. 146, fig. 254-255, 257.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; parages de Beira et de Mombasa.

OCÉAN INDIEN : mer Rouge, côtes des Indes; Indonésie; côtes d'Australie; canal de Mozambique; Afrique du Sud; « océan Indien »; Antarctique. (HENDEY, 1937; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce tropicale et sub-tropicale, toutefois signalée également (sauf confusion?) dans l'Antarctique.

Eucampia zodiacus Ehrenberg, 1839

EHRENBERG, 1839b, p. 156. HUSTEDT, 1930, p. 772, fig. 451. ALLEN et CUPP, 1935, p. 143, fig. 74. HENDEY, 1937, p. 286, pl. 12, fig. 7, et 1964, p. 107, pl. 7, fig. 1. SUBRAHMANYAN, 1946, p. 145, fig. 248, 250, 253.

La graphie assez fréquente « *E. zoodiacus* » est erronée.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : répartition semblable à celle de l'espèce précédente. (HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite.

Climacodium frauenfeldianum Grunow, 1867

GRUNOW, 1867b, p. 102, pl. 1 a, fig. 24. HUSTEDT, 1930, p. 776, fig. 453. HENDEY, 1937, p. 287, pl. 12, fig. 8. CUPP, 1943, p. 147, fig. 105. SUBRAHMANYAN, 1946, p. 146, fig. 249, 252, 258.
La graphie « *C. Frauenfeldii* » (*in* CLEVE, *et plur. auct.*) est erronée.

= *Climacodium atlanticum* Mangin

MANGIN, 1910, p. 382, fig. 6, et 1911, p. 362, fig. in text.

RÉCOLTES PERSONNELLES : espèce commune dans les récoltes littorales.

OCÉAN INDIEN : espèce abondante dans la zone inter-tropicale, rencontrée accessoirement jusque sous les latitudes sub-antarctiques. (HENDEY, 1937; SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : essentiellement tropicale et Méditerranéenne; Atlantique tempéré.

Triceratium favus Ehrenberg, 1840

EHRENBERG, 1840-41, p. 159, pl. 4, fig. 10. HUSTEDT, 1930, p. 798, fig. 462-463. HENDEY, 1937, p. 283, pl. 10, fig. 2-3, et 1964, p. 108, pl. 25, fig. 4.

= *Biddulphia favus* (Ehrenberg) Van Heurck

VAN HEURCK, 1885, p. 208, pl. 107, fig. 1-4; 1896, fig. 204, et p. 475, pl. 21, fig. 643. LEBOUR, 1930, p. 180, fig. 140. SPROSTON, 1949, p. 101, fig. 35.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : espèce courante sous toutes les latitudes, Antarctique inclus. (AMOSSÉ, 1924; HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tempérées et tropicales.

Triceratium Broeckii Leuduger-Fortmorel, 1878

LEUDUGER-FORTMOREL, 1878, p. 221, pl. 6, fig. 63. HEIDEN et KOLBE, 1928, p. 542. HUSTEDT, 1930, p. 802, fig. 465. CHIN, 1939c, p. 406.
La graphie « *T. Brookei* » est erronée.

RÉCOLTES PERSONNELLES : un seul exemplaire, récolté à Tuléar.

OCÉAN INDIEN : espèce très rare. Ceylan (localité-type); Aden; Zanzibar; Dar-es-Salaam. (AMOSSÉ, 1924).

DISTRIBUTION MONDIALE : encore incertaine, probablement tempérée-tropicale.

Le *T. robertsianum* de GREVILLE est-il bien une espèce distincte de celle-ci? Les caractères donnés comme distinctifs par DE-TONI et par HUSTEDT me semblent peu sûrs, et d'ailleurs en contradiction sur plusieurs points avec les deux descriptions originales. Les deux espèces ont vraisemblablement été souvent confondues. SCHMIDT figure en outre dans son atlas plusieurs formes voisines, tombées dans l'oubli, et qui mériteraient d'être reconsidérées à cette occasion.

Triceratium shadboltianum Greville, 1862

Pl. IV, fig. 25, et pl. XIII, fig. 84

GREVILLE, 1862, p. 28. SCHMIDT, 1882, pl. 80, fig. 18-20. VAN HEURCK, 1885, pl. 108, fig. 5-7. PERAGALLO, 1908, p. 389, pl. 106, fig. 1. HUSTEDT, 1930, p. 807, fig. 470.

= *Triceratium orbiculatum* Shadbolt, *pro parte*

BRIGHTWELL, 1856a, p. 276, pl. 17, fig. 20. PERAGALLO, *ibid.*, p. 388, pl. 106, fig. 2-5. *Plur. auct.*, *non* (?) SHADBOLT, 1854, p. 15, pl. 1, fig. 6, *nec* SILVA, 1956b, p. 49, pl. 4, fig. 1.

= *Triceratium (orbiculatum* var. ?) *elongatum* Grunow

GRUNOW, 1867a, p. 31, et 1877, p. 183, pl. 196, fig. 2. HUSTEDT, 1930, p. 809, fig. 471 (« *T. shadboltianum* var. *elongatum* Grunow »).

= *Triceratium elongatum* Grunow *in* A. Schmidt

SCHMIDT, 1876, pl. 80, fig. 12. PAVILLARD, 1925, p. 55, fig. 95.

= *Biddulphia orbiculata* (Shadbolt) Boyer

BOYER, 1900, p. 709, et 1926, p. 130.

= *Biddulphia shadboltiana* (Greville) Van Heurck *vel?* Mann

VAN HEURCK, 1896, p. 466, fig. 199 : « *B. (Triceratium) shabdoltiana* Grev. » *(nomen nudum?)*. MANN, 1907, p. 310 : « *Biddulphia shadboltiana* (Grev.) Mann ».

Non : Triceratium Shadboltii Bailey

BAILEY, 1861, p. 342, pl. 8, fig. 60-61.

Nec : Biddulphia pelagica Schröder (cf. p. suivante).

Cellules solitaires ou, plus rarement, formant de courtes chaînes. Frustules cylindriques, de hauteur pervalvaire très variable; bandes connectives circulaires ou légèrement ondulées, plus ou moins développées; limites de la ceinture et des manteaux valvaires marquées par des sutures bien visibles. Valves sub-circulaires (ou : à trois côtés convexes), portant trois apophyses tronquées, chacune flanquée ou non d'une épine oblique ou (exceptionnellement) de deux épines. Quand elles forment des chaînes, les cellules adhèrent les unes aux autres par leurs apophyses, et un large foramen se forme alors entre deux valves adjacentes. Parois robustes. Ornementation composée d'alvéoles relativement grosses et disposées selon un réseau hexagonal, environ 6 alvéoles en 10 μ.

Récoltes personnelles : Nossi-Bé; Tuléar; île Maurice. (Espèce assez fréquente dans les stations littorales, mais jamais abondante).

Océan Indien : rarement signalée. Indonésie; îles Cocos; Tuléar. (Kolbe, 1957; Travers, 1965).

Distribution mondiale : espèce néritique des eaux chaudes et tempérées, peu fréquente. Également signalée par Cleve-Euler (1951) dans les mers nordiques.

L'abondante synonymie dont cette espèce est entourée résulte de l'insuffisance de la description originale, ainsi que d'une mauvaise compréhension de la variabilité spécifique... : ce cas n'est que trop fréquent, comme on sait, dans l'histoire de la Diatomologie.

L'origine nous fait ici remonter à Shadbolt qui, sous le nom de *T. orbiculatum*, n'a que sommairement décrit et figuré une valve isolée, récoltée à « Port Natal » (Durban). Brightwell a, peu après, rattaché à cette espèce plusieurs spécimens d'origines diverses et dont il donne une description plus détaillée. Vint alors Greville qui, comparant les deux diagnoses, a cru devoir distinguer deux espèces, laissant à la première son nom originel, et nommant *T. shadboltianum* le taxon décrit par Brightwell. Cette discrimination n'est peut-être pas justifiée, car elle se base sur des caractères reconnus postérieurement comme variables (contour de la valve, présence ou absence d'épines). Les différences dans le système d'ornementation pourraient seules trancher la question, mais la description de Shadbolt est par trop imprécise sur ce point. Dans le doute, il a été résolu (Mann, Hustedt) d'écarter de l'espèce la version originale de Shadbolt, pour s'en tenir à la diagnose de Greville.

Hustedt a repris la distinction, introduite par Grunow, d'une variété *elongatum*, qu'il caractérise par ses valves circulaires : il est sur ce point en contradiction avec Grunow lui-même, qui reconnaissait ce caractère comme accessoire : « *valvis exacte orbicularis, vel in tribus locis leviter pluries undulatis, rarius late ovalibus...* », et en contradiction également avec Boyer, selon qui les cellules de section triangulaire ont les bandes connectives les plus développées. Cette distinction paraît donc finalement illusoire.

Triceratium pelagicum (Schröder) nov. comb.

Pl. IV, fig. 26-27, et pl. XI, fig. 70-71

= *Biddulphia pelagica* Schröder, 1908

Schröder, 1908, p. 619, fig. 4-5, et 1909, p. 211, fig. 1. Pavillard, 1931, p. 28, pl. 1, fig. 11.

= *Biddulphia catenata* Schussnig

Schussnig, 1915, p. 398, fig. 14.

= *Triceratium orbiculatum* Shadbolt, *apud* Silva

Silva, 1956b, p. 49, pl. 4, fig. 1. *Non al.*

Cellules solitaires ou formant de courtes chaînes. En vue connective, aspect d'un cyclindre légèrement rétréci et émoussé à ses extrémités, plus ou moins allongé : longueur pervalvaire 2-5 fois supérieure au diamètre valvaire (développement très variable des bandes connectives). En vue valvaire, valves à trois côtés convexes, portant trois protubérances très peu saillantes, dont chacune est flanquée d'un minuscule tubercule (ou épine?); entre ces trois protubérances, la surface des valves est presque plane. Lorsque les cellules forment des chaînes, les valves adjacentes paraissent contiguës sur toute leur surface (foramen absent) : voir fig. 27. Ornementation de la ceinture : réseau hexagonal de très fines ponctuations, 10-15 en 10 μ. Ornementation des valves : même disposition mais, au centre, ponctuations disposées irrégulièrement (fig. 71), et, sur les protubérances, ornementation beaucoup plus fine. Parois délicates. Chromatophores nombreux et très petits, répartis dans toute la cellule. Spores (?) volumineuses, formées par paire dans chaque cellule (fig. 26).

Diamètre valvaire : 55-130 μ.

Récoltes personnelles : Nossi-Bé (espèce assez abondante, nettement hivernale); Tuléar; île Maurice. Absente en milieu océanique (récoltes de l' « Anton Bruun »).

Océan Indien : espèce nouvelle pour cet océan.

Distribution mondiale : assez rare (sous réserve de confusion avec *T. shadboltianum* ?). Adriatique; Açores; Madère; au large de Barcelone; côtes d'Angola; Antilles. Cette espèce serait donc néritique et thermophile.

Dans sa description originale, Schröder rapproche cette espèce de *Biddulphia orbiculata* (Shadb.) Boyer, c'est-à-dire de *Triceratium shadboltianum* Grev. (voir p. 35). Les deux espèces me semblent bien distinctes (*contra* Hustedt, p. 809); d'ailleurs, Pavillard, qui a apporté plusieurs précisions à la diagnose de Schröder, cite dans le même travail (1931, p. 26) le « *Triceratium orbiculatum* » (c'est-à-dire *T. shadboltianum*) sans nulle allusion à un rapprochement possible entre les deux espèces.

Comme le préconise Pavillard, le *Biddulphia catenata* Schussnig doit vraisemblablement tomber en synonymie avec la présente espèce. En effet, Schussnig semble n'avoir décrit, sous ce dernier nom, qu'un frustule déformé de *T. pelagicum*; cependant, selon cet auteur, la formation des chaînes est réalisée au moyen de coussinets gélatineux, ce qui n'a jamais été observé par la suite.

Quant à l'exemplaire décrit et figuré par Silva *(loc. cit.)* sous le nom de *T. orbiculatum*, il semble bien se rapporter à notre *T. pelagicum;* toutefois Silva mentionne « um pequeno espinho » là où je ne vois qu'un minuscule tubercule...; il ne s'agit peut-être ici que d'une question de vocabulaire.

Enfin, il me semble nécessaire de transférer cette espèce dans le genre *Triceratium* où sa place — dans l'état actuel de la systématique de la famille — est assurément mieux justifiée.

Triceratium contortum Shadbolt, 1854

Pl. V, fig. 34

Shadbolt, 1854, p. 15, pl. 1, fig. 7 a-b. Pritchard, 1861, p. 853, pl. 6, fig. 18. Schmidt, 1886, pl. 87, fig. 9-11. Silva, 1956a, p. 41, pl. 5, fig. 6, et 1960, p. 25, pl. 11, fig. 3. Hendey, 1958, p. 49. Eskinazi et Sato, 1966, p. 88, pl. 13, fig. 4 (légendes 4-5 interverties).

= *Triceratium Shadboltii* Bailey

Bailey, 1861, p. 342, pl. 8, fig. 60-61. Wolle, 1890, pl. 64, fig. 10.

Cellules solitaires ou formant de courtes chaînes. Valves sub-triangulaires, à côtés légèrement concaves et bordés d'une double rangée de courtes épines; longueur d'un côté : 115-170 μ. A chaque sommet des valves, en position sub-marginale, une longue épine souvent infléchie; à chaque sommet également, et en position marginale, une apophyse bien développée et dirigée obliquement (d'où le nom spécifique). Ornementation de la valve : réseau hexagonal, auquel s'ajoutent trois paires de lignes partant du centre vers chaque sommet. Bandes connectives généralement bien développées, à ornementation également hexagonale (environ 8 ponctuations en 10 μ).

RÉCOLTES PERSONNELLES : Tuléar.

OCÉAN INDIEN : espèce très rare, apparemment confinée à la région du canal de Mozambique. Durban; côte du Mozambique; Zanzibar; côte occidentale de Madagascar. (SHADBOLT, SCHMIDT, SILVA, *loc. cit.*; AMOSSÉ, 1924).

DISTRIBUTION MONDIALE : quelques stations seulement sont à ajouter aux précédentes. Côtes du Brésil; Freetown; « Amérique du Nord ».

Notons qu'il existe une forme *tetragonum* (JANISCH *in* SCHMIDT, *ibid.*, pl. 87, fig. 8) récoltée par JANISCH au cours de l'expédition de la « Gazelle » (sans précision géographique), ainsi que par AMOSSÉ (1924) à Zanzibar.

Triceratium alternans Bailey, 1851

BAILEY, 1851a, p. 14, pl. 1, fig. 55-56, et 1851b, p. 40. SMITH, 1853, p. 26, pl. 5, fig. 45, et pl. 30, fig. 45. HUSTEDT, 1930, p. 825, fig. 488. SUBRAHMANYAN, 1946, p. 153, fig. 277, 282. CLEVE-EULER, 1951, p. 115, fig. 244.

= *Biddulphia alternans* (Bailey) Van Heurck

VAN HEURCK, 1885, p. 208, pl. 113, fig. 4-7, et 1896, p. 475, pl. 21, fig. 644. HENDEY, 1951, p. 34, pl. 7, fig. 10, et 1964, p. 102, pl. 25, fig. 5.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce peu fréquente. Côtes des Indes; mer d'Arabie; Ceylan; côte du Mozambique; Afrique du Sud. (KOLBE, 1957; SILVA, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce littorale, probablement cosmopolite mais plus fréquente dans les mers tempérées.

Triceratium pentacrinus (Ehrenberg) Wallich, 1858

EHRENBERG, 1840b, p. 205, et 1854, pl. 19, fig. 59 : « *Amphipentas? pentacrinus* ». WALLICH, 1858, p. 249, pl. 12, fig. 10. SCHMIDT, 1886, pl. 98, fig. 7-10, 13. PERAGALLO, 1908, p. 384, pl. 103, fig. 1-3. HUSTEDT, 1930, p. 812, fig. 474. SILVA, 1956c, p. 344, pl. 7, fig. 1-2.

f. ***quadratum*** Hustedt, 1930

Pl. XI, fig. 72-73

HUSTEDT, 1930, p. 814, *vix* fig. 475. MISRA, 1956, p. 542, fig. 15 (?).

Sous le nom spécifique :

WALLICH, *loc. cit.*, fig. 14. SCHMIDT, *loc. cit.*, fig. 11-12. PERAGALLO, *loc. cit.*, fig. 2. SILVA, 1956a, p. 42, pl. 6, fig. 1-2.

= *Triceratium junctum* A. Schmidt

SCHMIDT, 1886, pl. 98, fig. 1-3, 19, et pl. 152, fig. 20. AMOSSÉ, 1924, p. 254.

= *Biddulphia juncta* (A. Schmidt) Mann

MANN, 1925, p. 42. SKVORTZOW, 1932e, p. 335, pl. 49, fig. 1 (*non* 5?).

RÉCOLTES PERSONNELLES : parages de Beira.

OCÉAN INDIEN : forme très sporadique. Côte occidentale des Indes; canal de Mozambique; Seychelles; Ceylan; côte sud d'Australie. (SCHMIDT, AMOSSÉ, SKVORTZOW, SILVA, MISRA, *loc. cit.*).

DISTRIBUTION MONDIALE : très rare en dehors de l'océan Indien. Méditerranée. Toutefois, cette forme a pu être confondue avec *T. balearicum* f. *biquadratum* Hustedt.

Triceratium formosum Brightwell, 1856
f. ***formosum***

Pl. XII, fig. 80

BRIGHTWELL, 1856, p. 273. HUSTEDT, 1930, p. 819, fig. 481.

f. ***quadrangulare*** (Greville) Hustedt, 1930

Pl. XII, fig. 81

HUSTEDT, 1930, p. 820, fig. 483.

= *Triceratium formosum* var., *apud* Brightwell

BRIGHTWELL, 1856, p. 214, pl. 17, fig. 8.

= *Triceratium quadrangulare* Greville

GREVILLE, 1865b, p. 10, pl. 2, fig. 26.

f. ***quinquelobatum*** (Greville) Hustedt, 1930

Pl. XII, fig. 82

HUSTEDT, 1930, p. 820, fig. 482.

= *Triceratium quinquelobatum* Greville

GREVILLE, 1866, p. 83, pl. 9, fig. 21.

Pour les trois formes :

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice. Toujours rare.

OCÉAN INDIEN : espèce peu signalée. Madagascar; Indonésie; Tasmanie. (KOLBE, 1957; TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce littorale, mers tropicales et tempérées. Les exigences écologiques respectives des trois formes restent à étudier.

Triceratium reticulum Ehrenberg, 1844

EHRENBERG, 1844a, p. 88, et 1854, pl. 18, fig. 50, pl. 33, fig. 16/13. HUSTEDT, 1930, p. 823, fig. 485-486.

= *Biddulphia reticulum* (Ehrenberg) Boyer

BOYER, 1900, p. 724. ALLEN et CUPP, 1935, p. 147, fig. 83. SPROSTON, 1949, p. 101. HENDEY, 1964, p. 102, pl. 25, fig. 6.

Non : Biddulphia reticulata Roper

ROPER, 1859, p. 14, pl. 2, fig. 13-17. VAN HEURCK, 1885, pl. 102, fig. 1-3. SCHMIDT, 1888, pl. 121, fig. 11-15.

RÉCOLTES PERSONNELLES : Tuléar (rare).

OCÉAN INDIEN : Madagascar; Indonésie; Ceylan; côtes du Mozambique et d'Afrique du Sud; Zanzibar. (AMOSSÉ, 1924; SILVA, 1956a; CHOLNOKY, 1963).

DISTRIBUTION MONDIALE : espèce littorale, principalement tropicale, plus rare dans les mers tempérées (mer du Nord, côtes de Suède).

Isthmia japonica (Castracane) nov. comb.

Pl. XII, fig. 77-78

= *Isthmia enervis* var. *japonica* Castracane

CASTRACANE, 1886, p. 96, pl. 25, fig. 5.

= *Isthmia sp., apud* Schmidt

SCHMIDT, env. 1889, pl. 136, fig. 8, *vix* 9.

Valves très dissemblables : l'une (a) plus ou moins étirée et formant un cône excentrique; l'autre (b) moins haute, et bosselée en plusieurs points. Ornementation des valves composée de larges alvéoles alignées d'une part parallèlement à l'axe pervalvaire, d'autre part, moins distinctement, selon deux axes obliques; côtes absentes; alvéoles de la valve (a) plutôt subquadratiques, diminuant progressivement de taille vers le sommet; alvéoles de la valve (b) plutôt sub-hexagonales et de taille presque constante. Ceinture relativement peu développée, de hauteur inférieure au diamètre valvaire; ornementation de la ceinture plus fine que celle des valves : petites alvéoles sub-rectangulaires, disposées grossièrement suivant trois directions; au contact des valves, la ceinture est limitée par une rangée de grosses alvéoles.

Cellules solitaires ou formant de courtes chaînes linéaires; dans ce dernier cas, plusieurs points de contact entre deux cellules voisines : autant que la valve (b) compte de bosses.

Diamètre des valves : 55-80 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); île Maurice.

OCÉAN INDIEN : l'espèce semble nouvelle pour cet océan.

DISTRIBUTION MONDIALE : très rare. Mer du Japon; « Colon » (Panama, ou Galapagos?); « expédition de la Gazelle ». Cette *Isthmia* peut donc être provisoirement considérée comme néritique intertropicale.

Isthmia minima Harvey et Bailey, 1854

Pl. XI, fig. 76, et pl. XII, fig. 79

HARVEY et BAILEY, 1854, p. 430. PRITCHARD, 1861, p. 851. BAILEY et HARVEY, 1862, p. 177, pl. 9, fig. 11. WALK et CHASE, 1887, p. 5, pl. 5, fig. 9 (?). PETIT, 1902, p. 8, fig. 3 (légende de la figure : « *I. minima* var. *capensis* Grunow »). MANN, 1925, p. 85 (?). BOYER, 1926, p. 141.

= *Isthmia capensis* Grunow *in* A. Schmidt

Schmidt, env. 1889, pl. 136, fig. 4, et pl. 145, fig. 4-8.

= *Isthmia lindigiana* Grunow et Eulenstein

Grunow, 1867, p. 29. Schmidt, env. 1889, pl. 145, fig. 1-3.

= *Isthmiella minima* (Harvey et Bailey) De-Toni = *Isthmiella capensis* (Grunow) De-Toni = *Isthmiella lindigiana* (Grunow et Eulenstein) De-Toni.

De-Toni, 1894, p. 835-836.

Valves de forme assez variable, généralement dissemblables : l'une allongée, l'autre courte et ondulée ou bilobée. Côtes absentes. Ceinture bien développée, de hauteur égale ou supérieure au diamètre valvaire; ceinture couverte d'un réseau hexagonal très fin (environ 8 alvéoles en 10 µ), limitée — ou non — au contact des valves par une rangée d'alvéoles un peu plus grosses.

Cellules solitaires ou formant des chaînes ramifiées; dans ce dernier cas, un seul point de contact entre deux cellules voisines : ce point est situé d'une part au sommet d'une valve, d'autre part à la limite ceinture-manteau de la cellule voisine.

Diamètre des valves : 30-50 µ.

Récoltes personnelles : Nossi-Bé (espèce hivernale); Tuléar; île Maurice.

Océan Indien : Madagascar; Java; Ceylan; Le Cap; Indonésie. (Schmidt, De-Toni, *loc. cit.*).

Distribution mondiale : espèce peu connue, probablement plus commune qu'il ne paraît, du fait de confusions possibles avec *I. enervis*. Honduras; La Barbade; Rio de Janeiro. Cette espèce serait donc, comme la précédente, néritique et tropicale.

I. minima diffère essentiellement de *I. enervis* par la très fine ornementation de sa ceinture. Cependant, l'absence de côtes valvaires, caractère commun à *I. enervis*, a pu la faire fréquemment confondre avec cette dernière. On considère en effet trop souvent qu'il n'existe que deux espèces dans le genre, reconnaissables à la présence ou l'absence de côtes... Rappelons seulement à ce sujet que Mills, dans son index, n'énumère pas moins de 30 espèces et variétés — parmi lesquelles, il est vrai, de nombreux synonymes.

Lithodesmium undulatum Ehrenberg, 1840

Ehrenberg, 1840-41, p. 155, pl. 4, fig. 13. Gran, 1905, p. 112, fig. 149. Lebour, 1930, p. 185, fig. 145. Hustedt, 1930, p. 789, fig. 461. Cupp, 1943, p. 150, fig. 108. Subrahmanyan, 1946, p. 149, fig. 268-270. Hendey, 1964, p. 111, pl. 6, fig. 6.

Récoltes personnelles : Tuléar; île Maurice.

Océan Indien : espèce rarement citée. Mer de Java; côtes des Indes; sud-est de l'océan; canal de Mozambique. (Silva, 1956a, 1960; Travers, 1965).

Distribution mondiale : néritique et plutôt tempérée. Principalement : Manche et mer du Nord; Californie; côtes d'Australie et de Tasmanie; Méditerranée.

Ditylum Brightwellii (West) Grunow *in* Van Heurck, 1885

WEST, 1860, p. 149, pl. 7, fig. 6 : « *Triceratium Brightwellii* ». VAN HEURCK, 1885, p. 196, et cf. pl. 114, fig. 3-9. HUSTEDT, 1930, p. 784, fig. 457-459. HENDEY, 1937, p. 284, pl. 12, fig. 5-6, et 1964, p. 111, pl. 5, fig. 1. BODEN, 1950, p. 394, fig. 75-76.

La graphie « *Ditylium* » est erronée.

RÉCOLTES PERSONNELLES : côte d'Afrique du Sud, de Durban à Beira.

OCÉAN INDIEN : espèce courante sous les latitudes tropicales et tempérées. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique, mers tropicales et tempérées.

Ditylum sol (Van Heurck) De-Toni, 1894

Pl. III, fig. 15

VAN HEURCK, 1885, pl. 115, fig. 1-2 : « *Triceratium (Ditylium) sol (auctor?)* ». DE-TONI, 1894, p. 1018. HUSTEDT, 1930, p. 787, fig. 460. HENDEY, 1937, p. 285, pl. 12, fig. 4. Nom d'auteur souvent erroné.

= *Ditylum Pernodii* Schröder, et *D. trigonum* Schröder

SCHRÖDER, 1906, p. 355-356, fig. 24-25. OSTENFELD, 1915, p. 16, fig. 8.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; parages de Durban.

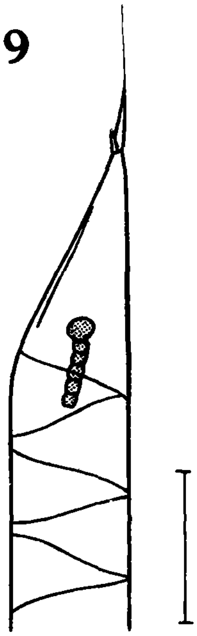
OCÉAN INDIEN : comme l'espèce précédente.

DISTRIBUTION MONDIALE : à la différence de *D. Brightwellii*, la présente espèce est essentiellement tropicale.

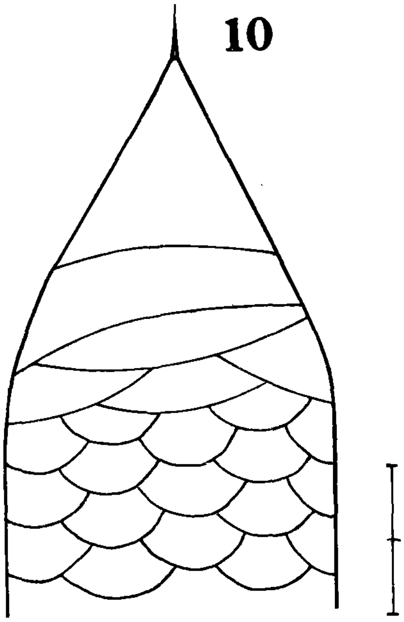
Le spécimen représenté sur la figure 15, observé en contraste de phase, montre de nombreuses bandes intercalaires, disposées perpendiculairement aux stries pervalvaires.

PLANCHE II : **9** — *Rhizosolenia styliformis* var. *longispina* Hust. **10** — *R. Temperei* var. *acuminata* H. Per. **11** a, b — *R. crassispina* Schröder; diamètre 25 μ (a) et 70 μ (b). **12** — *R. imbricata* var *Shrubsolei* (Cl.) Schröder : auxospore. **13** a, b — *R. Clevei* Ostf.; diamètre 80 μ (a) et 120 μ (b). **14** — *R. cochlea* Brun.

9



10



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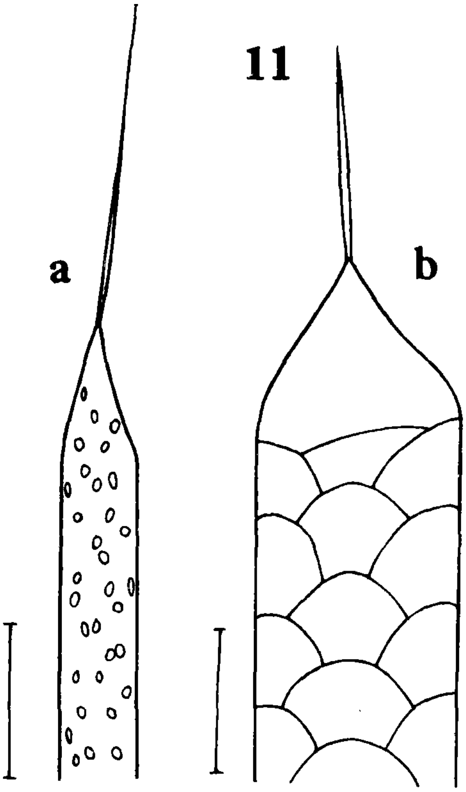
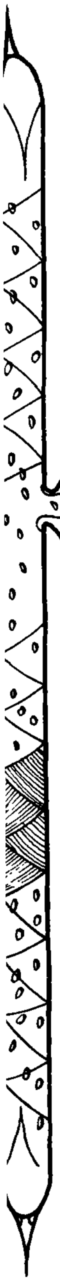
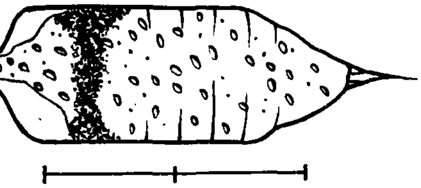
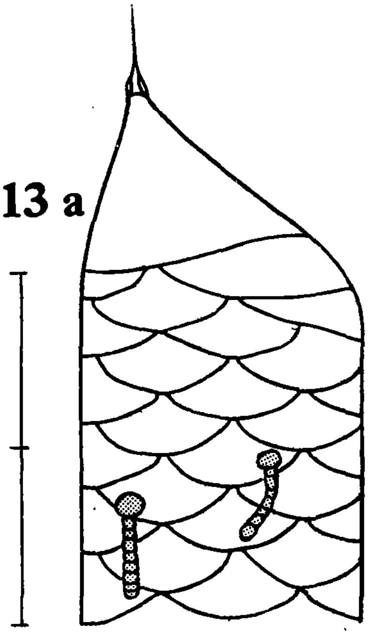




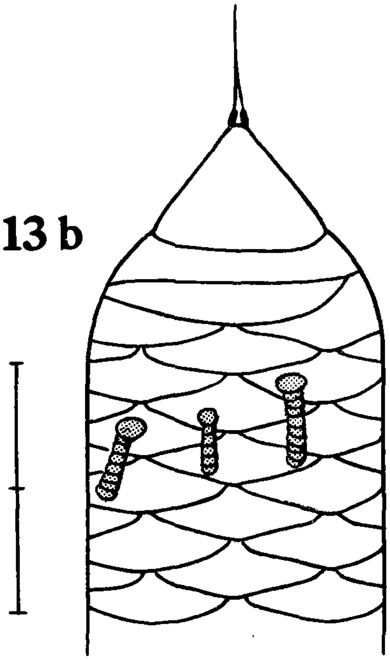


12

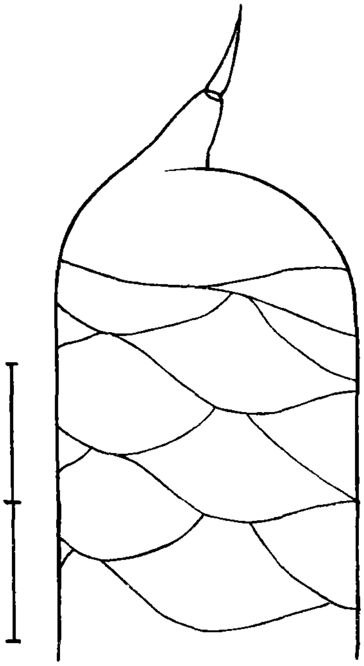
13 a



13 b



14



Bellerochea malleus (Brightwell) Van Heurck, 1885
f. ***malleus***

BRIGHTWELL, 1858b, p. 154, pl. 8, fig. 6-7 : « *Triceratium malleus* ». VAN HEURCK, 1885, p. 203, et cf. pl. 114, fig. 1. HUSTEDT, 1930, p. 782, fig. 456 a-c. HENDEY, 1964, p. 112, pl. 6, fig. 5, *non* 5 a.

« *Malleus* » : L'espèce a été ainsi désignée en raison de sa ressemblance avec le Lamellibranche *Malleus vulgaris* Lamarck. Le genre, dédié au Prof. BELLEROCHE, est souvent orthographié par erreur « *Bellarochia* ».

f. ***biangulata*** (Peragallo) Hustedt, 1930

PERAGALLO, 1908, p. 394 : « var. *biangulata* ». HUSTEDT, 1930, p. 782, fig. 456 d. HENDEY, 1964, *ibid.*, fig. 5 a : « f. *biangulata* Peragallo ».

= *Schmidtiella pelagica* Ostenfeld

OSTENFELD, 1903a, p. 23, fig. 20.

= *Schmidtiella elongata* Schröder

SCHRÖDER, 1906, p. 351, fig. 17. OKAMURA, 1911, p. 7, pl. 11, fig. 32.

Pour les deux formes (la troisième, f. *tetragona*, étant absente de mes récoltes) :

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); les deux formes ont été rencontrées en abondance dans les parages de Beira.

OCÉAN INDIEN : l'espèce est assez courante dans la zone intertropicale. (SILVA, 1956a, 1960).

DISTRIBUTION MONDIALE : espèce néritique, euryhaline, principalement tropicale, mais connue dans la Manche, la mer du Nord et la Méditerranée. Les répartitions respectives des trois formes demeurent à rechercher.

Streptotheca Tamesis Shrubsole, 1891
Pl. III, fig. 23

SHRUBSOLE, 1891, p. 260, pl. 13, fig. 4-6. GRAN, 1905, p. 101, fig. 131. HUSTEDT, 1930, p. 779, fig. 455. HENDEY, 1937, p. 287, pl. 12, fig. 11-12, et 1964, p. 113, pl. 7, fig. 2.

« *Tamesis* » : La Tamise (localité-type). Les graphies « *thamensis* » et « *thamesis* » sont erronées. La majuscule est facultative.

= *Streptotheca maxima* Cleve

CLEVE, 1901, p. 57, pl. 8, fig. 5. SCHMIDT, 1933, pl. 383, fig. 10.

= *Streptotheca indica* Karsten

KARSTEN, 1907, p. 395, pl. 46, fig. 8, et 1928, p. 237, fig. 282-283. OKAMURA, 1911, p. 11, pl. 13, fig. 57. ALLEN et CUPP, 1935, p. 144, fig. 77. SUBRAHMANYAN, 1946, p. 146, fig. 259-260.

Récoltes personnelles : Nossi-Bé (très rare); Tuléar; île Maurice; parages de Durban et de Beira. Une prolifération massive a été observée au large du cap Saint-André.

Océan Indien : espèce courante sous les basses latitudes. (Silva, 1956a, 1960; Taylor, 1967).

Distribution mondiale : mers tropicales et tempérées; espèce plutôt néritique.

La structure des bandes intercalaires apparaît, en contraste de phase, sous la forme de fines stries parallèles très serrées (cf. fig. 23 : cellule de grande taille, quelque peu déformée par le montage).

Je n'ai observé, dans le canal de Mozambique, aucune valve tripolaire.

Cerataulina pelagica (Cleve) Hendey, 1937

Cleve, 1889, p. 54 : « *Zygoceros? pelagicum* ». Hendey, 1937, p. 279, et 1964, p. 113, pl. 6, fig. 4. Hart et Currie, 1960, p. 215.

= *Cerataulina Bergonii* Peragallo

Hustedt, 1930, p. 869, fig. 517, *et plur. auct.*

= *C. Bergonii* var. *elongata* Schröder

Schröder, 1901, p. 30. Cleve-Euler, 1951, p. 122, fig. 265 a-b.

= *C. Bergonii* var. *lata* Cleve-Euler

Cleve-Euler, 1951, p. 122, fig. 265 c-d.

= *Cerataulina compacta* Ostenfeld *in* Ostenfeld et J. Schmidt

Ostenfeld et Schmidt, 1901, p. 153, fig. 7. Karsten, 1907, p. 395, pl. 46, fig. 7. Okamura, 1911, p. 10, pl. 12, fig. 49. Allen et Cupp, 1935, p. 150, fig. 87. Silva, 1952a, p. 592, pl. 4, fig. 11. Wood, 1963b, p. 195, pl. 2, fig. 42.

= *Cerataulina sp., apud* Wood

Wood, 1963b, p. 195, pl. 2, fig. 41, et pl. 5, fig. 5.

Non : Cerataulina curvata Wood
Wood, 1963b, p. 195, pl. 5, fig. 4, et pl. 2, fig. 40.
Nec : Cerataulina Chapmanii Crosby et Wood
Crosby et Wood, 1958, p. 502, pl. 32, fig. 28.

Récoltes personnelles : espèce courante dans la plupart des prélèvements littoraux.

Océan Indien : latitudes tropicales et tempérées. (Silva, 1956a, 1960; Travers, 1965; Taylor, 1967).

Distribution mondiale : cosmopolite, à tendance thermophile.

Hendey (1937) a fait valoir la priorité quelque peu épineuse du taxon de Cleve, quoiqu'il eût été préférable de s'en tenir à l'usage établi — qui ne prêtait d'ailleurs à aucune confusion. La nouvelle désignation ayant été suivie par certains Diatomistes ou planctologistes (Takano, 1960; Hart et Currie, *loc. cit.;* Wood, 1963a), il est maintenant souhaitable d'abandonner la dénomination illégale — si peu qu'elle le soit.

Au sujet du *C. compacta*, si certains caractères le distinguent de *C. pelagica*, ceux-ci sont mineurs, et si subtils que la confusion est de règle... (Voir descriptions comparées des « deux espèces » *in* Allen et Cupp, *loc. cit.*).

Les deux formes isolées par Schröder et par Cleve-Euler ne différeraient que par leurs proportions, ce qui ne saurait constituer un critère morphologique suffisant.

Enfin le *C. curvata* de Wood doit probablement être tenu pour espèce distincte, bien que sa description soit assez sommaire. Quant au *C. Chapmanii* de Crosby et Wood, il ne possède manifestement pas les caractères du genre.

Fam. CHAETOCERACEAE

Chaetoceros atlanticum Cleve, 1873
var. ***neapolitanum*** (Schröder) Hustedt, 1930

Schröder, 1901, p. 29, pl. 1, fig. 4 : « *Chaetoceros neapolitanum* ». Hustedt, 1930, p. 645, fig. 366. Hendey, 1937, p. 290. Hart et Currie, 1960, p. 216.

= *Chaetoceros neapolitanum* Schröder

Schröder, *loc. cit.* Gran et Yendo, 1914, p. 5, fig. 2. Hendey, 1964, p. 119, pl. 16, fig. 3.

Récoltes personnelles : Nossi-Bé; Tuléar; île Maurice; parages des Comores.

Océan Indien : variété assez peu signalée. Mer Rouge et mer d'Arabie; canal de Mozambique; Antarctique. (Boden, 1950; Silva, 1956a; Travers, 1965; Taylor, 1967).

Distribution mondiale : Méditerranée; Atlantique; Californie; mer du Japon; plus rarement, dans la mer du Nord.

var. ***skeleton*** (Schütt) Hustedt, 1930

Schütt, 1895, p. 45, pl. 2, fig. 19 : « *Chaetoceros skeleton* ». Hustedt, 1930, p. 643, fig. 365. Cupp, 1943, p. 104, fig. 59 B, b-c.

Récoltes personnelles : Tuléar; île Maurice.

Océan Indien : rare. Célèbes; côte du Mozambique; Antarctique (?); Afrique du Sud. (Silva, 1956a; Taylor, 1967).

Distribution mondiale : mers chaudes, assez rare.

Outre leurs caractères morphologiques, ces deux variétés se distinguent du type par leur répartition nettement thermophile. La variété-type (var. *atlanticum*) est elle-même exceptionnelle sous les basses latitudes.

Chaetoceros denticulatum Lauder, 1864

Pl. III, fig. 24

LAUDER, 1864b, p. 79, pl. 8, fig. 9. SCHRÖDER, 1906, p. 349, fig. 14 a (*non* b). OKAMURA, 1907, p. 91, pl. 4, fig. 66. SCHMIDT, 1921, pl. 337, fig. 7. ALLEN et CUPP, 1935, p. 135, fig. 53. SUBRAHMANYAN, 1946, p. 129, fig. 188-190. CROSBY et WOOD, 1958, p. 516, pl. 37, fig. 45.

Sans description ni illustration, *in :* CLEVE, 1873a, 1901; LEUDUGER-FORTMOREL, 1892; OSTENFELD et SCHMIDT, 1901; SUBRAHMANYAN, 1958; TAKANO, 1960; WOOD, 1962.

= *Chaetoceros denticulatum* f. *angustum* Hustedt *in* A. Schmidt

SCHMIDT, 1920, pl. 324, fig. 5.

Cellules isodiamétriques ou plus hautes que larges, robustes (diamètre apical : 20-32 µ), formant des chaînes courtes et droites. Foramen sub-losangique ou sub-hexagonal. Limites ceinture-manteau bien marquées. Valves portant une petite épine centrale, pas toujours visible. Cornes robustes, striées transversalement, et épineuses; à leur insertion, les cornes sont dirigées tout d'abord presque parallèlement à l'axe pervalvaire, puis deviennent brutalement presque perpendiculaires à cet axe, une forte dent marquant le niveau de l'inflexion; cette dent est absente des cornes terminales.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce courante dans la zone intertropicale, cependant nouvelle pour le canal de Mozambique; rare sous les latitudes tempérées. (TAYLOR, 1967).

DISTRIBUTION MONDIALE : cette espèce est presque inconnue en dehors de l'océan Indien et des mers indonésiennes. Hong-Kong (localité-type); côtes sud et est de l'Australie.

Une espèce très voisine de celle-ci est le *C. nanodenticulatum* Okamura, dont les caractères distinctifs sont les suivants : cellule environ deux fois plus large que haute; foramen elliptique; cornes dirigées, à leur insertion, obliquement par rapport à l'axe pervalvaire. *C. nanodenticulatum* est lui-même à rapprocher de *C. indicum* Karsten; les références de ces deux *Chaetoceros*, absents l'un et l'autre de mes récoltes, sont données ci-dessous à toutes fins utiles :

Chaetoceros nanodenticulatum Okamura, 1907

OKAMURA, 1907, p. 91, fig. in text. ALLEN et CUPP, 1935, p. 136, fig. 54.

= *C. denticulatum* Lauder, *apud* Schröder : SCHRÖDER, 1906, fig. 14 b (*non* a).

= *C. denticulatum* f. *latum* Hustedt *in* A. Schmidt : SCHMIDT, 1920, pl. 324, fig. 6-7. TAYLOR, 1967, pl. 89, fig. 10.

Chaetoceros indicum Karsten, 1907

KARSTEN, 1907, p. 387, pl. 43, fig. 2. IKARI, 1928, p. 250, fig. 5.

Non : Chaetoceros indicum Subrahmanyan, 1946. (Le nom de *C. capricornianum* a été récemment proposé par TAYLOR, 1967, en remplacement de ce taxon illégal.)

Chaetoceros coarctatum Lauder, 1864

LAUDER, 1864b, p. 79, pl. 8, fig. 8. HUSTEDT, 1930, p. 655, fig. 370. HENDEY, 1937, p. 293, pl. 6, fig. 7-8, et 1964, p. 121, pl. 12, fig. 1. MÜLLER-MELCHERS, 1949, p. 164, fig. 6-7.

RÉCOLTES PERSONNELLES : Nossi-Bé (saison chaude); Tuléar; île Maurice; dans le canal de Mozambique (récoltes « Anton Bruun »), nettement océanique. Très généralement associé à l'épiphyte *Vorticella.*

OCÉAN INDIEN : espèce très courante dans la zone tropicale. (HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce océanique, intertropicale, connue également dans l'Atlantique tempéré et la mer du Nord, et peut-être dans l'Antarctique (KARSTEN, 1905a).

Chaetoceros tetrastichon Cleve, 1897

CLEVE, 1897a, p. 22, pl. 1, fig. 7. GRAN, 1905, p. 69, fig. 81. PAVILLARD, 1925, p. 41, fig. 64 a. IKARI, 1926, p. 519, fig. 2 a-b. LEBOUR, 1930, p. 125, fig. 90. HUSTEDT, 1930, p. 657, fig. 371. SILVA, 1960, p. 21, pl. 20, fig. 5. WOOD, 1963b, p. 197, pl. 5, fig. 11. HENDEY, 1964, p. 123, pl. 11, fig. 1.

Sans description ni illustration, *in :* OSTENFELD et SCHMIDT, 1901; CLEVE, 1901; SCHRÖDER, 1906; KARSTEN, 1907; OSTENFELD, 1915; SUBRAHMANYAN, 1958; TAKANO, 1960; WOOD, 1962, 1963a.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); île Maurice. Toujours observé à l'état « libre », c'est-à-dire non associé à *Tintinnus.*

OCÉAN INDIEN : espèce courante dans la zone intertropicale. (SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tempérées et tropicales.

Chaetoceros Dadayi Pavillard, 1913

PAVILLARD, 1913, p. 131, fig. 2 B, et 1925, p. 41, fig. 64 b. IKARI, 1926, p. 519, fig. 2 c-d. HUSTEDT, 1930, p. 658, fig. 372. SKVORTZOW, 1931b, p. 105, pl. 6, fig. 1.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); île Maurice. Associé à *Tintinnus inquilinus.*

OCÉAN INDIEN : très rare. Mer d'Arafura; « océan Indien »; côtes d'Afrique du Sud. Espèce nouvelle pour la région étudiée. (TAKANO, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : encore incertaine. Méditerranée, mer du Japon. Probablement intertropicale.

Chaetoceros danicum Cleve, 1889

CLEVE, 1889, p. 55, fig. in text. GRAN, 1905, p. 70, fig. 83. HUSTEDT, 1930, p. 659, fig. 373. HENDEY, 1937, p. 294, et 1964, p. 122, pl. 10, fig. 5.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare, et seulement estivale). Tuléar?

OCÉAN INDIEN : espèce rare. Antarctique; côte occidentale des Indes; côtes d'Afrique du Sud. L'espèce est donc nouvelle pour le canal de Mozambique. (HENDEY, 1937; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce cosmopolite, particulièrement euryhaline (eaux saumâtres).

Chaetoceros rostratum Lauder, 1864

LAUDER, 1864b, p. 79, pl. 8, fig. 10. PAVILLARD, 1925, p. 42, fig. 66. IKARI, 1926, p. 520, fig. 3. HUSTEDT, 1930, p. 660, fig. 374. MÜLLER-MELCHERS, 1949, p. 166, fig. 13. MULFORD, 1964, p. 388, fig. 3.

= *Chaetoceros Glandazii* Mangin

MANGIN, 1910, p. 346, fig. 2, et 1912, p. 50, fig. 38. LEBOUR, 1930, p. 118, fig. 84. HENDEY, 1937, p. 292, et 1964, p. 121, pl. 9, fig. 4. SILVA, 1956a, p. 39, pl. 5, fig. 1. CURL, 1959, p. 294, fig. 51.

= *C. rostratum* var. *Glandazii* (Mangin) Taylor

TAYLOR, 1967,. p. 439, pl. 2, fig. 12.

RÉCOLTES PERSONNELLES : Nossi-Bé; île Maurice.

OCÉAN INDIEN : mer Rouge; côtes du Natal et du Mozambique; Indonésie. (SILVA, 1956a).

DISTRIBUTION MONDIALE : espèce tempérée ou tropicale. Mers de Chine et du Japon; Méditerranée; Atlantique tempéré.

TAYLOR *(loc. cit)* a tout récemment proposé de distinguer ici une variété *Glandazii* et une variété-type, mais le caractère invoqué (contour plus arrondi, chez la seconde, en vue connective) me semble incertain.

Voir aussi une espèce très voisine : *C. malayense* Steemann Nielsen, 1931.

Chaetoceros peruvianum Brightwell, 1856

BRIGHTWELL, 1856b, p. 107, pl. 7, fig. 16-18. PAVILLARD, 1925, p. 42, fig. 67. HUSTEDT, 1930, p. 671, fig. 380. HENDEY, 1937, p. 296, pl. 13, fig. 6, et 1964, p. 123, pl. 9, fig. 3. HASLE, 1960, p. 15, fig. 2. Voir aussi MANGIN, 1919 (monographie du « groupe *peruvianum* »).

? = f. *gracile* (Schröder) Hustedt, et f. *robustum* (Cleve) Hustedt

HUSTEDT, 1930, p. 672-673, fig. 381 a-b.

Non : Chaetoceros saltans Cleve.

Récoltes personnelles : Nossi-Bé, et presque toutes les stations littorales. La « forme » *gracile* est dominante, sauf à l'île Maurice où la « forme » *robustum* est seule représentée.

Océan Indien : espèce très courante sous toutes les latitudes, Antarctique compris. (Silva, 1956a, 1960; Travers, 1965; Taylor, 1967).

Distribution mondiale : espèce cosmopolite, mais nettement thermophile.

La distinction faite par Hustedt des deux formes mentionnées ci-dessus est peut-être superflue; les distributions géographiques respectives de ces deux présumés taxons demeurent toutefois inconnues.

Chaetoceros decipiens Cleve, 1873

Cleve, 1873b, p. 11, pl. 1, fig. 5. Hustedt, 1930, p. 675, fig. 383. Hendey, 1937, p. 298, et 1964, p. 123, pl. 12, fig. 2.

Récoltes personnelles : Nossi-Bé; île Maurice; sud du canal de Mozambique.

Océan Indien : espèce signalée sporadiquement dans la zone tropicale; abondante au large des côtes d'Afrique du Sud. (Hendey, 1937; Silva, 1956a, 1960; Travers, 1965; Taylor, 1967).

Distribution mondiale : cosmopolite, mais plus rare sous les basses latitudes.

J'ai occasionnellement (Nossi-Bé) rencontré cette espèce sous la forme très aplatie décrite par Schütt sous le nom de *C. Grunowii* (Schütt, 1895, p. 43, pl. 4-5, fig. 14 a-b).

Chaetoceros lorenzianum Grunow, 1863

Grunow, 1863, p. 157, pl. 5, fig. 13. Hustedt, 1930, p. 679, fig. 385. Allen et Cupp, 1935, p. 137, fig. 58. Hendey, 1937, p. 299, et 1964, p. 124, pl. 16, fig. 1. Frenguelli, 1939, p. 222, pl. 2, fig. 14.

Récoltes personnelles : toutes les stations littorales.

Océan Indien : espèce commune sous les latitudes tropicales. (Kolbe, 1957; Travers, 1965; Taylor, 1967).

Distribution mondiale : mers tropicales et tempérées; surtout néritique.

Chaetoceros Lauderi Ralfs *in* Lauder, 1864

Lauder, 1864b, p. 77, pl. 8, fig. 4, *vix* 3. Hustedt, 1930, p. 683, fig. 387. Allen et Cupp, 1935, p. 138, fig. 59. Subrahmanyan, 1946, p. 133, fig. 211-213, et pl. 2, fig. 3. Hendey, 1964, p. 125, pl. 13, fig. 3.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce peu fréquente. Côtes des Indes; mers indonésiennes; Inhaca; côte d'Afrique du Sud; divers sondages intertropicaux. (KOLBE, 1957; SILVA, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : néritique tropicale; espèce également connue dans l'Atlantique nord et ses dépendances, où elle est plutôt estivale (HENDEY).

Chaetoceros compressum Lauder, 1864

Pl. III, fig. 16

LAUDER, 1864b, p. 78, pl. 8, fig. 6. HUSTEDT, 1930, p. 684, fig. 388-389. HENDEY, 1937, p. 300, et 1964, p. 125, pl. 16, fig. 5.

= *Chaetoceros contortum* Schütt

GRAN, 1905, p. 78, fig. 93, *et plur. auct.*

RÉCOLTES PERSONNELLES : Nossi-Bé (plutôt estivale); Tuléar; île Maurice; parages de Durban et du cap Saint-André. Très polymorphe, souvent abondante. Association fréquente avec la Cyanophycée *Richelia*, ici épiphyte (fig. 16).

OCÉAN INDIEN : espèce fréquente, également signalée dans l'Antarctique. (HENDEY, 1937; SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : néritique; cosmopolite (ou psychrophile?).

Chaetoceros didymum Ehrenberg, 1845

var. ***didymum***

EHRENBERG, 1845, p. 75, et 1854, pl. 35 A, fig. 17/5 et 18/4. HUSTEDT, 1930, p. 688, fig. 390-391. HENDEY, 1937, p. 301, et 1964, p. 125, pl. 17, fig. 2.

= *C. didymum* var. *genuinum* Gran

GRAN, 1905, p. 80, fig. 94. OKAMURA, 1907, p. 95, pl. 4, fig. 48. GRAN et YENDO, 1914, p. 12. SKVORTZOW, 1931b, p. 103, pl. 5, fig. 3, 5. *Non :* CLEVE-EULER, 1951, p. 100 (qui réunit les variétés *genuinum* et *protuberans*).

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : ce taxon n'est signalé, en tant que variété-type, que par TAYLOR, 1967 (côte d'Afrique du Sud); les autres références sont portées sous le nom spécifique, ce qui laisse quelque incertitude sur la répartition géographique. Dans le canal de Mozambique : SILVA (1960). Voir par ailleurs WOOD (1963a).

DISTRIBUTION MONDIALE : néritique, mers tempérées (sous la même réserve).

Il semble très souhaitable de désigner comme ci-dessus la variété-type de l'espèce, afin d'éviter la confusion avec la variété suivante, ainsi qu'avec les var. *anglicum* (Grunow) Gran, *aggregatum* Mangin, et *heterosetoides* Subrahmanyan.

var. ***protuberans*** (Lauder) Gran et Yendo, 1914

LAUDER, 1864b, p. 79, pl. 8, fig. 11 : « *Chaetoceros protuberans* ». GRAN et YENDO, 1914, p. 12, fig. 5. HUSTEDT, 1930, p. 690, fig. 392.

= *Chaetoceros protuberans* Lauder

LAUDER, *ibid.* KARSTEN, 1928, p. 235, fig. 277 b. SKVORTZOW, 1931b, p. 103, pl. 5, fig. 4.

RÉCOLTES PERSONNELLES : Nossi-Bé; parages des Comores.

OCÉAN INDIEN : côtes des Indes; mers indonésiennes; côte d'Afrique du Sud. (SUBRAHMANYAN, 1946, 1958; TAYLOR, 1967). Cette variété est nouvelle pour la région étudiée.

DISTRIBUTION MONDIALE : variété plus thermophile que la précédente. Mers de Chine et du Japon; Méditerranée.

Chaetoceros affine Lauder, 1864

LAUDER, 1864b, p. 78, pl. 8, fig. 5. HUSTEDT, 1930, p. 695, fig. 396. FRENGUELLI, 1939, p. 223, pl. 2, fig. 16-17. HENDEY, 1964, p. 127, pl. 18, fig. 3.

= *Chaetoceros Ralfsii* Cleve

CLEVE, 1873a, p. 10, pl. 3, fig. 15. HENDEY, 1937, p. 302.

RÉCOLTES PERSONNELLES : Nossi-Bé (fin de la saison estivale); Tuléar; île Maurice; au large de Durban.

OCÉAN INDIEN : espèce courante, essentiellement tropicale. (HENDEY, 1937; SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite, plus abondante dans les mers tempérées; plutôt néritique.

Chaetoceros laciniosum Schütt, 1895

SCHÜTT, 1895, p. 38, pl. 4, fig. 5 a-b, et pl. 5, fig. 5 c. GRAN, 1905, p. 82, fig. 94. HUSTEDT, 1930, p. 701, fig. 401 a-b. HENDEY, 1937, p. 301, et 1964, p. 127, pl. 13, fig. 2. CUPP, 1943, p. 128, fig. 80.

= *Chaetoceros distans* Cleve, *pro parte* (voir page suivante).

RÉCOLTES PERSONNELLES : Nossi-Bé (hivernale); Tuléar; île Maurice; côte d'Afrique du Sud.

OCÉAN INDIEN : espèce probablement courante, mais souvent reportée sous le synonyme incertain de *C. distans* Cleve. (SILVA, 1956a, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique, mers tropicales et tempérées.

Cette espèce est très voisine du *C. pelagicum* Cleve, auquel elle a parfois été rattachée; elle s'en distingue comme suit : deux chromatophores (chez *C. pelagicum* : un seul); diamètre apical ordinairement supérieur à 10 µ (*C. p.* : inférieur à 10 µ); soies terminales épaissies. Cependant, la distinction n'est pas toujours évidente.

Au *C. laciniosum* doit être rattaché le *C. distans* de Cleve tel que figuré par cet auteur en 1894a (p. 14, pl. 2, fig. 2), mais non celui de la description originale (1873a, p. 9, pl. 2, fig. 11) chez lequel les soies terminales ne sont pas différenciées.

Chaetoceros pelagicum Cleve, 1873

Cleve, 1873 b, p. 11, pl. 1, fig. 4. Gran, 1905, p. 83, fig. 101. Hustedt, 1930, p. 704, fig. 402. Hendey, 1937, p. 302. Cupp, 1943, p. 129, fig. 81. Subrahmanyan, 1946, p. 141, fig. 234.

Récoltes personnelles : Nossi-Bé (espèce plutôt hivernale); Tuléar; sud du canal de Mozambique.

Océan Indien : espèce signalée sporadiquement sous toutes les latitudes, Antarctique compris. (Taylor, 1967). Nouvelle pour la région étudiée.

Distribution mondiale : espèce néritique, tempérée, peu courante.

Voir remarque concernant *C. laciniosum*, ci-dessus.

Chaetoceros breve Schütt, 1895

Schütt, 1895, p. 38, pl. 4, fig. 4 a, et pl. 5, fig. 4 b. Hustedt, 1930, p. 707, fig. 403. Hendey, 1937, p. 302, et 1964, p. 127, pl. 9, fig. 5.

Récoltes personnelles : Nossi-Bé; île Maurice; parages de Durban.

Océan Indien : mer d'Arabie; Indonésie; Afrique du Sud; côtes du Kénya et du Mozambique. (Silva, 1956a; Taylor, 1967).

Distribution mondiale : tempérée et tropicale, plutôt néritique.

Chaetoceros diversum Cleve, 1873

Cleve, 1873a, p. 9, pl. 2, fig. 12. Hustedt, 1930, p. 716, fig. 409. Cupp, 1943, p. 132, fig. 87. Hendey, 1964, p. 130, pl. 17, fig. 4.

Récoltes personnelles : Nossi-Bé; Tuléar; parages de Beira.

Océan Indien : espèce courante sous les latitudes tropicales. (Silva, 1956a, 1960; Kolbe, 1957; Travers, 1965; Taylor, 1967).

DISTRIBUTION MONDIALE : espèce néritique, intertropicale et méditerranéenne, signalée également dans l'Atlantique tempéré et la mer du Nord.

Voir remarque concernant *C. laeve*, ci-dessous.

Chaetoceros laeve Leuduger-Fortmorel, 1892

LEUDUGER-FORTMOREL, 1892, p. 38, pl. 6, fig. 2. SCHRÖDER, 1906, p. 351. SCHMIDT, 1921, pl. 339, fig. 4-6. HUSTEDT, 1930, cf. p. 718. ALLEN et CUPP, 1935, p. 142, fig. 72. CUPP, 1943, p. 133, fig. 88. WOOD *et al.*, 1959, p. 217, *non* pl. 17, fig. 35.

Non : Chaetoceros leve Schütt, 1895

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare).

OCÉAN INDIEN : Indonésie; mer d'Arabie. Espèce nouvelle pour la région du canal de Mozambique.

DISTRIBUTION MONDIALE : espèce néritique, probablement intertropicale, peu fréquente (Indo-Pacifique).

C. laeve ne semble différer de *C. diversum* que par l'orientation de ses soies : celles-ci sont tout d'abord dirigées perpendiculairement à l'axe pervalvaire de la chaîne, puis infléchies à angle droit. Aussi *C. laeve* pourrait ne constituer qu'une variété du *C. diversum*, comme le suggérait HUSTEDT; cet auteur rappelle toutefois que les spores de résistance demeurent inconnues dans les deux cas.

Chaetoceros messanense Castracane, 1875

CASTRACANE, 1875 (*fide* HUSTEDT, HENDEY). HUSTEDT, 1930, p. 718, fig. 410. HENDEY, 1937, p. 304, et 1964, p. 129, pl. 12, fig. 3.

= *Chaetoceros furca* Cleve

CLEVE, 1897a, p. 21, pl. 1, fig. 10. LEBOUR, 1930, p. 146, fig. 107.

RÉCOLTES PERSONNELLES : Nossi-Bé (espèce hivernale, très abondante), et toutes les stations littorales.

OCÉAN INDIEN : espèce principalement répandue dans la zone tropicale; côtes d'Afrique du Sud. (HENDEY, 1937; SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce intertropicale et méditerranéenne, accessoirement rencontrée dans la Manche.

Chaetoceros curvisetum Cleve, 1889

CLEVE, 1889, p. 55, fig. in text. HUSTEDT, 1930, p. 737, fig. 426. CUPP, 1943, p. 137, fig. 93. HENDEY, 1964, p. 133, pl. 17, fig. 6.

= *Chaetoceros secundum* Cleve, *pro parte?*

CROSBY et WOOD, 1958, p. 515, pl. 37, fig. 41. WOOD, 1963a. *Non?* CLEVE, 1873a.

Au sujet de ce taxon, voir HUSTEDT *(loc. cit.)* et PAVILLARD (1925, p. 51).

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; côte d'Afrique du Sud.

OCÉAN INDIEN : golfe d'Aden; mers indonésiennes; côtes des Indes et d'Australie; canal de Mozambique; Afrique du Sud; Antarctique (?). (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique, principalement tempérée mais cosmopolite.

Chaetoceros pseudocurvisetum Mangin, 1910

MANGIN, 1910, p. 349, fig. 3/2, 4/2. HUSTEDT, 1930, p. 739, fig. 427. CUPP, 1943, p. 138, fig. 94. HENDEY, 1964, p. 134, pl. 18, fig. 1.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : Indonésie; côte du Mozambique; îles Cocos; Afrique du Sud. (SILVA, 1956a, 1960; KOLBE, 1957; TAKANO, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce de découverte relativement récente, encore mal connue; néritique, tempérée ou tropicale.

Chaetoceros tortissimum Gran, 1900

GRAN, 1900, p. 122, pl. 9, fig. 25, et 1905, p. 95, fig. 122. MANGIN, 1915, p. 49, fig. 33. PAVILLARD, 1925, p. 52, fig. 87. IKARI, 1926, p. 532, fig. 15 a-b. LEBOUR, 1930, p. 165, fig. 127. HUSTEDT, 1930, p. 751, fig. 434. SKVORTZOW, 1931b, p. 105, pl. 6, fig. 2. HART, 1934, p. 165, et 1942, p. 292. CUPP, 1943, p. 142, fig. 99. TEIXEIRA et KUTNER, 1961, p. 54, pl. 3, fig. 3. HENDEY, 1964, p. 135, pl. 11, fig. 2. AVARIA, 1965, p. 94, pl. 6, fig. 4.

Sans description ni illustration, *in :* SILVA, 1956a, 1960; SUBRAHMANYAN, 1958.

= *Chaetoceros calvum* Cleve

CLEVE, 1901, p. 54, pl. 8, fig. 11.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice.

OCÉAN INDIEN : mer d'Arabie; Indonésie; côte du Mozambique; Afrique du Sud. (SILVA, 1956a; TAYLOR, 1967).

DISTRIBUTION MONDIALE : assez sporadique. Mer de Norvège; mer du Nord; golfe du Lion; mer du Japon; côtes de Californie; côtes du Brésil et du Chili; Antarctique. Cette espèce doit donc être maintenant considérée comme cosmopolite.

Fam. BACTERIASTRACEAE

Bacteriastrum elegans Pavillard, 1916

Pavillard, 1916, p. 28, pl. 1, fig. 2, et 1925, p. 39, fig. 60/2. Hustedt, 1930, p. 621, fig. 360. Lebour, 1930, p. 85. Subrahmanyan, 1946, p. 127, fig. 174.

Récoltes personnelles : Nossi-Bé (rare).

Océan Indien : côtes des Indes; Tuléar; îles Cocos. (Kolbe, 1957; Travers, 1965).

Distribution mondiale : Atlantique tempéré; Méditerranée.

Cette espèce serait moins rare qu'il ne paraît : elle a pu en effet être souvent désignée sous le nom de *B. varians* (cf. Pavillard, 1924, 1925).

Bacteriastrum comosum Pavillard, 1916

Pavillard, 1916, p. 29, pl. 1, fig. 3, et 1925, p. 39, fig. 60/3. Hustedt, 1930, p. 622, fig. 361. Hendey, 1937, p. 306. Sproston, 1949, p. 90.

Récoltes personnelles : Nossi-Bé; Tuléar; île Maurice; parages de Beira.

Océan Indien : Indonésie et océan Indien tropical. (Silva, 1956a, 1960; Kolbe, 1957; Travers, 1965; Taylor, 1967).

Distribution mondiale : Méditerranée; mer du Japon.

Bacteriastrum delicatulum Cleve, 1897

Cleve, 1897b, p. 298, pl. 1, fig. 16. Pavillard, 1925, p. 37, fig. 57. Ikari, 1927, p. 424, fig. 4. Hustedt, 1930, p. 612, fig. 353. Hendey, 1937, p. 307, et 1964, p. 139, pl. 6, fig. 2. Silva, 1956c, p. 343, pl. 1, fig. 3. Curl, 1959, p. 296, fig. 65.

Récoltes personnelles : Nossi-Bé (espèce hivernale); Tuléar; côte d'Afrique du Sud.

Océan Indien : comme l'espèce précédente.

Distribution mondiale : mers tempérées et tropicales.

Bacteriastrum elongatum Cleve, 1897

Cleve, 1897a, p. 19, pl. 1, fig. 19. Hustedt, 1930, p. 617, fig. 357. Hendey, 1937, p. 307, et 1964, p. 139, pl. 6, fig. 3. Curl, 1959, p. 296, fig. 66.

Récoltes personnelles : Nossi-Bé; sud du canal de Mozambique.

Océan Indien : régions tropicales et tempérées. (Silva, 1956a, 1960; Kolbe, 1957; Travers, 1965; Taylor, 1967).

Distribution mondiale : espèce tropicale et tempérée.

Bacteriastrum hyalinum Lauder, 1864

Lauder, 1864a, p. 8, pl. 3, fig. 7. Pavillard, 1916, p. 27, pl. 1, fig. 4, et 1925, p. 37, fig. 58. Ikari, 1927, p. 422, fig. 2. Hustedt, 1930, p. 615, fig. 354. Sproston, 1949, p. 89, fig. 38. Hendey, 1964, p. 139, pl. 6, fig. 1.

Récoltes personnelles : Nossi-Bé; Tuléar.

Océan Indien : Indonésie et océan Indien tropical (mêmes références que précédemment).

Distribution mondiale : espèce tempérée (?), souvent confondue avec *B. varians* (voir plus bas).

Bacteriastrum varians Lauder, 1864

Lauder, 1864a, p. 8, pl. 3, fig. 1-6. Karsten, 1905b, p. 170, pl. 34, fig. 1. Pavillard, 1924, p. 1084, fig. B. Ikari, 1927, p. 421, fig. 1. Hustedt, 1930, p. 616, fig. 356. Hart, 1934, p. 159. Hendey, 1937, p. 308. Subrahmanyan, 1946, p. 127, fig. 170-172, 175. Sproston, 1949, p. 90, fig. 37.

Cellules isodiamétriques, ou de hauteur et de diamètre peu différents; diamètre (apical) : 10-37, le plus souvent 20-30 μ. Soies internes bifurquées, contenues dans des plans perpendiculaires à l'axe pervalvaire (chez *B. hyalinum:* plans parallèles). Couronnes terminales isomorphes; soies terminales beaucoup plus épaisses que les soies internes, portant des spirales d'épines, et *brutalement infléchies* vers le centre de la chaîne (chez *B. hyalinum:* soies moins robustes et graduellement recourbées).

Récoltes personnelles : Nossi-Bé; parages de Mombasa.

Océan Indien : cette espèce est, en apparence du moins, la plus commune du genre — sous réserve de confusions possibles avec les espèces voisines. (Amossé, 1924; Travers, 1965; Taylor, 1967).

DISTRIBUTION MONDIALE : incertaine, vraisemblablement tropicale. Selon PAVILLARD (1925), l'espèce serait cantonnée à l'océan Indien et aux mers sino-japonaises : il n'existerait du moins pas de référence sûre en dehors de ces régions. Ultérieurement, HART (1934) signale *B. varians* dans l'Atlantique sub-tropical sud ainsi que dans les eaux des Aiguilles et du Benguela, ces deux courants pouvant être supposés à l'origine de l'immigration de l'espèce dans les eaux atlantiques.

Les caractères morphologiques indiqués ci-dessus apparaissent clairement dans l'excellente description *princeps* de LAUDER et l'iconographie qui l'accompagne. Cependant, *B. varians* a été largement confondue avec les espèces voisines. PAVILLARD, qui a longuement étudié le genre *Bacteriastrum* (1916, 1924, 1925) résume ainsi son opinion sur la présente espèce : « La soi-disant grande variabilité du *B. varians* n'est qu'une légende aussi commode que peu scientifique. Le *B. varians* - type de LAUDER n'existe probablement ni dans l'Atlantique, ni dans la Méditerranée, et les formes diverses signalées sous ce nom appartiennent à d'autres espèces » (PAVILLARD, 1925, p. 36).

Bacteriastrum minus Karsten, 1905

Pl. III, fig. 17

KARSTEN, 1905b, p. 171, pl. 33, fig. 21. MANGIN, 1910, p. 381, fig. 5, et 1911, p. 27, fig. in text. IKARI, 1927, p. 426, fig. 6. SKVORTZOW, 1931b, p. 109, pl. 8, fig. 4. SILVA, 1956a, p. 37, pl. 4, fig. 5. TAYLOR, 1967, p. 444, pl. 89, fig. 14.

Chaînes de longueur variable, du type isomorphe. Cellules aplaties ou, plus rarement, isodiamétriques (diamètre valvaire supérieur ou, plus rarement, égal à la hauteur pervalvaire). Valves sensiblement convexes. Soies courtes et délicates, non bifurquées, sub-marginales, dirigées obliquement par rapport à l'axe pervalvaire, et contenues dans des plans parallèles à cet axe. Cellules adjacentes non contiguës, seulement reliées l'une à l'autre par l'intermédiaire de leurs soies; les soies des cellules adjacentes ne sont pas soudées et se croisent à une certaine distance de leur insertion. Soies des couronnes terminales non différenciées, mais dirigées vers le centre de la chaîne.

(Seul parmi les auteurs cités, KARSTEN mentionne que les chaînes baignent dans une gangue mucilagineuse; je n'ai personnellement pas retrouvé ce caractère sur le matériel formolé — et n'ai pas observé l'espèce *in vivo*.)

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce rarement signalée. Karachi et côte occidentale des Indes; côte du Mozambique; Port Elisabeth. (KARSTEN, *loc. cit.;* CZAPEK, 1909; SILVA, 1956a, 1960; SUBRAHMANYAN, 1958).

DISTRIBUTION MONDIALE : quelques localités seulement s'ajoutent aux précédentes. Côte occidentale d'Afrique; diverses stations dans la mer du Japon.

B. minus demeure une Diatomée rare, que ni HUSTEDT ni PAVILLARD n'ont pu décrire. Elle figure heureusement dans l'excellente monographie consacrée par IKARI au genre *Bacteriastrum*. Certains auteurs font par ailleurs de cette espèce un synonyme de *B. hyalinum* (OKAMURA, 1911; MILLS, 1933; WOOD, 1963a) : aux termes de la description qui précède, un tel rapprochement est impossible.

Fam. LEPTOCYLINDRACEAE

Leptocylindrus danicus Cleve, 1889

CLEVE, 1889, p. 54, *vix* fig. in text. HUSTEDT, 1930, p. 558, fig. 318. HENDEY, 1937, p. 322, pl. 11, fig. 6, et 1964, p. 140, pl. 5, fig. 2.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; parages de Durban; cap Saint-André.

OCÉAN INDIEN : assez courante sous les latitudes tempérées et tropicales. (SILVA, 1956a, 1960; TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce néritique, cosmopolite mais plus commune dans les mers tempérées.

Leptocylindrus minimus Gran, 1915

GRAN, 1915, p. 72, fig. 5. HUSTEDT, 1930, p. 560, fig. 321. HENDEY, 1964, p. 140, pl. 5, fig. 3.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : rare. Côtes des Indes et du Mozambique. (SILVA, 1956a, 1960).

DISTRIBUTION MONDIALE : probablement comme l'espèce précédente; toutefois *L. minimus* est plus rarement signalé, du fait sans doute de ses plus petites dimensions.

Guinardia flaccida (Castracane) H. Peragallo, 1892

Pl. I, fig. 6

CASTRACANE, 1886, p. 74, pl. 29, fig. 4 (?) : « *Rhizosolenia? flaccida* ». PERAGALLO, 1892, p. 107, pl. 13, fig. 3-5. HUSTEDT, 1930, p. 562, fig. 322. HENDEY, 1937, p. 321, pl. 11, fig. 5, et 1964, p. 141, pl. 5, fig. 5.

RÉCOLTES PERSONNELLES : Nossi-Bé (poussées massives en saison chaude); Tuléar; côte d'Afrique du Sud entre Durban et Beira; cap Saint-André.

OCÉAN INDIEN : espèce courante, principalement dans la zone tropicale. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite, plus rare dans les mers froides; principalement néritique.

Cette espèce a été récemment étudiée en culture et dans les conditions naturelles par BIRNHAK *et al.* (1967); comme ces auteurs, j'ai observé que les développements massifs peuvent voisiner, dans le temps ou dans l'espace, avec des « eaux rouges » à *Trichodesmium.*

Schroederella delicatula (H. Peragallo) Pavillard, 1913

PERAGALLO, 1888, p. 81, pl. 6, fig. 46 : « *Lauderia delicatula* ». PAVILLARD, 1913, p. 126, fig. 1A.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; côte d'Afrique du Sud, de Durban à Beira.

OCÉAN INDIEN : mer Rouge; mer d'Arabie; côtes des Indes; mers indonésiennes; côtes d'Australie; canal de Mozambique; Afrique du Sud. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique des mers tempérées et tropicales, ou cosmopolite.

HUSTEDT et la quasi-unanimité des auteurs modernes incluent sous ce nom le *Schroederella Schroederi* considéré comme espèce distincte par PAVILLARD (1925). L'historique inextricable de cette question peut en fait être ramené à l'opposition de deux conceptions — qui ont pu se trouver successivement défendues par un même auteur (cf. PAVILLARD, HENDEY) :

— Une seule espèce, *sensu lato:* PAVILLARD, 1905, 1913, 1916; HUSTEDT, 1930; ALLEN et CUPP, 1935; CUPP, 1943; SUBRAHMANYAN, 1946; HENDEY, 1964.

— Deux espèces : PAVILLARD, 1925; LEBOUR, 1930; HENDEY, 1937; SILVA, 1960.

Un compromis semble devoir être retenu : l'espèce est unique, mais se présente sous deux « phases » (HENDEY, 1964) ou « formes (?) » (TAYLOR, 1967), différant assez nettement l'une de l'autre par leur morphologie et leur distribution; cette bivalence n'est autre, pour TAYLOR, que l'expression du cycle de reproduction (sexuée?) de la Diatomée, les deux formes survenant respectivement avant et après la production d'auxospores.

Du point de vue de la nomenclature, une désignation infraspécifique devient nécessaire, tant pour pallier l'ambiguïté du nom de « *S. delicatula* » que pour mieux juger à l'avenir du bien-fondé et de la signification de cette dualité. Le rang de forme semble ici le mieux justifié (cf. HENDEY, 1964, p. 55); d'où les propositions qui suivent. On ne saurait cependant dissimuler que la distinction morphologique est dans quelques cas incertaine ou impraticable (« stades de transition »), et que la discrimination écologique doit actuellement être considérée comme une hypothèse à vérifier.

f. ***delicatula***

Pl. X, fig. 64

= *Schroederella delicatula* (H. Peragallo) Pavillard, *pro parte*

PAVILLARD, *loc. cit.* LEBOUR, 1930, p. 68, fig. 40. HUSTEDT, 1930, fig. 314. HENDEY, 1937, p. 231.

= *Schroederella delicatula* (H. Perag.) Pav. *emend.* Pav., 1925

PAVILLARD, 1925, p. 22, fig. 33 d.

= *Lauderia delicatula* H. Peragallo

PERAGALLO, *loc. cit.*; 1892, p. 105, pl. 13, fig. 13, et 1908, p. 457, pl. 121, fig. 4. CLEVE, 1897a, p. 24, pl. 2, fig. 21.

Frustules robustes, étroits (diamètre $< 35\ \mu$), formant des chaînes d'aspect relativement rigide. Longueur de l'axe pervalvaire supérieur (jusqu'à six fois) au diamètre valvaire. Valves planes, sauf à l'insertion de l'épine centrale où se trouve une brève dépression. Entre deux cellules voisines, l'espace est très réduit (valves presque contiguës), l'épine centrale et les filaments connectifs peu développés.

Forme thermophile : mers tropicales et tempérées.

f. ***Schroederi*** (Bergon) nov. comb.

Pl. I, fig. 4

= *Lauderia Schroederi* Bergon, 1903

BERGON, 1903, p. 35, pl. 1, fig. 1-15.

= *Schroederella Schroederi* (Bergon) Pavillard

PAVILLARD, 1925, p. 23, fig. 33 a-c. LEBOUR, 1930, p. 68, fig. 41. HENDEY, 1937, p. 241.

= *Schroederella delicatula* (H. Peragallo) Pavillard, *pro parte*

HENDEY, 1964, pl. 7, fig. 6, *non* pl. 5, fig. 4. *Non* HUSTEDT, 1930, fig. 314.

Frustules plus délicats, plus larges (diamètre $< 55\ \mu$), formant des chaînes relativement souples. Longueur de l'axe pervalvaire inférieure au diamètre valvaire. Valves convexes, mais largement déprimées au centre. Entre deux cellules voisines, l'espace est plus grand, l'épine centrale et les filaments très apparents.

Forme psychrophile : préférentiellement mers froides, zones d' « upwelling ».

Dactyliosolen antarcticus Castracane, 1886
f. ***laevis*** (Karsten) Heiden et Kolbe, 1928

Pl. I, fig. 2

KARSTEN, 1905a, p. 93, pl. 9, fig. 11 : « *Dactyliosolen laevis* ». HEIDEN et KOLBE, 1928, p. 510. HASLE, 1960, p. 14, pl. 3, fig. 31-32.

= *Dactyliosolen laevis* Karsten

KARSTEN, *loc. cit.* VAN HEURCK, 1909, p. 29, pl. 4, fig. 76. HART, 1934, p. 158.

= *D. antarcticus* « *laevis* phase », *apud* Hendey

HENDEY, 1937, p. 324, pl. 6, fig. 2-3.

= *Dactyliosolen flexuosus* Mangin

MANGIN, 1915, p. 57, fig. 40. HART, *ibid.*

Frustules légèrement silicifiés; bandes intercalaires étroites, plus ou moins écailleuses chez les individus de grande taille, ornées partiellement de stries pervalvaires peu accentuées. Diamètre valvaire : 20-40 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); île Maurice.

OCÉAN INDIEN : sauf confusion (les références au nom spécifique sont imprécises), cette forme est nouvelle pour le canal de Mozambique, et n'est par ailleurs connue que dans les régions antarctiques. L'espèce elle-même n'aurait été qu'exceptionnellement rencontrée sous les basses latitudes :

— Par OSTENFELD et SCHMIDT (1901) dans le nord de la mer Rouge (rien ne permet de croire, comme le voudrait WOOD (1963a) à une confusion avec *D. mediterraneus*, qui est d'ailleurs cité dans le même travail).

— Par OSTENFELD (1903a) dans le golfe du Siam.

— Par SILVA (1960) à Inhaca (d'après la description donnée, il s'agit de la « phase » *borealis* de HENDEY).

DISTRIBUTION MONDIALE : la distribution de cette forme est actuellement difficile à distinguer, dans la bibliographie, de celle de l'espèce. Il semble que cette dernière est, sinon cosmopolite, du moins beaucoup moins psychrophile et sténotherme que son nom le laisse croire : mers froides des deux hémisphères, mers tempérées, et, accessoirement, mers tropicales...

La conception de l'espèce « polyphasique » de HENDEY (1937) peut être conciliée sans dommage aux exigences du Code de la Nomenclature botanique (LANJOUW *et al.*, 1966), à condition de donner aux « phases » intraspécifiques le rang de formes.

Dactyliosolen mediterraneus H. Peragallo, 1892

PERAGALLO, 1892, p. 104, pl. 13, fig. 8-9. HUSTEDT, 1930, p. 556, fig. 317. HENDEY, 1937, p. 324, pl. 6, fig. 4-6, et 1964, p. 142.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; au large de Durban.

OCÉAN INDIEN : espèce assez rarement signalée. Mer Rouge; Indonésie; canal de Mozambique; côtes d'Afrique du Sud. (SILVA, 1956a; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : largement répandue dans les mers tempérées et tropicales; plutôt néritique.

Detonula moseleyana (Castracane) Gran, 1900

Pl. I, fig. 5

CASTRACANE, 1886, p. 90, pl. 24, fig. 9 : « *Lauderia* (?) *moseleyana* ». GRAN, 1900, p. 113. OSTENFELD et SCHMIDT, 1901, p. 157. OSTENFELD, 1903a, p. 7. TAYLOR, 1967, p. 447, pl. 90, fig. 16-17.

= *Lauderia moseleyana* Castracane

CASTRACANE, *loc. cit.* PERAGALLO, 1892, p. 105, pl. 13, fig. 10.

Frustules cylindriques; valves aplaties, de diamètre 28-120 μ (récoltes personnelles : 60 μ environ), bordées d'une couronne d'épines difficilement visibles, 10-12 en 10 μ. Bandes intercalaires étroites et nombreuses, finement ornementées : 3-6 rangs de ponctuations hexagonales par bande. Axe pervalvaire : 90-200 μ. Chloroplastes nombreux, discoïdes.

RÉCOLTES PERSONNELLES : au large de Durban.

OCÉAN INDIEN : quelques rares stations. Mers indonésiennes; mer Rouge; côte d'Afrique du Sud. (TAYLOR, 1967).

DISTRIBUTION MONDIALE : l'espèce demeure inconnue en dehors de l'océan Indien « *sensu lato* ».

Le renforcement particulier d'une des bandes intercalaires, indiqué par CASTRACANE et par TAYLOR, est manifestement lié au processus de la division cellulaire.

J'ai pu en plusieurs occasions observer la présence de ce qui semblait être des frustules internes (fig. 5).

TAYLOR, qui a exhumé cette espèce d'un long oubli d'un demi-siècle, mentionne un dimorphisme écologique : en milieu néritique, les cellules sont plus larges et plus robustes, et les bandes intercalaires plus étroites que dans les prélèvements du large.

Lauderia annulata Cleve, 1873

CLEVE, 1873a, p. 8, pl. 1, fig. 7, et 1897a, pl. 2, fig. 13-15. CASTRACANE, 1886, p. 89, pl. 8, fig. 7. PERAGALLO, 1892, p. 105, pl. 13, fig. 11, et 1908, p. 456, pl. 21, fig. 3. ALLEN et CUPP, 1935, p. 124, fig. 25.

= *Lauderia borealis* Gran

GRAN, 1900, p. 110, pl. 9, fig. 5-9, et 1905, p. 23, fig. 22. HUSTEDT, 1930, p. 549, fig. 313. HENDEY, 1937, p. 240, et 1964, p. 143.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; côte du Mozambique.

OCÉAN INDIEN : espèce courante dans les eaux chaudes et tempérées, plus rare sous les hautes latitudes. (SILVA, 1956a, 1960; KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite.

Les deux *Lauderia* de CLEVE et de GRAN sont manifestement synonymes, comme l'affirmait déjà CLEVE (1903a, p. 49). On comprend d'ailleurs mal pourquoi certains auteurs ont considéré que *L. annulata* n'était pas une espèce homogène, ce que CLEVE du moins ne laisse jamais penser (1873a, 1897a, 1901, 1903a); rappelons aussi que le « *L. annulata* Castracane » cité par DE-TONI, MILLS, etc., n'a pas d'existence légale.

Enfin pour raison d'antériorité, le nom de *L. annulata* doit prévaloir, et non celui de *L. borealis* comme il apparaît chez CLEVE-EULER (1951, p. 86).

Chrysanthemodiscus floriatus Mann *emend.* Takano, 1965

Pl. I, fig. 1

MANN, 1925, p. 58, pl. 13, fig. 1. TAKANO, 1965, p. 7, pl. 1, fig. 12-14.

Étymologie : l'allusion phanérogamique tient au fait que les valves, très fragiles, peuvent se démanteler au cours du montage, et ressembler alors aux pétales d'une fleur.

= *Hyalodictya floriata* (Mann) Karsten

KARSTEN, 1928, p. 206, fig. 202.

= *Ethmodiscus* sp., *apud* Okuno
OKUNO, 1954, p. 173, pl. 1, fig. 2 a-c.

? = *Melchersiella hexagonalis* Teixeira
TEIXEIRA, 1958, p. 31, pl. 1-2.

Cellules sub-cylindriques, formant des chaînes ramifiées. Valves circulaires, convexes, portant un ombilic central qui occupe environ 1/8 du diamètre valvaire; ombilic orné de ponctuations disposées irrégulièrement mais formant un cercle périphérique régulier; le reste de la valve est orné de stries radiaires serrées, droites ou ondulées, parfois dédoublées mais non bifurquées. Bandes intercalaires au nombre de 3 à 7, bien développées, ornées d'un réseau hexagonal de fines ponctuations (5-6 en 10 μ). Parois très fines et très fragiles. Nombreux petits chromatophores discoïdes. Diamètre des valves : 40-200 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); Tuléar; île Maurice.

OCÉAN INDIEN : espèce seulement signalée par TRAVERS (1965) à Tuléar, sans certitude puisque sous le nom de *Melchersiella hexagonalis*.

DISTRIBUTION MONDIALE : étant donné que KARSTEN n'a fait que rebaptiser la découverte de MANN, et que d'autre part OKUNO et TAKANO ont étudié le même matériel, le nombre des récoltes mondiales demeure extrêmement réduit : Philippines (dragages); mer du Japon; côtes du Brésil (?); enfin AMOSSÉ (comm. pers.) a rencontré cette espèce dans un échantillon de vase provenant (sans certitude) d'Abidjan. On peut donc provisoirement définir *C. floriatus* comme espèce intertropicale littorale.

On doit à TAKANO la première description complète de cette Diatomée rare et fragile, dont MANN et KARSTEN n'avaient décrit que la valve, et OKUNO la ceinture. Par ailleurs, TEIXEIRA laisse pratiquement ignorer la structure valvaire de son *Melchersiella hexagonalis*, si bien que la synonymie n'est pas assurée.

C'est dans l'ignorance de la structure connective que MANN a placé son nouveau genre *Chrysanthemodiscus* parmi les Diatomées discoïdes, au voisinage du genre *Hyalodiscus*. L'inclusion dans la famille des *Leptocylindraceae*, aux côtés de *Lauderia*, est assurément mieux justifiée.

Fam. CORETHRONACEAE

Corethron criophilum Castracane, 1886

CASTRACANE, 1886, p. 85, pl. 21, fig. 14. HENDEY, 1937, p. 215, 325, pl. 7-8, et 1964, p. 144, pl. 7, fig. 4. HART, 1942, p. 288.

RÉCOLTES PERSONNELLES : cellules solitaires, extrêmement rares. Nossi-Bé; Tuléar; île Maurice; côte d'Afrique du Sud.

OCÉAN INDIEN : sous ses divers synonymes, l'espèce est largement représentée, particulièrement dans les régions antarctiques. (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite, essentiellement océanique.

Au terme de son étude de l'abondant matériel du « Discovery », HENDEY (1937) a montré que toutes les espèces décrites jusqu'ici ne sont que des formes écologiques d'une espèce unique, « polyphasique ».

Fam. RHIZOSOLENIACEAE

Rhizosolenia fragilissima Bergon, 1903

BERGON, 1903, p. 15, pl. 1, fig. 9-10. PAVILLARD, 1913, p. 130, fig. 1 b-c. HUSTEDT, 1930, p. 571, fig. 324. HENDEY, 1937, p. 315, et 1964, p. 147.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); sud du canal de Mozambique.

OCÉAN INDIEN : espèce assez peu courante. Mer d'Arabie; côte du Mozambique; au sud de l'Afrique; plus abondante semble-t-il dans l'Antarctique. (SILVA, 1956a; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce cosmopolite, plus abondante dans les mers tempérées.

Rhizosolenia cylindrus Cleve, 1897

Pl. I, fig. 7

CLEVE, 1897a, p. 24, pl. 2, fig. 12. HUSTEDT, 1930, p. 572, fig. 323. ALLEN et CUPP, 1935, p. 127, fig. 30. CUPP, 1943, p. 80, fig. 42. SUBRAHMANYAN, 1946, p. 114, fig. 111-112. HENDEY, 1964, p. 148, pl. 3, fig. 3.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); île Maurice; sporadique dans le canal de Mozambique.

OCÉAN INDIEN : Indonésie; mer Rouge; côtes des Indes; canal de Mozambique; Afrique du Sud; « convergence antarctique ». (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce probablement néritique intertropicale, assez rare. Californie; Atlantique tempéré; Adriatique; golfe du Siam; mer du Japon.

Rhizosolenia firma Karsten, 1907

Pl. III, fig. 20

KARSTEN, 1907, p. 377, pl. 41, fig. 2. PAVILLARD, 1925, p. 30, fig. 44. HEIDEN et KOLBE, 1928, p. 523. HUSTEDT, 1930, p. 574, fig. 326. KOLBE, 1957, p. 41, pl. 4, fig. 52.

RÉCOLTES PERSONNELLES : quelques spécimens seulement. Ile Maurice; parages de Durban et de Mombasa.

OCÉAN INDIEN : espèce rare. Originellement découverte par KARSTEN à l'ouest des îles Maldives, puis signalée par HEIDEN et KOLBE et par KOLBE dans diverses stations tropicales, enfin par SUBRAHMANYAN sur la côte occidentale des Indes. Nouvelle pour le canal de Mozambique.

DISTRIBUTION MONDIALE : encore très mal connue. En dehors de l'océan Indien, cette espèce n'a été signalée qu'en Méditerranée (PAVILLARD).

Rhizosolenia Bergonii H. Peragallo, 1892

PERAGALLO, 1892, p. 110, pl. 15, fig. 5. HUSTEDT, 1930, p. 575, fig. 327. HENDEY, 1937, p. 312, et 1964, p. 151, pl. 3, fig. 4.

RÉCOLTES PERSONNELLES : espèce largement répandue dans toute la région étudiée; à Nossi-Bé, principalement estivale.

OCÉAN INDIEN : courante sous les basses latitudes, plus rare dans les régions tempérées. (KOLBE, 1957; SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tropicales; Atlantique tempéré et Méditerranée. Plutôt océanique.

Rhizosolenia obtusa Hensen, 1887

Pl. I, fig. 8 a-b

HENSEN, 1887, p. 86, pl. 5, fig. 41. *Non* OSTENFELD, 1903b, p. 569, fig. 125. *Nec :* GRAN, 1905, p. 56, fig. 69. *Nec* MEUNIER, 1910, p. 255, pl. 38, fig. 15-17, 22. *Nec* LEBOUR, 1930, p. 91, fig. 62. *Nec* HARDY, 1935, p. 53, fig. 23. *Nec* HENDEY, 1964, p. 147.

Non : « Syn. = » *R. alata* var. *truncata* Gran

CLEVE, 1897a, p. 25.

Nec : « Syn. = » *R. alata* f. *inermis* (Castracane) Hustedt

HUSTEDT, 1930, p. 602, fig. 348, *et plur. auct.*

Nec « Syn. = » *Rhizosolenia acuminata* (Peragallo) Gran

GAARDER, 1954, p. 22, fig. 8.

Frustules cylindriques, de diamètre réduit (12-27 µ). Processus apical creux à sa base, inséré au sommet de la valve, dirigé de façon légèrement excentrique, sans oreillettes ni ailes, rectiligne ou très légèrement courbé, tubuliforme, tronqué à son extrémité. Bandes intercalaires disposées assez irrégulièrement : écailles larges, chacune couvrant tout le tour du frustule. Ornementation : à préciser. Chromatophores nombreux, petits, discoïdes.

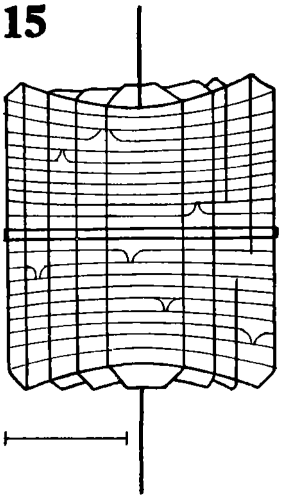
RÉCOLTES PERSONNELLES : deux spécimens seulement, récoltés à Nossi-Bé.

OCÉAN INDIEN : espèce nouvelle pour cet océan.

DISTRIBUTION MONDIALE : la seule référence sûre est celle de HENSEN : encore est-elle imprécise (Atlantique nord-ouest).

PLANCHE III : **15** — *Ditylum sol* (V.H.) De-Toni. **16** — *Chaetoceros compressum* Lauder. **17** — *Bacteriastrum minus* Karst. **18** — *Rhizosolenia pungens* Cl.-Euler. **19** a, b — *R. hyalina* Ostf. **20** — *R. firma* Karst. **21** — *R. squamifera* nom. nov. **22** — *R. Castracanei* H. Per. (voir texte). **23** — *Streptotheca Tamesis* Shrubs. **24** — *Chaetoceros denticulatum* Lauder.

PLANCHE III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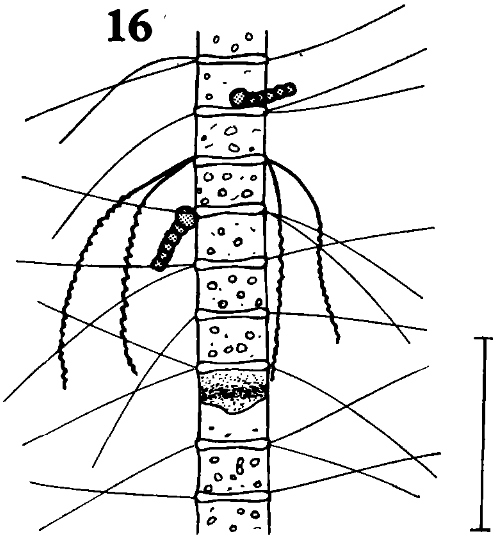
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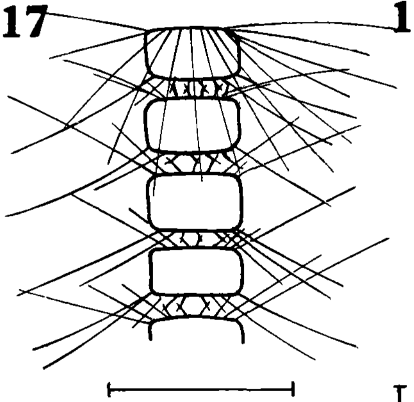
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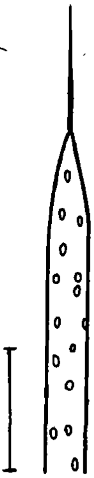
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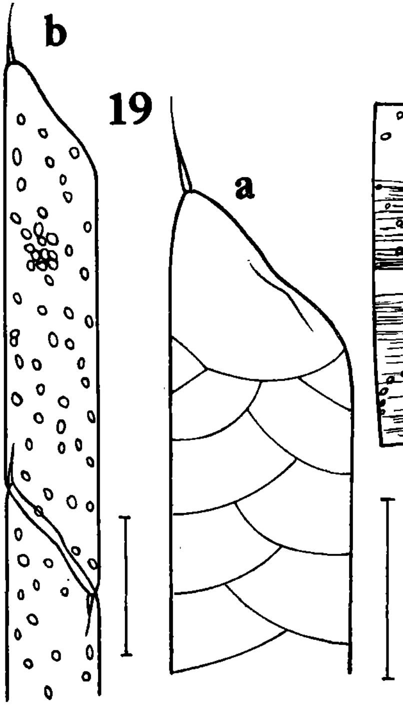
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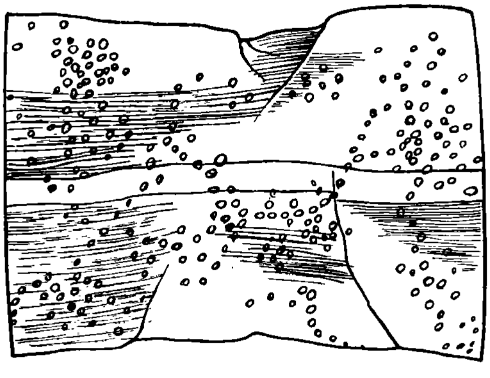
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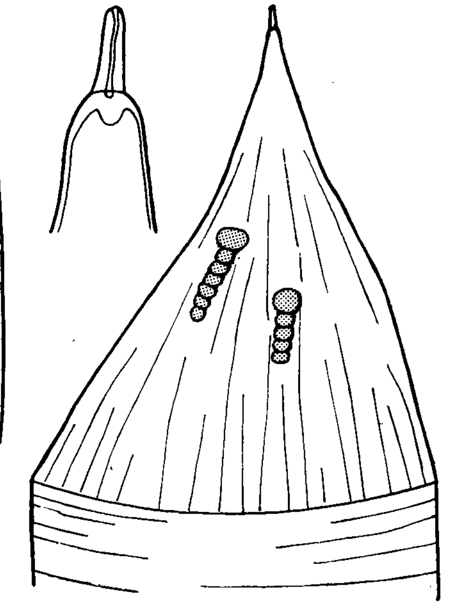
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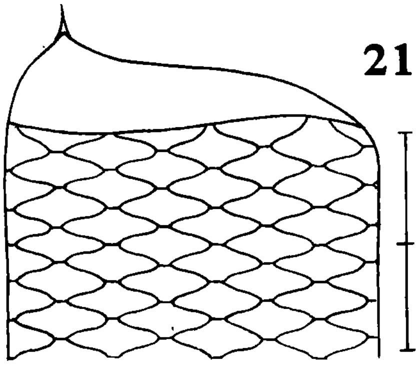
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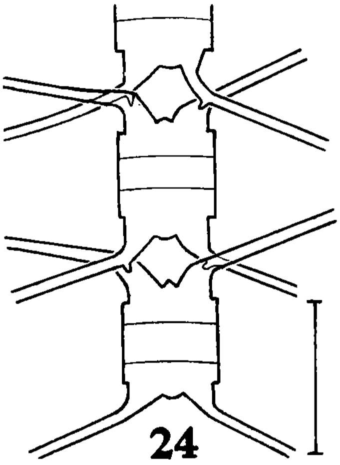
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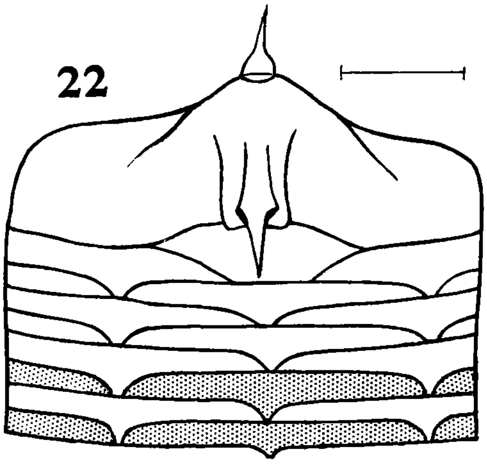
22

La description originelle de HENSEN est incomplète puisqu'elle laisse ignorer la structure des bandes intercalaires, mais elle révèle assez clairement, ainsi que l'illustration, l'originalité du processus apical. Aussi, la synonymie adoptée par CLEVE, GRAN et MEUNIER, refusée cependant par MANGIN (1915) et PAVILLARD (1925), mais consacrée par HUSTEDT et universellement admise à la suite de ce dernier, me paraît insoutenable.

Le problème a été reposé d'une façon toute différente par GAARDER. En effet, pour l'éminente spécialiste des Coccolithophorides, *R. obtusa* a bien été à tort assimilée à *R. alata* f. *inermis*, mais s'identifie à *R. acuminata*. Sous ce dernier nom, GAARDER figure plusieurs spécimens se rapportant manifestement à plusieurs espèces, et dont aucun à vrai dire ne ressemble à *R. obtusa*. De ce rapprochement pour le moins expéditif, cet auteur conclut que le nom de *R. obtusa* devrait remplacer celui de *R. acuminata* pour raison de priorité... Ce point de vue, qui bouleverse la systématique des *Rhizosolenia*, est une spéculation des plus hasardeuses et, actuellement du moins, injustifiée.

Enfin, plus récemment encore, HENDEY considère *R. obtusa* comme une espèce distincte de *R. alata*, mais les références qu'il présente (HENSEN, GRAN, LEBOUR) sont parfaitement contradictoires.

Rhizosolenia Stolterfothii H. Peragallo, 1888

PERAGALLO, 1888, p. 82, pl. 6, fig. 44, et 1908, p. 460, pl. 122, fig. 7. HUSTEDT, 1930, p. 578, fig. 329. HENDEY, 1937, p. 319, pl. 11, fig. 7-8, et 1964, p. 148, pl. 4, fig. 5. CUPP, 1943, p. 83, fig. 45. SHERER, 1965 (monographie).

RÉCOLTES PERSONNELLES : espèce courante à Nossi-Bé et dans presque toutes les récoltes néritiques. Ciliés épiphytes fréquents à Nossi-Bé.

OCÉAN INDIEN : fréquente sous les basses latitudes (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967). La présence de cette espèce dans les eaux antarctiques est incertaine.

DISTRIBUTION MONDIALE : cosmopolite, préférentiellement néritique.

Le polymorphisme de cette *Rhizosolenia* est remarquable : la longueur, le diamètre et l'incurvation des cellules sont en effet extrêmement variables; les exigences écologiques de cette espèce étant elles-mêmes très souples, on aurait là un matériel de choix pour l'étude des variations morphologiques en fonction des conditions du milieu.

Rhizosolenia robusta Norman *in* Pritchard, 1861

PRITCHARD, 1861, p. 866, pl. 8, fig. 42. HUSTEDT, 1930, p. 578, fig. 330. HENDEY, 1937, p. 317, pl. 11, fig. 13, et 1964, p. 148, pl. 2, fig. 5. CUPP, 1943, p. 83, fig. 46.

RÉCOLTES PERSONNELLES : Nossi-Bé (espèce plutôt estivale); Tuléar; Beira; centre et nord du canal de Mozambique.

OCÉAN INDIEN : espèce largement répandue, principalement dans les eaux tropicales. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite, thermophile, océanique.

Rhizosolenia imbricata Brightwell, 1858
var. ***imbricata***

Pl. X, fig. 65

BRIGHTWELL, 1858a, p. 94, pl. 5, fig. 6. HUSTEDT, 1930, p. 580, fig. 331. ALLEN et CUPP, 1935, p. 129, fig. 35. HENDEY, 1937, p. 316, et 1964, p. 149, pl. 3, fig. 1.

RÉCOLTES PERSONNELLES : cette variété-type est fréquente, mais toujours en petit nombre, dans la majorité des prélèvements littoraux.

OCÉAN INDIEN : largement répandue jusqu'au voisinage de l'Antarctique. (KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tropicales et tempérées.

var. ***Shrubsolei*** (Cleve) Schröder, 1906

Pl. II, fig. 12, et pl. X, fig. 66

CLEVE, 1881, p. 26 : « *Rhizosolenia Shrubsolei* ». SCHRÖDER, 1906, p. 346, *vix* fig. 8. HUSTEDT, 1930, p. 584, fig. 332. ALLEN et CUPP, 1935, p. 129, fig. 36. CUPP, 1943, p. 84, fig. 47. HART et CURRIE, 1960, p. 217.

= *Rhizosolenia Shrubsolei* Cleve

CLEVE, *loc. cit.* GRAN, 1905, p. 52, fig. 63. OKAMURA, 1911, p. 5, pl. 9, fig. 21. MEUNIER, 1915, p. 9, pl. 9, fig. 37. HENDEY, 1937, p. 318, et 1964, p. 149, pl. 3, fig. 2.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; sud et centre du canal de Mozambique. Souvent abondante.

OCÉAN INDIEN : beaucoup moins fréquente que la variété-type, avec laquelle elle a pu être confondue. Mer d'Arabie; mer de Java; îles Cocos; canal de Mozambique; côte d'Afrique du Sud. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : à la différence du type, cette variété est psychrophile, et plus commune dans l'Atlantique nord et les mers adjacentes.

Cette variété ne diffère morphologiquement du type que par son diamètre plus réduit et sa valve plus effilée — ces deux caractères variant de pair chez de nombreuses *Rhizosolenia;* aussi est-il mal fondé de distinguer ici deux espèces.

La variété *Shrubsolei* a vraisemblablement été souvent confondue avec le type et mentionnée sous le nom spécifique. La désignation du type sous l'expression var. *imbricata* devrait permettre à l'avenir d'éviter cette confusion et de préciser les caractères écologiques respectifs des deux variétés.

Rhizosolenia styliformis Brightwell, 1858
var. ***styliformis***

BRIGHTWELL, 1858a, p. 94, pl. 5, fig. 5 a-d, *non* e. HUSTEDT, 1930, p. 584, fig. 333. HENDEY, 1937, p. 320, pl. 11, fig. 15-17, et 1964, p. 150, pl. 2, fig. 1. CUPP, 1943, p. 87, fig. 48 A. WIMPENNY, 1946. ROBINSON et WALLER, 1966.

= *R. styliformis* var. *typica* Cleve-Euler

CLEVE-EULER, 1951, p. 89, fig. 69.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; centre et nord du canal de Mozambique.

OCÉAN INDIEN : variété largement répandue sous toutes les latitudes, Antarctique compris. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite; plutôt océanique.

var. ***longispina*** Hustedt *in* A. Schmidt, 1914

Pl. II, fig. 9

SCHMIDT, 1914, pl. 316, fig. 5-7, 12. HUSTEDT, 1930, p. 586, fig. 334. ALLEN et CUPP, 1935, p. 130, fig. 39. CUPP et ALLEN, 1938, pl. 6, fig. 15. CUPP, 1943, p. 87, fig. 48 B. SUBRAHMANYAN, 1946, p. 118, fig. 126, 128-129, *non* 127.

RÉCOLTES PERSONNELLES : Nossi-Bé (variété hivernale); île Maurice; diverses stations néritiques dans le canal de Mozambique.

OCÉAN INDIEN : côtes des Indes; Tuléar; îles Cocos; mer de Java; côtes d'Afrique du Sud. (SUBRAHMANYAN, 1946, 1958; KOLBE, 1957; TAYLOR, 1967).

DISTRIBUTION MONDIALE : difficile à distinguer de celle du type. La caractérisation morphologique de cette variété est d'ailleurs délicate, et les conceptions des auteurs cités plus haut s'avèrent dans l'ensemble assez disparates. Cette question reste à étudier.

var. ***polydactyla*** (Castracane) H. Peragallo, 1892

CASTRACANE, 1886, p. 71, pl. 24, fig. 2 : « *Rhizosolenia polydactyla* ». PERAGALLO, 1892, p. 111, pl. 16, fig. 7 : « *Rhizosolenia* (*styliformis* var.) *polydactyla* Castracane ». VAN HEURCK, 1909, p. 28, pl. 4, fig. 70, *vix* 75, *non* 66-67, 71, 74.

= *R. styliformis* var. *lata* Lemmermann

LEMMERMANN, 1899, p. 351.

= *Rhizosolenia styliformis* Brightwell, *pro parte*

Exclusivement : BRIGHTWELL, *loc. cit.*, fig. 5 e, *non al.*

PLANCHE IV : **25** — *Triceratium shadboltianum* Greville. **26**, **27** a, b — *T. pelagicum* (Schröder) n. comb. (**26** : sporulation ?). **28** a, b — *Hemiaulus membranaceus* Cl. : plan apical (a) et transapical (b). **29** a, b — *H. indicus* Karst. (a et b : *id.*). **30** a, b, c — *H. membranaceus* Cl. : polymorphisme. **31** — *Hemidiscus hardmanianus* (Grev.) Mann : en division. **32** — *Biddulphia schroederiana* Schussnig.

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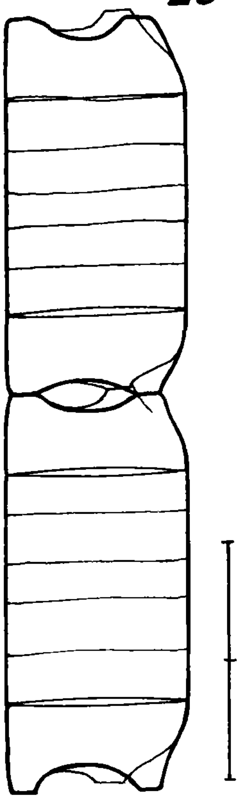

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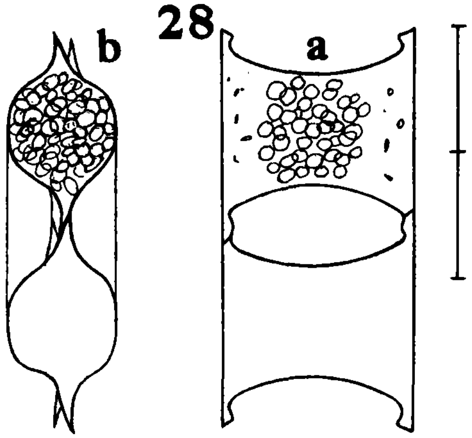

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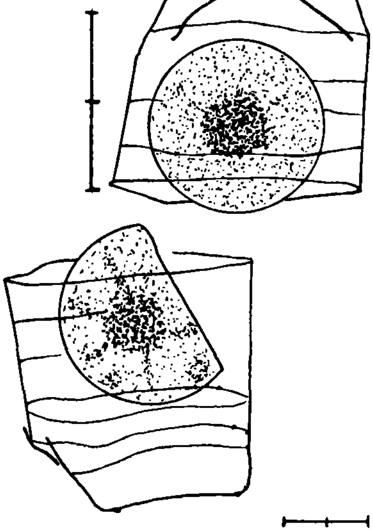

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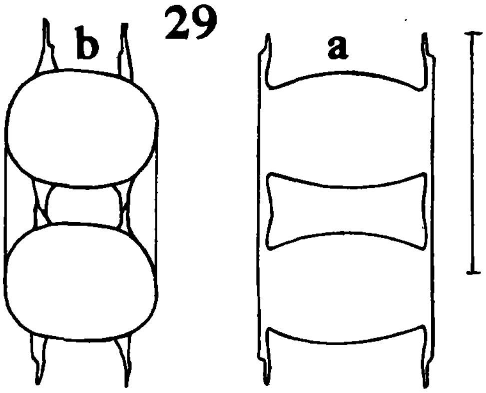

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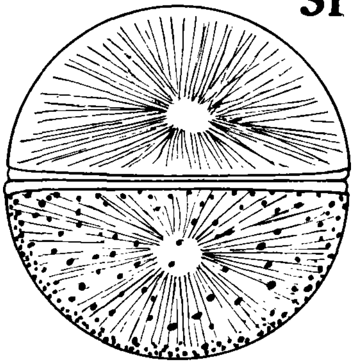

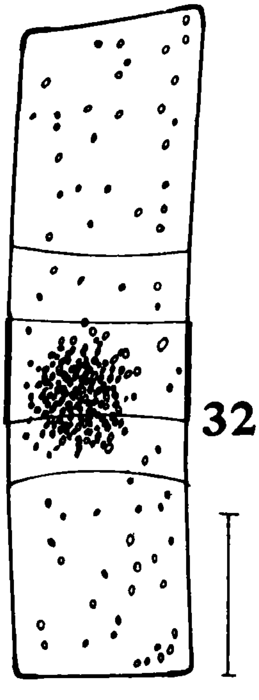

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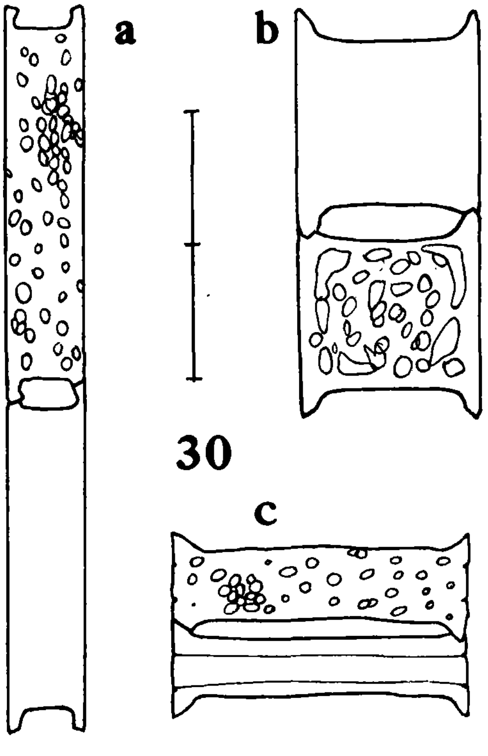

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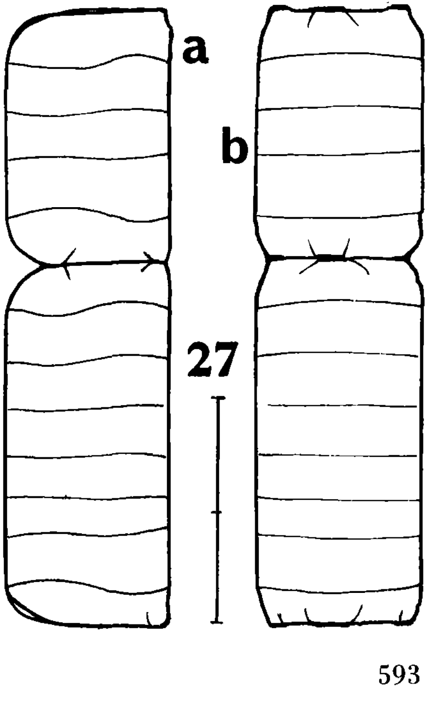


27

= « *R. styliformis* var. *latissima* Brightwell » *(nomen nudum)*

OSTENFELD, 1903a, p. 13. SCHRÖDER, 1906, p. 345, fig. 6. OKAMURA, 1911, p. 5, pl. 10, fig. 23 b-e. HUSTEDT, 1930, p. 586, fig. 335. ALLEN et CUPP, 1935, p. 130, fig. 40. SUBRAHMANYAN, 1946, p. 118, fig. 130-132, 143.

= *Rhizosolenia polydactyla* Castracane

CASTRACANE, *loc. cit.* MANGIN, 1915, p. 73, fig. 52. HEIDEN et KOLBE, 1928, p. 517 (?). HART, 1934, p. 161. HENDEY, 1937, p. 316.

= *Rhizosolenia formosa* H. Peragallo

PERAGALLO, 1888, p. 83, pl. 6, fig. 43; 1892, p. 110, pl. 14, fig. 2; 1908, p. 461, pl. 123, fig. 3. PAVILLARD, 1923, p. 33, fig. 51. DANGEARD, 1927, p. 391, fig. 49. SILVA, 1949, p. 311, pl. 1, fig. 11.

RÉCOLTES PERSONNELLES : très rare. Nossi-Bé (à la fin de l'été); île Maurice.

OCÉAN INDIEN : distribution sporadique sous toutes les latitudes. Mer Rouge; mer d'Arabie; côtes des Indes; Indonésie; côtes du Mozambique et d'Afrique du Sud; Antarctique. (SILVA, 1956a; TAYLOR, 1967).

DISTRIBUTION MONDIALE : Atlantique tropical; Méditerranée; Nouvelle-Zélande; golfe du Siam; mer du Japon; Antarctique. Cette variété semble donc cosmopolite, quoique plus fréquente dans les mers chaudes.

Cette variété a peut-être été observée pour la première fois par BRIGHTWELL *(loc. cit.)*, mais la désignation « var. *latissima* Brightw. » est purement posthume... En effet, dans sa description originelle de l'espèce, cet auteur présente, sous le nom unique de « *R. styliformis* n. sp. », diverses figures : l'une d'elles (fig. 5e) est bien l' « ancêtre » d'une variété distincte, mais BRIGHTWELL la nomme simplement (*ibid.*, légende pl. 5) : « portion of the broadest frustule yet found ». Le nom de « var. *latissima* Brightw. » est dû en fait à PERAGALLO (1892) mais n'a pas été publié validement par cet auteur, car seulement mentionné à titre de synonyme.

***Rhizosolenia hebetata* f. *semispina* (Hensen) Gran, 1905**

HENSEN, 1887, p. 84, pl. 5, fig. 39 : « *Rhizosolenia semispina* ». GRAN, 1905, p. 55, fig. 67. HUSTEDT, 1930, p. 592, fig. 338. HENDEY, 1937, p. 315 (« phase »), et 1964, p. 150, pl. 3, fig. 5. CUPP, 1943, p. 88, fig. 50 B.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; sporadique dans le canal de Mozambique.

OCÉAN INDIEN : courante sous toutes les latitudes, Antarctique inclus. (SILVA, 1956a; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cosmopolite, ou forme thermophile d'une espèce cosmopolite. Plus abondante dans les mers tempérées et tropicales, mais courante dans l'Atlantique nord et ses dépendances, et signalée dans les mers polaires.

La présence simultanée chez cette forme d'auxospores et de microspores a été observée par RAMSFJELL (1959).

A propos de la forme psychrophile de cette espèce (absente de mes récoltes) : le nom de « f. *hiemalis* Gran » est illégal, puisqu'il se rapporte au type de l'espèce (BAILEY, 1856), et doit être remplacé par celui de « f. *hebetata* ».

Rhizosolenia setigera Brightwell, 1858

BRIGHTWELL, 1858a, p. 95, pl. 5, fig. 7. GRAN, 1905, p. 53, fig. 64 a-b, *vix* c. HUSTEDT, 1930, p. 588, fig. 336. HENDEY, 1937, p. 318, et 1964, p. 149, pl. 4, fig. 1. CUPP, 1943, p. 88, fig. 49. WALHQUIST, 1966 (monographie).

RÉCOLTES PERSONNELLES : Nossi-Bé (poussées importantes en saison fraîche); Tuléar; île Maurice; côte d'Afrique du Sud. Répartition très voisine de celle de *R. pungens.*

OCÉAN INDIEN : espèce courante. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : néritique, cosmopolite.

BRIGHTWELL n'ayant pas poussé dans le détail sa description originelle de l'espèce, la structure des bandes intercalaires et celle du style n'ont été définies que postérieurement (GRAN, HUSTEDT, *loc. cit.*), de sorte que *R. setigera* a pu être confondue tout d'abord avec *R. hebetata* f. *semispina,* et même avec *R. styliformis.* Voir aussi ci-dessous, à propos de *R. pungens.*

Rhizosolenia pungens Cleve-Euler, 1937

Pl. III, fig. 18

CLEVE-EULER, 1937, p. 43, fig. 10, et 1951, p. 92, fig. 174. BRUNEL, 1962, p. 66, pl. 4, fig. 5-6.

Cellules droites, bacilliformes, solitaires. Diamètre : 8-15 μ; longueur (style compris) : 140-750 μ. Valves effilées; style très développé, en forme d'alène, renflé vers son milieu. Bandes intercalaires (selon BRUNEL) « rhombiques, en deux longues rangées, comme chez *R. setigera* ». Chromatophores petits et nombreux, discoïdes ou allongés.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; côte d'Afrique du Sud.

OCÉAN INDIEN : espèce seulement signalée par TRAVERS (1965) à Tuléar.

DISTRIBUTION MONDIALE : de découverte récente, cette espèce est encore très peu connue. Détroit d'Oresund (entre le Kattegat et la Baltique); baie des Chaleurs (Canada).

La rareté apparente de cette espèce tient en partie au fait qu'elle a vraisemblablement été souvent confondue avec *R. setigera,* comme le laissent croire par exemple certaines figures de GRAN (1905, fig. 64c), d'OKAMURA (1911, pl. 9, fig. 22) ou de MEUNIER (1913, pl. 8, fig. 13, 15). Les deux espèces sont-elles bien distinctes? Ce problème, posé par BRUNEL, reste à résoudre.

Rhizosolenia crassispina Schröder, 1906

Pl. II, fig. 11 a-b, et pl. X, fig. 67

SCHRÖDER, 1906, p. 345, fig. 5. OSTENFELD, 1915, p. 17, fig. 10. SCHMIDT, 1920, pl. 319, fig. 6-10. SUBRAHMANYAN, 1946, p. 119, *vix* fig. 138-139.

= *Rhizosolenia setigera* var. *daga* Müller-Melchers

MÜLLER-MELCHERS, 1957, p. 122, pl. 6, fig. 20.

Cellules isolées ou, exceptionnellement, appariées. Diamètre : 25-70 μ. Valves côniques, parfois légèrement dissymétriques (présentant dans ce cas, en vue connective, un côté concave et un côté convexe); valves d'autant plus allongées que le diamètre de la cellule est plus réduit. Style très développé, souvent incliné par rapport à l'axe pervalvaire, robuste, s'épaississant légèrement mais très visiblement à partir de son insertion, puis s'effilant rapidement, sétiforme dans sa partie distale; cette partie sétiforme est d'autant plus longue que le diamètre de la cellule est plus réduit et que la valve est plus allongée. Écailles arrondies, de forme rappelant celles de *R. Bergonii* ou de *R. acuminata* var. *Temperei*, mais relativement grandes (4 à 6 par circonférence). Ornementation : à préciser. Chromatophores discoïdes, petits, très nombreux.

RÉCOLTES PERSONNELLES : Nossi-Bé.

OCÉAN INDIEN : espèce rarement signalée. Côtes des Indes; mer d'Arabie; îles Cocos. (KOLBE, 1957). Nouvelle pour le canal de Mozambique.

DISTRIBUTION MONDIALE : également très rare. Singapour; sud de la mer de Chine; détroit de Formose; mer du Japon; îles Célèbes; côtes du Brésil. Cette espèce semble donc tropicale-tempérée, et néritique.

Sous le nom de *R. setigera* var. *daga*, MÜLLER-MELCHERS a seulement décrit l'extrémité d'une valve de *Rhizosolenia*, portant un style tout à fait assimilable à celui de la présente espèce.

SCHRÖDER, qui, pas plus que les auteurs postérieurs, n'a pu décrire la structure des bandes intercalaires, rapprochait cette espèce de *R. hebetata*, comme troisième forme possible à la suite de f. *hiemalis* et de f. *semispina*: ce point de vue ne semble plus guère soutenable. Par contre, je poserai, sans le résoudre, le problème des affinités possibles avec *R. pungens*. En effet, chez les plus petits spécimens de *R. crassispina* (diamètre : 25 μ) la valve est très étirée et la terminaison sétiforme du style très développée : ces cellules sont alors de proportions comparables à celles de *R. pungens* (dont le diamètre maximum est de 15 μ); toutefois, la structure des bandes intercalaires dans les deux cas reste à comparer, puisque les écailles de *R. pungens* sont assez mal définies, et que la présente description de ces formations chez *R. crassispina* s'applique à des individus de grande taille.

Les affinités entre *R. crassispina*, *R. pungens* et *R. setigera* restent donc à définir.

Rhizosolenia calcar-avis M. Schultze, 1858

SCHULTZE, 1858, p. 339, pl. 13, fig. 5-10. HUSTEDT, 1930, p. 592, fig. 339. HENDEY, 1937, p. 312, pl. 11, fig. 14, et 1964, p. 151, pl. 4, fig. 3.

RÉCOLTES PERSONNELLES : toutes les stations littorales.

OCÉAN INDIEN : espèce courante dans toute la zone intertropicale. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : mers tropicales et tempérées.

Cette espèce, récoltée en abondance, est très polymorphe : certains spécimens ont un diamètre très réduit (10 μ) et des valves très allongées; l'incurvation du style est alors peu marquée : cette relation inverse entre le diamètre de la cellule et l'étirement des valves est courante dans le genre *Rhizosolenia*.

Rhizosolenia cochlea Brun, 1891

Pl. *II*, fig. 14

BRUN, 1891, p. 43, pl. 19, fig. 9. PERAGALLO, 1892, p. 113, pl. 16, fig. 11. CLEVE, 1901, p. 56, pl. 8, fig. 12. KARSTEN, 1907, p. 381, pl. 41, fig. 6. OKAMURA, 1911, p. 6, pl. 10, fig. 25. SCHMIDT, 1920, pl. 319, fig. 1. SILVA, 1960, p. 21, pl. 20, fig. 4. WOOD, 1963b, p. 198, *vix* pl. 5, fig. 15.

= *Rhizosolenia calcar-avis* var. *cochlea* (Brun) Ostenfeld

OSTENFELD, 1903a, p. 10, fig. 5, *et cet. auct.*

Diamètre : 80-130 μ. Valves tordues, dissymétriques, étirées suivant une ébauche de spirale. Style bien développé, robuste, incurvé. Écailles larges (2 à 3 par circonférence). Chromatophores petits, arrondis, disposés en files distinctes.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); au large de Durban, de Beira et du cap Saint-André.

OCÉAN INDIEN : espèce sporadique dans la zone intertropicale. (KOLBE, 1957; SILVA, 1960).

DISTRIBUTION MONDIALE : très rare en dehors de l'océan Indien. Hong-Kong; golfe du Siam; mer du Japon.

Rhizosolenia alata Brightwell, 1858

BRIGHTWELL, 1858a, p. 95, pl. 5, fig. 8.

Je conserve ici pour raison de commodité la conception classique de l'espèce telle que donnée par HUSTEDT et suivie, dans son principe, par HENDEY et CUPP : cinq formes, dont une forme-type. Cependant, si les f. *inermis* et *curvirostris* sont assez nettement individualisées, par contre l'autonomie et la validité des trois autres formes sont extrêmement douteuses : les limites de taille choisies comme distinctives sont en effet purement arbitraires (cf. ROBINSON, 1957) et, du point de vue nomenclatural, le rang de forme, tel que défini récemment par HENDEY (1964, p. 55) n'est pas ici justifié. Il est souhaitable que des études biométriques, ainsi qu'une meilleure connaissance de la biologie de l'espèce (auxospores...) conduisent à l'avenir à une conception plus réaliste (ROBINSON, *ibid.;* WOODMANSEE, 1963).

La forme *inermis* (Castr.) Hust. est absente de mes récoltes.

f. ***alata***

BRIGHTWELL, *loc. cit.* HUSTEDT, 1930, p. 600, fig. 344. HENDEY, 1937, p. 310, et 1964, p. 146, pl. 2, fig. 2. CUPP, 1943, p. 90, fig. 52 A.

= *R. alata* f. *genuina* Gran

GRAN, 1905, p. 56, fig. 68 b-c. LEBOUR, 1930, p. 90, fig. 58. ALLEN et CUPP, 1935, p. 131, fig. 43. CLEVE-EULER, 1951, p. 90, fig. 171 a-d, 171 B a-b.

RÉCOLTES PERSONNELLES : Nossi-Bé (forme plutôt estivale); Tuléar; île Maurice; sporadique dans le canal de Mozambique, mais absente des régions oligotrophiques.

OCÉAN INDIEN : largement répandue, quoique plus rare sous les hautes latitudes. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : principalement tempérée et tropicale, mais assez imprécise car cette forme-type a souvent été désignée sous le nom spécifique, ce qui rend possible la confusion avec les autres formes.

f. ***gracillima*** (Cleve) Gran, 1905

Pl. I, fig. 3

CLEVE, 1881, p. 26, pl. 6, fig. 78 : « *Rhizosolenia* (*alata* var.?) *gracillima* ». GRAN, 1905, p. 56, fig. 68 d. HENDEY, 1937, p. 310 (« phase »), et 1964, p. 146, pl. 2, fig. 3.

= « *R. alata* f. *gracillima* (Cleve) Grunow » (nom d'auteur erroné)

HUSTEDT, 1930, p. 601, fig. 345, *et plur. auct.*

RÉCOLTES PERSONNELLES : comme la forme précédente, mais beaucoup plus abondante; à Nossi-Bé, donne lieu à des poussées estivales massives.

OCÉAN INDIEN ET OCÉAN MONDIAL : distribution difficile à distinguer de celle de la forme précédente; probablement plus franchement néritique, et plus thermophile.

f. ***indica*** (H. Peragallo) Gran, 1905

PERAGALLO, 1892, p. 116, pl. 18, fig. 16 : « *Rhizosolenia indica* ». GRAN, 1905, p. 56, fig. 68 a. HENDEY, 1937, p. 311 (« phase »), et 1964, p. 147, pl. 2, fig. 4.

= « *R. alata* f. *indica* (H. Perag.) Ostenf. » (nom d'auteur erroné)

HUSTEDT, 1930, p. 602, fig. 346, *et plur. auct.*

RÉCOLTES PERSONNELLES : Nossi-Bé (forme estivale); Tuléar; parages de Beira et du cap Saint-André.

OCÉAN INDIEN : à la différence des deux formes précédentes, celle-ci est essentiellement intertropicale. (Réf. plus haut).

DISTRIBUTION MONDIALE : mers tropicales et Méditerranée; également signalée dans l'Atlantique nord et ses dépendances.

f. ***curvirostris*** Gran, 1900

GRAN, 1900, p. 120, pl. 9, fig. 21-22, et 1905, p. 56. HUSTEDT, 1930, p. 602, fig. 347. CUPP, 1943, p. 93, fig. 52 D. HENDEY, 1964, p. 147.

? = *Rhizosolenia arafurensis* Wood, *non : R. arafurensis* Castracane

WOOD, 1963b, p. 198, pl. 5, fig. 12.

RÉCOLTES PERSONNELLES : très rare. Tuléar; parages de Durban.

OCÉAN INDIEN : forme nouvelle pour cet océan.

DISTRIBUTION MONDIALE : assez rare. Mer de Norvège; mer du Nord; côtes de Californie; Alaska.

Rhizosolenia Temperei var. ***acuminata*** H. Peragallo, 1892

Pl. II, fig. 10

PERAGALLO, 1892, p. 110, pl. 15, fig. 4. OSTENFELD, 1903a, p. 13, fig. 8.

= *Rhizosolenia acuminata* (H. Peragallo) Gran

GRAN, 1905, p. 50, fig. 59. PERAGALLO, 1908, p. 463, pl. 123, fig. 7-8 (« *Rh. acuminata* H.P. »). PAVILLARD, 1925, p. 35, fig. 53. HUSTEDT, 1930, p. 605, fig. 350. LEBOUR, 1930, p. 101, fig. 74 a (« *R. acuminata* (H. Perag.) Pav. »). GAARDER, 1954, p. 22 (?), fig. 8 a, *non* b-g. CURL, 1959, p. 297, fig. 67.

RÉCOLTES PERSONNELLES : espèce très rare. Quelques spécimens, récoltés à Tuléar, au large de Nossi-Bé, à l'île Maurice, et au large de Mombasa.

OCÉAN INDIEN : sporadique, essentiellement intertropicale. Mer d'Arabie; golfe d'Aden; mer d'Arafura; canal de Mozambique; côte d'Afrique du Sud. (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : Méditerranée et mers tropicales; toutefois présente dans l'Atlantique Nord jusqu'à la latitude 63° N.

PERAGALLO (1892) avait originellement créé pour sa *R. Temperei* cette variété *acuminata*, qui « diffère du type par sa taille un peu moindre et sa calyptre beaucoup plus allongée, différences en somme de peu d'importance ». Le même auteur est ensuite revenu sur son opinion (1908) pour créer une espèce distincte : « plus étroite que *R. Temperei*, mais avec la même imbrication, calyptre plus allongée toujours renflée vers son milieu, gaine d'emboîtement plus distincte ». Peu avant, GRAN (1905) avait séparé les deux espèces, et créé de plus la forme *R. acuminata* f. *debilis:* cette dernière distinction, « entièrement superflue » comme le note PAVILLARD (1925), n'a pas lieu d'être maintenue.

PAVILLARD (1916) déclare avoir observé tous les intermédiaires entre *R. Temperei* et *R. acuminata*, et réunit pour cette raison les deux taxons sous le premier nom. Cependant, lui aussi revient ultérieurement sur son opinion pour se déclarer (1925) « convaincu de l'autonomie de l'espèce *R. acuminata* », qu'il caractérise par sa valve cônique et son style deux fois plus long.

En fait, comme le suggère HUSTEDT, il ne faut voir, dans le cas présent comme dans celui de *R. alata* et de diverses *Rhizosolenia*, que l'expression d'une relation interne entre la taille du frustule et la forme de la valve : les individus les plus larges ont les valves les plus aplaties *(R. Temperei* var. *Temperei)*, et inversement (var. *acuminata*). L'existence de stades intermédiaires (*fide* PAVILLARD) rendrait même douteuse l'autonomie d'une « variété » *acuminata.*

Au sujet de la var. *acuminata* f. *inaequalis* de SCHRÖDER (1901, p. 25, pl. 1, fig. 6) : il s'agit en fait de la variété type, var. *Temperei;* l'individu décrit par SCHRÖDER possède des bandes intercalaires plus serrées à un pôle qu'à l'autre : ce cas doit être interprété, non comme une forme distincte, mais comme un exemple d'hétéromorphisme et une nouvelle preuve de la variabilité du nombre des écailles chez une même espèce.

A propos du *R. acuminata* de GAARDER, voir *R. obtusa*, p. 66.

Rhizosolenia Castracanei H. Peragallo, 1888

Pl. III, fig. 22

PERAGALLO, 1888, p. 83, pl. 6, fig. 42. HUSTEDT, 1930, p. 607, fig. 351. HENDEY, 1937, p. 313, et 1964, p. 151, pl. 4, fig. 4. CUPP, 1943, p. 94, fig. 54. CURL, 1959, p. 298, fig. 71. *Non :* CLEVE, 1889, p. 54, fig. in text.

= *Rhizosolenia magna* Stüwe

STÜWE, 1909, p. 276, pl. 1, fig. 3-4.

RÉCOLTES PERSONNELLES : très rare. Nossi-Bé, et côte nord-ouest de Madagascar.

OCÉAN INDIEN : côtes des Indes; mers indonésiennes; côtes d'Australie; canal de Mozambique; Afrique du Sud. (SILVA, 1956a; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce assez rare, essentiellement intertropicale, plutôt océanique.

Je rattache provisoirement à cette espèce un cas morphologique assez particulier (un seul spécimen, récolté à Nossi-Bé : fig. 22), que STÜWE a élevé au rang spécifique sous le nom de *R. magna :*

Valves circulaires, presque complètement aplaties mais formant une excroissance arrondie au niveau de l'insertion du style; écailles très aplaties, 6 à 8 fois plus larges que hautes, et au nombre de quatre par circonférence. Ornementation très apparente. Diamètre 190 μ.

Rhizosolenia Clevei Ostenfeld, 1903

Pl. II, fig. 13 a-b, et pl. X, fig. 68

OSTENFELD, 1903a, p. 11, fig. 6. OKAMURA, 1911, p. 5, pl. 9, fig. 20. SCHMIDT, 1933, pl. 384, fig. 2-3. ALLEN et CUPP, 1935, p. 128, fig. 34. CROSBY et WOOD, 1958, p. 521, pl. 38, fig. 68.

= *R. Castracanei* var. *rhomboidea* Subrahmanyan

SUBRAHMANYAN, 1946, p. 123, fig. 153-154, 156-160. SPROSTON, 1949, p. 87.

? = *Rhizosolenia debyana* H. Peragallo

PERAGALLO, 1892, p. 111, pl. 15, fig. 7.

Diamètre compris entre 40 et 200 μ, le plus souvent supérieur à 70 μ. Valves sub-côniques; style large et creux à sa base, puis brutalement rétréci, son extrémité étant sétiforme et plus ou moins longue (lorsque cette partie sétiforme est réduite — ou brisée — le style paraît tronqué); style pourvu de deux fines oreillettes basilaires peu évidentes. Bandes intercalaires formées d'écailles régulièrement décussées, au nombre de 5 à 8 par circonférence, sub-losangiques ou plus ou moins arrondies. Ornementation très difficilement visible (ponctuations ou stries hexagonales). Chromatophores très petits, arrondis, dispersés dans toute la cellule. Présence très générale de la Cyanophycée (endophyte) *Richelia.*

RÉCOLTES PERSONNELLES : Nossi-Bé; sud du canal de Mozambique; au large du cap Saint-André.

OCÉAN INDIEN : espèce rare, nouvelle pour la région étudiée. Mer de Java; côtes des Indes.

DISTRIBUTION MONDIALE : espèce peu connue, probablement intertropicale. Mers de Chine et du Japon; golfe du Siam; côte nord-est de l'Australie et mer de Corail; « océan Pacifique ».

Cette espèce ne me semble guère affine de *R. Castracanei*, comme le voudrait SUBRAHMANYAN. Par ailleurs, OSTENFELD l'apparente à *R. debyana;* cependant, cette dernière espèce n'a été décrite que de façon très fragmentaire par PERAGALLO (calyptres et « tubes » isolés), si bien qu'il serait par trop aléatoire d'accorder à *R. debyana* la priorité sur *R. Clevei.*

Rhizosolenia squamifera nom. nov.

Pl. III, fig. 21

= *Rhizosolenia squamosa* Karsten, 1907

KARSTEN, 1907, p. 382, pl. 42, fig. 3. (Homonyme postérieur, illégal.)

Non : Rhizosolenia squamosa Pantocsek, 1893

PANTOCSEK, 1893, pl. 35, fig. 496.

Frustules cylindriques, de diamètre 180-280 μ. Valves aplaties, seulement saillantes dans la région d'insertion du style; style assez court, d'insertion excentrique, et dirigé obliquement par rapport à l'axe pervalvaire. Bandes intercalaires formées d'écailles décussées au nombre de 6 à 8 par circonférence; chaque écaille est symétrique à elle-même par rapport à deux axes perpendiculaires l'un à l'autre. Ornementation (selon KARSTEN) : système hexagonal d'environ 9 ponctuations en 10 μ.

RÉCOLTES PERSONNELLES : un seul spécimen, récolté dans le centre du canal de Mozambique.

OCÉAN INDIEN ET OCÉAN MONDIAL : l'espèce semble n'avoir jamais été signalée depuis sa découverte par KARSTEN dans le sud-est de l'océan Indien (lat. 26° S., long. 93° E.).

Rhizosolenia hyalina Ostenfeld *in* Ostenfeld et J. Schmidt, 1901

Pl. III, fig. 19 a-b

OSTENFELD et SCHMIDT, 1901, p. 160, fig. 11. OSTENFELD, 1903a, p. 11. SCHMIDT, 1920, pl. 319, fig. 11-13. DANGEARD, 1927, p. 391, fig. 50. SKVORTZOW, 1931b, p. 115, pl. 10, fig. 6-8 (?). GAARDER, 1954, p. 26, fig. 13. MÜLLER-MELCHERS, 1957, p. 122. SILVA, 1960, p. 21, pl. 20, fig. 3. WOOD, 1963b, p. 198, pl. 5, fig. 14 (?).

= *Rhizosolenia pellucida* Cleve, *non* Schröder

CLEVE, 1901, p. 56, pl. 8, fig. 4. *Non :* SCHRÖDER, 1911, p. 631, fig. 6. (La publication de *R. hyalina* est de quelques mois antérieure à celle de CLEVE.)

Diamètre 28-60 μ; longueur 130-340 μ. Parois très fragiles, donnant au frustule un aspect général hyalin. Valve sub-cônique, mais légèrement déprimée à mi-hauteur, formant ainsi une ondulation caractéristique. Au tiers de sa longueur (à partir de l'insertion), le style est légèrement infléchi et devient sétiforme; oreillettes basilaires apparemment absentes. Bandes intercalaires très difficilement visibles, formées de larges écailles arrondies au nombre de 4 à 5 par circonférence.

RÉCOLTES PERSONNELLES : Nossi-Bé (espèce estivale); côte sud-ouest du canal de Mozambique.

OCÉAN INDIEN : mer Rouge; golfe d'Aden; mer d'Arabie; Indonésie; côte du Mozambique; Afrique du Sud. (SILVA, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce intertropicale, peu connue. Mers de Chine et du Japon; détroit de Banks; golfe du Siam; nord-est de la mer des Sargasses; au large des côtes du Sénégal et de Guinée; côtes du Brésil.

Fam. FRAGILARIACEAE

Fragilaria crotonensis Kitton, 1869

KITTON, 1869, p. 81, fig. 10. HUSTEDT, 1931, p. 143, fig. 658. CUPP, 1943, p. 181, fig. 131.

RÉCOLTES PERSONNELLES : Nossi-Bé (saison des pluies).

OCÉAN INDIEN ET OCÉAN MONDIAL : espèce dulcaquicole, rencontrée accessoirement dans les eaux marines littorales; probablement euryhaline (sa présence en saison des pluies dans la baie du Centre océanographique à Nossi-Bé peut être simplement causée par un afflux d'eaux douces).

Fragilaria Aurivillii Cleve, 1901

Pl. V, fig. 39 a-b

CLEVE, 1901, p. 21, 56, pl. 8, fig. 13.

Cellules formant de longues chaînes rubanées. En vue connective : cellules rectangulaires, à contour rectiligne ou légèrement ondulé; axe apical 2-7 fois plus long que l'axe pervalvaire; ceinture formée de stries parallèles très fines et très rapprochées. En vue valvaire : valves allongées, à contour sinueux (ornementation : inconnue). Chromatophores petits, arrondis, très nombreux. Longueur de l'axe apical : 25-80 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

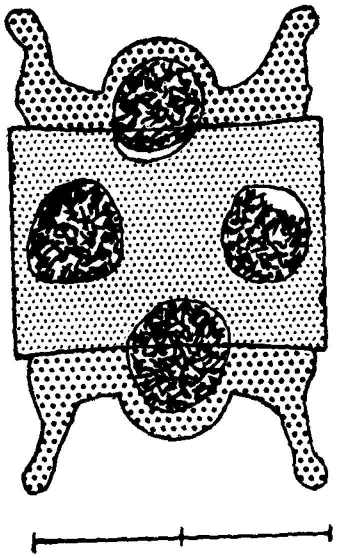
OCÉAN INDIEN ET OCÉAN MONDIAL : une seule référence (?), celle de CLEVE (*loc. cit.*, p. 21) : « Malay archipelago, June to September, not rare (t. 27,7, mean of 6 obs. max. 28,5, min. 25,7; s. 32, 85, max. 33, 88, min. 32, 43) ».

Fragilaria sp.

Pl. VI, fig. 41

Cellules adhérant les unes aux autres par les extrémités de leurs valves (et non par leurs surfaces valvaires, comme il est de règle dans le genre *Fragilaria*); chaînes ramifiées. Vue valvaire : non observée. Vue connective : contour rectangulaire, rectiligne ou très légèrement infléchi;

PLANCHE V : **33** — *Biddulphia tridens* (Ehr.) Ehr. : sporulation ? **34** — *Triceratium contortum* Shadbolt. **35** — *Navicula Wawrikae* Hust. **36** — *Pleurosigma directum* Grunow (ornementation non visible). **37** — *Stauroneis membranacea* (Cl.) Hust. **38** — *Asterionella Bleakeleyi* W. Smith. **39** a, b — *Fragilaria Aurivillii* Cl.



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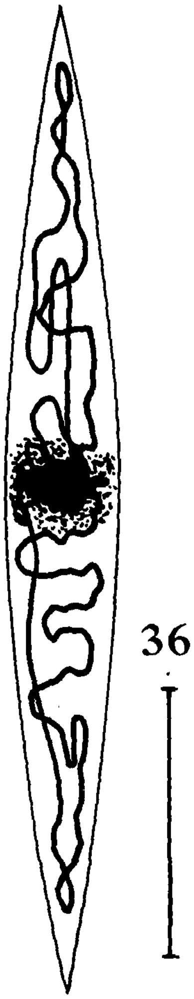

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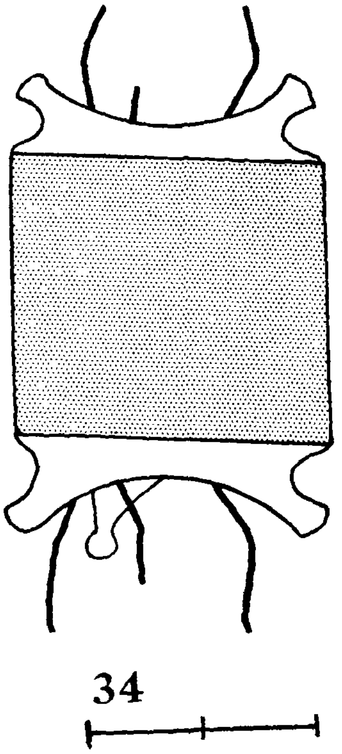

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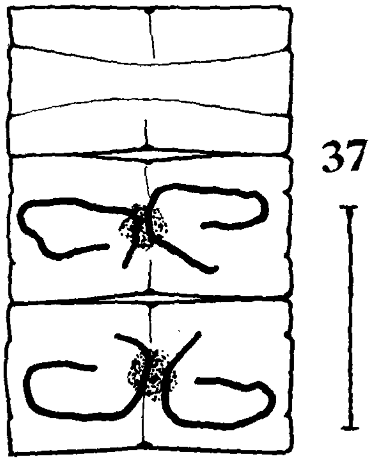

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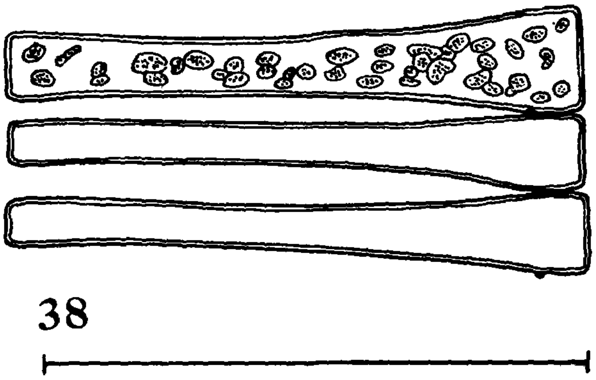

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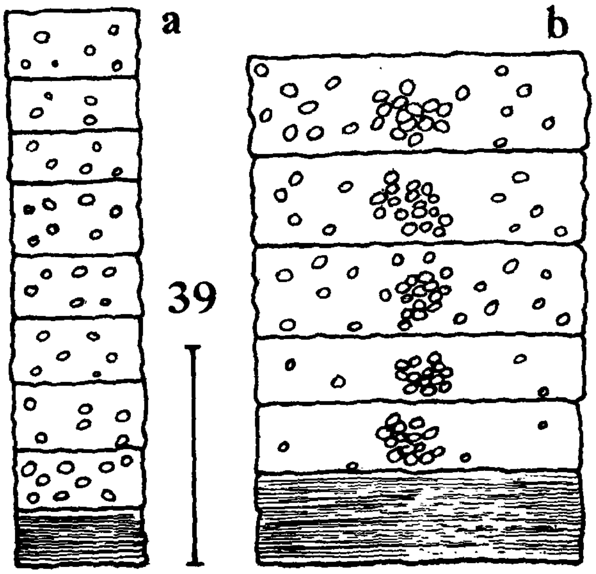

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ceinture formée de fines stries parallèles. Chromatophore unique, volumineux, lacinié. Longueur de l'axe apical : 70-120 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice. Espèce nettement littorale.

L'ignorance de la morphologie des valves m'empêche d'attribuer un nom — nouveau ou connu — à cette espèce.

Asterionella Bleakeleyi W. Smith, 1856
Pl. V, fig. 38

SMITH, 1856, p. 82. VAN HEURCK, 1885, pl. 52, fig. 1. PERAGALLO, 1908, p. 322, pl. 81, fig. 10-11. HUSTEDT, 1932, p. 253, fig. 732.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); île Maurice.

OCÉAN INDIEN : espèce très rarement signalée. Mers indonésiennes; « océan Indien »; Tuléar. (TRAVERS, 1965).

DISTRIBUTION MONDIALE : littorale tempérée?

Cette espèce est très mal connue, et sa description originale très imprécise : « Frustules linear, enlarged at the base. Length of frustule 0.0022 inch. » (sans illustration). HUSTEDT, ne l'ayant pas personnellement observée, se reporte à VAN HEURCK. Enfin PERAGALLO voyait ici une forme marine d'*A. formosa;* la question ne semble pas avoir progressé depuis.

Asterionella notata Grunow *in* Van Heurck, 1885
Pl. VI, fig. 44

VAN HEURCK, 1885, pl. 52, fig. 3. CLEVE, 1900a, p. 19, pl. 7, fig. 32. GRAN, 1905, p. 119, fig. 162. PERAGALLO, 1908, p. 322. pl. 81, fig. 12. PAVILLARD, 1925, p. 60, *vix* fig. 108 B. HUSTEDT, 1932, p. 254, fig. 733. HENDEY, 1937, p. 334, et 1964, p. 159. SPROSTON, 1949, p. 107. SILVA, 1956a, p. 45, pl. 7, fig. 9.

RÉCOLTES PERSONNELLES : Nossi-Bé (souvent abondante, et principalement hivernale); Tuléar; île Maurice.

OCÉAN INDIEN : espèce assez rare. Côte d'Australie; Indonésie; canal de Mozambique. (SILVA, 1956a; TRAVERS, 1965).

DISTRIBUTION MONDIALE : tempérée-tropicale; néritique.

Asterionella japonica Cleve *in* Cleve et Möller, 1882

CLEVE et MÖLLER, 1882, n° 307. GRAN, 1905, p. 118, fig. 160. HUSTEDT, 1932, p. 254, fig. 734. HENDEY, 1937, p. 333, pl. 11, fig. 3, et 1964, p. 158, pl. 21, fig. 1. SAUNDERS, 1964 (monographie).

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); sporadique dans le canal de Mozambique.

OCÉAN INDIEN : Indonésie; côtes des Indes; îles Cocos; canal de Mozambique; côte d'Afrique du Sud. (KOLBE, 1957; SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce cosmopolite, plus abondante dans les eaux tempérées; euryhaline (estuaires).

La publication de ce taxon par CLEVE et MÖLLER sous forme d'un *exsiccatum* peut être considérée comme effective, puisqu'antérieure à 1953 (cf. LANJOUW *et al.*, 1966).

Striatella unipunctata (Lyngbye) Agardh, 1832

LYNGBYE, 1819, p. 183, pl. 62, fig. G : « *Fragilaria unipunctata* ». AGARDH, 1832, p. 61. HUSTEDT, 1931, p. 32, fig. 560. CLEVE-EULER, 1953, p. 8, fig. 300. HENDEY, 1964, p. 161, pl. 26, fig. 17-18.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : espèce assez commune. Indonésie; Ceylan; canal de Mozambique. (SILVA, 1956a; TRAVERS, 1965).

DISTRIBUTION MONDIALE : mers tempérées (cosmopolite?).

Rappelons, sans pouvoir exprimer d'opinion personnelle à ce sujet, que l'étude de l'appareil plastidial conduit SIMON (1954) à distinguer ici deux espèces.

Striatella interrupta (Ehrenberg) Heiberg, 1863

EHRENBERG, 1838, p. 202 : « *Tessella interrupta* ». HEIBERG, 1863, p. 73, pl. 5, fig. 15. HUSTEDT, 1931, p. 34, fig. 562. CLEVE-EULER, 1953, p. 8, fig. 297.

= *Tessella interrupta* Ehrenberg

EHRENBERG, *loc. cit.* KÜTZING, 1844, p. 125, pl. 18, fig. 4, *et cet. auct.*

RÉCOLTES PERSONNELLES : seulement quelques spécimens, provenant de l'île Maurice.

OCÉAN INDIEN : espèce très rare (seulement connue dans les mers indonésiennes), nouvelle pour la région étudiée.

DISTRIBUTION MONDIALE : très sporadique, mais peut-être cosmopolite. Mers tropicales, tempérées et sub-polaires.

Striatella delicatula (Kützing) Grunow *in* Van Heurck, 1885

KÜTZING, 1844, p. 125, *vix* pl. 18, fig. 3/1 : « *Hyalosira delicatula* ». VAN HEURCK, 1885, p. 165, pl. 54, fig. 5-6. PERAGALLO, 1908, p. 360, pl. 89, fig. 2. HUSTEDT, 1931, p. 33, fig. 561. SUBRAHMANYAN, 1946, p. 161, fig. 317, 321. HENDEY, 1951, p. 41, pl. 10, fig. 7, et 1964, p. 161. CHOLNOKY, 1963, p. 79.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice.

OCÉAN INDIEN : mer Rouge; mer d'Arabie; mer d'Oman; côtes des Indes; Ceylan; côtes d'Afrique du Sud. Espèce nouvelle pour la région étudiée.

DISTRIBUTION MONDIALE : espèce littorale (tychoplanctonique), probablement cosmopolite.

Synedra hennedyana Gregory, 1857

GREGORY, 1857, p. 532, pl. 14, fig. 108. SCHMIDT, 1914, pl. 305, fig. 1-3. HUSTEDT, 1932, p. 222, fig. 713. HENDEY, 1964, p. 164, pl. 26, fig. 7.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; parages des Comores.

OCÉAN INDIEN : espèce rare. Ceylan; Indonésie; côte d'Afrique du Sud; nouvelle pour le canal de Mozambique.

DISTRIBUTION MONDIALE : tempérée et sub-tropicale; néritique.

Synedra hantzschiana, nom. nov.

Pl. VI, fig. 43

= *Synedra rostrata* (Hantzsch) Hustedt *in* A. Schmidt

HANTZSCH, 1863, p. 19, pl. 5, fig. 4 : « *Toxarium rostratum* ». SCHMIDT, 1914, pl. 305, fig. 7-9. BOYER, 1926, p. 211. (Homonyme postérieur, illégal).

Non : Synedra rostrata Ehrenberg

EHRENBERG, 1854, pl. 14, fig. 44. PRITCHARD, 1861, p. 789.

Nec : Synedra rostrata Pantocsek

PANTOCSEK, 1902, p. 76, pl. 8, fig. 204.

Nec : Synedra rostrata Meister

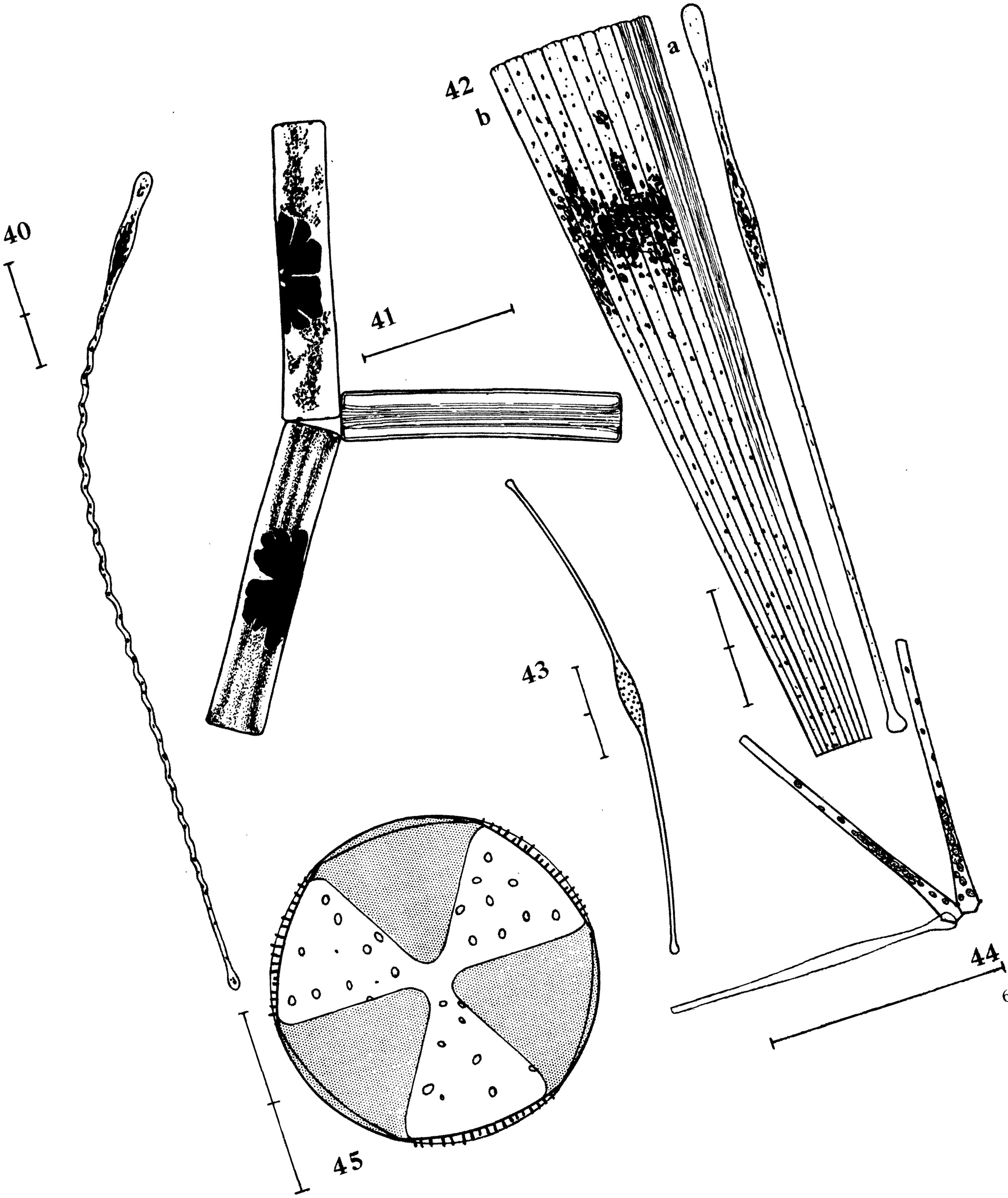
MEISTER, 1913, p. 307, pl. 4, fig. 7.

Valves très allongées, arquées, non ondulées, renflées au milieu et aux extrémités. Ornementation : ponctuations disposées irrégulièrement. Longueur de l'axe apical : 380 — 550 µ. Espèce morphologiquement très voisine de *S. hennedyana*.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN ET OCÉAN MONDIAL : l'espèce était jusqu'ici inconnue en dehors des « Indes orientales » (HANTZSCH, *ibid.; LEUDUGER-FORTMOREL*, 1892).

PLANCHE VI : **40** — *Licmosphenia* (?) *Mereschkowskyi* n. sp. **41** — *Fragilaria* sp. **42** a, b — *Licmophora Aurivillii* Cl. : vue valvaire d'une cellule (a) et vue connective d'une colonie (b). **43** — *Synedra hantzschiana* nom. nov. **44** — *Asterionella notata* Grunow : une cellule en vue valvaire, deux cellules en vue connective. **45** — *Actinoptychus trilingulatus* (Brightw.) Ralfs.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Synedra undulata (Bailey) Gregory, 1857

Bailey, 1854, p. 15, pl. 1, fig. 24-25 : « *Toxarium undulatum* ». Gregory, 1857, p. 531, pl. 14, fig. 107. Schmidt, 1914, pl. 305, fig. 4-6. Hustedt, 1932, p. 224, fig. 714. Cleve-Euler, 1953, p. 74, fig. 396. Hendey, 1964, p. 164.

Récoltes personnelles : Nossi-Bé; Tuléar.

Océan Indien : espèce rare. Ceylan; Sumatra; canal de Mozambique. (Silva, 1956a; Travers, 1965).

Distribution mondiale : mers tempérées et tropicales.

Thalassiothrix longissima Cleve et Grunow, 1880

Cleve et Grunow, 1880, p. 108. Hustedt, 1932, p. 247, fig. 726. Hendey, 1937, p. 336; 1958, p. 52; 1964, p. 165. Hasle et Mendiola, 1967, p. 114, fig. 20, 53.

Récoltes personnelles : Nossi-Bé (rare).

Océan Indien : espèce courante sous toutes les latitudes, mais plus abondante dans les régions antarctiques. (Kolbe, 1957; Silva, 1960; Taylor, 1967).

Distribution mondiale : espèce océanique, réputée arctique et antarctique mais, en fait, cosmopolite (sauf confusions avec d'autres *Thalassiothrix* « très longs »...). Elle prolifère parfois dans les mers froides, mais a été signalée sous toutes les latitudes.

Thalassiothrix Frauenfeldii (Grunow) Cleve et Möller, 1878

Grunow, 1863, p. 140, pl. 14, fig. 18 a, c, *non* b : « *Asterionella ? Frauenfeldii* ». Cleve et Möller, 1878, nº 145-146. Cleve et Grunow, 1880, p. 109. Hustedt, 1932, p. 247, fig. 726. Hendey, 1964, p. 165. Hasle et Mendiola, 1967, p. 113, fig. 9-10, 21, 38, 47-52.

Récoltes personnelles : Nossi-Bé (espèce commune) et toutes les stations littorales.

Océan Indien : espèce courante dans la zone intertropicale, de présence incertaine dans l'Antarctique.

Distribution mondiale : cosmopolite mais nettement thermophile; néritique.

Thalassiothrix mediterranea Pavillard, 1916

Pavillard, 1916, p. 39, pl. 2, fig. 3. Hustedt, 1932, p. 248, fig. 728. Curl 1959, p. 299, fig. 85.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : espèce seulement signalée par WOOD (1962) dans le sud-est de l'océan; nouvelle pour le canal de Mozambique.

DISTRIBUTION MONDIALE : encore peu connue, probablement sub-tropicale. Méditerranée; golfe du Mexique.

Thalassiothrix delicatula Cupp, 1943

CUPP, 1943, p. 188, fig. 137. HASLE, 1960, p. 20, fig. 8.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; sporadique dans le canal de Mozambique.

OCÉAN INDIEN : comme *T. mediterranea.*

DISTRIBUTION MONDIALE : espèce « sud-tempérée, sub-tropicale », du moins pour la côte occidentale des U.S.A. (CUPP). De découverte récente, elle demeure très peu connue (confusions probables avec les espèces voisines : *T. mediterranea, T. heteromorpha,* et même *T. longissima*).

Thalassionema nitzschioides Grunow *ex* Hustedt, 1932

HUSTEDT, 1932, p. 244, fig. 725. HENDEY, 1937, p. 336, et 1964, p. 165. CUPP, 1943, p. 182, fig. 133. HASLE, 1960, p. 18, pl. 4, fig. 38-41, 43-45. CHOLNOKY, 1963, p. 79. HASLE et MENDIOLA, 1967, p. 111, fig. 5, 11-17, 27-34, 39-44.

= *Thalassiothrix nitzschioides* Grunow *in* Van Heurck

VAN HEURCK, 1885, pl. 43, fig. 7-10. CLEVE-EULER, 1953, p. 75, fig. 400.

RÉCOLTES PERSONNELLES : espèce présente dans la majorité des récoltes, à l'exception de quelques stations de haute mer (centre du canal de Mozambique), et plus abondante dans les eaux littorales.

OCÉAN INDIEN : espèce fréquente sous toutes les latitudes, Antarctique compris. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : néritique, cosmopolite (cf. : SMAYDA, 1957).

Cette espèce est attribuée tantôt à GRUNOW, tantôt à HUSTEDT : en fait, le nom générique a été seulement suggéré par GRUNOW, dans le Synopsis de VAN HEURCK, au titre de synonyme possible, sans constituer une publication valide; HUSTEDT a ensuite repris ce nom et l'a publié validement, tout en l'attribuant à GRUNOW. D'où la désignation ci-dessus (cf. LANJOUW *et al.*, 1966, recomm. 46 C).

Licmophora remulus Grunow, 1867

GRUNOW, 1867b, p. 34. VAN HEURCK, 1885, pl. 46, fig. 4. PERAGALLO, 1908, p. 345, pl. 84, fig. 3. HUSTEDT, 1931, p. 57, fig. 580. SILVA, 1956a, p. 44, pl. 7, fig. 2.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; parages de Beira.

OCÉAN INDIEN : espèce inconnue en dehors du canal de Mozambique. (SILVA, 1956a; TRAVERS, 1965).

DISTRIBUTION MONDIALE : très rare. Adriatique et mer Ligure; Honduras.

Licmophora flabellata (Greville) Agardh, 1831

GREVILLE, 1827, pl. 289, fig. 1-2 : « *Exilaria flabellata* ». AGARDH, 1831, p. 41. HENDEY, 1964, p. 168, pl. 26, fig. 5.

= « *L. flabellata* (Carmichael) Agardh » (nom d'auteur erroné)

HUSTEDT, 1931, p. 58, fig. 581. HENDEY, 1951, p. 39, pl. 16, fig. 1-2, 12.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : mers indonésiennes; côte du Mozambique; Antarctique. (SILVA, 1956a, 1960).

DISTRIBUTION MONDIALE : espèce littorale, principalement tempérée.

Licmophora Lyngbyei (Kützing) Grunow *in* Van Heurck, 1885

KÜTZING, 1844, p. 121, pl. 9, fig. 10/3, et pl. 10, fig. 1/2 : « *Podosphenia Lyngbyei* ». VAN HEURCK, 1885, p. 158, pl. 46, fig. 1. GRAN, 1905, p. 121, fig. 164. LEBOUR, 1930, p. 203, fig. 165. HENDEY, 1937, p. 337; 1951, p. 40; 1964, p. 167.

= *Licmophora abbreviata* Agardh

HUSTEDT, 1931, p. 66, fig. 590. CLEVE-EULER, 1953, p. 17, fig. 318.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; côte d'Afrique du Sud.

OCÉAN INDIEN : Indonésie; côtes des Indes; canal de Mozambique; Antarctique (?); côte d'Afrique du Sud. (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce littorale, cosmopolite.

Licmophora grandis (Kützing) Grunow *in* Van Heurck, 1885

KÜTZING, 1844, p. 122, pl. 11, fig. 1 : « *Rhipidophora grandis* ». VAN HEURCK, 1885, pl. 48, fig. 2-3. PERAGALLO, 1908, p. 349, pl. 85, fig. 14. HUSTEDT, 1931, p. 79, fig. 608.

= *L. grandis* var. *divisa* (Kützing) Grunow *in* Van Heurck

VAN HEURCK, 1885, pl. 48, fig. 4-5. HUSTEDT, *ibid.*, fig. 609.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); île Maurice.

OCÉAN INDIEN : très rare. Indonésie; « océan Indien »; Inhaca. (SILVA, 1960).

DISTRIBUTION MONDIALE : espèce peu courante, probablement cosmopolite.

Licmophora Aurivillii Cleve, 1901

Pl. VI, fig. 42 a-b

CLEVE, 1901, p. 29, 58, fig. 2.

Cellules coloniales (type de colonies caractéristique du genre), de grande taille (axe apical : 300-800 μ). Valves extrêmement allongées, rectilignes ou légèrement infléchies, dissymétriques : sub-capituliformes à une extrémité, renflées à l'autre extrémité ainsi qu'au voisinage de celle-ci; largeur transapicale au niveau des renflements : 10-20 μ. Ornementation des valves (selon CLEVE) : deux rangées de stries transapicales très serrées, « au moins 28 en 10 μ » (?), laissant entre elles un pseudoraphé bien visible. Septa apparemment absents. Ceinture formée de stries parallèles très fines. Chromatophores nombreux, punctiformes, répartis dans toute la cellule mais partiellement concentrés au niveau du renflement sub-terminal. Parois très fines, colonies très fragiles.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice.

OCÉAN INDIEN ET OCÉAN MONDIAL : l'espèce semble ne pas avoir été signalée depuis sa découverte originelle par CLEVE (diverses stations dans l'archipel indonésien).

L'appartenance de cette espèce au genre *Licmophora* reste à confirmer, car, mis à part les septa — non décrits —, les affinités avec le genre voisin *Licmosphenia* sont manifestes (au sujet de ce dernier, voir MERESCHKOWSKY, 1902, et HUSTEDT, 1931, p. 85).

Licmosphenia (?) ***Mereschkowskyi,*** nov. sp.

Pl. VI, fig. 40

Cellulae solitariae (?). Valvae maxime productae, rectae vel plus minus curvatae; valvae duabus extremitatibus dissimilibus: una aperte capitulata, altera duobus tumoribus inflata; valvae inter extremitates undulatae, sicut « Synedra undulata ». Structura cinguli saeptorumque incognita. Tenuissimi parietes. Longitudo inter apices: 700-850 μ; *latitudo tumororum:* 15 μ.

Cellules solitaires (sauf information ultérieure). Valves extrêmement allongées, rectilignes ou plus ou moins incurvées, dissymétriques : nettement capituliformes à une extrémité, et doublement renflées à l'autre extrémité (les deux renflements étant presque contigus); à partir du renflement sub-terminal jusqu'à une distance variable du capitule, le contour des valves est ondulé, comme chez *Synedra undulata*. Ceinture et septa restent à décrire. Chromatophores très petits, répartis dans toute la cellule, mais partiellement concentrés au niveau du renflement sub-terminal. Parois très délicates. Longueur apicale : 700-850 μ; largeur transapicale, au niveau des renflements : 15 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé (très rare); Tuléar.

La présente description est malheureusement incomplète, puisque je n'ai pu discerner la structure connective; dans cette ignorance, le nom générique demeure incertain; les affinités sont cependant évidentes avec *Licmosphenia Clevei* et *L. Grunowii* (cf. MERESCHKOWSKY, 1902, et HUSTEDT, 1931, p. 87), ainsi qu'avec *Licmophora Aurivillii* (voir plus haut).

Je dédie cette espèce à l'auteur du genre, MERESCHKOWSKY, dont le vœu de « faire de ce genre un Panthéon diatomiste » se trouvera ainsi doublement comblé..., si toutefois le nom générique de ce taxon s'avère justifié.

Climacosphenia moniligera Ehrenberg, 1843

A la liste des synonymes de cette espèce donnés par HUSTEDT (1931) il faut ajouter, selon mon opinion personnelle, le *C. elongata* Bailey (épithète trompeuse...) tel que décrit par la majorité des auteurs. Toutefois, sous ce dernier nom, HUSTEDT et SUBRAHMANYAN ont figuré une Diatomée qui ne diffère de *C. moniligera* que par sa taille et ses proportions, et que je propose de considérer comme une variété : la distinction est en effet évidente, mais basée sur des caractères accessoires, et l'existence de stades intermédiaires n'est pas assurée; ce taxon sera dédié à HUSTEDT qui semble le premier à l'avoir observé.

var. ***moniligera***

EHRENBERG, 1843, p. 411, pl. 2/6, fig. 1. HUSTEDT, 1931, p. 89, fig. 625. CUPP, 1943, p. 178, fig. 128. SUBRAHMANYAN, 1946, p. 164, fig. 322, 325, 333-334.

= *Climacosphenia elongata* Bailey, *pro parte* :

BAILEY, 1853, p. 8, pl. 1, fig. 10-11. GRUNOW, 1862, p. 353, pl. 3, fig. 22. WOLLE, 1890, pl. 48, fig. 32-33. PERAGALLO, 1908, p. 352, pl. 86, fig. 1-4. *Non* HUSTEDT, *nec* SUBRAHMANYAN.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice.

OCÉAN INDIEN : mers indonésiennes; côtes des Indes, d'Australie; Tuléar. (TRAVERS, 1965).

DISTRIBUTION MONDIALE : mers tempérées et tropicales; littorale.

var. ***Hustedtii***, nom. nov.

= *Climacosphenia elongata* Bailey *pro parte* :

HUSTEDT *in* SCHMIDT, 1914, pl. 308, fig. 5-10; HUSTEDT, 1931, cf. p. 90, et fig. 626. SUBRAHMANYAN, 1946, p. 164, fig. 323, 327-329, 335. *Non al.*

? = *Climacosphenia truncata* Hustedt *in* A. Schmidt

SCHMIDT, 1914, fig. 1-4, 11.

Se distingue de la variété-type par lès caractères suivants : valves très allongées (longueur apicale : 500 - 1300 µ), en deux parties assez distinctes : l'une plus épaisse et la plus courte (moins de 1/5 de la longueur apicale), l'autre filiforme.

Récoltes personnelles : Nossi-Bé (très rare); île Maurice.

Océan Indien et océan mondial : distribution actuellement impossible à distinguer de celle de la variété-type : comme démontré ci-dessus, le nom de *C. elongata* est en effet à double sens; la présente variété semble néanmoins beaucoup plus rare.

Podocystis spathulata (Shadbolt) Van Heurck, 1896

Shadbolt, 1854, p. 14, pl. 1, fig. 3 : « *Euphyllodium spathulatum* ». Van Heurck, 1896, p. 365. Peragallo, 1908, p. 261, pl. 68, fig. 12. Hustedt, 1931, p. 133, fig. 653. Hendey, 1964, cf. p. 169, et pl. 27, fig. 3.

? = *Podocystis ovalis* Misra

Misra, 1956, p. 554, fig. 38.

Récoltes personnelles : île Maurice.

Océan Indien : espèce peu commune. Mers indonésiennes; Canal de Mozambique. (Shadbolt, 1854; Amossé, 1924; Travers, 1965).

Distribution mondiale : espèce littorale, principalement tempérée et tropicale (confusion fréquente avec *P. adriatica:* voir Hendey, *loc. cit.*).

Grammatophora marina (Lyngbye) Kützing, 1844

Lyngbye, 1819, p. 180, pl. 62 A : « *Diatoma marinum* ». Kützing, 1844, p. 128, pl. 17, fig. 24, et pl. 18, fig. 1. Hustedt, 1931, p. 43, fig. 569. Cleve-Euler, 1953, p. 12, fig. 305. Hendey, 1964, p. 170.

Récoltes personnelles : Nossi-Bé; Tuléar.

Océan Indien : peu fréquente, mais rencontrée sous toutes les latitudes. Indonésie; Ceylan; Tasmanie; Kerguelen; Afrique du Sud; Antarctique. Espèce nouvelle pour la région étudiée. (Taylor, 1967).

Distribution mondiale : cosmopolite (sous plusieurs variétés).

L'auxosporulation par voie sexuée a été récemment décrite chez cette espèce par Magne-Simon (1960, 1962).

Grammatophora undulata Ehrenberg, 1840

Ehrenberg, 1840a, p. 161; 1843, p. 322, pl. 3/7, fig. 33; 1854, pl. 18, fig. 87 b, et pl. 19, fig. 37. Kützing, 1844, p. 129, pl. 29, fig. 68. Hustedt, 1931, p. 48, fig. 576. Subrahmanyan, 1946, p. 163, fig. 320, 324, 326.

Récoltes personnelles : Nossi-Bé.

Océan Indien : Madagascar; Ceylan; côtes des Indes; mers indonésiennes; Antarctique (?).

Distribution mondiale : zone intertropicale et Méditerranée.

Rhabdonema adriaticum Kützing, 1844

Pl. XIII, fig. 86

Kützing, 1844, p. 126, pl. 18, fig. 7. Hustedt, 1931, p. 23, fig. 552. Hendey, 1937, p. 339, pl. 11, fig. 2, et 1964, p. 172.

? = *Rhabdonema sutum* Mann

Mann, 1925, p. 141, pl. 31, fig. 1-2.

Récoltes personnelles : Nossi-Bé; Tuléar; île Maurice.

Océan Indien : Madagascar; Ceylan; Indonésie; Tasmanie; île Saint-Paul. (Travers, 1965).

Distribution mondiale : espèce littorale cosmopolite, plus rare dans les mers froides.

Rhabdonema punctatum (Harvey et Bailey) Stodder *ex* Boyer, 1926

Pl. XIII, fig. 87

Harvey et Bailey, 1854, p. 430 : « *Hyalosira punctata* ». Boyer, 1926, p. 150. Cf. Stodder, 1880, p. 114.

= *Hyalosira punctata* Harvey et Bailey

Harvey et Bailey, *loc. cit.* Bailey et Harvey, 1860 et 1874, p. 181, pl. 9, fig. 29-30. Pritchard, 1861, p. 804.

= *Rhabdonema mirificum* W. Smith

Smith, 1856, p. 35. Walker-Arnott, 1858, p. 92. Brightwell, 1859, p. 180, pl. 9, fig. 11. Pritchard, 1861, p. 805, pl. 8, fig. 12. Janisch et Rabenhorst, 1863, p. 12, pl. 2, fig. 19. Schmidt, env. 1900, pl. 217, fig. 1-3. Subrahmanyan, 1946, p. 161, fig. 316, 318-319.

= *Climacosira mirifica* (W. Smith) Grunow

Grunow, 1862, p. 424, pl. 9, fig. 3 b-c. Van Heurck, 1896, p. 361, fig. 112.

Cellules aplaties, solitaires ou formant des chaînes rubanées. En vue connective : contour quadrangulaire, angles arrondis; ceinture formée de dissépiments alternant de part et d'autre d'un axe médian pervalvaire, et portant des ponctuations à intervalles plus ou moins réguliers.

En vue valvaire : valves bacilliformes, striées transversalement (environ 10-12 stries en 10 µ). Chromatophores aplatis et laciniés, formant des groupes étoilés répartis dans toute la cellule. Longueur de l'axe apical : 80-200 µ (exceptionnellement dans mes récoltes : 320 µ).

RÉCOLTES PERSONNELLES : Tuléar; île Maurice.

OCÉAN INDIEN : Madagascar; Ceylan; Indonésie; côtes des Indes; île Maurice; mer Rouge. (DE-TONI, 1891).

DISTRIBUTION MONDIALE : espèce littorale tropicale, rarement signalée en dehors de l'océan Indien et des mers indonésiennes : Tahiti; « Pacifique »; Honduras.

L'historique de cette espèce n'est pas sans un certain intérêt philosophique, et mérite d'être détaillé ici, « pour servir à l'Histoire de la Diatomologie » :

— 1854 et 1855 : Description par HARVEY et BAILEY de *Hyalosira punctata*, dans une sorte de « note préliminaire »; description assez précise, mais non illustrée.

— 1856 : Description par SMITH de *Rhabdonema mirificum;* description extrêmement vague, non illustrée.

— 1858 : WALKER-ARNOTT précise la diagnose de SMITH.

— 1859 : BRIGHTWELL en donne la première illustration.

— 1860 : Publication à tirage restreint (probablement non « effective ») d'un mémoire de BAILEY et HARVEY (cf. 1874).

— 1861 : RALFS, *in* PRITCHARD, reproduit les deux diagnoses, sous leurs noms respectifs, et sans suggérer aucun rapprochement (il n'avait en effet pas eu connaissance du travail précédent).

— 1874 : Publication « effective » du mémoire de BAILEY et HARVEY, comprenant deux figures du *Hyalosira punctata*. Il devient alors évident que les deux espèces sont synonymes.

— 1880 : STODDER réunit les deux espèces, sans proposer toutefois de nouvelle désignation, ce que fera ultérieurement BOYER (1926) en attribuant le nouveau taxon à STODDER.

Ce dernier auteur concluait à l'importance de l'iconographie dans les descriptions de Diatomées nouvelles, et citait à ce sujet l'opinion contraire d'un « éminent » contemporain (que je n'ai pu identifier) : « Figures are nothing, description is all... »

Fam. ACHNANTHACEAE

Achnanthes longipes Agardh, 1824

AGARDH, 1824, p. 1, et 1834, p. 54. HUSTEDT, 1933, p. 427, fig. 878. CUPP, 1943, p. 192, fig. 141. HENDEY, 1951, p. 42, pl. 1, fig. 1-9, pl. 2, fig. 1-12, pl. 3, fig. 1-12, pl. 16, fig. 6-7, pl. 18, fig. 2-5; 1964, p. 174, pl. 28, fig. 1-6 et pl. 42, fig. 2. CLEVE-EULER, 1953, p. 51, fig. 600. SCHMIDT, 1958, pl. 419, fig. 6-10.

RÉCOLTES PERSONNELLES : Nossi-Bé.

OCÉAN INDIEN : espèce peu courante, mais présente sous toutes les latitudes, Antarctique compris. (SILVA, 1960; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce littorale, principalement tempérée.

Achnanthes sp.

Pl. XIII, fig. 88

Cellules coloniales, adhérant entre elles soit par leurs surfaces valvaires, soit par leurs extrémités (dans ce dernier cas, par l'intermédiaire d'un coussinet gélatineux). Valves allongées, subelliptiques, légèrement comprimées au centre; deux rangées de stries transapicales (environ 15 stries en 10 µ), interrompues le long d'une ligne apicale (raphé ou pseudoraphé). En vue connective : flexion caractéristique du genre. Deux chromatophores centraux, presque contigus. Parois cellulaires très minces. Longueur apicale : 40-50 µ.

Récoltes personnelles : je n'ai récolté qu'une seule fois cette espèce, à Tuléar : une colonie de 100 cellules environ, observée sur matériel « brut » (simplement fixé au formol).

Les caractères énumérés ci-dessus laissent croire à une espèce nouvelle. Cependant, n'ayant pu réaliser de montage et décrire précisément les deux valves, je préfère laisser l'anonymat à cette Diatomée.

Campyloneis Grevillei (W. Smith) Grunow, 1867

Smith, 1853, p. 22, pl. 3, fig. 35 : « *Cocconeis Grevillii* ». Grunow, 1867, p. 10. Petit, 1878, p. 245, pl. 14, fig. 5. Hustedt, 1933, p. 321, fig. 781. Allen et Cupp, 1935, p. 155, fig. 99. Cleve-Euler, 1953, p. 3, fig. 484. Hendey, 1964, p. 184, pl. 27, fig. 9-11.

Récoltes personnelles : Nossi-Bé; île Maurice.

Océan Indien : Madagascar; côte d'Afrique du Sud; mer de Java; Tasmanie; sub-Antarctique. (Cholnoky, 1963).

Distribution mondiale : espèce littorale, tempérée-tropicale ou cosmopolite.

Fam. NAVICULACEAE

Navicula Wawrikae Hustedt, 1961

Pl. V, fig. 35

Hustedt, 1961, p. 52, fig. 1204.

Récoltes personnelles : Nossi-Bé (espèce assez fréquente); Tuléar; île Maurice; au large de Durban; cap Saint-André; parages de Nossi-Bé et des Comores.

Océan Indien et océan mondial : cette Navicule très curieuse n'est connue que dans la baie de Naples (localité-type), ainsi qu'à Tuléar (Travers, 1965).

J'ai observé en deux occasions chez cette espèce la formation de colonies du type *Nitzschia seriata.*

Stauroneis membranacea (Cleve) Hustedt, 1959

Pl. V, fig. 37

Cleve, 1897a, p. 24, pl. 2, fig. 25-28 : « *Navicula (Stauroneis) membranacea* ». Hustedt, 1959, p. 833, fig. 1176. Hendey, 1964, p. 221, pl. 21, fig. 3.

= *Navicula membranacea* Cleve

Cleve, *loc. cit.* Gran, 1905, p. 123, fig. 166. Karsten, 1905b, p. 174, pl. 34, fig. 4 (« var. ? »). Hendey, 1937, p. 345, pl. 11, fig. 4. Cupp, 1943, p. 193, fig. 142. Cleve-Euler, 1952, p. 24, fig. 1377. Wood, 1960, p. 226, pl. 4, fig. 49 (?).

= *Stauropsis membranacea* (Cleve) Meunier

Meunier, 1910, p. 319, pl. 33, fig. 37-40.

Récoltes personnelles : Nossi-Bé (espèce plutôt estivale).

Océan Indien : mer Rouge; mer d'Arabie; Indonésie; sud du canal de Mozambique; Antarctique (?). (Taylor, 1967).

Distribution mondiale : espèce largement répandue dans les mers tempérées et tropicales.

Mastogloia rostrata (Wallich) Hustedt, 1933

Wallich, 1860, p. 43, pl. 2, fig. 5-6 : « *Stigmaphora rostrata* ». Hustedt, 1933, p. 572, fig. 1007. Taylor, 1967, pl. 90, fig. 26-27.

Récoltes personnelles : Nossi-Bé.

Océan Indien : mers indonésiennes; golfe du Bengale et îles Nicobar (localité-type); « océan Indien »; côte d'Afrique du Sud. Espèce nouvelle pour le canal de Mozambique. (Wallich, Taylor, *loc. cit.*).

Distribution mondiale : espèce probablement tropicale, peut-être océanique, très peu connue en dehors de l'océan Indien et de l'Indonésie. Honduras.

Pleurosigma elongatum W. Smith, 1852

Smith, 1852, p. 6, pl. 1, fig. 4, et 1853, p. 64, pl. 20, fig. 199. Peragallo, 1890, p. 7, pl. 3, fig. 5-8. Allen et Cupp, 1935, p. 157, fig. 105. Subrahmanyan, 1946, p. 175, fig. 380-382. Hendey, 1964, p. 244.

Récoltes personnelles : Nossi-Bé.

Océan Indien : côtes des Indes; Indonésie; Kerguelen. Espèce nouvelle pour le canal de Mozambique.

Distribution mondiale : espèce littorale, cosmopolite, euryhaline.

Pleurosigma Normanii Ralfs *in* Pritchard, 1861

PRITCHARD, 1861, p. 919. ALLEN et CUPP, 1935, p. 157, fig. 106. SUBRAHMANYAN, 1946, p. 175, fig. 378-379, 385, 387. SILVA, 1952, p. 595, pl. 5, fig. 5. CHOLNOKY, 1963, p. 77. HENDEY, 1964, p. 244.

= *P. affine* var. *Normanii* (Ralfs) H. Peragallo

PERAGALLO, 1890, p. 10, pl. 4, fig. 6-7, et 1908, p. 162, pl. 32, fig. 4-6.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : Madagascar; Indonésie; côtes des Indes; Afrique du Sud. (TAYLOR, 1967; CHOLNOKY, *loc. cit.*).

DISTRIBUTION MONDIALE : espèce très courante, cosmopolite.

Pleurosigma directum Grunow *in* Cleve et Grunow, 1880

Pl. V, fig. 36

CLEVE et GRUNOW, 1880, p. 53. PERAGALLO, 1890, p. 14, pl. 5, fig. 29. KARSTEN, 1905a, p. 127, pl. 18, fig. 5. HARDY, 1935, p. 60. HENDEY, 1937, p. 348. SILVA, 1956a, p. 50, pl. 8, fig. 4.

Contour des valves lancéolé, presque symétrique par rapport aux axes apical et transapical; extrémités aiguës. Raphé presque droit. Ornementation très difficilement visible, environ 20 stries en 10 μ. Parois très légères. Deux chromatophores filiformes, sinueux, déployés dans toute la cellule. Longueur apicale : 180-600 μ; largeur transapicale : 35-45 μ.

(Voir aussi : var. *membranaceum* Subrahmanyan, 1946.)

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : rare sous les basses latitudes (Sumatra, mer d'Arabie, côte du Mozambique), plus fréquente dans l'Antarctique. (SILVA, 1956a; TAYLOR, 1967).

DISTRIBUTION MONDIALE : cette espèce est probablement cosmopolite. Plus commune dans les mers polaires, elle est également présente dans les eaux tempérées et chaudes (océan Indien, Méditerranée).

Gyrosigma balticum (Ehrenberg) Rabenhorst, 1853

EHRENBERG, 1834-35, p. 258, et 1838, p. 180, pl. 13, fig. 10 : « *Navicula baltica* ». RABENHORST, 1853, p. 47, pl. 5, fig. 6. CLEVE, 1894b, p. 118. SUBRAHMANYAN, 1946, p. 173, fig. 373-375. HENDEY, 1951, p. 61, pl. 11, fig. 9 et 1964, p. 248, pl. 35, fig. 9. (Espèce attribuée par erreur à CLEVE, 1894.)

= *Pleurosigma balticum* (Ehrenberg) W. Smith

SMITH, 1853, p. 66, pl. 22, fig. 207. PERAGALLO, 1891, p. 18, pl. 7, fig. 19-20, et 1908, p. 169, pl. 34, fig. 9-10.

RÉCOLTES PERSONNELLES : Nossi-Bé.

OCÉAN INDIEN : Tuléar; côtes d'Australie; Ceylan; Indonésie; côtes des Indes. (TRAVERS, 1965).

DISTRIBUTION MONDIALE : espèce largement répandue dans les eaux littorales tempérées et tropicales, et dans les estuaires; totalement euryhaline.

Fam. CYMBELLACEAE

Amphora cf. ***ostrearia*** Brébisson *in* Kützing, 1849

KÜTZING, 1849, p. 94. PERAGALLO, 1908, p. 219, pl. 49, fig. 13. SUBRAHMANYAN, 1946, p. 185, fig. 418-419. HENDEY, 1951, p. 71, et 1964, p. 266, pl. 38, fig. 5. SILVA, 1956a, p. 52, pl. 8, fig. 10.

RÉCOLTES PERSONNELLES : Nossi-Bé; île Maurice.

OCÉAN INDIEN : rare. Mer de Java; côtes des Indes.

DISTRIBUTION MONDIALE : probablement cosmopolite, sous diverses formes et variétés (cf. : CLEVE-EULER, 1953; HENDEY, 1964).

Amphora cf. ***decussata*** Grunow, 1867

GRUNOW, 1867a, p. 23, et 1877, p. 178, pl. 195, fig. 9. ALLEN et CUPP, 1935, p. 161, fig. 116. SUBRAHMANYAN, 1946, p. 185, fig. 414-415. HENDEY, 1964, p. 266, pl. 37, fig. 9.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare); île Maurice.

OCÉAN INDIEN : comme l'espèce précédente.

DISTRIBUTION MONDIALE : espèce rarement signalée, de distribution incertaine.

Fam. BACILLARIACEAE

Bacillaria paxillifer (O. F. Müller) Hendey, 1951

MÜLLER, 1786, p. 54, pl. 7, fig. 3-7 : « *Vibrio paxillifer* ». HENDEY, 1951, p. 74, et 1964, p. 274, pl. 21, fig. 5.

= *Bacillaria paradoxa* Gmelin

GRAN, 1905, p. 131, fig. 178. LEBOUR, 1930, p. 211, fig. 175. HUSTEDT, 1955, p. 43. CHOLNOKY, 1963, p. 41.

= *Nitzschia paradoxa* (Gmelin) Grunow

VAN HEURCK, 1885, p. 176, pl. 61, fig. 6. PERAGALLO, 1908, p. 280, pl. 72, fig. 16.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; île Maurice; Durban.

OCÉAN INDIEN : espèce courante, rencontrée jusque dans l'Antarctique. (SILVA, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce littorale, particulièrement euryhaline, cosmopolite.

Nitzschia spathulata Brébisson *in* W. Smith, 1853

SMITH, 1853, p. 40, pl. 31, fig. 268. VAN HEURCK, 1885, p. 177, pl. 62, fig. 7-8, et 1896, p. 393, pl. 16, fig. 523. PERAGALLO, 1908, p. 284, pl. 73, fig. 4. MEUNIER, 1910, p. 332, pl. 34, fig. 16-26. SILVA, 1949, p. 330, pl. 3, fig. 21. CLEVE-EULER, 1952, p. 71, fig. 1455. HENDEY, 1964, p. 281.

RÉCOLTES PERSONNELLES : Nossi-Bé (rare).

OCÉAN INDIEN : rare. Indonésie; côte du Mozambique. (SILVA, 1956a).

DISTRIBUTION MONDIALE : sporadique, mais cosmopolite; espèce toutefois plus abondante dans les mers tempérées.

Nitzschia closterium (Ehrenberg) W. Smith, 1853

EHRENBERG, 1841, p. 144, pl. 4, fig. 7 : « *Ceratoneis closterium* ». SMITH, 1853, p. 42, pl. 15, fig. 120. HENDEY, 1937, p. 352, pl. 11, fig. 1, et 1964, p. 283, pl. 21, fig. 8. CUPP, 1943, p. 200, fig. 153. HASLE, 1964, p. 16, fig. 1-10, pl. 5, fig. 1, pl. 7, fig. 1-13, pl. 8, fig. 1-9, pl. 9, fig. 1-9, et pl. 10, fig. 1-4.

= *N. longissima* var. *closterium* (W. Smith) Van Heurck

VAN HEURCK, 1885, p. 185, pl. 70, fig. 5, 7-8; 1896, p. 405, fig. 126, et pl. 17, fig. 570. CLEVE-EULER, 1952, p. 92, fig. 1508 d.

RÉCOLTES PERSONNELLES : Nossi-Bé (espèce parfois abondante) et presque toutes les récoltes néritiques.

OCÉAN INDIEN : espèce commune sous toutes les latitudes, Antarctique compris. (SILVA, 1956a, 1960; TRAVERS, 1965).

DISTRIBUTION MONDIALE : cosmopolite, essentiellement — mais non exclusivement — néritique.

Nitzschia longissima (Bréb. *in* Kützing) Ralfs *in* Pritchard, 1861

KÜTZING, 1849, p. 891 : « *Ceratoneis longissima* ». PRITCHARD, 1861, p. 783, pl. 4, fig. 23, *non* 22. CUPP, 1943, p. 200, fig. 154. HENDEY, 1951, p. 73, et 1964, p. 283. HASLE, 1964, p. 20, pl. 1, fig. 2, pl. 5, fig. 6, pl. 10, fig. 5-7, et pl. 11, fig. 1-4.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar; parages de Mombasa.

OCÉAN INDIEN : espèce fréquente dans toute la zone intertropicale, exceptionnelle dans l'Antarctique. (SILVA, 1956a, 1960; KOLBE, 1957; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : difficile à distinguer de celle de *N. closterium;* peut-être plus néritique? (cf. HASLE, *loc. cit.*).

Nitzschia cf. ***seriata*** Cleve, 1883

CLEVE, 1883, p. 478, pl. 38, fig. 75. CUPP, 1943, p. 201, fig. 155. CLEVE-EULER, 1952, p. 94, fig. 1514. HENDEY, 1964, p. 284, pl. 21, fig. 6. HASLE, 1965, p. 8, pl. 1, fig. 4, pl. 3, fig. 1-7, 10, pl. 4, fig. 1-2, et pl. 6, fig. 2.

RÉCOLTES PERSONNELLES : Nossi-Bé et presque toutes les stations littorales.

OCÉAN INDIEN : espèce fréquente sous toutes les latitudes, Antarctique compris. (SILVA, 1956a, 1960; TRAVERS, 1965; TAYLOR, 1967).

DISTRIBUTION MONDIALE : espèce néritique, réputée tempérée ou arctique, mais vraisemblablement cosmopolite (cf. HASLE, *loc. cit.*).

Au sujet des espèces voisines, que je n'ai pas cherché à distinguer, voir CUPP, CLEVE-EULER *(loc. cit.)*, CUPP et ALLEN (1938), HASLE (1960) et surtout la remarquable monographie de HASLE (1965) :

N. pungens Grunow, *N. pungens* var. *atlantica* Cleve, *N. pacifica* Cupp, *N. delicatissima* Cleve, *N. fraudulenta* Cleve, et *N. Heimii* Manguin.

Fam. SURIRELLACEAE

Campylodiscus biangulatus Greville, 1862

Pl. XIII, fig. 89

GREVILLE, 1862, p. 20, pl. 3, fig. 2. SCHMIDT, 1875, pl. 14, fig. 18-22, et 1900 (?), pl. 208, fig. 9-15. PERAGALLO, 1908, p. 242, pl. 55, fig. 9 (?). CROSBY et WOOD, 1959, p. 43, pl. 9, fig. 130.

? = *Campylodiscus zebuanus* Castracane

CASTRACANE, 1886, p. 62, pl. 11, fig. 10.

Non : Campylodiscus ~~decorus~~ Brébisson

Valves fortement ondulées; espace central large et rectiligne, arrondi aux extrémités apicales; côtes fortement marquées; chaque côte subit deux inflexions, plus évidentes vers les deux extrémités de l'axe apical. Diamètre : 80-110 μ.

RÉCOLTES PERSONNELLES : Nossi-Bé.

OCÉAN INDIEN : Ceylan; Indonésie; Madagascar; golfe d'Aden; Zanzibar; détroit de Bass. (AMOSSÉ, 1924).

DISTRIBUTION MONDIALE : espèce presque inconnue en dehors de l'océan Indien et de l'archipel indonésien. PERAGALLO *(loc. cit.)* et DE TONI (1891) la signalent sur les côtes atlantiques françaises et en Méditerranée.

Campylodiscus clypeus (Ehrenberg) Ehrenberg, 1840

EHRENBERG, 1836 (?) et 1838, p. 195 : « *Cocconeis clypeus* »; 1840b, p. 205, et 1854, pl. 10 (1), fig. 1, pl. 10 (2), fig. 21, pl. 13 (1), fig. 28. SCHMIDT, 1877, pl. 54, fig. 7-8, et pl. 55, fig. 1-3. VAN HEURCK, 1885, p. 191, pl. 75, fig. 1; 1896, p. 375, fig. 121, et pl. 14, fig. 598. PERAGALLO, 1908, p. 237, pl. 51, fig. 1-3. CLEVE-EULER, 1952, p. 128, fig. 1579.

RÉCOLTES PERSONNELLES : Nossi-Bé; Tuléar.

OCÉAN INDIEN : rare. Indonésie; Antarctique. Espèce nouvelle pour le canal de Mozambique.

DISTRIBUTION MONDIALE : espèce littorale, totalement euryhaline, probablement cosmopolite. (Abondante à l'état fossile.)

QUELQUES CONCLUSIONS

INNOVATIONS TAXINOMIQUES

La présente étude ne renferme qu'une seule espèce nouvelle pour la science : *Licmosphenia* (?) *Mereschkowskyi;* deux espèces insuffisamment observées sont ici laissées dans l'anonymat, quoique probablement nouvelles : *Achnanthes* sp. et *Fragilaria* sp.

Trois nouvelles combinaisons sont proposées : *Schroederella delicatula* f. *Schroederi* (Bergon), *Isthmia japonica* (Castracane), et *Triceratium pelagicum* (Schröder).

Une nouvelle variété *Hustedtii* est ici créée pour divers exemplaires de l'espèce *Climacosphenia moniligera*, différents du type et connus sous le nom (synonyme spécifique) de *C. elongata.*

A trois reprises, un nouveau nom spécifique a dû être proposé en remplacement d'une épithète illégale (homonyme postérieur : cf. LANJOUW *et al.*, 1966, article 64) : *Coscinodiscus Karstenii* (= *C. incertus* Karsten), *Rhizosolenia squamifera* (= *R. squamosa* Karsten), et *Synedra hantzschiana* (= *Synedra rostrata* [Hantzsch] Hustedt *in* A. Schmidt).

Enfin, en plusieurs occasions, on suggère dans ce travail de désigner le type d'une espèce sous un nom de variété-type ou de forme-type : *Rhizosolenia imbricata* Brightw. var. *imbricata*, *Chaetoceros didymum* Ehr. var. *didymum*, *Triceratium formosum* Brightw. f. *formosum*, etc. Ces pratiques ne constituent nullement des nouvelles combinaisons — ni même réellement des innovations taxinomiques — (cf. LANJOUW *et al.*, articles 24 et 26); leur but est de pallier l'imprécision du nom d'espèce et d'éviter la confusion avec les divers taxons infraspécifiques (dont les répartitions géographiques et les affinités écologiques respectives pourront ainsi, à l'avenir, être mieux connues). Un tel procédé est peut-être discutable du point de vue « philosophique » : voir à ce sujet VAN LANDINGHAM (1967, introduction : the « typifying variety » concept), mais son utilité, et la clarté qu'il introduit, me semblent incontestables.

RÉCAPITULATION BIOGÉOGRAPHIQUE

Les espèces, variétés et formes étudiées dans le présent travail constituent un total de 196 taxons, total dont il est intéressant d'examiner la signification biogéographique; rappelons à ce sujet, pour la même région, deux tentatives analogues de SOURNIA sur les Diatomées et Dinoflagellés planctoniques de Nossi-Bé (1968 a) et de Tuléar (1968 b).

Une catégorie préalable doit être établie pour les taxons « rares ou mal connus » qui, selon l'extension donnée à cette notion assez intuitive, s'élèvent au nombre de 30 à 50, soit un peu moins du quart de l'ensemble; parmi ceux-ci on notera particulièrement :

— *Biddulphia azorica, Rhizosolenia obtusa, R. squamifera, Fragilaria Aurivillii,* et *Licmophora Aurivillii:* signalés ici pour la première fois depuis leur découverte originelle.

— *Melosira sphaerica* (?), *Coscinodiscus Thorii, Biddulphia longicruris* var. *hyalina, B. azorica, Triceratium pelagicum, Isthmia japonica, Rhizosolenia obtusa,* et *R. alata* f. *curvirostris:* taxons nouveaux pour l'océan Indien.

Les distributions géographiques elles-mêmes, envisagées ici simplement sous l'aspect latitudinal, peuvent être groupées comme suit (divers taxons trop mal connus étant laissés de côté) :

— Cosmopolites : environ 66 taxons.

— Zones tropicales et tempérées de l'océan mondial (Diatomées thermophiles mais relativement eurythermes) : environ 63.

— Zone tropicale seule (Diatomées thermophiles sténothermes) : environ 26.

— Océan Indien : 5 taxons peuvent être provisoirement considérés comme « endémiques » dans cet océan (tel que défini *sensu lato*, p. 7); cette catégorie est toutefois de nature douteuse, et les espèces qui la constituent sont d'ailleurs mal connues : *Rhizosolenia squamifera*, *Hemiaulus indicus*, *Detonula moseleyana*, *Licmophora Aurivillii* et *Fragilaria Aurivillii*.

— Mers froides : 2 des espèces récoltées, *Dactyliosolen antarcticus* et *Pleurosigma directum*, étaient jusqu'ici réputées psychrophiles, mais ceci semble en fait assez douteux (voir p. 61 et 96).

— Une espèce enfin, rencontrée à Nossi-Bé en saison des pluies, semble d'origine dulcaquicole (*Fragilaria crotonensis*) ; par ailleurs, *Gyrosigma balticum*, récoltée uniquement elle aussi en zone littorale (Nossi-Bé), est à signaler pour son euryhalinité.

Il ressort de cette énumération que les taxons purement tropicaux sont peu nombreux (26 sur 196) et que, d'autre part, l'hypothèse d'un peuplement particulier à l'océan Indien est très peu probable; on voit d'ailleurs, en combinant les trois premiers groupes, que 155 Diatomées sur 196, soit les 4/5 des taxons que j'ai récoltés dans le canal de Mozambique, sont, à des titres divers (cosmopolites, eurythermes ou thermophiles), répandues dans les eaux tropicales des trois grands océans, le dernier cinquième étant essentiellement composé d'espèces encore trop mal connues pour que leur biogéographie puisse actuellement être esquissée.

REMARQUES SUR LA BIBLIOGRAPHIE

Une vue d'ensemble sur le présent travail montre que de très nombreux synonymes y sont cités (encore ai-je évité, sauf intérêt particulier, de reproduire les synonymies exposées par Hustedt ou Hendey). Il convient ici de distinguer entre :

— **Les synonymies « discutables »** : tantôt admises et tantôt rejetées, elles traduisent les fluctuations mêmes de la systématique; par exemple : *Coscinodiscus nobilis* Grunow = ? *C. concinnus* W. Smith. La résolution de tels problèmes suppose une étude de la variabilité spécifique et, souvent, la connaissance de la structure fine des frustules. Sous ces deux aspects, la diatomologie moderne dispose de deux auxiliaires, respectivement : la technique des cultures (à titre d'exemple, voir le *Coscinodiscus* étudié par Holmes et Reimann, 1966), et la microscopie électronique (diverses applications *in* Hasle, 1964, 1965, et Hasle et Mendiola, 1967).

Notons que, dans le cas de descriptions originelles insuffisantes, certaines synonymies de ce type restent à jamais insolubles; ainsi : *Triceratium orbiculatum* Shadbolt = ? *T. shadboltianum* Greville.

Rappelons aussi cette particularité de la systématique des Diatomées, à savoir que la notion d'espèce, dans ce groupe, se base uniquement sur le critère « morphologie externe ». Au sujet de la signification taxinomique possible du contenu cellulaire, voir Ross (1963), Hendey (1964), et, pour un exemple d'application, Simon (1954).

— **Les synonymies « indiscutables »** : leur origine tient le plus souvent à une insuffisance bibliographique, et leur sort relève uniquement (sinon « simplement »...) des règles fixées par le Code international de la nomenclature botanique (Lanjouw *et al.*, 1966). Ainsi : *Hyalosira punctata* Harvey et Bailey = *Rhabdonema mirificum* W. Smith. Regrettons ici le peu d'usage que font de ce livre les planctologistes : certains auteurs modernes, ignorant manifestement l'existence même de ce Code, n'en ont pas moins créé des espèces ou combinaisons nouvelles...

Le problème des synonymes n'est qu'un des aspects du malaise général qu'éprouve actuellement la diatomologie. Outre que cette science a progressé, au cours du XIX^{e} siècle et jusqu'à des temps assez récents, dans une liberté excessive, parfois selon les caprices de diatomophiles plus « collectionneurs » que scientifiques, il faut compter maintenant avec l'extrême dissémination des publications, les difficultés d'accès aux travaux très anciens, et le nombre trop restreint d'ouvrages récapitulatifs tels que monographies régionales, révisions génériques, index, etc. Sur ce dernier point, on doit louer la toute récente initiative de VAN LANDINGHAM (1967), qui a entrepris de remettre à jour l'index de MILLS (1933-35)*.

Deux remèdes à ce malaise bibliographique peuvent être envisagés : d'une part, un usage plus répandu (sinon obligatoire...) du Code de nomenclature et de l'index mentionné ci-dessus; d'autre part, la constitution d'un fichier taxinomique mondial (du moins pour les genres planctoniques), selon le type réalisé par DEFLANDRE pour les Flagellés fossiles**.

Dans l'état actuel de la diatomologie, il n'est finalement pas déraisonnable d'avancer qu'il existe dans la bibliographie davantage d'espèces (planctoniques) en sommeil qu'il ne reste dans les mers d'espèces nouvelles à découvrir...

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* C'est seulement au moment de rédiger ces « Quelques conclusions » que je reçois le premier volume de ce nouveau catalogue : je n'ai donc pu en tenir aucun compte dans la réalisation de ce travail, d'où les omissions et divergences possibles.

** Cf. *Fichier micropaléontologique général*(C.N.R.S.). Je dois à M. le Professeur G. DEFLANDRE, Directeur du Laboratoire de Micropaléontologie de l'École pratique des Hautes Études, de nombreux encouragements et conseils.

INDEX ALPHABÉTIQUE

Les taxons infraspécifiques auraient démesurément allongé cet index : celui-ci se limite donc aux genres et aux espèces.

En italique : Espèces synonymes, ou citées allusivement dans le cours du présent travail (certains taxons mentionnés de façon purement incidentelle ont été volontairement omis).

* : Avec figure(s) ou microphotographie(s).

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ADDENDUM

Au sujet de *Coscinodiscus Karstenii* (p. 16) :

Ce nom vient d'être publié par VAN LANDINGHAM dans le second volume de son « Catalogue ». On écrira donc : *C. Karstenii* Van Landingham, et non : *C. Karstenii* Sournia.

MICROPHOTOGRAPHIES

FIG. 46. — *Coscinodiscus nobilis* Grunow. Bord de la valve, montrant les spinules marginaux, les rayons correspondants et l'un des deux apicules. Distance entre deux spinules voisins : env. 10 µ.

FIG. 47. — *Coscinodiscus nodulifer* A. Schmidt. Diamètre valvaire : 90 µ.

FIG. 48. — *Coscinodiscus asteromphalus* Ehrenberg. Portion de la valve. Diamètre valvaire : 200 µ.

FIG. 49. — *Coscinodiscus Thorii* Pavillard. Le bombement de la valve rend la mise au point très partielle. Chromatophores caractéristiques. Diamètre valvaire : 160 µ.

FIG. 50. — *Coscinodiscus radiatus* Ehrenberg. Diamètre valvaire : 55 µ.

FIG. 51. — *Coscinodiscus centralis* var. *pacificus* Gran et Angst. Diamètre valvaire : 190 µ.

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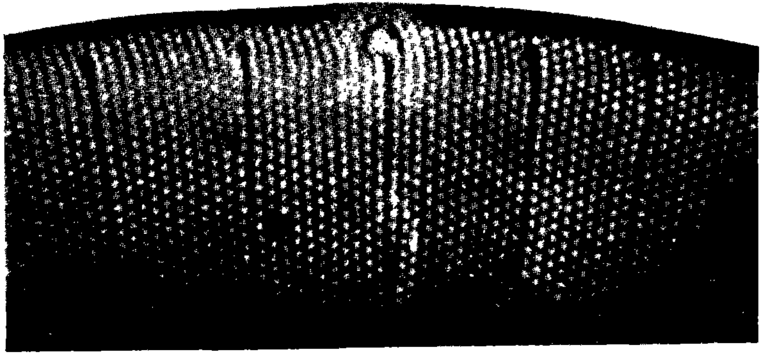

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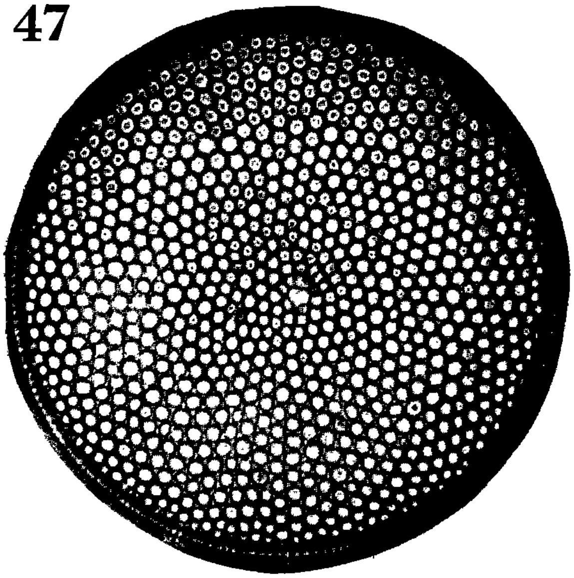

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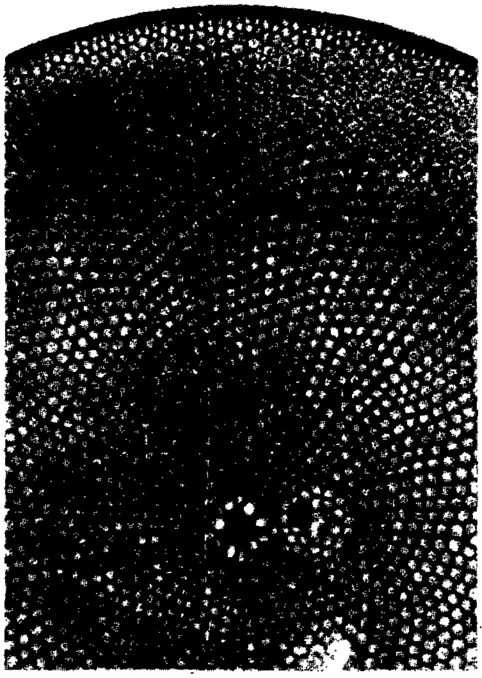

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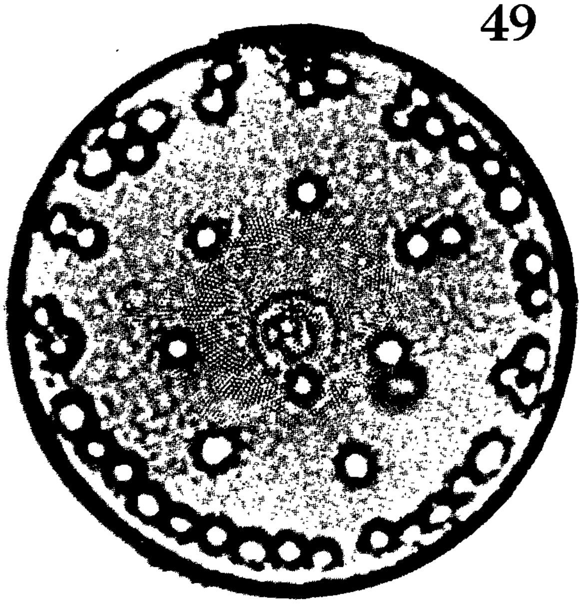

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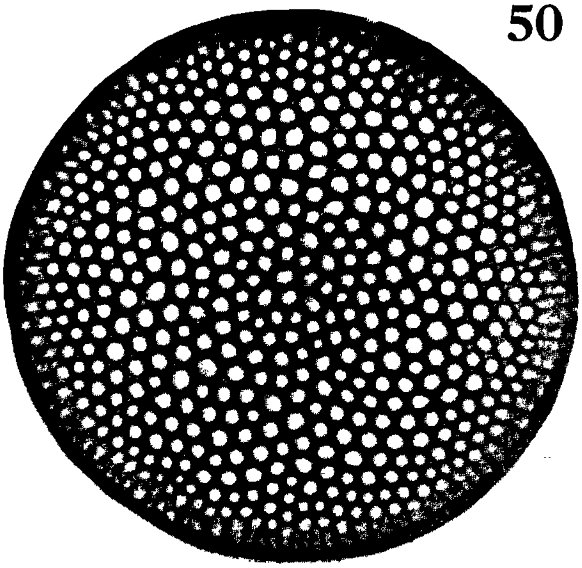

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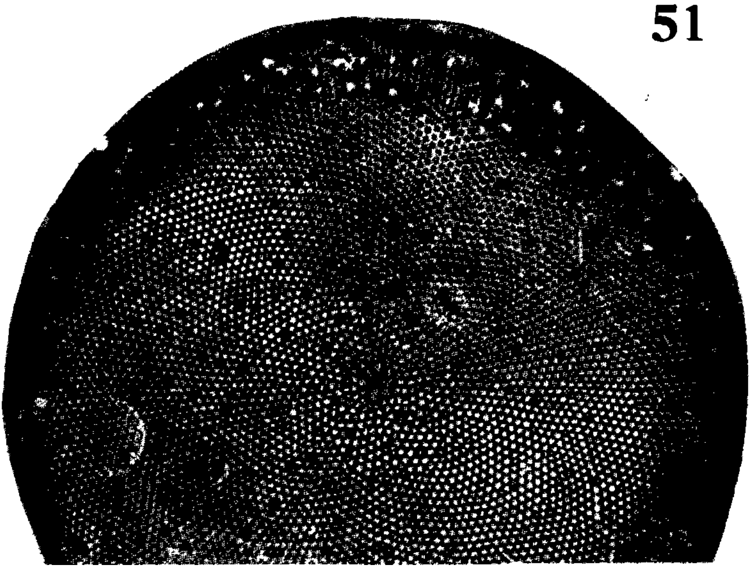

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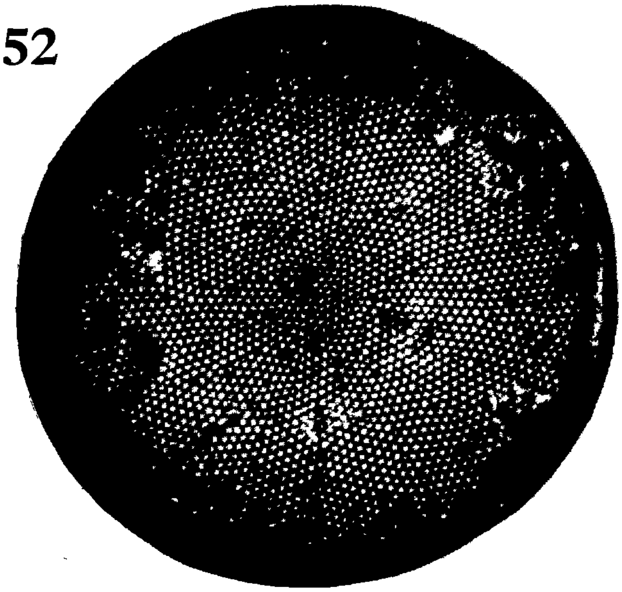

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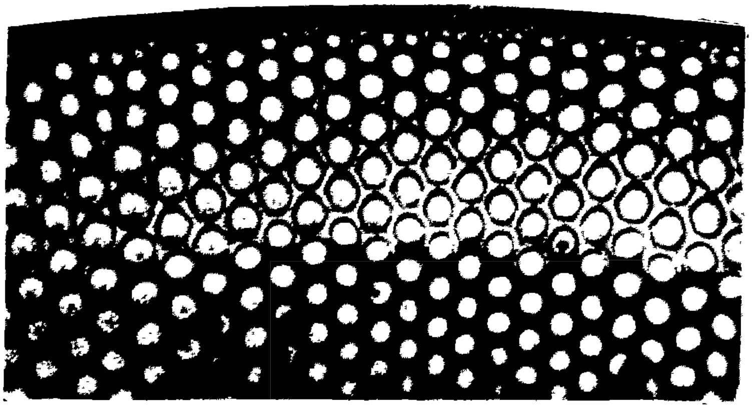

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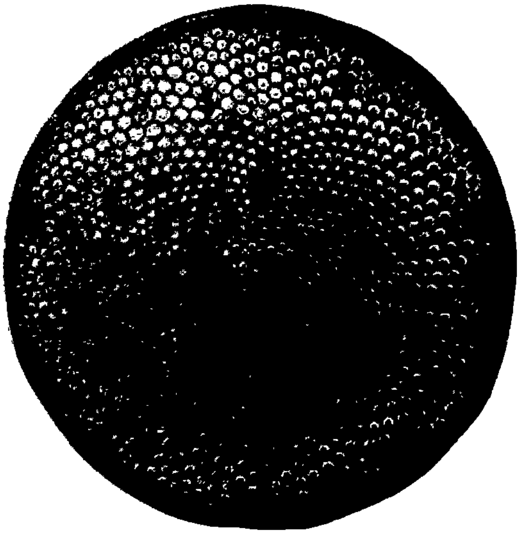

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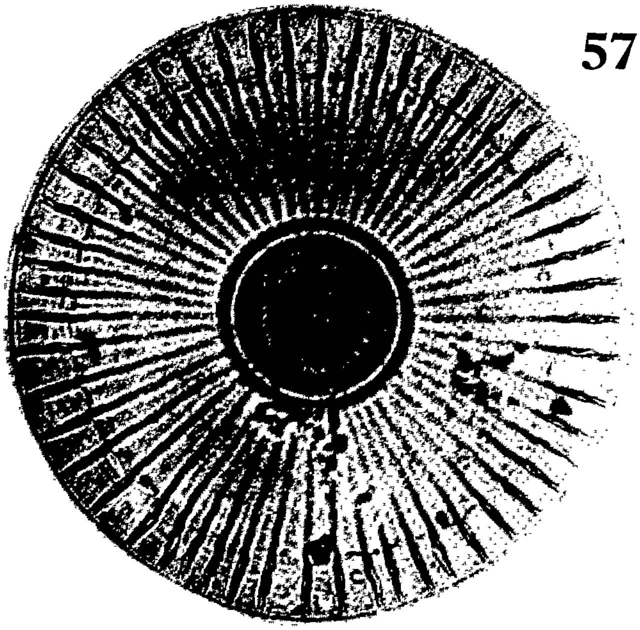

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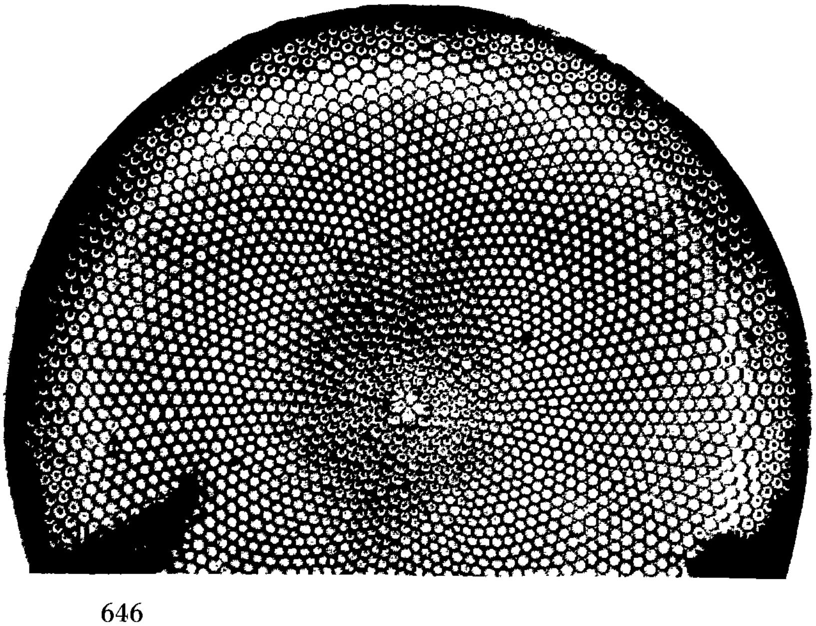

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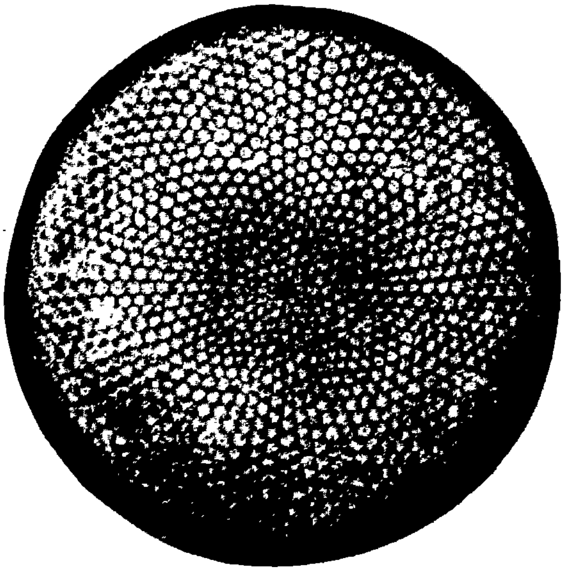

PLANCHE VIII

FIG. 52. — *Coscinodiscus Karstenii* nom. nov. Diamètre valvaire : 90 μ.

FIG. 53. — *Coscinodiscus gigas* var. *praetextus* Janisch *ex* Hustedt. Fragment du bord de la valve, montrant l'anneau marginal caractéristique de la variété. Dimensions rectangulaires du fragment : 40 × 75 μ.

FIG. 54. — *Coscinodiscus oculus-iridis* var. *borealis* (Bailey) Cleve. Diamètre valvaire : 115 μ.

FIG. 55. — *Coscinodiscus oculus-iridis* Ehrenberg var. *oculus-iridis*. Portion de la valve; diamètre : 280 μ.

FIG. 56. — *Coscinodiscus Janischii* var. *arafurensis* Grunow. Diamètre valvaire : 210 μ.

FIG. 57. — *Planktoniella sol* (Wallich) Schütt. Diamètre valvaire : 260 μ.

FIG. 58. — *Asteromphalus heptactis* (Brébisson) Ralfs *in* Pritchard. Diamètre valvaire : 95 μ.

FIG. 59. — *Asteromphalus elegans* Greville. Diamètre valvaire : 100 μ.

FIG. 60. — *Asteromphalus arachne* (Brébisson) Ralfs *in* Pritchard. Diamètre valvaire : 70 μ.

FIG. 61. — *Asteromphalus roperianus* (Greville) Ralfs *in* Pritchard. Diamètre valvaire : 85 μ.

FIG. 62. — *Roperia tessellata* (Roper) Grunow *in* Van Heurck. Diamètre valvaire : 80 μ. Le nodule marginal est indiqué par la flèche.

FIG. 63. — *Actinoptychus splendens* (Shadbolt) Ralfs *in* Pritchard. Portion de la valve; diamètre valvaire : 120 μ.

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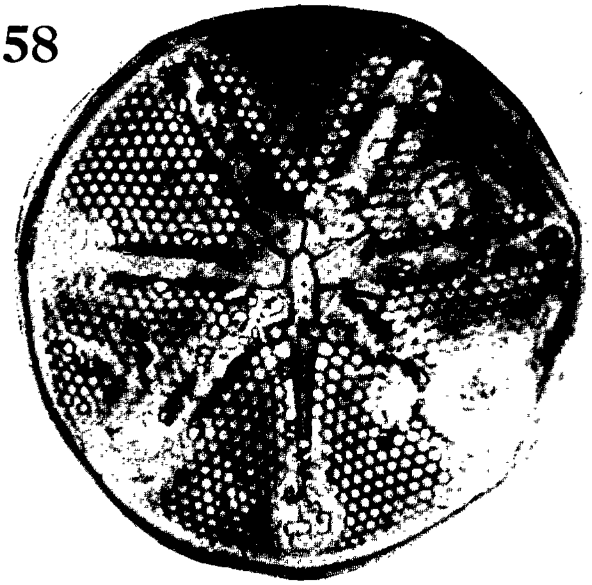

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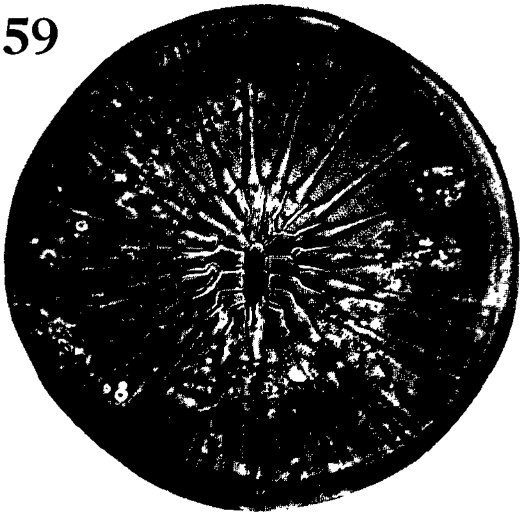

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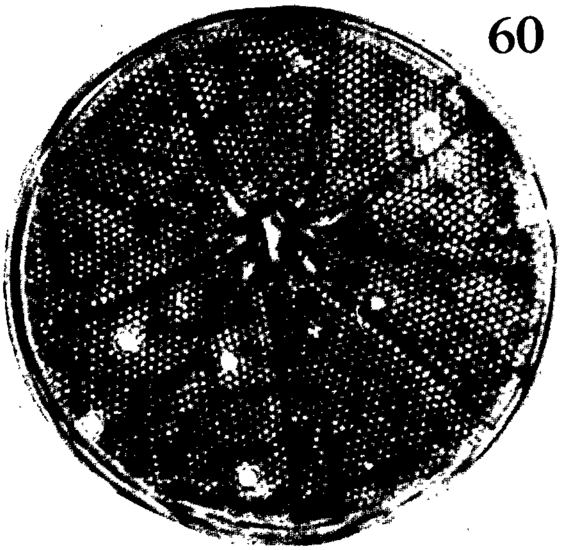

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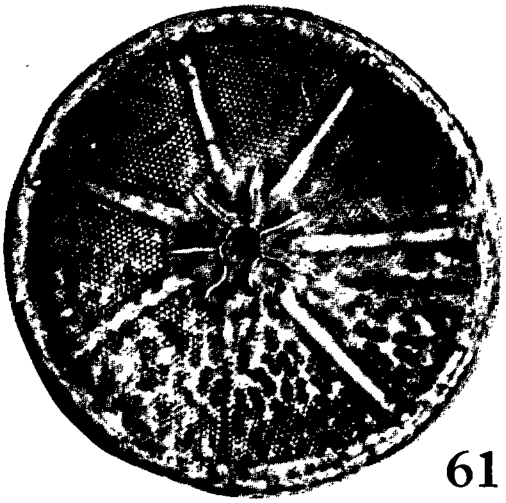

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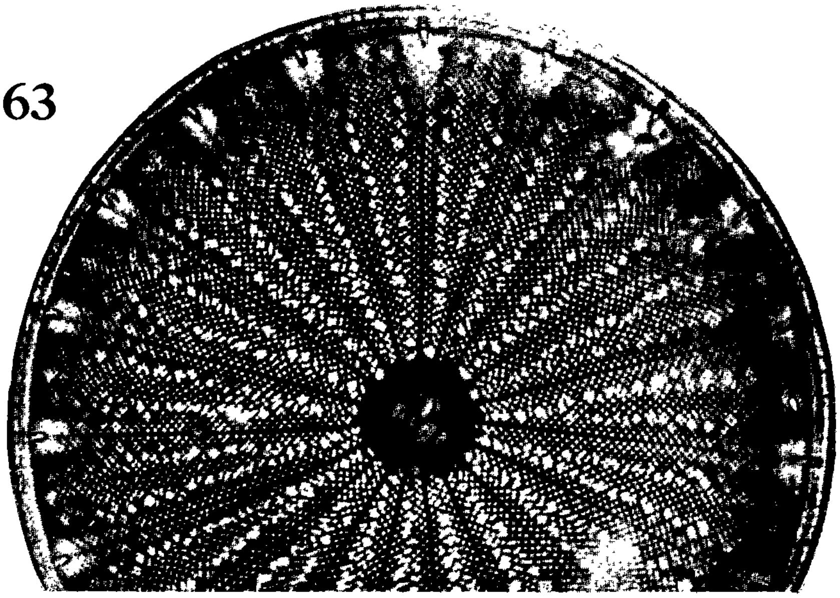

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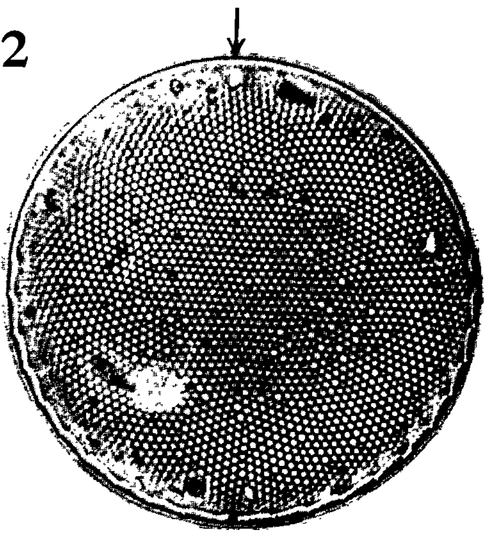

PLANCHE X

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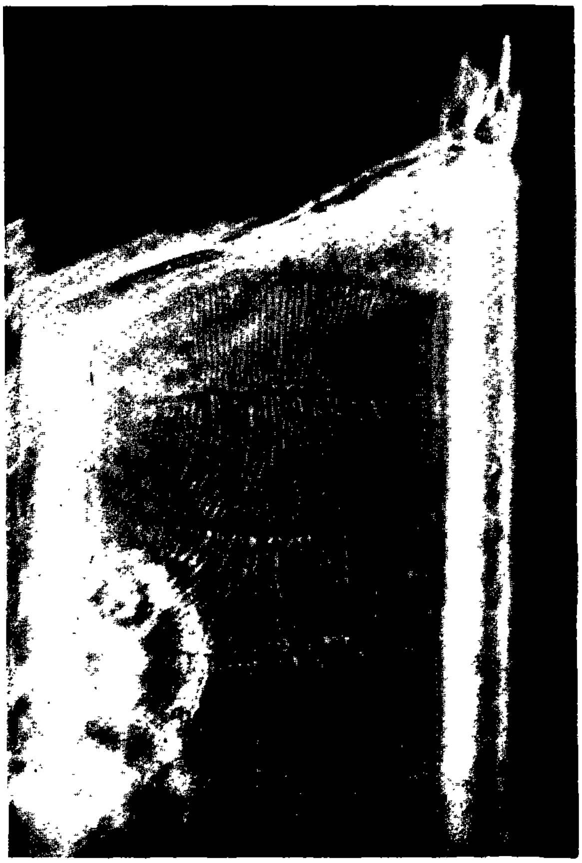

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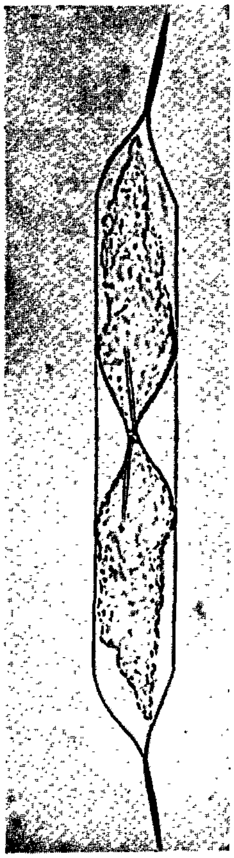

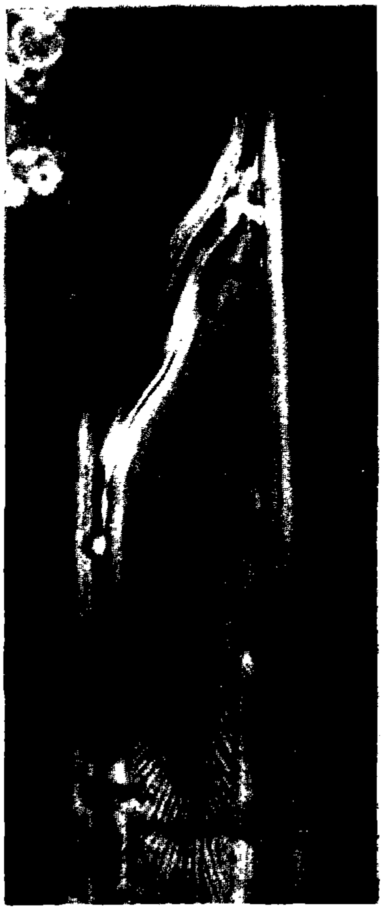

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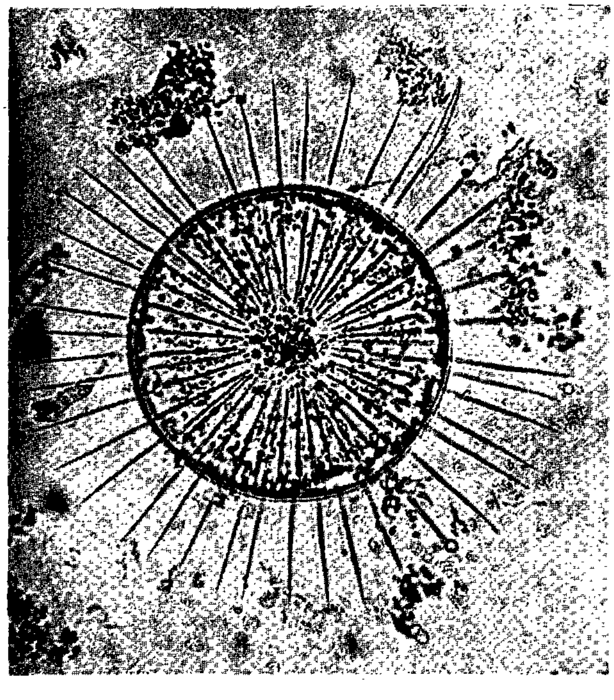

PLANCHE X

FIG. 64. — *Schroederella delicatula* (H. Peragallo) Pavillard f. *delicatula*. Auxosporulation. Diamètre valvaire : 30 µ.

FIG. 65. — *Rhizosolenia imbricata* Brightwell var. *imbricata*. Diamètre valvaire : 95 µ.

FIG. 66. — *Rhizosolenia imbricata* var. *Shrubsolei* (Cleve) Schröder. Diamètre valvaire : 30 µ.

FIG. 67. — *Rhizosolenia crassispina* Schröder. Fin d'une division. Diamètre valvaire : 60 µ.

FIG. 68. — *Rhizosolenia Clevei* Ostenfeld. Avec la Cyanophycée endophyte *Richelia intracellularis*. Diamètre valvaire : 75 µ.

FIG. 69. — *Gossleriella tropica* Schütt. Diamètre total : 280 µ.

FIG. 70-71. — *Triceratium pelagicum* (Schröder) nov. comb. Diamètre valvaire : env. 85 μ.
(70 : Extrémité d'une cellule en vue connective. 71 : Vue valvaire.)

FIG. 72-73. — *Triceratium pentacrinus* f. *quadratum* Hustedt. Longueur d'un côté de la valve : env. 105 μ.
(72 : Vue valvaire. 73 : Vue connective.)

FIG. 74. — *Biddulphia azorica* Pavillard. Deux cellules après division, en vue connective. Axe apical : 100 μ.

FIG. 75. — *Hemiaulus sinensis* Greville. Vue connective. Axe apical : 40 μ.

FIG. 76. — *Isthmia minima* Harvey et Bailey. Cellule en division. Axe apical : 50 μ.

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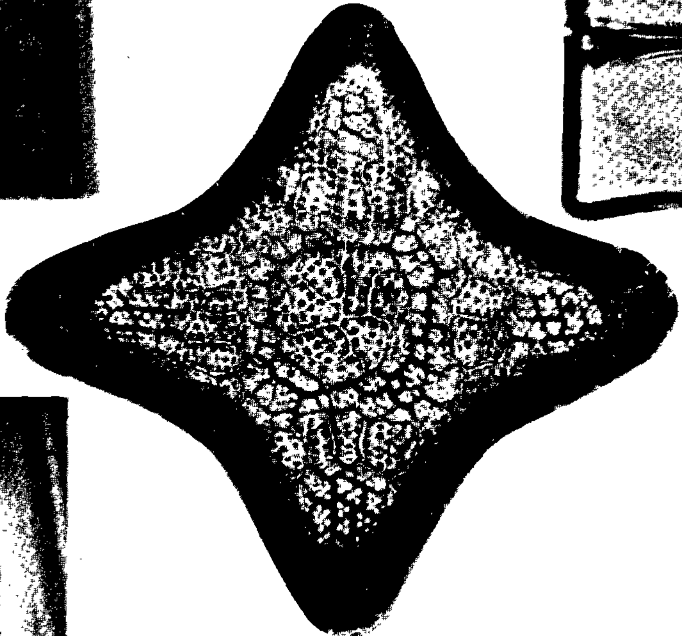

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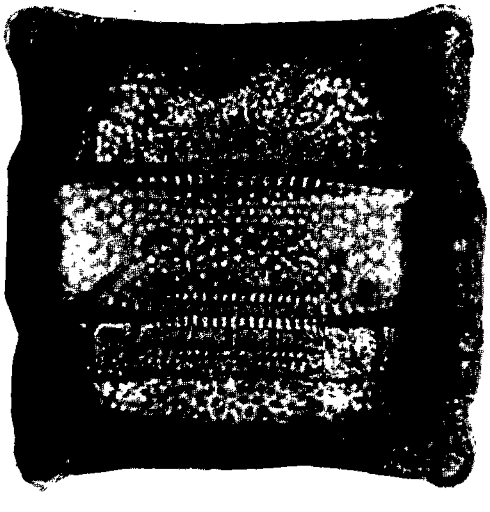

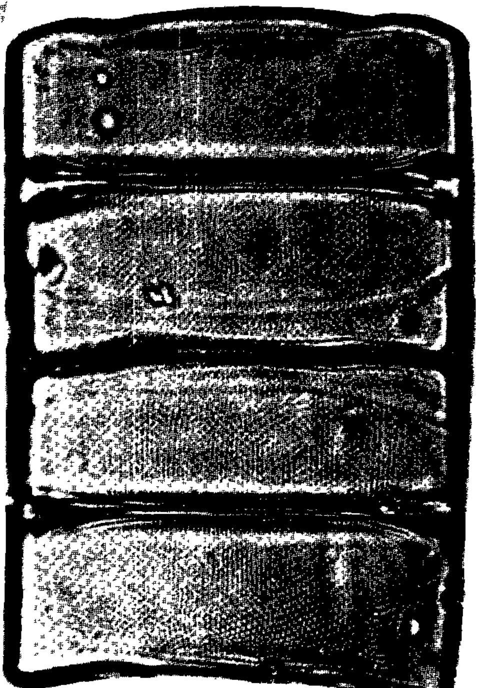

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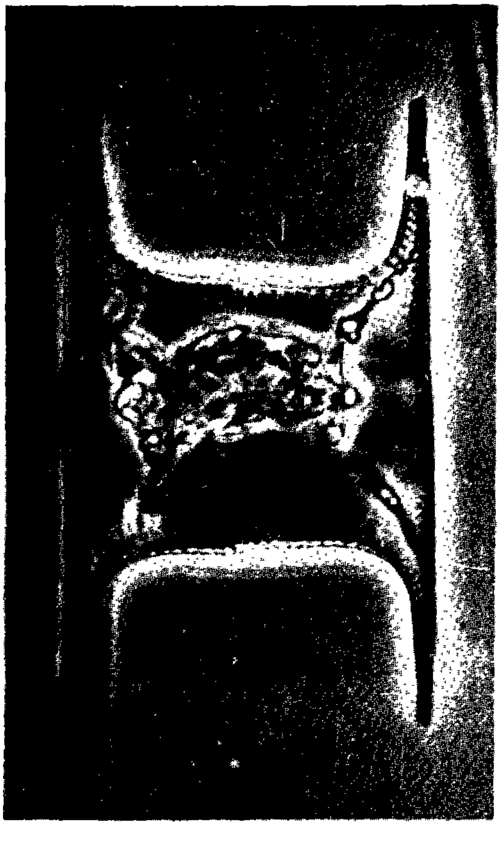

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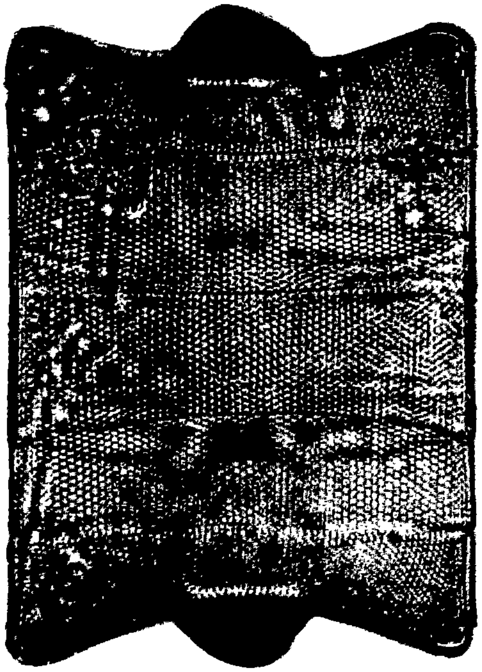

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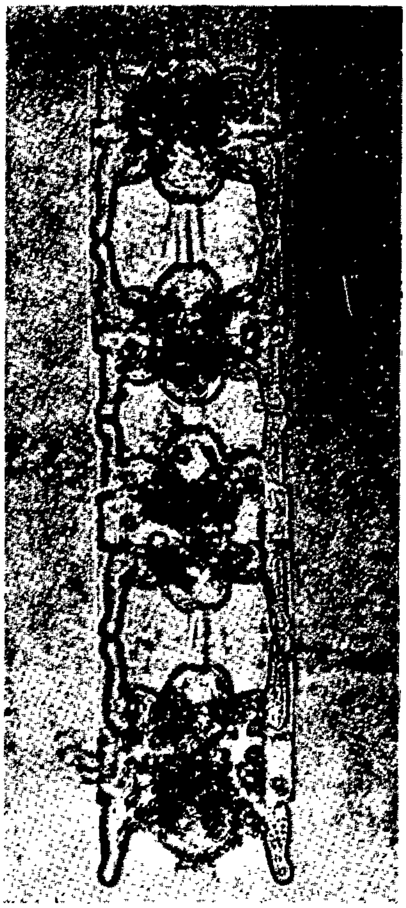

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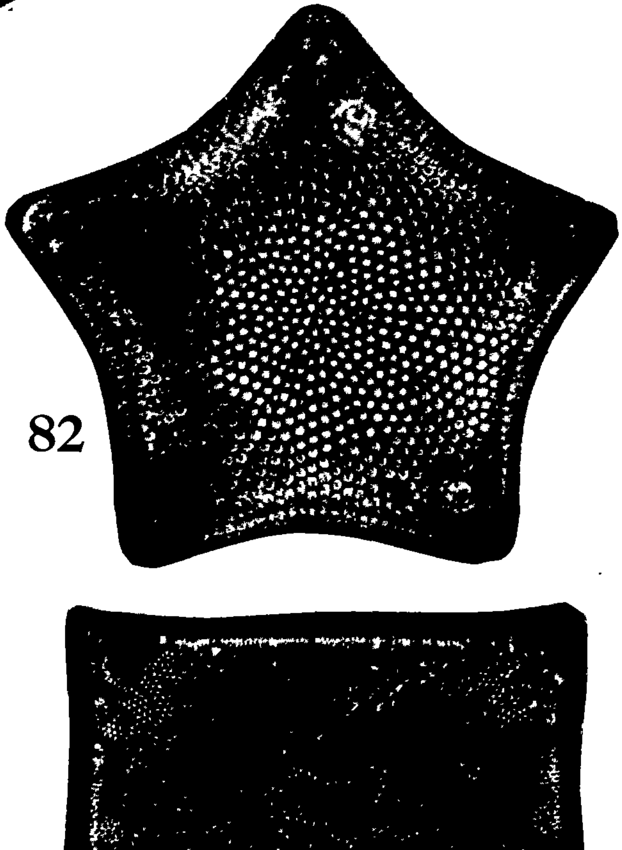

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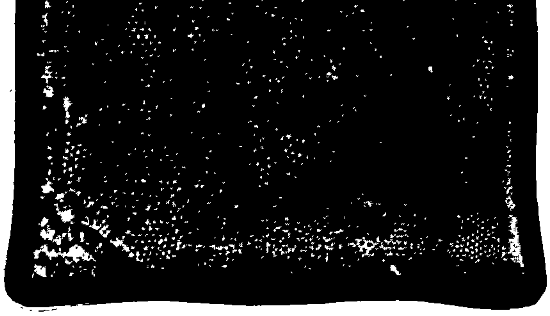

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PLANCHE XII

Fig. 77-78. — *Isthmia japonica* (Castracane) nov. comb. Axe apical : 75-80 μ. (77 : Cellule en division. 78 : Noter les nombreux points de contact entre les deux cellules voisines.)

Fig. 79. — *Isthmia minima* Harvey et Bailey. Axe apical : 30 μ.

Fig. 80. — *Triceratium formosum* Brightwell f. *formosum*. Vue connective. Longueur d'un côté de la valve : 110 μ.

Fig. 81. — *Triceratium formosum* f. *quadrangulare* (Greville) Hustedt. Vue valvaire. Longueur d'un côté de la valve : 90 μ.

Fig. 82. — *Triceratium formosum* f. *quinquelobatum* (Greville) Hustedt. Vue valvaire. Longueur d'un côté de la valve : 95 μ.

Fig. 83. — *Biddulphia tridens* (Ehrenberg) Ehrenberg. Axe apical : 55 μ.

FIG. 84. — *Triceratium shadboltianum* Greville. Extrémité d'une cellule, montrant exceptionnellement deux épines sur chacune des trois protubérances valvaires. Longueur d'un côté de la valve : 80 µ.

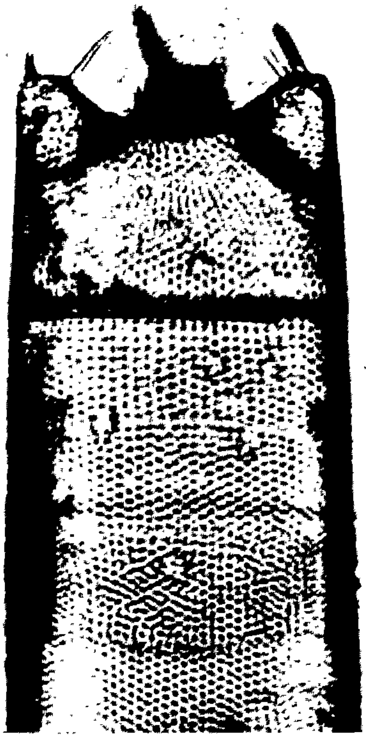
FIG. 85. — *Hemidiscus cuneiformis* Wallich. Longueur du côté sub-rectiligne de la valve : 115 µ.

FIG. 86. — *Rhabdonema adriaticum* Kützing. Axe apical : 170 µ.

FIG. 87. — *Rhabdonema punctatum* (Harvey et Bailey) Stodder *ex* Boyer. Axe apical : 190 µ.

FIG. 88. — *Achnanthes* sp. Axe apical : 40-50 µ.

FIG. 89. — *Campylodiscus biangulatus* Greville Axe apical : 105 µ.



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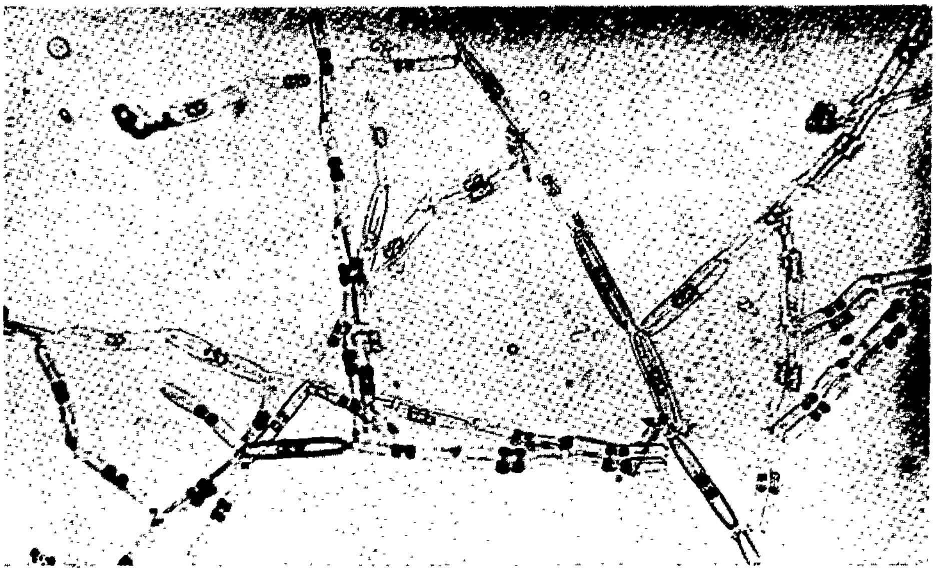

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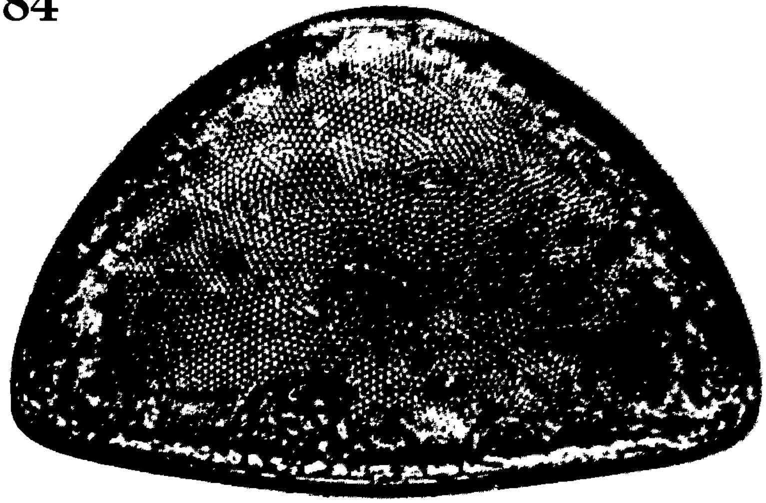

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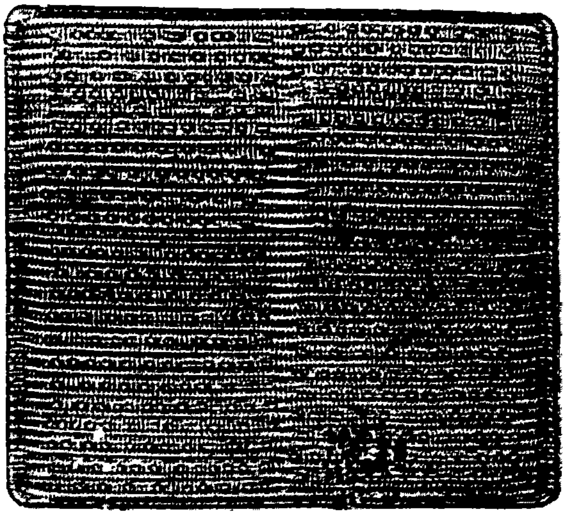

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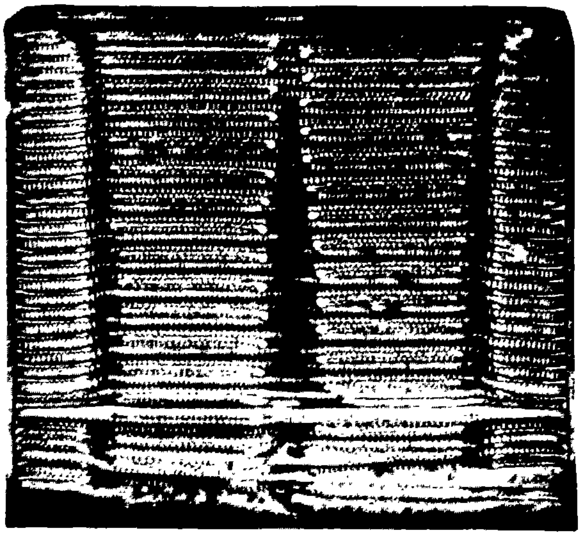

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Reprinted from *Israel J. Bot.*, vol. 17, 1968, p. 1-118

CONTRIBUTIONS TO THE KNOWLEDGE OF THE RED SEA NO. 42

A HISTORY, CATALOGUE, AND BIBLIOGRAPHY OF RED SEA BENTHIC ALGAE*

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During March and April of 1962, it was my privilege to be a participant in the Israel South Red Sea Expedition, which was based on Entedebir Islet in the Dahlak Archipelago, Ethiopia. The marine algae collected then are now being studied. By way of preparation for this study, I started shortly after my return to Berkeley to compile a list of the species of algae previously reported from the Red Sea. As the compilation progressed, it became evident that this was a larger undertaking than I had anticipated. With the encouragement of Professor H. Steinitz, the leader of the 1962 Israel Expedition, it was later decided to make a complete survey of the literature. The present paper, therefore, constitutes a historical review, a summary (in the form of an annotated catalogue of the species and taxa of lower rank), and a bibliography of what has been done up to the present on Red Sea benthic algae.

HISTORICAL REVIEW

The Red Sea has been a region of natural history exploration by European scientists for more than 200 years. Previous to the completion of the Suez Canal in 1869, travelers started their journies of exploration either from the east coast of Egypt (usually Suez), whence vessels to the Arabian coast could be obtained and thence to the Ethiopian coast, or they entered the Red Sea from the south through the Strait of Bab el Mandeb, having come by ship via the Cape of Good Hope.

The first record of marine algae from the Red Sea was by STRAND (1756, see also 1759) a pupil of LINNAEUS'S, who in his thesis on the flora of Palestine listed

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* I am indebted to the National Science Foundation in two ways in connection with this paper. Firstly, my involvement in Red Sea algae is attributable to my participation in the Israel South Red Sea Expedition of 1962. The travel and other expenses connected with my participation were borne by the United States Program in Biology for the International Indian Ocean Expedition, which Program received its funds from the National Science Foundation. Secondly, this paper was prepared with the aid of a grant from the Foundation (GB-1656). To the University of California I am indebted for granting me a leave-of-absence with salary to enable me to participate in the Israel Expedition.

I greatly appreciate having been invited to participate in the Israel South Red Sea Expedition. Special thanks are due Professor H. Steinitz of the Hebrew University of Jerusalem, the leader of the Expedition, for the encouragement that I received from him in connection with the preparation of this paper and for his help in numerous ways. Mr. G. Blumenfeld of the Geological Survey of Israel, Jerusalem, kindly drew the accompanying map of the Red Sea, for which I thank him very much.

Received January 14, 1967

(without giving the precise locality) three species that were collected, presumably in 1752, by another pupil of LINNAEUS'S, F. HASSELQUIST.

The next person to collect algae in the Red Sea was Petrus FORSSKÅL (1775). He was the first to describe new species from the region. Carl CHRISTENSEN (1918) has given an account of FORSSKÅL and of his journey to Egypt and Arabia* (see also the review of CHRISTENSEN's book by HARMS, 1918, and the fascinating book on this expedition by HANSEN, 1964). FORSSKÅL was born in Finland in 1732. He grew up in Sweden and studied natural history under LINNAEUS. He was appointed naturalist to a Danish expedition to Arabia which left Copenhagen by the naval vessel *Grønland* on 4 January 1761. Another member of the expedition was the German mathematician Carsten NIEBUHR, who functioned as geographer. The *Grønland* took them as far as Constantinople, whence they obtained passage on a Turkish ship to Alexandria, where they arrived 27 September 1761. From Alexandria they went to Cairo, where they stayed until 28 August 1762. They left Suez on 8 October 1762 on board an Arabian ship bound for Jiddah, where they arrived on 29 October. On 14 December they left Jiddah on board an Arabian ship bound for Luhaiya, where they arrived 29 December, having briefly visited Qunfida en route. On 20 April 1763 they departed by caravan for Mocha and on 9 June they left Mocha for the interior of Arabia. FORSSKÅL died in Jerim on 11 July 1763. His manuscripts were published by Niebuhr, the only survivor of the original group of six people.

In the course of time a number of botanists examined FORSSKÅL's specimens, which are preserved in the botanical museum of the University of Copenhagen, and most of his new species were maintained; some of his names, however, were not adopted. As far as the algae are concerned, FORSSKÅL's names that had the right of priority were resurrected by BØRGESEN in 1932 in his revision of FORSSKÅL's algae. FORSSKÅL is commemorated by *Siphonocladus forsskalii* (KÜTZING) BORNET ex DETONI and *Sargassum forsskalii* (MERTENS) PAPENFUSS.

The next person to describe algae from the Red Sea was the distinguished British algologist Dawson TURNER (1808, 1809, 1811, 1819). His material was collected by Viscount VALENTIA (see ANNESLEY, 1809) during his travels in the Red Sea (mostly in the southern part but also in the Suez area; no specific localities are mentioned, however, as sources of his material) from April to August 1804 and December 1804 to February 1806.** Some of TURNER's specimens were collected by Viscount VALENTIA's secretary, Henry SALT, who accompanied him on his travels, and who later (see SALT, 1814) was sent by the British Government on a mission to Ethiopia. SALT

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*I have not seen Carl CHRISTENSEN's work and am indebted to Dr. Tyge CHRISTENSEN for an English abstract of the most relevant parts.

**On page 345 of volume 3 of his "Voyages and travels . . . " Viscount VALENTIA remarks: "I also greatly increased my collection of sea weeds, with which the Red Sea abounds . . . ", and farther on on the same page, "My friend, Mr. Dawson TURNER, in his beautiful work on the Fuci, has given drawings of many of the specimens which I brought home . . .".

went by the merchant ship *Marian* via the Cape of Good Hope and was in the southern Red Sea in the latter part of 1809 and the first half of 1810. Viscount VALENTIA. SALT, and TURNER, are commemorated by: *Hypnea valentiae* (TURNER) MONTAGNE, *Sargassum saltii* (TURNER) C. AGARDH, and *Liagora turneri* ZANARDINI.

Napoleon invaded Egypt in July 1798. A party of 165 French scientists, artists, and men of letters accompanied Bonaparte's expeditionary force. The results of the scientific investigations appeared in the "Description de l'Égypte . . .", published in Paris from 1809 to 1828. The algae, including several species from the Red Sea (Suez), were reported upon by DELILE (1813, 1824). LAMOUROUX in his Essai (1813, p. 36, f.n. 2) says that DELILE gave him all his specimens of marine plants from the Red Sea and Alexandria. These specimens are, therefore, presumably in LAMOUROUX's herbarium at Caen. DELILE is commemorated by *Bangia delilei* (MONTAGNE) ZANARDINI, *Asparagopsis delilei* MONTAGNE [= *A. taxiformis* (DELILE) TREVISAN], and *Acanthophora delilei* LAMOUROUX [= *A. najadiformis* (DELILE) PAPENFUSS].

EHRENBERG and HEMPRICH in 1820 made a scientific journey of six years' duration to Egypt, West Asia, and Ethiopia. A preliminary report of their travels was published by Alexander VON HUMBOLDT in the memoirs of the Berlin academy for 1826 (published in 1829). EHRENBERG himself in 1828 published a short historical account of the early part of their journey. A full account apparently was never published. During the latter part of 1823 and the early part of 1824, EHRENBERG spent five months in Tor, where he occupied himself principally with corals. In 1823 and 1824 both men also visited the islands on the Arabian side of the Red Sea from Aqaba to Moile (= Mueleh = Al Muwaylih, 27°41′N, 35°31′E). In November of 1824 they sailed from Suez for Jiddah. From Jiddah they went to Mecca and thence to Qunfida. Next they visited the volcanic Island of Ketumbul (= Qadimbal, 17°53′N, 41°42′E) and the Farasan Archipelago. From Qizan, which is on the Arabian mainland due east of the Farasan Archipelago, they went to Luhaiya, from there to Kamaran Island and thence to Massawa, on the Ethiopian coast, which they reached on 24 April 1825. En route to Massawa they visited Onachil Islet and the Dahlak Archipelago. HEMPRICH died in Massawa and was buried on the Islet of Toalut (see *Ann. Mag. nat. Hist.*, ser. 4, 19 : 113–116, 1877). EHRENBERG returned to Europe via Koseir and Alexandria, from where he sailed in November 1825.

EHRENBERG himself reported on only two of the marine algae collected by him. He (1830) described the free-floating, blue-green algal genus *Trichodesmium*, with the then only species, *T. erythraeum*, which has an accessory red pigment that at times obscures the other pigments. If, at such times, the alga forms a bloom, it causes the surface waters to appear red—hence the Red Sea. EHRENBERG (1833) also reported the coralline alga *Pocillopora polymorpha* (=*Lithophyllum incrustans*) from Koseir.

EHRENBERG's Egyptian algae and a few of those from other parts of the Red Sea that were present in the Berlin herbarium were reported by MUSCHLER (1908) in his enumeration of the algae of Egypt. EHRENBERG is commemorated by *Sargassum vaysierianum* var. *ehrenbergii* GRUNOW.

In 1834 DECAISNE reported on the algae collected along the shores of the Sinai Peninsula by BOVÉ (who himself, 1834, reported on a few of those collected at Suez). BOVÉ was sent in 1830 by Ibrahim Pasha of Cairo to Arabia to obtain plants and seeds of coffee. *Sargassum boveanum* and *S. decaisnei* were erected by J. AGARDH in honor of BOVÉ and DECAISNE.

In 1834 Wilhelm SCHIMPER made a journey of several years' duration to Egypt, Arabia and Ethiopia under the auspices of the Unio Itineraria* and the Government of Baden. He collected marine algae principally at Tor and Nuweiba on the Sinai Peninsula and also at Jiddah and Koseir. The specimens were determined by HERING and MARTENS and were distributed to subscribers in 1835 and 1837. On the basis of specimens collected by SCHIMPER at Tor, HERING and MARTENS (in MARTENS and HERING, 1836) described the elegant *Amansia jungermannioides,* which later was made the type of the genus *Leveillea* DECAISNE. RUPRECHT (1849) and ZANARDINI (1858) have given lists of the algae distributed to subscribers to SCHIMPER's plants. RUPRECHT, who never visited the Red Sea, based his paper of 1849, titled "Die Vegetation des Rothen Meeres . . .", largely on the material collected by SCHIMPER.

Duplicates of some of SCHIMPER's algae are present in many herbaria, including that of the University of California, and are especially well represented in the herbarium of the University of Hamburg. In addition to *Leveillea jungermannioides, Codium arabicum* KÜTZING, *Sphacelaria rigidula* KÜTZING, *Zonaria schimperi* KÜTZING, *Chnoospora implexa* J. AGARDH, *Galaxaura schimperi* DECAISNE, and *Spyridia aculeata* (C. AGARDH ex DECAISNE) KÜTZING are based on material collected by SCHIMPER.

J. AGARDH in 1837 reported on a collection of marine algae made at Tor and especially in Ethiopia (probably in 1832) by Dr. Eduard RÜPPELL, a distinguished zoologist on the staff of the Senckenberg Museum in Frankfurt a.M. This material is at that institution. *Sargassum rueppellii* J. AGARDH [= *S. subrepandum* var. *rueppellii* (J. AGARDH) J. Agardh] and Rüppellia Islet in the Dahlak Archipelago commemorate RÜPPELL, and *S. fresenianum* J. AGARDH commemorates Dr. Georg FRESENIUS, a botanist on the staff of the Senckenberg museum who published on RÜPPELL's terrestrial plants from Ethiopia and who asked J. AGARDH to determine RÜPPELL's marine algae.

Doctors G. H. SCHUBERT, M. ERDL, and J. R. ROTH in 1836 and 1839 traveled in Egypt, Arabia, and Syria. SCHUBERT (1839, pp. 290 and 291) in his "Reise in das Morgenland . . ." mentioned five species of marine algae obtained at Tor. The collection as a whole was reported on by KUMMER (see SCHENK, 1840). This material should be at Munich [see Linnaea 15, 1841, Litt. -Bericht, p. 18; and Ber. Deutsch. Bot. Ges. 9, 1891, pp. (15)-(26)].

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* The Unio Itineraria was a society for the promotion of natural history travel that was established by STEUDAL and HOCHSTETTER in Esslingen (see *Hooker's J. Bot.* 2:29–34, 1840; *Ann. Sc. nat. Bot.*, sér. 2, 1:318–319, 1834; LASÈGUE, 1845, p. 109).

In 1841 DECAISNE published the marine algae collected by Paul-Émile BOTTA (1841), a naturalist traveler of the natural history museum of Paris (see LASÈGUE, 1845, p. 427) in 1836 in Egypt (Koseir and Tor), Saudi Arabia (Yenbo and Jiddah) and Yemen (Hodeida). It is in this paper that DECAISNE described the elegant reticulate green algal genus *Microdictyon,* naming the type and then only species *M. agardhianum* in honor of J. AGARDH. For almost a century this species was known only from the type specimen. When CROSSLAND became director of the Ghardaqa Marine Laboratory in Egypt, Professor SETCHELL of the University of California, the monographer of *Microdictyon,* asked him to search especially for *M. agardhianum.* It was rediscovered (at Ghardaqa) in 1933 and in 1935 SETCHELL published some notes on the species and also gave an excellent illustration of it.

In 1843 MONTAGNE described *Batrachospermum requienii,* the type of the genus *Trichogloea* KÜTZING (1847), on material collected in the Red Sea by REQUIEN. In 1849 he reported on four species from the Red Sea, some of the specimens having been collected by Dr. LALLEMAND, after whom *Dasya lallemandi* [= *Lophocladia lallemandi* (MONTAGNE) SCHMITZ] was named. Other specimens were furnished by HUSSON, the director of the botanical garden in Cairo, who is commemorated by *Dasya hussoniana* MONTAGNE.

ARNAUD and VAYSIÈRE from 1847 to 1849 collected a number of species of algae at Hodeida. This material was also studied by MONTAGNE (1850). Two of the new species, *Sargassum arnaudianum* MONTAGNE and *S. vaysierianum* MONTAGNE, were named in honor of these men.

In 1853 A. FIGARI and G. DE NOTARIS reported on the brown algae collected by themselves in the Red Sea and also on a few collected by HUSSON. FIGARI and DE NOTARIS are commemorated by *Sargassum figarianum* DE NOTARIS [= *S. subrepandum* var. *figarianum* (DE NOTARIS) J. AGARDH], *S. notarisii* ZANARDINI [= *S. forsskalii* var. *notarisii* (ZANARDINI) PAPENFUSS], *Polysiphonia figariana* ZANARDINI, and *Dictyota notarisii* KÜTZING [= *Dilophus fasciola* (ROTH) HOWE].

ZANARDINI in 1851 published a preliminary account of a large collection of algae made by PORTIER at the Dahlak Archipelago, Massawa, Berenice, Koseir, Suez, Tor, Aqaba, Jiddah, Hodeida, and Mocha. Twenty-three new taxa were described in this paper. In 1855 ZANARDINI published the most comprehensive account to appear up to that time of the algae of the Red Sea. The basis of this monograph was the collection of PORTIER's and also material in the herbarium of FIGARI. This work included a review of previous work on Red Sea algae. Many new species and two new genera, *Sarconema* and *Chloroplegma* (= *Avrainvillea* DECAISNE), were described in this paper. *Sargassum portierianum* ZANARDINI commemorates PORTIER.

PICCONE (1884, 1886, 1889, 1893, 1900a, 1900b, 1900c) published seven papers that dealt wholly or in part with Red Sea algae. The first of these papers treated of material that was collected at various places on the coast of Eritrea by Giovanni CARAMAGNA, the captain of an Italian naval vessel, Giacomo DORIA, the Director of the natural history museum of Genoa, Cesare MARCACCI, a naval officer, and Professor Arturo ISSEL, a malacologist. The new species were co-authored with A. GRUNOW of Vienna, the monographer of *Sargassum,* who described many new taxa of this genus from the Red Sea. DORIA, MARCACCI, and ISSEL are commemorated by *Sargassum doriae* GRUNOW [= *S. cuneifolium* var. *doriae* (GRUNOW) GRUNOW], *S. marcaccii* GRUNOW, and *Zonaria isselii* PICCONE ET GRUNOW [= *Pocockiella variegata* (LAMOUROUX) PAPENFUSS], respectively.

PICCONE's paper of 1886 dealt with material collected during the round-the-world cruise of the corvette *Vettor Pisani* from 1882 to 1885 and included a number of species obtained at Massawa. In 1889 he reported on additional material collected by members of the Italian Royal Navy (Francesco ORSINI and Cesare MARCACCI) in the southern Red Sea (Assab, Edd, Bay of Anfila, Dissei Islet, Adjuz Islet, Assarca Islets, and Massawa). In this paper GRUNOW described *Sargassum picconii* [= *S. boveanum* var. *picconii* (GRUNOW) GRUNOW] among other new taxa of *Sargassum.* The paper of 1893 was a preliminary account of the algae collected at Mandola Islet, Arafali, Dissei Islet, Shumma Islet, and Berenice during the hydrographic voyage of the Italian naval vessel *Scilla* in 1892 under the command of Captain G. Cassanello. The three papers of 1900 dealt mostly with algae from the southern Red Sea, but a few from Berenice and Suez were also included.

In 1885 Professor G.B. LICATA and F. BALSAMO both published on the algae collected by the former at Assab.

HAUCK in 1887, 1888, and 1889 reported on the algae collected by J. M. HILDEBRANDT in the Red Sea in 1872 during his journey to the Red Sea and the Indian Ocean. GRUNOW worked up the material of *Sargassum* and among other new taxa described *S. hildebrandtii,* based in part on material obtained at Hodeida.

BORNET in 1888 published on a collection of algae made by L. FAUROT, a marine zoologist, at Obock (French Somaliland) and Kamaran Island. Ten taxa were reported from Kamaran Island, where they were collected in November and December 1885.

Also in 1888 DETONI and PAOLETTI reported on 31 species of algae collected by R. BRESSANIN, a ship's doctor, at Massawa and Suakin. GRUNOW determined the material of *Sargassum. S. fresenianum* var. *bressaninii* (GRUNOW) GRUNOW is named after BRESSANIN and *S. cinctum* var. *detonianum* GRUNOW commemorates the distinguished Italian phycologist J. B. DETONI.

REINBOLD in 1903 published on 33 taxa of marine algae collected at Tor during 1901 and 1902 by Professor PLATE, a zoologist, for the institute of oceanography of the University of Berlin. In 1907 the same author listed five species that were collected in the Red Sea during the *Valdivia* Tiefsee-Expedition of 1898 and 1899.

As was mentioned above in connection with EHRENBERG, MUSCHLER in 1908 gave an enumeration of the algae of Egypt. MUSCHLER included in this enumeration material of his own, EHRENBERG's Egyptian material, specimens from FIGARI's collection, and several other collections, deposited in the Berlin herbarium. He also included specimens from SICKENBERGER's herbarium in the Cairo School of Medicine.

In 1908 HARVEY-GIBSON reported on material collected chiefly in the vicinity of Suakin and Trinkitat in the Sudan by Cyril CROSSLAND in 1904 and 1905. In 1913 HARVEY-GIBSON and Margery KNIGHT reported on specimens collected by CROSSLAND at Dungunab Bay in the Sudan.

LYLE in 1926 reported on the algae obtained by the Cambridge Expedition of 1924 to the Suez Canal. The expedition was organized by Professor J. Stanley GARDINER, who, however, did not himself participate in it.

BØRGESEN in 1932 revised FORSSKÅL's algae and cleared up the confusion that had existed about some of FORSSKÅL's species. In the same year LAMI (1932) reported on the algae collected by Professor GRUVEL in 1932 in Great Bitter Lake, through which the Suez Canal passes.

CROSSLAND in 1930 became director of the University of Egypt's marine biological station at Ghardaqa on the Red Sea coast (see *Nature* 134:743-744, 1934), the construction of which started in 1932. In late 1932 scientific work got underway at Ghardaqa and in 1934 A. H. NASR started work there on marine algae. His floristic studies resulted in a number of publications on Red Sea algae (one on blue-green algae in collaboration with FRÉMY, 1938) and culminated in 1947 with the appearance of his comprehensive "Synopsis of the marine algae of the Egyptian Red Sea coast". In 1955 he published his observations on the ecology of the algae at Ghardaqa. NASR was Assistant Director of the Ghardaqa laboratory from 1939 to 1943 and is now Professor of Cryptogamic Botany in the University of Alexandria. *Schizothrix nasri* FRÉMY commemorates NASR and *Ceramium nayalii* NASR is named after Dr. A. A. NAYAL, Lecturer in Botany in the Egyptian University and student of Egyptian freshwater algae, who from time to time studied marine plants at Ghardaqa.

Miss Linda M. NEWTON of the British Museum in 1953 published on many of the algae obtained by the John Murray Expedition of 1933 and 1934 to the western Indian Ocean. Ten species were reported from the Hanish Islands.

More recently contributions to knowledge of the Red Sea algae have come largely through the efforts of Israeli scientists. The late Professor Tscharna RAYSS (1959, 1965) of the Hebrew University of Jerusalem and RAYSS and DOR (1963) have added much to knowledge of the algae of the Sinai Peninsula and the Gulf of Aqaba. Professor Wm. Randolph TAYLOR (1964, 1965, 1966) of the University of Michigan has published on the material of the genus *Turbinaria*, some of which was collected by the Israel South Red Sea Expedition of 1962. Two new species, *T. elatensis* and *T. papenfussii*, were recognized by him in the collections from the Red Sea. LEMOINE (1966) has reported on the coralline algae collected by STEINITZ, BEN-TUVIA, and OREN in the Gulf of Aqaba and the southern Red Sea. (Previously, 1965, she had published on the calcareous red algae collected by Professor DRACH during a cruise of the *Calypso* in the Red Sea.) Professor STEINITZ is commemorated by *Petroderma steinitzii* RAYSS et DOR and *Dermatolithon steinitzii* LEMOINE.

CATALOGUE OF THE TAXA

The places whence species have been reported are given in Table I. They are listed in a clockwise sequence, beginning with Bay of Assab in Ethiopia and ending with Mocha in Yemen. A map of the Red Sea which shows these places is given at the end of the paper.

A complete set of HOHENACKER's "Algae marinae siccatae" was not available to me and it must be assumed that he distributed a few species from the Red Sea in addition to those cited in this catalogue.

Accepted generic and specific names which are based on Red Sea types are marked with an asterisk (*). Following the bibliography there is an index of the species and synonyms.

TABLE I

PLACES WHENCE SPECIES OF MARINE ALGAE HAVE BEEN REPORTED

Locality	*Lat. N*	*Long. E*
ETHIOPIA		
Bay of Assab		
Assab	13°01′	42°47′
Hanish Islands	13°43′	42°45′
Edd	13°57′	41°38′
Bay of Anfila (also as Bay of Amfile)		
Mandola Islet	14°44′	40°54′
Gulf of Zula		
Arafali	15°03′	39°43′
Dissei Islet	15°27′	39°45′
Onachil Islet (Howakil Islet)	15°10′	40°16′
Adjuz Islet (S. Massawa Channel)	15°14′	40°15′
Dahlak Archipelago		
Shumma Islet	15°31′	40°00′
Assarca Islets	15°32′	39°55′
Entedebir Islet	15°43′	39°54′
Derom Islet	15°54′	40°23′
Romia Islet	16°32′	40°02′
Bay of Archico		
Sheik Said Islet	15°36′	39°29′
Massawa	15°37′	39°28′

Locality	*Lat. N*	*Long. E*
SUDAN		
Trinkitat	18°41′	37°46′
Tella Tella Kebir Islet	18°49′	38°09′
Suakin	19°08′	37°17′
Port Sudan	19°38′	37°07′
Dungunab Bay	21°03′	37°09′
EGYPT		
Mirear Islet	23°15′	35°41′
Berenice	23°57′	35°17′
Wâdi Gimâl Islet	24°40′	35°07′
Daedalus Reef	24°55′	35°51′
Koseir	26°04′	34°15′
The Brothers		
Safaga	26°43′	33°55′
Gifatin Islet	27°14′	33°56′
Ghardaqa (Hurghada)	27°17′	33°47′
Shadwân Islet	27°30′	34°00′
Ashrâfi Islet	27°47′	33°42′
Strait of Jubal		
Gulf of Suez		
Ras Ghârib	28°21′	33°06′
Suez	29°59′	32°33′
Ras Abu Zenîma	29°03′	33°06′

(TABLE I cont'd)

Locality	*Lat. N*	*Long. E*
Ras Abu Rudeis	28°54′	33°12′
Tor	28°14′	33°36′
Ras Muhammad	27°44′	34°15′
Sharm el Sheikh	27°51′	34°16′
Ras Nusrâni	27°58′	34°25′
Abu Zabad	28°09′	34°27′
Shora el Manqata	28°12′	34°25′
Nuweiba	28°59′	34°40′
Farun Islet	29°28′	34°52′
ISRAEL		
Eilat*	29°33′	34°57′
JORDAN		
Aqaba	29°31′	35°01′
SAUDI ARABIA		
Maqsur Islet	27°56′	35°12′
Tiran Island	27°56′	34°33′
Mashabih Islet	25°38′	36°27′
Yenbo	24°07′	38°04′
Jiddah	21°30′	39°10′
Qunfida	19°09′	41°07′
Farasan Archipelago		
Abulad Islets	16°48′	42°10′
Sulein Islets	16°46′	42°11′
KAMARAN ISLAND	15°20′	42°33′
YEMEN		
Luhaiya	15°44′	42°42′
Hodeida	14°50′	42°58′
Mocha	13°20′	43°16′

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* Also spelled Elat (Ed.).

CHLOROPHYCOPHYTA

VOLVOCALES

CHLAMYDOMONADACEAE

Platymonas WEST

***Platymonas intermedia** NASR

NASR, 1944, p. 32, fig. 2; 1947, p. 18, fig. 3.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

POLYBLEPHARIDACEAE

Dunaliella TEODORESCO

Dunaliella salina (DUNAL) TEODORESCO

NASR, 1947, p. 18.
Red Sea distr.: Ghardaqa.

ULOTRICHALES

CHAETOPHORACEAE

Entocladia REINKE

Entocladia viridis REINKE

Record under syn.
Endoderma viride (REINKE) LAGERHEIM. RAYSS and DOR, 1963, p. 18.

Red Sea distr.: Abu Zabad, Eilat.

Phaeophila HAUCK

Phaeophila dendroides (P.L. et H.M. CROUAN) BATTERS

Record under syn.
Phaeophila floridearum HAUCK. NASR, 1947, p. 24, fig. 5.

Red Sea distr.: Ghardaqa in *Dictyosphaeria*.

Pringsheimiella VON HÖHNEL

Pringsheimiella conchyliophila var. ***vitriseda** RAYSS et DOR

RAYSS and DOR, 1963, p. 18, fig. 3.
Type loc.: Eilat.†
Distr.: Eilat.

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† Also spelled Elat (Ed.).

ULVACEAE

Enteromorpha LINK (*nom. cons.*)

Enteromorpha clathrata var. **erecta** (LYNGBYE) LE JOLIS

RAYSS, 1959, p. 6.
Red Sea distr.: Eilat.

Enteromorpha compressa (LINNAEUS) GREVILLE

DECAISNE. 1841, p. 117. MONTAGNE, 1850, p. 248. ZANARDINI, 1858, p. 294. PICCONE, 1900*a*, p. 253. HARVEY-GIBSON, 1908, p. 78. MUSCHLER, 1908, p. 158. LYLE, 1926, p. 40. LAMI, 1932, p. 355. NASR, 1947, p. 21.

Records under other names
Solenia compressa var. *crinita* (ROTH) C. AGARDH. DECAISNE, 1834, p. 10.
Ulva compressa var. *crinita* (ROTH) C. AGARDH. ZANARDINI, 1858, p. 294. PICCONE, 1886, p. 24.
Ulva compressa var. *crispa* ZANARDINI, 1858, p. 294.
Ulva compressa LINNAEUS. STRAND, 1756, p. 32; 1759, p. 467. DETONI and PAOLETTI, 1888, p. 75.
Solenia compressa (LINNAEUS) C. AGARDH. SCHUBERT, 1839, p. 291.

Red Sea distr.: Gulf of Zula, Massawa, Suakin, Koseir, Ghardaqa, Suez Bay, Suez Canal, Tor, Aqaba, Jiddah, Hodeida.

Enteromorpha flexuosa (WULFEN) J. AGARDH

LYLE, 1926, p. 39. NASR, 1947, p. 21. RAYSS, 1959, p. 6. RAYSS and DOR, 1963, p. 23.
Red Sea distr.: Massawa, Ghardaqa, Suez Canal, Eilat.

Enteromorpha intestinalis (LINNAEUS) GREVILLE

LYLE, 1926, p. 39. NASR. 1947, p. 22.
Red Sea distr.: Ghardaqa, Suez Canal.

Ulva THURET *(nom. cons. prop.)*

***Ulva cuneata** FORSSKÅL

FORSSKÅL, 1775, p. 188.
Type loc.: Tor.
Distr.: Tor.
Note: The identity of this species is unknown. Voucher material apparently does not exist. ZANARDINI (1858, p. 287) listed the name as a synonym of *Caulerpa chemnitzia* (=*C. racemosa* var. *turbinata*).

Ulva granulata sensu FORSSKÅL

FORSSKÅL, 1775, p. cxxvi.

Distr.: Mocha.

Note: The identity of the material on which this record is based is unknown.

Ulva lactuca auct. (non LINNAEUS)

LICATA, 1885, p. 186. BALSAMO, 1885, p. 11. DETONI and PAOLETTI, 1888, p. 75. PICCONE, 1900*c*, p. 119. NASR, 1939*a*, p. 50; 1947, p. 23. RAYSS, 1959, p. 7.

Red Sea distr.: Assab, Massawa, Suakin, Koseir, Suez, Eilat.

Ulva lactuca var. **latissima** auct.

LYLE, 1926, p. 39.

Records under other names

Ulva latissima auct. (non LINNAEUS). FORSSKÅL, 1775, p. cxxvi. SCHIMPER, 1835–37, no. 265. DECAISNE, 1841, p. 117. ZANARDINI, 1858, p. 294.

Ulva lactuca sensu MUSCHLER, 1908, p. 157.

Red Sea distr.: Koseir, Suez, Suez Canal, Tor, Aqaba, Jiddah, Mocha.

***Ulva reticulata** FORSSKÅL

FORSSKÅL, 1775, pp. cxxvi and 187. DECAISNE, 1834, p. 10; 1841, p. 117. SCHIMPER, 1835–37, no. 929. MONTAGNE, 1850, p. 248. ZANARDINI, 1858, p. 294. PICCONE, 1884, p. 292; 1886, p. 22; 1889, p. 66; 1893, p. 380; 1900*a*, p. 253; 1900*b*, p. 118. LICATA, 1885, p. 186. BALSAMO, 1885, p. 11. DETONI and PAOLETTI, 1888, p. 75. MUSCHLER, 1908, p. 156. BØRGESEN, 1932, p. 2. NASR, 1947, p. 22. RAYSS, 1959, p. 7.

Type loc.: "Ad Gomfodae & Mochhae littora".

Red Sea distr.: Bay of Assab, Edd, Mandola Islet, Shumma Islet, Massawa, Koseir, Qunfida, Hodeida, Mocha.

Ulva rigida var. **rigida**

PICCONE, 1889, p. 67.

Records under another name

Ulva lactuca sensu PICCONE, 1884, p. 292; 1886, p. 21.

Red Sea distr.: Bay of Assab, Edd, Massawa.

Ulva uncialis (KÜTZING) MONTAGNE

MONTAGNE, 1850, p. 248.

Red Sea distr.: Hodeida.

Note: It is doubtful that the Red Sea material belongs to this South African species.

Ulva vesiculis ovatis FORSSKÅL

FORSSKÅL. 1775, pp. cxxvi and 188.
Type loc.: Mocha.
Distr.: Mocha.

Note: The identity of this species is unknown. Voucher material apparently does not exist. ZANARDINI (1858, p. 211) considered the taxon related to *Caulerpa racemosa* var. *turbinata*.

CHROOLEPIDACEAE

Pilinia KÜTZING

***Pilinia erythraea** (NASR) PAPENFUSS

Records under syn.
Sporocladopsis erythraea NASR, 1944, p. 34, figs. 3 and 4; 1947, p. 25, figs. 6 and 7.

Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Note: PAPENFUSS (1962) has reduced *Sporocladopsis* NASR to a synonym of *Pilinia*.

CLADOPHORALES

CLADOPHORACEAE

Chaetomorpha KÜTZING *(nom. cons.)*

Chaetomorpha aerea (DILLWYN) KÜTZING

MUSCHLER, 1908, p. 160. NASR, 1947, p. 37. RAYSS, 1959, p. 8.
Red Sea distr.: Massawa, Koseir, Ghardaqa.

Chaetomorpha antennina (BORY) KÜTZING

NASR, 1947, p. 37.
Red Sea distr.: Suez Canal.

Chaetomorpha indica (KÜTZING) KÜTZING

MUSCHLER, 1908, p. 160.

Record under syn.
Conferva indica KÜTZING. ZANARDINI, 1858, p. 296.

Red Sea distr.: Suez, Tor.

Chaetomorpha linum (O.F. MÜLLER) KÜTZING

PICCONE, 1886, p. 26; 1900*a*, p. 253. MUSCHLER, 1908, p. 159. HARVEY-GIBSON and KNIGHT, 1913, p. 306. NASR, 1947, p. 36.

Records under syns.
Conferva chlorotica MONTAGNE. ZANARDINI, 1858, p. 296.
Chaetomorpha chlorotica (MONTAGNE) KÜTZING. PICCONE, 1889, p. 67.

Red Sea distr.: Assab, Gulf of Anfila, Massawa, Sudanese coast, Ghardaqa, Suez, Aqaba.

Cladophora KÜTZING *(nom. cons)*

Cladophora albida (HUDSON) KÜTZING
MUSCHLER, 1908, p. 163. NASR, 1947, p. 35. RAYSS, 1959, p. 8.

Record under syn.
Conferva albida HUDSON. ZANARDINI, 1858, p. 296.

Red Sea distr.: Suez, Abu Zabad, Tor, Eilat, Aqaba.

Cladophora coelothrix KÜTZING
NEWTON, 1953, pp. 396 and 402.
Red Sea distr.: Hanish Islands.

Cladophora crystallina (ROTH) KÜTZING
MUSCHLER. 1908, p. 163. NASR, 1947, p. 53.

Record under another name
Conferva sericea LYNGBYE. ZANARDINI, 1858, p. 296.

Red Sea distr.: Ghardaqa, Suez.

Cladophora dalmatica KÜTZING
NASR, 1947, p. 35.
Red Sea distr.: Koseir.

Cladophora fascicularis (MERTENS ex C. AGARDH) KÜTZING
MUSCHLER, 1908, p. 163. NASR, 1947, p. 34, pl. 3, fig. 1.

Records under other names
Conferva fascicularis MERTENS ex C. AGARDH. ZANARDINI, 1858, p. 296.
Conferva cristata ZANARDINI, 1851, p. 38 (non *Cladophora cristata* KÜTZING, 1849, p. 404).

Red Sea distr.: Koseir, Suez.

Cladophora heteronema (C. AGARDH) KÜTZING
NASR, 1947, p. 34.
Red Sea distr.: Koseir.

Cladophora prolifera (ROTH) KÜTZING

DETONI, 1889, p. 306.
Red Sea distr.: Red Sea.

***Cladophora prolixa** (MONTAGNE) DETONI

NASR, 1947, p. 35.

Record under syn.
Conferva prolixa MONTAGNE, 1850, p. 248.

Type loc.: Hodeida.
Red Sea distr.: Koseir, Ashrafi Islet, Hodeida.

Cladophora ramulosa MENEGHINI

RAYSS, 1959, p. 8.
Red Sea distr.: Massawa, Tor.

Cladophora sericea (HUDSON) KÜTZING

LYLE, 1926, p. 40.
Red Sea distr.: Suez Canal.

Codiolum BRAUN

Codiolum petrocelidis KUCKUCK

NASR, 1947, p. 19, fig. 4.
Red Sea distr.: Ghardaqa in *Liagora*.

Note: KORNMANN (1961) has shown that *Codiolum petrocelidis* is the sporophytic stage of *Spongomorpha lanosa*. Since *Spongomorpha* is not known to occur in the Red Sea, the endophyte observed by NASR probably is not *C. petrocelidis*.

Rhizoclonium KÜTZING

Rhizoclonium kochianum KÜTZING

NASR, 1947, p. 37.
Red Sea distr.: Ghardaqa.

Rhizoclonium tortuosum (DILLWYN) KÜTZING

Record under syn.
Chaetomorpha callithrix KÜTZING. PICCONE, 1886, p. 25.

Red Sea distr.: Massawa.

ANADYOMENACEAE

*Microdictyon DECAISNE

***Microdictyon agardhianum** DECAISNE

DECAISNE, 1841, p. 115. SETCHELL, 1929, p. 479, figs. 1–5; 1935, p. 129, pls. 13–15. NASR, 1939*a,* p. 52; 1947, p. 30, fig. 8. RAYSS and DOR, 1963, p. 19.

Type loc.: Jiddah.

Red Sea distr.: Ghardaqa, Eilat, Jiddah.

Note: *Microdictyon agardhianum* is the type of its genus.

SIPHONOCLADALES

SIPHONOCLADACEAE

Boergesenia FELDMANN

Boergesenia forbesii (HARVEY) FELDMANN

BØRGESEN, 1948, p. 21.

Record under syn.

Pseudovalonia forbesii (HARVEY) IYENGAR. NASR, 1947, p. 28, pl. 2, fig. 3.

Red Sea distr.: Koseir, Safâga, Ghardaqa.

Note: This taxon was first recognized as a new species *(Valonia forbesii)* by HARVEY on the basis of specimens collected in Ceylon and distributed by him in 1853 as number 75 of his Ceylon Algae. A diagnosis was not included on the label and it has been assumed that the species remained undescribed until 1887 when J. AGARDH (p. 96) furnished a diagnosis. It should be noted, however, that the species was described by HARVEY (1859, p. 333) in his generally overlooked account of the algae of the North Pacific Exploring Expedition under Captain Rodgers.

Cladophoropsis BØRGESEN *(nom. cons.)*

Cladophoropsis zollingeri (KÜTZING) BØRGESEN

NASR, 1947, p. 31.

Record under syn.

Siphonocladus zollingeri (KÜTZING) BORNET ex DETONI. REINBOLD, 1903, p. 228.

Red Sea distr.: Ghardaqa, Tor.

Note: It is doubtful that this taxon is distinct from the earlier described *Cladophoropsis herpestica* (MONTAGNE) HOWE.

Siphonocladus SCHMITZ

***Siphonocladus forsskalii** (KÜTZING) BORNET ex DETONI

DETONI, 1889, p. 359. MUSCHLER, 1908, p. 164. LYLE, 1926, p. 40.

Records under syns.

Cladophora forsskalii KÜTZING, 1849, p. 416. LICATA, 1885, p. 186. BALSAMO, 1885, p. 11.
Aegagropila forsskalii (KÜTZING) KÜTZING, 1854, p. 14, pl. 68, figs. B and b.
Conferva forsskalii (KÜTZING) ZANARDINI, 1858, p. 295.

Type loc.: Red Sea.

Red Sea distr.: Assab, Koseir, Suez Canal, Tor, Red Sea.

Note: KÜTZING (1849, 1854) stated that his material of this species was obtained in the Red Sea by FORSSKÅL, who had determined it as *Conferva aegagropila.* However, FORSSKÅL (1775, p. lxxviii) gave the locality of *C. aegagropila* as "As.", which, as is explained on page 1 of his work, means that the material was growing spontaneously at Alexandria. It is likely, therefore, that the type of *Siphonocladus forsskalii* was obtained at Alexandria instead of in the Red Sea. *Siphonocladus forsskalii* probably is a species of *Cladophoropsis.*

Siphonocladus pusillus (KÜTZING) HAUCK

RAYSS and DOR, 1963, p. 20, fig. 4.

Red Sea distr.: Eilat.

BOODLEACEAE

Boodlea MURRAY et DETONI

Boodlea composita (HARVEY) BRAND

NASR, 1947, p. 32.

Record under syn.

Boodlea siamensis REINBOLD. REINBOLD, 1903, p. 228.

Red Sea distr.: Daedalus Reef, Ghardaqa, Tor.

Note: *Boodlea siamensis* has been reduced to a synonym of *B. composita* by BØRGESEN (1946, p. 16)

Struvea SONDER *(nom. cons.)*

Struvea anastomosans (HARVEY) PICCONE et GRUNOW

NASR, 1947, p. 38.

Red Sea distr.: Ghardaqa.

VALONIACEAE*

Dictyosphaeria DECAISNE ex ENDLICHER

***Dictyosphaeria cavernosa** (FORSSKÅL) BØRGESEN

BØRGESEN, 1932, p. 2, pl. 1, fig. 1. NASR, 1939*a*, p. 51; 1947, p. 29. RAYSS, 1955, p. 12; 1959, p. 8.

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*The organism reported under the name *Ascothamnion intricatum* (CLEMENTE) KÜTZING by MONTAGNE (1850, p. 248) from Hodeida and by ZANARDINI (1858, p. 293) from Suez and Tor (and which in the past usually was considered as related to *Valonia*) is a bryozoan, *Zoobotryon pellucidum,* a fact pointed out by RUPRECHT already in 1849 (p. 84).

Records under syns.
Ulva cavernosa FORSSKÅL, 1775, pp. cxxvi and 187.
Valonia favulosa C. AGARDH. ZANARDINI, 1858, p. 292.
Dictyosphaeria favulosa (C. AGARDH) DECAISNE. PICCONE, 1884, p. 293; 1900*c*, p. 119. HARVEY-GIBSON, 1908, p. 77. MUSCHLER, 1908, p. 164. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Type loc.: Mocha.
Red Sea distr.: Archipelago of Assab, Dungunab Bay, Sudanese coast, Daedalus Reef, Koseir, Ghardaqa, Suez, Ras Nusrani, Aqaba, Mocha.

Dictyosphaeria intermedia var. ***solida** NASR

NASR, 1944, p. 36, fig. 5; 1947, p. 29, pl. 1, fig. 1.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Valonia C. AGARDH

Valonia aegagropila C. AGARDH

PICCONE, 1884, p. 292. REINBOLD, 1903, p. 228. HARVEY-GIBSON and KNIGHT, 1913, p. 306. NASR, 1939*a*, p. 51; 1947, p. 28. NEWTON, 1953, pp. 396 and 401. RAYSS, 1959, p. 7.
Red Sea distr.: Archipelago of Assab, Hanish Islands, Massawa, Sudanese coast, Ghardaqa, Tor, Abu Zabad, Shora el Manqata.

Valonia macrophysa KÜTZING

PICCONE, 1900*c*, p. 119.
Red Sea distr.: Suez.

***Valonia rhizophora** PICCONE et GRUNOW

PICCONE, 1884, p. 293, pl. 7, fig. 10.
Type loc.: Not specified, Suakin, Bay of Assab.
Distr.: Bay of Assab, Suakin.
Note: MURRAY and BOODLE (1888, p. 281) regarded *Valonia rhizophora* as the juvenile stage of a species of *Struvea*, but, to judge from the figure of PICCONE, the taxon probably is representative of *Cladophoropsis*.

Valonia utricularis (ROTH) C. AGARDH

ZANARDINI, 1858, p. 292. PICCONE, 1884, p. 293.
Red Sea distr.: Red Sea, Bay of Assab.

Valonia ventricosa J. AGARDH

NASR, 1947, p. 27. RAYSS and DOR, 1963, p. 19.
Red Sea distr.: Ghardaqa, Abu Zabad, Eilat.

CAULERPALES

DERBESIACEAE

Derbesia SOLIER

Derbesia lamourouxii (J. AGARDH) SOLIER

LYLE, 1926, p. 40.
Red Sea distr.: Suez Canal.

Derbesia tenuissima (MORIS et DENOTARIS) P.L. et H.M. CROUAN

NASR, 1947, p. 46.
Red Sea distr.: Ghardaqa.

BRYOPSIDACEAE

Bryopsis LAMOUROUX

Bryopsis corymbosa J. AGARDH

NASR, 1947, p. 44.
Red Sea distr.: Ghardaqa.

Bryopsis hypnoides LAMOUROUX

ZANARDINI, 1858, p. 293. MUSCHLER, 1908, p. 165. NASR, 1947, p. 44. RAYSS, 1959, p. 10.

Record under another name
Bryopsis plumosa sensu DECAISNE, 1841, p. 125.

Red Sea distr.: Ghardaqa, Suez, Tor, Sharm el Sheikh, Aqaba, Jiddah.

Bryopsis implexa DENOTARIS

HARVEY-GIBSON and KNIGHT, 1913, p. 306.
Red Sea distr.: Sudanese coast.
Note: The status of this species is uncertain.

Bryopsis plumosa (HUDSON) C. AGARDH

HARVEY-GIBSON, 1908, p. 78. LYLE, 1926, p. 40. NASR, 1947, p. 44.
Red Sea distr.: Trinkitat, Suakin, Ghardaqa, Suez Canal.

Trichosolon MONTAGNE

***Trichosolon papillata** (NASR) TAYLOR

Record under syn.
Pseudobryopsis papillata NASR, 1944, p. 37, fig. 6, pl. 1; 1947, p. 45, fig. 12, pl. 2, fig. 1.

Type loc.: Strait of Jubal.

Distr.: Strait of Jubal.

Note: TAYLOR (1962) has obtained evidence showing that *Trichosolon* is an older name for the genus long known as *Pseudobryopsis*.

CAULERPACEAE

Caulerpa LAMOUROUX

Caulerpa cupressoides var. **lycopodium** (J. AGARDH) WEBER-VAN BOSSE

HARVEY-GIBSON, 1913, p. 306.

Red Sea distr.: Sudanese coast.

***Caulerpa lentillifera** J. AGARDH

J. AGARDH, 1837, p. 173; 1872*b*, p. 42. ZANARDINI, 1858, p. 287. WEBER-VAN BOSSE, 1898, p. 380, pl. 34, figs. la and lb. MUSCHLER, 1908, p. 171. NASR, 1947, p. 57.

Type loc.: Coast of Ethiopia.

Red Sea distr.: Coast of Ethiopia, Koseir, Ghardaqa, Suez, Tor, Jiddah.

Caulerpa mexicana SONDER ex KÜTZING

Records under other names

Caulerpa taxifolia var. *crassifolia* C. AGARDH, 1822, p. 436. KÜTZING, 1849, p. 495. ZANARDINI, 1858, p. 284. MUSCHLER, 1908, p. 168.

Caulerpa pinnata WEBER-VAN BOSSE, 1898, p. 289 (non *Fucus pinnatus* LINNAEUS fil.).

Fucus pinnatus sensu TURNER, 1808, p. 117, pl. 53.

Caulerpa crassifolia (C. AGARDH) J. AGARDH. NASR, 1939*a*, p. 56.

Red Sea distr.: Koseir, Yenbo, Jiddah.

Note: The nomenclature of this species has been discussed by PAPENFUSS (1956).

Caulerpa prolifera (FORSSKÅL) LAMOUROUX

MUSCHLER, 1908, p. 167.

Red Sea distr.: Suez

Note: The occurrence of this species in the Red Sea seems doubtful.

Caulerpa racemosa var. ***gracilis** (ZANARDINI) WEBER-VAN BOSSE

Record under syn.

Caulerpa clavifera var. *gracilis* ZANARDINI, 1851, p. 37; 1858, p. 286, pl. 14, fig. 1.

Type loc.: Tor.

Red Sea distr.: Tor.

Caulerpa racemosa var. ***lamourouxii** (TURNER) WEBER-VAN BOSSE

WEBER-VAN BOSSE, 1898, p. 368.

Records under syns.

Fucus lamourouxii TURNER, 1819, p. 79, pl. 229.

Caulerpa clavifera var. *lamourouxii* (TURNER) C. AGARDH, 1822, p. 438. DECAISNE, 1834, p. 10; 1841, p. 121. ZANARDINI, 1858, p. 286.

Caulerpa clavifera var. *nudiuscula* ZANARDINI, 1851, p. 37; 1858, p. 286.

Herpochaeta requienii MONTAGNE, 1856, p. 454.

Chauvinia clavifera var. *lamourouxii* (TURNER) KÜTZING, 1849, p. 498.

Caulerpa requienii (MONTAGNE) J. AGARDH, 1872*b*, p. 9. MUSCHLER, 1908, p. 166.

Caulerpa racemosa var. *lamourouxii* f. *requienii* (MONTAGNE) WEBER-VAN BOSSE, 1898, p. 369.

Chauvinia clavifera f. *nuda* KÜTZING and f. *elongata laxiuscula* KÜTZING, 1857, p. 6, pl. 14, figs. a, c, and d.

Caulerpa racemosa var. *laxa* J. AGARDH, 1872*b*, p. 35.

Type loc.: Red Sea.
Red Sea distr.: Red Sea, Suez, Aqaba.

Caulerpa racemosa var. **peltata** (LAMOUROUX) EUBANK

Records under syns.

Caulerpa peltata LAMOUROUX. DECAISNE, 1841, p. 121. HARVEY-GIBSON, 1908, p. 77. MUSCHLER, 1908, p. 170.

Caulerpa chemnitzia var. *peltata* (LAMOUROUX) ZANARDINI, 1858, p. 287.

Caulerpa peltata var. *typica* WEBER-VAN BOSSE, 1898, p. 375.

Red Sea distr.: Dungunab Bay, Daedalus Reef, Ghardaqa, Suez, Tor, Maqsur Island.

Note: From the list of MUSCHLER (1908) the impression is gained that the EHRENBERG localities cited are all from Egypt. However, Maqsur Island (given by MUSCHLER as Ile Maksere), where EHRENBERG collected *Caulerpa racemosa* var. *peltata,* is on the Arabian side of the Red Sea (27°56′ N/ 35°12′ E), as was shown by EHRENBERG (1828), who gave it as Maksura Island on his map.

***Caulerpa racemosa** var. **racemosa**

Records under other names

Fucus racemosus FORSSKÅL, 1775, pp. lxxviii and 191. WEBER, 1804, p. 134.

Caulerpa racemosa (FORSSKÅL) J. AGARDH, 1872*b*, p. 35. MUSCHLER, 1908, p. 170. BØRGESEN, 1932, p. 9. LAMI, 1932, p. 355. NASR, 1939*a*, p. 56; 1947, p. 55, pl. 4. RAYSS, 1959, p. 9.

Fucus clavifer TURNER, 1808, p. 126, pl. 57.

Caulerpa clavifera (TURNER) C. AGARDH, 1822, p. 437. MONTAGNE, 1850, p. 247. ZANARDINI, 1858, p. 285. MUSCHLER, 1908, p. 169.

Chauvinia clavifera (TURNER) KÜTZING, 1849, p. 498.

Caulerpa racemosa var. *clavifera* (TURNER) WEBER-VAN BOSSE, 1898, p. 361, pl. 33, fig. 1. LYLE, 1926, p. 40.

Fucus uvifer TURNER, 1819, p. 81, pl. 230 (non FORSSKÅL, 1775).

Caulerpa clavifera var. *uvifera* C. AGARDH, 1822, p. 438. SCHIMPER, 1835–37, nos. 470 and 930. DECAISNE, 1841, p. 121. RUPRECHT, 1849, p. 82. ZANARDINI, 1858, p. 285.

Caulerpa racemosa var. *uvifera* (C. AGARDH) J. AGARDH, 1872*b*, p. 35. PICCONE, 1893, p. 380; 1900*a*, p. 254. WEBER-VAN BOSSE, 1898, p. 362. REINBOLD, 1903, p. 227. HARVEY-GIBSON, 1908, p. 76. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Type loc: Suez.
Red Sea distr.: Mandola Islet, Sudanese coast, Berenice, Koseir, Ghardaqa, Suez, Tor, Ras Nusrani, Nuweiba, Aqaba, Jiddah, Hodeida.

Note: The nomenclature of this variety has been discussed by PAPENFUSS and EGEROD (1957, p. 88). NASR (1947, p. 56) has obtained cultural evidence showing that variety *lamourouxii* of this species is the same as variety *racemosa.*

Caulerpa racemosa var. ***turbinata** (J. AGARDH) EUBANK

Records under syns.

Caulerpa clavifera var. *turbinata* J. AGARDH, 1837, p. 173.

Caulerpa racemosa var. *racemosa* J. AGARDH, 1872*b*, p. 35.

Caulerpa racemosa var. *chemnitzia* f. *turbinata* (J. AGARDH) WEBER-VAN BOSSE, 1898, p. 370.

Caulerpa chemnitzia (ESPER) LAMOUROUX. DECAISNE, 1841, p. 121. ZANARDINI, 1858, p. 286. MUSCHLER, 1908, p. 170.

Type loc.: Tor.
Red Sea distr.: Koseir, Suez, Tor, Jiddah.

Caulerpa scalpelliformis var. ***denticulata** (DECAISNE) WEBER-VAN BOSSE

WEBER-VAN BOSSE, 1898, p. 287, pl. 23, figs. 8 and 10.

Records under other names

Caulerpa denticulata DECAISNE, 1841, p. 120, pl. 6, figs. B1–B10. MONTAGNE, 1850, p. 247. J. AGARDH, 1872*b*, p. 13. MUSCHLER, 1908, p. 167.

Caulerpa scalpelliformis (BROWN ex TURNER) C. AGARDH. MONTAGNE, 1850, p. 247. ZANARDINI, 1858, p. 284. MUSCHLER, 1908, p. 167. HARVEY-GIBSON and KNIGHT, 1913, p. 306. NASR, 1939*a*, p. 56; 1947, p. 54.

Caulerpa scalpelliformis var. *intermedia* WEBER-VAN BOSSE, 1898, p. 287, pl. 23, fig. 9.

Type loc.: Not specified, "ad littora Arabiae occidentalis, Tor, Djedda, etc."
Red Sea distr.: Sudanese coast, Koseir, Suez, Tor, Aqaba, Jiddah, Hodeida.

***Caulerpa selago** (TURNER) C. AGARDH

C. AGARDH, 1822, p. 442. J. AGARDH, 1837, p. 174; 1872*b*, p. 27. ZANARDINI, 1858, p. 285. WEBER-VAN BOSSE, 1898, p. 296. MUSCHLER, 1908, p. 169.

Records under syns.

Fucus selago TURNER, 1808, p. 122, pl. 55.

Chauvinia selago (TURNER) KÜTZING, 1857, p. 5, pl. 11, fig. I.

Type loc.: Red Sea.
Red Sea distr.: Ethiopian coast, Koseir, Jiddah, Hodeida, Mocha.

***Caulerpa serrulata** (FORSSKÅL) J. AGARDH

J. AGARDH, 1837, p. 174; 1872*b*, p. 19. Børgesen, 1932, p. 5, pl. 1, fig. 2. NASR, 1947, p. 55, pl. 3, fig. 2. RAYSS, 1959, p. 9. RAYSS and DOR, 1963, p. 23.

Records under syns.

Fucus serrulatus FORSSKÅL, 1775, pp. cxxv and 189.

Caulerpa freycinetii C. AGARDH. SCHIMPER, 1835–37, no. 471. DECAISNE, 1841, p. 122. RUPRECHT, 1849, p. 82. KÜTZING, 1849, p. 495; 1857, p. 2, pl. 4, fig. III. MONTAGNE, 1850, p. 248. ZANARDINI, 1858, p. 283. PICCONE, 1884, p. 293. DETONI and PAOLETTI, 1888, p. 75. MUSCHLER, 1908, p. 169.

Caulerpa freycinetii var. *serrulata* (FORSSKÅL) ZANARDINI, 1858, p. 283.

Caulerpa freycinetii var. *integerrima* ZANARDINI, 1858, p. 283. WEBER-VAN BOSSE, 1898, p. 317, pl. 25, fig. 1.

Caulerpa freycinetii var. *boryana* (J. AGARDH) WEBER-VAN BOSSE, 1898, p. 315, pl. 25, fig. 10. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Caulerpa freycinetii var. *typica* f. *serrulata* (FORSSKÅL) WEBER-VAN BOSSE, 1898, p. 314, pl. 25, fig. 6.

Type loc.: Mocha.

Red Sea distr.: Ethiopian coast, Massawa, Suakin, Sudanese coast, Koseir, Ghardaqa, Suez, Abu Rodeis, Tor, Eilat, Aqaba, Jiddah, Hodeida, Mocha.

Caulerpa sertularioides (GMELIN) HOWE

BØRGESEN, 1932, p. 7.

Records under other names

Fucus plumaris FORSSKÅL, 1775, pp. cxxv and 190.

Caulerpa plumaris (FORSSKÅL) C. AGARDH, 1822, p. 436. ZANARDINI, 1858, p. 285. DETONI and PAOLETTI, 1888, p. 75.

Fucus sertularioides GMELIN. VAHL, 1791, p. 105.

Fucus taxifolius sensu TURNER, 1808, p. 120, pl. 54.

Red Sea distr.: Massawa, Berenice, Aqaba, Jiddah, Hodeida, Mocha.

Caulerpa webbiana MONTAGNE

DECAISNE, 1841, p. 122. WEBER-VAN BOSSE, 1898, p. 269. MUSCHLER, 1908, p. 166. NASR, 1947, p. 54.

Red Sea distr.: Ghardaqa, Suez, Jiddah.

CODIACEAE

Codium STACKHOUSE

***Codium arabicum** KÜTZING

KÜTZING, 1856, p. 35, pl. 100, fig. II. ZANARDINI, 1858, p. 292. SCHMIDT, 1923, p. 30. RAYSS and DOR, 1963, p. 22.

Records under other names

Codium adhaerens sensu SCHIMPER, 1835–37, no. 469. Sensu MUSCHLER, 1908, p. 171. Sensu NASR, 1947, p. 52. Sensu RAYSS, 1959, p. 11.

Spongodium adhaerens sensu DECAISNE, 1841, p. 126.

Lamarckia adhaerens sensu RUPRECHT, 1849, p. 82.

Type loc.: Tor.

Red Sea distr.: Ghardaqa, Suez, Tor, Abu Zabad.

Note: KÜTZING did not name the collector of the type. According to SCHMIDT, the type is a SCHIMPER specimen (no. 469).

Codium dwarkense BØRGESEN

RAYSS and DOR, 1963, p. 22.

Record under another name
Codium vermilara sensu Rayss, 1959, p. 11.

Red Sea distr.: Abu Zabad.

Codium repens P.L. et H.M. Crouan

Nasr, 1947, p. 52.
Red Sea distr.: Ghardaqa.
Note: This record is probably based on a misidentification.

Codium tenue Kützing

Harvey-Gibson and Knight, 1913, p. 306.
Red Sea distr.: Sudanese coast.
Note: The material from the Red Sea almost certainly is not *Codium tenue*.

Codium tomentosum Stackhouse

Schimper, 1835–37, no. 468. Zanardini, 1858, p. 291. Piccone, 1884, p. 294; 1900*c*, p. 119. Reinbold, 1903, p. 227. Muschler, 1908, p. 172. Harvey-Gibson, 1908, p. 77. Harvey-Gibson and Knight, 1913, p. 306. Schmidt, 1923, p. 39.

Records under other names
Lamarckia tomentosa (Stackhouse) Stackhouse. Ruprecht, 1849, p. 82.
Codium dichotomum sensu Nasr, 1939*a*, p. 56; 1947, p. 53.

Red Sea distr.: Bay of Assab, Suakin, Sudanese coast, Koseir, Ghardaqa, Suez, Tor, Aqaba.
Note: It is doubtful that the material from the Red Sea determined as *Codium tomentosum* actually is representative of this species. It may belong to *C. dwarkense* (see Rayss and Dor, 1963, p. 22).

UDOTEACEAE

Avrainvillea Decaisne

Avrainvillea amadelpha (Montagne) A. et E.S. Gepp

Gepp and Gepp, 1911, p. 42, Lami, 1932, p. 355, Nasr, 1947, p. 48. Rayss, 1959, p. 10.

Records under other names
Chloroplegma sordidum Zanardini, 1858, p. 291, pl. 13, fig. 1.
Avrainvillea lacerata sensu Harvey-Gibson, 1908, p. 77. Sensu Harvey-Gibson and Knight, 1913, p. 306.

Red Sea distr.: Sudanese coast, Ghardaqa, Suez, Abu Rudeis, Tor, Ras Nusrani, Gesireh (as given by Rayss = Farun Island), Aqaba.

Avrainvillea erecta (BERKELEY) A. et E.S. GEPP

Record under another name

Avrainvillea papuana (ZANARDINI) G. MURRAY et BOODLE. HARVEY-GIBSON, 1908, p. 77.

Red Sea distr.: Suakin.

Halimeda LAMOUROUX *(nom. cons.)*

Halimeda discoidea DECAISNE

HILLIS, 1959, p. 352.
Red Sea distr.: Red Sea.

***Halimeda macroloba** DECAISNE

DECAISNE, 1841, p. 118; 1842, p. 103. KÜTZING, 1849, p. 504; 1857, p. 8, pl. 22, fig. I. ZANARDINI, 1858, p. 287. J. AGARDH, 1887, p. 81. BORNET, 1888, p. 17. BARTON, 1901, p. 24. REINBOLD, 1903, p. 228. MUSCHLER, 1908, p. 173. HILLIS, 1959, p. 375.
Type loc.: Jiddah.
Red Sea distr.: Koseir, Suez, Tor, Aqaba, Yenbo, Jiddah, Kamaran Island.

Halimeda monile (ELLIS et SOLANDER) LAMOUROUX

ZANARDINI, 1858, p. 289. MUSCHLER, 1908, p. 174.

Records under other names

Halimeda incrassata f. *monilis* (ELLIS et SOLANDER) BARTON. HARVEY-GIBSON, 1908, p. 77.
Halimeda incrassata f. *cylindrica* BØRGESEN. NASR, 1939*a*, p. 55, pl. 1, fig. 1; 1947, p. 51.

Red Sea distr.: Koseir, Suez, Aqaba, Tiran Island.
Note: It is doubtful that any of the material referred to this taxon was correctly determined.

***Halimeda nervata** ZANARDINI

ZANARDINI, 1858, p. 289, pl. 12, fig. 2. MUSCHLER, 1908, p. 174.
Type loc.: Koseir.
Distr.: Koseir, Suez.
Note: The status of this species is uncertain. According to HILLIS (1959, p. 377) the figure of ZANARDINI suggests *Halimeda opuntia*.

Halimeda opuntia var. **opuntia**

HILLIS, 1959, pp. 360 and 362.

Records under other names

Halimeda opuntia (LINNAEUS) LAMOUROUX. DECAISNE, 1841, p. 118; 1842, p. 102. ZANARDINI, 1858, p. 288. PICCONE, 1893, p. 380; 1900*a*, p. 254. BARTON, 1901, p. 18, pl. 2, fig. 21 (as *Halimeda opuntia* f. *cordata*). REINBOLD, 1903, p. 228. MUSCHLER, 1908, p. 174. HARVEY-GIBSON, 1908, p. 77. HARVEY-GIBSON and KNIGHT, 1913, p. 306 (as *Halimeda opuntia* f. *typica*, f. *triloba*, and f. *cordata*). NASR, 1947, p. 50. RAYSS, 1959, p. 11.

Halimeda multicaulis sensu SCHIMPER, 1835–37, no. 932.
Halimeda triloba DECAISNE. ZANARDINI, 1858, p. 288.
Halimeda cordata J. AGARDH, 1887, p. 83.
Halimeda opuntia f. *triloba* (DECAISNE) BARTON. HARVEY-GIBSON, 1908, p. 77.
Halimeda opuntia var. *triloba* (DECAISNE) J. AGARDH. MUSCHLER, 1908, p. 174.

Red Sea distr.: Bay of Assab, Mandola Islet, Dissei Islet, Suakin, Sudanese coast, Koseir, Ghardaqa, Suez, Tor, Ras Nusrani, Aqaba, Jiddah.

***Halimeda papyracea** ZANARDINI

ZANARDINI, 1851, p. 37; 1858, p. 288, pl. 13, fig. 2. MUSCHLER, 1908, p. 173.
Type loc.: Not specified, Suez, Tor.
Distr.: Suez, Tor.

Note: The status of this species is uncertain. For comments on it see HILLIS (1959, p. 377).

Halimeda tuna (ELLIS et SOLANDER) LAMOUROUX

HARVEY-GIBSON and KNIGHT, 1913, p. 306. NASR, 1947, p. 50.
Red Sea distr.: Sudanese coast, Koseir, Ghardaqa.

Note: The records of the occurrence of this species in the Red Sea may be based on misidentifications.

Rhipiliopsis A. et E.S. GEPP

***Rhipiliopsis aegyptiaca** NASR

NASR, 1939*a*, p. 53, figs. 3 and 4; 1944, p. 40; 1947, p. 47, pl. 2, fig. 2.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Tydemania WEBER-VAN BOSSE

***Tydemania mabahithae** NASR

NASR, 1939*a*, p. 55; 1944, p. 40; 1947, p. 51.
Type loc.: Mashabih Island.
Distr.: Mashabih Island.

Udotea LAMOUROUX

***Udotea argentea** ZANARDINI

ZANARDINI, 1858, p. 290, pl. 12, fig. 1. MUSCHLER, 1908, p. 172. HARVEY-GIBSON, 1908, p. 77. GEPP and GEPP, 1911, p. 125. HARVEY-GIBSON and KNIGHT, 1913,

p. 306, LYLE, 1926, p. 40. NASR, 1939*a*, p. 55; 1947, p. 49. RAYSS, 1955, p. 28; 1959, p. 10.

Type loc.: Suez.

Red Sea distr.: Sudanese coast, Dungunab Bay, Ghardaqa, Suez, Suez Canal, Aqaba.

Udotea flabellum (ELLIS et SOLANDER) HOWE

GEPP and GEPP, 1911, p. 131.

Red Sea distr.: Red Sea.

Udotea javensis (MONTAGNE) A. et E.S. GEPP

NASR, 1939*a*, p. 51, fig. 5; 1947, p. 49.

Red Sea distr.: Ghardaqa.

Udotea minima ERNST

Record under syn.

Flabellaria minima (ERNST) A. et E.S. GEPP. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Red Sea distr.: Sudanese coast.

Note: It seems likely that the material on which this record is based actually is representative of *Udotea javensis*.

DASYCLADALES

DASYCLADACEAE

Acetabularia LAMOUROUX *(nom. cons.)*

Acetabularia acetabulum (LINNAEUS) SILVA

Records under syns.

Fucus callo-pilophorus FORSSKÅL, 1775, p. lxxvii *(nom. nud.)*.
Acetabularia mediterranea LAMOUROUX. LYLE, 1926, p. 40.

Red Sea distr.: Suez, Suez Canal.

Note: The placement of *Fucus callo-pilophorus* FORSSKÅL as a synonym of *Acetabularia acetabulum* is based on the statement of WEBER (1804, p. 135).

Acetabularia calyculus QUOY et GAIMARD

NASR, 1939*c*, p. 347; 1947, p. 40, fig. 10. RAYSS, 1959, p. 9.

Red Sea distr.: Ghardaqa, Shora el Manqata.

Acetabularia exigua SOLMS-LAUBACH

NASR, 1947, p. 42.

Red Sea distr.: Ghardaqa.

Acetabularia moebii SOLMS-LAUBACH

NASR, 1939*a*, p. 52; 1947, p. 42, fig. 11.
Red Sea distr.: Ghardaqa.

Neomeris LAMOUROUX

Neomeris annulata DICKIE

NASR, 1947, p. 39, fig. 9.
Red Sea distr.: Ghardaqa.

SPECIES INQUIRENDA

Conferva LINNAEUS *(nom. rej.)*

Conferva capillaris sensu FORSSKÅL

FORSSKÅL, 1775, p. cxxvi.
Red Sea distr.: Mocha.

Note: The identity of the material on which this record is based is unknown. According to CHRISTENSEN (1922, p. 37) the material is present in FORSSKÅL's herbarium.

***Conferva plana** FORSSKÅL

FORSSKÅL, 1775, pp. cxxvi and 188.
Type loc.: Mocha.
Red Sea distr.: Mocha.

Note: The identity of this species is unknown. Voucher material apparently is not in existence. C. AGARDH (1828, p. 53) listed the name as a likely synonym of the red alga *Rytiphlaea tinctoria,* but the presence of this species in the Red Sea is somewhat doubtful (see p. 101).

CHRYSOPHYCEAE

CHRYSOCAPSALES

CHRYSOCAPSACEAE

Phaeocystis LAGERHEIM

Phaeocystis giraudii (DERBÈS et SOLIER) LAGERHEIM

NASR, 1941, p. 59, fig. 2.
Red Sea distr.: Ghardaqa.

PHAEOPHYCOPHYTA

ECTOCARPALES

ECTOCARPACEAE

Ectocarpus LYNGBYE *(nom. cons.)*

Ectocarpus elachistaeformis HEYDRICH

NASR, 1947, p. 60, fig. 13. RAYSS and DOR, 1963, p. 23.

Red Sea distr.: Ghardaqa on *Codium*, Eilat on *Lithoderma*.

Ectocarpus siliculosus (DILLWYN) LYNGBYE

ZANARDINI, 1858, p. 253. MUSCHLER, 1908, p. 195. HARVEY-GIBSON, 1908, p. 79. NASR, 1947, p. 60.

Red Sea distr.: Suakin, Koseir, Ghardaqa, Suez Bay, Aqaba.

Feldmannia HAMEL

Feldmannia irregularis (KÜTZING) HAMEL

Records under syns.

Ectocarpus irregularis KÜTZING. BØRGESEN, *1941*, pp. *23–31*.

Ectocarpus arabicus FIGARI et DENOTARIS, 1853, p. 169, fig. V. ZANARDINI, 1858, p. 253. PICCONE, 1886, p. 30. MUSCHLER, 1908, p. 195. LYLE, 1926, p. 40. NASR, 1939*a*, p. 58, figs. 6 and 7; 1947, p. 62. RAYSS, 1959, p. 11.

Ectocarpus arabicus KÜTZING, 1855, p. 21, pl. 72, fig. II (non FIGARI et DENOTARIS).

Ectocarpus coniger var. *arabicus* NASR, 1941, pp. 60–62, figs. 3 and 4.

Red Sea distr.: Massawa, Daedalus Reef, Koseir, Ghardaqa, Suez, Suez Canal, Eilat.

Note: See BØRGESEN (1941, pp. 23–31) for a discussion of this species and its synonymy. SCHIFFNER (1934, p. 117) reported this species (as *Ectocarpus arabicus* FIGARI et DENOTARIS) from Gischen (=Qishn), which he thought was on the Arabian side of the Red Sea. However, as is pointed out in the footnote on page 42 of the present paper, Qishn is a place on the Arabian Sea.

Giffordia BATTERS

***Giffordia ghardaqaensis** (NASR) PAPENFUSS, comb. nov.

Records under syn.

Ectocarpus ghardaqaensis NASR, 1939*a*, p. 59, figs. 8 and 9; 1944, p. 41; 1947, p. 65.

Type loc.: Ghardaqa.

Distr.: Ghardaqa.

Giffordia indica (Sonder) Papenfuss et Chihara, comb. nov.†

Record under syn.
Ectocarpus duchassaingianus Grunow. Nasr, 1947, p. 63, figs. 14 and 15.

Red Sea distr.: Ghardaqa.

Note: See Børgesen (1941, pp. 16–22) for an account of this species. The taxon is referable to *Giffordia*.

Giffordia mitchellae (Harvey) Hamel

Record under syn.
Ectocarpus mitchellae Harvey. Nasr, 1947, p. 63, pl. 5, fig. 1.

Red Sea distr.: Koseir, Ghardaqa.

RALFSIACEAE

Lithoderma J.E. Areschoug

Lithoderma subextensum var. ***intermedia** Rayss et Dor
Rayss and Dor, 1963, p. 23, fig. 5.
Type loc.: Eilat.
Distr.: Eilat.

Petroderma Kuckuck

Petroderma maculiforme (Wollny) Kuckuck
Rayss and Dor, 1963, p. 25, fig. 6a.
Red Sea distr.: Eilat.

***Petroderma steinitzii** Rayss et Dor
Rayss and Dor, 1963, p. 26, figs. 6b–6d.
Type loc.: Eilat.
Distr.: Eilat.

Ralfsia Berkeley

Ralfsia verrucosa var. ***erythraea** Piccone et Grunow
Piccone and Grunow, *in* Piccone, 1884, p. 295.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.

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†Basionym: *Ectocarpus indicus* Sonder, *in* Zollinger, Syst. Verz. ind. Arch. gesamm. sowie Japan empf. Pfl. p. 3. 1854.

SPHACELARIALES

SPHACELARIACEAE

Sphacelaria LYNGBYE

Sphacelaria furcigera KÜTZING

ZANARDINI, 1858, p. 253. SAUVAGEAU, 1901, p. 145. MUSCHLER, 1908, p. 195. NASR, 1939*a*, p. 60; 1947, p. 73. RAYSS, 1959, p. 13.

Records under syn.

Sphacelaria cirrhosa var. *minima* FIGARI et DENOTARIS, 1858, p. 167. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Red Sea distr.: Sudanese coast, Daedalus Reef, Koseir, Ghardaqa, Suez, Tor, Eilat.

***Sphacelaria intermedia** SAUVAGEAU

SAUVAGEAU, 1901, p. 117, fig. 26.

Type loc.: Kamaran Island on *Turbinaria* (in error as Ile de Karaman).

Distr.: Kamaran Island.

***Sphacelaria rigidula** KÜTZING

KÜTZING, 1843, p. 292; 1849, p. 463; 1855, p. 25, pl. 86, fig. I. ZANARDINI, 1858, p. 252. PICCONE, 1886, p. 30; 1889, p. 68.

Records under another name

Sphacelaria cervicornis sensu RUPRECHT, 1849, p. 81. Sensu? BORNET, 1888, p. 18.

Type loc.: Nuweiba on *Hormophysa triquetra.*

Distr.: Assab, Assarca Islet, Massawa, Nuweiba, ?Kamaran Island.

Note: SAUVAGEAU does not mention this species in his monograph of the Sphacelariales. DETONI (1895, p. 507) gives the name as a synonym of the younger name *Sphacelaria furcigera.*

Sphacelaria tribuloides MENEGHINI

SAUVAGEAU, 1901, p. 123. REINBOLD, 1903, p. 230. NASR, 1947, p. 74. RAYSS, 1959, p. 14.

Records under other names

Sphacelaria cervicornis sensu SCHIMPER, 1835–37, no. 476. Sensu DECAISNE, 1841, p. 127. Sensu FIGARI and DENOTARIS, 1853, p. 166, fig. VI. Sensu ZANARDINI, 1858, p. 252.

Sphacelaria rigida sensu KÜTZING, 1855, p. 26, pl. 90, fig. I. Sensu ZANARDINI, 1858, p. 252. Sensu PICCONE, 1884, p. 294. Sensu? HARVEY-GIBSON, 1908, p. 79.

Red Sea distr.: Bay of Assab, Massawa, Ghardaqa, Gulf of Suez, Tor, Shora el Manqata, Eilat.

STYPOCAULACEAE

Halopteris KÜTZING

Halopteris scoparia (LINNAEUS) SAUVAGEAU

RAYSS, 1959, p. 13.

Red Sea distr.: Aqaba.

CUTLERIALES

CUTLERIACEAE

Zanardinia NARDO

Zanardinia collaris (C. AGARDH) P.L. et H.M. CROUAN

HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Red Sea distr.: Sudanese coast.

Note: It seems likely that the material referred to this species by HARVEY-GIBSON and KNIGHT is representative of *Pocockiella variegata.*

DICTYOTALES

DICTYOTACEAE

Dictyopteris LAMOUROUX *(nom. cons.)*

Dictyopteris membranacea (STACKHOUSE) BATTERS

NASR, 1947, p. 81.

Record under syn.

Halyseris polypodioides (DESFONTAINES) C. AGARDH. DETONI and PAOLETTI, 1888, p. 71.

Red Sea distr.: Massawa, Strait of Jubal.

Dictyota LAMOUROUX *(nom. cons.)*

Dictyota ciliolata KÜTZING

RAYSS and DOR, 1963, p. 28.

Records under syn.

Dictyota ciliata J. AGARDH (non LAMOUROUX). ZANARDINI, 1858, p. 248. PICCONE, 1884, p. 296; 1886. p. 32; 1900*a*, p. 257.

Red Sea distr.: Bay of Assab, Dissei Islet, Shumma Islet, Tor, Eilat, Yemen.

Dictyota dichotoma (HUDSON) LAMOUROUX

PICCONE, 1900*a*, p. 257. HARVEY-GIBSON, 1908, p. 79. NASR, 1947, p. 79.

Red Sea distr.: Gulf of Zula, Tella Tella Kebir Island, Ghardaqa.

Dictyota dichotoma var. ***fimbriata** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 296.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Dictyota dichotoma var. **intricata** (C. AGARDH) GREVILLE

DECAISNE, 1841, p. 138. RAYSS, 1959, p. 14.

Records under syns.

Dictyota implexa (DESFONTAINES) LAMOUROUX. DELILE, 1813*a*, p. 81; 1813*b*, p. 293, pl. 56, fig. 2; 1824, pp. 114 and 397, pl. 56, fig. 2.

Zonaria dichotoma var. *intricata* C. AGARDH. DECAISNE, 1834, p. 10.

Dictyota dichotoma var. *implexa* (DESFONTAINES) S.F. GRAY. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Red Sea distr.: Sudanese coast, Suez, Abu Rudeis. Tor. Ras Nusrani, Eilat, Jiddah.

Note: The nomenclature of this variety has been discussed by PAPENFUSS (1944).

Dictyota dichotoma var. **patens** KÜTZING *(nom. nud.)*

PICCONE, 1884, p. 296.
Red Sea distr.: Massawa.

Dictyota divaricata LAMOUROUX

NASR, 1947, p. 80.
Red Sea distr.: Ghardaqa.

Dictyota indica SONDER ex KÜTZING

NASR, 1947, p. 79. RAYSS, 1959, p. 14.
Red Sea distr.: Ghardaqa, Ras Nusrani.

Dictyota sandvicensis SONDER ex KÜTZING

PICCONE, 1884, p. 296; 1886, p. 32; 1900*a*, p. 257.
Red Sea distr.: Gulf of Zula, Dissei Islet, Massawa.

Dilophus J. AGARDH

Dilophus fasciola (ROTH) HOWE

NASR, 1947, p. 80. pl. 11, fig. 1.

Records under other names

Fucus linearis FORSSKÅL, 1775, pp. cxxv and 190 (non HUDSON, 1762).

Zonaria fasciola (ROTH) C. AGARDH, 1820, p. 136.

Dictyota fasciola (ROTH) LAMOUROUX. FIGARI and DENOTARIS, 1853, p. 160. ZANARDINI, 1858, p. 247.

PICCONE, 1900*c*, p. 120. MUSCHLER, 1908, p. 190.
Dictyota implexa sensu? DECAISNE, 1841, p. 138.
Dictyota acuminata KÜTZING, 1849, p. 555; 1859, p. 7, pl. 15, fig. III.
?*Dictyota abyssinica* KÜTZING, 1859, p. 9, pl. 21, fig. III.
Dictyota notarisii KÜTZING, 1859, p. 11, pl. 25, fig. III.

Red Sea distr.: Koseir, Ghardaqa, Suez, Tor, Aqaba, Jiddah, Mocha.

Note: C. AGARDH, (1820, p. 136) saw a specimen of *Fucus linearis* FORSSKÅL (a later homonym of *Fucus linearis* HUDSON, 1762) in Herbarium Hornemann (Copenhagen) and identified it with the species now known as *Dilophus fasciola*. The specimen seen by C. AGARDH is now lost, according to BØRGESEN (1932, p. 6).

Padina ADANSON *(nom. cons.)*

Padina commersonii BORY

HAUCK, 1887, p. 44.
Red Sea distr.: Red Sea.

Padina pavonica (LINNAEUS) THIVY

Records under syns.
Fucus pavonicus LINNAEUS. FORSSKÅL, 1775, p. cxxv.
Padina pavonia (LINNAEUS) LAMOUROUX. SCHIMPER, 1835-37, no. 463. DECAISNE, 1841, p. 138. J. AGARDH, 1848, p. 113. RUPRECHT, 1849, p. 81. FIGARI and DENOTARIS, 1853, p. 156. ZANARDINI, 1858, p. 244. PICCONE, 1884, p. 298; 1886, p. 35; 1889, p. 68; 1893, p. 381; 1900*a*, p. 256; 1900*c*, p. 120. LICATA, 1885, p. 186. BALSAMO, 1885, p. 12. BORNET, 1888, p. 19. DETONI and PAOLETTI, 1888, p. 71. REINBOLD, 1903, p. 230. MUSCHLER, 1908, p. 189. HARVEY-GIBSON, 1908, p. 78. HARVEY-GIBSON and KNIGHT, 1913, p. 306. LYLE, 1926, p. 40. NASR, 1947, p. 77. RAYSS, 1959, p. 14.

Red Sea distr.: Bay of Assab, Gulf of Zula, Dissei Islet, Massawa, Trinkitat, Suakin, Sudanese coast, Koseir, Safâga, Ghardaqa, Suez, Suez Canal, Tor, Sharm el Sheikh, Ras Nusrani, Eilat, Aqaba, Jiddah, Kạmaran Island, Mocha.

Note: More than one species are probably involved in these records.

Padina tetrastromatica HAUCK

NEWTON, 1953, pp. 396 and 405.
Red Sea distr.: Hanish Islands.

Pocockiella PAPENFUSS

Pocockiella variegata (LAMOUROUX) PAPENFUSS

RAYSS, 1959, p. 15.

Records under syns.

Zonaria variegata (LAMOUROUX) C. AGARDH. MONTAGNE, 1850, p. 243. ZANARDINI, 1858, p. 245. PICCONE, 1886, p. 35. DETONI and PAOLETTI, 1888, p. 71. HARVEY-GIBSON and KNIGHT, 1913, p. 306. NASR, 1939, p. 60; 1947, p. 76.

Zonaria latissima KÜTZING, 1859, p. 30, pl. 75, fig. I.

Zonaria isselii PICCONE et GRUNOW, *in* PICCONE, 1884, p. 297, pl. 7, figs. 1–4, and pl. 9, fig. 1.

Red Sea distr.: Ethiopian coast, Massawa, Suakin, Sudanese coast, Daedalus Reef, Ghardaqa, Eilat, Hodeida, Yemen.

Note: J. AGARDH (1882, p. 131) suspected that *Zonaria latissima,* which was described by KÜTZING from material from the Ethiopian coast, was the juvenile form of *Z. schimperi,* but KÜTZING's figures show that *Z. latissima* is the same as *Pocockiella variegata.*

Spatoglossum KÜTZING

***Spatoglossum intermedium** KÜTZING

KÜTZING, 1863, p. 14.

Type loc.: Not specified, Red Sea.

Note: The status of this species is uncertain.

***Spatoglossum variabile** FIGARI et DENOTARIS

FIGARI et DENOTARIS, 1853, p. 158, fig. IV. ZANARDINI, 1858, p. 246. MUSCHLER, 1908, p. 189. NASR, 1947, p. 78.

Records under syn.

Spatoglossum lubricum FIGARI et DENOTARIS, 1853, p. 158, fig. I. KÜTZING, 1859, p. 20, pl. 48, fig. I.

Type loc.: Not specified, Suez, Aqaba.

Red Sea distr.: Ethiopian coast, Koseir, Suez, Aqaba.

***Stoechospermum** KÜTZING

***Stoechospermum marginatum** (C. AGARDH) KÜTZING

KÜTZING, 1843, p. 339; 1849, p. 560; 1859, p. 17, pl. 40, fig. I. J. AGARDH, 1848, p. 99. MONTAGNE, 1850, p. 243. ZANARDINI, 1858, p. 247. PICCONE, 1884, p. 297; 1900*a,* p. 256. LICATA, 1885, p. 186. BALSAMO, 1885, p. 12. MUSCHLER, 1908, p. 189. RAYSS, 1959, p. 14.

Records under syns.

Zonaria marginata C. AGARDH, 1824, p. 266. BOVÉ, 1834, p. 77. DECAISNE, 1834, p. 10.

Dictyota marginata (C. AGARDH) GREVILLE. DECAISNE, 1841, p. 138.

Zonaria patens HERING, *in* SCHIMPER, 1835–37, no. 473 *(nom. nud.).*

Stoechospermum patens J. AGARDH, 1848, p. 99. RUPRECHT, 1849, p. 81. FIGARI and DENOTARIS, 1853, p. 160. KÜTZING, 1859, p. 17, pl. 40, fig. II.

Type loc.: Red Sea (leg. FORSSKÅL).

Red Sea distr.: Bay of Assab, Gulf of Zula, Suez, Tor, Sinai Peninsula, Aqaba, Jiddah, Hodeida.

Stypopodium KÜTZING

Stypopodium zonale (LAMOUROUX) PAPENFUSS

Records under syn.

Zonaria zonalis (LAMOUROUX) HOWE. NASR, 1947, p. 76. RAYSS, 1959, p. 15.

Red Sea distr.: Ghardaqa, Abu Rudeis, Abu Zenîma.

Zonaria C. AGARDH *(nom. cons.)*†

***Zonaria schimperi** KÜTZING

KÜTZING, 1849, p. 565; 1859, p. 30, pl. 74. ZANARDINI, 1858, p. 245. MUSCHLER, 1908, p. 188. HARVEY-GIBSON, 1908, p. 78. NASR, 1949, p. 76.

Record under syn.

Zonaria ambigua FIGARI et DENOTARIS, 1853, p. 157.

Type loc.: Nuweiba.

Distr.: Strait of Jubal, Suez, Nuweiba.

Note: The generic position of this species is uncertain.

CHORDARIALES

CHORDARIACEAE

Eudesme J. AGARDH

***Eudesme flavescens** (ZANARDINI) DETONI

DETONI, 1895, p. 404. MUSCHLER, 1908, p. 192.

Records under other names

Mesogloia flavescens ZANARDINI, 1858, p. 251, pl. 4, fig. 2.

Mesogloia vermicularis var. *gracilis* sensu? DECAISNE, 1841, p. 129. Sensu FIGARI and DENOTARIS, 1853, p. 164, fig. II.

Castagnea flavescens (ZANARDINI) NASR, 1947, p. 67, pl. 5, fig. 2.

Type loc.: Not specified, Suez, Aqaba.

Distr.: Ghardaqa, Suez, ?Tor, Aqaba.

Note: The identity of this species is uncertain.

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†KÜTZING (1859, p. 27, pl. 68, fig. I) described and illustrated a plant from Koseir under the name *Phycopteris costata. Phycopteris* KÜTZING is a synonym of *Zonaria* but *P. costata* has not, as yet, been transferred to *Zonaria*. To judge from KÜTZING's figures of *P. costata,* the plant appears to be a species of *Zonaria,* but formal removal to this genus had best be delayed until the type has been examined.

Eudesme virescens (CARMICHAEL) J. AGARDH

Record under syn.
Castagnea virescens (CARMICHAEL) THURET. HARVEY-GIBSON, 1908, p. 79.

Red Sea distr.: Suakin, Gulf of Suez.

Note: The identity of the material referred to this species by HARVEY-GIBSON is uncertain.

Myriogloia KUCKUCK

***Myriogloia ramosissima** (ZANARDINI) PAPENFUSS, comb. nov.

Records under other names:
Mesogloia ramosissima ZANARDINI, 1858, p. 250, pl. 4, fig. 1.
Mesogloia vermicularis sensu FIGARI and DENOTARIS, 1853, p. 164.
Castagnea ramosissima (ZANARDINI) NASR, 1947, p. 66, fig. 16.

Type loc.: Not specified, Suez, Aqaba.
Distr.: Ghardaqa, Suez, Aqaba.

Note: From NASR's description and illustration of this species, it is evident that it is not representative either of *Mesogloia* C. AGARDH (which does not form plurilocular sporangia) or of *Castagnea* DERBÈS et SOLIER (=*Cladosiphon* KÜTZING), but of *Myriogloia* KUCKUCK.

SPERMATOCHNACEAE

Nemacystus DERBÈS et SOLIER

***Nemacystus erythraeus** (J. AGARDH) SAUVAGEAU
KYLIN, 1940, p. 46.

Records under other names
Cladosiphon erythraeus J. AGARDH, 1848, p. 55. ZANARDINI, 1858, p. 251.
Mesogloia vermicularis var. *gracilis* HERING, *in* SCHIMPER, 1835–37, no. 475 *(nom. nud.)*.
Mesogloia gracilis sensu KÜTZING, 1858, p. 5, pl. 10, fig. 1. Sensu J. AGARDH, 1882, p. 33.
Mesogloia mediterranea sensu RUPRECHT, 1849, p. 81.

Type loc.: Red Sea [Tor] on *Sargassum.*
Distr.: Tor.

Stilophora J. AGARDH *(nom. cons.)*

***Stilophora erythraea** (MONTAGNE) PAPENFUSS, comb. nov.

Records under syns.
Chordaria erythraea MONTAGNE, 1849, p. 288.
Stilophora arabica FIGARI et DENOTARIS, 1853, p. 162, fig. 111. ZANARDINI, 1858, p. 248. MUSCHLER, 1908, p. 191.

Type loc.: Red Sea.
Distr.: Suez, Tor, Aqaba.

Stilophora rhizodes (TURNER) J. AGARDH

ZANARDINI, 1858, p. 248. MUSCHLER, 1908, p. 191. NASR, 1947, p. 67.
Red Sea distr.: Koseir, Ghardaqa, Suez, Tor, Aqaba, Jiddah.

SPOROCHNALES

SPOROCHNACEAE

Nereia ZANARDINI

Nereia filiformis (J. AGARDH) ZANARDINI

NASR, 1947, p. 70.
Red Sea distr.: Ghardaqa.

Sporochnus C. AGARDH

Sporochnus comosus C. AGARDH

NASR, 1947, p. 69.
Red Sea distr.: Strait of Jubal.

DICTYOSIPHONALES

STRIARIACEAE

Striaria GREVILLE

Striaria attenuata f. **ramosissima** (KÜTZING) HAUCK

LYLE, 1926, p. 40.
Red Sea distr.: Suez Canal.

PUNCTARIACEAE

Colpomenia (ENDLICHER) DERBÈS et SOLIER

Colpomenia sinuosa (MERTENS ex ROTH) DERBÈS et SOLIER

MUSCHLER, 1908, p. 193. LAMI, 1932, p. 355. NASR, 1947, p. 71. RAYSS, 1959, p. 12.

Records under syns.

Stilophora sinuosa (MERTENS ex ROTH) C. AGARDH. DECAISNE, 1841, p. 139.

Encoelium sinuosum (MERTENS ex ROTH) C. AGARDH. SCHIMPER, 1835–37, nos. 964 and 965.

Asperococcus sinuosus (MERTENS ex ROTH) BORY. J. AGARDH, 1848, p. 75. RUPRECHT, 1849, p. 81. FIGARI and DENOTARIS, 1853, p. 163. ZANARDINI, 1858, p. 249.

Hydroclathrus sinuosus (MERTENS ex ROTH) ZANARDINI. DETONI and PAOLETTI, 1888, p. 74. HARVEY-GIBSON and KNIGHT, 1913, p. 306.

Red Sea distr.: Massawa, Sudanese coast, Koseir, Ghardaqa, Suez, Tor, Eilat Aqaba.

Hydroclathrus BORY

Hydroclathrus clathratus (C. AGARDH) HOWE

NASR, 1947, p. 72. RAYSS, 1959, p. 12.

Records under syns.

Hydroclathrus cancellatus BORY. DECAISNE, 1841, p. 138. PICCONE, 1900*c*, p. 120. MUSCHLER, 1908, p. 193. HARVEY-GIBSON, 1908, p. 78. HARVEY-GIBSON and KNIGHT, 1913, p. 306. FORTI, 1928, pp. 1449 and 1451, pl. 25, figs. 1 and 2.

Asperococcus clathratus (C. AGARDH) BORY ex J. AGARDH, 1848, p. 75. RUPRECHT, 1849, p. 81. FIGARI and DENOTARIS, 1853, p. 163. ZANARDINI, 1858, p. 249. LICATA, 1885, p. 186. BALSAMO, 1885, p. 11.

Encoelium clathratum C. AGARDH. SCHIMPER, 1835–37, no. 933.

Red Sea distr.: Assab, Sudanese coast, Koseir, Ghardaqa, Suez, Tor, Eilat, Aqaba, Hodeida.

Rosenvingia BØRGESEN

Rosenvingia intricata (J. AGARDH) BØRGESEN

NASR, 1947, p. 72. RAYSS, 1959, p. 13.

Records under syn.

Asperococcus intricatus J. AGARDH. ZANARDINI, 1858, p. 250. MUSCHLER, 1908, p. 194.

Red Sea distr.: Suez, Eilat, Mocha.

Rosenvingia orientalis (J. AGARDH) BØRGESEN

Record under syn.

Asperococcus orientalis J. AGARDH. ZANARDINI, 1858, p. 249.

Red Sea distr.: Mocha.

Scytosiphon C. AGARDH *(nom. cons.)*

Scytosiphon lomentaria (LYNGBYE) ENDLICHER

LAMI, 1932, p. 356.

Red Sea distr.: Suez Canal (Great Bitter Lake).

CHNOOSPORACEAE

Chnoospora J. AGARDH

***Chnoospora implexa** J. AGARDH

J. AGARDH, 1848, p. 172. RUPRECHT, 1849, p. 81. FIGARI and DENOTARIS, 1853, p. 155. ZANARDINI, 1858, p. 244. KUTZING, 1859, p. 36, pl. 87, fig. II. MUSCHLER, 1908, p. 192.

Records under other names

Sphaerococcus implexus HERING et MARTENS, *in* SCHIMPER, 1835–37, no. 474 *(nom. nud.)*. KÜTZING, 1849, p. 775.

Zonaria dichotoma var. *intricata* sensu SCHIMPER, 1835–37, no. 934.

Type loc.: Tor.
Red Sea distr.: Koseir, Suez, Tor, Aqaba.

FUCALES†

CYSTOSEIRACEAE

Cystoseira C. AGARDH *(nom. cons.)*

Cystoseira amentacea (C. AGARDH) BORY

HARVEY-GIBSON and KNIGHT, 1913, p. 306.
Red Sea distr.: Sudanese coast.
Note: This record may be based on a misidentification.

Cystoseira concatenata (LINNAEUS) C. AGARDH

Note: TURNER (1819, p. 128) reported this taxon (as *Fucus granulatus* var. *concatenatus*) from the Red Sea. The identity of the material in question is wholly uncertain. ROBERTS (1967, p. 347) has found that the type of *Cystoseira concatenata* is representative of *C. foeniculacea*.

Cystoseira foeniculacea (LINNAEUS) GREVILLE

Records under syn.

Fucus foeniculaceus LINNAEUS, STRAND, 1756, p. 32; 1759, p. 467. TURNER, 1819, p. 134.

Red Sea distr.: Not specified.
Note: The identity of the material from the Red Sea referred to this species is uncertain.

Cystoseira myrica (S.G. GMELIN) C. AGARDH

C. AGARDH, 1824, p. 282. DECAISNE, 1834, p. 10; 1841, p. 145. SCHIMPER, 1835–37, no. 922. SCHENK, 1840, p. 3. J. AGARDH, 1848, p. 222. RUPRECHT, 1849, p. 81. MONTAGNE, 1850, p. 242. FIGARI and DENOTARIS, 1853, p. 154. ZANARDINI, 1858, p. 243. PICCONE, 1884, p. 299; 1886, p. 42; 1889, p. 68; 1893, p. 380; 1900*a*, p. 256; 1900*c*, p. 120. DETONI and PAOLETTI, 1888, p. 74. BORNET, 1888, p. 18. REINBOLD, 1903, p. 229; 1907, p. 563. MUSCHLER, 1908, p. 185. HARVEY-GIBSON, 1908, p. 78. SAUVAGEAU, 1912, p. 367. LYLE, 1926, p. 40. LAMI, 1932, p. 355. BØRGESEN, 1932, p. 6. NASR, 1939*a*, p. 61; 1947, p. 83. RAYSS, 1959, p. 15. PAPENFUSS and JENSEN, 1967, p. 22,

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† STRAND (1756, p. 32; 1759, p. 467) reported *Fucus barbatus* LINNAEUS from the Red Sea. The identity not only of Strand's plant but of LINNAEUS's species is uncertain.

Records under syns.

Fucus myrica S.G. GMELIN. TURNER, 1811, p. 137, pl. 192.

Fucus seticulosus FORSSKÅL, 1775, pp. cxxv and 190.

Fucus antennulatus DELILE, 1813*a*, p. 80; 1813*b*, p. 291, pl. 55, fig. 1; 1824, pp. 113 and 394, pl. 55, fig. 1.

Phyllacantha myrica (S.G. GMELIN) KÜTZING, 1849, p. 598; 1860, p. 14, pl. 37, fig. I.

Phyllacantha myrica var. *hispida* KÜTZING *(nom. nud.)*. HOHENACKER, 1860, no. 432.

Cystoseira myrica var. *muricata* SCHIMPER, 1835–37, no. 935 *(nom. nud.)*.

Cystoseira myrica var. *tenella* HERING et MARTENS, *in* SCHIMPER, 1835–37, no. 953 *(nom. nud.)*.

Red Sea distr.: Bay of Assab, Mandola Islet, Dissei Islet, Dahlak Archipelago, Massawa, Sudanese coast, Koseir, Ghardaqa, Suez, Suez Canal, Abu Rudeis, Tor, Ras Muhammad, Ras Nusrani, Nuweiba, Eilat, Aqaba, Jiddah, Kamaran Island, Hodeida, Mocha.

***Cystoseira trinodis** (FORSSKÅL) C. AGARDH

C. AGARDH, 1820, p. 67; 1824, p. 286. BOVÉ, 1834, p. 77. DECAISNE, 1834, p. 10; 1841, p. 145. KÜTZING, 1843, p. 358. RUPRECHT, 1849, p. 81. PAPENFUSS and JENSEN, 1967, p. 21.

Records under other names

Fucus trinodis FORSSKÅL, 1775, pp. cxxv and 192. DELILE, 1813*a*, p. 80; 1813*b*, p. 290, pl. 54, fig. 1; 1824, pp. 113 and 392, pl. 54, fig. 1.

Cystophyllum trinode (FORSSKÅL) J. AGARDH, 1848, p. 230. FIGARI and DENOTARIS, 1853, p. 154. ZANARDINI, 1858, p. 242. PICCONE, 1884, p. 300. REINBOLD, 1903, p. 229. MUSCHLER, 1908 p. 184. BØRGESEN, 1932, p. 12. NASR, 1947, p. 84. RAYSS, 1959, p. 16.

Fucus onustus var. *trinodis* (FORSSKÅL) MERTENS, 1819, p. 183.

Fucus granulatus sensu WEBER, 1804, p. 134.

Cystoseira trinodis var. *confluens* C. AGARDH, 1824, p. 286. SCHIMPER, 1835–37, nos. 462 and 954.

Sirophysalis trinodis (FORSSKÅL) KÜTZING, 1849, p. 603.

Sirophysalis trinodis var. *confluens* (C. AGARDH) KÜTZING, 1849, p. 603; 1860, p. 21, pl. 58, fig. II.

Sirophysalis trinodis var. *enodis* KÜTZING, 1860, p. 22, pl. 59, fig. I.

Blossevillea arabica KÜTZING, 1849, p. 630.

Type loc.: Tor.

Red Sea distr.: Bay of Assab, Massawa, Koseir, Ghardaqa, Suez, Abu Rudeis, Tor, Nuweiba, Aqaba, Jiddah, Hodeida.

Hormophysa KÜTZING

Hormophysa triquetra (C. AGARDH) KÜTZING

KÜTZING, 1843, p. 359; 1849, p. 603; 1860, p. 22, pl. 60, fig. 1. PICCONE, 1884, p. 299. BØRGESEN, 1937, p. 317. NASR, 1947, p. 82. RAYSS, 1959, p. 15.

Records under other names

Fucus articulatus FORSSKÅL, 1775, pp. lxxviii and 191 (non S.G. GMELIN, 1768, p. 77, pl. 11, fig. 1).

Cystoseira articulata J. AGARDH, 1848, p. 216. RUPRECHT, 1849, p. 81.

Hormosira articulata (J. Agardh) Zanardini, 1858, p. 243. Muschler, 1902, p. 188, Børgesen, 1932, p. 11.

Hormophysa articulata (J. Agardh) Kützing, Piccone, 1884, p. 299.

Fucus triqueter Linnaeus (non S.G. Gmelin). Delile, 1813*a*, p. 80; 1824, p. 113.

Cystoseira triquetra C. Agardh, 1820, p. 61. Decaisne, 1834, p. 10. Schimper, 1835–37, no. 837.

Moniliformia triquetra (C. Agardh) Decaisne, 1841, p. 145.

Hormosira triquetra (C. Agardh) Decaisne. Hohenacker, 1852, no. 71. Figari and DeNotaris, 1853, p. 155.

Fucus foeniculaceus sensu Weber, 1804, p. 134.

Red Sea distr.: Bay of Assab, Ghardaqa, Suez, Abu Rudeis, Abu Zabad, Nuweiba, Aqaba.

Note: Papenfuss (1968) has discussed the nomenclature of this species.

SARGASSACEAE[†]

Sargassum C. Agardh *(nom. cons.)*[††]

***Sargassum acinaciforme** Montagne

Montagne, 1850, p. 239. Figari and DeNotaris, 1853, p. 144. Zanardini, 1858, p. 237. Kützing, 1861, p. 9, pl. 29. Piccone, 1884, p. 308. Grunow, 1916, p. 20.

Type loc.: Hodeida.

Distr.: Bay of Assab, Koseir, Aqaba, Hodeida.

Sargassum acinaciforme var. ***yemense** (Figari et DeNotaris) Grunow

Grunow, 1916, p. 20.

Record under syn.

Sargassum yemense Figari et DeNotaris, 1853, p. 152.

Type loc.: Yemen.

Distr.: Yemen.

Sargassum acinaria var. **hildebrandtii** f. **obockianum** Grunow

Grunow, 1916, p. 155.

Red Sea distr.: Shumma Islet, Hodeida.

[†] Schiffner in 1934 described and illustrated (p. 115, pl. 4) a monotypic new genus of Sargassaceae, *Acystis heinii,* and gave as the source of his material: "Rotes Meer: Arabien bei Gischin auf einem Rollsteine. 7 Februar 1902, Dr. Wilhelm Hein." However, Gischin (Qishn, in modern maps) is not situated on the Red Sea, but on the Arabian Sea (Aden Protectorate), 15° 25′ N., 51° 40′ E. For an account of the archeologist Hein and his work, see Müller, D.H., 1909. Mehri-Hadrami-Texte gesammelt im Jahre 1902 in Gischin von Dr. Wilhelm Hein. Südarabische Expedition, Vol. 9. K. Akad. Wiss. Wien. xxviii + 200 pp.

[††] The gender of the names of subspecific taxa of *Sargassum* proposed by Grunow has been corrected to neuter throughout this paper.

Sargassum acinaria var. ***hodeidense** GRUNOW

GRUNOW, 1916, p. 156.
Type loc.: Hodeida.
Red Sea distr.: Hodeida.

Sargassum acinaria var. ***humile** GRUNOW

GRUNOW, *in* PICCONE, 1884, p. 305.

Record under syn.
Sargassum acinaria f. *humile* (GRUNOW) GRUNOW, 1916, p. 154.

Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Sargassum acinaria var. ***subdentatum** (GRUNOW) GRUNOW

GRUNOW, 1916, p. 155.

Record under syn.
Sargassum boveanum var. *subdentatum* GRUNOW, *in* PICCONE, 1884, p. 307.

Type loc.: Archipelago of Assab.
Distr.: Archipelago of Assab.

Sargassum angustifolium (TURNER) C. AGARDH

DECAISNE, 1834, p. 10. SCHUBERT, 1839, p. 290.
Red Sea distr.: Sinai Peninsula.

Note: The identity of the Red Sea material referred to this species by DECAISNE and SCHUBERT is uncertain.

Sargassum aquifolium (TURNER) C. AGARDH

DECAISNE, 1834, p. 10; 1841, p. 143. J. AGARDH, 1889, p. 102. MUSCHLER, 1908, p. 179. NASR, 1947, p. 89. RAYSS, 1959, p. 16.
Red Sea distr.: Koseir, Suez, Eilat, Jiddah.

***Sargassum arnaudianum** MONTAGNE

MONTAGNE, 1850, p. 236. PICCONE, 1886, p. 43. GRUNOW, 1915, p. 387.

Record under syn.
Sargassum subrepandum var. *arnaudianum* (MONTAGNE) MUSCHLER, 1908, p. 176.

Type loc.: Hodeida.
Distr.: Massawa, Hodeida.

Sargassum arnaudianum var. ***assarkaense** GRUNOW

GRUNOW, 1915, p. 387.
Type loc.: Red Sea, presumably Assarca Islets.
Distr.: Red Sea, presumably Assarca Islets.

***Sargassum asperifolium** HERING et MARTENS ex J. AGARDH

J. AGARDH, 1848, p. 334; 1889, p. 103. RUPRECHT, 1849, p. 79. KÜTZING, 1849, p. 609; 1861, p. 4, pl. 10, fig. 1. MUSCHLER, 1908, p. 180. GRUNOW, 1916, p. 27. LYLE, 1926, p. 40. NASR, 1947, p. 87, pl. 7.

Records under other names
Sargassum linifolium sensu DECAISNE, 1841, p. 143.
Sargassum asperifolium var. *fimbriatum* FIGARI et DENOTARIS, 1853, p. 149.

Type loc.: Red Sea.
Distr.: Ghardaqa, Suez, Suez Canal, Aqaba.

Sargassum asperifolium var. ***dissimile** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 74. GRUNOW, 1916, p. 27.
Type loc.: Adjuz Islet.
Distr.: Adjuz Islet.

Sargassum biserrulum var. ***prionocarpum** GRUNOW

GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 73. PICCONE, 1889, p. 70. GRUNOW, 1915, p. 416.
Type loc.: Southern Red Sea.
Red Sea distr.: Coast of Ethiopia, Assarca Islets.

Sargassum biserrulum var. **prionocarpum** f. ***hodeidense** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 416.

Record under syn.
Sargassum biserrulum var. *hodeidense* GRUNOW, *in* HAUCK, 1889, p. 190.

Type loc.: Hodeida.
Distr.: Red Sea, Hodeida.

***Sargassum botruosum** MONTAGNE

MONTAGNE, 1850, p. 241. GRUNOW, 1916, p. 168.
Type loc.: Hodeida.
Distr.: Massawa, Suez, Hodeida.

Sargassum botruosum f. ***perangustum** Grunow

Grunow, *in* DeToni and Paoletti, 1888, p. 73.

Type loc.: Massawa.

Distr.: Massawa.

Note: Grunow (1915, 1916) failed to include this taxon in his monograph on *Sargassum.*

Sargassum botruosum f. ***rigidulum** Grunow

Grunow, 1916, p. 168.

Type loc.: Suez.

Distr.: Suez.

***Sargassum boveanum** J. Agardh

J. Agardh, 1848, p. 333; 1889, p. 115. Figari and DeNotaris, 1853, p. 145. Zanardini, 1858, p. 236. Piccone, 1884, p. 306; 1889, p. 73; 1900*a*, p. 255; 1900*b*, p. 118. Hauck, 1889, p. 189. Grunow, 1916, p. 156.

Records under other names

Fucus acinarius sensu Forsskål, 1775, p. cxxv. Sensu Turner, 1808, p. 109, *pro parte,* and incl. var. *megalocarpus.*

Sargassum acinaria sensu Decaisne, 1841, p. 143 (incl. var. *megalocarpum*). Sensu Piccone, 1900*a*, p. 255. Sensu Grunow, 1916, p. 153.

Sargassum boveanum var. *rigidum* Grunow, *in* Piccone, 1884, p. 306.

Type loc.: Red Sea.

Red Sea distr.: Bay of Assab, Mandola Islet, Shumma Islet, Assarca Islets, Aqaba, Hodeida, Mocha.

Sargassum boveanum var. ***aterrimum** Grunow

Grunow, *in* Piccone, 1884, p. 306. Grunow, 1916, p. 156 (as *Sargassum boveanum* f. *aterrimum*).

Type loc.: Bay of Assab.

Distr.: Bay of Assab.

Sargassum boveanum var. ***fuscescens** Grunow

Grunow, *in* Piccone, 1884, p. 307. Grunow, 1916, p. 157.

Type loc.: Bay of Assab.

Distr.: Bay of Assab.

Sargassum boveanum var. ***picconii** (Grunow) Grunow

Grunow, 1916, p. 157.

Record under syn.
Sargassum picconii GRUNOW, *in* PICCONE, 1889, p. 69.

Type loc.: Dissei Islet.
Distr.: Dissei Islet.

***Sargassum calophyllum** DENOTARIS

DENOTARIS, *in* ZANARDINI, 1858, p. 228. PICCONE, 1884, p. 303. MUSCHLER, 1908, p. 175. GRUNOW, 1915, p. 421.

Record under another name
Sargassum cuneifolium sensu FIGARI et DENOTARIS, 1853, p. 140.

Type loc.: Not specified, Suez, Aqaba.
Distr.: Bay of Assab, Suez, Aqaba.

Sargassum cinctum var. ***detonianum** GRUNOW

GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 73. PICCONE, 1889, p. 73. GRUNOW, 1915, p. 418 (as var. *tonianum*).
Type loc.: Not specified, Assarca Islets and Massawa.
Distr.: Assarca Islets, Massawa.

Sargassum cinctum var. **detonianum** f. ***phyllocystum** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 73.
Type loc.: Bay of Anfila.
Distr.: Bay of Anfila.

Sargassum cinctum var. **detonianum** f. ***serrulatum** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 73.
Type loc.: Dissei Islet.
Distr.: Dissei Islet.

Sargassum cinctum var. ***elatum** GRUNOW

GRUNOW, *in* PICCONE, 1884, p. 302. GRUNOW, 1915, p. 420.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Sargassum cinctum var. **elatum** f. ***apiculatum** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 420.

Record under syn.
Sargassum apiculatum GRUNOW, *in* PICCONE, 1884, p. 303.

Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Sargassum confusum sensu DECAISNE

DECAISNE, 1841, p. 144. Sensu MUSCHLER, 1908, p. 183.
Distr.: Red Sea, Luhaiya.

Note: The identity of the material from the Red Sea that DECAISNE and MUSCHLER reported under this name is uncertain.

Sargassum coriifolium var. ***bicuspidatum** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 436.

Record under syn.
Sargassum cinctum var. *bicuspidatum* GRUNOW, *in* PICCONE, 1884, p. 302.

Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Sargassum crassifolium var. ***oblongifolium** GRUNOW

GRUNOW, 1915, p. 391.
Type loc.: Red Sea.
Distr.: Red Sea.

***Sargassum cuneifolium** J. AGARDH

J. AGARDH, 1837, p. 172. GRUNOW, 1915, p. 429.
Type loc.: Coast of Ethiopia.
Distr.: Assab, Coast of Ethiopia.

Sargassum cuneifolium var. ***doriae** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 430.

Record under syn.
Sargassum doriae GRUNOW, *in* PICCONE, 1884, p. 300. pl. 8, figs. 4–6.

Type loc.: Adjuz Islet.
Distr.: Adjuz Islet.

Sargassum cuneifolium var. **doriae** f. ***kamaranense** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 431.

Record under syn.
Sargassum fresenianum var. *kamaranense* GRUNOW, *in* BORNET, 1888, p. 19.

Type loc.: Kamaran Island.
Distr.: Kamaran Island.

Sargassum cuneifolium var. ***integerrimum** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 431.

Records under syns.

Sargassum fresenianum var. *integerrimum* GRUNOW, *in* BORNET, 1888, p. 18.

Sargassum fresenianum var. *obtusiusculum* GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 72. PICCONE, 1889, p. 71.

Type loc.: Kamaran Island.
Distr.: Bay of Anfila, Massawa, Kamaran Island.

Sargassum cuneifolium var. ***obscurum** GRUNOW

GRUNOW, *in* PICCONE, 1884, p. 311. GRUNOW, 1915, p. 430.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Sargassum cuneifolium var. ***rigescens** (GRUNOW) GRUNOW

GRUNOW, *in* PICCONE, 1900*b*, p. 118. GRUNOW, 1915, p. 430.

Record under syn.

Sargassum fresenianum var. *rigescens* GRUNOW, *in* PICCONE, 1889, p. 72.

Type loc.: Dissei Islet.
Distr.: Assab, Dissei Islet.

***Sargassum cylindrocystum** FIGARI et DENOTARIS

FIGARI and DENOTARIS, 1853, p. 145. GRUNOW, 1915, p. 433.
Type loc.: Hodeida.
Distr.: Hodeida.

Sargassum cylindrocystum var. ***abyssinicum** GRUNOW

GRUNOW, 1915, p. 434.
Type loc.: Coast of Ethiopia.
Distr.: Coast of Ethiopia.

Sargassum cylindrocystum var. ***dubium** GRUNOW

GRUNOW, 1915, p. 435.
Type loc.: Red Sea.
Distr.: Red Sea.

Sargassum cylindrocystum var. ***levianum** GRUNOW

GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 72. GRUNOW, 1915, p. 435.
Type loc. Massawa.
Distr.: Massawa.

***Sargassum decaisnei** J. AGARDH

J. AGARDH, 1848, p. 329; 1889, p. 101. MUSCHLER, 1908, p. 179. GRUNOW, 1916, p. 19. NASR, 1947, p. 88.

Type loc.: Red Sea.

Distr.: Koseir, Ghardaqa, Suez.

Sargassum decaisnei var. ***abyssinicum** GRUNOW

GRUNOW, 1916, p. 19.

Type loc.: Coast of Ethiopia.

Distr.: Coast of Ethiopia.

***Sargassum densifolium** ZANARDINI

ZANARDINI, 1858, p. 240. GRUNOW, 1916, p. 24.

Type loc.: Suez.

Distr.: Coast of Ethiopia, Suez.

Sargassum densifolium var. ***subcompressum** GRUNOW

GRUNOW, *in* PICCONE, 1884, p. 310. GRUNOW, 1916, p. 25.

Type loc.: Bay of Assab.

Distr.: Bay of Assab.

***Sargassum dentifolium** (TURNER) C. AGARDH

C. AGARDH, 1820, p. 8; 1824, p. 295. BOVÉ, 1834, p. 77. DECAISNE, 1834, p. 10; 1841, p. 142. SCHIMPER, 1835–37, nos. 460 and 958. J. AGARDH, 1848, p. 319. RUPRECHT, 1849, p. 79. FIGARI and DENOTARIS, 1853, p. 142. ZANARDINI, 1858, p. 229. PICCONE, 1884, p. 301; 1900*a*, p. 255; 1900*c*, p. 120. REINBOLD, 1907, p. 562. MUSCHLER, 1908, p. 178. HARVEY-GIBSON, 1908, p. 78. HARVEY-GIBSON and KNIGHT, 1913, p. 306. GRUNOW, 1916, p. 17.

Records under other names

Fucus dentifolius TURNER, 1809, p. 64, pl. 93.

Carpacanthus dentifolius (TURNER) KÜTZING, 1849, p. 623; 1861, p. 12, pl. 39, fig. II.

Fucus denticulatus FORSSKÅL, 1775, pp. lxxviii and 191 (non N.L. BURMAN, 1768, p. 28 [32]). DELILE, 1813*a*, p. 80; 1813*b*, p. 292, pl. 55, fig. 2; 1824, pp. 113 and 395, pl. 55, fig. 2.

Sargassum denticulatum BØRGESEN, 1932, p. 9, fig. 2. NASR, 1947, p. 88, pl. 9. RAYSS, 1959, p. 17.

Fucus natans sensu VAHL, 1791, p. 105.

Fucus bacciferus sensu WEBER, 1804, p. 134.

Fucus tetragonus DELILE, 1813*a*, p. 80; 1813*b*, p. 293, pl. 56, fig. 3; 1924, pp. 113 and 398, pl. 56, fig. 3 *(nom. illeg.)*.

Type loc.: Red Sea.

Red Sea distr.: Bay of Assab, Mandola Islet, Massawa, Trinkitat, Sudanese coast, Ghardaqa, Ras Gharib, Suez, Tor, Sharm el Sheikh, Nuweiba, Aqaba, Jiddah.

Sargassum diversifolium sensu DECAISNE

DECAISNE, 1841, p. 144.

Note: The identity of the material from the Red Sea reported under this name by DECAISNE is uncertain.

Sargassum echinocarpum var. ***ambiguum** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 383.

Record under syn.

Sargassum binderi var. *ambiguum* GRUNOW, *in* PICCONE, 1886, p. 48.

Type loc.: Massawa.
Distr.: Massawa, Jiddah.

Sargassum filifolium C. AGARDH

MUSCHLER, 1908, p. 178.
Red Sea distr.: Suez.

Sargassum flavicans (MERTENS) C. AGARDH

MONTAGNE, 1850, p. 242. ZANARDINI, 1858, p. 228. MUSCHLER, 1908, p. 175. NASR, 1947, p. 86. RAYSS, 1959, p. 17.

Red Sea distr.: Massawa, Koseir, Suez, Aqaba, Hodeida.

Note: The identity of the material from the Red Sea referred to this species is uncertain.

***Sargassum forsskalii** (MERTENS) PAPENFUSS, comb. nov.

Records under other names

Fucus forsskalii MERTENS, 1819, p. 178, f.n.

Sargassum crispum C. AGARDH, 1824, p. 297. BOVÉ, 1834, p. 77. DECAISNE, 1834, p. 10; 1841, p. 143. SCHIMPER, 1835–37, no. 956. SCHUBERT, 1839, p. 290. J. AGARDH, 1848, p. 320; 1889, p. 97, pl. 8. RUPRECHT, 1849, p. 79. FIGARI and DENOTARIS, 1853, p. 137. ZANARDINI, 1858, p. 231. MUSCHLER, 1908, p. 177. HARVEY-GIBSON, 1908, p. 78. GRUNOW, 1915, p. 438. LYLE, 1926, p. 40. BØRGESEN, 1932, p. 9. NASR, 1939*a*, p. 61; 1947, p. 86.

Fucus crispus FORSSKÅL, 1775, pp. lxxviii and 191 (non HUDSON, 1762). DELILE, 1813*a*, p. 80; 1824, p. 113.

Fucus undulatus J.F. GMELIN, 1792, p. 1381 (non *Sargassum undulatum* J. AGARDH).

Fucus latifolius sensu DELILE, 1813*a*, p. 80; 1813*b*, p. 291, pl. 54, fig. 2; 1824, pp. 113 and 393, pl. 54, fig. 2.

Sargassum telephifolium sensu KÜTZING, 1849, p. 607; 1861, p. 2, pl. 3, fig. II.

Type loc.: Red Sea.
Distr.: Koseir, Ghardaqa, Suez, Suez Canal, Tor, Nuweiba, Aqaba, Jiddah.

Sargassum forsskalii var. ***notarisii** (ZANARDINI) PAPENFUSS, comb. nov.

Records under other names

Sargassum notarisii ZANARDINI, 1858, p. 232. MUSCHLER, 1908, p. 183. NASR, 1947, p. 87.
Sargassum crispum var. *notarisii* (ZANARDINI) GRUNOW, 1915, p. 438.
Sargassum crispum sensu KÜTZING, 1861, p. 2, pl. 4, fig. I.

Type loc.: Not specified, Suez, Aqaba.
Distr.: Ghardaqa, Suez, Aqaba.

***Sargassum fresenianum** J. AGARDH

J. AGARDH, 1837, p. 172. PICCONE, 1900*a*, p. 255. REINBOLD, 1903, p. 229. GRUNOW, 1915, p. 431.
Type loc.: Coast of Ethiopia.
Distr.: Coast of Ethiopia, Arafali, Tor.

Sargassum fresenianum var. ***bressaninii** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 432.

Record under syn.

Sargassum cylindrocystum var. *bressaninii* GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 72.

Type loc.: Massawa.
Distr.: Massawa.

Sargassum fresenianum var. ***ilicifolioides** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 72. GRUNOW, 1915, p. 433.
Type loc.: Adjuz Islet.
Distr.: Adjuz Islet, Kamaran Island.

Sargassum fresenianum var. ***squarrulosum** GRUNOW

GRUNOW, 1915, p. 433.
Type loc. Massawa.
Distr.: Massawa.

***Sargassum glandulifolium** GRUNOW

GRUNOW, *in* PICCONE, 1900*b*, p. 118. GRUNOW, 1916, p. 20.
Type loc.: Assab.
Distr.: Assab.

Sargassum hildebrandtii GRUNOW

GRUNOW, *in* HAUCK, 1889, p. 188.
Red Sea distr.: Hodeida.

Sargassum ilicifolium (TURNER) C. AGARDH

PICCONE, 1886, p. 45; 1900*a*, p. 254.
Red Sea distr.: Dissei Islet, Massawa.
Note: The identity of the material from the Red Sea referred to this species by PICCONE is uncertain.

Sargassum ilicifolium var. ***clonocarpum** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 402.

Record under syn.
Sargassum clonocarpum GRUNOW, *in* PICCONE, 1889, p. 69.

Type loc.: Massawa.
Distr.: Massawa.

Sargassum ilicifolium var. **conduplicatum** f. ***erythraeum** GRUNOW

GRUNOW, 1915, p. 406.
Type loc.: Massawa.
Red Sea distr.: Massawa.

Sargassum ilicifolium var. ***euryphyllum** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 404.

Records under syn.
Sargassum subrepandum var. *euryphyllum* GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 73. PICCONE, 1889, p. 70.

Type loc.: Southern Red Sea.
Distr.: Assarca Islet, Massawa.

Sargassum ilicifolium var. **microdon** GRUNOW

GRUNOW, 1915, p. 404.
Red Sea distr.: Red Sea.

***Sargassum latifolium** (TURNER) C. AGARDH

BOVÉ, 1834, p. 77. DECAISNE, 1834, p. 10; 1841, p. 143. J. AGARDH, 1848, p. 336; 1889, p. 103. MONTAGNE, 1850, p. 242. FIGARI and DENOTARIS, 1853, p. 148. ZANARDINI, 1858, p. 240. PICCONE, 1884, p. 310; 1900*a*, p. 255. LICATA, 1885, p. 186. BALSAMO, 1885, p. 11. DETONI and PAOLETTI, 1888, p. 74. MUSCHLER, 1908, p. 180.

HARVEY-GIBSON, 1908, p. 78. GRUNOW, 1916, p. 28. NASR, 1939*a*, p. 62; 1947, p. 89, pl. 10.

Records under syns.
Fucus latifolius TURNER, 1809, p. 66, pl. 94.
Carpacanthus latifolius (TURNER) KÜTZING, 1849, p. 625; 1861, p. 15, pl. 47.

Type loc.: Red Sea.
Red Sea distr.: Bay of Assab, Gulf of Zula, Dissei Islet, Shumma Islet, Massawa, Cape Berenice, Koseir, Ghardaqa, Suez, Tor, Aqaba, Jiddah, Hodeida.

Sargassum latifolium f. ***polycarpum** (FIGARI et DENOTARIS) GRUNOW
GRUNOW, 1916, p. 28.

Records under other names
Sargassum polycarpum FIGARI et DE NOTARIS, 1853, p. 147. ZANARDINI, 1858, p. 238. PICCONE, 1884, p. 310.
Sargassum subrepandum sensu KÜTZING, 1849, p. 606; 1861, p. 1, pl. 2, fig. I.

Type loc.: Not specified, Suez, Aqaba.
Distr.: Bay of Assab, Shumma Islet, Suez, Tor, Aqaba.

Sargassum latifolium var. **zanzibaricum** GRUNOW
GRUNOW, *in* BORNET, 1888, p. 19.
Red Sea distr.: Kamaran Island.

Note: presumably the type locality of this variety is Zanzibar, but only Kamaran Island was given as a locality in BORNET's paper. GRUNOW did not include the taxon in his monograph of *Sargassum;* its status, therefore, must be regarded as uncertain.

Sargassum linifolium (TURNER) C. AGARDH
HARVEY-GIBSON and KNIGHT, 1913, p. 306.
Red Sea distr.: Sudanese coast.

Note: FIGARI and DENOTARIS (1853, p. 150) also reported this species from the Red Sea, but ZANARDINI (1858, p. 241) suspects that their material was obtained at Alexandria.

***Sargassum marcaccii** GRUNOW
GRUNOW, *in* PICCONE, 1884, p. 309, pl. 8, figs. 1–3. GRUNOW, 1916, p. 165.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.

***Sargassum neglectum** FIGARI et DENOTARIS
FIGARI and DENOTARIS, 1853, p. 142. GRUNOW, 1916, p. 18.

Records under another name

Sargassum parvifolium sensu ZANARDINI, 1858, p. 230. Sensu MUSCHLER, 1908, p. 178. Sensu NASR, 1947, p. 88.

Type loc.: Not specified, Suez, Aqaba.
Distr.: Suez, Aqaba.

***Sargassum nigrescens** ZANARDINI

ZANARDINI, 1858, p. 235. GRUNOW, 1916, p. 157.
Type loc.: Not specified, Jiddah, Hodeida.
Distr.: Jiddah, Hodeida.

***Sargassum portierianum** ZANARDINI

ZANARDINI, 1858, p. 232. GRUNOW, 1916, p. 145.
Type loc.: Koseir.
Distr.: Koseir, Suez, Tor.

Sargassum portierianum var. ***eiddense** (GRUNOW) GRUNOW

GRUNOW, 1916, p. 145.

Record under syn.

Sargassum lendigerum var. *eiddense* GRUNOW, *in* PICCONE, 1889, p. 74.

Type loc.: Edd.
Distr.: Edd.

Sargassum portierianum var. ***phyllocystum** GRUNOW

GRUNOW, 1916, p. 145.
Type loc.: Red Sea.
Distr.: Red Sea.

Sargassum portierianum var. ***rigidulum** GRUNOW

GRUNOW, 1916, p. 145.
Type loc.: Red Sea.
Distr.: Red Sea.

***Sargassum pterocystum** ZANARDINI

ZANARDINI, 1858, p. 233. MUSCHLER, 1908, p. 177. GRUNOW, 1915, p. 375.
Type loc.: Koseir.
Distr.: Koseir.

***Sargassum saltii** (TURNER) C. AGARDH

Record under syn.

Fucus saltii TURNER, 1819, p. 37, pl. 213.

Type loc.: Red Sea.

Distr.: Red Sea.

Note: The status of this species is uncertain. KÜTZING (1861, pl. 38, fig. II) has reproduced a mirror image of TURNER's figures of the taxon.

Sargassum saltii var. ***dancalense** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 72. GRUNOW, 1915, p. 426.

Type loc.: Edd.

Distr.: Edd, Red Sea.

Sargassum spathulaefolium var. ***amfilense** GRUNOW

GRUNOW, 1916, p. 23.

Type loc.: Mandola Islet.

Distr.: Mandola Islet.

Sargassum spathulaefolium var. ***hybridum** (GRUNOW) GRUNOW

GRUNOW, 1916, p. 23.

Records under other names

Sargassum hybridum GRUNOW, *in* PICCONE, 1884, p. 303. PICCONE, 1889, p. 73.

Sargassum spathulaefolium J. AGARDH. J. AGARDH, 1889, p. 102.

Type loc.: Archipelago of Assab.

Distr.: Archipelago of Assab.

Sargassum spathulaefolium var. **hydridum** f. ***suboppositum** (GRUNOW) GRUNOW

GRUNOW, 1916, p. 23.

Record under syn.

Sargassum hybridum var. *suboppositum* GRUNOW, *in* PICCONE, 1884, p. 304.

Type loc.: Bay of Assab.

Distr.: Bay of Assab.

Sargassum spathulaefolium var. ***petiolatum** (GRUNOW) GRUNOW

GRUNOW, 1916, p. 23.

Record under syn.

Sargassum petiolatum GRUNOW, *in* PICCONE, 1884, p. 304.

Type loc.: Bay of Assab.
Distr.: Bay of Assab.

***Sargassum subrepandum** (FORSSKÅL) C. AGARDH

C. AGARDH, 1820, p. 8; 1824, p. 295. SCHIMPER, 1835–37, no. 459. DECAISNE, 1841, p. 142. J. AGARDH, 1848, p. 319. FIGARI and DENOTARIS, 1853, p. 139. ZANARDINI, 1858, p. 230. PICCONE, 1884, p. 301; 1886, p. 46; 1900*a*, p. 255. LICATA, 1885, p. 186. BALSAMO, 1885, p. 11. MUSCHLER, 1908, p. 175. HARVEY-GIBSON, 1908, p. 78. HARVEY-GIBSON and KNIGHT, 1913, p. 306. GRUNOW, 1915, p. 422. BØRGESEN, 1932, p. 12. NASR, 1947, p. 86, pl. 6.

Records under other names
Fucus subrepandus FORSSKÅL, 1775, pp. cxxv and 192.
Fucus natans sensu TURNER, 1808, p. 99, *pro parte*.
Sargassum vulgare sensu BOVÉ, 1834, p. 77. Sensu DECAISNE, 1834, p. 10; 1841, p. 142. Sensu? SCHUBERT, 1839, p. 290.

Type loc.: Tor.
Distr.: Bay of Assab, Mandola Islet, Adjuz Islet, Massawa, Trinkitat, Sudanese coast, Koseir, Ghardaqa, Suez, Tor, Aqaba, Jiddah.

Sargassum subrepandum var. ***brevifolium** J. AGARDH

J. AGARDH, 1889, p. 96. GRUNOW, 1915, p. 425.
Type loc.: Not specified, Red Sea.
Distr.: Red Sea, Koseir.

Sargassum subrepandum var. **brevifolium** f. ***edentatum** GRUNOW

GRUNOW, 1915, p. 425.
Type loc.: Jiddah.
Distr.: Jiddah.

Sargassum subrepandum var. ***dentatum** J. AGARDH

J. AGARDH, 1889, p. 95. REINBOLD, 1903, p. 229. GRUNOW, 1915, p. 423.
Type loc.: Not specified, Red Sea.
Distr.: Red Sea, Tor.

Sargassum subrepandum var. ***figarianum** (DENOTARIS) J. AGARDH

J. AGARDH, 1889, p. 96. GRUNOW, 1915, p. 424.

Record under syn.
Sargassum figarianum DENOTARIS, *in* FIGARI and DENOTARIS, 1853, p. 150.

Type loc.: Not specified, Suez, Aqaba.
Distr.: Koseir, Suez, Aqaba.

Sargassum subrepandum var. **figarianum** f. ***angustifolium** GRUNOW

GRUNOW, 1915, p. 424.
Type loc.: Red Sea.
Distr.: Red Sea.

Sargassum subrepandum var. **figarianum** f. ***hemiphylloides** GRUNOW

GRUNOW, 1915, p. 424.
Type loc.: Koseir.
Distr.: Koseir.

Sargassum subrepandum var. **figarianum** f. ***parcedentatum** GRUNOW

GRUNOW, 1915, p. 424.
Type loc.: Koseir.
Distr.: Koseir.

Sargassum subrepandum var. ***forsskalii** J. AGARDH

J. AGARDH, 1889, p. 95. MUSCHLER, 1908, p. 176. GRUNOW, 1915, p. 422.
Type loc.: Red Sea.
Distr.: Suez, Tor.

Sargassum subrepandum var. **forsskalii** f. ***angustifolium** GRUNOW

GRUNOW, 1915, p. 423.
Type loc.: Not specified, Red Sea and Suez.
Distr.: Red Sea, Suez.

Sargassum subrepandum var. **forsskalii** f. ***paucidentatum** GRUNOW

GRUNOW, 1915, p. 422.
Type loc.: Red Sea.
Distr.: Red Sea.

Sargassum subrepandum var. ***rueppellii** (J. AGARDH) J. AGARDH

J. AGARDH, 1889, p. 96. REINBOLD, 1903, p. 229. GRUNOW, 1915, p. 423. RAYSS, 1959, p. 17.

Record under syn.
Sargassum rueppellii J. AGARDH, 1837, p. 171.

Type loc.: Coast of Ethiopia.
Distr.: Coast of Ethiopia, Massawa, Tor, Ras Nusrani, Eilat.

Sargassum subrepandum var. **rueppellii** f. ***biauriculatum** GRUNOW

GRUNOW, 1915, p. 424.
Type loc.: Not specified, Gulf of Berenice, Shumma Islet.
Distr.: Shumma Islet, Gulf of Berenice.

Note: The material of this taxon was collected by Captain CASSANELLO during the voyage of the *Scilla* and was sent to GRUNOW by PICCONE. PICCONE (1893, p. 381) in error referred to the Gulf of Berenice as "Golfo di Beresine", an error passed on to GRUNOW, who wrote "Golfo di Beresina". In a second paper on the algae of the *Scilla*, PICCONE (1900*a*) referred to the locality in question by its correct name, Golfo di Berenice.

Sargassum subrepandum var. **rueppellii** f. ***massauense** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 423.

Record under syn.
Sargassum subrepandum var. *massauense* GRUNOW, *in* PICCONE, 1886, p. 46.

Type loc.: Massawa.
Distr.: Massawa.

Sargassum subrepandum var. **rueppellii** f. ***parvifolium** GRUNOW

GRUNOW, 1915, p. 423.
Type loc.: Red Sea.
Distr.: Red Sea.

Sargassum subrepandum var. **rueppellii** f. ***turneri** (KÜTZING) GRUNOW

GRUNOW, 1915, p. 423.

Records under syns.
Carpacanthus turneri KÜTZING, 1849, p. 624; 1861, p. 13, pl. 41, fig. II.
Fucus natans var. *acanthicarpus* TURNER, 1808, p. 99.

Type loc.: Red Sea.
Distr.: Red Sea, Koseir.

Sargassum subrepandum var. ***schweinfurthii** GRUNOW

GRUNOW, 1915, p. 425.
Type loc.: Mirear Islet.
Distr.: Mirear Islet.

Sargassum subrepandum var. **schweinfurthii** f. ***apiculiferum** GRUNOW

GRUNOW, 1915, p. 425.
Type loc.: Bay of Berenice.
Distr.: Bay of Berenice.

Sargassum subrepandum var. **schweinfurthii** f. ***fissidens** GRUNOW

GRUNOW, 1915, p. 425.
Type loc.: Red Sea.
Distr.: Red Sea.

***Sargassum telephifolium** (TURNER) C. AGARDH

DECAISNE, 1841, p. 143. J. AGARDH, 1848, p. 337; 1889, p. 107. FIGARI and DE-NOTARIS, 1853, p. 149. ZANARDINI, 1858, p. 241. PICCONE, 1884, p. 311. GRUNOW, 1915, p. 395.

Record under syn.
Fucus telephifolius TURNER, 1809, p. 68, pl. 95.

Type loc.: Red Sea.
Distr.: Archipelago of Assab, Massawa, Koseir, Suez, Tor, Aqaba, Jiddah.

Sargassum tenue J. AGARDH

REINBOLD, 1907, p. 562.
Red Sea distr.: Red Sea.
Note: This record is probably based on a misidentification of the material.

Sargassum tenuissimum var. ***kosseirense** GRUNOW

GRUNOW, 1915, p. 370.
Type loc.: Koseir.
Distr.: Koseir.

Sargassum teretifolium J. AGARDH

J. AGARDH, 1889, p. 101. GRUNOW, 1916, p. 21.

Record under syn.
Sargassum lasiophyllum GRUNOW, *in* PICCONE, 1884, p. 308.

Red Sea distr.: Bay of Assab, Red Sea.

***Sargassum vaysierianum** MONTAGNE

MONTAGNE, 1850, p. 237. PICCONE, 1884, p. 308; 1900*a*, p. 255. GRUNOW, 1915, p. 427.
Type loc.: Hodeida.
Distr.: Bay of Assab, Massawa, Hodeida.

Sargassum vaysierianum var. ***acinarioides** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 70. GRUNOW, 1915, p. 428.
Type loc.: Adjuz Islet.
Red Sea distr.: Adjuz Islet.

Sargassum vaysierianum var. **acinarioides** f. ***macrocarpum** GRUNOW

GRUNOW, *in* PICCONE, 1889, p. 71.
Type loc.: Dissei Islet.
Distr.: Dissei Islet.

Sargassum vaysierianum var. ***assabiense** (GRUNOW) GRUNOW

GRUNOW, 1915, p. 427.

Records under other names

Sargassum acinaria var. *assabiense* GRUNOW, *in* PICCONE, 1884, p. 305.
Sargassum vaysierianum var. *disseiense* GRUNOW, *in* PICCONE, 1889, p. 71 (see GRUNOW, 1915, p. 428).
Sargassum vaysierianum sensu KÜTZING, 1861, p. 10. pl. 30, fig. I.

Type loc.: Bay of Assab.
Distr.: Bay of Assab, Dissei Islet, Hodeida.

Sargassum vaysierianum var. ***assarkaense** GRUNOW

GRUNOW, *in* DETONI and PAOLETTI, 1888, p. 73. PICCONE, 1889, p. 71. GRUNOW, 1915, p. 428.
Type loc.: Assarca Islet.
Distr.: Assarca Islet, Suakin.

Sargassum vaysierianum var. ***ehrenbergii** GRUNOW

GRUNOW, 1915, p. 429.
Type loc.: Qunfida.
Distr.: Qunfida.

Sargassum vaysierianum var. ***microcystum** GRUNOW

GRUNOW, *in* PICCONE, 1884, p. 308.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.
Note: GRUNOW failed to include this variety in his monograph on *Sargassum*.

***Sargassum verrucosum** ZANARDINI

ZANARDINI, 1858, p. 235. PICCONE, 1884, p. 301.
Type loc.: Not specified, Suez, Aqaba.
Distr.: Adjuz Islet, Suez, Aqaba.

Sargassum verrucosum var. ***acuminatum** GRUNOW

GRUNOW, 1915, p. 426.
Type loc.: Gulf of Berenice.
Distr.: Gulf of Berenice.
Note: The type locality was in error given by GRUNOW as "Golfo di Beresina". See note under *Sargassum subrepandum* var. *rueppellii* f. *biauriculatum*.

Sargassum verrucosum car. ***djeddahense** GRUNOW

GRUNOW, 1915, p. 426.
Type loc.: Jiddah.
Distr.: Jiddah.

***Sargassum virescens** FIGARI et DENOTARIS

FIGARI and DENOTARIS, 1853, p. 151. GRUNOW, 1916, p. 26.
Type loc.: Not specified, Koseir, Suez, Aqaba.
Distr.: Koseir, Suez, Aqaba.

Sargassum virgatum f. ***erythraeum** GRUNOW

GRUNOW, *in* HAUCK, 1889, p. 189. PICCONE, 1889, p. 73. GRUNOW, 1916, p. 27.

Records under other names
Sargassum virgatum var. *majus* sensu? DECAISNE, 1841, p. 143.
Sargassum virgatum sensu ZANARDINI, 1858, p. 236. Sensu NASR, 1947, p. 87, pl. 8.

Type loc.: Red Sea.
Distr.: Gulf of Archico, Ghardaqa, Jiddah, Hodeida.

Sargassum zanardinii SCHIFFNER

SCHIFFNER, 1934, p. 118.

Record under another name
Sargassum yemense sensu ZANARDINI, 1858, p. 237, pl. 3, fig. 1.

Red Sea distr.: Yemen.
Note: SCHIFFNER gave Gischin as the type locality of this species, believing it to be a place on the Red Sea. However, as is explained in the footnote on p. 42, Gischin is not situated on the Red Sea.

Turbinaria LAMOUROUX

***Turbinaria elatensis** TAYLOR

TAYLOR, 1965, p. 99, figs. 1–11.

Record under another name

Turbinaria decurrens sensu RAYSS, 1959, p. 16, *pro parte.*

Type loc.: Eilat.

Distr.: Abu Rudeis, Abu Zenima, Sharm el Sheikh, Eilat.

***Turbinaria papenfussii** TAYLOR

TAYLOR, 1964, p. 477, pl. 1, figs. 1–9.

Type loc.: Romia Islet.

Distr.: Romia Islet, Suez.

Note: TAYLOR cited the type as coming from "Sheik Said I. (Romia I.)", which may give the impression that Romia Islet is another name for Sheik Said Islet. Sheik Said Islet is near Massawa, whereas Romia Islet is an islet in the Dahlak Archipelago. The type came from Romia Islet and, as far as is known, this species does not occur at Sheik Said Islet.

***Turbinaria triquetra** (J. AGARDH) J. AGARDH

J. AGARDH, *in* KÜTZING, 1849, p. 621. DECAISNE, 1841, p. 145 *(nom. nud.)*. FIGARI and DENOTARIS, 1853, p. 154. ZANARDINI, 1858, p. 242. PICCONE, 1884, p. 300. BORNET, 1888, p. 18. TAYLOR, 1964, p. 479, pl. 1, figs. 10–21; 1966, p. 93.

Records under other names

Turbinaria vulgaris var. *triquetra* J. AGARDH, 1848, p. 267. MONTAGNE, 1850, p. 242.

Fucus conoides FORSSKÅL, 1775, pp. cxxv and 192 [non *Turbinaria conoides* (J. AGARDH) KÜTZING].

Turbinaria denudata sensu KÜTZING, 1849, p. 621, *pro parte.*

Turbinaria conoides sensu PICCONE, 1884, p. 300.

Fucus turbinatus sensu VAHL, 1790, p. 85. Sensu DELILE, 1813*a*, p. 80; 1824, p. 113.

Sargassum turbinatum (LINNAEUS) C. AGARDH, 1820, p. 41, *pro parte,* not as to type. Sensu DECAISNE, 1834, p. 10. Sensu SCHIMPER, 1835–37, nos. 458, 936, and 955.

Turbinaria decurrens sensu DECAISNE, 1841, p. 145. Sensu FIGARI and DENOTARIS, 1853, p. 153. Sensu HOHENACKER, 1854, no. 168. Sensu ZANARDINI, 1858, p. 242. Sensu PICCONE, 1884, p. 300; 1886, p. 43; 1889, p. 69; 1893, pp. 380 and 381; 1900*a*, p. 256; 1900*b*, p. 118. Sensu DETONI and PAOLETTI, 1888, p. 74. Sensu CARUEL, 1890, p. 456. Sensu BARTON, 1891, p. 217. Sensu REINBOLD, 1903, p. 230. Sensu MUSCHLER, 1908, p. 184. Sensu HARVEY-GIBSON and KNIGHT, 1913, p. 306. Sensu BØRGESEN, 1932, p. 11. Sensu NASR, 1939*a*, p. 61; 1947, p. 84. Sensu NEWTON, 1953, p. 406. Sensu ?RAYSS, 1959, p. 16, *pro parte.*

Turbinaria vulgaris var. *decurrens* (BORY) J. AGARDH, 1848, p. 267, *pro parte,* not as to type. Sensu BALSAMO, 1885, p. 12.

Turbinaria vulgaris sensu LICATA, 1885, p. 186.

Turbinaria membranacea RUPRECHT, 1849, p. 80.

Turbinaria tetraedra RUPRECHT, 1849, p. 80.

Type loc.: Red Sea.

Red Sea distr.: Bay of Assab, Hanish Islands, Dissei Islet, Gulf of Zula, Shumma Islet, Entedebir Islet, Massawa, Suakin, Sudanese coast, Daedalus Reef, Koseir, Ghardaqa, Suez, Tor, Nuweiba, Eilat, Aqaba, Jiddah, Kamaran Island, Hodeida.

Note: The taxonomy and nomenclature of *Turbinaria triquetra* were in an extremely confused state until recently, when TAYLOR (1964), through examination of the types of this species and of *T. decurrens*, was able to show that the Red Sea plant commonly determined as *T. decurrens* is not this species (which does not occur in the Red Sea), but *T. triquetra*.

CYANOPHYCEAE

CHROOCOCCALES

CHROOCOCCACEAE

Coccochloris SPRENGEL

Coccochloris stagnina SPRENGEL

Record under syn.
Chroococcus minutus (KÜTZING) NÄGELI, RAYSS, 1959, p. 4.

Red Sea distr.: Ras Muhammad, Abu Zabad.

Note: DROUET and DAILY (1956) have reduced *Chroococcus minutus* to a synonym of *Coccochloris stagnina*.

Gomphosphaeria KÜTZING

Gomphosphaeria aponina KÜTZING

RAYSS, 1959, p. 4.
Red Sea distr.: Tor with *Lyngbya confervoides*.

ENTOPHYSALIDACEAE

Entophysalis KÜTZING

Entophysalis conferta (KÜTZING) DROUET et DAILY

Records under syn.
Dermocarpa prasina (REINSCH) BORNET. HARVEY-GIBSON and KNIGHT, 1913, p. 305. NASR, 1947, p. 6.

Red Sea distr.: Sudanese coast, Ghardaqa.

Entophysalis deusta (MENEGHINI) DROUET et DAILY

Record under syn.
Aphanocapsa litoralis HANSGIRG, NASR, 1947, p. 5.

Red Sea distr.: Ghardaqa.

NOSTOCALES

OSCILLATORIACEAE

Lyngbya C. AGARDH ex GOMONT

***Lyngbya complectens** FRÉMY et NASR

FRÉMY and NASR, 1938, p. 33, pl. 2.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Lyngbya confervoides C. AGARDH ex GOMONT

GOMONT, 1893, p. 136. MUSCHLER, 1908, p. 144. NASR, 1947, p. 10. RAYSS, 1959, p. 5.

Records under syn.
Lyngbya protensa ZANARDINI, 1858, p. 298. LYLE, 1926, p. 39.

Red Sea distr.: Ghardaqa, Suez, Suez Canal, Tor.

Lyngbya epiphytica HIERONYMUS ex KIRCHNER

RAYSS and DOR, 1963, p. 13.
Red Sea distr.: Abu Zabad, Eilat.

Lyngbya majuscula [DILLWYN] HARVEY ex GOMONT

GOMONT, 1893, p. 131. MUSCHLER, 1908, p. 145. NASR, 1939*a*, p. 48; 1947, p. 10. RAYSS, 1959, p. 5.

Records under other names
[*Lyngbya rigidissima* ZANARDINI, 1858, p. 297.]
[*Lyngbya major* sensu KÜTZING. PICCONE, 1884, p. 291; 1900*a*, p. 252.]
[*Lyngbya prasina* MONTAGNE. BORNET, 1888, p. 17. PICCONE, 1889, p. 66; 1900*a*, p. 252.]

Red Sea distr.: Mandola Islet, Gulf of Zula, Massawa, Koseir, Ghardaqa, Suez, Abu Zabad, Shora el Manqata, Kamaran Island.

Lyngbya meneghiniana [KÜTZING] PICCONE ex GOMONT

PICCONE, 1884, p. 291.
Red Sea distr.: Massawa.

Lyngbya nordgardhii WILLE

NASR, 1947, p. 11.
Red Sea distr.: Koseir.

Lyngbya semiplena [C. AGARDH] J. AGARDH ex GOMONT

HARVEY-GIBSON and KNIGHT, 1913, p. 305. NASR, 1947, p. 11.
Red Sea distr.: Sudanese coast, Ghardaqa.

Lyngbya sordida [ZANARDINI] GOMONT

NASR, 1947, p. 10, RAYSS and DOR, 1963, p. 14.
Red Sea distr.: Ghardaqa, Eilat.

Microcoleus DESMAZIÈRES ex GOMONT

Microcoleus tenerrimus GOMONT

RAYSS and DOR, 1963, p. 14.
Red Sea distr.: Eilat.

Oscillatoria VAUCHER ex GOMONT

Oscillatoria corallinae [KÜTZING] GOMONT

NASR, 1947, p. 8.
Red Sea distr.: Ghardaqa.

Note: LINSTEDT (1943, p. 61) doubts that *Oscillatoria corallinae* should be maintained as a species distinct from *O. nigro-viridis.*

Oscillatoria margaritifera KÜTZING ex GOMONT

RAYSS, 1959, p. 5.
Red Sea distr.: Tor.

Oscillatoria nigro-viridis THWAITES ex GOMONT

RAYSS and DOR, 1963, p. 13.
Red Sea distr.: Abu Zabad, Eilat.

Phormidium KÜTZING ex GOMONT

Phormidium ectocarpi f. ***fuscescens** FRÉMY

FRÉMY, *in* NASR, 1941, p. 58, fig. 1.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Phormidium fragile [MENEGHINI] GOMONT

NASR, 1947, p. 9.
Red Sea distr.: Ghardaqa.

Phormidium penicillatum f. ***vaginata** FRÉMY

FRÉMY, *in* NASR, 1944, p. 31, fig. 1; 1947, p. 9, fig. 1. RAYSS, 1959, p. 6.
Type loc.: Ghardaqa.
Distr.: Ghardaqa, Eilat.

Schizothrix KÜTZING ex GOMONT

***Schizothrix nasri** FRÉMY

FRÉMY, *in* FRÉMY and NASR, 1938, p. 31, pl. 1.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Sirocoleum KÜTZING ex GOMONT

Sirocoleum guyanense KÜTZING ex GOMONT

NASR, 1947, p. 7.
Red Sea distr.: Ghardaqa.

Spirulina KÜTZING ex GOMONT

Spirulina major KÜTZING ex GOMONT

RAYSS and DOR, 1963, p. 13.
Red Sea distr.: Abu Zabad, Eilat.

***Trichodesmium** EHRENBERG ex GOMONT *(nom. cons.)*

***Trichodesmium erythraeum** EHRENBERG ex GOMONT

GOMONT, 1893, p. 196, pl. 5, figs. 27–30. EHRENBERG, 1830, p. 506. MONTAGNE, 1844, pp. 335 and 347. KÜTZING, 1849, p. 286; 1846–49, p. 49, pl. 91, fig. III. MUSCHLER, 1908, p. 145.

Records under syns.
[*Oscillaria erythraea* (EHRENBERG) KÜTZING, 1843, p. 188.]
[*Trichodesmium ehrenbergii* MONTAGNE, CARTER, 1863, p. 183.]
Skujaella erythraea (EHRENBERG ex GOMONT) J. DETONI. NASR, 1947, p. 7. RAYSS, 1959, p. 5.

Type loc.: Tor.
Red Sea distr.: Southern Red Sea, Ghardaqa, Suez, Tor, Eilat.
Note: MUSCHLER (1908, p. 146) gave Rubor as a locality in Egypt whence EHRENBERG had material of this species. I have not been able to find this name on any map of Egypt or the Red Sea area.

NOSTOCACEAE

Anabaena BORY ex BORNET et FLAHAULT

Anabaena torulosa [CARMICHAEL] LAGERHEIM ex BORNET et FLAHAULT

Record under syn.
[*Sphaerozyga carmichaeli* Harvey. Harvey-Gibson and Knight, 1913, p. 305.]

Red Sea distr.: Sudanese coast.

Anabaena variabilis Kützing ex Bornet et Flahault

Nasr, 1939*a*, p. 50; 1947, p. 16.
Red Sea distr.: Ghardaqa.

MICROCHAETACEAE

Microchaete Thuret ex Bornet et Flahault *(nom. cons.)*

Microchaete vitiensis Askenasy

Nasr, 1947, p. 15.
Red Sea distr.: Ghardaqa.

RIVULARIACEAE

Calothrix C. Agardh ex Bornet et Flahault

[***Calothrix caulerpae** Zanardini]

Zanardini, 1851, p. 38; 1858, p. 298.
Type loc.: Red Sea on *Caulerpa serrulata.*
Distr.: Red Sea.
Note: The identity of this taxon is uncertain; see Bornet and Flahault (1886, p. 370).

Calothrix confervicola [Roth] C. Agardh ex Bornet et Flahault

Zanardini, 1858, p. 298. Muschler, 1908, p. 146. Nasr, 1947, p. 13. Rayss and Dor, 1963, p. 14.
Red Sea distr.: Red Sea on *Centroceras;* Ghardaqa, Abu Zabad on *Herposiphonia* and *Laurencia;* Eilat on *Lithoderma.*

Calothrix crustacea Thuret ex Bornet et Flahault

Nasr, 1947, p. 13. Rayss and Dor, 1963, p. 15.
Red Sea distr.: Ghardaqa, Eilat.

Calothrix parasitica [Chauvin] Thuret ex Bornet et Flahault

Harvey-Gibson and Knight, 1913, p. 305. Nasr, 1947, p. 12.
Red Sea distr.: Sudanese coast, Ghardaqa.

Calothrix scopulorum C. AGARDH ex BORNET et FLAHAULT

NASR, 1939*a*, p. 49; 1947, p. 13, fig. 2. RAYSS and DOR, 1963, p. 15.
Red Sea distr.: Ghardaqa, Eilat.

*Dichothrix ZANARDINI ex BORNET et FLAHAULT

***Dichothrix eylathensis** RAYSS et DOR

RAYSS and DOR, 1963, p. 15, fig. 2.
Type loc.: Eilat.
Distr.: Eilat.

***Dichothrix penicillata** ZANARDINI ex BORNET et FLAHAULT

BORNET and FLAHAULT, 1886, p. 379. ZANARDINI, 1858, p. 297, pl. 14, fig. 3. DETONI and PAOLETTI, 1888, p. 76. NASR, 1947, p. 14. RAYSS, 1959, p. 6.
Type loc.: Red Sea on *Spyridia filamentosa.*
Red Sea distr.: Red Sea, Massawa, Ghardaqa, Ras Nusrani.
Note: *Dichothrix penicillata* is the type of its genus.

Rivularia C. AGARDH ex BORNET et FLAHAULT

Rivularia polyotis [J. AGARDH] BORNET et FLAHAULT

NASR, 1939*a*, p. 50, figs. 1 and 2; 1947, p. 15.
Red Sea distr.: Daedalus Reef, Ghardaqa.

RHODOPHYCOPHYTA

BANGIOPHYCIDAE

GONIOTRICHALES

GONIOTRICHACEAE

Goniotrichum KÜTZING

Goniotrichum alsidii (ZANARDINI) HOWE

RAYSS and DOR, 1963, p. 30.

Records under syns.
Bangia elegans CHAUVIN. ZANARDINI, 1858, p. 295.
Goniotrichum elegans (CHAUVIN) LEJOLIS. REINBOLD, 1903, p. 232. NASR, 1947, p. 91.

Red Sea distr.: Red Sea, Ghardaqa, Tor, Eilat.

BANGIALES

ERYTHROPELTIDACEAE

Erythrotrichia J.E. ARESCHOUG *(nom. cons.)*

Erythrotrichia carnea (DILLWYN) J. AGARDH

NASR, 1939*a*, p. 63; 1947, p. 90. RAYSS and DOR, 1963, p. 29.
Red Sea distr.: Daedalus Reef, Ghardaqa, Eilat.

Erythrotrichia obscura BERTHOLD

RAYSS and DOR, 1963, p. 29.
Red Sea distr.: Eilat.

BANGIACEAE

Bangia LYNGBYE

***Bangia delilei** (MONTAGNE) ZANARDINI

ZANARDINI, 1858, p. 295.

Records under syn.
Arachnophyllum delilei MONTAGNE, 1857, p. 141. KÜTZING, 1866, p. 12, pl. 32, figs. f and g.

Type loc.: Red Sea.
Distr.: Red Sea.
Note: The systematic position and status of this species are uncertain.

Porphyra C. AGARDH *(nom. cons.)*

Porphyra umbilicalis (LINNAEUS) J. AGARDH

RAYSS and DOR, 1963, p. 29.

Record under syn.
Wildemannia umbilicalis (LINNAEUS) DETONI. LYLE, 1926, p. 40.

Red Sea distr.: Suez Canal, Eilat.

FLORIDEOPHYCIDAE

NEMALIONALES

ACROCHAETIACEAE

Acrochaetium NÄGELI

Acrochaetium robustum BØRGESEN

Record under syn.
Rhodochorton robustum (BØRGESEN) DREW. NASR, 1947, p. 93.

Red Sea distr.: Ghardaqa on *Sargassum* and *Turbinaria.*

Chromastrum PAPENFUSS

Chromastrum crassipes (BØRGESEN) PAPENFUSS

Record under syn.
Rhodochorton crassipes (BØRGESEN) DREW. NASR, 1939*a*, p. 64, figs. 11 and 12; 1947, p. 93.

Red Sea distr.: Koseir, Ghardaqa.

Chromastrum moniliforme (ROSENVINGE) PAPENFUSS

Record under syn.
Acrochaetium moniliforme (ROSENVINGE) BØRGESEN. RAYSS and DOR, 1963, p. 30.

Red Sea distr.: Eilat on *Herposiphonia.*

Chromastrum secundatum (LYNGBYE) PAPENFUSS

Record under syn.
Callithamnion secundatum (LYNGBYE) C. AGARDH. ZANARDINI, 1858, p. 282.

Red Sea distr.: Red Sea on *Spatoglossum.*

HELMINTHOCLADIACEAE

Liagora LAMOUROUX

***Liagora farinosa** LAMOUROUX

LAMOUROUX, 1816, p. 240. NASR, 1947, p. 96.

Records under syn.
Liagora elongata ZANARDINI, 1851, p. 35; 1858, p. 274, pl. 6, fig. 1. KÜTZING, 1858, p. 45, pl. 94, fig. II. REINBOLD, 1903, p. 230. MUSCHLER, 1908, p. 196.

Type loc.: In the vicinity of Suez.
Red Sea distr.: Ghardaqa, the vicinity of Suez, Tor.

***Liagora fragilis** ZANARDINI

ZANARDINI, 1851, p. 36; 1858, p. 272, pl. 7, fig. 2. KÜTZING, 1858, p. 45, pl. 94, fig. I. MUSCHLER, 1908, p. 197. NASR, 1947, p. 96.
Type loc.: Red Sea.
Red Sea distr.: Berenice, Koseir, Ghardaqa, Suez, Tor.

***Liagora rugosa** ZANARDINI

ZANARDINI, 1851, p. 36; 1858, p. 273, pl. 6, fig. 2. PICCONE, 1884, p. 312. DETONI and PAOLETTI, 1858, p. 69. NASR, 1947, p. 97, pl. 11, fig. 2.
Type loc.: Red Sea.
Red Sea distr.: Bay of Assab, Massawa, Ghardaqa, Suez, Tor, Aqaba.

***Liagora turneri** ZANARDINI

ZANARDINI, 1851, p. 35; 1858, p. 273. KÜTZING, 1858, p. 43, pl. 90, fig. I. MUSCHLER, 1908, p. 196. RAYSS, 1959, p. 17.

Records under other names
Fucus viscidus sensu TURNER, 1809, p. 127, pl. 119.
Liagora viscida sensu DECAISNE, 1834, p. 10; 1841, p. 119. Sensu SCHIMPER, 1835–37, no. 927. Sensu?

MUSCHLER, 1908, p. 196. Sensu? HARVEY-GIBSON and KNIGHT, 1913, p. 307.
Liagora coarctata ZANARDINI, 1851, p. 36. KÜTZING, 1858, p. 43, pl. 90, fig. II.
Liagora turneri var. *coarctata* (ZANARDINI) ZANARDINI, 1858, p. 274.

Type loc.: Red Sea.
Distr.: Sudanese coast, Koseir, Suez, Tor, Ras Nusrani, Aqaba, Yenbo.

***Trichogloea** KÜTZING

***Trichogloea requienii** (MONTAGNE) KÜTZING

KÜTZING, 1847, p. 54; 1849, p. 544; 1857, p. 37, pl. 92, fig. II. ZANARDINI, 1858, p. 275, pl. 7, fig. 1. J. AGARDH, 1876, p. 514. MUSCHLER, 1908, p. 196. NASR, 1939*a*, p. 64, figs. 13 and 14; 1947, p. 94, fig. 17.

Record under syn.
Batrachospermum requienii MONTAGNE, 1843, p. 355.

Type loc.: Red Sea.
Red Sea distr.: Ghardaqa, Suez, Tor.

CHAETANGIACEAE

Actinotrichia DECAISNE

***Actinotrichia fragilis** (FORSSKÅL) BØRGESEN

BØRGESEN, 1932, p. 6, pl. 1, fig. 4. NASR, 1947, p. 99. RAYSS, 1959, p. 18.

Records under other names
Fucus fragilis FORSSKÅL, 1775, pp. cxxv and 190. WEBER, 1804, p. 135.
Galaxaura rigida LAMOUROUX. DECAISNE, 1841, p. 128.
Actinotrichia rigida (LAMOUROUX) DECAISNE, 1842, p. 118. ZANARDINI, 1858, p. 272. REINBOLD, 1903, p. 230. MUSCHLER, 1908, p. 198.
Galaxaura indurata sensu KÜTZING, 1858, p. 14, pl. 31, fig. I.

Type loc.: Mocha.
Red Sea distr.: Ghardaqa, Suez, Tor, Sharm el Sheikh, Aqaba, Jiddah, Mocha.
Note: *Actinotrichia* is a monotypic genus.

Galaxaura LAMOUROUX

Galaxaura cylindrica (ELLIS et SOLANDER) LAMOUROUX

KÜTZING, 1858, p. 14, pl. 31, fig. II. MUSCHLER, 1908, p. 197. NASR, 1947, p. 98. RAYSS 1959, p. 18.
Red Sea distr.: Red Sea, Ghardaqa, Suez, Sharm el Sheikh.

***Galaxaura dactyliophora** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 312, pl. 8, fig. 7.
Type loc.: Bay of Assab.

Distr.: Bay of Assab.

Note: This species, which Piccone and Grunow suspected of perhaps being only a variety of *Galaxaura cylindrica,* was overlooked by Kjellman (1900) when he monographed the genus.

Galaxaura lapidescens (Ellis et Solander) Lamouroux

Decaisne, 1842, p. 116. Zanardini, 1858, p. 271. DeToni and Paoletti, 1888, p. 70. Muschler, 1908, p. 198. Rayss, 1959, p. 19.

Red Sea distr.: Massawa, Suez, Sharm el Sheikh, Abu Zabad, Eilat, Aqaba.

Note: It is somewhat doubtful that the Red Sea material referred to this species is representative of it.

Galaxaura lapidescens var. ***annuligera** Piccone et Grunow

Piccone and Grunow, *in* Piccone, 1884, p. 312.

Type loc.: Bay of Assab.

Distr.: Bay of Assab.

Galaxaura oblongata (Ellis et Solander) Lamouroux

Record under another name

Galaxaura adriatica Zanardini. Harvey-Gibson and Knight, 1913, p. 307, figs. 1 and 2.

Red Sea distr.: Sudanese coast.

Note: *Galaxaura adriatica* is generally considered to be a synonym of *G. oblongata* (see Børgesen, 1927, p. 72; Svedelius, 1945, pp. 21–24). Whether the material from the Sudanese coast referred to *G. adriatica* by Harvey-Gibson and Knight actually is representative of *G. oblongata* can only be settled by examination of the specimens in question. The putative occurrence of cystocarps and tetrasporangia on the same plant, as reported by Harvey-Gibson and Knight, has been shown by Svedelius (1945, pp. 24–27) to be an error.

Galaxaura rugosa (Ellis et Solander) Lamouroux

Zanardini, 1858, p. 271. Muschler, 1908, p. 198.

Red Sea distr.: Koseir, Suez, Aqaba.

Note: It is not certain that the Red Sea material referred to this species actually is representative of it.

***Galaxaura schimperi** Decaisne

Decaisne, 1842, p. 116. Ruprecht, 1849, p. 82. Zanardini, 1858, p. 271. Kjellman 1900, p. 61, pl. 7, figs. 20–26, pl. 8, figs. 15–22, pl. 20, figs. 1 and 2.

Records under other names

Galaxaura annulata sensu SCHIMPER, 1835–37, no. 478.
Galaxaura fragilis sensu MUSCHLER, 1908, p. 198. Sensu NASR, 1947, p. 98. Sensu RAYSS, 1959, p. 18.

Type loc.: Red Sea.

Distr.: Ghardaqa, Suez, Sharm el Sheikh, Aqaba.

Note: SVEDELIUS (1945, pp. 18, 39, and 42) considers *Galaxaura schimperi* to be a synonym of *G. oblongata.*

BONNEMAISONIACEAE

Asparagopsis MONTAGNE

Asparagopsis armata HARVEY

Note: The record of the occurrence of *Asparagopsis armata* in the Red Sea (Ghardaqa) is based on NASR's report (1947, p. 143, fig. 24) of *Falkenbergia rufolanosa* (HARVEY) SCHMITZ, which is generally considered to be the tetrasporangial stage of *A. armata.* It seems highly likely, however, that NASR had *F. hillebrandii* in hand, which has been shown by CHIHARA (1961) to be the tetrasporangial stage of *A. taxiformis,* a species known to occur in the Red Sea.

Asparagopsis taxiformis (DELILE) TREVISAN

Records under syn.

Asparagopsis delilei MONTAGNE. ZANARDINI, 1858, p. 260. MAZZA, 1926, p. 1864.

Red Sea distr.: Suez, Tor, Aqaba, Hodeida.

GELIDIALES

GELIDIELLACEAE

Gelidiella FELDMANN et HAMEL

***Gelidiella acerosa** (FORSSKÅL) FELDMANN et HAMEL

NASR, 1939*a*, p. 66; 1947, p. 100. NEWTON, 1953, pp. 396 and 407.

Records under other names

Fucus acerosus FORSSKÅL, 1775, pp. cxxv and 190. WEBER, 1804, p. 135.
Echinocaulon acerosum (FORSSKÅL) BØRGESEN, 1932, p. 5, pl. 1, fig. 3.
Fucus spinosus sensu VAHL, 1791, p. 105.
Gelidium rigidum GREVILLE. J. AGARDH, 1851, p. 468. PICCONE, 1884, p. 315; 1900*a*, p. 257. HARVEY-GIBSON, 1908, p. 79. MUSCHLER, 1908, p. 199.
Fucus corneus var. *setaceus* TURNER, 1819, p. 147.
Gelidium corneum var. *setaceum* (TURNER) KÜTZING. ZANARDINI, 1858, p. 270.
Gelidium latifolium sensu MUSCHLER, 1908, p. 199.
Gelidium pectinatum sensu ZELLER, *in* CHRISTENSEN, 1922, p. 31.

Type loc.: Mocha.

Red Sea distr.: Archipelago of Assab, Hanish Islands, Mandola Islet, Massawa, Trinkitat, Koseir, Ghardaqa, Suez, Mocha.

Note: *Fucus corneus* var. *setaceus* TURNER is here referred, with doubt, to *Gelidiella acerosa. Gelidiella acerosa* is the lectotype of its genus.

GELIDIACEAE

Gelidium LAMOUROUX *(nom. cons.)*

***Gelidium ambiguum** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 316. PICCONE, 1886, p. 76.

Type loc.: Bay of Assab.

Distr.: Bay of Assab, Massawa.

Gelidium corneum (HUDSON) LAMOUROUX

HARVEY-GIBSON, 1908, p. 79. LYLE, 1926, p. 40. NASR, 1947, p. 102.

Red Sea distr.: Trinkitat, Ghardaqa, Suez Canal.

Gelidium crinale (TURNER) LAMOUROUX

PICCONE, 1884, p. 316; 1900*a*, p. 257. HARVEY-GIBSON and KNIGHT, 1913, p. 307.

Red Sea distr.: Archipelago of Assab, Mandola Islet, Sudanese coast.

Gelidium crinale var. ***perpusillum** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 317.

Type loc.: Massawa.

Distr.: Massawa.

Gelidium latifolium (GREVILLE) BORNET et THURET

NASR, 1947, p. 101.

Red Sea distr.: Ghardaqa, Suez.

Gelidium pusillum (STACKHOUSE) LEJOLIS

NASR, 1947, p. 101. RAYSS and DOR, 1963, p. 30.

Red Sea distr.: Ghardaqa, Eilat.

Gelidium pusillum var. ***conchicola** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 316.

Type loc.: Massawa.

Distr.: Massawa.

***Gelidium semipinnatum** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 315, pl. 9, fig. 2.
Type loc.: Bay of Assab.
Distr.: Bay of Assab.

Gelidium spathulatum (KÜTZING) BORNET

LYLE, 1926, p. 40.
Red Sea distr.: Suez Canal.

CRYPTONEMIALES

DUMONTIACEAE

Dudresnaya P.L. et H.M. CROUAN *(nom. cons.)*

Dudresnaya verticillata (WITHERING) LEJOLIS

Record under syn.
Dudresnaya coccinea (C. AGARDH) P.L. et H.M. CROUAN. HARVEY-GIBSON and KNIGHT, 1913, p. 308.

Red Sea distr.: Sudanese coast.

RHIZOPHYLLIDACEAE

Chondrococcus KÜTZING

Chondrococcus hornemannii (LYNGBYE) SCHMITZ

MUSCHLER, 1908, p. 224.

Records under syns.
Plocamium cincinnatum MONTAGNE, 1850, p. 243. KÜTZING, 1866, p. 16, pl. 47, figs. a–c.
Desmia cincinnata (MONTAGNE) PICCONE, 1889, p. 75.
Portieria coccinea ZANARDINI, 1851, p. 33.
Desmia coccinea (ZANARDINI) ZANARDINI, 1858, p. 263. PICCONE, 1884, p. 314; 1893, pp. 380 and 381; 1900*a*, p. 259.

Red Sea distr.: Bay of Assab, Mandola Islet, Dissei Islet, Suez, Hodeida, Mocha.

Note: PAPENFUSS (1940, p. 216) has discussed the nomenclature and the possible source of the type material of this species. It seems likely that the original material had been collected by FORSSKÅL in the Red Sea.

SQUAMARIACEAE

Peyssonelia DECAISNE

***Peyssonelia conchicola** PICCONE et GRUNOW

PICCONE and GRUNOW, *in* PICCONE, 1884, p. 317, pl. 7, figs. 5–8. MAZZA, 1916, p. 1042.
Type loc.: Massawa.
Distr.: Massawa.

Peyssonelia dubyi P.L. et H.M. CROUAN

PICCONE, 1884, p. 317.

Red Sea distr.: Massawa.

***Peyssonelia involvens** ZANARDINI

ZANARDINI, 1858, p. 269, pl. 9, fig. 2. MUSCHLER, 1908, p. 225 (in error as *Paponnelia involvens*). LEMOINE, 1966, p. 21.

Type loc.: Red Sea.

Distr.: Red Sea, Suez, Eilat.

Peyssonelia rubra (GREVILLE) J. AGARDH

PICCONE, 1884, p. 317. NASR, 1939*a*, p. 66; 1947, p. 103.

Red Sea distr.: Assab, Massawa, Ghardaqa.

Peyssonelia squamaria (GMELIN) DECAISNE

MUSCHLER, 1908, p. 225 (in error as *Paponnelia squamaria*).

Red Sea distr.: Suez.

CORALLINACEAE

Amphiroa LAMOUROUX

Amphiroa fragillissima (LINNAEUS) LAMOUROUX

RAYSS, 1959, p. 19.

Red Sea distr.: Abu Zabad.

Choreonema SCHMITZ

Choreonema thuretii (BORNET) SCHMITZ

RAYSS, 1959, p. 20.

Record under syn.

Melobesia thuretii BORNET. HARVEY-GIBSON and KNIGHT, 1913, p. 308.

Red Sea distr.: Sudanese coast, Ras Nusrani (at both localities on *Jania rubens*).

Corallina LINNAEUS

Corallina tenella (KÜTZING) HEYDRICH

HARVEY-GIBSON, 1908, p. 80.

Record under syn.

Jania rubens var. *tenella* (KÜTZING) PICCONE, 1884, p. 319.

Red Sea distr.: Assab, Suakin.

Dermatolithon FOSLIE

Dermatolithon cystoseirae (HAUCK) HUVÉ

Lemoine, 1965, p. 5; 1966, p. 6.
Red Sea distr.: Eilat, Abulad Islets.

Dermatolithon geometricum (Lemoine) Lemoine

Lemoine, 1965, p. 6; 1966, p. 7, fig. 1.
Red Sea distr.: Eilat, Abulad Islets, southern Red Sea.

Dermatolithon pustulatum (Lamouroux) Foslie

Record under syn.
Melobesia pustulata Lamouroux. Piccone, 1900*a*, p. 263.

Red Sea distr.: Red Sea.

***Dermatolithon steinitzii** Lemoine

Lemoine, 1966, p. 9, figs. 2–4, pl. [1], fig. A.
Type loc.: Eilat.
Distr.: Eilat.

Fosliella Howe

Fosliella farinosa (Lamouroux) Howe

Records under syn.
Melobesia farinosa Lamouroux. Zanardini, 1858, p. 269. Piccone, 1884, p. 318; 1886, p. 65; 1889, p. 77; 1900*a*, p. 262; 1900*b*, p. 118; 1900*c*, p. 120. Licata, 1885, p. 186. Balsamo, 1885, p. 12. DeToni and Paoletti, 1888, p. 70. Nasr, 1947, p. 106. Rayss, 1959, p. 20. Lemoine, 1966, p. 20.

Red Sea distr.: Bay of Assab, Bay of Anfila, Mandola Islet, Arafali, Dissei Islet, Massawa, Ghardaqa, Suez, Tor, Eilat.

Fosliella lejolisii (Rosanoff) Howe

Records under syn.
Melobesia lejolisii Rosanoff. Piccone, 1884, p. 318. Rayss, 1959, p. 20.

Red Sea distr.: Bay of Assab, Tor.

Jania Lamouroux

Jania adhaerens Lamouroux

Kützing, 1849, p. 710. Piccone, 1889, p. 77; 1900*a*, p. 263; 1900*c*, p. 120.

Record under syn.
Corallina adhaerens (Lamouroux) Kützing, 1858, p. 40, pl. 83, fig. II.

Red Sea distr.: Red Sea, Dissei Islet, Gulf of Zula, Assarca Islet, Suez.

***Jania lobata** Zanardini

Zanardini, 1858, p. 267, pl. 3, fig. 2.
Type loc.: Yemen.
Distr.: Yemen.

Jania micrarthrodia LAMOUROUX

ZANARDINI, 1858, p. 268. LYLE, 1926, p. 40.

Record under syn.

Corallina micrarthrodia (LAMOUROUX) MUSCHLER, 1908, p. 227.

Red Sea distr.: Red Sea, Suez, Suez Canal.

Jania pumila LAMOUROUX

LAMOUROUX, 1816, p. 269, pl. 9, fig. 2. KÜTZING, 1849, p. 710. PICCONE, 1889, p. 78.

Records under syn.

Corallina pumila (LAMOUROUX) KÜTZING, 1858, p. 39, pl. 83, fig. I. REINBOLD, 1903, p. 232. MUSCHLER, 1908, p. 226. LYLE, 1926, p. 40. NASR, 1947, p. 107.

Red Sea distr.: Assab, Assarca Islet, Suez Canal, Tor.

Note: This species was erected by LAMOUROUX on material from both the Red Sea and the East Indies.

Jania rubens (LINNAEUS) LAMOUROUX

ZANARDINI, 1858, p. 268 (excl. syn. *Jania adhaerens*). PICCONE, 1884, p. 319; 1886, p. 66; 1889, p. 77; 1900*a*, p. 263; 1900*b*, p. 118. HARVEY-GIBSON and KNIGHT, 1913, p. 309. LAMI, 1932, p. 356. NASR, 1939*a*, p. 67; 1947, p. 107. NEWTON, 1953, pp. 396 and 407. RAYSS, 1959, p. 19.

Records under syns.

Jania gibbosa LAMOUROUX, 1816, p. 269.

Corallina rubens LINNAEUS. REINBOLD, 1903, p. 232. MUSCHLER, 1908, p. 227.

Red Sea distr.: Bay of Assab, Hanish Islands, Edd, Mandola Islet, Gulf of Zula, Dissei Islet, Massawa, Sudanese coast, Koseir, Ghardaqa, Shadwân Islet, Suez Canal, Tor, Sharm el Sheikh, Ras Nusrani, Abu Zabad.

Note: It is not certain that *Jania gibbosa*, which is based on material from the Red Sea, is synonymous with *J. rubens*.

Litholepis FOSLIE

Litholepis indica FOSLIE

LEMOINE, 1966, p. 18, figs. 8–10.

Red Sea distr.: Southern Red Sea, Derom Islet, Eilat.

Litholepis mediterranea FOSLIE

LEMOINE, 1966, p. 19, fig. 11.

Red Sea distr.: Eilat.

Lithophyllum PHILIPPI

Lithophyllum acrocamptum HEYDRICH

LEMOINE, 1965, p. 2.

Red Sea distr.: Abulad Islets.

Lithophyllum affine (FOSLIE) FOSLIE

HARVEY-GIBSON, 1908, p. 80. LEMOINE, 1965, p. 3.

Records under syns.
Lithothamnium affine FOSLIE, 1897, p. 13.
Lithophyllum kotschyanum f. *affinis* (FOSLIE) FOSLIE. FOSLIE, 1929, pl. 65, fig. 10.

Red Sea distr.: Massawa, Suakin, Sulein Islets, Abulad Islets.

Lithophyllum byssoides (LAMOUROUX) FOSLIE

HEYDRICH, 1901, p. 537.
Red Sea distr.: Red Sea.

Lithophyllum fasciculatum (LAMARCK) FOSLIE

Record under syn.
Lithothamnium fasciculatum (LAMARCK) J.E. ARESCHOUG. HARVEY-GIBSON and KNIGHT, 1913, p. 308.

Red Sea distr.: Sudanese coast.

Lithophyllum incrustans PHILIPPI

MUSCHLER, 1908, p. 226.

Record under another name
Pocillopora polymorpha sensu EHRENBERG, 1833, p. 353.

Red Sea distr.: Koseir.

***Lithophyllum kaiseri** (HEYDRICH) HEYDRICH

REINBOLD, 1903, p. 232. CROSSLAND, 1939, p. 522. NASR, 1939*a*, p. 67, pl. 1, figs. 2 and 3; 1947, p. 105. LEMOINE, 1966, p. 6.

Records under other names
Lithothamnium kaiseri HEYDRICH, 1897*a*, p. 64, pl. 3, figs. 8, 12, and 13.
Lithophyllum kotschyanum sensu FOSLIE, 1929, pl. 65, figs. 2 and 4.

Type loc.: Tor.
Distr.: Southern Red Sea, Massawa, Daedalus Reef, Ghardaqa, Tor, Eilat, Sulein Islets, Abulad Islets.

Lithophyllum okamurai f. **trincomaliensis** FOSLIE

LEMOINE, 1965, p. 4; 1966, p. 6 (as *Lithophyllum okamurai*).
Red Sea distr.: Southern Red Sea, Eilat, Abulad Islets.

Lithophyllum racemus (LAMARCK) FOSLIE

Records under syns.
Lithothamnium racemus (LAMARCK) J.E. ARESCHOUG. PICCONE, 1884, p. 319.
Lithothamnium crassum PHILIPPI. BORNET, 1888, p. 20.

Red Sea distr.: Massawa, Kamaran Island.

Lithophyllum subreduncum FOSLIE

Record under syn.
Lithophyllum kotschyanum f. *subreduncum* (FOSLIE) FOSLIE. FOSLIE, 1929, pl. 65, figs. 11 and 13.

Red Sea distr.: Assab, Tor.

Note: LEMOINE (1965, pp. 3 and 11) regards this as an autonomous species.

Lithoporella (FOSLIE) FOSLIE

Lithoporella melobesioides (FOSLIE) FOSLIE

Record under syn.
Mastophora melobesioides FOSLIE, 1904, p. 75.

Red Sea distr.: Tor.

Lithothamnium† PHILIPPI

Lithothamnium crispatum HAUCK

Record under syn.
Lithophyllum crispatum (HAUCK) HAUCK. HARVEY-GIBSON and KNIGHT, 1913, p. 309.

Red Sea distr.: Sudanese coast.

Lithothamnium indicum f. **subtilis** FOSLIE

LEMOINE, 1965, p. 9.

Record under another name
Lithothamnium fruticulosum sensu PICCONE, 1900*a*, p. 263.

Red Sea distr.: Bay of Anfila, Abulad Islets.

Lithothamnium lenormandii (J.E. ARESCHOUG) FOSLIE

Record under syn.
Lithophyllum lenormandii (J.E. ARESCHOUG) ROSANOFF. PICCONE, 1884, p. 318.

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†The spelling *Lithothamnion*, as used by some authors, has been corrected to *Lithothamnium* throughout this catalogue.

Red Sea distr.: Bay of Assab.

Note: This record is probably based on a misidentification of the material in question (see Lemoine, 1966, p. 5).

Lithothamnium polymorphum (Linnaeus) J.E. Areschoug

Piccone, 1884, p. 318. Harvey-Gibson and Knight, 1913, p. 308.

Red Sea distr.: Massawa, Sudanese coast.

Lithothamnium purpurascens (Foslie) Foslie

Lemoine, 1965, p. 9.

Red Sea distr.: Abulad Islets.

Lithothamnium siamense Foslie

Lemoine, 1965, p. 10; 1966, p. 17.

Red Sea distr.: Eilat, Abulad Islets.

Lithothamnium yendoi (Foslie) Lemoine

Lemoine, 1965, p. 10.

Red Sea distr.: Abulad Islets.

Melobesia Lamouroux

Melobesia membranacea (Esper) Lamouroux

Zanardini, 1858, p. 269. Piccone, 1884, p. 318; 1889, p. 76; 1900*a*, p. 262. Licata, 1885, p. 186. Balsamo, 1885, p. 12.

Records under syns.

Lithothamnium membranaceum (Esper) Foslie. Muschler, 1908, p. 226. Nasr, 1947, p. 106.

Epilithon membranaceum (Esper) Heydrich. Rayss, 1959, p. 19.

Red Sea distr.: Bay of Assab, Assab, Mandola Islet, Massawa, Ghardaqa, Suez.

Mesophyllum Lemoine

Mesophyllum simulans (Foslie) Lemoine

Lemoine, 1965, p. 9; 1966, p. 16, fig. 7.

Red Sea distr.: Eilat, Abulad Islets.

Metamastophora Setchell

Metamastophora lamourouxii (Harvey) Setchell

Rayss, 1959, p. 20.

Red Sea distr.: Eilat.

Note: The material from Eilat was referred to this species with doubt by Rayss.

*Neogoniolithon SETCHELL et MASON

*Neogoniolithon assitum (FOSLIE) SETCHELL et MASON

Records under other names

Goniolithon assitum FOSLIE, 1907, p. 23; 1929, pl. 47, fig. 3.

Lithothamnium engelhartii f. *pseudocrispata* sensu FOSLIE, *in* REINBOLD, 1903, p. 232.

Type loc.: Tor.
Red Sea distr.: Tor.

*Neogoniolithon fosliei (HEYDRICH) SETCHELL et MASON

LEMOINE, 1965, p. 7; 1966, p. 13.

Records under syns.

Lithothamnium fosliei HEYDRICH, 1897*a*, p. 58, fig. 1, pl. 3, figs. 9–11.

Goniolithon fosliei (HEYDRICH) FOSLIE. REINBOLD, 1903, p. 232. FOSLIE, 1904, fig. 19A, pl. 9, fig. 1; 1929, pl. 46, fig. 2.

Type loc.: Tor.

Red Sea distr.: Southern Red Sea, Adjuz Islet (= ? Hedjaz of LEMOINE), Tor, Abu Zabad, Eilat, Jiddah, Sulein Islets, Abulad Islets.

Note: *Neogoniolithon fosliei* is the type of its genus. FOSLIE (1904, pl. 9, fig. 1) has illustrated the habit of an isotype and in text-figure 19A of the same work a vertical section through the same specimen.

Neogoniolithon frutescens (FOSLIE) SETCHELL et MASON

RAYSS, 1959, p. 21. LEMOINE, 1965, p. 7; 1966, p. 13.
Red Sea distr.: Sharm el Sheikh, Eilat, Abulad Islets.

*Neogoniolithon myriocarpum (FOSLIE) SETCHELL et MASON

Records under syns.

Lithothamnium myriocarpum FOSLIE, 1897, p. 19.

Goniolithon myriocarpum (FOSLIE) FOSLIE, *in* REINBOLD, 1903, p. 232. FOSLIE, 1904, pl. 9, fig. 6; 1929, pl. 46, fig. 6. HARVEY-GIBSON, 1908, p. 80.

Lithothamnium oblimans HEYDRICH, 1897*a*, p. 55, pl. 3, fig. 17.

Type loc.: Massawa.
Red Sea distr.: Massawa, Suakin, Tor.

Neogoniolithon myriocarpum f. confragosum (FOSLIE) LEMOINE

LEMOINE, 1966, p. 14.

Record under another name

Neogoniolithon myriocarpum (FOSLIE) SETCHELL et MASON. LEMOINE, 1965, p. 8.

Red Sea distr.: Southern Red Sea, Eilat, Abulad Islets.

Neogoniolithon propinquum (FOSLIE) LEMOINE

LEMOINE, 1966, p. 14, pl. [1], fig. E.
Red Sea distr.: Eilat.

Porolithon FOSLIE

Porolithon onkodes (HEYDRICH) FOSLIE

LEMOINE, 1965, p. 6; 1966, p. 10, figs. 5 and 6, pl. [1], figs. B-D.
Red Sea distr.: Southern Red Sea, The Brothers, Eilat, Abulad Islets.

Pseudolithophyllum LEMOINE

Pseudolithophyllum expansum (PHILIPPI) LEMOINE

Record under syn.
Lithophyllum expansum PHILIPPI. HARVEY-GIBSON and KNIGHT, 1913, p. 309.

Red Sea distr.: Sudanese coast.

***Sporolithon** HEYDRICH

***Sporolithon crassum** HEYDRICH

HEYDRICH, 1897*b*, p. 417.
Type loc.: Tor.
Distr.: Tor.
Note: The status of this species is uncertain.

***Sporolithon erythraeum** (ROTHPLETZ) KYLIN

KYLIN, 1956, p. 205.

Records under syns.
Lithothamnium erythraeum ROTHPLETZ, 1893, p.5.
Archaeolithothamnium erythraeum (ROTHPLETZ) FOSLIE, 1904, p. 39, pl. 5, figs. 1 and 2; 1929, pl. 42, figs. 1 and 2.
Sporolithon ptychoides HEYDRICH, 1897*a*, p. 67, figs. 2, and 3, pl. 3, figs. 15–23, (incl. f. *dura* and f. *mollis*); 1897*b*, p. 415, pl. 18. MAZZA, 1917, p. 1090.
Sporolithon molle (HEYDRICH) HEYDRICH, 1897*b*, p. 416.

Type loc.: Red Sea.
Red Sea distr.: Massawa, Tor.

Note: A number of authors have accepted the generic name *Archaeolithothamnium* instead of *Sporolithon* for members of this complex of algae, believing the former name to have been validly published by ROTHPLETZ (1891, p. 310) and hence to have priority over *Sporolithon* HEYDRICH (1897*a*). However, *Archaeolithothamnium* was proposed as a provisional name by ROTHPLETZ and he himself did not accept it. The name was validated for the first time by FOSLIE (1898) subsequent to the establishment of *Sporolithon* by HEYDRICH. A part of the type of *S. erythraeum* has been illustrated by FOSLIE (1904, pl. 5, fig. 1).

CRYPTONEMIACEAE

Grateloupia C. AGARDH

Grateloupia filicina (LAMOUROUX) C. AGARDH

MAZZA, 1914, p. 750. NASR, 1947, p. 109.
Red Sea distr.: Suez.

Halymenia C. AGARDH

***Halymenia dilatata** ZANARDINI

ZANARDINI, 1851, p. 35; 1858, p. 280, pl. 5, fig. 1.
Type loc.: Massawa.
Distr.: Massawa.

Halymenia durvillaei var. **ceylanica** (KÜTZING) WEBER-VAN BOSSE

NASR, 1947, p. 109.
Red Sea distr.: Suez.

Halymenia floresia (CLEMENTE) C. AGARDH

ZANARDINI, 1858, p. 280. DETONI and PAOLETTI, 1888, p. 68. MUSCHLER, 1908, p. 223. NASR, 1947, p. 108.

Record under syn.
Fucus floresius CLEMENTE. TURNER, 1819, p. 144.

Red Sea distr.: Massawa, Suakin, Koseir, Strait of Jubal, Suez, Aqaba, Hodeida, Mocha.

KALLYMENIACEAE

Euthora J. AGARDH

Euthora cristata (TURNER) J. AGARDH

Note: TURNER (1808, p. 48) described a plant from the Red Sea under the name *Fucus cristatus* var. *valentiae*. The identity of this taxon, which has been overlooked, is wholly uncertain.

GIGARTINALES

CRUORIACEAE

Cruoriopsis DUFOUR

***Cruoriopsis marisrubri** RAYSS et DOR

RAYSS and DOR, 1963, p. 31, figs. 7 and 8.
Type loc.: Eilat.
Distr.: Eilat.

NEMASTOMACEAE

Platoma SCHMITZ

Platoma incrassata BORNET

NASR, 1940, pp. 200 and 216.

Red Sea distr.: Egyptian Red Sea coast.

Note: NASR in 1940 reported this species as occurring in the northern Red Sea. No reference to it was made in his publication of 1947.

Titanophora (J. AGARDH) FELDMANN

Titanophora pikeana (DICKIE) FELDMANN

Record under syn.

Platoma pikeana (DICKIE) WEBER-VAN BOSSE. NASR, 1940, pp. 200 and 216.

Red Sea distr.: Egyptian Red Sea coast.

Note: NASR in 1940 reported this species as occurring in the northern Red Sea. No reference to it was made in his subsequent publications. In the Herbarium of the University of California are two of NASR's specimens of this species (NASR no. 6). In a letter to SETCHELL, dated 6 December 1936, he stated that the specimens were obtained by dredging at 40 fathoms, but the locality was not given. It was SETCHELL's suggestion to NASR that the species was *Platoma pikeana*.

GRACILARIACEAE

Gracilaria GREVILLE *(nom. cons.)*

***Gracilaria arcuata** ZANARDINI

ZANARDINI, 1858, p. 265, pl. 5, fig. 2. PICCONE, 1884, p. 320. REINBOLD, 1903, p. 230. NASR, 1947, p. 111.

Type loc.: Aqaba.

Red Sea distr.: Bay of Assab, Ghardaqa, Tor, Aqaba.

***Gracilaria cacalia** (J. AGARDH) DAWSON

Records under other names

Corallopsis cacalia J. AGARDH, 1852*a*, p. 583. ZANARDINI, 1858, p. 267. PICCONE, 1884, p. 320. MUSCHLER, 1908, p. 207.

Corallopsis salicornia sensu DECAISNE, 1841, p. 184.

Gracilaria crassa sensu NASR, 1947, p. 111.

Type loc.: Red Sea.

Red Sea distr.: Red Sea, Bay of Assab, Koseir, Suez, Tor, Jiddah.

Note: DAWSON (1954) has shown that *Corallopsis* GREVILLE (1830) is congeneric with *Gracilaria* GREVILLE (1830), a conserved name. For an excellent treatment of the taxonomy and nomenclature of several species of *Gracilaria* from the Indian Ocean and Red Sea reference should be made to the paper by NEWTON (1953).

Gracilaria canaliculata (KÜTZING) SONDER

NEWTON, 1953, pp. 396 and 413, pl. 3, fig. 4.

Records under other names

Fucus wrightii TURNER, 1811, p. 31, *pro parte,* as to specimen from the Red Sea.
Plocaria wrightii (TURNER) MONTAGNE, 1850, p. 243, as to specimen from the Red Sea.
Gracilaria wrightii sensu PICCONE, 1884, p. 320; 1889, p. 75; 1900*a,* p. 258. Sensu? MUSCHLER, 1908, p. 206.

Red Sea distr.: Red Sea, Bay of Assab, Hanish Islands, Mandola Islet, Massawa, Koseir?, Suez?, Hodeida.

Gracilaria compressa (C. AGARDH) J. AGARDH

NEWTON, 1953, pp. 396 and 414.
Red Sea distr.: Hanish Islands.

***Gracilaria debilis** (FORSSKÅL) BØRGESEN

BØRGESEN, 1932, p. 7, pl. 1, fig. 5.

Records under other names

Fucus debilis FORSSKÅL, 1775, pp. cxxv, 191.
Gracilaria poitei sensu PICCONE, 1884, p. 320.

Type loc.: Mocha.
Red Sea distr.: Bay of Assab, Mocha.
Note: The plant which for a long time passed as "*Gracilaria poitei* (LAMOUROUX) J. AGARDH" was found by HOWE to be a species of *Laurencia.*

***Gracilaria disticha** (J. AGARDH) J. AGARDH

J. AGARDH, 1852*a,* p. 594. ZANARDINI, 1858, p. 266. LYLE, 1926, p. 40.

Record under syn.

Sphaerococcus distichus J. AGARDH, 1837, p. 172.

Type loc.: Ethiopian coast.
Red Sea distr.: Ethiopian coast, Berenice, Koseir, Suez Canal.

***Gracilaria foliifera** (FORSSKÅL) BØRGESEN

BØRGESEN, 1932, p. 7, fig. 1. NASR, 1947, p. 112.

Records under other names

Fucus foliifer FORSSKÅL, 1775, pp. cxxv and 191.
Fucus laminosus FORSSKÅL, 1775, pp. cxxv and 191. BØRGESEN, 1932, p. 7.

Fucus aeruginosus TURNER, 1811, p. 29, pl. 147.
Rhodymenia multipartita (CLEMENTE) MONTAGNE, 1850, p. 243.
Gracilaria corticata sensu ZANARDINI, 1858, p. 265. Sensu PICCONE, 1884, p. 320; 1900*a*, p. 258. Sensu HAUCK, 1888, p. 89. Sensu DETONI and PAOLETTI, 1888, p. 69. Sensu MUSCHLER, 1908, p. 206. Sensu NASR, 1947, p. 111, pl. 12, fig. 7.

Type loc.: Mocha.
Red Sea distr.: Gulf of Assab, Gulf of Zula, Massawa, Koseir, Suez, Tor, Aqaba, Hodeida, Mocha.

Gracilaria minor (SONDER) DURAIRATNAM

Record under syn.
Corallopsis minor (SONDER) J. AGARDH. PICCONE, 1884, p. 319.

Red Sea distr.: Bay of Assab.

Gracilaria radicans HAUCK

PICCONE, 1884, p. 320.
Red Sea distr.: Bay of Assab.

Gracilaria verrucosa (HUDSON) PAPENFUSS

Records under syn.
Gracilaria confervoides (LINNAEUS) GREVILLE. HAUCK, 1888, p. 89. NASR, 1947, p. 111.

Red Sea distr.: Suez, Hodeida.

SOLIERIACEAE

*Meristotheca J. AGARDH

***Meristotheca papulosa** (MONTAGNE) J. AGARDH

J. AGARDH, 1872*a*, p. 37. KYLIN, 1932, p. 25, figs. 5B and 5C, pl. 12, fig. 27.

Records under other names
Kallymenia papulosa MONTAGNE, 1850, p. 246. ZANARDINI, 1858, p. 279.
Euhymenia papulosa (MONTAGNE) KÜTZING, 1867, p. 22, pl. 73, figs. e–g.
Kallymenia exasperata ZANARDINI, 1851, p. 35.
Sebdenia ceylanica sensu MUSCHLER, 1908, p. 208.

Type loc: Hodeida.
Distr.: Suez, Aqaba, Yenbo, Jiddah, Hodeida, Mocha.
Note: *Meristotheca papulosa* is the lectotype of its genus. See KYLIN (1932, pp. 25–28) for a discussion of the morphology of this species and of the genus.

*Sarconema ZANARDINI

Sarconema filiforme f. **curta** RAYSS

RAYSS, 1965, p. 98.
Red Sea distr.: Yemen.

Note: In the light of NEWTON's (1953, pp. 408 and 409) observations it seems very likely that forma *curta* is not representative of *Sarconema filiforme*, which is based on a PREISS specimen (not on HARVEY's Australian Algae No. 316) and probably is a species of *Dicranema*. Forma *curta* probably is representative of *Sarconema furcellatum*.

***Sarconema furcellatum** ZANARDINI

ZANARDINI, 1858, p. 264, pl. 10, fig. 1. DETONI and PAOLETTI, 1888, p. 69. PICCONE, 1900*a*, p. 258. MAZZA, 1907, p. 132. NASR, 1947, p. 112, pl. 12, fig. 2. NEWTON, 1953, pp. 396 and 408, pl. 2, fig. 1.

Records under syns.

Plocaria furcellata MONTAGNE, 1850, p. 243.
Gracilaria furcellata (MONTAGNE) ZANARDINI, 1858, p. 266.
Trematocarpus furcellatus (MONTAGNE) KÜTZING, 1869, p. 27, pl. 73, figs. c and d.
Dicranema montagnei GRUNOW, 1873–74, p. 43 (non *D. furcellata* J.D. HOOKER et HARVEY).
Sarconema montagnei (GRUNOW) KYLIN, 1932, p. 21, pl. 8, fig. 16.
Dicranema furcellata (MONTAGNE) J. AGARDH. PICCONE, 1884, p. 320; 1893, p. 381.

Type loc.: Not specified, Berenice, Suakin.

Red Sea distr.: Bay of Assab, Hanish Islands, Gulf of Zula, Dahlak Archipelago, Massawa, Suakin, Berenice, Koseir, Hodeida.

Note: *Sarconema furcellatum* is the type of its genus. See NEWTON (1953, pp. 408 and 409) for a discussion of the nomenclature of this species.

Solieria J. AGARDH

***Solieria dura** (ZANARDINI) SCHMITZ

SCHMITZ, 1895, pp. 139 and 149. MUSCHLER, 1908, p. 204.

Record under syn.

Rhabdonia dura ZANARDINI, 1858, p. 278, pl. 11, fig. 1.

Type loc.: Not specified, Hodeida, Mocha.

Red Sea distr.: Suez, Hodeida, Mocha.

HYPNEACEAE

Hypnea LAMOUROUX

Hypnea cornuta (KÜTZING) J. AGARDH

NASR, 1947, p. 114. RAYSS, 1959, p. 21.

Red Sea distr.: Ghardaqa, Ras Muhammad.

Note: LAMOUROUX is usually given as the parenthetic author of this species, but he never described it. KUTZING (1849, p. 741) first described it as *Chondroclonium cornutum*. HAUCK (1887, p. 19) and BØRGESEN (1943, p. 59) are of the opinion that *H. cornuta* and *H. hamulosa* are merely forms of *H. valentiae*. However, if the type of *H. hamulosa* actually is a species of *Hypnea* (see PAPENFUSS, 1958, pp. 105 and 106 for a discussion of this question), the name *H. hamulosa* would be the correct name for these taxa.

Hypnea esperi BORY

RAYSS and DOR, 1963, p. 36.
Red Sea distr.: Eilat.

Hypnea musciformis (WULFEN) LAMOUROUX

SCHENK, 1840, p. 2. DECAISNE, 1841, p. 182. LYLE, 1926, p. 40. FORTI, 1928, pp. 1445 and 1450, pl. 20, fig. 1. BØRGESEN, 1932, p. 3. NASR, 1947, p. 114. RAYSS, 1959, p. 21.

Records under other names
Conferva seticulosa FORSSKÅL, 1775, p. 188, *pro parte*, excl. lectotype.
Sphaerococcus musciformis (WULFEN) C. AGARDH. DECAISNE, 1834, p. 10.

Red Sea distr.: Massawa, Ghardaqa, Suez, Suez Canal, Tor, Aqaba, Jiddah, Mocha.

Hypnea nidifica J. AGARDH

PICCONE, 1900*a*, p. 258.
Red Sea distr.: Mandola Islet.

Hypnea rugulosa MONTAGNE

NOTE: MONTAGNE (1850, p. 245) referred material from Hodeida to this species. The exact identity of this material is uncertain.

Hypnea spinella (C. AGARDH) KÜTZING

PICCONE, 1884, p. 314.
Red Sea distr.: Massawa.

***Hypnea valentiae** (TURNER) MONTAGNE

J. AGARDH, 1851, p. 450. ZANARDINI, 1858, p. 270. PICCONE, 1884, p. 314; 1889, p. 76; 1900*a*, p. 258. DETONI and PAOLETTI, 1888, p. 70. MUSCHLER, 1908, p. 208. HARVEY-GIBSON, 1908, p. 79. HARVEY-GIBSON and KNIGHT, 1913, p. 308, figs. 3 and 4. LYLE, 1926, p. 40. NASR, 1939*a*, p. 67; 1947, p. 113, pl. 13, fig. 1.

Records under other names
Fucus valentiae TURNER, 1809, p. 17, pl. 78.
Fucus hamulosus sensu? TURNER, 1809, p. 19, pl. 79.
Hypnea hamulosa sensu? MONTAGNE, 1850, p. 244. Sensu? ZANARDINI, 1858, p. 270. Sensu? PICCONE, 1884, p. 314; 1900*a*, p. 258. Sensu? MUSCHLER, 1908, p. 207. Sensu? FORTI, 1928, p. 1450, pl. 22, fig. 2. Sensu? NASR, 1947, p. 114.
Hypnea valentiae var. *hamulosa* sensu? DECAISNE, 1841, p. 183.

Type loc.: Red Sea.

Red Sea distr.: Bay of Assab, Gulf of Zula, Shumma Islet, Massawa, Sudanese coast, Suakin, Berenice, Koseir, Ghardaqa, Suez, Suez Canal, Tor, Aqaba, Jiddah, Hodeida.

Note: See PAPENFUSS (1958, p. 105) for a discussion of the nomenclature of *Hypnea hamulosa*. In regard to the location of Gischin, whence SCHIFFNER (1934, p. 117) reported *H. hamulosa,* see the footnote on p. 42.

GIGARTINACEAE

Gigartina STACKHOUSE

Gigartina teedii (ROTH) LAMOUROUX

ZANARDINI, 1858, p. 279. DETONI and PAOLETTI, 1888, p. 69. MUSCHLER, 1908, p. 201.

Red Sea distr.: Massawa, Koseir, Suez.

Iridaea BORY *(nom. cons.)*

***Iridaea** ? **reticulata** MONTAGNE

MONTAGNE, 1850, p. 246.

Type loc.: Hodeida.

Distr.: Hodeida.

***Iridaea yemensis** MONTAGNE

MONTAGNE, 1850, p. 245.

Type loc.: Hodeida.

Distr.: Hodeida.

Note: The identity of both the species of *Iridaea* described by MONTAGNE from Hodeida is wholly uncertain.

RHODYMENIALES

RHODYMENIACEAE

Botryocladia (J. AGARDH) KYLIN

Botryocladia chiajeana (MENEGHINI) KYLIN

NASR, 1947, p. 116.

Red Sea distr.: Ghardaqa.

Botryocladia leptopoda (J. AGARDH) KYLIN

NASR, 1939*a*, p. 69; 1947, p. 117.

Red Sea distr.: Strait of Jubal.

Chrysymenia J. AGARDH

Chrysymenia ventricosa (LAMOUROUX) J. AGARDH

NASR, 1939*a*, p. 68, figs. 15 and 16; 1947, p. 116.
Red Sea distr.: Strait of Jubal.

Rhodymenia GREVILLE *(nom. cons.)*

***Rhodymenia erythraea** ZANARDINI

ZANARDINI, 1858, p. 276. PICCONE, 1884, p. 328.

Record under another name
Rhodymenia palmata sensu MONTAGNE, 1850, p. 243.

Type loc.: Hodeida.
Red Sea distr.: Suez, Jiddah, Hodeida.
Note: The generic position of this species is uncertain.

CHAMPIACEAE

Champia DESVAUX

***Champia irregularis** (ZANARDINI) PICCONE

PICCONE, 1884, p. 313. MUSCHLER, 1908, p. 209. NASR, 1947, p. 118.

Records under syn.
Lomentaria irregularis ZANARDINI, 1851, p. 34, 1858, p. 262, pl. 10, fig. 2.

Type loc.: Not specified, Suez, Berenice, Hodeida, Mocha.
Red Sea distr.: Bay of Assab, Berenice, Ghardaqa, Suez, Hodeida, Mocha.

Champia kotschyana ENDLICHER et DIESING

PICCONE, 1884, p. 313.
Red Sea distr.: Bay of Assab.

***Champia tripinnata** ZANARDINI

ZANARDINI, 1851, p. 34; 1858, p. 277, pl. 11, fig. 2. PICCONE, 1884, p. 313; 1889, p. 74.
Type loc.: Not specified, Suez, Aqaba.
Distr.: Bay of Assab, Suez, Aqaba.

Lomentaria LYNGBYE

Lomentaria squarrosa (KÜTZING) LEJOLIS

HARVEY-GIBSON and KNIGHT, 1913, p. 308.
Red Sea distr.: Sudanese coast.

CERAMIALES

CERAMIACEAE

Antithamnion NÄGELI

Antithamnion antillarum BØRGESEN

Record under another name
Antithamnion lherminieri (P.L. et H.M. CROUAN) BORNET. NASR, 1941, p. 66, figs. 9 and 10.

Red Sea distr.: Ghardaqa.

Note: NASR reduced *Antithamnion antillarum* to a synonym of *A. lherminieri*, which name, however, is a *nomen nudum*.

Antithamnion pygmaeum GARDNER

NASR, 1939*a*, p. 69; 1947, p. 127.
Red Sea distr.: Strait of Jubal.

Callithamnion LYNGBYE

Callithamnion byssoides ARNOT ex HARVEY

NASR, 1947, p. 125, fig. 21.
Red Sea distr.: Ghardaqa on *Codium*.

***Callithamnion hamelii** NASR

NASR, 1941, p. 62, figs. 5–8.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Centroceras KÜTZING

Centroceras clavulatum (C. AGARDH) MONTAGNE

RUPRECHT, 1849, p. 79. ZANARDINI, 1858, p. 282. RAYSS, 1959, p. 23.

Records under syns.
Centroceras championianum ZANARDINI, 1851, p. 37.
Ceramium clavulatum C. AGARDH. REINBOLD, 1903, p. 231. MUSCHLER, 1908, p. 223.

Red Sea distr.: Suez, Tor, Ras Muhammad, Ras Nusrani, Shora el Manqata, Aqaba.

Ceramium ROTH *(nom. cons.)*

Ceramium diaphanum (LIGHTFOOT) ROTH

NASR, 1947, p. 130.
Red Sea distr.: Ghardaqa.

Ceramium diaphanum var. **elegans** (ROTH) FELDMANN-MAZOYER

Record under syn.

Ceramium elegans (ROTH) DUCLUZEAU. PICCONE, 1884, p. 313.

Red Sea distr.: Bay of Assab.

Ceramium gracillimum (KÜTZING) GRIFFITHS et HARVEY

ZANARDINI, 1858, p. 282. PICCONE, 1884, p. 313.

Red Sea distr.: Bay of Assab, Massawa.

Ceramium gracillimum var. **byssoideum** (HARVEY) MAZOYER

NASR, 1939*a*, p. 70, pl. 1, figs.4 and 5. RAYSS, 1959, p. 22. RAYSS and DOR, 1963, p. 36.

Record under syn.

Ceramium gracillimum sensu NASR, 1947, p. 130.

Red Sea distr.: Koseir, Ghardaqa, Suez Canal, Abu Zabad, Shora el Manqata, Eilat.

***Ceramium nayalii** NASR

NASR, 1941, p. 69, figs. 11, 11 *bis*, 12–15.

Type loc.: Ghardaqa.

Distr.: Ghardaqa.

Ceramium rubrum (HUDSON) C. AGARDH

ZANARDINI, 1858, p. 282. NASR, 1947, p. 131.

Red Sea distr.: Red Sea, Ghardaqa.

Ceramium strictum GREVILLE ex HARVEY

NASR, 1947, p. 131.

Red Sea distr.: Ghardaqa.

Ceramium tenuissimum (ROTH) J. AGARDH

ZANARDINI, 1858, p. 282. MUSCHLER, 1908, p. 221. RAYSS, 1959, p. 23.

Red Sea distr.: Berenice, Koseir, Suez, Shora el Manqata.

Note: *Ceramium tenuissimum* (ROTH) J. AGARDH (1851) is invalidated by *C. tenuissimum* BONNEMAISON (1828) but the correct name of the taxon has not been established.

Crouania J. Agardh

Crouania attenuata (C. Agardh) J. Agardh
Nasr, 1947, p. 126.
Red Sea distr.: Ghardaqa, Strait of Jubal.

Griffithsia C. Agardh

Griffithsia tenuis C. Agardh
Nasr, 1947, p. 122.
Red Sea distr.: Ghardaqa.

Haloplegma Montagne

Haloplegma duperreyi var. **sublittorale** Weber-van Bosse
Nasr, 1939*a*, p. 70; 1947, p. 129.
Red Sea distr.: Ghardaqa, Strait of Jubal.

Pleonosporium (Nägeli) Nägeli ex Hauck *(nom. cons.)*

Pleonosporium borreri (J.E. Smith) Nägeli ex Hauck
Nasr, 1947, p. 123, fig. 20.
Red Sea distr.: Ghardaqa.

Ptilothamnion Thuret

Ptilothamnion pluma f. ***minor** Nasr
Nasr, 1944, p. 38; 1947, p. 120.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Spermothamnion J.E. Areschoug

Spermothamnion investiens var. ***arabica** Nasr
Nasr, 1944, p. 39, fig. 7; 1947, p. 121, fig. 18.
Type loc.: Ghardaqa.
Distr.: Ghardaqa.

Spyridia Harvey

***Spyridia aculeata** (C. Agardh ex Decaisne) Kützing

Kützing, 1843, p. 377; 1849, p. 668. J. Agardh, 1851, p. 342. Zanardini, 1858, p. 281. Muschler, 1908, p. 221. Lyle, 1926, p. 40. Nasr, 1947, p. 128, pl. 14, fig. 1.

Records under other names

Ceramium aculeatum C. Agardh ex Decaisne, 1841, p. 179. Schimper, 1835–37, no. 966.
Bindera sp. an *insignis* sensu Ruprecht, 1849, p. 79.
Spyridia berkeleyana sensu Montagne, 1849, p. 290.
Spyridia horrida Zanardini, 1851, p. 37.

Type loc.: Nuweiba.
Red Sea distr.: Koseir, Ghardaqa, Suez, Suez Canal, Nuweiba, Aqaba.

Spyridia clavata Kützing

Lyle, 1926, p. 40.
Red Sea distr.: Suez Canal.

Spyridia filamentosa (Wulfen) Harvey

Zanardini, 1858, p. 281. DeToni and Paoletti, 1888, p. 69. Piccone, 1900*c*, p. 120. Reinbold, 1903, p. 231. Harvey-Gibson, 1908, p. 79. Harvey-Gibson and Knight, 1913, p. 307. Rayss, 1959, p. 23. Nasr, 1947, p. 128.

Records under syns.

Spyridia filamentosa var. *griffithsiana* (J.E. Smith) J. Agardh, 1851, p. 341.
Spyridia vilosissima Zanardini, 1851, p. 36.
Spyridia confervoides Zanardini, 1851, p. 36. Piccone, 1893, p. 381; 1900*a*, p. 262.

Red Sea distr.: Massawa, Sudanese coast, Gulf of Berenice, Daedalus Reef, Koseir, Ghardaqa, Suez, Tor, Ras Muhammad, Shora el Manqata, Aqaba.

DELESSERIACEAE

Hypoglossum Kützing

Hypoglossum spathulatum (Sonder) Kützing

Nasr, 1947, p. 145, fig. 25.
Red Sea distr.: Ghardaqa.

Martensia Hering *(nom. cons.)*

Martensia elegans Hering

Piccone, 1900*a*. p. 260.
Red Sea distr.: Mandola Islet.

Myriogramme Kylin

Myriogramme okhaensis Børgesen

Nasr, 1947, p. 144.
Red Sea distr.: Ghardaqa.

Nitophyllum GREVILLE *(nom. cons.)*

Nitophyllum punctatum (STACKHOUSE) GREVILLE

LYLE, 1926, p. 40. NASR, 1947, p. 145.
Red Sea distr.: Strait of Jubal, Suez Canal.

DASYACEAE

Dasya C. AGARDH *(nom. cons.)*

***Dasya flocculosa** ZANARDINI

ZANARDINI, 1858, p. 259, pl. 8, fig. 1. LYLE, 1926, p. 40. NASR, 1947, p. 141.
Type loc.: Berenice.
Distr.: Berenice, Koseir, Suez Canal.

***Dasya hussoniana** MONTAGNE

MONTAGNE, 1849, p. 290. ZANARDINI, 1858, p. 259. MUSCHLER, 1908, p. 218.

Record under syn.
Dasya divaricata ZANARDINI, 1851, p. 34.

Type loc.: Red Sea.
Distr.: Red Sea, Suez.

Heterosiphonia MONTAGNE *(nom. cons.)*

Heterosiphonia wurdemanni (BAILEY ex HARVEY) FALKENBERG

NASR, 1947, p. 142.
Red Sea distr.: Ghardaqa, Strait of Jubal.

RHODOMELACEAE

Acanthophora LAMOUROUX

Acanthophora najadiformis (DELILE) PAPENFUSS, comb. nov.

Records under other names
Fucus nayadiformis DELILE, 1813*a*, p. 80; 1813*b*, p. 292, pl. 56, fig. 1; 1824, pp. 113 and 396, pl. 56, fig. 1.
Acanthophora delilei LAMOUROUX, 1813, p. 132 *(nom. nud.)*. DECAISNE, 1841, p. 185. MONTAGNE, 1850, p. 245. ZANARDINI, 1858, p. 256. J. AGARDH, 1863, p. 817. PICCONE, 1884, p. 322. DETONI and PAOLETTI, 1888, p. 70. MUSCHLER, 1908, p. 213. LYLE, 1926, p. 40. NASR, 1939*a*, p. 71; 1947, p. 135.
Chondria delilei C. AGARDH, 1822, p. 363; 1824, p. 209.
Fucus acanthophora sensu TURNER, 1808, p. 68.

Type loc.: Not specified, Alexandria and Suez.
Red Sea distr.: Bay of Assab, Massawa, Berenice, Koseir, Ghardaqa, Suez, Suez Canal, Tor, Aqaba, Jiddah, Hodeida.

Note: This species is well known by the name *Acanthophora delilii.* However, this name, when proposed by LAMOUROUX (1813), was not validated by a description. In the same year DECAISNE described the species as *Fucus nayadiformis.* It is necessary, therefore, to reinstate this epithet. The combination *A. najadiformis* was made by LEMAN (1816, p. 14) in synonymy and is invalid according to Art. 34 of the Code (1961 edition).

Alsidium C. AGARDH

***Alsidium vagum** (ZANARDINI) ZANARDINI

ZANARDINI, 1858, p. 256. MUSCHLER, 1908, p. 214.

Records under syns.

Laurencia vaga ZANARDINI, 1851, p. 33.

Chondriopsis vaga (ZANARDINI) GRUNOW, *in* PICCONE, 1900*a*, p. 261.

Type loc.: Suez.

Distr.: Shumma Islet, Gulf of Berenice, Suez.

Note: The status of this species is uncertain.

Chondria C. AGARDH *(nom. cons.)*

Chondria collinsiana HOWE

NASR, 1947, p. 135.

Red Sea distr.: Ghardaqa.

***Chondria seticulosa** (FORSSKÅL) C. AGARDH

C. AGARDH, 1822, p. 345.

Records under other names

Conferva seticulosa FORSSKÅL, 1775, pp. cxxvi and 188.

Laurencia seticulosa (FORSSKÅL) GREVILLE, 1830, p. lii. J. AGARDH, 1852*b*, p. 758 (excl. syn. *Fucus uvifer* FORSSKÅL). ZANARDINI, 1858, p. 262. KÜTZING, 1865, p. 19, pl. 52. PICCONE, 1884, p. 321. MUSCHLER, 1908, p. 212. YAMADA, 1931, p. 217.

Laurencia hypnoides BØRGESEN, 1932, p. 4.

Chondria hypnoides (BØRGESEN) BØRGESEN, 1939*a*, p. 9.

Fucus cespitosus FORSSKÅL?, 1775, pp. cxxv and 190.

Fucus obtusus sensu WEBER, 1804, p. 132, *pro parte*.

Type loc.: Mocha.

Distr.: Bay of Assab, Berenice, Suez, Mocha.

Note: BØRGESEN (1939*a*) has pointed out that FORSSKÅL's material of *Conferva seticulosa* was a mixture of three genera: *Chondria, Hypnea,* and *Acanthophora.* C. AGARDH (1822, p. 345) was the first to lectotypify *Conferva seticulosa,* lectotypifying it with the material of *Chondria.* BØRGESEN's subsequent lectotypification of *Conferva seticulosa* with the material of *Hypnea* was, therefore, not justified. Hence, *Chondria hypnoides* (BØRGESEN) BØRGESEN must be treated as a synonym of *Chondria seticulosa* (FORSSKÅL) C. AGARDH.

Chondria tenuissima (GOODENOUGH et WOODWARD) C. AGARDH

RAYSS, 1959, p. 24.

Red Sea distr.: Shora el Manqata.

Digenea C. AGARDH

Digenea simplex (WULFEN) C. AGARDH

DECAISNE, 1841, p. 129. ZANARDINI, 1858, p. 258. PICCONE, 1884, p. 322; 1900*a*, p. 262; 1900*c*, p. 120. REINBOLD, 1903, p. 231. MUSCHLER, 1908, p. 216. HARVEY-GIBSON and KNIGHT, 1913, p. 307. LYLE, 1926, p. 40. LAMI, 1932, p. 356. NASR, 1939*a*, p. 71; 1947, p. 137. RAYSS, 1959, p. 24.

Records under syns.

Fucus lycopodium STACKHOUSE. TURNER, 1819, p. 6, pl. 199.

Digenea lycopodium (STACKHOUSE) HERING, *in* SCHIMPER, 1835–37, no. 931. HOHENACKER, 1853, no. 144.

Red Sea distr.: Archipelago of Assab, Mandola Islet, Sudanese coast, Koseir, Ghardaqa, Suez, Suez Canal, Tor, Ras Muhammad, Sharm el Sheikh, Ras Nusrani, Shora el Manqata, Aqaba, Jiddah.

Endosiphonia ZANARDINI

Endosiphonia clavigera FALKENBERG

REINBOLD, 1903, p. 231. NASR, 1938, pp. 125–128, 7 figs., 1 pl.; 1939*a*, p. 72; 1947, p. 140.

Red Sea distr.: Ghardaqa, Tor.

Herposiphonia NÄGELI

Herposiphonia tenella (C. AGARDH) AMBRONN

NASR, 1939*a*, p. 72; 1947, p. 138, fig. 22. NEWTON, 1953, pp. 396 and 414. DOR, 1961, p. 39, figs. 1*b* and 3. RAYSS and DOR, 1963, p. 37.

Red Sea distr.: Hanish Islands, Daedalus Reef, Ghardaqa, Strait of Jubal, Eilat.

Laurencia LAMOUROUX *(nom. cons.)*

Laurencia intricata LAMOUROUX

PICCONE, 1884, p. 321.

Red Sea distr.: Assab.

Laurencia obtusa (HUDSON) LAMOUROUX

MONTAGNE, 1850, p. 247. ZANARDINI, 1858, p. 261. REINBOLD, 1903, p. 231. MUSCHLER, 1908, p. 212. HARVEY-GIBSON and KNIGHT, 1913, p. 308. NASR, 1939*a*, p. 71; 1947, p. 134, pl. 14, fig. 2. RAYSS, 1959, p. 23.

Records under other names

Chondria obtusa (HUDSON) C. AGARDH. DECAISNE, 1834, p. 10; 1841, p. 184. SCHUBERT, 1839, p. 290.
Fucus diaphanus sensu DELILE?, 1813*a*, p. 80; 1824, p. 113.

Red Sea distr.: Sudanese coast, Koseir, Ghardaqa, Suez, Tor, Ras Muhammad, Ras Nusrani, Aqaba, Jiddah, Hodeida.

Laurencia obtusa var. ***divaricata** YAMADA

YAMADA, 1931, p. 223.

Records under syn.

Laurencia divaricata J. AGARDH, 1852*b*, p. 754 (non SUHR, 1840). ZANARDINI, 1858, p. 261. REINBOLD, 1903, p. 231. MUSCHLER, 1908, p. 211. HARVEY-GIBSON, 1908, p. 79.

Type loc.: Red Sea.
Red Sea distr.: Red Sea, Suez, Tor, Aqaba.

***Laurencia papillosa** (C. AGARDH) GREVILLE

GREVILLE, 1830, p. lii. SCHENK, 1840, p. 2. KÜTZING, 1849, p. 855. MONTAGNE, 1850, p. 247. J. AGARDH, 1852*b*, p. 756. ZANARDINI, 1858, p. 261. PICCONE, 1884, p. 321; 1893, pp. 380 and 381; 1900*a*, p. 261; 1900*c*, p. 120. BORNET, 1888, p. 20. MUSCHLER, 1908, p. 211. HARVEY-GIBSON, 1908, p. 79. MAZZA, 1909, p. 294. HARVEY-GIBSON and KNIGHT, 1913, p. 308. LYLE, 1926, p. 40. YAMADA, 1931, p. 190, pl. 1, figs. a and b. LAMI, 1932, p. 356. BØRGESEN, 1932, p. 6. NASR, 1947, p. 134.

Records under other names

Fucus papillosus FORSSKÅL, 1775, pp. cxxv and 190 (nec S.G. GMELIN, 1768; non BURMAN, 1768). DELILE, 1813*a*, p. 80; 1824, p. 113.
Chondria papillosa C. AGARDH, 1822, p. 344. DECAISNE, 1834, p. 10; 1841, p. 185.
Fucus thyrsoides var. *major* TURNER, 1808, p. 38.
Fucus obtusus sensu WEBER, 1804, p. 132, *pro parte*.
Laurencia oophora sensu? PICCONE, 1884, p. 321; 1889, p. 76.

Type loc.: Mocha.
Red Sea distr.: Bay of Assab, Gulf of Zula, Shumma Islet, Massawa, Sudanese coast, Suakin, Ghardaqa, Suez, Suez Canal, Tor, Aqaba, Jiddah, Kamaran Island, Mocha.

Note: The invariably accepted basionym of this species, *Fucus papillosus* FORSSKÅL, is illegitimatized by the earlier homonyms *F. papillosus* S.G. GMELIN (1768) and *F. papillosus* BURMAN (1768). There are several generally accepted synonyms of *Laurencia papillosa* that probably are based on genuine *L. papillosa*, but until the types of these names have been examined, it would be hazardous to adopt any of them as the correct name for this species. Therefore, I am retaining the binomial *L. papillosa,* starting the epithet with C. AGARDH (1822), who called the taxon *Chondria papillosa.*

Laurencia pinnatifida (HUDSON) LAMOUROUX

ZANARDINI, 1858, p. 261. MUSCHLER, 1908, p. 213. HARVEY-GIBSON, 1908, p. 79. NASR, 1947, p. 133.

Record under syn.
Fucus pinnatifidus var. *muricatus* TURNER, 1808, p. 40.

Red Sea distr.: Red Sea, Ghardaqa, Suez Bay, Hodeida.

Laurencia uvifera (FORSSKÅL) BØRGESEN

BØRGESEN, 1932, p. 12, figs. 3 and 4, pl. 1, fig. 6.

Records under other names
Fucus uvifer FORSSKÅL, 1775, pp. cxxv and 192.
Fucus obtusus sensu WEBER, 1804, p. 132, *pro parte.*

Red Sea distr.: Mocha.

Note: The type locality of this species is Constantinople. Whether the material from Mocha actually is representative of the species is uncertain.

*Leveillea DECAISNE

***Leveillea jungermannioides** (HERING et MARTENS) HARVEY

REINBOLD, 1903, p. 231. MUSCHLER, 1908, p. 216. NASR, 1947, p. 139. RAYSS, 1959, p. 24, fig. 2.

Records under syns.
Amansia jungermannioides HERING et MARTENS, *in* MARTENS and HERING, 1836, p. 485, figs. 1–4. SCHIMPER, 1835–37, no. 472.
Leveillea schimperi DECAISNE, 1839, p. 376 *(nom. illeg.)*; 1841, p. 161, pl. 6, figs. A1–A10. KÜTZING, 1849, p. 882; 1865, p. 3, pl. 7, figs. a–c.
Polyzonia jungermannioides (HERING et MARTENS) J. AGARDH, 1841, p. 25; 1863, p. 1169. RUPRECHT, 1849, p. 78. ZANARDINI, 1858, p. 255. PICCONE, 1884, p. 322. DETONI and PAOLETTI, 1888, p. 70. HARVEY-GIBSON, 1908, p. 79. LYLE, 1926, p. 40.

Type loc.: Tor.

Red Sea distr.: Bay of Assab, Massawa, Trinkitat, Daedalus Reef, Ghardaqa, Suez Canal, Tor.

Note: *Leveillea jungermannioides* is the type of its genus.

Lophocladia (J. AGARDH) SCHMITZ

***Lophocladia lallemandi** (MONTAGNE) SCHMITZ

SCHMITZ, 1893, p. 223. SCHMITZ and FALKENBERG, 1897, p. 447, fig. 250. FALKENBERG, 1901, p. 552. MAZZA, 1910, p. 352.

Records under syns.

Dasya lallemandi MONTAGNE, 1849, p. 289. ZANARDINI, 1858, p. 260. J. AGARDH, 1863, p. 1231. KÜTZING, 1864, p. 26, pl. 71, figs. a–d.

Polysiphonia hirsuta ZANARDINI, 1851, p. 34.

Lophothalia lallemandi (MONTAGNE) J. AGARDH, 1890, p. 64.

Type loc.: Red Sea.
Distr.: Red Sea, Dahlak Archipelago, Suakin.

Polysiphonia GREVILLE *(nom. cons.)*

***Polysiphonia figariana** ZANARDINI

ZANARDINI, 1858, p. 257. MUSCHLER, 1908, p. 215. LYLE, 1926, p. 40.
Type loc.: Not specified, Suez, Aqaba, Tor, Koseir.
Distr.: Koseir, Suez, Suez Canal, Tor, Aqaba.

Polysiphonia gorgoniae HARVEY

NASR, 1941, p. 73, fig. 16.
Red Sea distr.: Ghardaqa.

***Polysiphonia utricularis** ZANARDINI

ZANARDINI, 1851, p. 34; 1858, p. 257, pl. 8, fig. 2. MUSCHLER, 1908, p. 215. HARVEY-GIBSON and KNIGHT, 1913, p. 308. LYLE, 1926, p. 40.
Type loc.: Suez.
Distr.: Sudanese coast, Suez, Suez Canal.

Rytiphloea C. AGARDH

Rytiphloea tinctoria (CLEMENTE) C. AGARDH

MUSCHLER, 1908, p. 217.

Record under syn.

Fucus purpureus ESPER. TURNER, 1819, p. 68.

Red Sea distr.: Red Sea, Suez.

Note: TURNER (1819, p. 68) remarked that this species had been "Sent in great quantity from the Red Sea to Sir Joseph Banks." Since the only other record of the occurrence of this species in the Red Sea is that by MUSCHLER, it seems likely that these authors had a different plant in hand or that their material had been obtained in the Mediterranean.

Spirocladia Børgesen

***Spirocladia minor** Nasr

Nasr, 1939*b*, p. 332, figs. 1–8.
Type loc.: Strait of Jubal.
Distr.: Strait of Jubal.

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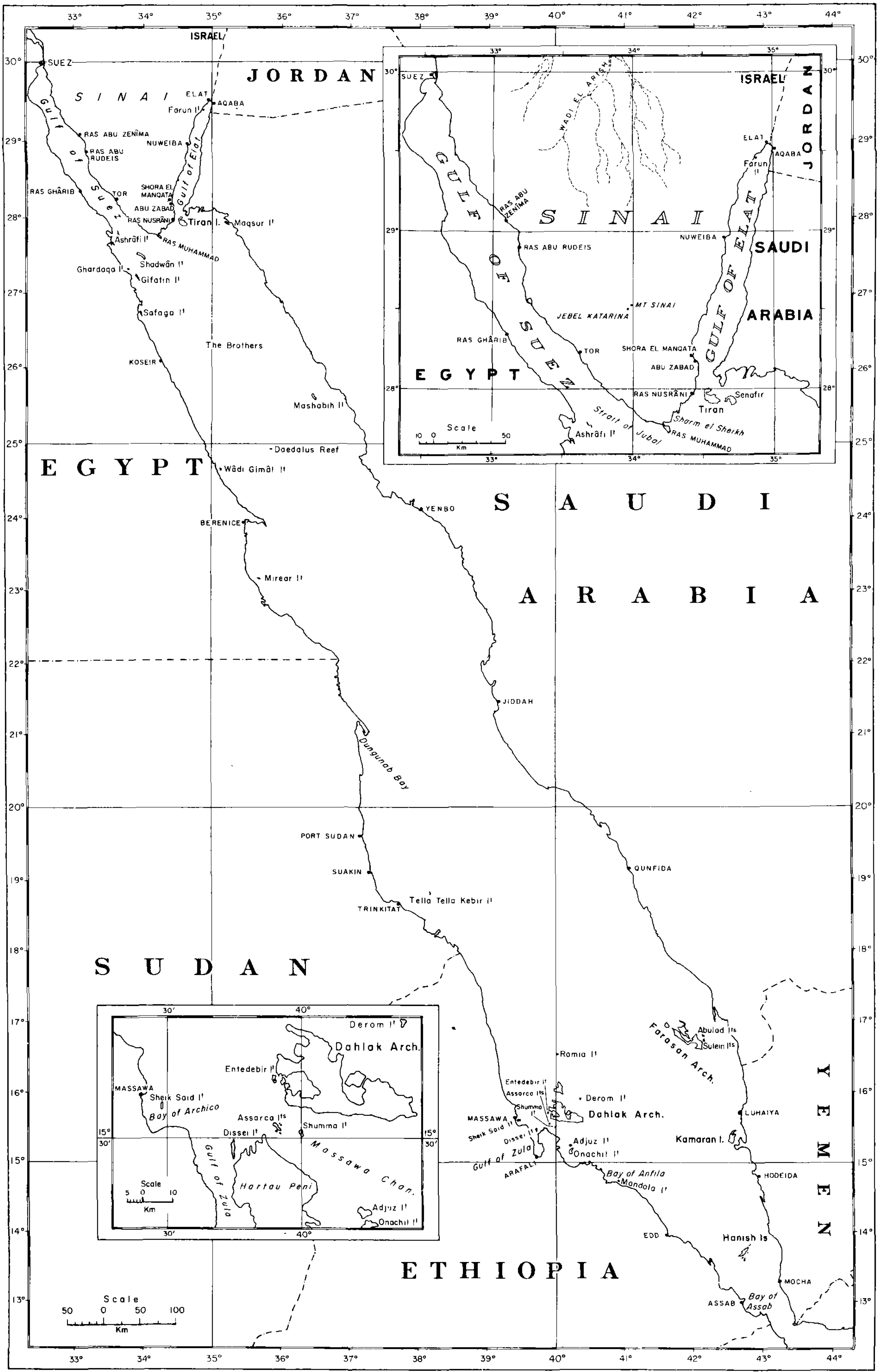

Map of the Red Sea showing the places whence species of marine algae have been reported

Reprinted from *Ibis*, no. 110, 1968, p. 27-34

STORM-PETRELS *OCEANODROMA* SPP. IN THE INDIAN OCEAN

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Received on 12 December 1966

There are few previous records of all-dark storm-petrels in the Indian Ocean. Nevertheless, Bourne (1960) thought it possible that one species at least may stray west into the tropical Indian Ocean from the Pacific Ocean, but the extent and regularity of such wanderings has remained undocumented. As a result of ornithological work carried out on board the R.V. 'Atlantis II' and the R.R.S. 'Discovery', during the International Indian Ocean Expedition (I.I.O.E.), it is clear that at least two species of dark storm-petrels occur regularly and in fair numbers in the tropical Indian Ocean. This paper reviews the past records and summarizes our own observations. The work was carried out between June and November 1963, and between March and September 1964, on board 'Discovery'; and between August and November 1963, and February and August 1965, on the 'Atlantis II'. Three species of small all-dark Procellariiformes are considered; two of them have previously been collected in the Indian Ocean.

PREVIOUS RECORDS

BULWERIA BULWERII Bulwer's Petrel

Bulwer's Petrel breeds in the northern subtropical Pacific Ocean during the summer, and winters in the tropical Pacific Ocean (Bourne 1960). Although not strictly a storm-petrel, this small petrel is roughly the same size as the largest species of *Oceanodroma*, and consequently may be confused with them at sea. Jouanin's Petrel *B. fallax* is considerably larger than *B. bulwerii* and will not be considered here (see Bailey 1966).

The only definite example of *B. bulwerii* from the Indian Ocean is a female captured on 23 August 1958 on Fedu in the Maldive Islands at 00° 36′ S., 73° 00′ E. (Phillips 1959). Otherwise, the most westerly record is of three south of Singapore on 22 September 1961 (T. F. S. Fripp quoted by Bourne 1964). As they were not distinguished from other large storm-petrels, however, the record must be considered doubtful.

OCEANODROMA MONORHIS Swinhoe's Storm-petrel

O. monorhis, which has been treated as a subspecies of *O. leucorhoa* by Austin (1952), breeds on islands off Japan and Formosa in the summer. It is frequently found as far west as Singapore Strait and some are known to reach the Straits of Malacca (Gibson-Hill 1953). The only definite records from the Indian Ocean are of a male found exhausted on the shore in Ceylon on 3 July 1927 (Gibson-Hill 1953), and another found on a beach at Eilat, in the Gulf of Aqaba at the head of the Red Sea, on 13 January 1958. The latter, which weighed 23 gm., that is considerably less than the two specimens we captured (see Table 1), is preserved in the University of Tel Aviv (Merom 1960). A bird, reported as belonging to this species, was captured on board ship in the Arabian Sea to the west of the Laccadive Islands on 10 June 1923 by Tomlinson (1924) but, as it was released, and no critical description was published, the exact identity seems doubtful. Finally, Ferrar (1932) records the capture of a petrel similar to *Fregetta tropica melanogaster* in measurements and colouration, but lacking white markings except at the bases of some feathers, at Port Blair, Andaman Is., on 24 December. It seems most likely that this was *O. monorhis.*

Contribution No. 1956 from the Woods Hole Oceanographic Institution.

In addition to the two collected specimens, there are a few sight records. Norris (1952) recorded seeing an all-dark storm-petrel in the Gulf of Aden in August 1951 and Lieutenent A. Y. Norris (quoted by Bourne 1965) reported several *O. monorhis* near Ceylon and in the southern Bay of Bengal in October 1960. Finally, Commander G. S. Willis (unpublished) recorded seeing three small dark storm-petrels similar in size and flight to Leach's Petrel *O. leucorhoa* off the southwest coast of India at 09° 07′ N., 75° 39′ E. on 6 May 1962.

OCEANODROMA MATSUDAIRAE Matsudaira's Storm-petrel

A warm water species, *O. matsudairae* breeds on the Volcano Islands (25° N.) in the subtropical western Pacific Ocean from January to early June (Kuroda 1966). The summering areas are not known, but specimens have been collected around the breeding island in every month from January to August, inclusive. A sibling species, Tristram's Storm-petrel *O. tristrami* breeds on the Volcano Islands from October to April (Kuroda 1966) and is a cool water species which summers to the north, off Japan.

There are no definite records of either *O. matsudairae* or *O. tristrami* in the Indian Ocean, although Bourne (1960) speculated that the former might wander into the Indian Ocean. Recently Captain P. P. O. Harrison recorded a large dark storm-petrel, which could have been *O. matsudairae*, at 1° N., 78° E. on 25 July 1964 (Bourne 1966).

To sum up: there is one definite record of *B. bulwerii* in the western Indian Ocean, and there are two of *O. monorhis*. There is also some evidence that the latter species may stray westward to the Indian Ocean with some regularity.

OBSERVATIONS ON THE I.I.O.E.

During the International Indian Ocean Expedition, ornithological observations were concentrated in the western Indian Ocean north of 20° S. and west of 80° E. No observations were made east of Ceylon except on a cruise up the west coast of Australia in July 1965.

Our records of all-dark storm-petrels are listed in the Appendix and are plotted in Fig. 1. Although sight records must be open to some doubt, it is clear that at least two species were involved, a small one about the size of *O. oceanicus*, which is taken to be *O. monorhis*, and a large one, which appears to have been *O. matsudairae*. In spite of this doubt we have included all our records to show that we were dealing with a large population of each species and not isolated vagrants.

TABLE 1. *Weights and measurements (in gm. and mm.) of storm-petrels collected.*

SPECIES	DATE	WEIGHT	WING	TAIL	CULMEN	TARSUS	MIDDLE TOE AND CLAW
O. monorhis	18 Aug. 1963	*c.* 40	152	75	14	23	24
O. monorhis	15 Mar. 1964	38–40	150	70	16	24.5	25
O. matsudairae	27 July 1965	—	183	102	18	31	28
O. matsudairae	29 July 1965	—	186	100	19	27	30

Note. All measurements were made on the fresh specimens by the authors, so are not directly comparable with previous published measurements.

The following specimens were collected (see Table 1 for measurements):

1. *O. monorhis.* One at 15° 47′ N., 52° 25′ E. at 04.00 hours on 18 August 1963 (Bailey 1966). Photographs of this bird have been published elsewhere (see Bailey 1965, p. 54). The stomach and gizzard contained a few very small " pumice-like " stones, and some unidentifiable chitinous remains.
2. *O. monorhis.* One at 06° 45′ N., 57° 59′ E. on 15 March 1964, weighed 38–40 gm. The brood patch was covered with a thin layer of feathers, but was prominent.

The wings and tail were in moult: the three outermost primaries were old, the rest new. The body feathers above the tail and some belly feathers were in pin. Both specimens of *O. monorhis* are preserved in the British Museum (Natural History).

3. *O. matsudairae.* One collected at 16° 06′ S., 118° 03′ E. on 27 July 1965 is now in the collection of the Smithsonian Institution, Washington, D.C. Photographs were taken of it in the company of *Oceanites oceanicus.*
4. *O. matsudairae.* A male collected at 13° 26′ S., 120° 19′ E. on 29 July 1965 is now in the collection of the Yamashina Institute, Tokyo (Kuroda 1966). This specimen was in moult; the new feathers were very black, and the primaries half-moulted.

Dr. G. E. Watson of the Smithsonian Institution kindly informs us that, in his opinion, neither of the *O. matsudairae* are separable from specimens collected in the Pacific Ocean. Although the lengths of the tarsi lie at the extremes recorded for this species (see Kuroda 1966), we consider there to be no justification for supposing that the birds collected in the Indian Ocean were from a different population.

From our sight records (Fig. 1) it is clear that a large all-dark storm-petrel, thought to be *O. matsudairae* (see section on identification), is quite common in the equatorial region of the western Indian Ocean. In addition a smaller species, which appeared to be *O. monorhis*, was seen rather less frequently, and mostly in the Arabian Sea. By contrast, most of our records of the larger species were within 5° of the equator (Fig. 1), in a belt which was characterized by slightly higher levels of zooplankton abundance (Royal Society 1965), and often by a complete lack of wind. It may well be that, during its time in the Indian Ocean, *O. matsudairae* is adapted to feed on the surface planktonic communities associated with local upwellings and convergences near the equator, but the exact distribution of these has not yet been worked out in the Indian Ocean. No pattern is discernible from the few records of *B. bulwerii*, but their distribution is at least consistent with the view that small numbers move westward from the Pacific outside the breeding season.

Observations near the equator in all the months between March and early November, inclusive, suggest that *O. matsudairae* is most common in the western Indian Ocean from June to September, and that it is present at least from March to November. Primary moult was recorded in June, July, and September; this is consistent with a spring breeding season, and strongly supports the view that the birds in the Indian Ocean are from the population on the Volcano Islands, where *O. matsudairae* breeds in the spring (Kuroda 1960).

In addition Captain D. Stam (pers. comm. from Dr. J. Wattel) of M.V. ‘ Forest Town ’ kindly informs us that he saw two to three all-black storm-petrels, which he considered were about the same size as *O. leucorhoa*, at 02° 20′ S., 46° 30′ E. on 18 September 1965, and another at 03° 37′ N., 48° 54′ E. on the following day. Mr. M. Palmieri, third officer aboard R.V. ‘Atlantis II ’, made six sightings of *B. bulwerii* in the Indian Ocean in 1965, all of which he considers to be positive (see Appendix).

IDENTIFICATION AT SEA

The three species of storm-petrels listed above are all small petrels between 17·5 and 28 cm. in length. Except for some indication of pale markings on the secondary coverts their plumages are entirely black or dark brown. Both species of *Oceanodroma* have forked tails, whereas *B. bulwerii* has a wedge-shaped tail. The tails of all of them could, however, appear quite long at sea, and the forked tail may not be noticeable except at close range; indeed, the lack of a forked tail may well be extremely difficult to ascertain.

There are detailed field descriptions for neither species of *Oceanodroma*, so our own sight identifications are to some extent tentative; in the case of *O. matsudairae*,

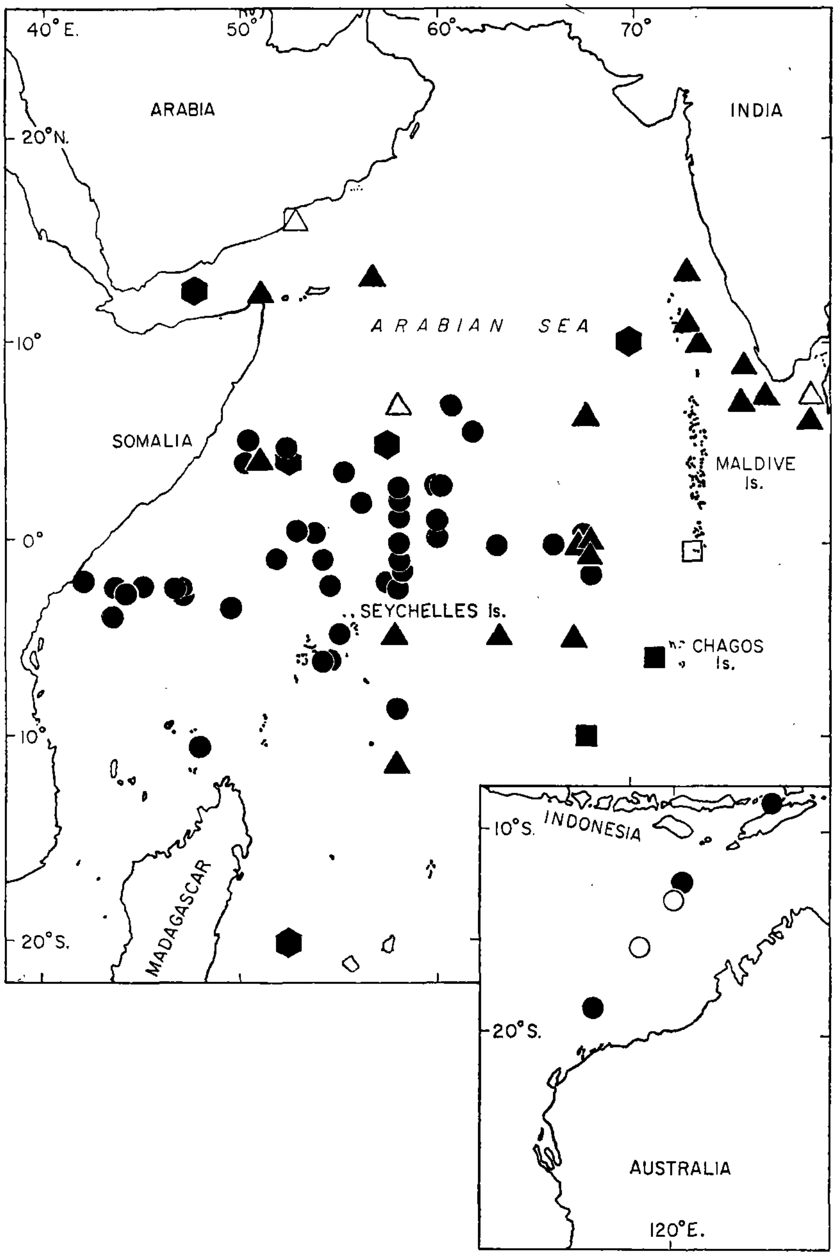

FIGURE 1. Records of black storm-petrels *Oceanodroma* spp. and *Bulweria bulwerii* in the Indian Ocean. Collected specimens: ○, *O. matsudairae*; △, *O. monorhis*; □, *B. bulwerii*. Sight records: ●, *O. matsudairae*; ▲, *O. monorhis*; ■, *B. bulwerii*; ⬢, unidentified.
Note. Sight records include those of birds identified only by their size. Previous published records are also shown.

however, some sight records were later supported by the capture of specimens. The field descriptions given below, which we believe pertain to the species under discussion, are taken from our own field-notes and are supplemented by descriptions quoted by Bourne (1960, 1964, 1965).

O. monorhis is a small storm-petrel, dark all over save for its slightly paler secondary coverts. It is about the same size as, or slightly larger than, *Oceanites oceanicus*, but is slimmer and has a longer, forked tail, longer thinner wings, and short legs. In addition, *O. monorhis* has a distinctive flight, in which it bounds and swoops over the water. It patters rarely, if at all.

O. matsudairae is considerably larger than *O. monorhis*. It has distinctive pale shafts to the primaries which are often visible at sea as a small white patch beyond, i.e. distal from, the bend of the wing, especially when the bird turns in flight or spreads its wings. It has quite long wings and a long, forked tail, but the wings appear much wider than those of *O. monorhis*. The forked tail, furthermore, is not always visible at sea. *O. matsudairae* has a much slower flight than *O. monorhis*; it flaps and then glides for a short distance. In calm conditions it usually has a slow, sluggish flight with very short glides, and, even in strong winds, its flight is quite slow, except when flying downwind when it progresses with long, swift glides. On occasions, however, even in calm areas, *O. matsudairae* was suddenly seen to change to an erratic twisting flight low over the water. The function of this was not clear but it is unlikely to be a feeding flight because the birds were also seen to feed by landing on the water with wings raised, or occasionally by settling on the water.

To summarize, *O. monorhis* and *O. matsudairae* should not be difficult to separate at sea by the difference in size and flight. In the hand, the white bases of the primary shafts is said to be a reliable character for distinguishing *O. matsudairae* from *O. tristrami* but it is perhaps worth pointing out that *O. monorhis* also has white bases to its primary shafts, so this character alone may be unreliable in the present context.

B. bulwerii, also, might be confused with *O. matsudairae* but, according to Bourne (1960), its flight is faster, more active and more like that of a gad-fly petrel *Pterodroma* spp. At close range it should also be possible to distinguish its long wedge-shaped tail.

CONCLUSIONS

The proven occurrence of *O. monorhis* and *O. matsudairae* in the Indian Ocean, and the large number of sight-records of birds tentatively identified as belonging to these two species, strongly indicate the existence of a regular migration from the Pacific to the Indian Ocean. This migration of *O. matsudairae* appears to have passed unnoticed by previous observers, and we believe it to be the first recorded occurrence of an extensive migration from the subtropical Pacific to the Indian Ocean in any sea-bird. The distance travelled, assuming that the birds are from the population breeding on the Volcano Islands, is of the order of 5,000–6,000 miles. The possibility that they belong to a local Indian Ocean population, hitherto undiscovered, has been considered. We think it unlikely because most islands in the Indian Ocean have been visited by ornithologists at least occasionally, and the Seychelles Islands, the Maldive Islands and the islands off northwest Australia, that is those nearest to the birds' known range in the Indian Ocean, are quite well known ornithologically (see, for instance, Serventy 1952; Loustau-Lalanne 1963 ; Phillips 1963 ; Serventy & Marshall 1964). In addition, the presence of *O. matsudairae* inseparable from those breeding on the Volcano Islands in the eastern Indian Ocean at the end of July provides additional evidence in favour of their being migrants from the Pacific Ocean.

Although *O. monorhis* has been seen off Singapore regularly, *O. matsudairae* has never been seen there. Since the latter has now been recorded off northwestern Australia, it may well be that the two species enter the Indian Ocean by different routes—*monorhis* through the Straits of Malacca, *matsudairae* through the Indonesian chain.

It is possible, but we consider very unlikely, that other species of storm-petrels either as yet undiscovered or from the eastern Pacific Ocean, could also occur in the

Indian Ocean. Until there is evidence that such is the case, it must be supposed that only those species from the western Pacific Ocean listed above are involved.

ACKNOWLEDGMENTS

This work was sponsored by NSF Grant GP281 and a grant from the Nuffield Foundation. To both of these bodies we are most grateful. We also wish to thank 3rd-Officer M. Palmieri, Captain D. Stam and the Royal Naval Bird-watching Society, for permission to use their valuable observations. Dr. G. E. Watson kindly communicated to us the results of his examination of our specimens, and Dr. W. R. P. Bourne read the paper in manuscript. To all these people we owe our gratitude.

The first author also wishes to express his gratitude to Mr. R. I. Currie and Dr. J. C. Swallow of the National Institute of Oceanography, and to the late Dr. M. N. Hill of the Department of Geodesy and Geophysics, for making every facility available on board the ' Discovery ', and to the National Institute of Oceanography for including the present work in the ship's programme.

SUMMARY

In the course of the International Indian Ocean Expedition two storm-petrels, thought to be *Oceanodroma matsudairae* and *O. monorhis*, were encountered in the western Indian Ocean in some numbers. Two specimens of each species were collected, *monorhis* in the Arabian Sea, *matsudairae* off N.W. Australia. *O. matsudairae*, which had not been recorded before from these waters, appeared to be concentrated within 5° of the equator and the birds probably belonged to the spring-breeding population of Volcano Island. *O. monorhis* was found mostly in the Arabian Sea.

Bulweria bulwerii, for which there was but one certain Indian Ocean record, was also encountered several times.

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APPENDIX

Sight records of storm-petrels during the I.I.O.E.

Below are listed all our records of all-black storm-petrels observed in the Indian Ocean. Doubtful records are given question marks; all others are thought by the authors to be positive sightings, but, in almost all cases, identification was based on the size of the birds, which is often difficult to ascertain at sea.

Month	Year	Day	Latitude	Longitude	Species, numbers & remarks	
March	1964	29	11° 31′ S.	57° 57′ E.	*O. monorhis*, 2, ?	One was chased but not caught by a Great Skua *Catharacta skua*.
	1965	14	10° 53′ N.	72° 45′ E.	*O. monorhis*	50 to 60 small all-dark storm-petrels.
		15	13° 32′ N.	72° 44′ E.	*O. monorhis*	One positive, 35+ others too far for positive identification.
		1	08° 58′ N.	51° 42′ E.	*B. bulwerii*, 1	
		4	09° 06′ N.	51° 55′ E.	*B. bulwerii*, 1	
		5	08° 58′ N.	52° 35′ E.	*B. bulwerii*, 1	
		23	22° 49′ N.	61° 19′ E.	*B. bulwerii*, 1	
	1964	20–21	00° 00′	58° 00′ E.	*O. matsudairae*	Three to five. Forked tail seen on one bird.
April	1964	27	00° 47′ S.	67° 40′ E.	*O. monorhis*, 1, ?	
		29	00° 03′ S.	67° 35′ E.	*O. monorhis*, 1, ?	
		25	01° 51′ S.	67° 47′ E.	*O. matsudairae*, 1	Forked tail seen.
		29	00° 09′ N.	67° 34′ E.	*O. matsudairae*, 1, ?	
		20	10° 11′ S.	67° 30′ E.	*B. bulwerii*, 5, ?	Flight different from large *Oceanodroma*; long sweeping glides with very little flapping. Wings more pointed, more slender, almost scythe-like.
			10° 03′ S.	67° 29′ E.		
			09° 25′ S.	67° 34′ E.		
	1965	8	06° 52′ N.	75° 30′ E.	*O. monorhis*, 3	
		21	05° 04′ S.	50° 30′ E.	*B. bulwerii*, 1	
		24	01° 00′ S.	51° 48′ E.	*B. bulwerii*, 1	
		21	05° 04′ S.	50° 30′ E.	*O. matsudairae*, 1	Two white spots half-way out along each wing.
		24	01° 00′ S.	51° 48′ E.	*O. matsudairae*, 3	In the company of two *Oceanites oceanicus*.
May	1964	3	06° 19′ N.	67° 32′ E.	*O. monorhis*, 1	
		20	09° 58′ N.	73° 22′ E.	*O. monorhis*, 1, ?	South of Laccadive Islands.
		28	13° 09′ N.	56° 47′ E.	*O. monorhis*, 1	
	1965	21	05° 04′ S.	66° 46′ E.	*O. monorhis*, 1	Lighter upper-wing coverts noted.
		22	05° 00′ S.	63° 09′ E.	*O. monorhis*, 1	Feeding on garbage with two *Oceanites oceanicus*.
June	1964	8	05° 00′ S.	57° 52′ E.	*O. monorhis*, 1, ?	
		19	00° 22′ S.	67° 25′ E.	*O. monorhis*, 1	
		1	02° 37′ N.	58° 00′ E.	*O. matsudairae*, 1, ?	
		2	02° 02′ N.	58° 04′ E.	*O. matsudairae*, 2, ?	
		3	01° 08′ N.	57° 59′ E.	*O. matsudairae*, 3	
		4	00° 02′ N.	58° 02′ E.	*O. matsudairae*, 8	
		5	01° 00′ S.	58° 03′ E.	*O. matsudairae*, 1	
		13	01° 28′ S.	58° 07′ E.	*O. matsudairae*, 1	
		15	00° 56′ N.	59° 59′ E.	*O. matsudairae*, 1	Two were in primary moult.
			00° 16′ N.	60° 01′ E.	*O. matsudairae*, 5	
		17	00° 07′ S.	62° 58′ E.	*O. matsudairae*, 3	
		18	00° 07′ S.	65° 45′ E.	*O. matsudairae*, 3	
		19	00° 25′ N.	67° 16′ E.	*O. matsudairae*, 1	
	1965	12	20° 02′ S.	52° 28′ E.	*O. monorhis*, 3, ?	
July	1964	15	08° 36′ S.	57° 56′ E.	*O. matsudairae*, 1	In primary moult.
		16	06° 41′ S.	57° 32′ E.	*O. matsudairae*, 1, ?	
		18	09° 05′ S.	52° 31′ E.	*O. matsudairae*, 1, ?	
		22	10° 32′ S.	47° 50′ E.	*O. matsudairae*, 1, ?	
	1965	26	18° 50′ S.	115° 50′ E.	*Oceanodroma* sp., 2	(*matsudairae*?)
		27	15° 48′ S.	118° 18′ E.	*O. matsudairae*, *c.* 30	One collected.

Month	Year	Day	Latitude	Longitude	Species, numbers & remarks	
July	1965	28	13° 28′ S.	120° 12′ E.	*O. matsudairae*, 15+	In the wake over garbage with one *Oceanites oceanicus.*
		29	13° 30′ S.	120° 15′ E.	*O. matsudairae*, 20	One collected. With *Oceanites oceanicus.*
		30	12° 30′ S.	120° 30′ E.	*O. matsudairae*, 6	With one *Oceanites oceanicus*; feeding on garbage.
		31	08° 27′ S.	125° 00′ E.	*O. matsudairae*, 2	We continued to see *O. matsudairae* daily up to the equator (00° 10′ S. 126° 43′ E.).
August	1963	29	06° 50′ N.	60° 38′ E.	*O. matsudairae*, 1, ?	
	1964	11	03° 59′ N.	50° 53′ E.	*O. monorhis*, 1	
		28	12° 12′ N.	50° 57′ E.	*O. monorhis*, 3	
		10	03° 56′ N.	50° 18′ E.	*O. matsudairae*, 1	
		14	04° 41′ N.	52° 19′ E.	*O. matsudairae*, 1	A small white patch near the bend of the wing.
		11	03° 58′ N.	50° 25′ E.	*Oceanodroma* sp.	Size not established.
		12	03° 46′ N.	52° 23′ E.	*Oceanodroma* sp.	
		13	04° 14′ N.	52° 40′ E.	*Oceanodroma* sp.	
September	1963	18	04° 53′ N.	57° 20′ E.	*O. monorhis*, ?	
		1	05° 27′ N.	61° 49′ E.	*O. matsudairae*, 1, ?	
		4	02° 45′ N.	60° 15′ E.	*O. matsudairae*, 1, ?	
		7	02° 50′ N.	59° 59′ E.	*O. matsudairae*, 1, ?	
		8	01° 53′ N.	56° 11′ E.	*O. matsudairae*, 1, ?	
		9	00° 23′ N.	52° 50′ E.	*O. matsudairae*, 1, ?	
		11	02° 46′ S.	44° 09′ E.	*O. matsudairae*, 1, ?	
		16	02° 05′ S.	41° 59′ E.	*O. matsudairae*, 1, ?	
		19	02° 29′ S.	43° 37′ E.	*O. matsudairae*, 1, ?	
			02° 27′ S.	43° 24′ E.	*O. matsudairae*, 1, ?	
		19	02° 23′ S.	43° 25′ E.	*O. matsudairae*, 1, ?	
		20	02° 28′ S.	44° 59′ E.	*O. matsudairae*, 1, ?	
			02° 41′ S.	44° 47′ E.	*O. matsudairae*, 6, ?	
			02° 27′ S.	44° 59′ E.	*O. matsudairae*, 1, ?	
		21	02° 34′ S.	46° 29′ E.	*O. matsudairae*, 1, ?	
			02° 34′ S.	46° 51′ E.	*O. matsudairae*, 1, ?	
			02° 47′ S.	47° 03′ E.	*O. matsudairae*, 2, ?	
		22	02° 50′ S.	47° 03′ E.	*O. matsudairae*, 1, ?	
		24	03° 30′ S.	49° 36′ E.	*O. matsudairae*, 1, ?	
		27	02° 23′ S.	54° 29′ E.	*O. matsudairae*, 1, ?	
		28	02° 27′ S.	57° 59′ E.	*O. matsudairae*, 2, ?	
		29	02° 07′ S.	57° 24′ E.	*O. matsudairae*, 3	
			02° 11′ S.	57° 23′ E.	*O. matsudairae*, 3, ?	
			02° 08′ S.	57° 23′ E.	*O. matsudairae*, 12	
October	1963	6	06° 23′ S.	54° 09′ E.	*O. matsudairae*, 2, ?	The scarcity of records west of the Seychelles indicates a drop in numbers in this region between September and October.
		9	06° 16′ S.	54° 25′ E.	*O. matsudairae*, 1, ?	
		15	02° 32′ S.	44° 54′ E.	*O. matsudairae*, 1, ?	
		27	04° 00′ S.	43° 26′ E.	*O. matsudairae*, 1, ?	
		22	06° 15′ S.	71° 10′ E.	*B. bulwerii*, ?	Just west of Eagle I., Chagos Arch., in a mixed flock were *Puffinus pacificus*, *P. l'herminieri*, a gad-fly petrel —probably *Bulweria fallax*, *Oceanites oceanicus*, and an all black petrel intermediate in size between the last two. Relatively long tail, tern-like flight, too large for *O. monorhis* with no pale primary shafts or forked tail showing.
November	1963	2	04° 48′ S.	55° 04′ E.	*O. matsudairae*, 2	White mark seen at base of primaries.
		5	00° 59′ S.	54° 15′ E.	*O. matsudairae*, 1, ?	
			00° 22′ S.	53° 43′ E.	*O. matsudairae*, 1, ?	
		6	03° 22′ N.	55° 16′ E.	*O. matsudairae*, 1, ?	

Reprinted from *Ibis*, no. 110, 1968, p. 493-519

THE PELAGIC DISTRIBUTION OF SEA-BIRDS IN THE WESTERN INDIAN OCEAN

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Received on 2 June 1967

INTRODUCTION

The primary purpose of the present paper is, so far as possible, to describe the pelagic distribution of sea-birds of the tropical Indian Ocean and to relate it to the marine environment.* The area covered is the central Indian Ocean north of 20° S and west of 80° E (Fig. 1); I have also fixed an arbitrary northern limit at 15° N, but have not

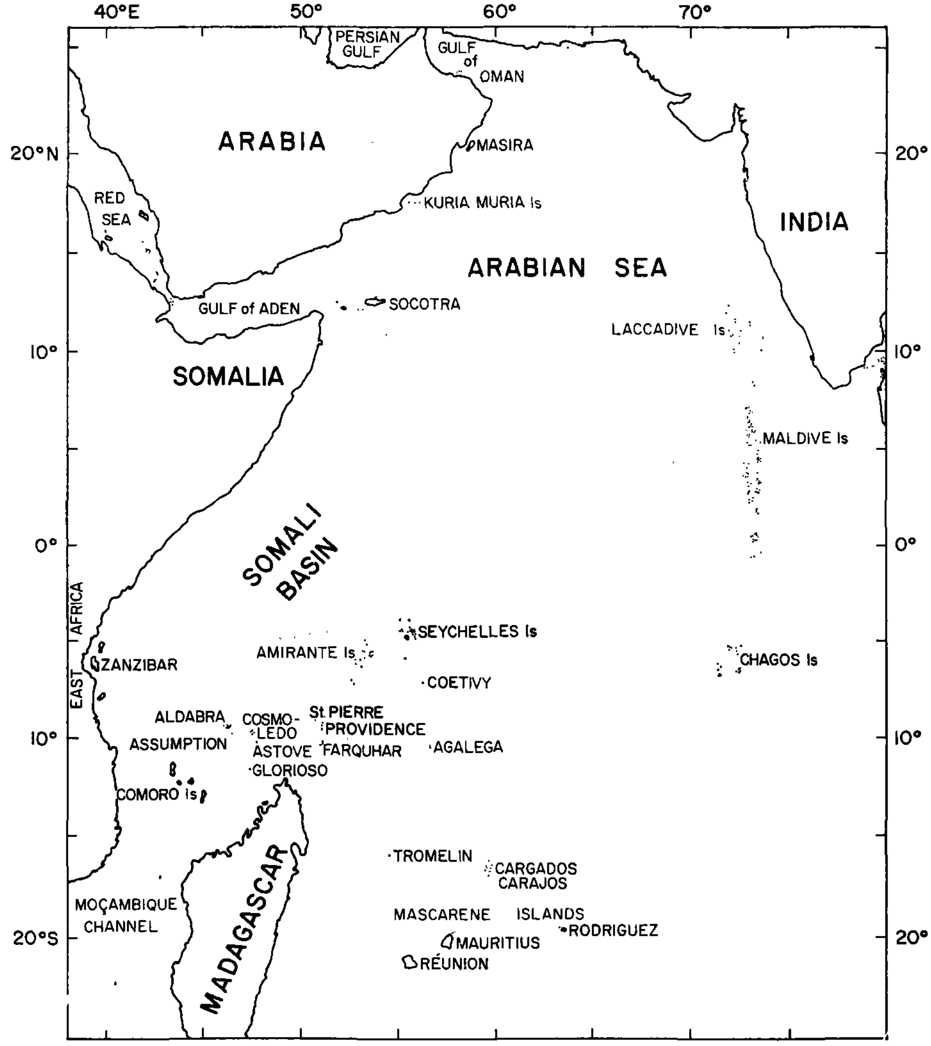

Figure 1. The western Indian Ocean, showing positions of island groups.

***Since this paper was written two important papers have been published: Ashmole & Ashmole (1967); Gill (1967). While many incidental references are made to them, full comparisons with the present observations have not been possible.**

adhered to it strictly in discussion. Nomenclature follows that used by Alexander (1955) except as mentioned.

The present account is based on observations made by myself on a series of transects across the Indian Ocean from 23 August to 14 November 1963 and from 7 March to 28 July 1964 (Fig. 2), during the International Indian Ocean Expedition on board the R.R.S. ' Discovery '. Whereas in 1963 biological work was limited to occasional Neuston Net hauls (David 1965a) carried out by myself, in 1964 the ship carried a full complement of biologists and oceanographers, so the observations made on this cruise are treated in the greatest detail. The work in 1964 consisted of a series of transects across the equator, the purpose of which was to investigate the system of equatorial currents and to record the changes which occur at the onset of the Southwest Monsoon in May. In general the ship's track was designed to pass through deep water as far from land as possible, to avoid the modifying effects of land and shallow banks.

In 1964 biological stations were occupied at regular intervals of about 120 nautical miles. Details of the procedure at these stations, their geographical positions and preliminary results are described elsewhere (Royal Society 1965; see also Bailey 1966,

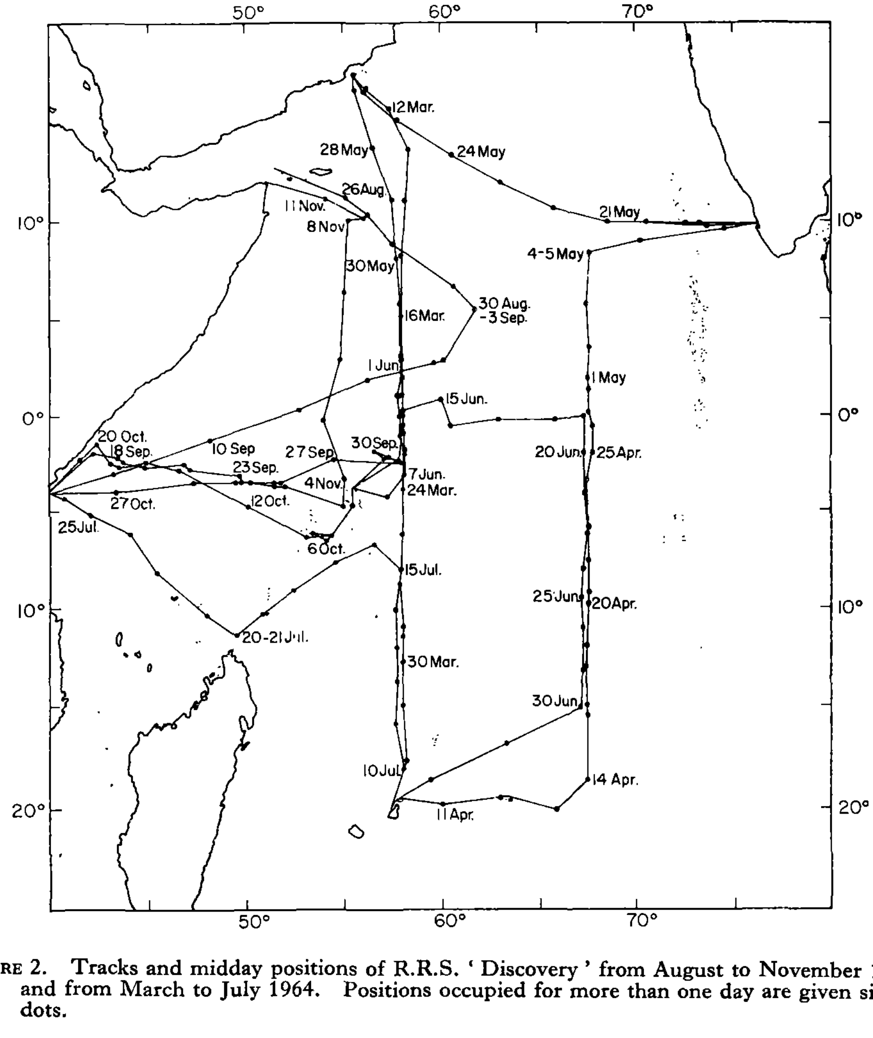

FIGURE 2. Tracks and midday positions of R.R.S. ' Discovery ' from August to November 1963 and from March to July 1964. Positions occupied for more than one day are given single dots.

1967). During the cruises I made 606 observations for sea-birds, each lasting an average of one hour, on a total of 208 days in the area covered in the present paper. The procedure during each observation is given in greater detail elsewhere (Bailey 1966, 1967) but, briefly, all birds seen were recorded with notes on their flight direction, behaviour, age etc. In addition, I collected 17 birds attracted on board ship by lights at night and a further 20 during a short visit to Desnoeufs Is. in the Amirantes on 11 October 1963. All specimens have been deposited in the collection of the British Museum (Natural History).

THE MARINE ENVIRONMENT

The following description is based on Sverdrup *et al.* (1942), the cruise reports of the R.R.S. ' Discovery ' during the International Indian Ocean Expedition (Royal Society 1965) and original data kindly put at my disposal by the National Institute of Oceanography.

Almost all the Indian Ocean included in this survey lies in the Tropical Zone of surface water, the southern boundary of which is defined by the Tropical Convergence, which occurs roughly where the 23° C isotherm meets the sea-surface (Deacon 1933). In the Indian Ocean the Tropical Convergence has been recorded between 16° and 20° S during the southern winter and spring, but its position during the southern summer does not seem to have been recorded (Baker 1965).

The Tropical Convergence is less well defined than the Antarctic and Subantarctic Convergences of higher latitudes, and is therefore not so complete a barrier to marine organisms (Murphy 1936). Nevertheless, Baker (1965) found that some species of Euphausiids are much commoner to the north of the Tropical Convergence than to its south, so that there appear to be some distinctive elements of the tropical as distinct from the subtropical marine fauna. The surface water of the Tropical Zone varies between 23° and 30° C and is separated from cooler water below the surface by a layer in which the temperature drops very rapidly. Owing to the low concentrations of nutrient salts and the resulting scarcity of phytoplankton, the water is clear blue and supports a specialised fauna rich in blue-pigmented forms (David 1965b). The abundance of all living organisms near the sea-surface is generally very low, although augmented by vertical migration to the surface at night.

The surface currents of the northern Indian Ocean change seasonally with the monsoon winds, the effects of which diminish gradually to the south but are still noticeable several degrees south of the equator. In the northern winter the light dry Northeast Monsoon, which is analogous to the Northeast Trade-winds in other oceans, blows across the entire Arabian Sea and is separated from the Southeast Trades by a zone of calms on the equator. In the northern summer there is a reversal of winds in the Arabian Sea and the Southeast Trades are continued across the equator as the Southwest Monsoon.

In the Arabian Sea surface currents are also reversed seasonally: in the northern winter there is a westward drift over the whole area and the westward-flowing North Equatorial Current is well-developed north of 4° S, where it is demarcated from the eastward-flowing Equatorial Counter-current. From about 7° to 20° S the South Equatorial Current flows to the west throughout the year, reaching its fullest intensity in the northern summer when the Southeast Trades are strongest. From April to May, as the Northeast Monsoon is replaced by the much stronger Southwest Monsoon, the surface currents are reversed, first at the periphery, but eventually over the entire Arabian Sea. Throughout the northern summer till September, the Southwest Monsoon Current flows to the east and upwelling occurs off the Arabian and Somali coasts, where strong boundary currents develop (Bailey 1966 and in prep.). At this time the Counter-current does not exist as a distinct current but easterly flow of surface water extends south to about 6° S.

Over much of the Tropical Zone there is little or no upward exchange of material over the discontinuity layer. In March 1964, however, the catches of zooplankton at the equator were considerably higher than at stations to the north and south (Fig. 3), indicating some vertical circulation similar to that found on the equator in other oceans (Graham 1941, Sverdrup *et al.* 1942).

Another highly characteristic feature of the Tropical Zone is the almost ubiquitous occurrence of flying-fishes (Exocoetidae) at the sea-surface. In addition, schools of predatory fish (probably mainly tuna) were found in some areas but appeared to have a patchy distribution. Finally, Cetacea (dolphins, Pilot Whales, Sperm Whales, rorquals and Humpback Whales) were occasionally seen in mid-ocean, perhaps on migration.

PREVIOUS WORK

Except in the Arabian Sea, which is crossed regularly by ships, little has been published on the pelagic distribution of sea-birds in the western Indian Ocean, though an important recent paper is that of Gill (1967). Since access to many of the islands is difficult, even the breeding distribution of sea-birds in the Indian Ocean is incompletely known, though much of the available information was admirably summarised by Watson *et al.* (1963). Other information used in plotting breeding stations in Figs. 6 to 9 was obtained from the sources listed elsewhere (Bailey 1967).

Owing to the economic importance of their eggs as food (Cott 1953–54), some species of sea-birds of the Seychelles and Amirante Is. have been studied intensively (Ridley & Percy 1958), but our knowledge of most other islands is derived from short visits which only by chance have coincided with the local breeding season.

THE DISTRIBUTION OF SEA-BIRDS OVER THE OCEAN

Sea-birds were distributed neither uniformly nor randomly over the Tropical Indian Ocean; indeed, most species had an extremely patchy distribution. Variations in the density of sea-birds over the ocean can be due to several factors, among which the most important are probably the vicinity of suitable breeding islands and the properties of the surface water, with which may be correlated the distribution of food. In the present section I shall describe my observations for birds made on each transect across the Indian Ocean and compare them with observations made concurrently in the sea. Discussion is restricted to the resident pantropical species.

INDIVIDUAL TRANSECTS

15° *N*–20° *S along* 58° *E:* 10 *March–4 April* 1964

The Northeast Monsoon, blowing over the Arabian Sea, was separated from the Southeast Trades south of about 10° S by a belt of light westerly winds with calms on the equator. The surface currents consisted of the westward-flowing North Equatorial Current on the equator, the eastward-flowing Equatorial Counter-current from about 3¾° to 7° S, and the westward-flowing South Equatorial Current from 7° to 20° S.

Sea-surface temperatures ranged from 25° C off Arabia to 30° C just south of the equator, but a small decrease of about 1° C within a degree of the equator suggested that local upwelling may have been in progress. There were no sudden changes in surface-temperature anywhere on the transect, even at the boundaries of opposing surface currents.

Nutrients and plankton were scarce near the surface at all stations, though there was a small concentration of zooplankton at 1½° N (Fig. 3). Floating seaweed, indicating the possible presence of a convergence, was encountered at the northern boundary of the Equatorial Counter-current, the surface-water of which looked distinctly greener than that further north. Flying-fish, first seen at 14° N, were common throughout the transect, particularly from 4° to 6° N.

Birds were completely absent on no part of the transect, though they were very rare in the southern Arabian Sea and from 10° to 15° S. Sooty Terns *Sterna fuscata* were almost confined to the belts of the Trade-winds north and south of the equator (Fig. 4). Several large flocks at about 5° N were associated with shoals of flying-fish, but the concentrations south of 15° S may have been due to the proximity of breeding stations.

By contrast, most other resident species of sea-birds were apparently absent from the zone of the North Equatorial Current, despite the probable existence of upwelling and more abundant plankton near the equator. Instead, Wedge-tailed Shearwaters *Puffinus pacificus*, White-tailed Tropic-birds *Phaethon lepturus*, and White Terns *Gygis alba* were concentrated in the Equatorial Counter-current (Fig. 5).

20° *S*–8½° *N along* 67½° *E:* 14 *April–4 May* 1964

In April the Southeast Trades were prominent south of 9½° S, whereas the wind had a westerly component at all latitudes further north. Surface currents, which were not well-developed, consisted of the South Equatorial Current south of 4° S, and an

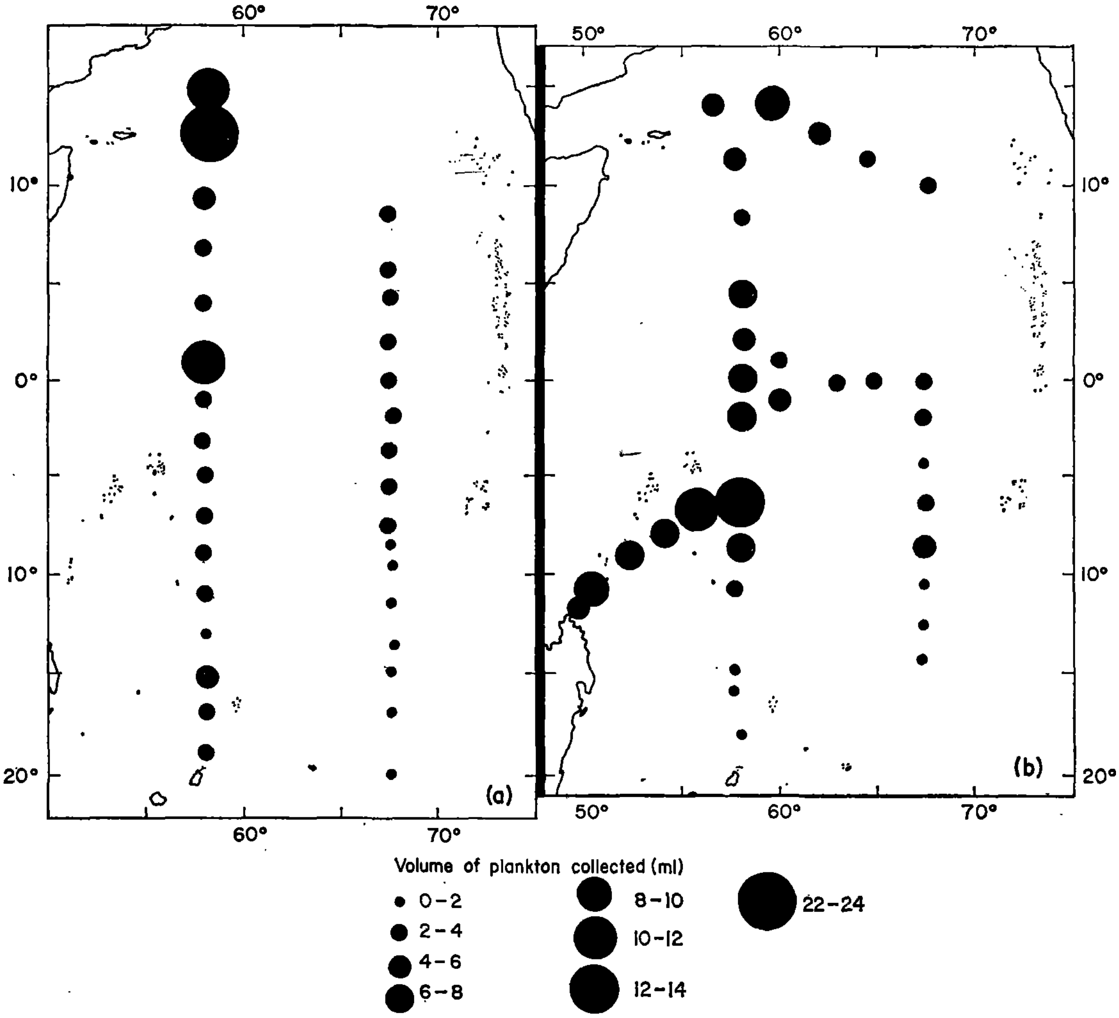

FIGURE 3. Volume of zooplankton collected in vertical hauls of a 70 cm net from 200 m to sea-surface.
(a) March-May 1964; (b) May-July 1964.

easterly surface current from there to 5° N. Sea-surface temperatures ranged from 27° to 30° C, but there was no sign of upwelling in the equatorial region. Zooplankton abundance was roughly equal to that at 58° E in March, except in the South Equatorial Current, where it was only one-third as abundant as further north (Fig. 3). Flying-fish were scarcer than at 58° E and showed no obvious peaks in numbers.

The abundance of birds at 67½° E did not differ greatly from that at 58° E. The distribution of *S. fuscata* showed no clear-cut pattern as it did at 58° E, although few were seen in the region of the South Equatorial Current (Fig. 4), where plankton was also scarce. *Puffinus pacificus* and *Phaethon lepturus* appeared to be concentrated within three degrees of the equator (Fig. 5). Thus, the zone of concentration of these two species was in the eastward-flowing currents in March at 58° E and in April at 67½° E, even though the comparable zones were at different latitudes.

From 21–27 May 1964, the ship crossed the Arabian Sea from 10° N, 67½° E to the Kuria Muria Islands, southeast Arabia. *S. fuscata*, which occurred north to 12½° N, was the only pantropical sea-bird species seen. On approaching the Arabian coast plankton increased as did the numbers of sea-birds typical of the Arabian coastal upwelling area (Bailey 1966).

15° *N–*5° *S along* 58° *E:* 28 *May–*8 *June* 1964

This was a partial repeat of the transect in March.

By late May the Southwest Monsoon was blowing in the Arabian Sea and the Southeast Trade-winds had advanced several degrees further north than in March. Calms were encountered on the equator. Surface currents were variable north of the equator, although a strong eastward-flowing extension of the Somali Current was encountered at 10° N. From the equator to 5° S the surface current was eastward-flowing, but much weaker than in March.

Plankton was sparse in the Arabian Sea, although less so than in March. A small concentration on the equator (Fig. 3) may have resulted from vertical circulation in the upper layers of the sea associated with divergent surface currents there. Flying-fish seemed rather less common in the Arabian Sea than they were in March, but I again recorded a small peak in abundance at 5° N.

Birds were generally more abundant in June than on the corresponding part of the same transect in March. While this was partly the result of arrivals of long-distance migrants from the south, it was also due to the increased numbers of dark petrels (see below). *S. fuscata* was not seen north of 9° N but, as in March, a peak in numbers occurred between 5° and 7° N (Fig. 4), where flying-fish were particularly common. These terns were apparently still absent from the southern Arabian Sea and the belt of calms on the equator, although a few were seen at the end of the transect between 4° and 5° S. Thus, as in March, *S. fuscata* was restricted to areas of consistent winds. *P. pacificus*, *P. lepturus*, and frigate-birds *Fregata* spp. were also seen further north than in March, but not in sufficient numbers to suggest a general northward movement.

Between the end of this transect and the beginning of the next, the ship visited the Seychelles Is. and then worked eastwards along the equator. Between 7 and 15 June the northern edge of the Southeast Trades had advanced northwards to the equator. The abundance of zooplankton was higher at 60° E than at 67½° E (Fig. 3), as were the numbers of both flying-fish and birds, especially *P. pacificus* and *S. fuscata* (Figs 4 and 5). The appearance of *S. fuscata* on the equator since early June may have been associated with the northward advance of the Southeast Trades.

1° *N–*15° *S along* 67½° *E:* 19–30 *June* 1964

The whole of this transect lay in the belt of the Southeast Trade-winds. Surface currents were variable in the north, but seemed to be predominantly northeastwards on the equator and southwards from 2° to 6° S, while the South Equatorial Current was encountered south of 6° S. Floating seaweed was seen at 2° S, indicating a possible convergence.

Zooplankton was generally scarce (Fig. 3), especially in the South Equatorial Current south of 9° S, and flying-fish were scarce except between 5° and 10° S.

P. lepturus and *S. fuscata* seemed to be slightly commoner than they were on the corresponding part of the transect in April (Fig. 4), but *P. pacificus* less common (Fig. 5). Whereas *P. lepturus* was slightly commoner north of 6° S than further south, *S. fuscata* seemed to be most numerous from 3° to 7° S at the northern boundary of the South Equatorial Current, and around 13° to 14° S, but I can suggest no obvious interpretation of its distribution on this transect.

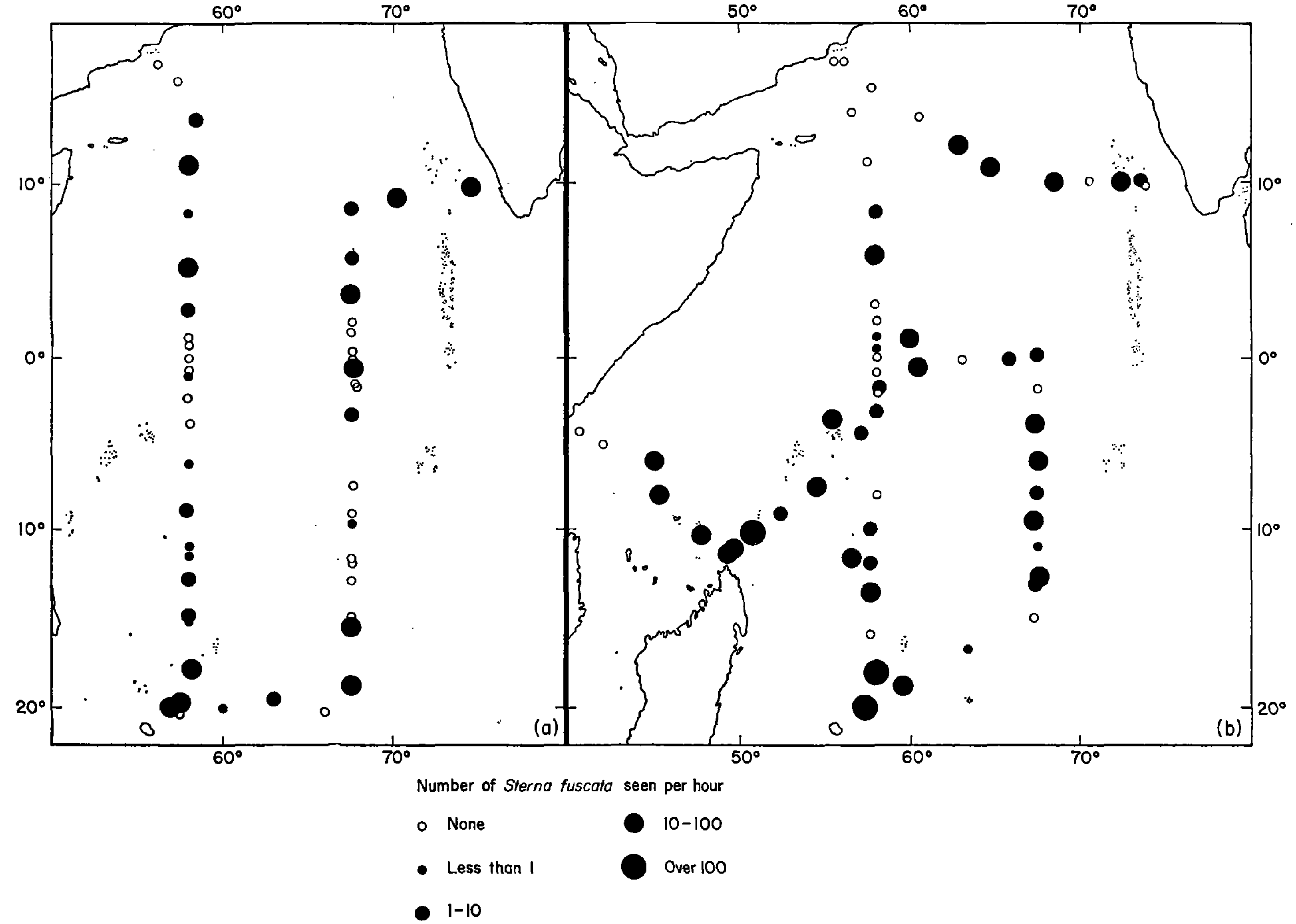

FIGURE 4. Abundance of Sooty Terns *Sterna fuscata* over the Indian Ocean. (a) March-May 1964; (b) May-July 1964.

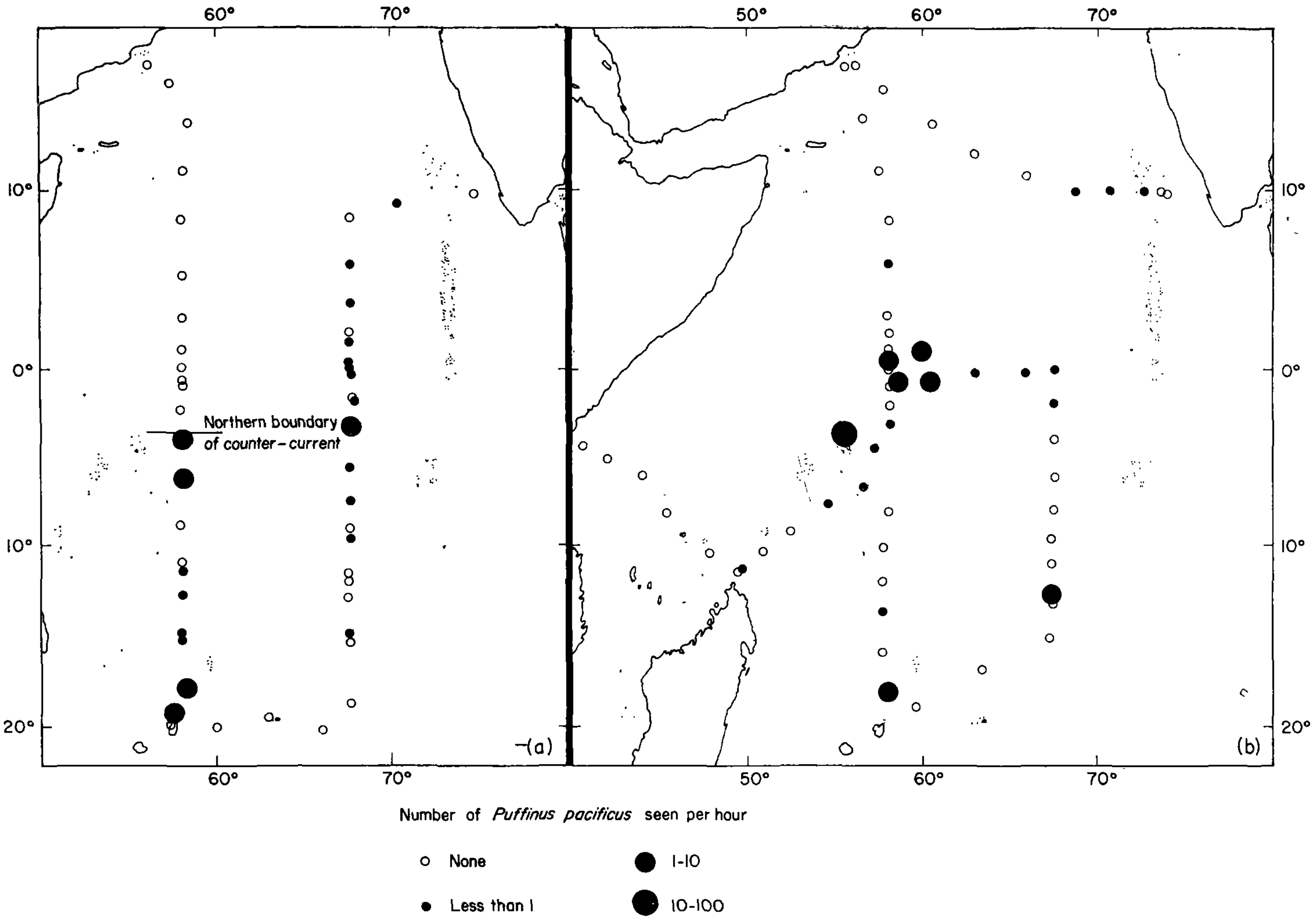

FIGURE 5. Abundance of Wedge-tailed Shearwaters *Puffinus pacificus* over the Indian Ocean. (a) March-May 1964; (b) May-July 1964.

From the southern end of the transect at 67½° E the ship steamed straight to Mauritius. Birds were scarce in this area, though *S. fuscata* was seen commonly as we approached Mauritius.

20° *S*–7° *S along* 58° *E:* 9–16 *July* 1964

A partial repeat of the transect at 58° E in March showed several changes by July. In particular, the Southeast Trades had intensified and the sea-surface temperature had dropped to between 23° and 26° C. Zooplankton was very scarce in the south, but north of 10° S its abundance was about four times the average in mid-ocean (Fig. 3), a striking increase since March. Flying-fish were scarce.

S. fuscata, which was the only pantropical species seen commonly anywhere on the transect, was abundant north of Mauritius but rather few were seen north of about 12° S (Fig. 4).

ANALYSIS OF SEA-BIRD DISTRIBUTION

Most species of sea-birds were seen too infrequently to warrant a full analysis of their pelagic distribution. For species with sufficient data, namely *Sterna fuscata*, *Puffinus pacificus* and *Phaethon lepturus*, I have analysed the percentage of one-hour counts on which each species was seen in relation to the distance from the nearest land, the sea-surface temperature, the wind speed and the abundance of flying-fish (Exocoetidae) at the sea-surface (Tables 1 to 4). For the analyses I have used only those counts made south of 15° N, west of 68° E, and more than 100 miles from the African and Asian coasts.

Though all the species considered were seen most frequently close to land, none were restricted to the vicinity of islands; indeed, *P. pacificus* was seen as far from land as I observed (Table 1). It may well be that these species concentrate near land for breeding purposes only but, as it is impossible to distinguish between breeding and non-breeding birds at sea, there is no way of testing whether this is true.

TABLE 1. *Frequency of occurrence of sea-birds at different distances from the nearest land.*

	DISTANCE FROM THE NEAREST LAND (nautical miles)									
	0–50	50–100	100–150	150–200	200–250	250–300	300–350	350–400	400–500	> 500
Total number of counts	41	53	77	56	49	59	80	36	43	18
Birds (all species)										
No. of counts on which seen	41	43	47	39	40	34	44	17	36	13
%	100%	81%	61%	70%	82%	58%	55%	47%	84%	72%
Puffinus pacificus										
No. of counts on which seen	15	15	11	6	1	6	9	5	5	1
%	37%	28%	14%	11%	2%	10%	11%	14%	12%	6%
Phaethon lepturus										
No. of counts on which seen	14	8	5	5	1	4	7	1	1	0
%	34%	15%	6%	9%	2%	7%	9%	3%	2%	0%
Sterna fuscata										
No. of counts on which seen	35	32	21	11	11	11	9	2	11	2
%	86%	60%	27%	20%	22%	19%	11%	6%	26%	11%

Note. In all three species the χ^2 value due to linear regression (Maxwell 1961 : 65–68) is highly significant; $P<0{\cdot}001$.

All the observations considered in the present analysis were made in the Tropical Zone of surface water, the surface temperature of which varied between 23° and 31° C. Within this range I found no appreciable association between the frequency with which I saw sea-birds and the sea-surface temperature, except in the case of *S. fuscata*, which was seen more frequently in cool than in warm water (Table 2). This is surprising in view of the fact that this species does not inhabit the areas of cool water off Arabia and Somalia (Bailey 1966 and in prep.).

TABLE 2. *Frequency of occurrence of sea-birds in water of different sea-surface temperatures.*

	Sea-surface temperature (°C)						
	<25°	25°	26°	27°	28°	29°	>29°
Total number of counts	50	68	62	74	94	134	17
Birds (all species)							
No. of counts on which seen	35	51	43	51	65	86	12
%	70%	75%	69%	69%	69%	64%	71%
Puffinus pacificus							
No. of counts on which seen	4	7	13	6	14	26	0
%	8%	10%	21%	8%	15%	19%	0%
Phaethon lepturus							
No. of counts on which seen	8	5	7	5	6	12	1
%	16%	7%	11%	7%	6%	9%	6%
*Sterna fuscata**							
No. of counts on which seen	29	24	24	21	30	27	4
%	58%	35%	39%	30%	32%	20%	24%

Note. * In *S. fuscata* the χ^2 value due to linear regression (Maxwell 1961: 65–68) is highly significant; $P<0\cdot001$.

The observed lack of association between the distribution of both *P. pacificus* and *P. lepturus* and the sea-surface temperature may suggest that the two species can feed freely over the entire Tropical Zone. I have shown elsewhere (Bailey 1966), however, that tropical species rarely enter the cool-water areas off Arabia and Somalia, suggesting that they are restricted to areas above a certain sea-surface temperature. Unfortunately, I could make no observations on the southern limits of the range of tropical species in the Indian Ocean, though Gill's (1967) observations suggest that few range beyond the Tropical Convergence over and into subtropical surface water.

Sea-birds are likely to be affected by variations in the atmosphere as well as by those in the sea. An analysis of my data with respect to the wind-speed shows no clear correlations except that *S. fuscata* was seen most frequently in areas where the wind was strongest (Table 3). It is possible that these terns are most conspicuous when the wind is strong, but the increase in height of the swell in such conditions suggests that the opposite is more likely.

TABLE 3. *Analysis of occurrence of sea-birds with respect to wind speed.*

	Wind speed (Beaufort Scale)							
	0	1	2	3	4	5	6	7
Number of counts	16	30	48	88	160	93	37	13
Birds (all species)								
No. of counts on which seen	14	24	39	57	91	68	30	10
%	88%	80%	81%	65%	57%	73%	81%	77%
Puffinus pacificus								
No. of counts on which seen	3	6	9	12	18	12	7	0
%	19%	20%	19%	14%	11%	13%	19%	0%
Phaethon lepturus								
No. of counts on which seen	0	4	6	5	14	7	7	1
%	0%	13%	12%	6%	9%	8%	19%	8%
*Sterna fuscata**								
No. of counts on which seen	3	10	13	31	30	38	22	5
%	19%	33%	27%	35%	19%	41%	60%	39%

Note. * In *S. fuscata* the χ^2 value due to linear regression (Maxwell 1961: 65–68) is significant; $P<0\cdot05$.

As the distribution of *S. fuscata* at sea appeared to be correlated with the wind-speed, it is of interest that the onset of its breeding on the Seychelles Is. appears to be controlled proximally by the onset of the Southeast Monsoon, i.e. when the northern boundary of the Southeast Trade-wind zone reaches the latitude of the islands (Ridley & Percy 1958). The ultimate control of breeding is not clear but it may be timed to occur when food is most abundant in the surrounding seas. Some evidence in support of this is the general increase in abundance of zooplankton recorded between March and July in the seas around the Seychelles and Amirante islands (see Fig. 3). In addition, my data might suggest either that *S. fuscata* can only feed readily in quite strong winds, or possibly that it requires winds above a minimum speed to remain airborne continuously for the several months between its breeding seasons, as Ashmole (1963a) has shown must happen.

Sea-birds of all species taken together were seen most frequently in areas where flying-fish were commonest (Table 4), but I found no significant correlation for any species taken separately, despite the fact that many tropical sea-birds are known to include flying-fish in their diet (Ashmole & Ashmole 1967).

TABLE 4. *Analysis of sea-bird occurrences with respect to the abundance of flying-fish (Exocoetidae) at the sea-surface.*

	Number of flying-fish seen in one hour's observation					
	0	1–3	4–10	11–30	31–100	more than 100
Number of counts	64	108	42	41	21	8
Birds (all species)						
No. of counts on which seen	41	62	29	31	16	6
%	64%	57%	69%	76%	76%	75%
Puffinus pacificus						
No. of counts on which seen	16	12	5	5	4	1
%	27%	12%	14%	15%	19%	12%
Phaethon lepturus						
No. of counts on which seen	9	7	3	4	3	1
%	14%	6%	7%	10%	14%	12%
Sterna fuscata						
No. of counts on which seen	22	30	17	15	9	3
%	34%	28%	41%	37%	43%	38%

Note. * In all three species taken together the χ^2 value due to regression (Maxwell 1961: 65–68) of bird numbers on flying-fish numbers is significant; $P<0{\cdot}05$.

In a separate analysis I tested for correlations between the numbers of birds seen per hour and the abundance of zooplankton, but found no evidence for any correlation with zooplankton abundance either at the sea-surface, as sampled by the Neuston Net (David 1965a), or in the top 200 m of the water column as sampled in vertical hauls of the 70 cm net (Currie & Foxton 1957).

Owing to the scarcity of sea-birds over the ocean, I have insufficient data to carry out a multiple analysis to show the relative importance of each factor on sea-bird distribution. I am also unable to test for correlations between the abundance of sea-birds and that of their food, because I could not sample their food organisms quantitatively.

SPECIES DISTRIBUTION

I have summarised below my observations of sea-birds recorded in the Tropical Indian Ocean from R.R.S. ' Discovery '. A copy of my records will eventually be deposited with the collection of the Royal Naval Bird-watching Society at the British Museum (Nat. Hist.). Since there are few published accounts of visits to Bird Is., Seychelles (03° 43′ S, 55° 12′ E), and Desnoeufs Is., Amirantes (06° 14′ S, 53° 03′ E), outside the recognised breeding season, my observations are summarised in Table 5.

TABLE 5. *Sea-birds recorded on Bird Is., Seychelles, and Desnoeufs Is., Amirantes.*

DESNOEUFS IS. 15.00–16.00 hrs, 11 Oct. 1963

Species	No. seen	State of breeding
Puffinus pacificus	*c.* 20	Visiting burrows*
Sula dactylatra	*c.* 200	Eggs (mostly C/2) and chicks in all stages of development
Fregata spp.	5–10	Immatures robbing boobies returning with food
Sterna fuscata	Very numerous	Adults seemed to outnumber the young, all of which were within a week or so of flying; no dead young seen
Thalasseus bergii	*c.* 10	Two juveniles seen possibly with adults‡
Anous stolidus	Much smaller nos. than *S. fuscata*	More advanced than *S. fuscata* and several young could fly. A few were also seen sitting on eggs, at least one of which contained an embryo

BIRD IS. 05.00–08.00 hrs, 4 Nov. 1963

Species	No. seen	State of breeding
Sterna fuscata	*c.* 20,000	Mostly well-feathered young, some of which could already fly; many fewer adults
Sterna albifrons	*c.* 100	Resting on beach
Thalasseus bergii	*c.* 100	Adults
Anous stolidus	20–30	Perched on coconut palms: possibly nesting
Gygis alba	*c.* 200	Mainly in pairs among *Casuarina* trees. A young chick in down found on the ground was the only definite evidence of breeding

Notes. * Ridley & Percy (1958) have recorded *P. pacificus* roosting ashore on Desnoeufs Is. well before the breeding season commences.

‡ In view of Ashmole & Tovar's (1968) recent findings, these juveniles could have been hatched elsewhere.

PHOEBETRIA SP.

An immature was seen on 20 July 1964 at 11° 19′ S, 49° 41′ E, 40 miles off the northern tip of Madagascar. Although the species itself is doubtful, Sir Hugh Elliott, Mr. John Warham and Dr. Lance Tickell have independently identified the bird as *Phoebetria* sp. from a photograph taken by Mr. M. V. Angel. This is the most northerly record of this genus in the Indian Ocean, though the Sooty Albatross *P. fusca*, which breeds on St. Paul Is. at 39° S (Paulian 1953), has previously been collected at Mauritius (Meinertzhagen 1912).

PACHYPTILA SP.

Without being able to determine the species, I recorded prions on six occasions during June and July 1964, all south of 10° S in areas of surface temperature 23°–26° C. Prions have previously been recorded in the northern summer on a number of islands in the Indian Ocean (Hartlaub 1877, Newton 1888, Rountree *et al.* 1952), but it is not clear which species occurs most frequently. In addition Voous (1966) saw two at 10° S off East Africa in July 1965, and G. S. Willis saw two at 2½° S, 47° E on 5 September 1952 (W. R. P. Bourne, pers. comm.).

PUFFINUS CARNEIPES Pale-footed Shearwater

Outside an area off southeast Arabia, where its regular occurrence during the northern summer is well established (Bourne 1960, Bailey 1966), I saw *P. carneipes* only in May and early June during its post-nuptial migration. Several small flocks were seen west of the Laccadive Is. and in the central Arabian Sea, mostly heading N.W. or west.

P. carneipes is obviously rare south of the equator in the western Indian Ocean, though it is listed by Vesey-Fitzgerald (1936) as having occurred in the Seychelles and there are records from South Africa (Clancey 1965, 1966) and Amsterdam Is. (Paulian 1953, listed as *P. pacificus* (W. R. P. Bourne, pers. comm.)). This fact and the flight directions of migrants seen in the Arabian Sea suggest that most migrate to Arabia direct from their breeding grounds and not clockwise around the Indian Ocean, as was suggested by Gibson-Hill (1953).

PUFFINUS PACIFICUS Wedge-tailed Shearwater

In the Indian Ocean *P. pacificus* breeds only in warm-water areas in the Southern Hemisphere. At sea I recorded them, often in flocks, over a wide area (Fig. 6) but their similarity to other species of dark petrels often made certain identification difficult, so I did not ascertain the limits of their distribution. They were clearly not restricted to the vicinity of land, though they were commonest south of the equator and only small numbers were identified for certain further north, almost all in the northern summer. This may suggest that part of the population disperses north into the Arabian Sea during the Southwest Monsoon, i.e. outside the breeding season, as suggested by Bourne (1960). There are also some previous records of *P. pacificus* in the Arabian Sea, mainly in the northern summer, and a few birds have been collected (Gibson-Hill 1953; others summarised by Bailey 1966).

It is noteworthy that *P. pacificus* neither breeds nor occurs in any numbers to the west of the Amirante Is., or among the islands north of Madagascar. Apart from a single breeding station off southwestern Madagascar (Appert 1965), it is evidently a mid-oceanic species in the Indian Ocean.

PUFFINUS LHERMINIERI Audubon's Shearwater

My records in the central Indian Ocean suggest that their oceanic range is largely confined to within 50 miles of their breeding grounds (Fig. 6), though a few were seen up to 120 miles from the Seychelles in March 1964, and a few others much further out to sea at other times. The few previous records at sea are mostly near known breeding stations (e.g. Gill 1967). Most birds I saw were in flocks, often with Common Noddies *Anous stolidus* and Brown-winged Terns *Sterna anaethetus*.

PTERODROMA MOLLIS Soft-plumaged Petrel

Single gad-fly petrels with brownish grey upperparts, white throat and underparts, and a dark unpatterned underwing, were seen at 18° S, 58° E on 10 July 1964, and at 16° S, 57½° E the following day, in water of surface-temperature about 24° C. As no other known species of *Pterodroma* has this combination of characters, I believe they were *P. mollis*. The only previous records north of the Tropic in the Indian Ocean were much further east in June and July (Bourne 1961, 1966). Off eastern Africa the most northerly record is at 26° S (Lawson 1963). The nearest known breeding station is on St. Paul Is. (Paulian 1953).

PTERODROMA SPP.

Other unidentifiable gad-fly petrels of both dark and light phases were seen on several occasions, usually far out to sea. They may have belonged to the Trinidade Petrel *P. arminjoniana*, which breeds on Round Is. off Mauritius (Rountree *et al.* 1952), though one smaller bird may have been a species from the western Pacific Ocean (see also Gill 1967). I recorded no Barau's Petrels *P. baraui* so, since Gill's (1967) records in March were all south of Réunion, its only known breeding station (Jouanin & Gill 1967), it may well be that the species feeds mainly in the Subtropical Zone of surface water south of about 20° S.

BULWERIA FALLAX Jouanin's Petrel

Although I saw *B. fallax* in the greatest numbers off the coast of Arabia (Bailey 1966), I recorded them south to 6½° N in November 1963 and south to the equator in June 1964 (Fig. 6). A bird with all the characteristics of the species was also seen at 8½° S, 58° E on 15 July 1964. Thus, *B. fallax* disperses south in the northern summer much further than has previously been recognised, despite the fact that this is the time of year when it is thought to breed (Jouanin 1957, Bailey 1966).

Unequivocal records of *B. fallax* in the Arabian Sea are very few, mainly because the species was long misidentified as *P. pacificus* or the Réunion Petrel *Pterodroma aterrima* (compare, for instance, Alexander 1954 and Jouanin 1957). Collected specimens support my own sight records in being concentrated off southern Arabia, though birds have also been collected in the Arabian Sea and in Kenya (see Bailey 1966). There are also numerous sight-records of dark petrels in the Arabian Sea, especially during the Southwest Monsoon, many of them probably of this species.

OCEANITES OCEANICUS Wilson's Storm-petrel

Although most *O. oceanicus* arrive in the seas off Arabia in May and June (Bourne 1960), several were seen and two were collected south of the equator in April 1964. During May several more were seen west of southern India and one was collected off Cochin. In June, more were seen in the southern Arabian Sea, especially near the equator, indicating that migration was still in progress. None were seen south of the equator in July, however, so presumably the migration had finished by then.

By contrast, I saw no *O. oceanicus* in the central Arabian Sea in August 1963, though a few were seen around the Seychelles Is. in November. This suggests that *O. oceanicus* occurs far out to sea in the Indian Ocean only during the northern spring and autumn, that is when on migration to and from its breeding grounds in the Southern Ocean. Furthermore, since my records in the northern spring were of small numbers widely scattered over the ocean, it seems most likely that they migrate north over a broad front. This contrasts markedly with the mass southerly migration reported off Ceylon and southern India in two successive Novembers by Phillips (1954, 1955). There are remarkably few previous records of *O. oceanicus* far out to sea in the Indian Ocean, all of them from April to November, inclusive (Betts 1940, Roberts 1940, Rountree *et al.* 1952, Bourne 1960, Phillips 1963, Pocklington & Risebrough 1964, Bourne 1965).

PELAGODROMA MARINA White-faced Storm-petrel

In addition to my records off Arabia (Bailey 1966), I recorded small numbers on migration south of the Laccadive Is. and in the central Arabian Sea in late May and early June 1964, but none south of the equator in June and July (Fig. 6).

P. marina is clearly quite common in the western Indian Ocean in the northern summer (Bourne 1960, Morzer Bruyns & Voous 1964, Bailey 1966), but there are very few records south of the equator west of 80° E (Vesey-Fitzgerald 1936, Bourne 1959, Morzer Bruyns & Voous 1964, Gill 1967). The reports in May and June from off southern India (Bourne 1961, Bailey & Bourne 1963), together with my own off the Laccadive Is., suggest that the main postnuptial migration from Australia passes direct from the breeding grounds to the wintering area in the Arabian Sea.

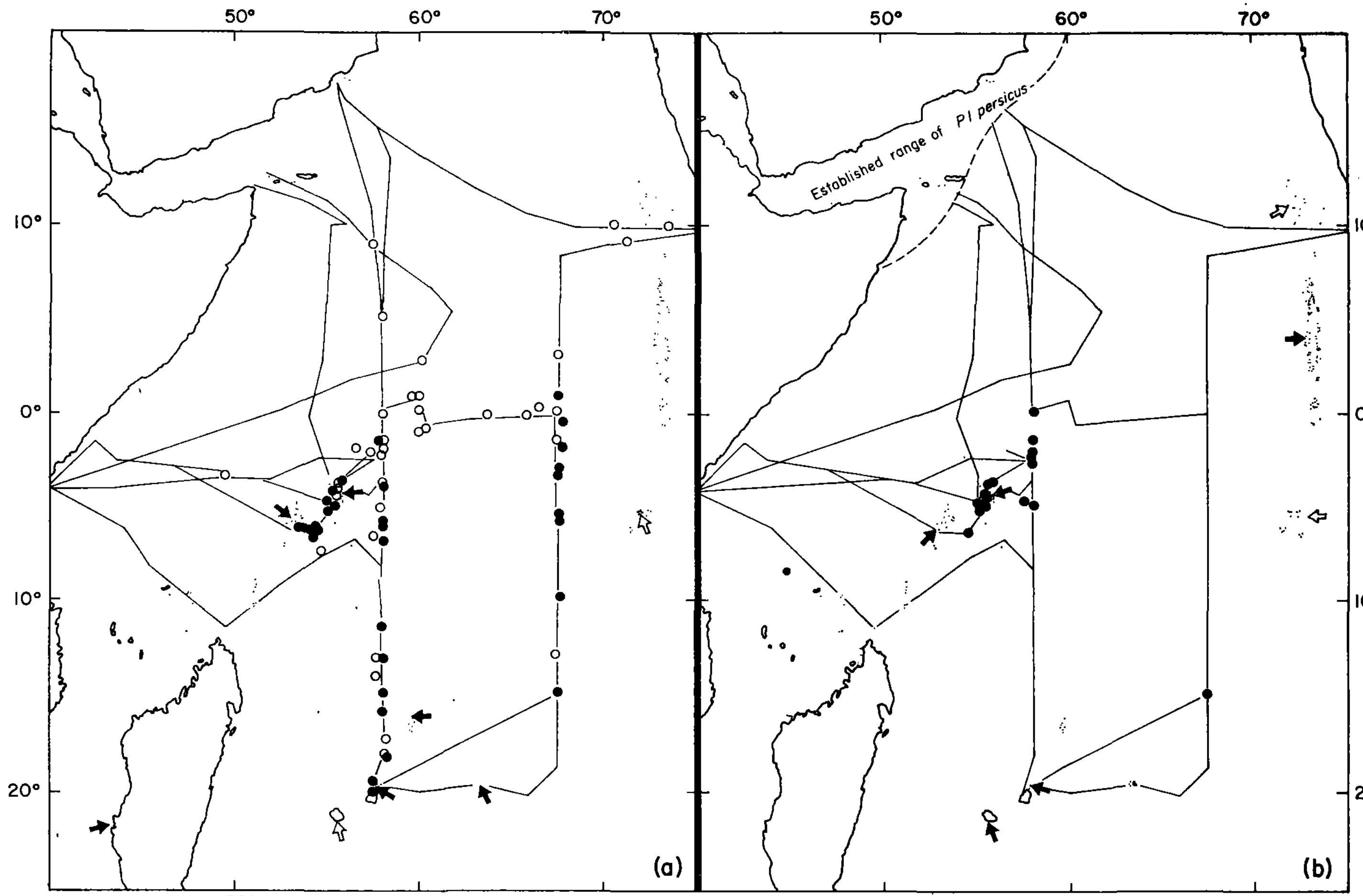

FIGURE 6. Records of petrels (Procellariiformes) observed from the R.R.S. 'Discovery' in the western Indian Ocean in 1963 and 1964.
(a) *Puffinus pacificus.* ○, Records from May to September, inclusive; ●, records from October to November 1963 and March to April 1964.
(b) *Puffinus lherminieri.*
Breeding stations 🡅; possible breeding stations ⇧. Tracks are a simplified version of those shown in Fig. 2.

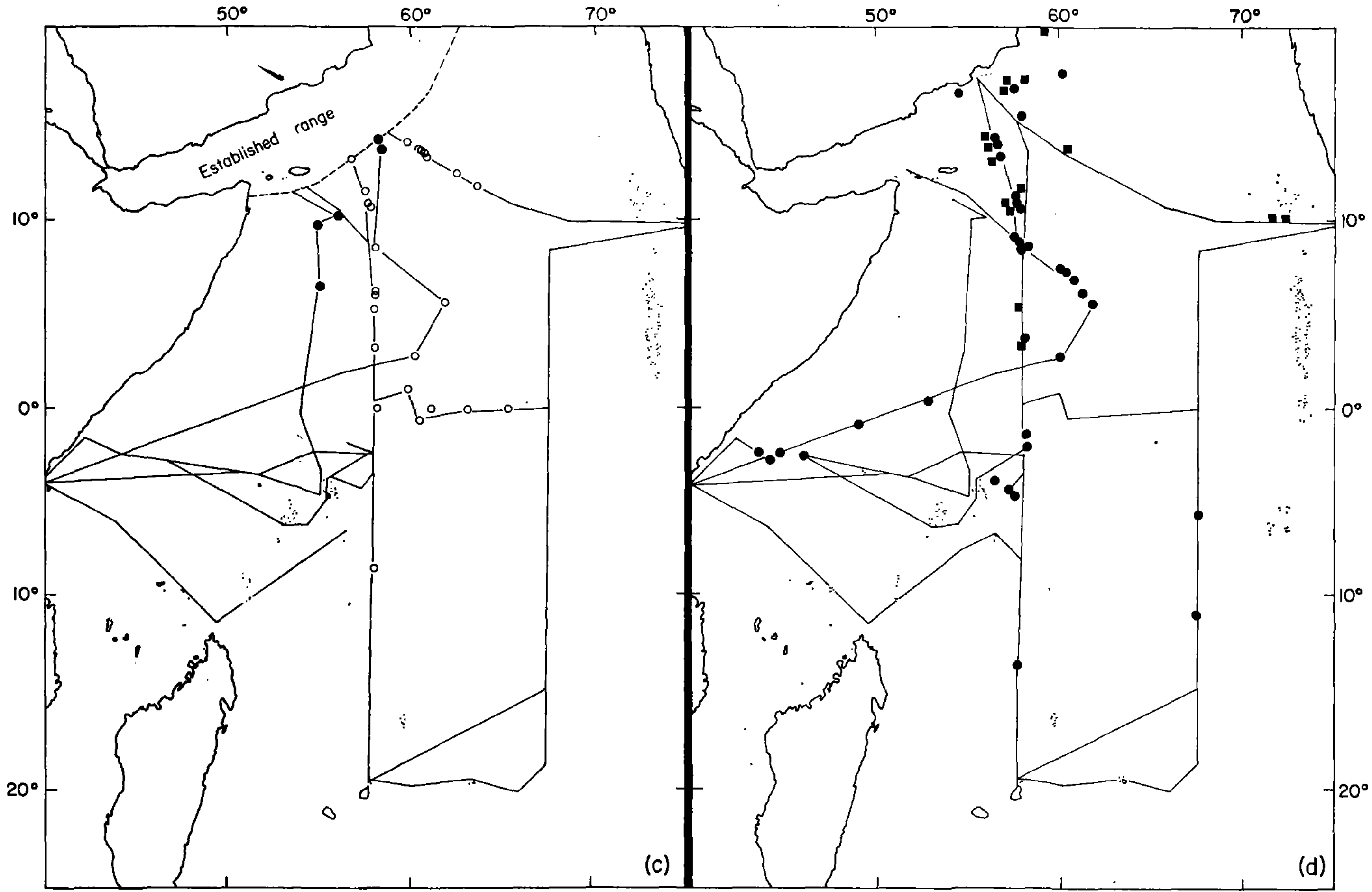

FIGURE 6.

(c) *Bulweria fallax.* ○, Records from May to September, inclusive; ●, records from October to November 1963 and March to April 1964.

(d) *Fregetta* sp. ● and *Pelagodroma marina* ■ (including records already published in Bailey (1966).

FREGETTA SP.

Though I saw only three *Fregetta* sp. off southeast Arabia in 1963 (Bailey 1966), two of them certainly *F. tropica*, in late August and September I found them quite common in the central Arabian Sea (Fig. 6). In September I also saw small numbers much further south off East Africa but only one there in October, and none in the Arabian Sea in November. Presumably most had migrated south sometime between mid-September and mid-October.

In 1964 *Fregetta* sp. were not seen until late May, when they already appeared to be common in the western Arabian Sea. Further south in June and July they were less common, though a few were seen in widely-scattered areas (Fig. 6). Many of the *Fregetta* storm-petrels I saw in the Indian Ocean had clear black lines down their abdomen, so were certainly Black-bellied Storm-petrels *Fregetta tropica* (see Bourne in Palmer 1962). I saw none which I thought were White-bellied Storm-petrels *F. grallaria*, though it now seems likely that this species, or possibly a white-bellied phase of *F. tropica*—*F. t. melanoleuchen*—also occurs (Jones 1964, Bourne 1965, Bourne 1966, Cheke 1966).

There are now many records of *Fregetta* sp. in the northwestern Indian Ocean, almost all from the Arabian Sea between May and September (e.g. Phillips 1947, 1954, Bailey & Bourne 1963). There are also a few reports from further south (Roch & Newton 1863, Bourne 1959, 1960).

OCEANODROMA SPP.

The available records of *Oceanodroma* spp. in the Indian Ocean have recently been summarised by Bailey, Pocklington & Willis (1968), though others not included have also been seen by Gill (1967). To summarise briefly, a species thought to be Matsudaira's Storm-petrel *Oceanodroma matsudairae* was common in the equatorial region, and Swinhoe's Storm-petrel *Oceanodroma monorhis* was seen in small numbers in the Arabian Sea.

PHAETHON AETHEREUS Red-billed Tropic-bird

Compared with southeast Arabia and eastern Somalia (Bailey 1966, in prep.), I saw very few *P. aethereus* in the central Arabian Sea, in confirmation of the pelagic distribution given by Gibson-Hill (1952). The southern and eastern limits of its pelagic range in the Indian Ocean are not known, though there are several sight-records off the Laccadive Is., southern India and Ceylon, and a specimen was taken off Cape Comorin in February 1956 (Phillips 1958). There are also several records from the Bay of Bengal (Bourne & Radford 1962, Bourne 1965), but whether these were birds from the Arabian Sea is not clear, because the species is said to breed on the Paracel Is. in the South China Sea (Delacour & Jabouille 1931).

PHAETHON RUBRICAUDA Red-tailed Tropic-bird

In the Indian Ocean *P. rubricauda* breeds only in the zone of the Southeast Trade winds, i.e. south of the equator (Fig. 7). I recorded several in June and July 1964 north of Mauritius (Fig. 7), but none in the same area in March and April.

PHAETHON LEPTURUS White-tailed Tropic-bird

My records were concentrated in a belt from the equator to 10° S, particularly around the Seychelles Is. and to their east (Fig. 7). The species was much rarer north of the equator, and my most northerly record was at 8° N in late May. Though my records do not appreciably extend the known range of *P. lepturus*, they show that it disperses at sea up to several hundred miles from its breeding stations. It also appears to extend further north in the eastern Arabian Sea than in the west, though the northern limit of its pelagic range is not known.

Tropic-birds of any species were rare in the central Arabian Sea, so it seems unlikely that the usual pelagic ranges of *P. lepturus* and *P. aethereus* overlap, except possibly between the Laccadive Is., the Maldive Is., and Ceylon, where both species have been recorded. This situation may be compared with that in the Atlantic Ocean where both species breed on Ascension Is. and Fernando Noronha (Murphy 1936). It is not known whether the Atlantic birds feed together at sea, however.

SULA DACTYLATRA Blue-faced Booby

I saw *S. dactylatra* over a wide area south of the equator, but only one in the central Arabian Sea, and very few west of the Seychelles Is. (Fig. 7). Consequently, there can be little overlap in the normal pelagic ranges of the populations breeding north and south of the Arabian Sea respectively, though they all belong to a single subspecies, *S. d. melanops*. Many of my records far from land were of immature birds (Fig. 7). Most adults seemed to be confined to the seas within 100 or 200 miles of known breeding stations.

SULA SULA Red-footed Booby

In the western Indian Ocean *S. sula* certainly breeds only on the islands to the north and east of Madagascar, and most of my records at sea were near recognised breeding stations (Fig. 7). I also recorded fair numbers of both adults and immatures (recognised by their brown tails (Hindwood *et al.* 1963)) much further north between the Seychelles and East Africa in September and October 1963, and several immatures far outside their known range in the southern Arabian Sea in September, but not at other times of year. Most adults I saw were white-phase and I saw a brown-phase adult (with a white tail) for certain only once, off northern Madagascar. As in the case of *S. dactylatra*, only immature *S. sula* were seen at great distances from breeding islands.

Both the pelagic and breeding distributions of *S. sula* in the western Indian Ocean are largely complementary to those of *S. dactylatra* (Fig. 7): *S. sula* always nests on islands with trees or bushes, whereas *S. dactylatra* nests on the ground on more barren islands (Vesey-Fitzgerald 1941). Consequently, it may well be that their distribution is dependent on that of their nesting habitat, as suggested by Murphy (1936), though there is no obvious reason why their pelagic ranges should not overlap.

FREGATA SPP.

As the two resident frigate-birds of the western Indian Ocean are difficult to distinguish at sea, and the immatures impossible, they are considered together. In the western Indian Ocean the Great Frigate-bird *F. minor* breeds only on islands north and east of Madagascar; the Lesser Frigate-bird *F. ariel* shares all the stations of *F. minor* and also breeds on the Maldive and Chagos Is. (Fig. 7).

At sea I recorded frigate-birds, both alone and in flocks of Sooty Terns *Sterna fuscata*, over a large area, but rarely north of the equator and there only in the northern summer (Fig. 7). Almost all I saw were unidentifiable immatures with white heads, which may indicate that adults wander only small distances from their breeding stations.

CATHARACTA SKUA Great Skua

In addition to my records of *C. skua* off southeast Arabia in 1963 (Bailey 1966), I saw single birds on six occasions in 1964, four of them in March and April south of the equator, one near the equator in June, the last north of Mauritius in July. Previous records are mostly from the northwestern Arabian Sea and off southern India, where they have been seen from March to December inclusive (Bourne 1961, 1964, 1965, Morzer Bruyns & Voous 1965).

STERCORARIUS SP.

On 27 October 1963 at 4° S, 44° E, that is some 200 miles off East Africa, I saw two skuas flying southwest. One was a light-phase bird with an apparently pale rump; the other was darker and appeared to be a light-phase immature. Although I could not see the shape of the tail of either bird, their flight and light build suggested Arctic Skuas *S. parasiticus*.

LARUS FUSCUS Lesser Black-backed Gull

L. fuscus has rarely been seen far out to sea in the Indian Ocean, though one has recently been recorded on Aldabra (Dawson 1966). I saw an adult on 15 and 16 October 1963 at 2½° S, 45° E, some 200 miles off East Africa.

STERNA ANAETHETUS Brown-winged Tern

In the area covered by this paper I saw *S. anaethetus* only around the Seychelles Is., where it breeds, in October and November 1963 and June 1964. Usually they were in mixed flocks. In mid-ocean I could possibly have missed birds of this species among flocks of *S. fuscata*, but the pale colouration of *anaethetus* is usually obvious, so it seems unlikely that it was common far from land. Reliable records far out to sea in the Indian Ocean are very few (e.g. Cheke 1966). Although Alexander (1955) wrote of *S. anaethetus* as an oceanic species, it was seen only within 50 miles of land, so is offshore rather than pelagic in Wynne-Edwards' (1935) terminology (see also Bailey 1966).

STERNA FUSCATA Sooty Tern

At sea *S. fuscata* was commonest around its breeding stations at least when breeding was in progress, but it was clearly not restricted to the vicinity of land. Indeed, south of the equator it seemed to be the commonest and most widespread sea-bird and it was also seen in varying abundance in the Arabian Sea north to 12° N (Fig. 8). The areas of abundance appeared to change at different times of year (see Fig. 4): east of the Seychelles, for example, they were uncommon in March but

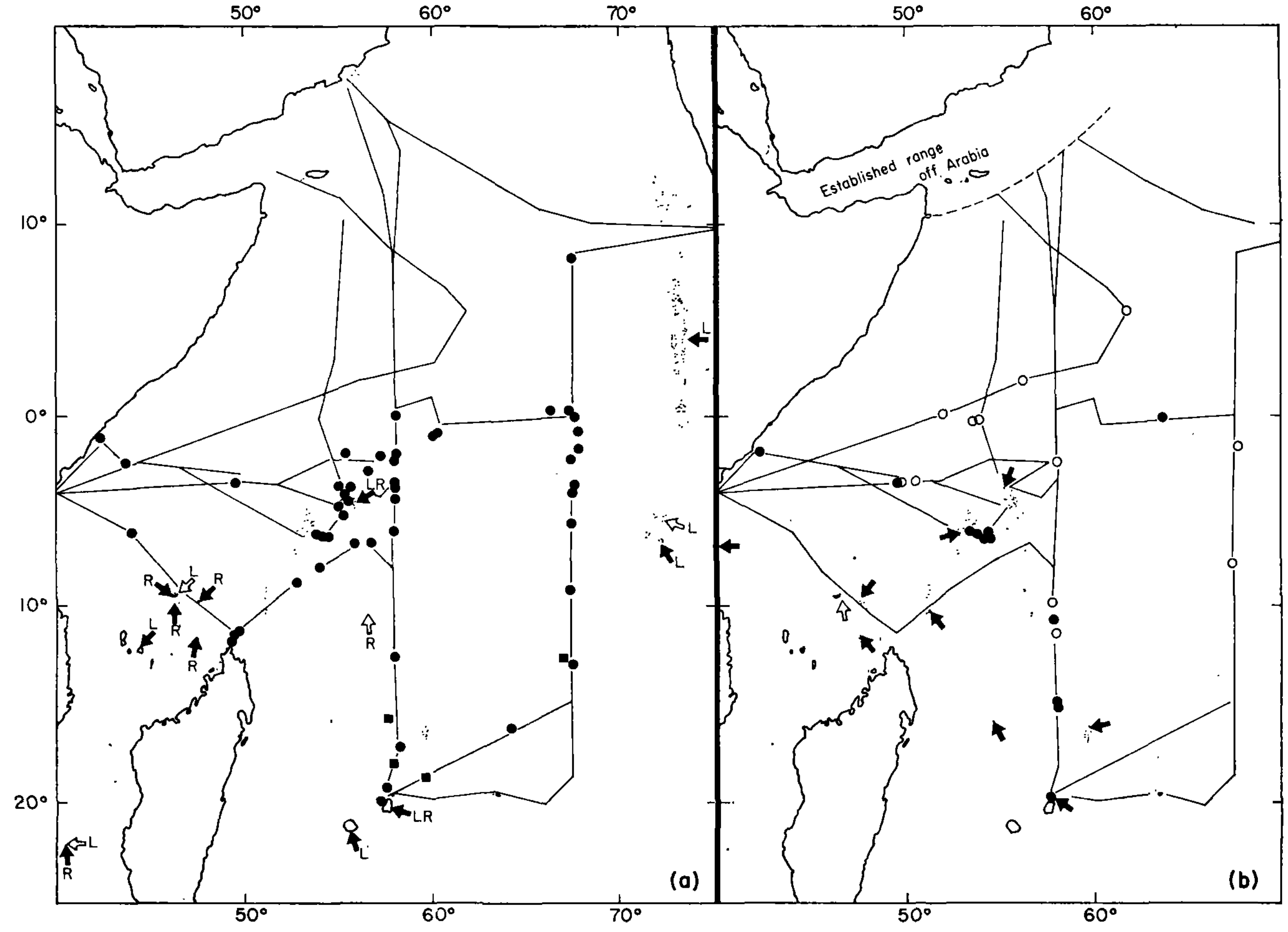

FIGURE 7. Records of Pelecaniformes observed from the R.R.S. ' Discovery ' in the western Indian Ocean in 1963 and 1964.
(a) *Phaethon lepturus* ● and *P. rubricauda* ■.
Breeding stations ⬆ ; possible breeding stations ⇧ : *P. lepturus* L; *P. rubricauda* R.
(b) *Sula dactylatra*: adults ● ; immatures ○ .
Breeding stations ⬆ ; possible breeding stations ⇧.

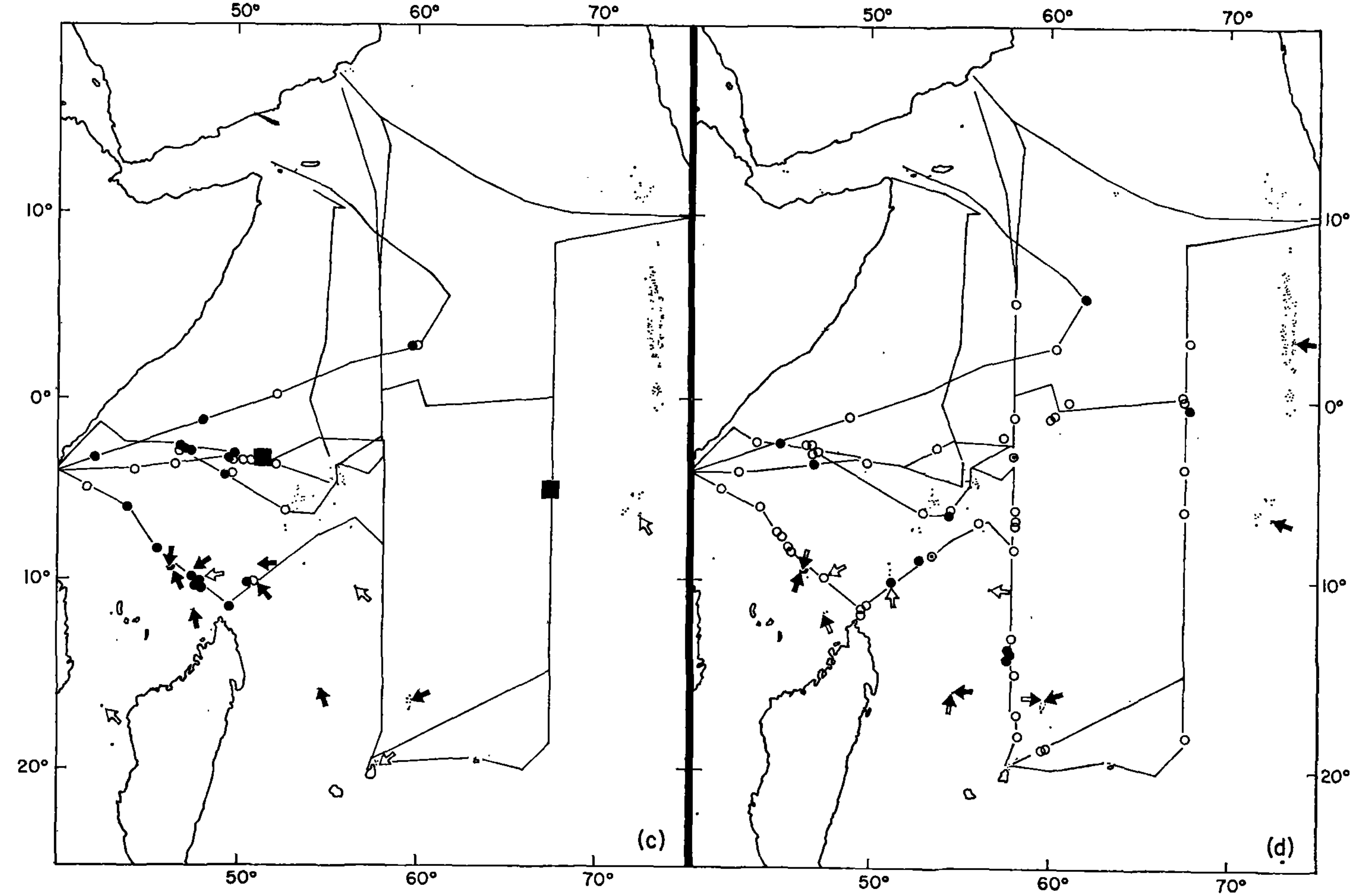

Figure 7.

(c) *Sula sula*: adults ● ; immatures ○ ; immatures collected ■.
Breeding stations ⬆ ; possible breeding stations ⇧.
(d) *Fregata* spp.: *F. ariel* ● ; *F. minor* ◉ ; unidentified (mostly immatures) ○.
Breeding stations: *F. ariel* ⬆ ; *F. minor* ⇑ ; species not known ⇧.
Tracks are a simplified version of those shown in Fig. 2.

common in June 1964; similarly, there seemed to be far fewer between East Africa and the Seychelles in October 1963 than there were in September. On the Seychelles Bank, they were rare in October and November 1963, but common in June 1964. The breeding of *S. fuscata* on the Seychelles and Amirante Is. is from June to October (Ridley & Percy 1958), so the observed changes may well have been due to prenuptial concentration near the breeding stations and eventual dispersal respectively.

Considering the huge numbers of *S. fuscata* which breed in the western Indian Ocean, I saw very few juvenile birds at sea (Fig. 8), either in flocks of adults or alone. In one case the presence of two adults suggested that the juvenile concerned was with its parents, as Ashmole (1963a) suspected might occur. It is impossible to tell how long they retain their first plumage, but my observations indicate that they disperse far out to sea before moulting.

While individual birds were occasionally seen, more usually I saw flocks of from 20–200 birds, and flocks of several thousand were recorded occasionally. Few of the birds I saw were obviously feeding, which suggests that they must spend a considerable part of their time at sea foraging for food, as suggested by Ashmole (1963a). Sometimes the flocks were seen high over the sea, and once several birds were watched circling around to a height of about 100 m presumably using air currents.

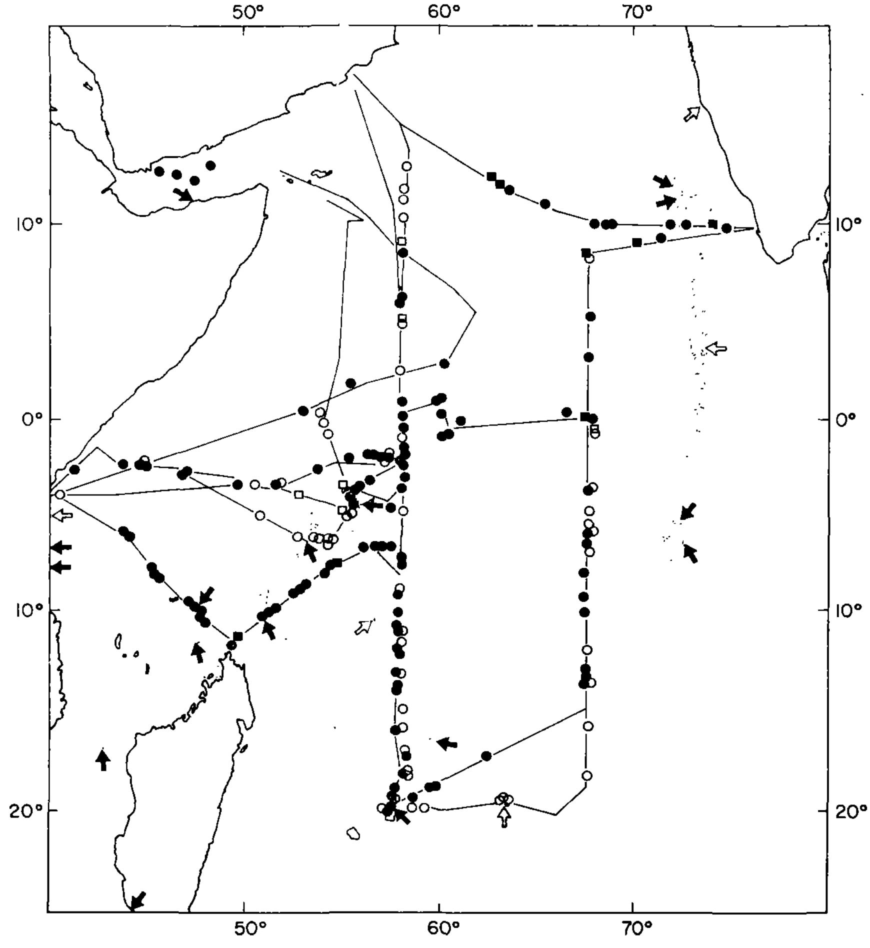

FIGURE 8. Records of *Sterna fuscata* observed from the R.R.S. ' Discovery ' in the western Indian Ocean in 1963 and 1964.
Breeding stations ↑ ; possible breeding stations ⇧.
Adults: October-November & March-April o ; May to September ● .
Juveniles: October-November & March-April □ ; May to September ■ .
Tracks are a simplified version of those shown in Fig. 2.

ANOUS STOLIDUS Common Noddy

At sea I saw *A. stolidus* commonly within 20 miles of its breeding stations, often feeding with other sea-bird species, but rarely any further offshore (Fig. 9). Since so few have been seen far from land either by myself or previously, most are probably tied to the breeding grounds throughout the year. In contrast, the species appears to leave its breeding stations between breeding seasons on Ascension Is. (Dorward & Ashmole 1963) and the islands off western Australia (Serventy & Whittell 1962).

ANOUS TENUIROSTRIS Lesser Noddy

Apart from one on 12 July 1964 at 13° S, 57½° E, i.e. 200 miles from the nearest known breeding station on Cargados Carajos, I saw *A. tenuirostris* on only three further occasions, all off Mauritius (Fig. 9). This and the lack of previous records at sea in the western Indian Ocean largely support earlier conclusions that this species frequents its breeding colonies throughout the year (Ashmole 1962, Serventy & Whittell 1962).

GYGIS ALBA White Tern

I saw large numbers of *G. alba* only around islands where they breed, and particularly on the Seychelles Bank, usually in flocks of other species. More than 50 miles from land I saw only a few flocks: off the Seychelles Is. in March, and off Mauritius and Cargados Carajos in July (Fig. 9). Nevertheless, they seemed to disperse slightly further from land than *A. stolidus* (see Table 6).

OTHER SPECIES OF TERNS

My observations of the Roseate Tern *Sterna dougalli*, the Little Tern *S. albifrons* and the Crested Tern *Thalasseus bergii* add little to what is already known. None of them were seen far from land.

DISCUSSION

Most of the sea-birds seen in the central Indian Ocean belong to the resident pantropical breeding species. Migrants from the south were seen during migration periods, but few appeared to spend the northern summer in the Tropical Zone south of the equator. Instead, they moved on to moult in the Arabian Sea, and especially the Arabian coast upwelling area noted for its richness of marine life at that time of year (Bourne 1960, Bailey 1966). They may thus have been taking advantage of the seasonal increase in the food available; further south, where less extreme seasonal changes occur, there is unlikely ever to be a large surplus of available food which is not taken by the relatively constant populations of resident breeding species.

Conversely, the pantropical species were mostly confined to warm-water areas, as found by Murphy (1936) off western South America. Although it seems likely that the seasonal occurrence of upwelling of cold subsurface water in the northern Arabian Sea has in some way led to the formation of a distinct sea-bird fauna there (Bailey 1966), it is by no means clear why the warm-water forms do not feed in the rich seas of the upwelling areas. Flying-fish, which are important items of food to many warm-water sea-birds (Ashmole & Ashmole 1967), are virtually absent from the cool-water upwelling area off Arabia (Bailey 1966), so warm-water sea-birds may be excluded by the absence of sufficient food. Since food for other forms of sea-birds is evidently rich in these areas, however, as indicated by the large numbers of birds found in them, different adaptations may be needed for feeding in the clear blue water of mid-ocean and the more opaque plankton-rich seas of the upwelling areas.

It was rarely possible to recognise clear patterns of sea-bird distribution at sea, although *Puffinus pacificus* and *Phaethon lepturus* appeared in March and April 1964 to be concentrated in the eastward-flowing Equatorial Counter-current (Fig. 5), and in March *Gygis alba* was concentrated at the northern boundary of this current at 58° E. While it would be unwise to generalise on the basis of so few transects, these observations agree with earlier findings in the Pacific Ocean, where King & Pyle (1957) found birds most numerous in the region of the Counter-current and especially at its northern boundary, but less common in the zone of divergence on the equator. These authors also found that the differences in the abundance of birds were correlated with similar differences in the abundance of plankton and shoals of predatory fish at the sea-surface.

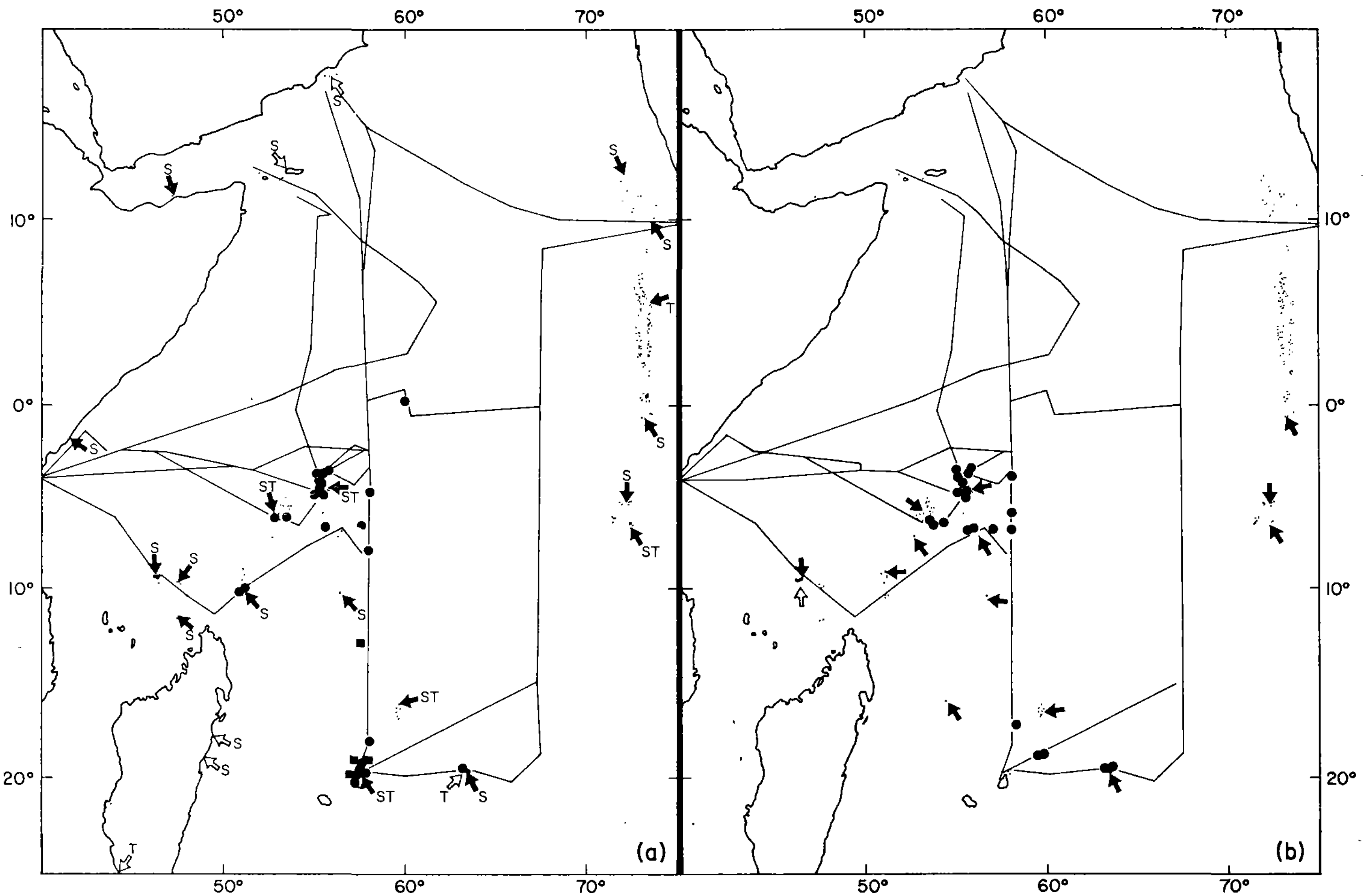

Figure 9. Records of *Anous* spp. and *Gygis* observed from the R.R.S. 'Discovery' in the western Indian Ocean in 1963 and 1964.
(a) *Anous stolidus* ● and *A. tenuirostris* ■.
Breeding stations ⬆ ; possible breeding stations ⇧ : *A. stolidus* S; *A. tenuirostris* T.
(b) *Gygis alba*.
Breeding stations ⬆ ; possible breeding stations ⇧.
Tracks are a simplified version of those shown in Fig. 2.

In the Atlantic and Pacific Oceans a high rate of organic production has been reported in the surface layers at the equator (Hentschel 1933, quoted by Sverdrup ***et al.*** 1942; King & Demond 1953), where upwelling of subsurface water facilitates an increased growth of phytoplankton by replenishing the euphotic layer with nutrient salts. In the Pacific Ocean there is additional evidence of upwelling at the northern boundary of the Equatorial Counter-current, with sinking at its southern boundary, but it is difficult to compare this with the Indian Ocean because the Counter-current occurs in the Northern and Southern Hemispheres in the Pacific and Indian Oceans respectively. Nevertheless, the observations made on board the ' Discovery ' suggest that local replenishment of nutrients at the equator occurs in the Indian Ocean at least in certain months; as in the Pacific Ocean resident sea-birds were no more abundant there than elsewhere. Storm-petrels (*Oceanodroma* spp.) were however, concentrated on the equator (Bailey, Pocklington & Willis 1968), and this may have been because they feed on planktonic organisms.

Whereas King & Pyle (1957) stressed the importance of upwelling in concentrating sea-birds in the equatorial region, the Ashmoles (1967) now consider that it is the sinking of water at convergences which is most important in attracting sea-birds, because it tends to concentrate floating and buoyant organisms. The concentrations of sea-birds I recorded in an area of convergence in March 1964 support this suggestion.

Although there is little information, it seems likely that several days or perhaps weeks elapse between the upwelling of subsurface water and the subsequent development or concentration of organisms upon which sea-birds can feed. Depending on the speed of the surface currents this stage will be reached at varying distances from the area of upwelling, which in itself may be of no importance to sea-birds, most of which occupy a position high in the food-chain. This could also help to explain the apparent absence of any correlation between sea-bird numbers and plankton abundance.

The transects summarised above (see also Figs 4 to 8) demonstrate the tendency for sea-birds to be commoner at 58° E than at 68° E, and at the latter meridian to be commoner in the north than in the south. Though this pattern of distribution may in part be due to the fact that our transects passed closer to land in the east than in the west, it may also indicate the existence of an area in the central Indian Ocean, at the centre of the great gyral of surface currents, where sea-birds are rare, i.e. the equivalent of the Sargasso Sea in the north Atlantic Ocean (Jespersen 1929).

The frequency with which I saw sea-birds feeding at sea was very low, suggesting that most species spend much of their time, at least in daylight, searching for places where food may be present. For those species known to do most of their feeding during the day, this is perhaps the most direct evidence that food for tropical sea-birds is both scarce and patchy, as suggested by several recent studies of the breeding biology of tropical sea-birds (mostly summarised by Lack (1966)). On the few occasions on which I saw birds feeding, there were almost always large numbers and frequently several species together, especially near islands. Some flocks were clearly feeding among shoals of predatory fish at the sea-surface, the importance of which was realised by Ashmole (1963b).

The Ashmoles (1967) have convincingly demonstrated how interspecific competition between sea-birds breeding on Christmas Is., Pacific Ocean, is reduced, if not obviated, by their taking at least partly different foods, either by feeding in a different manner or in a different feeding zone. Evidence for the latter was mainly gleaned from the literature pertaining to other sea areas, or indirectly from the length of time the breeding adults spent away from their nests during the incubation and fledging periods. For several species the pelagic range was very poorly known. While the present study has not provided information on how far from land individual breeding adults of each species feed, it indicates a little more exactly how some sea-birds, at least in the Indian Ocean, fit into the pattern outlined by the Ashmoles. The relatively high degree of our coverage enables some tentative conclusions to be drawn, these are summarised in Table 6.

TABLE 6. *Feeding zones of resident sea-birds seen in the central western Indian Ocean from the R.R.S. ' Discovery ' in* 1963 *and* 1964

	No. of observations	Distances from land (in nautical miles) within which 50% and 90% of observations were made	
		50%	90%
Puffinus pacificus	74	120	380
Puffinus lherminieri	13	40	160
Phaethon lepturus	46	115	310
Sula dactylatra	25	150	510
Sula sula	28	225	300
Fregata spp.	38	150	320
Sterna fuscata	164	120	370
Anous stolidus	22	15	80
Gygis alba	21	20	110

Notes. Since unequal amounts of time were spent in each feeding zone, the figures above cannot be taken to represent the usual distances from land at which each species feeds; they are presumably valid for comparative purposes, however.

Phaethon rubricauda was seen on four occasions between 110 and 430 miles from land; *Sterna anaethetus* was seen on four occasions less than five miles from land, once at ten miles and once at 50 miles from land; *Anous tenuirostris* was seen twice, once at 30 miles from land, once less than five miles from land.

As the Ashmoles (1967) concluded, *Sterna fuscata* ranges much further out to sea than *Anous stolidus* (Table 6). There is some evidence also that *Gygis alba* feeds slightly further from land than *Anous stolidus,* in support of the Ashmoles' conclusion that it is intermediate in this respect between the offshore and truly pelagic species. Of the species not considered by the Ashmoles, *Puffinus pacificus, Phaethon lepturus, Sula dactylatra, Sula sula* and *Fregata* spp. are clearly pelagic in Wynne-Edwards' (1935) terminology, whereas *Puffinus lherminieri* and *Sterna anaethetus* (a close relative of the pelagic *S. fuscata*) are offshore.

Thus, the distances from land at which closely-related species feed suggest in some cases how they avoid competition. The three tropic-birds do not obviously differ in this respect, however, though *Phaethon aethereus* occurs in a different sea-area (the northwestern Indian Ocean) from *P. lepturus* and *P. rubricauda,* which themselves are very different in size, suggesting that they feed on largely different foods or sizes of food. Likewise, the boobies *Sula dactylatra* and *S. sula,* both of which feed far out to sea, seem to occur in complementary areas at sea.

ACKNOWLEDGMENTS

I would first like to thank Dr. David Lack for his invaluable advice throughout the present study, for reading and criticising an early draft of the manuscript, and for making available every facility at the Edward Grey Institute while I was working up the results. I am also grateful to Mr. R. I. Currie, who gave me all facilities and advice while I was working on the ' Discovery '. To him and to the Director of the National Institute of Oceanography I am grateful for including my work in the programme of the ' Discovery ' during the International Indian Ocean Expedition.

I wish to thank Dr. W. R. P. Bourne, who not only introduced me to my subject, but has also given me continued encouragement and advice. I am also grateful to Mr. R. E. Moreau for suggesting that I should apply for the post on the ' Discovery ', and for giving me invaluable advice throughout. I am grateful to both of them for reading this paper in manuscript.

During my time on the ' Discovery ' I received help from many members of the scientific staff and from the Ship's officers and crew. I am particularly grateful to Dr. J. C. Swallow and the late Dr. M. N. Hill, who led the scientific work on part of the cruises and to Mr. P. M. David for helpful advice during the field work and for reading an early draft of this paper. I was also entirely dependent on the Ship's captains—Captain C. Alexander, D.S.C., and Captain R. R. A. Davies in 1963 and 1964 respectively—for allowing me access to all parts of the ship.

During the preparation and writing-up of the present study I was helped by many other people, but I would especially like to thank Captain G. S. Tuck, D.S.O., R.N., for giving me access to the reports of the Royal Naval Bird-watching Society, and to Mr. J. D. Macdonald, who gave me access to the collections of the British Museum (Nat. Hist.). I am also grateful to Dr. M. Bulmer of the Unit of Biometry at Oxford for advice on the statistical treatment of my data.

My especial thanks are due to my wife, who typed several drafts of this paper.

From January 1963 to March 1965 I was generously supported by the Nuffield Foundation, and from April to October 1965 by the British Ornithologists' Union. I am most grateful to both of these bodies.

SUMMARY

The present paper summarises observations made during the International Indian Ocean Expedition on board the R.R.S. ' Discovery ', from August to November 1963 and from February to September 1964 in the Indian Ocean north of 20° S and west of 70° E. In 1963 work was carried out in the Somali Basin. In 1964 a series of transects were made over the ocean, the main purpose of which was to investigate the system of equatorial currents and the changes in the sea associated with the onset of the Southwest Monsoon in May.

The Tropical Indian Ocean is briefly described. Except for local concentrations, the surface layers are poor in nutrient salts and plankton. There is a seasonal reversal of winds and surface currents in the Arabian Sea, but seasonal changes become less marked further south.

Previous ornithological observations in the western Indian Ocean are mostly confined to the Arabian Sea or to the island groups. Thus, existing information on the pelagic range of pantropical species is incomplete.

Observations made on each transect across the Indian Ocean in 1964 are summarised and compared with oceanographic data collected at the same time. General conclusions are not possible on the basis of so little information, though there appeared to be some relationship between the distribution of certain species and wind or current belts. The only marked discontinuity recorded was a concentration of *Puffinus pacificus* and *Gygis alba* at the northern edge of the Equatorial Counter-current at 58° E in March. Observations made on transects that were repeated before and after the onset of the Southwest Monsoon suggested that *Sterna fuscata* concentrates in the equatorial region as the monsoon develops. In general, both plankton and sea-birds were more abundant at 58° E than at 67½° E.

An analysis of the presence or absence of sea-birds during each observation period, which lasted an average of one hour, established the difference between pelagic species and those largely restricted to within 50 miles of their breeding stations. There was no evidence of any correlation with zooplankton abundance, though birds of all species taken together were commonest where flying-fish were most abundant and *S. fuscata* appeared to be commonest in cool-water areas with strong winds, i.e. the Trade-wind belts. It was not possible to sample the food organisms of sea-birds quantitatively.

Sea-bird observations in the Indian Ocean more than 200 miles from the continental coasts are summarized and compared with previous observations.

The little information collected in the Indian Ocean agrees with previous work in the Pacific Ocean, where sea-birds are commonest in areas of convergence, and not where local upwelling and an associated concentration of plankton occur, such as on the equator. This may be due to the fact that populations of organisms on which sea-birds feed develop or concentrate a considerable time after upwelling of nutrient-rich water occurs.

Since few sea-birds were seen feeding, it seems likely that available food is scarce and that much time is required to locate areas where it is abundant.

Finally, evidence is presented to indicate how some sea-bird species may avoid or reduce competition by feeding at different distances offshore, or in different geographical areas.

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Reprinted from *Marine Biol.*, vol. 2, no. 3, 1969, p. 252-263

Les Appendiculaires du Golfe du Bengale

Expédition Internationale de l'Océan Indien (croisières du «Kistna», juin-août 1964)

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Abstract

The appendicularians of the Bay of Bengal. International Indian Ocean Expedition (voyages of "Kistna", June-August 1964)

Appendicularians from 76 hauls made from June to August 1964 in the Bay of Bengal, aboard the R. V. "Kistna", have been examined. Of the 26 species determined, 10 are new for the Bay of Bengal and, amongst these, 2 were unknown in the Indian Ocean. The composition of the group formed by the most abundant and most frequent species is characteristic of the fauna of the Indian Ocean. *Oikopleura longicauda* represents 50% of the total number of individuals collected, followed by *O. rufescens* 14%, *Megalocerus huxleyi* 8%, *O. fusiformis* and *Fritillaria borealis* f. *sargassi* 6%, *O. cophocerca* and *Stegosoma magnum* 2%. No other species reached 1%. The density of the species in the occidental zone decreased fairly regularly with latitude: 21 species in the south, then going on towards the north, 14, 11 and 2. In the area south of the strait of Malacca only 5 species were found, in its opening into the Bay of Bengal, 18. The Oikopleuridae were present in all the hauls, but the Fritillaridae were absent from 25. The geographical distribution of each species has been studied. *Oikopleura* longicauda is the only one which is clearly more abundant in the north; most of the other species show a decreasing gradient from south to north. The characteristic difference between the different zones cannot be established from the hydrological data (temperature and salinity). It seems, therefore, that the indigenous species are not very common, and that others originate from the Indian Ocean, transported by the south-north currents present at that time of year.

Introduction

La répartition des Appendiculaires dans l'océan Indien est assez peu connue et le golfe du Bengale est la région qui, jusqu'à présent, avait été la moins prospectée de cet océan. Les renseignements dont on dispose actuellement se limitent à quelques lignes de Lohmann (1931), relatives à 3 stations effectuées entre les îles Nicobar et Ceylan, ainsi qu'à une courte note de Ganapati et Bhavanarayama (1958) concernant les Appendiculaires des eaux de Waltair (Vishakhapatnam). Enfin Tokioka (1955) relate les résultats de 2 prises panctoniques pratiquées à proximité des îles Nicobar.

Lohmann (1931) indique la présence de 15 espèces dans les stations 214 (7°43′2″ N; 88°44′9″ E) et 215 (7°1′2″ N; 85°56′5″ E). La station 213 n'ayant rapporté aucun Appendiculaire. Les espèces signalées sont les suivantes: *Megalocercus huxleyi, Stegosoma magnum, Pelagopleura verticalis, Oikopleura albicans, O. cophocerca, O. fusiformis, O. gracilis, O. longicauda, O. rufescens, Fritillaria borealis, F. formica, F. fraudax, F. gracilis, F. haplostoma, F. pellucida.*

Ganapati et Bhavanarayama (1958) signalent dans la baie de Lawson, à proximité de Waltair, la présence durant toute l'année de *Oikopleura longicauda, O. fusiformis* et *O. dioica*. Au cours de la période s'étendant de juillet-août à décembre, caractérisée par une basse salinité et une température élevée, ils ont trouvé en plus, *O. cophocerca, Fritillaria lucibila* et *F. campila* (toutes deux synonymes de *F. haplostoma*) et *F. formica*. Le reste de l'année, lorsque la température de la mer est plus basse et la salinité plus élevée, les auteurs ont récolté *F. borealis* f. *sargassi, F. pellucida, F. haplostoma, F. limpida (= F. haplostoma), Althoffia pacifica (= Pelagopleura gracilis)* et *O. rufescens*.

Tokioka (1955) mentionne la capture de *Oikopleura fusiformis, O. cophocerca* et *O. formica*. Le nombre des espèces décrites dans cette région s'élève ainsi à 17.

Matériel et méthodes

Dans le cadre de l'I.I.O.E., les navires «Anton Bruun» et «Kistna» ont effectué en 1963 et 1964, une série de croisières océanographiques dans le golfe du Bengale. Les Appendiculaires provenant du plancton récolté au cours de ces campagnes ont été triés à l'Indian Ocean Biological Center d'Ernakulam. Ils nous ont été confiés pour étude par le comité consultatif de l'I.I.O.E.

Le matériel de l'«Anton Bruun» est malheureusement dans un tel mauvais état qu'une détermination même approximative des individus est impossible. Celà est d'autant plus regrettable que le trajet de ce navire incluait des zones complémentaires à celles prospectées par le «Kistna».

Il nous a donc été possible d'étudier les Appendiculaires des croisières 15, 16, 17, 19 et 20 du «Kistna», représentant 76 stations planctoniques. Celles-ci sont réparties, pour les trois premières campagnes, sur des radiales Ouest-Est s'échelonnant du nord du golfe jusqu'à la hauteur de Ceylan. Les deux dernières s'étirent de part et d'autre des îles Nicobar et s'enfoncent plus ou moins profondément dans le détroit de Malacca (Fig. 1).

Les pêches ont été verticales, de 200 m à la surface, lorsque les fonds le permettaient, ce qui est le cas le plus fréquent. Le filet utilisé est le filet standard adopté par tous les navires participant à l'Expédition Internationale (Currie, 1963).

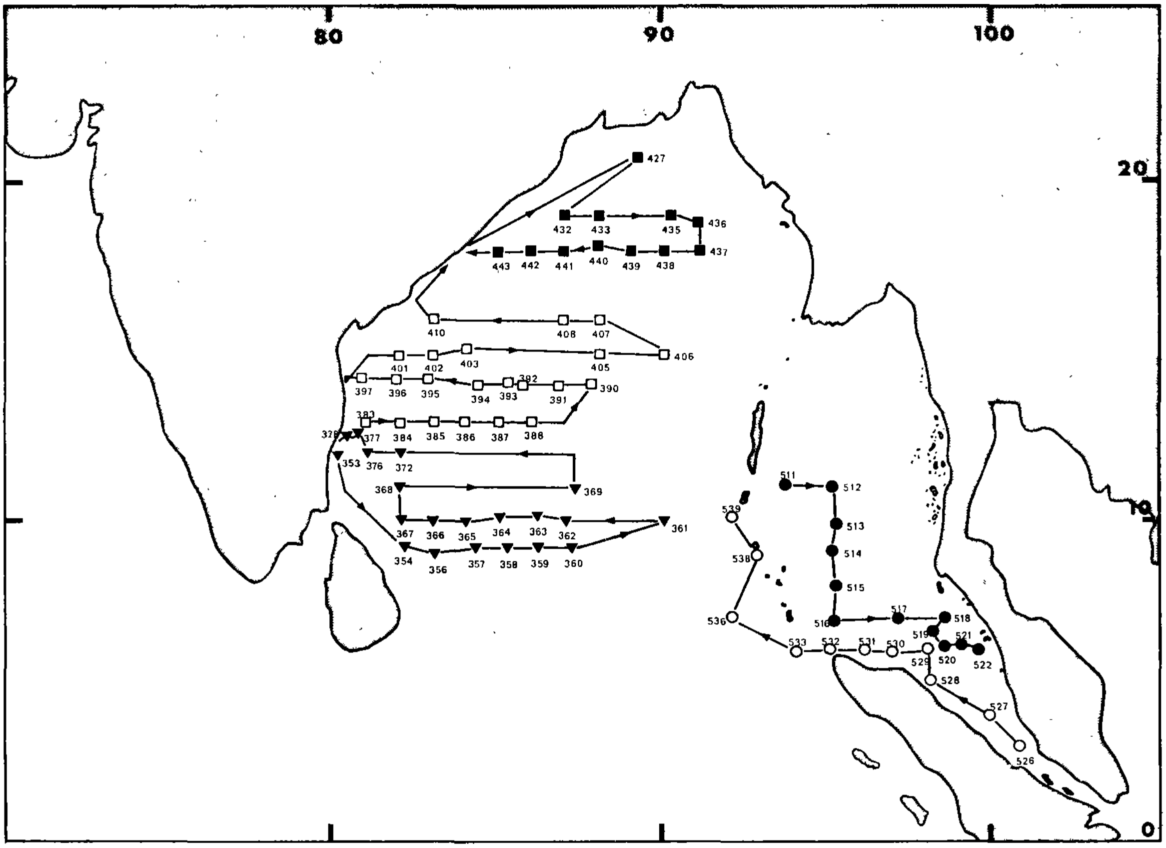

Fig. 1. Stations exploitées pendant les différentes croisières. ▼ «Kistna» n° 15; □ n° 16; ■ n° 17; ● n° 19; ○ n° 20

Le tri réalisé à l'I.O.B.C. a été effectué sur des portions de chaque pêche variant de 15% à 90%. Nous avons donc été dans l'obligation de ramener toutes les campagnes à 100% pour établir des comparaisons valables. Tous les chiffres ont été arrondis à l'unité supérieure dans les cas ou le calcul nous avait donné des décimales.

Deux faits importants sont à signaler: La conservation des individus est variable suivant les pêches et le pourcentage des individus non déterminables varie de 0 à 24%, la moyenne générale étant de 7%. D'autre part, nous avons pu examiner, à Ernakulam, le reste des pêches après tri des différents groupes. Nous y avons trouvé un assez grand nombre d'Appendiculaires de petite taille. Les estimations quantitatives sont donc grevées de cette erreur dès le départ et représentent ainsi en dehors d'autres considérations, un minimum.

Résultats

Liste des espèces rencontrées.

Famille des Oikopleuridae LOHMANN, 1933
Sous famille des Oikopleurinae LOHMANN, 1933
Genre *Pelagopleura* LOHMANN, 1926
  Pelagopleura sp.
Genre *Stegosoma* CHUN, 1888
  Stegosoma magnum (LANGERHANS, 1880)
Genre *Megalocercus* CHUN, 1888
  Megalocercus huxleyi CHUN, 1888
Genre *Oikopleura* MERTENS, 1831
  O. albicans (LEUCKART, 1854)
  O. cophocerca (GEGENBAUR, 1855)
  O. dioica FOL, 1872
  O. fusiformis FOL, 1872
  **O. fusiformis* f. *cornutogastra* (AIDA, 1907)
  O. graciloides LOHMANN et BÜCKMANN, 1924
  **O. intermedia* LOHMANN, 1896
  O. longicauda (VOGT, 1854)
  **O. parva* LOHMANN, 1896
  O. rufescens FOL, 1872

Famille des Fritillaridae SEELIGER, 1895
Genre *Tectillaria* LOHMANN, 1926
  **Tectillaria fertilis* (LOHMANN, 1896)
Genre *Fritillaria* QUOI et GAIMARD, 1833—1836
  F. borealis f. *sargassi* LOHMANN, 1905
  **F. charybdae* LOHMANN, 1899
  F. formica f. *digitata* LOHMANN et BÜCKMANN, 1926
  F. fraudax LOHMANN, 1896

F. gracilis LOHMANN, 1896
F. haplostoma FOL, 1872
**F. megachile* FOL, 1872
**F. pacifica* TOKIOKA, 1958
F. pellucida (BUSCH, 1851)
**F. pellucida* var. *omani* FENAUX, 1966
F. tenella LOHMANN, 1896
**F. venusta* LOHMANN, 1896.

26 espèces ont donc été récoltées. 10 nouvelles pour le golfe du Bengale sont précédées d'une astérique dans la liste ci-dessus et, parmi celles-ci, 2 n'avaient pas encore été signalées dans l'Océan Indien.

47270 Appendiculaires ont été déterminés, parmi eux 43369 Oikopleuridae représentant 91% de la population totale et 3901 Fritillaridae. Notons l'absence des Kowalevskiidae qui n'ont jamais été signalés jusqu'à présent, dans l'Océan Indien. Sept espèces représentent 88% du nombre total: *O. longicauda*, à elle seule 50%; *O. rufescens*, 14%; *M. huxleyi*, 8%; *O. fusiformis* et *F. borealis* f. *sargassi*, 6%; *O. cophocerca* et *S. magnum* 2%. Aucune des autres espèces n'atteint 1%. On trouvera les chiffres correspondant à chaque croisière dans le Tableau 1.

La fréquence (nombre de pêches positives) des différentes espèces rencontrées dans les 76 stations analysées est la suivante: *O. longicauda* 76, *M. huxleyi* 73, *O. rufescens* 71, *O. cophocerca* 58, *O. fusiformis* 54, *O. intermedia* 37, *F. formica* f. *digitata* 36, *S. magnum* 36, *F. borealis* f. *sargassi* 30, *F. pellucida* 13, *F. pellucida* var. *omani* 13, *O. fusiformis* f. *cornutogastra* 10, *F. venusta* 8, *O. albicans* 6, *Pelagopleura* sp. 4, *F. haplostoma* 4, *F. tenella* 4, *T. fertilis* 4, *O. parva* 3, *F. gracilis* 3, *O. graciloides* 3, *F. fraudax* 1, *F. pacifica* 1, *O. dioica* 1, *F. charybdae* 1, *F. megachile* 1.

Densité des populations

Les prélèvements n'ont jamais été effectués dans les eaux côtières. L'absence pratiquement totale de *Oikopleura dioica* (2 individus), espèce dont le caractère néritique affirmé est bien connu, en est une illustration. Nous n'avons donc pas de renseignements sur cette zone importante. En haute mer, nous voyons (Fig. 2) que la densité des populations est assez hétérogène. Cependant, dans la partie occidentale du golfe, les zones de forte densité (plus de 1000 individus par pêche) sont généralement situées sur une ligne sensiblement parallèle à la côte, à quelques 500 km au large. Encore faut-il signaler une exception en face de

Tableau 1. *Détail du nombre des individus des différentes espèces, récoltées durant les croisières*

Espèce	Croisière					Total
	15	16	17	19	20	
Oikopleura albicans	47					
O. cophocerca	553	144	50	292	165	1204
O. dioica	2					2
O. fusiformis	1289	342	326	405	584	2946
O. fusiformis cornutogastrata		5	2	19	15	41
O. graciloides	18				2	20
O. intermedia	128	59	22	45	29	283
O. longicauda	3368	6020	6942	4053	3164	23547
O. parva			8	2		10
O. rufescens	1702	1059	1516	2018	477	6772
Pelagopleura sp.		7			1	8
Megalocercus huxleyi	1640	1102	287	477	292	3798
Stegosoma magnum	879	138	38	44	160	1259
Indéterminés	651	454	1249	711	367	3432
Tectillaria fertilis	66					66
Fritillaria borealis sargassi	2429	112	44	148	201	2934
F. charybdae	2					2
F. formica digitata	211	33	70	67	82	463
F. fraudax	4					4
F. gracilis	11			2		13
F. haplostoma	24				7	31
F. megachile					3	3
F. pacifica				2		2
F. pellucida	49	3		14	44	110
F. pellucida omani	18			34	105	157
F. tenella	17				8	25
F. venusta	10	35		2	44	91
Nbre Oikopleuridae	10277	9330	10440	8066	5256	43369
Nbre Fritillaridae	2841	183	114	269	494	3901
Total	13118	9513	10554	8335	5750	47270

Madras où la zone riche se trouve bien plus près de la côte.

Dans la région sud-est, les aires d'abondance se situent à l'entrée du détroit de Malacca et de part et d'autre des Nicobar.

Trois stations ont permis la récolte de plus de 3000 individus par pêche: les stations 378, 4328; 518, 3276; 437, 2752. Deux autres contenaient moins de 10 Appendiculaires: 393, 4; 402, 3.

Tableau 2. *Distribution des Appendiculaires dans les différentes stations*

Espèce	Croisière 15																			
	353	354	356	357	358	359	360	361	362	363	364	365	366	367	368	369	372	376	377	378
Oikopleura albicans						●	●		●			●	●		●					
O. cophocerca	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
O. dioica																				●
O. fusiformis	●	●		●	●	●	●	●	●	●	●	●	●	●	●		●	●		●
O. fusiformis cornuto-gastrata																				
O. graciloides						●														●
O. intermedia	●	●		●	●		●				●		●	●	●	●	●		●	●
O. longicauda	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
O. parva																				
O. rufescens		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Pelagopleura sp.																				
Megalocercus huxleyi	●	●	●	●	●	●	●		●	●	●	●	●	●	●	●	●	●	●	●
Stegosoma magnum	●	●		●	●	●		●	●	●	●		●	●	●	●	●	●		●
Tectillaria fertilis						●	●						●							
Fritillaria borealis sargassi		●				●	●			●	●			●				●	●	●
F. charybdae											●									
F. formica digitata		●				●				●	●		●	●				●	●	●
F. fraudax		●																		
F. gracilis		●		●																
F. haplostoma		●																		●
F. megachile																				
F. pacifica																				
F. pellucida		●				●	●				●			●						●
F. pellucida omani						●				●										●
F. tenella		●								●	●									
F. venusta		●													●					●
Nbre Oikopleuridae	6	7	3	7	7	8	7	5	7	6	5	6	8	7	8	6	7	6	5	9
Nbre Fritillaridae	0	8	0	1	0	5	3	0	0	4	7	0	2	3	1	0	0	2	2	6
Total	6	15	3	8	7	13	10	5	7	10	12	6	10	10	9	6	7	8	7	15

Densités des espèces

Le nombre des espèces récoltées dans une station varie de 1 (station 393) à 15 (station 354 et 378). Si on examine des zones étendues dans la partie occidentale du golfe, la densité des espèces décroît assez régulièrement avec la latitude (Fig. 3). Ainsi, 21 espèces ont été trouvées durant la croisière n° 15 effectuée approximativement entre les latitudes 09° N et 12°40′ N; 14 pendant la croisière n° 16 qui a eu lieu entre les latitudes 13° N et 16° N et 11 dans la croisière n° 17 qui s'est déroulée entre les latitudes 18° N et 19° N. La première station qui se situe à 20°40′ N, a apporté 2 espèces seulement.

En ce qui concerne la zone sud-est du golfe (croisières n° 19 et 20) un maximum d'espèces (18) a été trouvé au début du détroit de Malacca, côté golfe; un minimum (5) au fond du détroit, et un nombre moyen (14) autour des îles Nicobar.

Les Oikopleuridae sont présentes dans tous les prélèvements. Le nombre des espèces varie de 1 à 9. Les zones où elles sont nombreuses (plus de 6 dans chaque pêche) sont situées au sud du 13° parallèle, dans une aire centrale entre le 15° et le 20° parallèle et dans les deux branches d'une tenaille partant du détroit de Malacca, pour atteindre les Nicobar et les Andaman. Les espèces sont en nombre restreint dans la partie nord du golfe et dans une langue ouest-est au niveau des bouches du Godavari.

Les Fritillaridae sont absentes dans 25 pêches et le nombre maximal d'espèces est de 8 à la station 354 à proximité de Ceylan. La plupart des stations qui n'ont pas fourni de Fritillaires sont situées au centre du golfe ainsi que dans une avancée est-ouest se dirigeant vers la côte aux environs du 14° parallèle. On peut observer un gradient sud-nord dans la densité des espèces de Fritillaires. La région Sud-Est a permis de reconnaitre 10 espèces. Dans la région occidentale: la partie Sud a fourni 11 espèces, la partie centrale 4 espèces et la partie Nord 2 espèces seulement.

Répartition des différentes espèces

Oikopleura longicauda (Vogt, 1854)

A de très rares exceptions près, cette espèce est la plus commune de toutes les régions océaniques chaudes et tempérées. Dans les aires de l'Océan Indien où les Appendiculaires ont été prospectés, elle est d'assez loin la plus fréquente, avec un pourcentage de 90 à 100% (Fenaux, 1964; Tokioka, 1956). Nous l'avons récoltée dans toutes les stations du golfe du Bengale et le nombre des individus atteint 50% du nombre total des Appendiculaires.

Tableau 3. *Distribution des Appendiculaires dans les différentes stations*

Espèce	Croisière 16																					
	383	384	385	386	387	388	390	391	392	393	394	395	396	397	401	402	403	405	406	407	408	410
Oikopleura albicans			●	●	●	●	●	●	●				●	●			●	●	●	●	●	●
O. cophocerca																						
O. dioica				●	●	●	●	●				●	●		●		●	●			●	●
O. fusiformis																					●	
O. fusiformis cornuto-gastrata																						
O. graciloides																						
O. intermedia	●		●	●	●	●		●	●				●				●				●	
O. longicauda	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
O. parva																						
O. rufescens	●	●	●	●	●	●	●		●		●	●	●	●	●	●	●	●	●	●	●	
Pelagopleura sp.				●			●						●									
Megalocercus huxleyi	●	●	●	●	●	●	●	●	●		●	●	●	●		●	●	●	●	●	●	●
Stegosoma magnum	●	●	●	●									●									
Tectillaria fertilis																						
Fritillaria borealis sargassi	●		●	●	●				●													
F. charybdae																						
F. formica digitata				●		●		●	●				●				●				●	●
F. fraudax																						
F. gracilis																						
F. haplostoma																						
F. megachile																						
F. pacifica																						
F. pellucida													●	●								
F. pellucida omani																						
F. tenella																						
F. venusta																				●		
Nbre Oikopleuridae	5	4	6	8	6	6	6	5	5	1	3	4	8	4	3	3	6	5	4	4	7	4
Nbre Fritillaridae	1	0	1	2	1	1	0	1	2	0	0	0	2	1	0	0	1	0	0	0	2	1
Total	6	4	7	10	7	7	6	6	7	1	3	4	10	5	3	3	7	5	4	4	9	5

Si on compare la moyenne par pêche (M) des individus provenant des croisières 15, 16 et 17, on s'aperçoit qu'il existe une assez nette variation latitudinale de ce nombre. Dans la zone Sud (Cr. 15) M = 183; dans la zone centrale (Cr. 16) M = 273; dans la zone Nord (Cr. 17) M = 578. Dans le secteur Sud-Est, la moyenne est légèrement plus élevée M = 378 dans la zone du détroit de Malacca, tandis qu'autour des Nicobar et des Andaman M = 267.

Megalocercus huxleyi (Ritter, 1905)

Cette espèce se rencontre uniquement dans le Pacifique, l'Océan Indien et la mer Rouge. Nous l'avons trouvée ici dans 73 prélèvements. Le pourcentage de fréquence atteint donc 96%, valeur beaucoup plus élevée que dans les autres régions connues de l'océan Indien. Tokioka (1956) indique 13% autour des îles Chagos et Fenaux (1964), 62% dans la mer d'Oman, 39% dans le golfe d'Aden et seulement 1% dans le golfe d'Oman et le golfe Persique.

Le nombre des individus récoltés représente un pourcentage de 8% du total des Appendiculaires, ce qui place cette espèce au troisième rang d'abondance. Nous avons pour *Megalocercus huxleyi* retrouvé une variation latitudinale du nombre moyen par pêche. Au contraire de ce que nous avons observé pour *Oikopleura longicauda*, il y a décroissance de cette moyenne depuis le sud vers le nord. Les valeurs atteintes étant respectivement de 82, 50 et 24. Dans la région Sud-Est, le fond du détroit de Malacca et les stations bordant la côte Nord de Sumatra sont pauvres en *M. huxleyi*: M = 6, alors que cette espèce est plus abondante dans le reste de la zone prospectée: M = 47.

Oikopleura rufescens Fol, 1872

Cette espèce est généralement très fréquente dans les océans Pacifique et Indien, un peu moins dans l'océan Atlantique, alors qu'elle est assez rare en

Méditerranée. Dans la région concernée, nous l'avons déterminée dans 71 pêches. Son pourcentage de fréquence est donc de 93%; il atteignait 76% dans le golfe d'Oman (Fenaux, 1964) et 84% autour des Chagos (Tokioka, 1956).

Oikopleura rufescens est nettement plus abondante que *Megalocercus huxleyi* car son pourcentage atteint 14% du nombre total des Appendiculaires récoltés. La partie centrale de la région Ouest du golfe est plus pauvre que les autres, puisque les valeurs moyennes atteignent du sud au nord: 85, 47, 126. Deux aires se différencient plus nettement dans la région Sud-Est. La moyenne des individus récoltés dans le détroit de Malacca atteint 194, alors que dans le reste de l'aire elle est de 32.

Tableau 4. *Distribution des Appendiculaires dans les différentes stations*

Espèce	Croisière 17											
	427	432	433	435	436	437	438	439	440	441	442	443
Oikopleura albicans												
O. cophocerca			●	●		●		●	●	●	●	●
O. dioica												
O. fusiformis		●	●	●	●	●		●	●	●	●	●
O. fusiformis cornutogastrata			●									
O. graciloides												
O. intermedia						●	●			●		
O. longicauda	●	●	●	●	●	●	●	●	●	●	●	●
O. parva						●						
O. rufescens		●	●	●	●	●	●	●	●	●	●	●
Pelagopleura sp.												
Megalocercus huxleyi	●	●	●	●	●	●	●	●	●	●	●	●
Stegosoma magnum			●			●			●	●		
Tectillaria fertilis												
Fritillaria borealis sargassi						●		●				
F. charybdae												
F. formica digitata		●	●	●		●		●	●	●	●	
F. fraudax												
F. gracilis												
F. haplostoma												
F. megachile												
F. pacifica												
F. pellucida												
F. pellucida omani												
F. tenella												
F. venusta												
Nbre Oikopleuridae	2	4	7	5	4	8	4	5	6	7	5	5
Nbre Fritillaridae	0	1	1	1	0	2	0	2	1	1	1	0
Total	2	5	8	6	4	10	4	7	7	8	6	5

Oikopleura cophocerca (Gegenbaur, 1855)

Espèce commune des eaux chaudes et tempérées qui remonte cependant très haut vers le nord dans l'Atlantique. Elle est généralement parmi les espèces les plus fréquentes de l'océan Indien. Dans le golfe du Bengale sa fréquence a été de 75%. Par contre le nombre des individus récoltés est assez faible, il n'atteint que 2%.

Cette espèce paraît plus abondante dans la région Sud du golfe. Ainsi, les nombres moyens par pêche pour les croisières 15, 19 et 20 sont respectivement de 28, 27 et 17, alors que pour les croisières 16 et 17 ils sont de 7 et 4.

Oikopleura fusiformis Fol, 1872

Cette espèce est bien répandue dans les régions océaniques chaudes et tempérées. Sa répartition dans les océans Pacifique et Atlantique présente une curieuse inversion; elle est plus abondante dans le Sud du premier et dans le Nord du second. *Oikopleura fusiformis* a été assez régulièrement récoltée dans l'océan Indien avec des pourcentages de fréquence de 70% dans la mer d'Oman, 100% dans le golfe d'Aden, 80% dans le golfe d'Oman, alors qu'elle paraît assez rare dans le golfe Persique (Fenaux, 1964). D'après les chiffres de Tokioka (1956) le pourcentage de fréquence de cette espèce atteint 94% autour des Iles Chagos.

Dans le golfe du Bengale nous l'avons récolté dans 54 pêches, avec un pourcentage de 71%. C'est la dernière espèce dont la fréquence soit supérieure à 50%.

Le nombre des individus déterminés représente 6% du total des Appendiculaires. *O. fusiformis* arrive donc au quatrième rang dans l'échelle d'abondance. La densité des populations de cette espèce est nettement supérieure dans la zone Sud du golfe, aussi bien à l'ouest qu'à l'est, les moyennes variant de 38 à 65, alors que dans le centre et le Nord elles n'atteignent que 15 et 18.

Oikopleura intermedia Lohmann, 1896

Cette espèce, relativement bien répandue dans les eaux chaudes et tempérées de l'Atlantique et du Pacifique a, jusqu'à présent, été assez rarement signalée dans l'Océan Indien. Lorsqu'elle a été récoltée, c'est généralement avec un pourcentage de fréquence assez bas. Ainsi Tokioka (1956) mentionne sa présence dans une pêche, soit un pourcentage de 5% et Fenaux (1964) dans 13 prélèvements sur 79 ce qui correspond à une fréquence de 16%.

Oikopleura intermedia n'avait jamais été signalée dans le golfe du Bengale. Nous l'avons récoltée avec un pourcentage de fréquence atteignant 48%. Le nombre des pêches positives est surtout important dans la portion Sud de la région occidentale du golfe et au débouché du détroit de Malacca.

Le nombre des individus déterminés représente seulement 0,5% du total des Appendiculaires.

Fritillaria formica f. *digitata* Lohmann et Bückmann, 1926

C'est la forme la plus répandue de l'espèce, encore est-il difficile de porter un jugement certain, car plusieurs auteurs se bornent à signaler le nom spécifique dans leur répartition. Dans l'océan Indien, elle a été mentionnée avec certitude par Tokioka (1956) et par Fenaux (1964). Dans le golfe du Bengale, nous avons rencontré seulement cette forme; son pourcentage de fréquence est de 47%. Sa répartition géographique ne semble pas strictement délimitée, on l'a rencontrée dans toutes les croisières. La station n° 378 à hauteur de Madras, est de loin celle qui a fourni le plus grand nombre d'individus; 116, ce qui correspond au quart du nombre total récolté dans les 5 croisières.

Tableau 5. *Distribution des Appendiculaires dans les différentes stations*

Espèce	Croisières 19 + 20																					
	511	512	513	514	515	517	518	519	520	521	522	526	527	528	529	530	531	532	533	536	538	539
Oikopleura albicans																						
O. cophocerca	●	●	●	●		●	●	●	●	●					●	●	●	●	●	●	●	
O. dioica																						
O. fusiformis	●	●	●			●	●	●	●	●	●				●	●	●	●	●	●		
O. fusiformis cornutogastrata						●	●		●	●	●			●			●	●				
O. graciloides																		●				
O. intermedia		●				●	●	●	●	●	●				●	●	●	●				
O. longicauda	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
O. parva	●																					
O. rufescens	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Pelagopleura sp.														●								
Megalocercus huxleyi	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Stegosoma magnum							●		●	●	●	●	●	●		●	●	●		●		
Tectillaria fertilis																						
Fritillaria borealis sargassi	●			●	●			●	●	●				●	●	●	●	●	●	●		●
F. charybdae																						
F. formica digitata	●	●	●			●			●	●			●		●		●	●		●		
F. fraudax																						
F. gracilis									●													
F. haplostoma															●		●					
F. megachile															●							
F. pacifica				●																		
F. pellucida	●			●		●	●								●					●		
F. pellucida omani			●				●	●	●	●					●	●	●		●			
F. tenella																	●					
F. venusta	●													●	●		●					
Nbre Oikopleuridae	6	6	5	4	3	7	8	6	8	8	7	4	4	6	6	7	8	9	5	6	4	3
Nbre Fritillaridae	4	1	2	3	1	2	2	2	4	3	0	0	1	2	6	2	6	2	2	3	0	1
Total	10	7	7	7	4	9	10	8	12	11	7	4	5	8	12	9	14	11	7	9	4	4

Stegosoma magnum (Langerhans, 1880)

Espèce des régions régions océaniques chaudes et tempérées qu'on retrouve dans l'Antarctique. Elle est très commune dans l'Océan Indien. Fenaux (1964) la signale dans la mer d'Arabie avec un pourcentage de fréquence de 53%. Tokioka (1956) la récolte dans 63% des pêches effectuées au nord-ouest des Chagos. Lohmann et Bückmann (1926) trouvent cette espèce au sud du Capricorne, dans 56% des prélèvements. Ici nous l'avons récoltée avec une fréquence de 47%. Ce pourcentage atteint 100% dans certains régions, car cette espèce est répartie d'une façon assez stricte dans la zone Sud de la partie Ouest du golfe. Il faut cependant signaler 4 pêches positives dans le Nord.

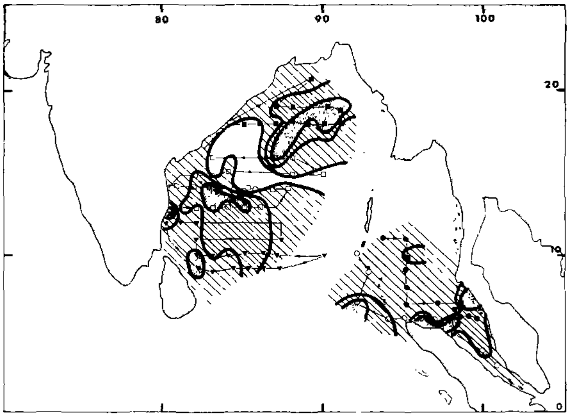

Fig. 2

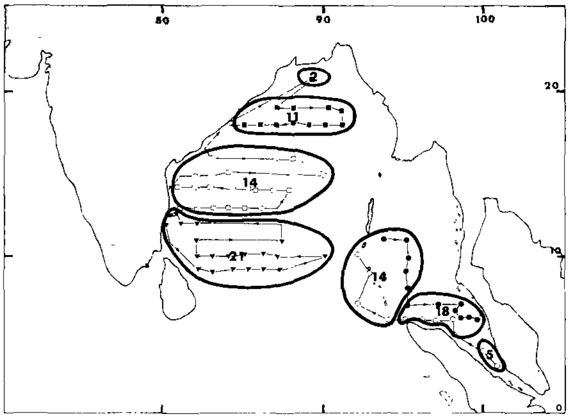

Fig. 3

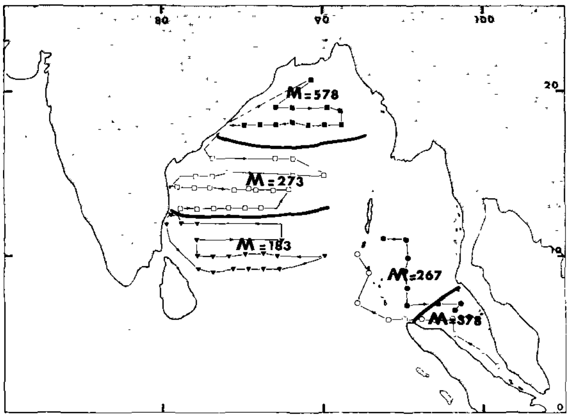

Fig. 4

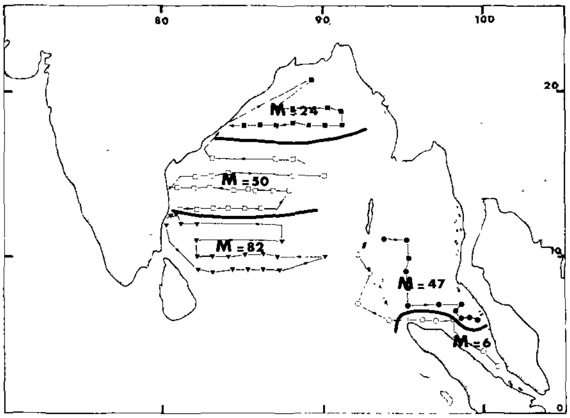

Fig. 5

Fig. 2. Densité des populations d'Appendiculaires
Fig. 3. Densités des espèces dans les différents secteurs
Fig. 4. Variation du nombre moyen de *Oikopleura longicauda* dans les différents secteurs
Fig. 5. Variation du nombre moyen de *Megalocercus huxleyi* dans les différents secteurs

Le nombre des individus qui ne dépasse pas 2% du total des Appendiculaires, est également beaucoup plus important dans le Sud où le maximum d'exemplaires récoltés dans une pêche est de 468 à la station 378, alors qu'il est de 16 dans le Nord à la station 437. Dans la partie Sud-Est, *Stegosoma magnum* est assez strictement limité à la zone du canal de Malacca.

Fritillaria borealis f. *sargassi* Lohmann, 1905

C'est une des deux formes thermophile de l'espèce, la seconde étant *intermedia*; la forme *typica* est cryophile.

Nous avons signalé cette espèce avec un pourcentage de fréquence de 50% dans la mer d'Oman et le golfe d'Aden, alors qu'elle était absente dans le golfe Persique (Fenaux, 1964). Au nord-est des Chagos, Tokioka (1956) a déterminé cette forme dans 47% des prélèvements.

Dans le golfe du Bengale nous l'avons rencontrée dans 39% des prélèvements et le pourcentage du nombre des individus récoltés atteint 6% du total des Appendiculaires. Cette représentation assez élevée est due, en grande partie, à une seule pêche. En effet la station 378 a fourni 1824 exemplaires sur un total de 2934.

La répartition de *Fritillarie borealis* f. *sargassi* est assez dispersée; néanmoins, on peut remarquer que les pêches positives sont toujours groupées et forment ainsi un certain nombre de zones qui, sauf une peu importante, sont situées au dessous du 14° parallèle.

Fritillaria pellucida (Busch, 1851)

Espèce assez commune dans les eaux chaudes et tempérées, on la rencontre également dans l'Antarctique.

Elle a été la fritillaire la plus commune récoltée dans la mer d'Arabie (Fenaux, 1964) avec un pourcentage de fréquence de 52%. Au nord des Chagos, Tokioka (1956) l'a déterminée seulement dans 21% des prélèvements. Elle semble encore plus rare dans le sud de l'océan Indien où, d'après les résultats de la Süd-Polar Expedition, elle a été présente dans 11% des pêches seulement.

Dans le golfe du Bengale, *Fritillaria pellucida* a été récoltée le long de la côte de Coromandel, dans 6 stations de la croisière n° 17, an sud du 11° parallèle. Dans le secteur Sud Est elle est relativement fréquente, mais absente dans le Sud du détroit de Malacca.

Le maximum d'individus récoltés dans une pêche est de 40 à la station 529.

Fritillaria pellucida var. *omani* Fenaux, 1966

Nous avons signalé cette variété récemment dans la partie nord-est de la mer d'Oman. Elle était présente dans 5 pêches sur un total de 79. Nous l'avons retrouvée ici plus fréquemment; dans 12 stations sur 76. D'autre part, alors que le rapport entre la fréquence de l'espèce typique et la variété était de 0,1 dans la mer d'Arabe, il est ici presque égal à 1. Le nombre des individus récoltés est même supérieur à celui de l'espèce normale: 157 pour 110.

La répartition de cette variété est, dans l'ensemble, comparable à celle de la forme typique. *Fritillaria pellucida* var. *omani* est totalement absente dans les régions du centre et du Nord du golfe du Bengale. Elle est relativement plus fréquente et plus abondante que la forme typique dans la partie Nord du détroit de Malacca.

Oikopleura fusiformis f. *cornutogastra* (Aida, 1907)

Cette forme a été signalée jusqu'à présent dans les océans Atlantique, Pacifique et Indien. Elle est généralement peu fréquente dans l'océan Indien. Dans le mer d'Arabie nous l'avons récoltée dans 7% des stations (Fenaux, 1964) et Tokioka (1956) dans 5% des pêches effectuées aux alentours des îles Chagos. Ici elle a encore été moins fréquente puisque sa présence n'est signalée que dans 1% des prélèvements avec 8 pêches positives. Six d'entre elles se situent au débouché du canal de Malacca dans le golfe et les deux autres dans la partie Nord du golfe.

C'est la première fois que cette forme est signalée dans le golfe du Bengale. Au total 41 exemplaires ont été déterminés.

Fritillaria venusta Lohmann, 1896

Cette espèce thermophile est cependant très eurytherme puisqu'on la rencontre dans l'Antarctique et la mer de Norvège.

Dans l'Océan Indien elle a été trouvée dans le golfe d'Aden et tout au long de la côte sud-est de l'Arabie avec, pour l'ensemble de la mer d'Arabie, un pourcentage de fréquence de 1,7% (Fenaux, 1964).

Nous la signalons pour la première fois dans le golfe du Bengale oú nous avons déterminé 91 individus répartis dans 8 stations, c'est à dire avec une fréquence qui ne dépasse pas 1%. Les pêches positives n'ont pas de répartition géographique remarquable.

Oikopleura albicans (Leuckart, 1854)

C'est une espèce qui se rencontre assez généralement dans toutes les eaux chaudes et tempérées. Elle a été signalée peu fréquemment dans l'océan Indien. Lohmann et Bückmann (1926) l'ont déterminée dans 2 pêches, sur les 6 effectuées au sud du tropique du Capricorne pendant la Süd Polar Expedition; soit un pourcentage de présence de 22%. Tokioka (1956) l'a rencontrée dans 31% des pêches (Iles Chagos) et Fenaux (1964) ne mentionne qu'un seul exemplaire dans le golfe d'Oman.

Dans le golfe du Bengale nous avons récolté 47 individus de cette espèce. Tous proviennent du matériel de la croisière n° 16, c'est-à-dire de la partie Occidentale du golfe, au sud du 11° parallèle.

Pelagopleura sp. Lohmann, 1926

Les 8 exemplaires de ce genre étaient dans un trop mauvais état pour permettre une détermination spécifique, notons simplement que, jusqu'à présent, seule les espèces *verticalis* et *gracilis* ont été signalées dans l'océan Indien. 7 individus proviennent des stations 386, 390 et 396 de la croisière n° 16, et 1 individu a été récolté à la station 528 de la croisière n° 20.

Fritillaria haplostoma Fol, 1872

Cette espèce présente une distribution assez large dans les eaux chaudes et tempérées. On la rencontre parfois dans l'océan Antarctique. On trouve généralement *Fritillaria haplostoma* en petit nombre dans les eaux du large; par contre, les eaux côtières sont parfois susceptibles d'en fournir une grande quantité.

Dans l'océan Indien, cette espèce a été signalée dans toutes les expéditions, mais toujours avec des pourcentages de fréquence inférieure ou à peu près égaux à l'unité. Nous avons récolté 31 individus dans le golfe du Bengale, dans 4 stations situées à une relative proximité des côtes et en dessous du 13° parallèle. Rappelons que *F. haplostoma* est fréquemment récoltée dans les eaux côtières de Waltair (Ganapati et Bhavanarayama, 1958).

Fritillaria tenella Lohmann, 1896

Bien que généralement peu fréquente, cette espèce se rencontre un peu partout, dans les eaux chaudes, tempérées ou froides sauf dans l'océan Arctique.

Dans l'océan Indien elle a été signalée dans la mer d'Arabie avec un pourcentage de fréquence inférieur à

1% (FENAUX, 1964) et au sud du Capricorne avec une fréquence plus élevée (LOHMANN et BÜCKMANN, 1926).

C'est la première fois que *Fritillaria tenella* est signalée dans le golfe du Bengale. Nous avons récolté 25 individus répartis dans 4 stations, 3 appartenant à la croisière n° 15 et 1 à la croisière n° 8. Toutes ces pêches se situent dans la partie Sud du golfe, en dessous du 11° parallèle.

Tectillaria fertilis (LOHMANN, 1896)

Cette espèce est nettement limitée aux aires océaniques chaudes ou tempérées.

Dans l'océan Indien *Tectillaria fertilis* est connue jusqu'à présent, uniquement par un exemplaire récolté dans le golfe d'Aden (FENAUX, 1964). Ici nous avons déterminé 66 individus, répartis dans trois stations effectuées durant la première partie de la croisière n° 15, au sud du 11° parallèle.

Oikopleura parva LOHMANN, 1896

C'est une espèce thermophile eurytherme assez peu courante mais qu'on rencontre dans tous les océans.

Dans l'océan Indien elle a été signalée dans le golfe d'Aden et la mer d'Oman (FENAUX, 1964), au nord des Iles Chagos (TOKIOKA, 1956) et au sud du tropique du Capricorne (LOHMANN et BÜCKMANN, 1926). Dans le golfe du Bengale nous avons récolté 10 individus répartis dans 2 stations: l'une située au nord, n° 437 et l'autre au Sud-Est n° 531 à la pointe de Sumatra.

Fritillaria gracilis LOHMANN, 1896

La distribution de cette espèce est très vaste. Elle a été signalée dans toutes les mers sauf les océans Arctique et Antarctique, mais elle est rare. Dans l'océan Indien elle a été mentionnée dans une pêche par TOKIOKA (1956).

Dans le golfe du Bengale nous en avons récolté 13 exemplaires répartis dans 3 stations, toutes situées au sud du 10° parallèle: stations n° 354 et 357 de la croisière 15 et station n° 520 de la croisière 19.

Oikopleura graciloides LOHMANN et BÜCKMANN, 1924

Nous assimilons cette espèce à *Oikopleura gracilis* (FENAUX, 1967a). Elle a été signalée dans tous les océans sauf l'Arctique. Dans l'océan Indien on l'a récoltée peu fréquemment; dans une pêche provenant du golfe d'Aden (FENAUX, 1964) et dans 3 pêches au nord-ouest des îles Chagos (TOKIOKA, 1956).

Ici, nous avons déterminé 20 exemplaires de cette espéce répartis dans trois prélèvements, deux provenant de la croisière n° 15 (stations 359 et 378) et le dernier de la croisière n° 20 (station 533).

Fritillaria fraudax LOHMANN, 1896

Cette espèce a été signalée dans tous les océans, sauf l'Arctique et la mer de Norvège, mais jamais en grande quantité. Dans l'océan Indien elle est mentionnée dans une pêche par TOKIOKA (1956) an nord-ouest des Chagos.

Dans le golfe du Bengale nous en avons rencontré 4 exemplaires à la station 353 au large de Madras.

Fritillaria pacifica TOKIOKA, 1958

Cette espèce était connue, jusqu'à présent, uniquement dans le Pacifique. Nous en avons récolté 2 exemplaires à la station n° 513 située à l'est du canal du 10° degré entre les Andaman et les Nicobar.

Oikopleura dioica FOL, 1872

C'est de loin la plus eurytherme et la plus euryhaline des espèces. On l'a signalée dans toutes les mers, sauf l'océan antarctique. Elle est généralement plus abondante dans les eaux tempérées que dans les eaux tropicales. Rare en mer ouverte, cette espèce est à la fois fréquente et très abondante dans les eaux côtières.

Elle a été signalée dans presque toutes les croisières de l'océan Indien, mais toujours peu fréquemment car les prélèvements interessaient généralement des eaux du large. C'est encore ce qui se passe dans le golfe du Bengale où nous avons récolté seulement 2 individus à la station 378 au nord-est de Madras.

Fritillaria charybdae LOHMANN, 1899

Cette espèce a été signalée jusqu'à présent dans la Méditerranée (LOHMANN, 1899; FENAUX, 1963) et la mer du Japon (TOKIOKA, 1951). Nous en avons rencontré 2 exemplaires à la station 364, approximativement sur le 10° parallèle, au nord-est de Ceylan.

Fritillaria megachile FOL, 1872

Espèce qui se récolte en petit nombre dans les diverses régions océaniques chaudes et tempérées. On la rencontre aussi dans l'océan Antarctique.

TOKIOKA l'a signalée en 1956 dans deux prélèvements effectués au nord-ouest des Chagos. Ici, nous avons déterminé 2 individus appartenant à cette espèce dans le matériel de la station 529, située au débouché du canal de Malacca dans le golfe du Bengale.

Discussion et conclusions

Compte tenu de leur fréquence et de leur abondance dans les eaux du large, les Appendiculaires du golfe du Bengale peuvent être rassemblés en 5 groupes.

(1) Espèces à la fois très fréquentes et abondantes: *Oikopleura longicauda, Megalocercus huxleyi, Oikopleura rufescens.*

(2) Espèces fréquentes et relativement abondantes: *Oikopleura fusiformis, O. cophocerca, Fritillaria borealis* f. *sargassi, Stegosoma magnum.*

(3) Espèces relativement fréquentes et peu abondantes: *Fritillaria formica* f. *digitata, F. pellucida, F. pellucida* var. *omani.*

(4) Espèces peu fréquentes et peu abondantes: *Oikopleura fusiformis* f. *cornutogastra, Fritillaria venusta, O. albicans.*

(5) Espèces rares: *Pelagopleura* sp., *Fritillaria haplostoma*, *F. tenella*, *Tectillaria fertilis*, *Oikopleura parva*, *F. gracilis*, *O. graciloides*, *F. fraudax*, *F. pacifica*, *O. dioica*, *F. charybdae*, *F. megachile*.

Les 7 espèces formant les groupes 1 et 2 constituent, à elles seules, 88% du nombre total des Appendiculaires récoltés. Ce phénomène n'est pas typique à la population des Appendiculaires du golfe du Bengale ni de l'océan Indien. Chaque fois que des prélèvements assez nombreux ont été effectués dans un océan, on s'est aperçu que 6 ou 7 espèces constituent plus de 85% du nombre total. Par contre, la composition du groupe formé par ces espèces est variable et caractéristique de la région considérée.

Dans le cas présent et comme cela se produit très généralement dans les zones tropicales et tempérées, *O. longicauda* est à la fois l'espèce la plus nombreuse et la plus fréquente. La suite du groupe de tête est constituée par *O. rufescens*, *M. huxleyi*, *S. magnum* et *O. fusiformis*.

Ces résultats confirment les travaux antérieurs sur les Appendiculaires de l'océan Indien et la prédominance de cet ensemble d'espèces semble caractériser d'une façon assez constante les zones équatoriales et tropicales de cet océan.

La population des Appendiculaires de cette région présente en outre un certain nombre de caractéristiques importantes, tant au point de vue qualitatif que quantitatif.

Aspect qualitatif: Les espèces sont nettement plus nombreuses dans la zone Sud (21) et il existe un gradient décroissant vers le nord (13 puis 11). Le nombre d'espèce des Oikopleuridae est peu variable, les chiffres relevés du sud au nord sont 10, 9 et 9. Par contre les espèces de Fritillaridae passent de 11 à 4 puis à 2. Dans la première famille la plupart des espèces se retrouvent dans toutes les zones. Quelques exceptions cependant: *O. albicans* et *O. graciloides* ont été récoltées uniquement dans la partie Sud, alors que *O. fusiformis* f. *cornutogastra* et *O. parva* ont été seulement déterminées dans quelques pêches des zones centrale et septentrionale.

Chez les Fritillaridae la situation est différente: toutes les espèces récoltées dans le nord et le centre se retrouvent dans la partie Sud. *F. borealis* f. *sargassi* et *F. formica* f. *digitata* sont les seules espèces de la zone nord. Elles sont accompagnées, dans la partie centrale, par *F. pellucida* et *F. venusta*.

Aspect quantitatif: Toutes les espèces qui existent dans la zone Sud ont une représentation affectée d'un gradient décroissant du sud vers le nord, à part 4 exceptions. La première exception est importante puisqu'il s'agit de *O. longicauda*. Celle-ci est nettement plus abondante dans les zones centrale et septentrionale. *O. rufescens* et *F. formica* f. *digitata* sont par contre un peu moins abondantes dans la partie centrale. Enfin *F. venusta*, absente dans le nord, est plus nombreuse au centre qu'au sud.

Nous pensons qu'il est possible de rapprocher ces différentes constatations du fait que la direction des courants de surface est S-N dans la partie occidentale du golfe, durant la période considérée. Les espèces autochtones seraient assez peu nombreuses, en particulier chez les Fritillaridae, alors que la plupart des espèces seraient immigrantes de l'océan Indien. Seuls des prélèvements à des saisons différentes pourraient confirmer ou infirmer cette hypothèse. Une étude plus étendue du reste de l'océan Indien nous permettrait également de mieux comprendre l'originalité de la biogéographie des Appendiculaires de cette région. Malheureusement, le matériel provenant de nombreuses croisières couvrant l'ensemble de cet océan nous est parvenu dans un très mauvais état; il est impossible d'en envisager une étude sérieuse.

Nous insisterons encore une fois (Fenaux, 1964; 1967a, b) sur le fait que nos observations ont été limitée à une période de 2 mois environ. Nous avons montré qu'en Méditerranée (Fenaux, 1963), les variations saisonnières des Appendiculaires sont à la fois quantitatives et qualitatives. Comme il n'existe actuellement aucun travail sur les variations saisonnières des Appendiculaires des régions équatoriales et tropicales, il nous est impossible de savoir si les espèces et les répartitions décrites sont valables pour les autres saisons. Cette restriction est d'autant plus valable que la mousson apporte dans cette région de fortes variations climatiques et de circulation. Les observations de Ganapati et Bhavanarayama (1958) dans les eaux côtières, semblent d'ailleurs confirmer l'existence de changements qualitatifs assez importants.

Résumé

1. Les Appendiculaires provenant de 76 stations effectuées de juin à août 1964 dans le golfe du Bengale, à bord du navire «Kistna», ont été examinés. 26 espèces ont été déterminées. 10 sont nouvelles pour le golfe du Bengale et, parmi celles-ci, 2 étaient inconnues dans l'océan Indien.

2. La composition du groupe formé par les espèces les plus abondantes et les plus fréquentes est caractéristique de la faune de l'océan Indien. *Oikopleura longicauda* représente 50% du nombre total des individus récoltés, elle est suivie par *Oikopleura rufescens* 14%, *Megalocercus huxleyi* 8%, *Oikopleura fusiformis* et *Fritillaria borealis* f. *sargassi* 6%, *Oikopleura cophocerca* et *Stegosoma magnum* 2%. Aucune autre espèce n'atteint 1%.

3. La densité des espèces dans la partie occidentale décroît assez régulièrement avec la latitude, 21 espèces dans le sud, puis en remontant vers le nord: 14, 11 et 2. Le fond du détroit de Malacca est pauvre en espèce: 5, alors que son débouché dans le golfe du Bengale est plus riche: 18. Les Oikopleuridae sont présentes dans tous les prélèvements mais les Fritillaridae sont absentes dans 25 pêches, principalement dans la partie centrale et nord.

4. La répartition de chaque espèce a été étudiée. *Oikopleura longicauda* est la seule qui soit nettement

plus abondante dans le nord. La plupart des autres espèces montrent un gradient décroissant du sud vers le nord.

5. Les données hydrologiques (température et salinité) ne nous ont pas permis d'établir des zones bien différenciées entre le sud et le nord. Il semble donc que les espèces autochtones soient peu nombreuses; les autres proviendraient de l'océan Indien, portées par les courants de direction sud-nord qui existent à cette période de l'année.

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Date of final manuscript acceptance: December 10, 1968. Communicated by J. M. Peres, Marseille

Reprinted from *Crustaceana*, vol. 16, part 2, 1969, p. 125-134

A REDESCRIPTION OF *PSEUDODIAPTOMUS MARINUS* SATO (COPEPODA, CALANOIDA) AND ITS OCCURRENCE AT THE ISLAND OF MAURITIUS [1]

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The Japanese copepod *Pseudodiaptomus marinus* Sato, 1913, was collected by the second author in Port Louis harbor, Mauritius, in the Indian Ocean. Thirteen specimens were obtained in a net suspended about 2 meters below the water surface from the side of the Research Vessel "Anton Bruun" while at the dockside. The net was set during the night from 2200 hours to 0800 hours on June 14-15, 1964. The harbor of Port Louis is only a short distance from the open ocean but the salinity of the harbor waters may be reduced by the discharge of a few small rivers which empty into it. No species of *Pseudodiaptomus* have previously been recorded from the island of Mauritius. The genus *Pseudodiaptomus* contains neritic, estuarine and freshwater species. *P. marinus* is a neritic marine species. The following description is based on the specimens from Mauritius. Differences between these specimens and specimens obtained from Japan and Hawaii are noted in the discussion.

Pseudodiaptomus marinus Sato, 1913 (figs. 1-26)

Material. — Thirteen specimens, comprising one adult male and twelve adult females, two of which were ovigerous, from Port Louis harbor, Mauritius, have been deposited in the South African Museum, Cape Town, and the Woods Hole Oceanographic Institution (S.A.M. A12084, A12085, A12086, W.H.O.I. 2084).

Description. — Female: Length 1.28-1.31 mm (mean of twelve specimens 1.29 mm). Prosome slender, viewed dorsally approximately 2½ times as long as wide, rounded anteriorly (figs. 1, 2). Fourth and fifth pedigerous segments fused. Posterior angles of metasome produced into sharp outwardly directed spines.

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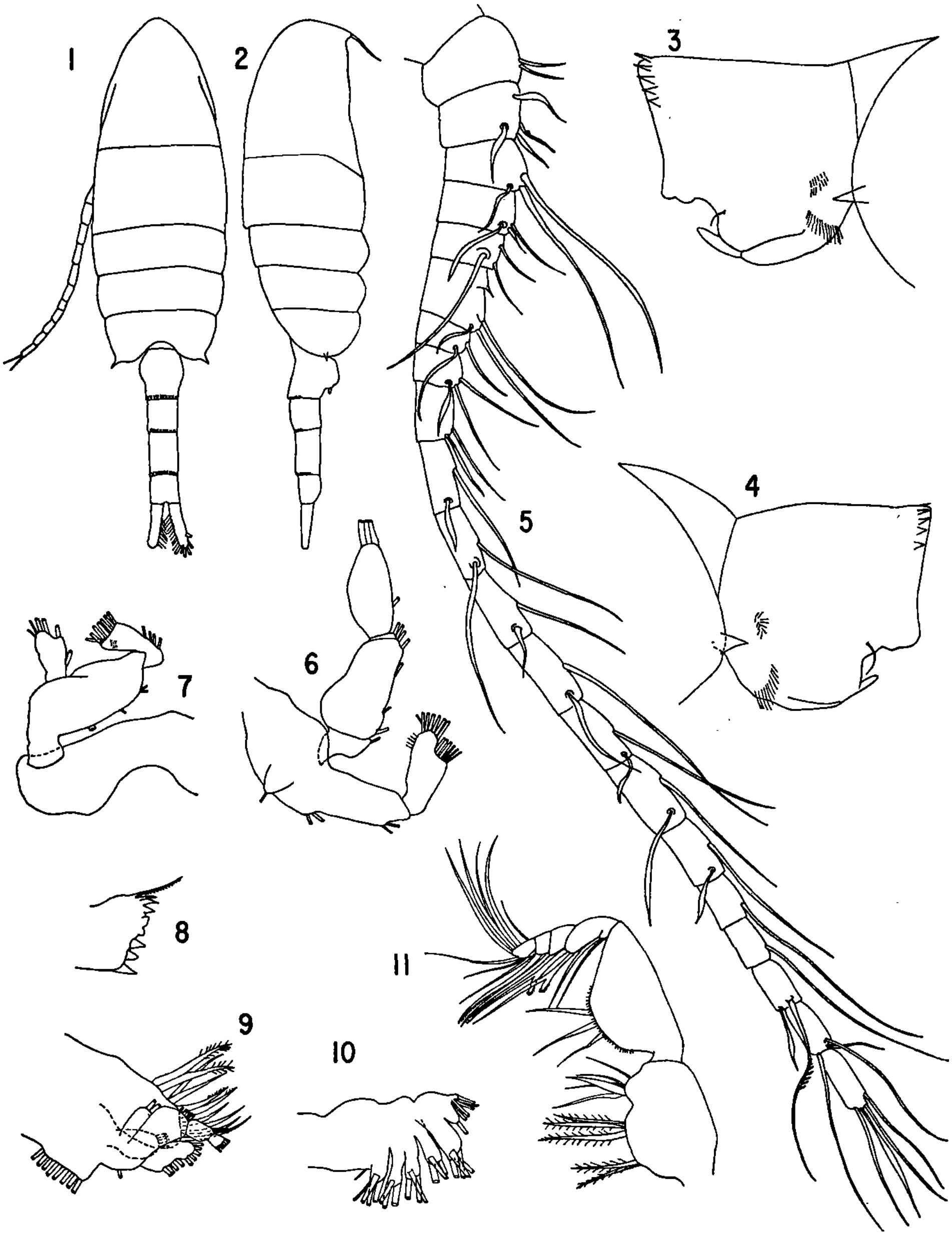
[1] Contribution No. 2143 from the Woods Hole Oceanographic Institution. This study was supported in part by National Science Foundation grant (GB 6052) and United States Program in Biology of the International Indian Ocean Expedition.

Rostrum strongly developed with two long filaments which reach second segment of first antennae.

Urosome 4-segmented and less than 2/3 length of prosome. Genital segment (fig. 3, 4) slightly asymmetrical, with slight swellings laterally and a prominent



Figs. 1-11. *Pseudodiaptomus marinus* Sato, 1913, female. 1, dorsal view; 2, lateral view; 3, genital segment, right side; 4, genital segment, left side; 5, antenna 1; 6, antenna 2; 7, mandibular palp; 8, gnathal lobe of mandible; 9, first maxilla; 10, second maxilla; 11, maxilliped.

genital boss ventrally. A small patch of fine setae is present on each side of the segment and a fringe of stiff setae runs across the ventral surface. The genital flaps are prominent and there is a single seta on each side near their distal ends. The first three urosome segments are furnished with rows of coarse teeth on their posterodorsal margins. The caudal rami are symmetrical, divergent and four times as long as wide. They are furnished with fine hairs on their inner margins. The five caudal setae are jointed and slightly thicker proximal to the joint. There is a small sensory bristle between the fourth and fifth setae.

Antenna 1 (fig. 5) of 21 segments, reaching the posterior margin of the genital segment when extended. Proportional length of the segments, setation and arrangement of aesthetascs as shown in figure 5. A specialized seta armed with recurved comb-like teeth near its middle is present on the third from the last segment. Modified setae, apparently of varying form, have been described on this segment of the first antenna of the female and the unmodified antenna of the male from a number of widely scattered species within the genus (Grindley, 1963).

Antenna 2 (fig. 6) with basipod bearing two lateral and two terminal setae and a single seta on a small medial protuberance. Exopod 1-segmented only, bearing 7 terminal and 6 sub-terminal setae and a lateral fringe of fine hairs. Endopod apparently 4-segmented, third segment small and indistinct, bearing 1 seta on segment 1, 3 lateral and 2 distal on segment 2, 2 on segment 3 and 1 lateral and 3 terminal on segment 4.

Mandible (figs. 7, 8) with gnathal lobe heavily chitinized and bearing about 8 fine teeth and a fine plumose seta. Basipod of palp with four inner marginal setae. Exopod apparently unsegmented bearing 4 lateral and 7 terminal setae. There are some fine hairs on the medial surface of the exopod and the middle terminal seta is markedly crooked.

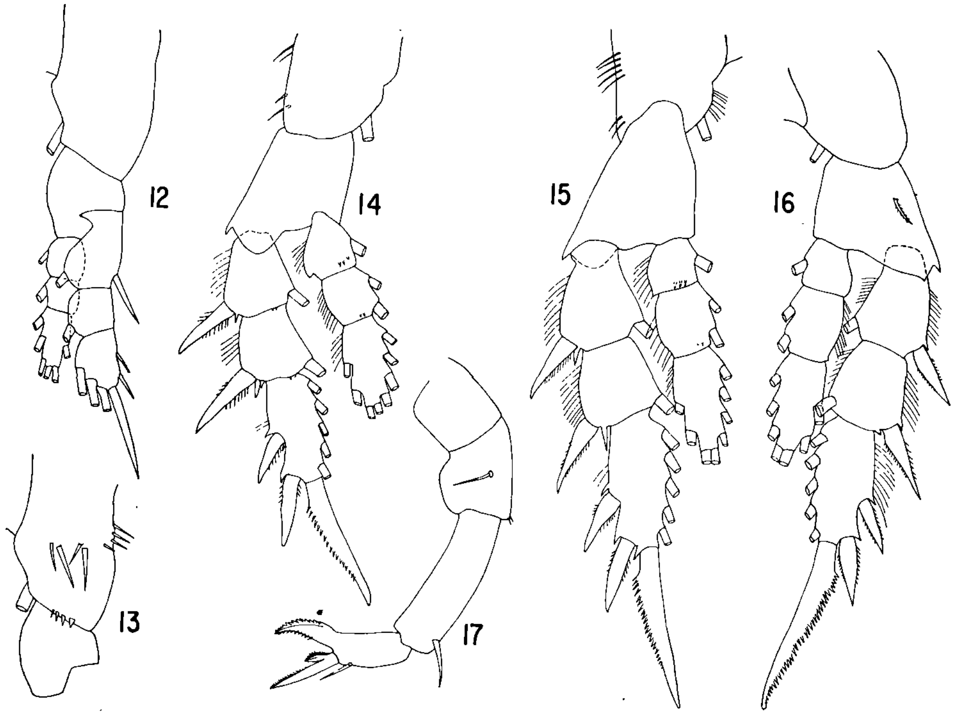
Maxilla 1 (fig. 9) with first inner lobe or gnathobase bearing 10 strong spines, small second inner lobe bearing 2 setae and third inner lobe bearing 4 terminal setae. Outer lobe or coxal epipod bearing 8 long setae. Exopod with 9 marginal setae. One small marginal seta arises between outer lobe and exopod. Second basal segment with 5 setae. Endopod 2-segmented, bearing 2 setae medially on the first segment and 6 terminal setae on the second.

Maxilla 2 (fig. 10) with five large medial lobes or endites and two smaller terminal lobes. The terminal lobes bear 5 setae and 1 seta, the marginal lobes 4, 3, 3, 3, and 4 setae, and there is one separate proximal seta.

Maxilliped (fig. 11) 6-segmented, 2 basal segments large, 4 distal segments small and decreasing in size distally. First segment bearing on its medial border, two plumose setae, three plumose setae, and four fine setae and a spine. Second segment expanded medially with 3 setae and a fringe of short fine hairs on the medial margin. Third segment bearing 2 setae proximally and 2 peculiarly divided setae distally. Fourth segment bearing 1 seta, fifth segment 2 setae, sixth segment 7 setae of which 2 are medial. The peculiarly divided setae on the third segment each bear a short spatulate branch near their middle fringed with fine bristles.

Similar divided setae have been reported in a number of other species of *Pseudodiaptomus* (cf. Grindley, 1963).

Swimming legs 1 to 4 biramous, with 2-segmented basipodite and 3-segmented exopod and endopod. They are similar in both sexes. The first pair (figs. 12, 13) are different from the following three pairs. The spines of the exopod are not serrate and blade-like. The first segment of the exopod has one outer edge spine, the second no spine, and the terminal segment has two short lateral spines and a slender terminal spine. There are fewer setae than on the remaining swimming legs. There are several spinules on the first basal segment (fig. 13).



Figs. 12-17. *Pseudodiaptomus marinus* Sato, 1913, female. 12, first swimming leg; 13, basipodal segments of first swimming leg, anterior view; 14, second swimming leg; 15, third swimming leg; 16, fourth swimming leg; 17, fifth leg.

Swimming legs 2 to 4 (figs. 14-16) bear serrated blade-like outer and terminal exopod spines, with small spine-like processes at their bases. There are small spinules near the distal margins of the first two segments of the endopod and exopod of leg 2 and the endopod of leg 3. There are some fringes of fine hairs on the margins of the endopods and exopods of legs 2 to 4, and some fine hairs on the basipodites of swimming legs 2 and 3. A seta is present on the second basipod segment of the fourth pair of swimming legs.

Details of the setation and spinulation of the swimming legs are presented in table I. All the setae on the swimming legs are pointed and slightly thicker proximal to the joint.

TABLE I

Setation and spinulation of the swimming legs of *P. marinus* Sato (Mauritius specimens)

Leg	Basipod				Endopod							Exopod						
	1		2		1		2		3			1		2		3		
	Si	Se	Si	Se	Si	Se	Si	Se	Si	St	Se	Si	Se	Si	Se	Si	St	Se
P_1	1	0	0	0	1	0	1	0	3	2	1	1	I	1	0	3	I	II
P_2	1	0	0	0	1	0	2	0	4	2	2	1	I	1	I	5	I	II
P_3	1	0	0	0	1	0	2	0	4	2	2	1	I	1	I	5	I	II
P_4	1	0	0	1	1	0	2	0	4	2	2	1	I	1	I	5	I	II

Si, Se, St represent internal, external and terminal spines of setae respectively. The number of setae is shown in Arabic numerals and spines in Roman numerals.

The fifth pair of legs in the female (fig. 17) is uniramous, 4-segmented and symmetrical. The second basal segment bears two small spinules on the outer angle and a seta on the posterior surface. The first segment of the ramus bears a spine near the distal end of the outer margin. The second segment bears a spine on the outer distal angle and is produced distally on the medial side into a curved spiniform process, serrated medially, reaching almost to the tip of the terminal spine. The terminal spine is less than half the length of the third segment and it bears a short serrated spine near its base. There is no distinct separate basal portion to the terminal spine.

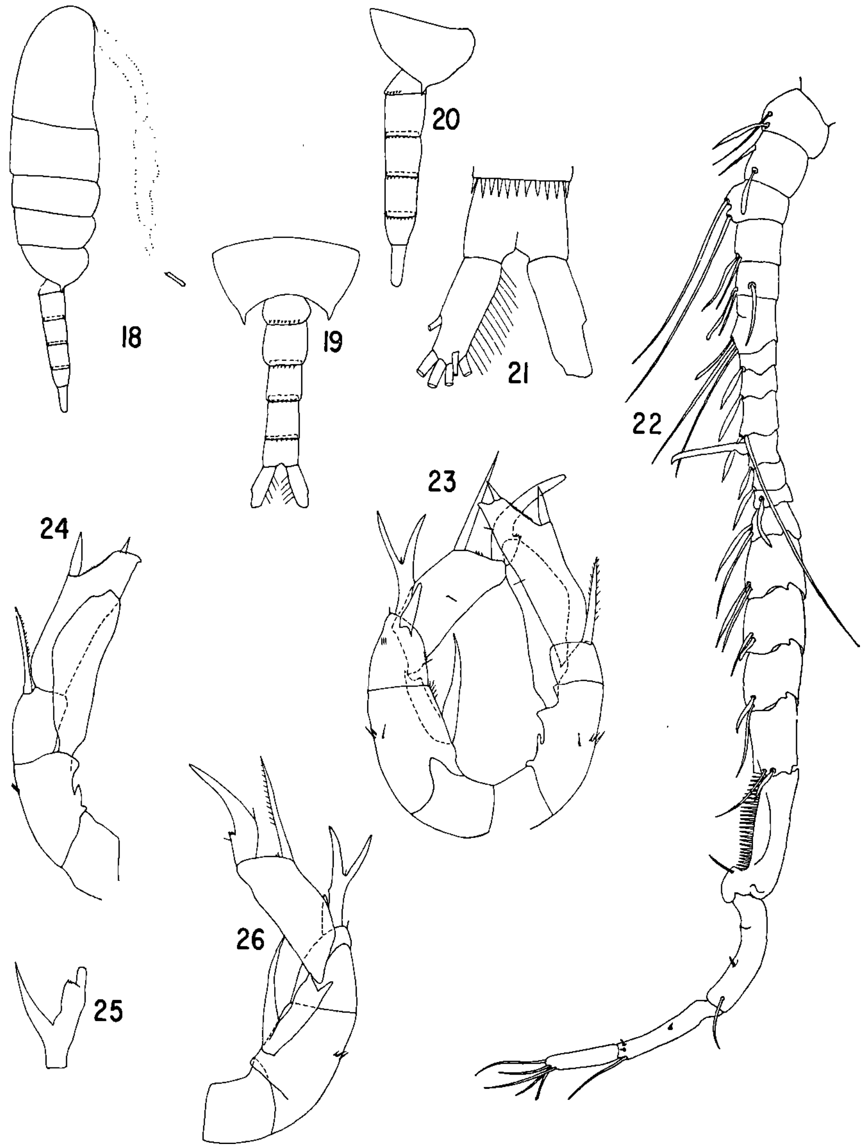
The eggsac is single, and contained 17 eggs in each of the two ovigerous specimens examined.

Male: Length 0.99 mm. Prosome (fig. 18) similar to that of the female, but tapering more posteriorly and the spines on the posterior angles of the metasome directed posteriorly (figs. 19, 20). Rostral filaments shorter than in female. Urosome 5-segmented, half as long as prosome, uniformly slender, first and last segments shorter than the remainder. Posterior dorsal margins of urosome segments 1 to 4 fringed with rows of coarse teeth, extending laterally also on segments 2 to 4. Caudal rami three times as long as wide (fig. 21).

Appendages similar to those of female except for right antenna 1 and fifth legs.

Right antenna 1 geniculate, of 21 segments (fig. 22). There are three free segments distal to the articulation. Proportional lengths of segments, arrangement of aesthetascs and setation as shown in fig. 22. There is a hooked spine on segment 10 and a serrated margin to segment 18.

Male fifth legs (figs. 23-26) biramous, basipods 2-segmented, exopods 2-segmented, endopods 1-segmented. In the right leg the first basal segment is naked. The second basal segment is larger, bears three small spinules on its outer margin, a posterior seta and a characteristic forked endopod. The endopod has one slender pointed ramus and one shorter, stouter ramus ending in two points. The first exopod segment bears a few spinules on the inner and outer margins, and on the



Figs. 18-26. ***Pseudodiaptomus marinus*** Sato, 1913, male. 18, lateral view; 19, urosome, dorsal view; 20, urosome, lateral view; 21, caudal rami, dorsal view; 22, right antenna 1; 23, fifth legs, posterior view; 24, left fifth leg, anterior view; 25, endopod of right fifth leg, medial view; 26, right fifth leg, anterior view.

outer distal corner a 'Y' shaped bifurcated spine with a subsidiary spinule in the fork. At its base is a stout blunt spine of about half its length. The forked spine reaches beyond the base of the spine on the next segment. The second exopod segment bears a long straight partly plumose spine on the distal part of the outer margin, and a small spinule near its middle. The terminal hook has a thickened basal portion and bears two small spinules. It is barely longer than the straight spine. In the left leg the first basal segment is naked. The second basal segment bears a few spinules on the outer margin, a posterior seta and a long naked endopod. The first exopod segment bears a straight plumose spine on its outer distal angle. The second exopod segment is elongate and truncate distally bearing a short terminal spine and an outer marginal spine opposite the tip of the endopod. Between these two spines the margin is fringed with numerous tiny spinules. The medial margin is straight and bears two small spinules.

DISCUSSION

Pseudodiaptomus marinus Sato, 1913, together with *P. ardjuna* Brehm, 1953, *P. beieri* Brehm, 1951, *P. colefaxi* Bayly, 1966, and *P. hickmani* Sewell, 1912, form a closely related group of species within the genus *Pseudodiaptomus.* They are all characterized by the possession in the fifth legs of the male of both left and right endopods of which the right is forked or 'Y' shaped. These species have many features in common but may be distinguished most readily by small differences in the fifth legs of the males. They all occur in oriental regions.

Many features such as the setation of the swimming legs and details of the mouth parts and antennae which appear important in deciding the relationships of *Pseudodiaptomus* species are known for so few species that at present studies of affinity must be based largely on the structure of the fifth legs of the male. Studies of the grouping of the species of the Pseudodiaptomidae, and the relationships and evolutionary significance of these groups (Grindley, in press) have emphasized the need for more detailed descriptions of *Pseudodiaptomus* species.

The finding of *P. marinus* at Mauritius, reported here, and in brackish waters of Hawaii by Jones (1966) poses interesting zoogeographic problems. The species was originally described from Japanese coastal waters and inland seas. The two species of *Pseudodiaptomus* from nearby Madagascar have more characters in common with the African species of the genus (Grindley, 1963). *P. stuhlmanni* Poppe & Mrâzek, 1895, *P. salinus* Giesbrecht, 1896, and *P. cornutus* Nicholls, 1944, which occur on the western, northern and eastern sides of the Indian Ocean respectively are to some degree intermediate between the African and Madagascar species of the genus, and the oriental species including *P. marinus.* These three intermediate species also have a divided right endopod in the fifth legs of the male, but one is bulbous and the other is tapered and bears a terminal or sub-terminal seta. The oriental group of species which includes *P. marinus,* occurs from India eastwards and *P. marinus* is in fact the most easterly representative of the group. Its isolated occurrence at the remote Indian Ocean island of Mauritius far to the west, and at Hawaii in the mid-Pacific is thus most peculiar. It does not fit the otherwise regular pattern of relationships and distribution found within the family Pseudodiaptomidae (Grindley, in press).

Jones (1966) speculated that this species might have reached Hawaii from Japan in ship's ballast water tanks. We had independently come to the same conclusion regarding the Mauritius population, for this appears to be the most plausible explanation. Jones dismisses the possibility of transport by ocean currents because the time required would exceed the life span of the individuals, which are restricted to neritic waters usually of reduced salinity. The possibility of transport by ocean currents of individuals from Japan to Mauritius in the southern Indian Ocean (20°30′S 57°30′E) is even more remote. Japanese tuna fishing vessels frequently use Port Louis in their fishing operations in the southern Indian Ocean. Several such vessels were at anchor during the visit of R/V "Anton Bruun" in June 1964.

There is also a possibility that *P. marinus* might have adhered to algae or other fouling organisms attached to the hull of fishing vessels leaving Japanese coastal waters for the Indian Ocean. It has been reported by Jacobs (1961) that *P. coronatus* Williams occurring on the Atlantic coast of the United States is able to attach to various substrates. Once attached they are able to withstand considerable current without being dislodged. Jacobs also reported that *P. coronatus* is euryhaline, and grows well in a variety of laboratory conditions. Unpublished observations by the present authors on *P. coronatus* (by Grice) and *P. hessei* (Mrázek) and *P. stuhlmanni* (by Grindley) confirm the tenacity and hardiness of these species of the genus. If *P. marinus* has similar characteristics it would be well fitted to make long journeys in ship's tanks or even perhaps attached to fouling.

The specimens obtained from Mauritius show a number of minor differences from specimens obtained from Japan and from Hawaii, and from previously published descriptions. Indeed the differences from the descriptions and figures of Sato (1913), Brodsky (1950) and Chiba (1956) were so great as to prompt us initially to regard the Mauritius specimens as representing an undescribed species. However, after comparing our Port Louis specimens with material from Japan kindly sent to us by R. Hirota, we considered that our specimens were referable to *P. marinus*. The inadequacy of the previous descriptions of *P. marinus* impressed us with the need to present a detailed description of this species.

Examination of Hawaiian specimens sent to us by Jones and comparison of this material with that from Japan and Mauritius and the previously published descriptions and figures, indicate that there is considerable intraspecific variation. (1) The Mauritius specimens (♀ 1.28-1.31, ♂ 0.99 mm) do not appear to differ significantly in size from those from Hawaii (♀ 1.08-1.31, ♂ 0.94-1.01 mm) or from Japan (♀ 1.3, ♂ 1.0-1.04 mm) although Sato in his original description reported larger specimens (♀ 1.3-1.6, ♂ 1.3 mm). (2) In the fifth legs of the male from Mauritius the spine at the base of the forked spine on the right first exopod is much longer than in specimens from Japan or Hawaii. (3) In the fifth legs of the male, the right endopod varies considerably. The slender ramus is considerably longer than the stouter ramus in the Mauritius specimens, longer or equal in the Japanese specimens and slightly longer in the Hawaiian specimens. The published figures depict the slender endopod ramus as shorter (Sato, 1913), longer (Brodsky, 1950) or equal (Chiba, 1956). (4) The above-mentioned stouter endopod ramus which ends in two points in the Mauritius specimen bore four points in the Japanese and two blunter points in the Hawaiian specimens. The published figures depicted three points (Sato, Brodsky) or a single lobe (Chiba) but the latter drawing apparently lacks finer detail. (5) In the fifth legs of the females the first exopodal segment was relatively shorter in the specimens from Mauritius than in any of the other specimens or published figures.

However, after careful comparison, we decided that these variations did not indicate even sub-specific differentiation of the Mauritius population. We consider that they might represent ecophenotypes, or perhaps minor geographical variations derived from different parts of the Japanese region.

ACKNOWLEDGEMENTS

We are grateful to R. Hirota and E. C. Jones for sending us specimens from Japan and Hawaii for comparison, and to Dr. S. Motoda, of Hokkaido University, for translating Sato's original account of *Pseudodiaptomus marinus.*

ZUSAMMENFASSUNG

Das Vorkommen von *Pseudodiaptomus marinus* Sato, 1913, ist für Port Louis auf der Insel Mauritius festgestelt worden. Die Art wird beschrieben und hier zum ersten Mal detailliert abgebildet. Sie steht in Beziehung zu einer orientalischen Gruppe von Arten derselben Gattung. Ihres abnormalen zoogeographischen Verhaltens wegen wird angenommen, dass die Art durch Schiffe von Japan nach Mauritius transportiert worden ist. Intraspezifische Variationen zwischen Exemplaren von verschiedenen Lokalitäten werden beschrieben.

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Received for publication 26 June 1968.

Reprinted from *Crustaceana*, vol. 16, part 1, 1969, p. 103-104

A NOTE ON THE ECOLOGY OF *CONCHODERMA VIRGATUM* (SPENGLER, 1790) (CIRRIPEDIA, LEPADOMORPHA)

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In discussing the settlement of *Conchoderma virgatum* (Spengler, 1790), Jones, Rothschild & Shomura (1968) suggest "...on the one hand, that the species is an opportunistic settler; on the other hand, it has not been reported from such common floating objects as glass fish-net floats, pumice, feathers, or organisms such as *Velella* or *Ianthina,* all of which are common substrata for *Lepas*".

An analysis of thirty-nine references which record original occurrences of this species confirms this and gives the following settlement sites:

Ships' hulls:	16	Crabs:	3
Fishes:	14	Buoys:	2
Whales:	8	Ropes:	1
Turtles:	7	Telegraph-cables:	1
Seasnakes:	4		

Hutchins (1952), who was not concerned with occurrences on living organisms, gives a similar analysis, including some from the same references, of 23 occurrences on ships, 6 on buoys and 3 on test surfaces.

Although several authors make general statements that *C. virgatum* attaches to seaweed, driftwood or floating logs, no records of this have been found in the literature. However, a few recently settled *C. virgatum* var. *hunteri* R. Owen, 1830, were found on a piece of floating wood collected in November 1964, from the Gulf of Aden, amongst a large number of attaching cypris larvae and recently settled *Lepas anserifera* Linnaeus, 1767. Another group of similar specimens collected from the same area and in the same month, on a floating bottle, were entirely *L. anserifera.* Specimens from meters and floats of expanded polystyrene on two current meter assemblies, collected in December 1964 in the Bab el Mandeb, showed a conspicuous separation, *L. anserifera* settling on one of the surface floats and *C. virgatum* var. *hunteri* settling on floats at about 40 and 45 metres. At these stations the temperature and salinity at the surface and at 40-45 m were virtually the same, the latter being at the top of the thermocline. Snyder (1963) has previously stated that *Conchoderma* occurs plentifully on buoyed instruments in warm waters.

These results suggest that, unlike most *Lepas* species, *Conchoderma virgatum* shows a preference for settling below the surface. *Lepas hilli* (Leach, 1818), which is frequently associated with *C. virgatum* on ships' hulls, turtle carapaces and fishes, may require similar conditions for settlement. Annandale (1909) states that *C. virgatum* "occurs at the bottom, both on inanimate objects and on crustacea". His further statement that "although *Conchoderma virgatum* is reported to be a common species, the actual number of specimens recorded is by no means a large one", presumably reflects the settlement of the species on sub-surface objects, unlike *Lepas* species which, settling on floating objects, are more often noticed. Many examples of *C. virgatum* have been reported on other organisms, such as turtles, fishes and seasnakes, which were themselves taken as specimens, or on whales taken for commercial purposes.

I am indebted to Dr. Jürgen Lenz, of the Institut für Meereskunde, Kiel, for the specimens and environmental data from the Gulf of Aden, taken during the International Indian Ocean Expedition in 1964.

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Received for publication 19 July 1968.

Reprinted from *Int. J. syst. Bact.*, vol. 19, no. 3, 1969, p. 295-307

HYPHOMICROBIUM INDICUM SP. NOV. (HYPHOMICROBIACEAE DOUGLAS)

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ABSTRACT. During the eighth cruise of the R/V Anton Bruun, as part of the International Indian Ocean Expedition a bacterium was isolated from bottom mud at a depth of 400 meters. The extreme pleomorphism of this organism commended it for detailed study. It was subsequently named Hyphomicrobium indicum and a comparative study with other Hyphomicrobium sp. undertaken.

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MATERIALS AND METHODS

Source of cultures: Hyphomicrobium neptunium, Leifson 1964 (ATCC 15444).

H. vulgare Stutzer and Hartleb 1899. Strains 4 and 5 from Dr. Jean Schmidt, Arizona State University; strains V and VA from Mrs. Sharon Gentry, Department of Bacteriology, University of California, Berkeley.

Two marine species of Vibrio designated as Y and 418 were from cultures isolated during the 1964 Indian Ocean Expedition.

Escherichia coli (Migula) Castellani and Chalmers 1919. From the departmental stock culture.

Maintenance of cultures: H. indicum, H. neptunium and the marine vibrios were maintained on M-2 medium. H. vulgare (4 strains) were maintained on medium designated as P-Y, the M-2 medium above with substitution of distilled water for sea water, and with addition of one or two drops of methanol to each culture. Escherichia coli was maintained on trypticase soy agar (BBL) prepared with distilled water. In the preparation of cultures for DNA isolation and

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routine growth, the same media were employed for each organism, unless otherwise indicated.

Morphological characterization: Cultures used for morphological studies were prepared by inoculation of slants or broth and incubated for varying lengths of time. Smears were gram stained using Hucker's modification (12).

Motility was demonstrated by means of the Rhodes (11) flagella stain as well as by hanging drop preparations.

Cell walls were stained using the method of Webb (15).

Photomicrographs were obtained using Panatomic X film (Kodak) in a Leitz Ortholux microscope with an Orthomat microcamera attachment.

Physiological characterization: Carbohydrate media consisted of 1% of the appropriate sugar in M-2 or P-Y broth. Indol, gelatin, nitrate, and MRVP tests were performed using rehydrated Difco media. Hydrogen sulfide production was determined using the lead acetate paper strip method (12). Starch and casein media were prepared by adding 2% soluble starch and 2% powdered milk (Carnation) respectively to M-2 or P-Y agar. Starch hydrolysis was tested by flooding the plates with Lugol's iodine solution. Chapman-Stone agar and MacConkey agar, as well as S-S agar, were prepared using dehydrated media (Difco). Glucose metabolism was determined by means of Hugh-Leifson medium (4). Antibiotic sensitivity was tested using commercial discs (Difco) of low concentration.

Possible inhibition by pteridine was determined by use of filter paper impregnated with a saturated solution of pteridine 1/129 (Allan and Hanbury LTD.).

Oxidase, urease, lysine decarboxylase and phenylalanine deaminase activities were determined by the use of Patho-Tec paper strips (Warner-Chilcott Laboratories).

Amino acid requirements were determined using sterilized stock solutions containing 10 mg of the appropriate amino acid in 5 ml of sea water. One ml of the amino acid stock solution was added to 5 ml of basal medium (1% glucose in sea water) and the tubes were inoculated with 0.1 ml each of a twice-washed suspension of cells.

The ability to use single carbon sources was determined as follows: the basal medium for H. indicum and H. neptunium consisted of sea water plus 0.01% dibasic ammonium phosphate. The composition of the two basal media used with the H. vulgare strains is given in Table 1. The carbon compounds were added to the basal medium to give a final concentration of 0.5% tubed in 5 ml amounts and sterilized, except for methanol which was added aseptically after sterilization.

Table 1. Basal media used for single carbon source tests with *Hyphomicrobium vulgare*.

Medium A

KH_2PO_4-1.5 gm; $NaNO_3$-1.0 gm; NaCl-0.5 gm; $MgSO_4 \cdot 7H_2O$-0.5 gm; $CaCl_2 \cdot 2H_2O$-0.3 gm; $MnCl_2 \cdot 4H_2O$-0.03 gm; $FeSO_4 \cdot 7H_2O$-0.025 gm; distilled water-1 liter.

Medium B

$NaNO_3$-1.0 gm; KH_2PO_4-1.0 gm; NaCl-0.5 gm; $MgSO_4 \cdot 7H_2O$-0.5 gm; tap water-1 liter.

Strains of *Hyphomicrobium* were grown to light turbidity, washed twice with sterile basal medium, and 0.1 ml of the washed culture inoculated into the respective media.

Isolation of bacterial DNA: DNA was isolated according to the method of Marmur (8) with the following modifications:

1. Sipex, a sulfated fatty alcohol, was used for lysis of the cells.
2. With *H. indicum* it was necessary to pretreat the cell suspension with 10 mg of lysozyme (Nutritional Biochemicals) at 37°C for 30 minutes, followed by lysis with Sipex, as above.
3. Ribonuclease (5X: Nutritional Biochemicals) used in the procedure was first heated at 80°C for 15 minutes to destroy any residual deoxyribonuclease activity.

Following isolation, samples of the dissolved DNA were diluted in saline-citrate (0.15 M NaCl + 0.015 M sodium citrate, pH 7.0) to an absorbance of 0.5 at 260 mμ. The 230/260 and 280/260 absorbancy ratio of the DNA were determined with a Coleman Autoset spectrophotometer, in order to assess the purity of the DNA. Values of 0.55 and 0.50 respectively were considered indicative of a good preparation.

Determination of base composition: The base composition of the purified DNA was obtained using the thermal denaturation method of Marmur and Doty (9). Absorbance was determined with a special cuvette holder. A Haake model F constant temperature water bath served as a temperature control. Base ratio analysis of *H. indicum* and

E. coli DNA was also performed using the chromatographic method described by Bendich (1).

RESULTS

Description of *Hyphomicrobium indicum* sp. nov.

Morphology. After 24 hours incubation on M-2 agar at 25°C, isolated colonies of *H. indicum* are circular, 1 to 2 mm in diameter, thin, white and creamy in consistency. Although no pigmentation occurs, the colonies tend to yellow with age. No pellicle formation occurs in broth; however, a ropy sediment is produced in glucose-peptone sea water broth.

The pleomorphic character of the organism is obvious. Gram stains and simple stains from agar slants or broth show predominantly plump Gram-negative rods, 0.7 to 1.0 μ in width by 2.0 to 6.0 μ in length. Many of the cells contain Gram-positive refractile granules. However, in broth cultures and less frequently on solid media long cells appear six to nine hours after inoculation which attain lengths of 40 to 50 μ. Although they do not appear to have crosswalls, as determined by cell wall stains, they apparently subsequently fragment to produce rods of the size described above.

A striking feature of the pleomorphic morphology is the production in broth and agar cultures, of Gram-negative coccoid cells varying in diameter from 1.0 to 2.5 μ. These are joined by slender filaments, 0.5 to 2.0 μ in length. This type of morphology is suggestive of the budding mechanism of reproduction, known to be characteristic of the *Hyphomicrobiaceae*. Figure 1 illustrates this variable morphology. The shorter rods and coccoid forms are motile in hanging drop mounts and possess polar monotrichous flagella. The long cells had no flagella. *H. indicum* is nonacid fast and does not sporulate.

Physiological characteristics. A comparison between *H. indicum*, *H. neptunium*, and the four strains of *H. vulgare* was made in terms of growth requirements and biochemical characteristics. The range of temperatures and hydrogen ion concentrations for growth are shown in Table 2. Table 3 shows the effect of specific ions on growth and the sea water tolerance of each strain.

Table 4 reveals the biochemical characteristics of each strain, while the enzymatic activity and antibiotic susceptibility of each is shown in Table 5. The ability of various organic compounds and amino acids to serve as single carbon

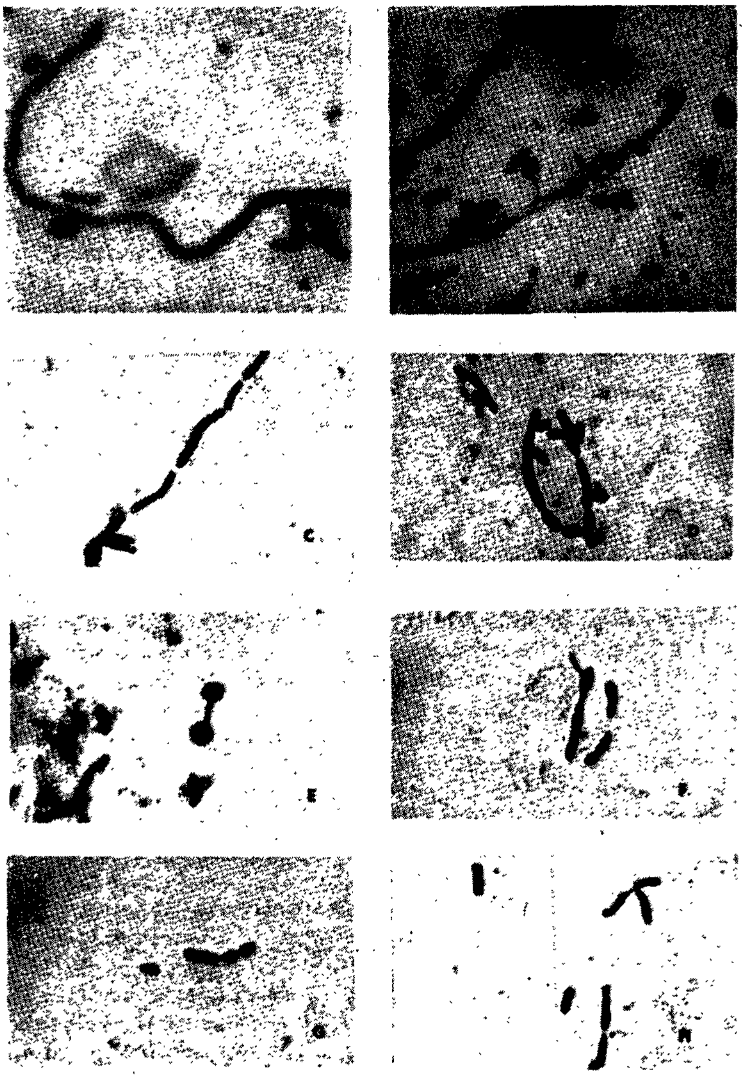

Figure 1. Characteristic variable morphology of H. indicum. A. Long cell with buds. B. Cell wall stain of long cells showing lack of crosswalls. C. Fragmentation of long cell to bacillary types. D. "Budding" chain of cells. E. "Dumbbell" cells. F, G, H. Filament formation and budding chains. All except B stained with crystal violet X 1000.

Table 2 Temperature requirements and pH range of *Hyphomicrobium species*

Species	Temperature (C)						
	4	10	18	25	30	37	55
H. indicum	+(1)	+	+	+	-	-	-
H. neptunium	-(1)	-	+	+	+	+	-
H. vulgare							
strain 5	-	+	+	+	+	+	+
strain 4	-	-	+	+	+	+	+
strain V	-	-	+	+	+	+	+
strain VA	-	-	-	+	+	+	-

	pH							
	4	4.5	5	5.5	6-8.5	9	9.5	10
H. indicum	-	+	+	+	+	+	+	-
H. neptunium	-	-	-	+	+	+	+	-
H. vulgare								
strain 5	-	-	-	+	+	+	+	+
strain 4	-	-	-	+	+	+	+	+
strain V	-	-	-	+	+	+	+	+
strain VA	-	-	-	+	+	+	+	+

I. +growth (-) no growth

Table 3 Sea water tolerance and effect of ions on *Hyphomicrobium* species

Species	Concentration of Sea Water 100%	75%	50%	25%	0%
H. indicum	+ (*)	+	+	-	-
H. neptunium	+	+	+	+	+
H. vulgare					
strain 5	-	-	+	+	+
strain 4	-	-	+	+	+
strain V	-	-	+	+	+
strain VA	-	-	+	+	+
	Growth in peptone-yeast extract plus distilled water plus:				
	no addition	3% NaCl		0.1% $CaCl_2$	0.1% $MgCl_2$
H. indicum	-	-	-	-	-
H. neptunium	+	+	+	+	+
H. vulgare					
strain 5	+	+	+	+	+
strain 4	+	+	+	+	+
strain V	+	+	+	+	+
strain VA	+	+	+	+	+

(*) + = growth
- = nongrowth

Table 4 Biochemical Characteristics of Hyphomicrobium species

	H. indicum	H. neptunium	H. vulgare			
			strains			
			5	4	V	VA
Glucose (Hugh-Leifson)						
Aerobic	+[1]	-	-	-	-	-
Anaerobic	+	-	-	-	-	-
Maltose	+	-	-	-	-	-
Sucrose	+	-	-	-	-	-
Lactose	-	-	-	-	-	-
Arabinose	-	-	-	NG	NG	NG
Xylose	NG[2]	-	-	-	NG	NG
Indol	+[3]	-	-	-	-	-
Nitrate	+	-	-	-	-	-
H_2S	+	-	-	-	-	-
MRVP	NG	NG	NG	NG	NG	NG
Gelatin	-	NG	NG	NG	NG	NG
Casein	-	-	-	-	-	-
Starch	-	-	-	-	-	-
MacConkey agar	NG	NG	NG	NG	NG	NG
Chapman-Stone agar	NG	NG	NG	NG	NG	NG
S-S agar	NG	NG	NG	NG	NG	NG

1 - acid produced from sugar
2 - no growth
3 - positive test or growth

Table 5 Enzyme activity and antibiotic susceptibility of Hyphomicrobium species

	H. indicum	H. neptunium	H. vulgare			
			5	4	V	VA
Urease	-	-	-	-	-	-
Catalase	-	+	-	-	-	-
Oxidase	-	-	-	-	-	-
Lysine Decarboxylase	-	+	+	+	-	-
Phenylalanine Deaminase	+	-	-	-	-	-
Chloromycetin	+[1]	+	-	-	-	-
Neomycin	+	-	-	-	-	-
Erythromycin	-	-	-	-	-	-
Kanamycin	+	-	+	+	+	+
Novobiocin	+	+	-	-	-	-
Tetracycline	-	-	-	-	-	-
Streptomycin	+	-	-	+	+	+
Penicillin	-	-	-	-	-	-
Pteridine 0/129	-	-	-	-	-	-

[1] + = inhibition
- = no inhibition

sources for growth was studied. Glucose, methanol, acetate, citrate, succinate, glycerol, lactic acid, phenol, and formaldehyde were used. *H. indicum* was able to use only citrate as a sole carbon source, while *H. neptunium* utilized only succinate. None of the *H. vulgare* strains grew in any of the single carbon source media with basal medium A, however, with medium B, growth occurred with all single carbon sources and showed slight growth in this basal medium alone.

H. indicum did not grow in any of the media containing amino acids as sole nitrogen sources. These media employed glycine, L-cysteine, L-histidine, DL-valine, L-asparagine, DL-tyrosine, DL-serine, and L-glutamic acid alone and in various combinations.

DNA analysis: Lysis to obtain DNA and the thermal denaturation for obtaining the percentage of guanine, plus cytosine worked well with *E. coli*, the two *Vibrios* and *H. neptunium*. Lysis of the 4 *H. vulgare* strains and recovery of DNA from them was not possible for us by these methods. Mandel (personal comm.) indicated similar difficulty in lysing strains of *Hyphomicrobium vulgare*. *H. indicum* required additional lysozyme prior to lysis, however, on thermal denaturation the *H. indicum* DNA showed a continuous increase in O. D. with temperature. Use of the chromatographic method of Bendich (1) showed that *H. indicum* had a guanine-cytosine content of 40%. This figure was confirmed by Dr. Mandel using buoyant density analysis (pers. comm.).

DISCUSSION

There is no mention in the description of *H. vulgare* in the 7th edition of Bergey's Manual (2) of the long filamentous cells or pleomorphism characteristics which *H. indicum* possesses. These characteristics were not observed by the authors in the four strains of *H. vulgare* and the single strain of *H. neptunium*.

The coccoid cells are connected by filaments, about 0.3 μ in diameter and typically shorter than those of *H. vulgare* or *H. neptunium*. In general, the budding cells are somewhat larger than those of the other hyphomicrobia, however, Hirsch (13) has reported larger cells up to 5 μ in diameter in some cultures of *H. vulgare*. *H. indicum* does not form rosettes, although some aggregation of budding cells has been noted. The pattern of budding in *H. indicum* is also similar in certain respects to that of *Rhodomicrobium vannielii*. The latter organism produces a string of interconnected buds and filaments, with some branching of the filaments. Several pictures of *H. indicum* show this pattern, and indeed, networks of buds and filaments have been noted.

The significance of the long filamentous cells in cultures of *H. indicum* has not been resolved. They may represent a stage in the life cycle or be the product of adverse cultural conditions in the medium. Leifson (6) reported long cell variants of *Caulobacter*, a stalked bacterium, when psychrophiles and halophobes were grown respectively at 37°C and in broth containing 1% NaCl. *H. indicum* grows optimally at 25°C in a peptone-yeast extract medium with artificial sea water, and under these conditions the long cells are obvious.

Tyler and Marshall (14) have also reported pleomorphy in strains of *Hyphomicrobium* sp. both in the natural environment and in pure cultures on various media. The primary manifestations are extensive branching of the filaments and bizarre swollen cells.

The results of several physiological tests (Tables 4 and 5) indicate a gradation in characteristics among the *Hyphomicrobium* species studied. The existence of such a gradation is very likely when one considers that only two other species have been ascribed to the genus in addition to our isolate. This gradation is also shown with respect to sea water tolerance and the effect of specific ions on growth in a distilled water medium (Table 3).

The capability of *Hyphomicrobium* species to grow with single carbon sources also indicate the gradation existing among these species. *H. vulgare* was originally thought to be autotrophic in its metabolism (5). This argument was based mainly on slow growth rates and faint growth in media containing no organic carbon compounds. *H. vulgare* does grow in basal media at the expense of volatile 1-carbon compounds in the atmosphere, but Hirsch (13) has shown that the organism is chemoheterotrophic and utilizes primarily 1-carbon compounds such as methanol, urea, methylamine, and formamide. Thus, the four strains of *H. vulgare* grew in all single carbon source media as well as in the basal medium B, but *H. neptunium* was able to grow only with succinate as the sole carbon source, and *H. indicum* only with citrate.

H. indicum is more active metabolically than either *H. neptunium* or *H. vulgare*, its principal trait being the active fermentation of glucose, sucrose and maltose. Growth is inhibited in the presence of the five-carbon sugar xylose, and this inhibition was also observed for several strains of *H. vulgare* in the presence of xylose and arabinose. Nitrate reduction was observed for *H. indicum* but not for *H. neptunium*, although Leifson (7) reported the latter as nitrate positive on a gelatin-nitrate medium. All other tests performed on *H. neptunium* agreed with Leifson's results.

Hirsch and Mandel (Hirsch, pers. comm.) have analyzed the base contents of some 110 strains of *H. vulgare* which have a range of 55 to 68% guanine + cytosine. It is obvious the base ratio of *H. indicum* is low at 40%; however, pending study of additional species of *Hyphomicrobium* this would appear to be the best possible genera for this marine isolate. Hirsch has also observed the culture and agrees that it appears to bud.

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Reprinted from *Aust. J. mar. freshwat. Res.*, vol. 20, 1969, p. 51-54

SEASONAL VARIATIONS IN THE INDIAN OCEAN ALONG 110°E.

II.* PARTICULATE CARBON

By B. S. Newell†

[*Manuscript received July* 28, 1967]

Summary

Particulate carbon at 0, 50, 100, 150, and 200 m was measured by a combustion method. Mineral carbon appeared to be negligible. Some particulate material escaped the Whatman GF/C filters used. The amount of suspended carbon decreased with depth at most stations from values of 20 μg/l. or more at 0 and 50 m, to 15 μg/l. at 150 m, and 10 μg/l. at 150 and 200 m. Higher values were found at all depths at the two southernmost stations (25–30 μg/l. at 0 and 50 m decreasing to 15 μg/l. at 150 and 200 m) and at shallow depths at the northernmost stations (20–25 μg/l. at 0 and 50 m). At all stations and at all depths, least carbon occurred in March.

I. Introduction

The series of cruises aimed at obtaining some measure of the biomass in the area at all levels of the food chain. Zooplankton and micronekton were collected by routine methods, using various nets, and their biomass was determined as wet weight or carbon equivalent. Biomass at the primary level, however, presented more difficulty. Routine determinations of chlorophylls were also made but are not a reliable measure of either the total algal population or the total suspended organic material. Strickland (1960), reviewing this problem, concluded that particulate carbon represents the most realistic measure of primary biomass. The collection and measurement of total suspended carbon were therefore included in our programme.

II. Methods

Water was collected in a 6-l. plastic sampler (Jitts 1964) at 0, 50, 100, 150, and 200 m. Each sample was filtered through two Whatman GF/C glass paper filters 25 mm in diameter, supported by a Millipore HA membrane and filter pad. The initial vacuum used was 10 in. of mercury, rising to 20 in. as filtration slowed down (usually after about 2 l. had been filtered). The GF/C filters, with contents, were sucked dry and stored in Perspex holders for analysis at Cronulla by the method of Dal Pont and Newell (1963). This method involves combustion of the sample in a stream of oxygen at 700°c, with subsequent absorption of the CO_2 produced in 0·005N NaOH. The change in conductance of the NaOH is a measure of the CO_2 absorbed. The usual recovery for glucose or EDTA standards up to 608 μg C is 99–101%. All results from samples collected in August–December 1962 were rejected because of contamination by smoke particles.

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* Part I, *Aust. J. mar. Freshwat. Res.*, 1969, **20**, 1–50.

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Two criticisms may be made of the methods used. Firstly, GF/C filters are a felt of glass fibres about 0·5 μ long, with no defined porosity, so that the lower size limit of the collected material is not known. On some occasions we observed a faint green or brown stain on the supporting HA membrane after filtration, but the amount appeared negligible compared with the material retained by the overlying GF/C filters. Secondly, our particulate carbon values include any mineral carbon present. Lisitzin (1964) has shown that calcium carbonate carbon generally provides less than 10% of total carbon in marine suspended material. The data of Armstrong and Atkins (1950) on total suspended matter in the English Channel showed that calcium

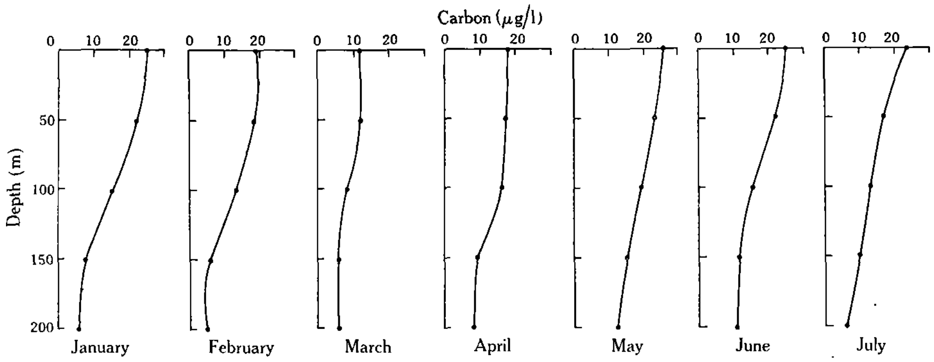

Fig. 1.—Average particulate carbon (μg/l.) at each depth, regardless of latitude, for all stations.

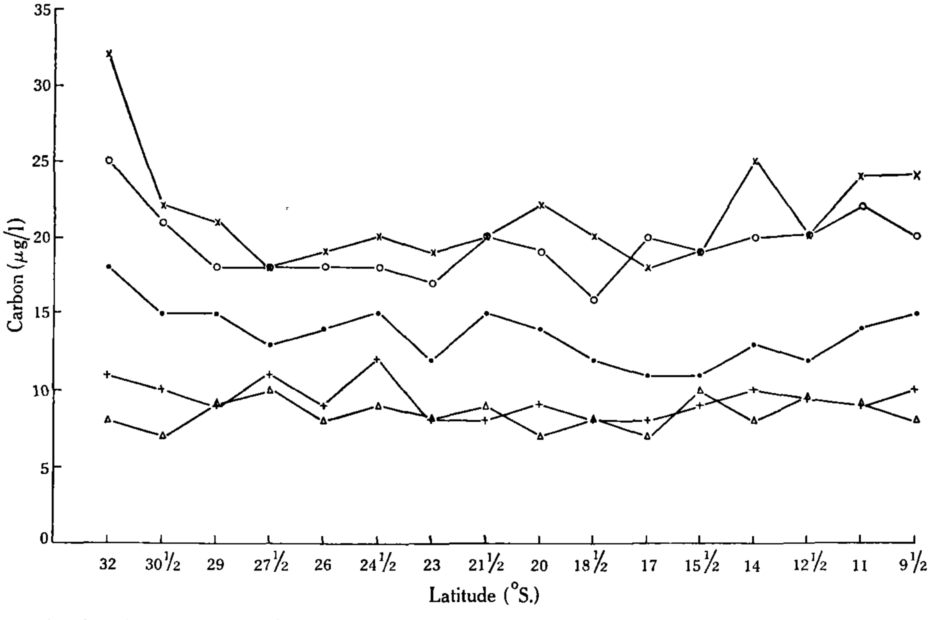

Fig. 2.—Average particulate carbon (μg/l.) at each depth for all stations. ×—×, 0 m; ○—○, 50 m; ●—●, 100 m; +—+, 150 m; △—△, 200 m.

carbonate provided some 3–5% of total carbon. We halved GF/C membranes containing suspended matter from the eastern Indian Ocean, and, before combustion, treated one half with 0·2 ml of 0·005N HCl in a silica boat. The results, which will be discussed fully in a subsequent publication, showed no significant decrease in carbon content due to acid treatment. Therefore, inorganic carbon was of little importance in our samples.

III. RESULTS

Figure 1 shows the average monthly particulate carbon (in μg/l.) at each depth for all the stations sampled, regardless of latitude. Surface values were minimal in March, falling from the January level of 24 μg/l. to only 12 μg/l. In all months values were high at 0 and 50 m, falling away rapidly through 100 m to low, and similar, values at 150 and 200 m.

Figure 2 shows the average particulate carbon at each depth in each latitude sampled, regardless of time. In general, values were highest in the south (15–30 μg/l.) and least in midlatitudes (5–20 μg/l.) at all depths. In the north, deeper values remained low, but the level of particulate carbon at 0 and 50 m tended to rise slightly to 20–25 μg/l. Like Figure 1, Figure 2 shows diminution of carbon values with depth.

No diurnal variation was observed.

IV. DISCUSSION

The only other measurements of particulate carbon in the Seasonal Biological Cruise area, available for comparison with the results described in this paper, are those of Lisitzin (1964). Lisitzin separated the suspended matter from 150–200 metric ton quantities of surface water by centrifugation and filtration, and carried out analyses for carbon, $CaCO_3$, SiO_2, TiO_2, Fe, Mn, P, Ra, and rare-earth elements. Carbon was estimated by a combustion technique normally applied to bottom sediment samples, inorganic carbon being first removed by acid treatment. At the three stations (63, 64, 65) worked along the 100°E. meridian between 32°S. and 20°S. latitude the organic particulate carbon was found to be 21, 15, and 15 μg/l. respectively.

Some measurements of total suspended matter ("seston") in the Seasonal Biological Cruise area have been published by Hagmeier (1964) but these are given as mg dry wt/m^3. Fortunately, Lisitzin (1964) also gives total suspended matter in mg/m^3 for all his stations, and at stations 63, 64, and 65, the organic carbon forms 11·0%, 9·3%, and 5·3% of the total suspended matter, respectively. On these values, the seston weights published by Hagmeier correspond approximately to particulate carbon values in the range 10–20 μg/l.

Our measurements are therefore within the range of values previously reported, despite the difference in methods. However, the measurements are low compared with the values of 100–200 μg/l. reported for the north-eastern Pacific Ocean (Parsons and Strickland 1962), the western North Atlantic (Menzel and Ryther 1964), the North Sea (Steele and Baird 1961), and the Arabian Sea (Menzel 1964). These high values of particulate carbon reported elsewhere, however, are, in general, associated with much higher levels of primary production than those found along the 110°E. meridian (Jitts 1968).

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Reprinted from *Aust. J. mar. freshwat. Res.*, vol. 20, 1969, p. 55-64

SEASONAL VARIATIONS IN THE INDIAN OCEAN ALONG 110°E.

V.* ZOOPLANKTON BIOMASS

By D. J. TRANTER† and J. D. KERR‡

[*Manuscript received July* 28, 1967]

Summary

Samples of the zooplankton in the upper 200 m were taken with the Indian Ocean Standard Net and Clarke–Bumpus sampler, and their wet weights were determined. Biomass ranged from 3 to 525 mg/m^3, the general level being 25–100 mg/m^3. The average value by day was 0·6 times that by night. Biomass was fairly uniform over a wide central region (16–27 S.), increasing further north and decreasing further south. The biomass was greatest in September and March and least in December and June.

I. INTRODUCTION

Earlier observations (Bogorov and Vinogradov 1961; Tranter 1962) showed that zooplankton biomass was usually higher near the coasts of Australia and Indonesia than in the central part of the south Indian Ocean. Particularly high values were recorded to the south of Java and the Lesser Sunda Islands in the region of upwelling (Wyrtki 1962). Vinogradov, Voronina, and Sukhanova (1961) observed that the various trophic levels were progressively displaced towards the south, away from the centre of enrichment. The present investigation, of which this is the first report, was designed to study these phenomena. A later report will describe the distribution of various zooplankton taxa.

II. MATERIAL AND METHODS

The zooplankton programme consisted of vertical sampling (200–0 m) with the Indian Ocean Standard Net (IOSN, Currie 1963), and horizontal sampling with the Clarke–Bumpus sampler (CBS, Tranter 1966). The nominal depths for horizontal sampling were 0, 50, 100, and 200 m, but in practice the sampling range extended to 300 m. The CBS was also used to sample the 200–0 m layer by oblique haul during cruises G 4/62 and Dm 4/62 when the IOSN was lost; by day it was used in the standard way, by night it was attached to the warp of the midwater trawl. Further details of sampling procedure and the method of measuring biomass are given in Oceanographical Cruise Reports. Zooplankton biomass is taken to be the wet weight of the preserved zooplankton catch.

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* Part IV, *Aust. J. mar. Freshwat. Res.*, 1969, **20**, 65–75.

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representation of these effects, trigonometric curves were used for time of day and time of year, polynomial curves for latitude, and mixtures of both for depth. Because of the lack of orthogonality resulting from missing values, the sums of squares are dependent on the order in which the significance of the various effects are tested (Tables 1 and 2). The level of significance adopted was probability not exceeding 5%. However, the only groups of variables dropped from the regression after making an F-test were those for which the probability that the effect was random exceeded 10%.

TABLE 1

CHLOROPHYLL CONCENTRATION REGRESSIONS

Values are those obtained from F-tests of significance made in the order given

Effect	D.F.	F-value	Action
Chlorophyll *a*			
Diurnal by seasonal	4, 1037	0·38 NS	Omitted
Depth by seasonal	8, 1037	12·31 ***	Retained
Depth by diurnal	7, 1037	1·07 NS	Omitted
Latitude by seasonal	4, 1037	4·53 **	Retained
Latitude by diurnal	4, 1037	1·52 NS	Omitted
Latitude by depth	7, 1037	9·21 ***	Retained
Seasonal	4, 1037	16·25 ***	Retained
Diurnal	2, 1037	0·56 NS	Omitted
Depth	5, 1037	16·01 ***	Retained
Latitude	4, 1037	4·52 **	Retained
Chlorophyll *c*			
Diurnal by seasonal	4, 1037	0·34 NS	Omitted
Depth by seasonal	8, 1037	3·28 **	Retained
Depth by diurnal	7, 1037	1·32 NS	Omitted
Latitude by seasonal	4, 1037	2·74 *	Retained
Latitude by diurnal	4, 1037	3·48 **	Retained
Latitude by depth	7, 1037	4·06 ***	Retained
Seasonal	4, 1037	10·66 ***	Retained
Diurnal	2, 1037	1·57 NS	Omitted
Depth	5, 1037	3·72 **	Retained
Latitude	4, 1037	5·43 ***	Retained

Statistics

Chlorophyll *a*:	mean of observations	0·168 μg/l.
	crude S.D.	0·117
	error variance after regression	0·00806†
	S.D. after regression	0·090
	percentage of crude variance ascribable to fitted variates	39%
Chlorophyll *c*:	mean of observations	0·222 μg/l.
	crude S.D.	0·140
	error variance after regression	0·0154‡
	S.D. after regression	0·124
	percentage of crude variance ascribable to fitted variates	19%

* Significant at 5% level; ** at 1% level; *** at 0·1% level; N.S. not significant. † 1054 degrees of freedom. ‡ 1050 degrees of freedom.

In the case of the column values, both the main effect of depth, and all interactions with depth, were omitted from the analysis following tests of significance. From the results of the analysis, regression equations were calculated and used to estimate the fitted values for given values of latitude, time of year, time of day, and depth. By means of grids of closely spaced points, contour maps of certain surfaces were drawn. These contour diagrams (Figs. 2–8) are approximations and are subject to the limitations of the methods used in obtaining the regression equations.

TABLE 2

COLUMN CHLOROPHYLL REGRESSIONS

Values are those obtained from *F*-tests of significance made in the order given

Effect	D.F.	*F*-value	Action
Chlorophyll *a*			
Diurnal by seasonal	8, 150	1·11 NS	Omitted
Diurnal by latitude	4, 150	1·34 NS	Retained
Diurnal	2, 150	0·22 NS	Omitted
Seasonal	4, 150	0·15 NS	Omitted
Latitude by seasonal	16, 164	8·78 ***	Retained
Latitude	4, 164	2·34 *	Retained
Chlorophyll *c*			
Diurnal by seasonal	8, 150	0·91 NS	Omitted
Diurnal by latitude	4, 150	1·78 NS	Retained
Diurnal	2, 150	0·72 NS	Omitted
Seasonal	4, 150	0·84 NS	Omitted
Latitude by seasonal	16, 150	7·16 ***	Retained
Latitude	4, 150	2·40 †	Retained

Statistics

Chlorophyll *a*:	mean of observations	26·7 mg/m^2
	crude S.D.	9·45
	error variance after regression	53·3‡
	S.D. after regression	7·35
	percentage of crude variance ascribable to fitted variates	35%
Chlorophyll *c*:	mean of observations	34·5 mg/m^2
	crude S.D.	13·5
	error variance after regression	116·8‡
	S.D. after regression	10·8
	percentage of crude variance ascribable to fitted variates	27%

* Significant at 5% level; *** at 0·1% level. † Between 5 and 10% levels. ‡ 164 degrees of freedom.

III. RESULTS

(*a*) *Diurnal Variation*

No significant difference was found between day and night concentrations of chlorophylls *a* and *c* at the various depths (Table 1), or in the water column (Table 2). Combinations of diurnal effect with depth, latitude, and season were insignificant except for the diurnal-latitude combination for chlorophyll *c* at individual depths (Fig. 1). Because of this significant diurnal-latitude combination for chlorophyll *c*, in subsequent figures the day and night values were not pooled as they were for *a* and only the 0800 hr values are shown.

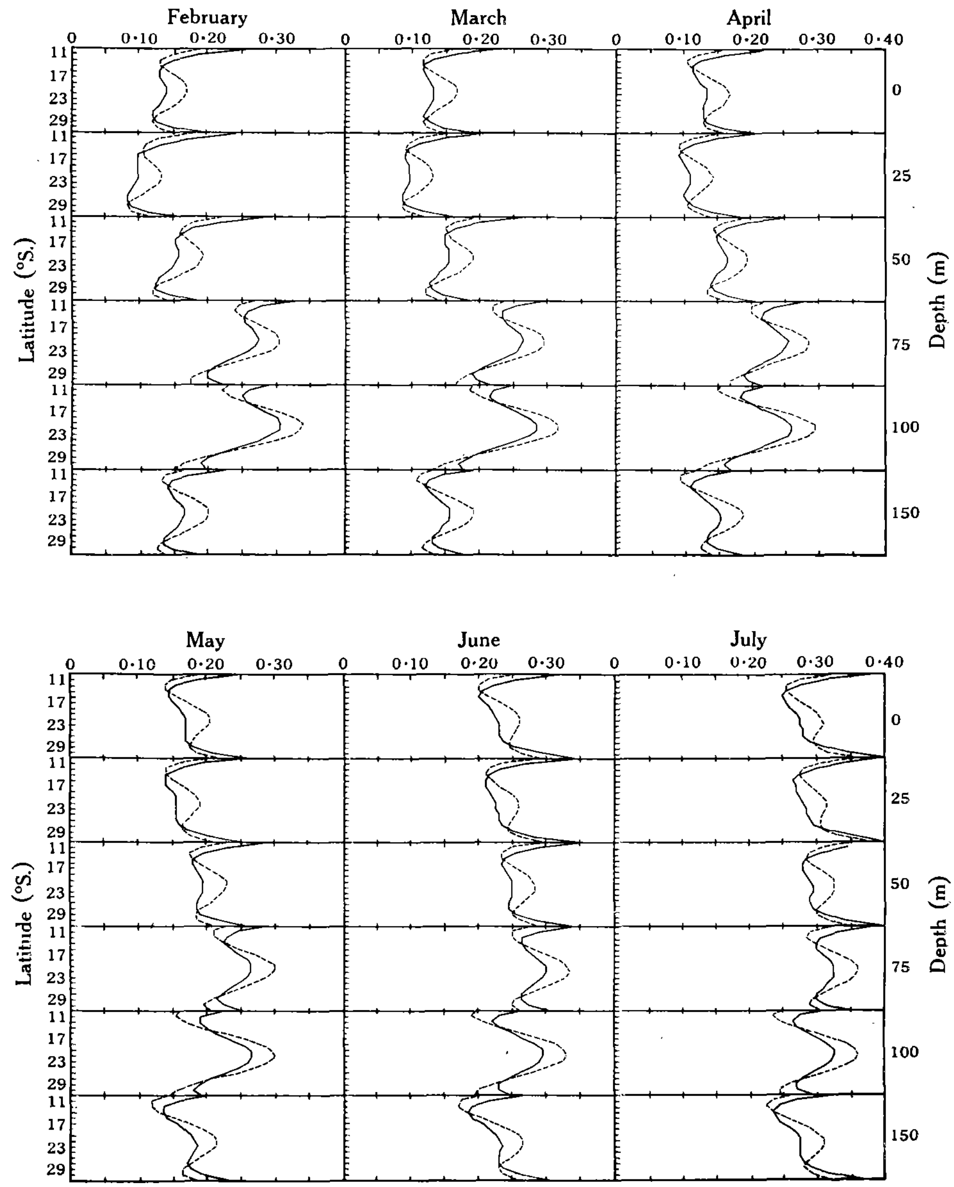

Fig. 1.—Diurnal variation of chlorophyll *c* (μg/l.) with latitude for each depth and month (—— day, - - - night). S.D. varied between 0·124 and 0·129 μg/l.

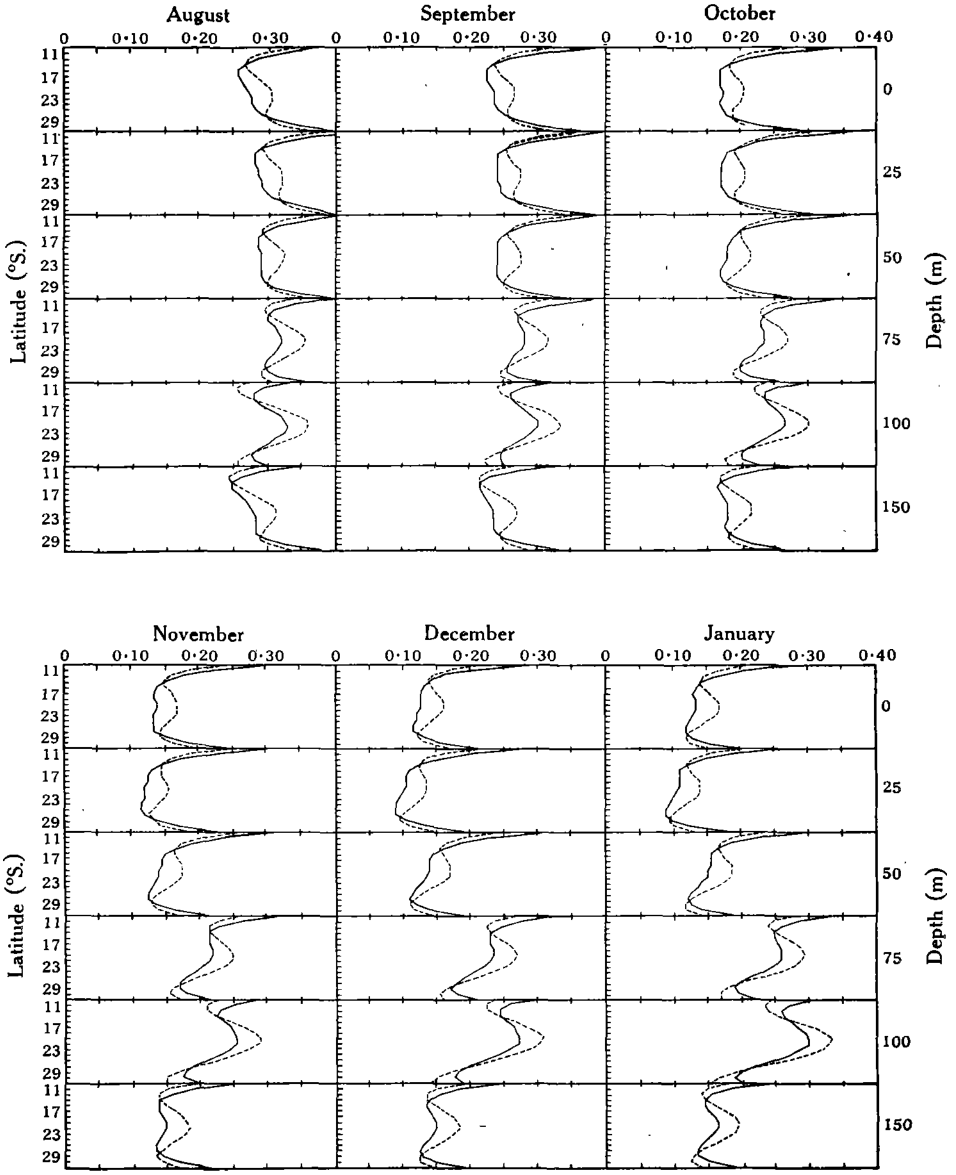

Fig. 1 (*Continued*).

(*b*) *Depth*

Both chlorophylls *a* and *c* varied significantly with depth (Table 1). There were also significant interactions of depth with latitude and season. Figures 2 and 3 show the monthly variation of chlorophylls *a* and *c* according to depth for each latitude sampled.

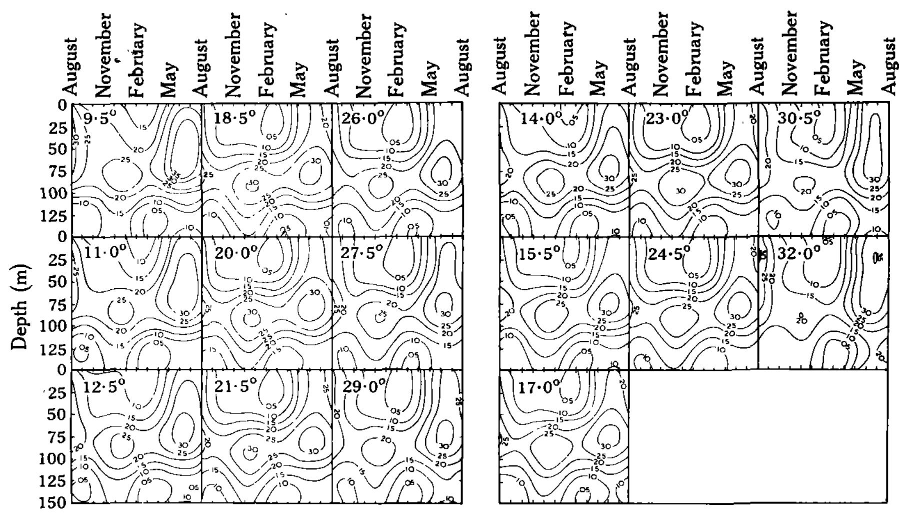

Fig. 2.—Concentration of chlorophyll *a* (μg/100 l.) as a function of depth and month, for each latitude. S.D. varied between 9·0 and 9·3 μg/100 l.

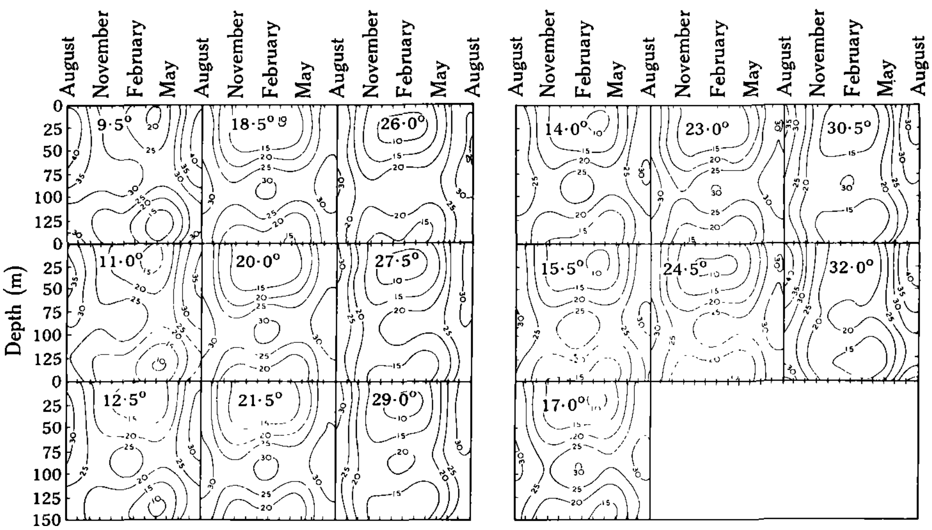

Fig. 3.—Concentration of chlorophyll *c* (μg/100 l. at 0800 hr) as a function of depth and month, for each latitude. S.D. varied between 12·4 and 12·9 μg/100 l.

(*c*) *Latitude*

The distributions of chlorophylls *a* and *c* (shown in Figs. 4–6) were significantly related to latitude, both as concentrations for a given depth (Table 1) and for the water column (Table 2). There was a significant interaction of latitude with season.

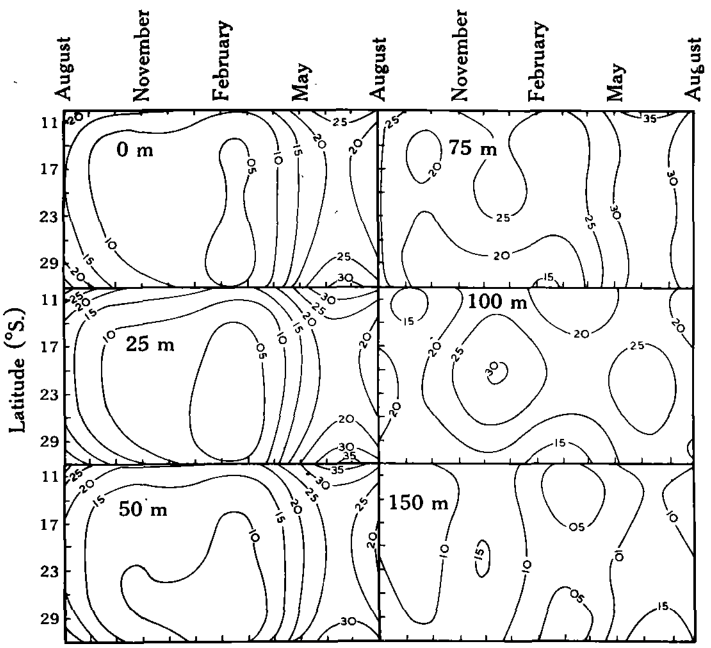

Fig. 4.—Concentration of chlorophyll *a* (μg/100 l.) as a function of month and latitude, for each depth. S.D. varied between 9·0 and 9·3 μg/100 l.

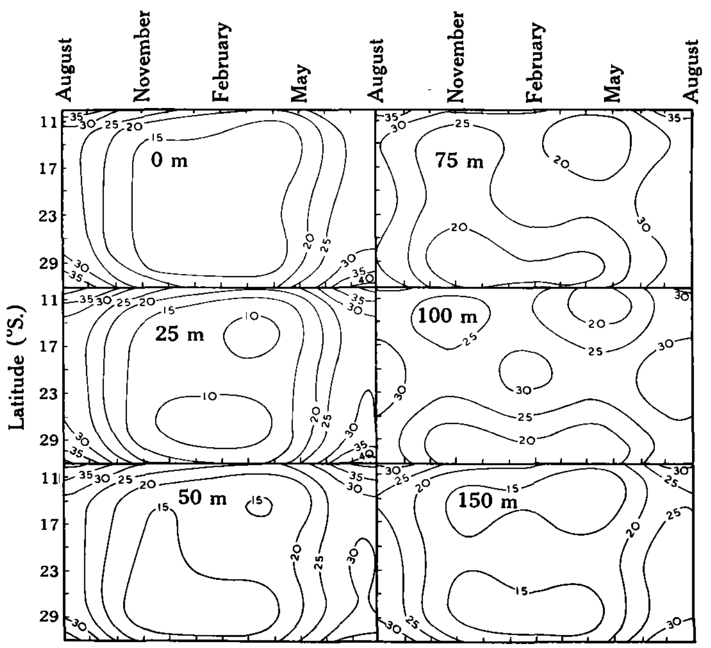

Fig. 5.—Concentration of chlorophyll *c* (μg/100 l. at 0800 hr) as a function of month and latitude, for each depth. S.D. varied between 12·4 and 12·9 μg/100 l.

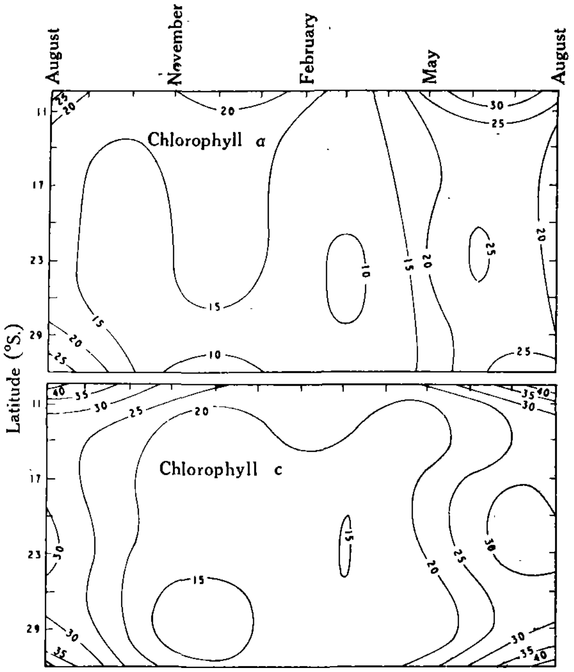

Fig. 6.—Amounts of chlorophylls *a* (mg/m²) and *c* (mg/m² at 0800 hr) as functions of month and latitude. S.D. varied between 7·4 and 9·3 mg/m² for chlorophyll *a* and between 10·9 and 13·8 mg/m² for chlorophyll *c*.

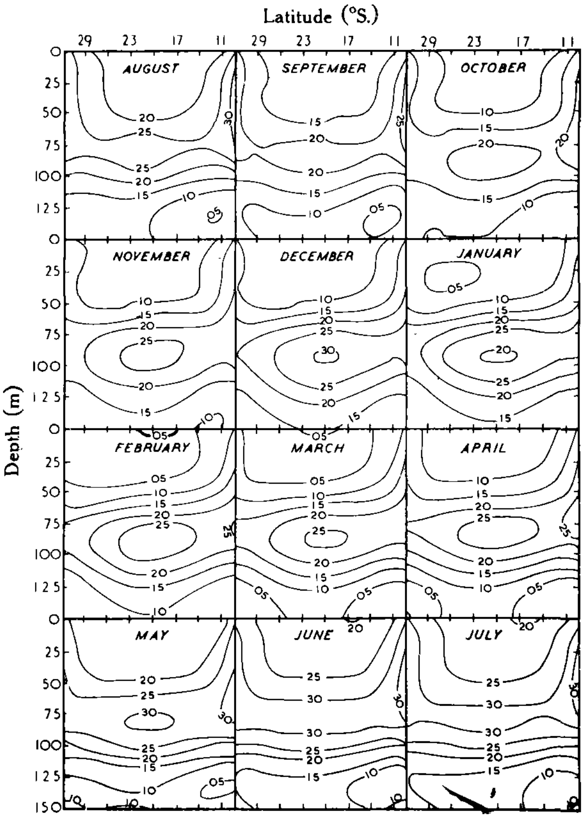

Fig. 7.—Concentration of chlorophyll *a* (μg/100 l.) as a function of latitude and depth, for each month. S.D. varied between 9·0 and 9·3 μg/100 l.

(*d*) *Season*

The effect of month of sampling was significant for the concentration of chlorophylls *a* and *c* at all depths (Table 1) but not for the column concentrations (Table 2). Figures 7 and 8 show the depth–latitude variations for each month.

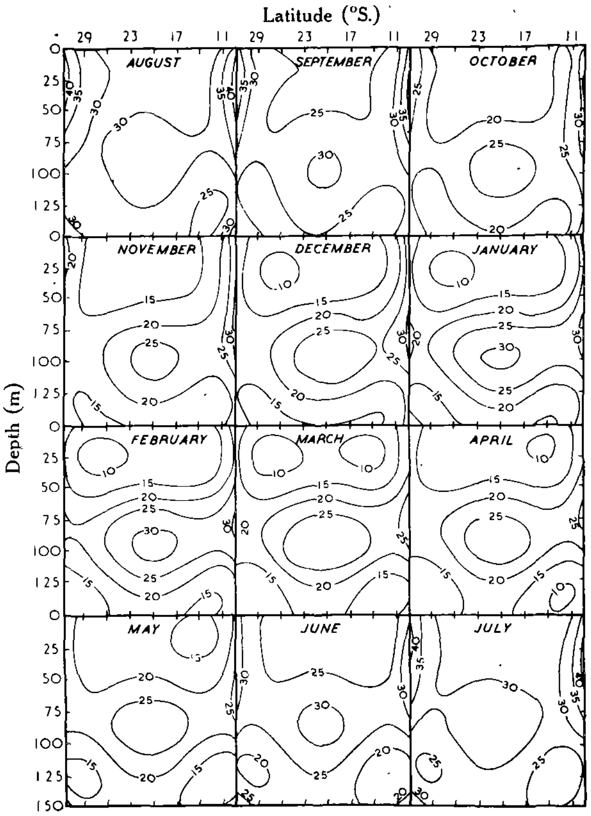

Fig. 8.—Concentration of chlorophyll *c* (μg/100 l. at 0800 hr) as a function of latitude and depth, for each month. S.D. varied between 12·4 and 12·9 μg/100 l.

IV. Discussion

The biggest concentration of chlorophyll *a* was 1·1 μg/l. and was found at Station Dm2/75/63 at 2030 hr at 11°S. at a depth of 25 m. The biggest concentration of chlorophyll *c* was also 1·1 μg/l. found at Station Dm3/90/63 at 0800 hr at 32°S. at a depth of 50 m. Therefore, the intensive sampling along the 110° line has shown that concentrations of chlorophylls are sometimes twice as great as those previously recorded in American (McGill and Lawson, personal communication 1966), Australian (Humphrey 1966), or Japanese (Saijo 1965; Shimonoseki Univ. Fish. 1965) studies on the south-east Indian Ocean. Perhaps if other sections were regularly studied, higher values would be obtained in them also. As found by all workers, 75 m was the most frequent depth at which the chlorophylls were maximal.

Samples collected at 2030 hr usually had higher concentrations of both chlorophylls than those collected at 0800 hr but the differences were not statistically significant. The diurnal–latitude combination of effects was significant for chlorophyll *c*, 21°30′S. showing the biggest difference (Fig. 1). The night curve crossed the day curve near the ends of the section, for both chlorophylls.

The highest concentrations of chlorophylls were in June–August. This finding agrees with that of Humphrey (1966) for the south-east Indian Ocean. In the water column down to 150 m, the amount of chlorophyll *a* was between 10 and 30 mg/m^2 and the amount of chlorophyll *c* between 15 and 40 mg/m^2 (Fig. 6); the highest amounts were in June–August. These results are higher than those of Humphrey (1966) for the south-east Indian Ocean.

It is not possible to make other generalizations from the original results. The regression analyses, however, showed that depth, latitude, and season affected the concentration of the chlorophylls. Latitude and season affected the amount of the chlorophylls in the water column to 150 m.

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Reprinted from *Aust. J. mar. freshwat. Res.*, vol. 20, 1969, p. 65-75

SEASONAL VARIATIONS IN THE INDIAN OCEAN ALONG 110°E.

IV.* PRIMARY PRODUCTION

By H. R. JITTS[†]

[*Manuscript received July* 28, 1967]

Summary

Mean productivity (light saturated photosynthesis), *Ps*, for the meridian rose from 50 mg C/(hr m^2) in August 1962 to a maximum of 62 in October, then fell to a minimum of 4 in January, whereafter it rose slowly to 25 in April–May, then sharply to 45 in late May, and remained at that level till August 1963. Mean *Ps* for the year was 37 mg C/(hr m^2). The depth of the layer of photosynthetic organisms varied between 130 m in October and 60 m in January, with a mean of 85 m. Maximum *Ps* occurred at 25 m in 36% of the stations, at 0 m in 29%, and at 50 m in 24%.

In January–February the whole meridian was occupied by waters of low productivity, approximately 4 mg C/(hr m^2) from the centre of the south Indian Ocean. In April–May the *Ps* remained uniform along the meridian but rose to 24. At other times four latitudinal intervals along the meridian, with distinctive seasonal variations of productivity characteristics, were found. From 9 to 15°S., waters with high *Ps* (69 mg C/(hr m^2)), and sharp stratification at 50 m, caused by equatorial upwelling, occurred from May to October. From 15 to 24 and 24 to 30°S., waters with high *Ps* (60 mg C/(hr m^2)) and (100 m) deep layers of photosynthetic organisms were found during October–November and May–July respectively. From 30 to 32°S., waters of high productivity (70 mg C/(hr m^2)) and a deep layer (100 m) were found in the period July–August.

The daily rate of primary production, *Pa*, of the whole meridian varied from 0·13 g C/(day m^2) in August to 0·08 from October to early May, rising sharply in late May to 0·18 and again in early August to 0·27. The depth of the euphotic layer varied between 76 m in October and 63 m in July–August, with a mean of 68 m.

I. INTRODUCTION

Many measurements reported in this paper are of the rates of photosynthetic fixation of carbon dioxide by phytoplankton in oceanic samples exposed to constant artificial light of approximately saturating intensity. As in earlier papers (Jitts 1965; Dyson, Jitts, and Scott 1965) these measurements will be referred to as "productivity" although the term will be frequently abbreviated to "*Ps*". *Ps* is identical with Steemann Nielsen's (1965) "light saturated rate of photosynthesis" or Saijo's (1965) "rate of photosynthesis measured by tank experiments". *Ps* should not be confused with other measurements, also reported in this paper, of *in situ* daily rates of actual

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* Part III, *Aust. J. mar. Freshwat. Res.*, 1969, **20**, 55–64.

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production of organic matter in the sea, which will be abbreviated as "*Pa*". *Ps* is a function of the phytoplankton composition, their numbers, and their optimal ability to photosynthesize. *Pa* is a function of both *Ps* and the photosynthetic response of the phytoplankton to the varying natural light conditions prevailing at the time. *Ps* cannot be converted to *Pa* except by using empirical factors (Steemann Nielsen and Aabye Jensen 1957). However, *Ps* is easier to measure than *Pa*; this facilitates more extensive and intensive studies of regional and seasonal variations of oceanic productivity characteristics. Furthermore *Ps* can provide information on the phytoplankton at depths where natural light attenuation would limit or eliminate *Pa*.

The productivity of the eastern Indian Ocean was surveyed from 1959 to 1962 by Jitts (unpublished data). This survey showed that winter (April–September) *Ps* in the region was more than twice that of summer (October–March). It also showed the presence of waters of high *Ps* south of Java in winter, and of waters of very low *Ps*, dominating the whole area, in summer. Owing to the scatter of the stations, both in time and place, only a broad idea of the seasonal changes of *Ps* was obtained. The work described in the present paper complements the earlier survey.

II. METHODS

(*a*) *Primary Productivity* (Ps)

Primary productivity, *Ps*, was measured by the methods described by Dyson, Jitts, and Scott (1965). Samples from standard depths of 0, 25, 50, 75, 100, and 150 m were collected with twin 6 l. plastic samplers. One clear and one dark 300 ml Pyrex bottle was filled from the samplers, 10 μCi of ^{14}C added, and the samples incubated for 4 hr in a fluorescent light bath at about 1100 f.c. The samples were filtered through Millipore HA filters and their activities measured with a windowless Geiger counter. The *Ps* at each depth was calculated in mg C/(hr m^3). From these, the *Ps* at each station of the column under 1 m^2 from 0 to 150 m was calculated in mg C/(hr m^2).

The depth of the layer of photosynthetic organisms is assumed in this study to be the depth above which values of *Ps* of more than 0·10 mg C/(hr m^3) are found, i.e. the depth of the layer in which significant amounts of photosynthesis can be measured in samples exposed to constant saturating light.

During January and February 1963 there was evidence that the samples were poisoned by the use of new plastic samplers which had been insufficiently cleaned. This effect was measured on subsequent cruises and the results showed that the January and February measurements might be low by a factor of about 2. No corrections have been made because, even if doubled, the values in January and February are much lower than during the rest of the year.

(*b*) *Daily Rates of Production* (Pa)

The daily rate of production, *Pa*, defined here as the photosynthetic production of organic matter by phytoplankton in the ocean under natural or quasi-natural light conditions during one daylight period, was measured from noon to sunset by the simulated *in situ* method described by Jitts (1963). Blue glass filters and sunlight were used for incubating samples collected by "balance-by-depth" submarine photometry. Results were calculated in mg C/(day m^3) at each depth, and in g C/(day m^2) for the column under 1 m^2.

The greatest sampling depth, where about 2% of incident sunlight is found, is assumed in this study to roughly approximate the depth of the euphotic layer, i.e. the layer in which net production of organic matter occurs in the ocean.

Owing to unsuitable weather and frequent instrument failures, measurements of *Pa* were made at an average of only 10 of the 16 stations on each cruise.

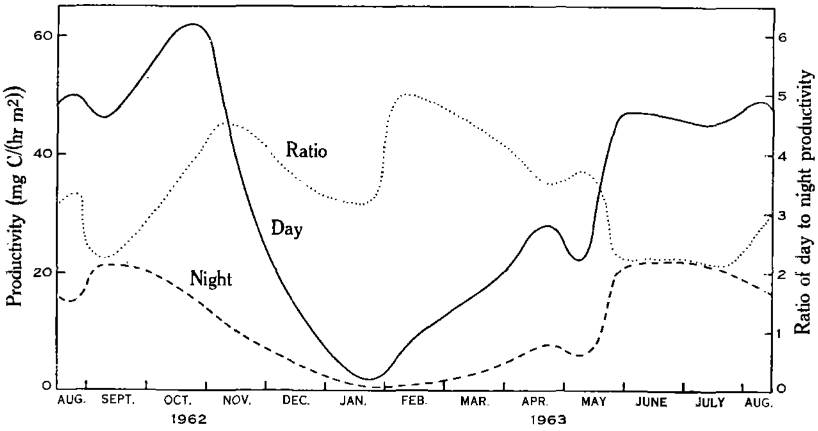

Fig. 1.—Mean productivity of day and night samples of the column under 1 m^2 for the whole meridian. The ratio of day to night productivity is also shown.

III. Results

(*a*) *Mean Seasonal Variations along the Whole Meridian*

The means of the productivities of the column under 1 m^2 for the whole 110°E. meridian, as a function of the monthly mean date, are given in Figure 1. The *Ps* of morning station samples was always higher (2–5 times) than that of evening station samples. The irregularity of this diurnal variation made it impossible to combine the night samples with the day samples, even by using empirical correction factors. Both morning and evening samples showed similar patterns of high *Ps* in winter and low *Ps* in summer. In all subsequent analyses only the day samples were considered, as most of the evening sample values were only just above the level of sensitivity of the method.

From late August to early November 1962 the *Ps* of the meridian was high, varying between 46 and 62 mg C/(hr m^2). By January the *Ps* had fallen to a very low mean of 2 mg C/(hr m^2). From February to early May the *Ps* rose gradually to about 25 mg C/(hr m^2), then sharply to about 45 mg C/(hr m^2) in late May and remained at that level through to early August 1963.

(*b*) *Seasonal Variations in Relation to Latitude*

The seasonal variations of the productivity of the column under 1 m^2, in relation to latitude along the meridian, are given in Figures 2 and 3. In Figure 2 the meridian was arbitrarily divided into four latitudinal intervals: 9–15, 15–24, 24–30, and 30–32°S.

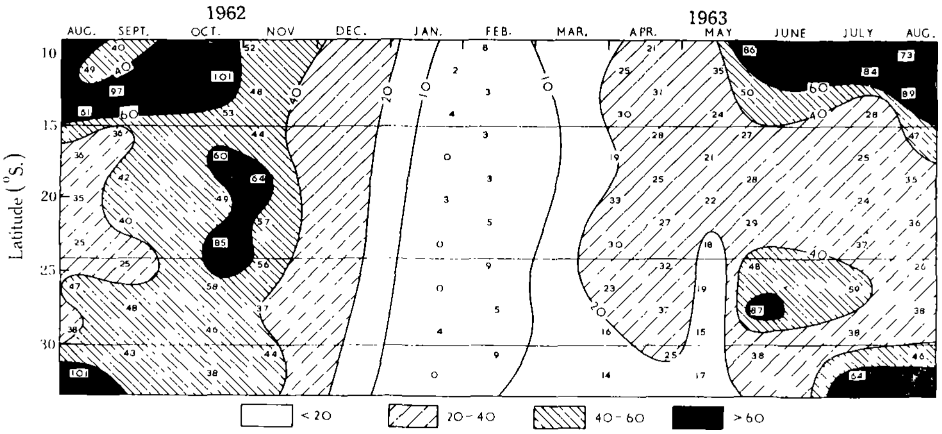

Fig. 2.—Seasonal variation with latitude of the productivity, day samples in mg C/(hr m^2), of the column under 1 m^2.

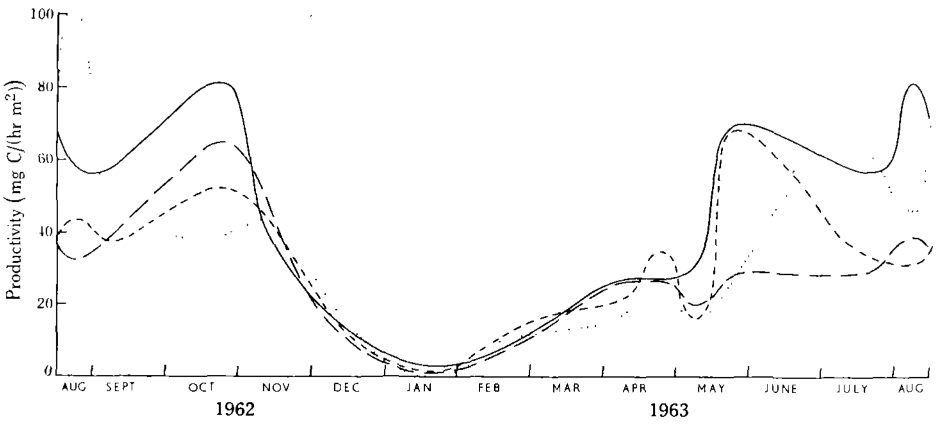

Fig. 3.—Mean productivities under 1 m^2 in four latitudinal intervals: ——— 9–15°S. — — — 15–24°S., - - - - 24–30°S., ······· 30–32°S.

Between latitudes 9 and 15°S. the mean *Ps* (Fig. 3) in August 1962 was 60 mg C/(hr m^2), rising to 80 in late October. It decreased to 50 in November and continued to decrease rapidly to 3 in January. From February to early May it rose slowly to 30, then rose sharply to 70 in late May. From late May to August 1963 it remained high, varying between 60 and 80.

The interval from 15 to 24°S. had a moderate *Ps* of 30 mg C/(hr m^2) in August 1962 which rose to 65 in late October. From November to May the *Ps* was indistinguishable from that between 9 and 15°S. However, it showed no sharp increase in late May, but only a very slow increase to 50 in August 1963.

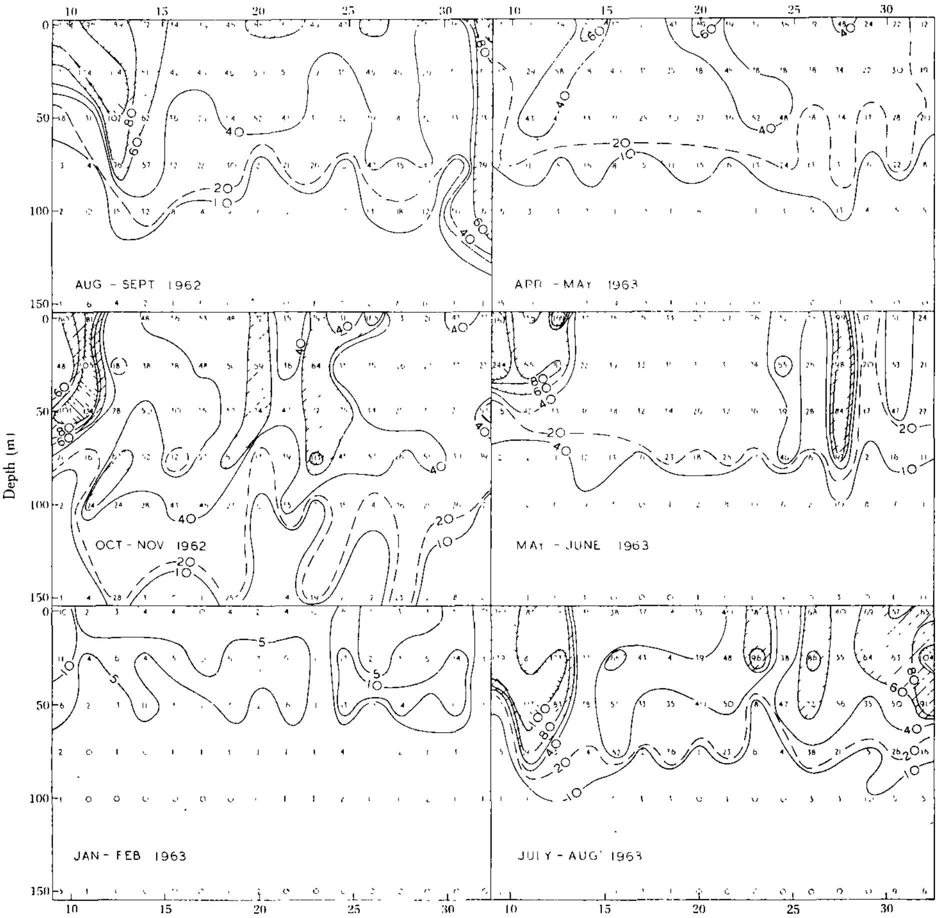

Fig. 4.—Vertical sections along the 110°E. meridian of productivity, in 100 × mg C/(hr m^3), for each of the six cruises from August 1962 to August 1963.

The 24–30°S. interval had a moderate *Ps* of 40 mg C/(hr m^2) in August 1962, and this rose less than that between 15 and 24°S. to only 50 mg C/(hr m^2) in October. Again, from November to May, the *Ps* was the same as in the 9–15 and 15–24°S. intervals. As in the northern interval, the *Ps* rose sharply in late May to 75 mg C/(hr m^2) but then fell steadily to 30 in August 1963.

The southernmost interval between 30 and 32°S. had a very high *Ps* of 100 mg C/(hr m^2) in August 1962 which fell sharply to 40 in September, where it remained until November. Thereafter, until May, it was the same as further north. From late May the *Ps* rose steadily to 65 in July, then fell to 45 in August 1963.

(*c*) *Variations in Relation to Depth*

Vertical sections along the 110°E. meridian, for each of the six cruises, are given in Figure 4. During August–September 1962 the mean depth of the 0·10 mg C/(hr m^3) contour, i.e. the depth of the layer of photosynthetic organisms, was 95 m. In October–November the mean depth increased to 130 m. In January–February most of the *Ps* values were too low, but at five stations the layer was at about 60 m. In April the depth of the layer increased to 80 m, then decreased to 75 m in May–June and July–August. The mean depth of the layer of photosynthetic organisms throughout the year was 85 m.

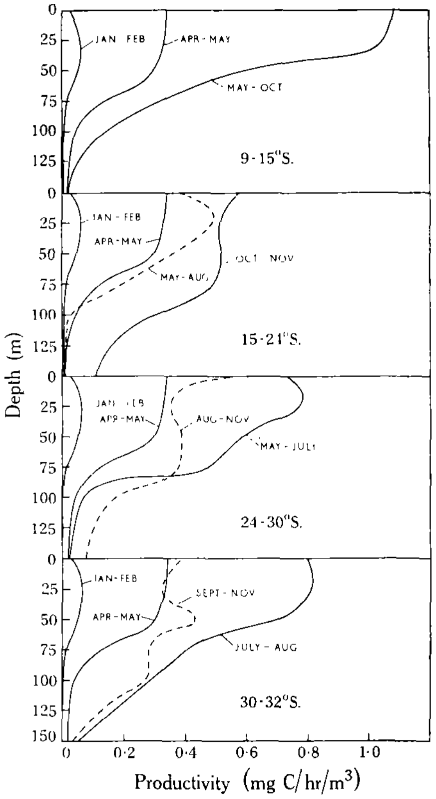

Fig. 5.—Mean vertical profiles of productivity during selected periods in four latitudinal intervals along the 110°E. meridian.

Maximum *Ps* occurred with greatest frequency at 0 m during August–September, at 75 m during October–November, at 25 m in January–February, at 0 m in April, and at 25 m during both May–June and July–August. In the 96 stations on all six cruises, the maximum *Ps* occurred at 25 m in 36% of stations, at 0 m in 29%, at 50 m in 24%, at 75 m in 8%, and at 100 m in 2%.

Seasonal variations of the mean vertical profiles of *Ps* during selected periods, in the four latitudinal intervals described earlier in Section III(*b*), are shown in Figure 5. There was no distinguishable variation with latitude during the periods January–February and April–May. During January–February *Ps* was low along the whole meridian, varying from 0·03 to 0·06 mg C/(hr m^3) in the upper 50 m and falling to 0·01 at 75 m. During April–May the *Ps* increased to values of 0·34–0·30 mg C/(hr m^3) in the upper 50 m, again falling sharply at 75 m to 0·12.

From 9 to 15°S. (Fig. 5) the *Ps* of the surface layers increased sharply to over 1·0 mg C/(hr m^3) in the period May to October, but decreased sharply at 50 m. From 15 to 24°S. (Fig. 5), *Ps* increased only slightly in the period May–August, but in October–November the *Ps* increased markedly, and this was accompanied by a deepening of the layer of photosynthetic organisms to 100 m.

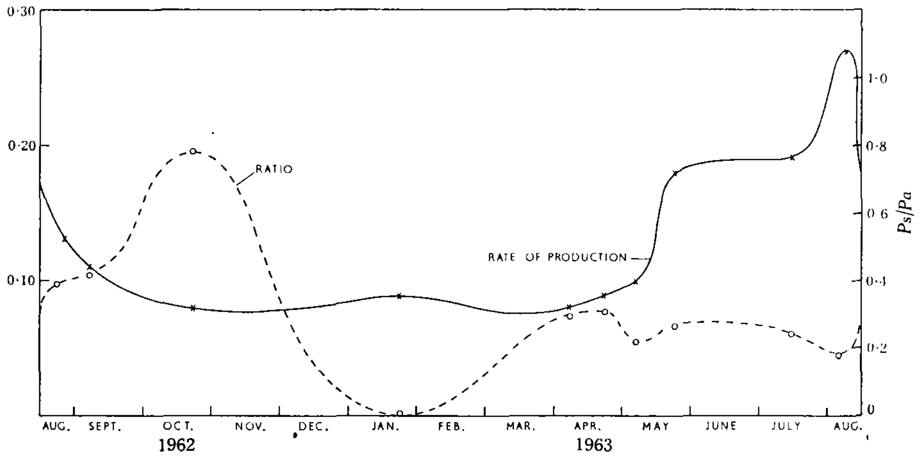

Fig. 6.—Seasonal variation of the mean daily rate of production, *Pa*, along the whole meridian. The ratio of productivity, *Ps*, in mg C/(hr m^2) to daily rate of production, in mg C/(day m^2), is also shown.

Between 24 and 30°S. (Fig. 5) the *Ps* also increased sharply in the period May–July to over 0·7 mg C/(hr m^3) in the surface layers. This was accompanied by a deepening of the layer of photosynthetic organisms to 100 m. A decrease in *Ps* followed in the period August–November.

From 30 to 32°S. (Fig. 5) there was no marked increase in *Ps* until the period July–August, when it was again accompanied by a deepening of the layer of photosynthetic organisms. The *Ps* decreased in the period September–November.

The results given in this and the preceding section are summarized in Table 1.

(*d*) *Daily Rate of Primary Production* (Pa)

The seasonal variation of the mean *Pa* of the whole meridian is shown in Figure 6. The *Pa* fell from 0·13 g C/(day m^2) in August 1962 to 0·08 in October and remained at about that value through to early May. In late May the *Pa* rose sharply to 0·18 g C/(day m^2) and rose further in early August 1963 to 0·27.

Figure 6 also shows the variation of the ratio of the mean *Ps* under 1 m^2 to the mean *Pa*. The ratio varied from 0·4 in August 1962 to 0·8 in October, to 0·01 in January, then rose to between 0·3 and 0·2 from April to August 1963.

Seasonal variations of *Pa* in relation to latitude are given in Figure 7. The low number of stations from November to March made the contouring suspect, but this figure does show some similarity to Figure 2. It shows high values north of 15°S. in August, falling to low values in January–February, then rising to high values in late May north of 15°S. and between 24 and 30°S.

Vertical sections of *Pa* for each of the six cruises are given in Figure 8. The approximate depth of the euphotic layer, i.e. the depth of the deepest sample, varied between 55 and 80 m in August–September, with a mean of 64 m. In October the depth of the layer increased to between 65 and 85 m, with a mean of 76 m. In January the mean depth had decreased to 70 m and remained at about that depth through to June; in July–August it decreased to 63 m. The mean depth of the euphotic layer for all the stations was 68 m.

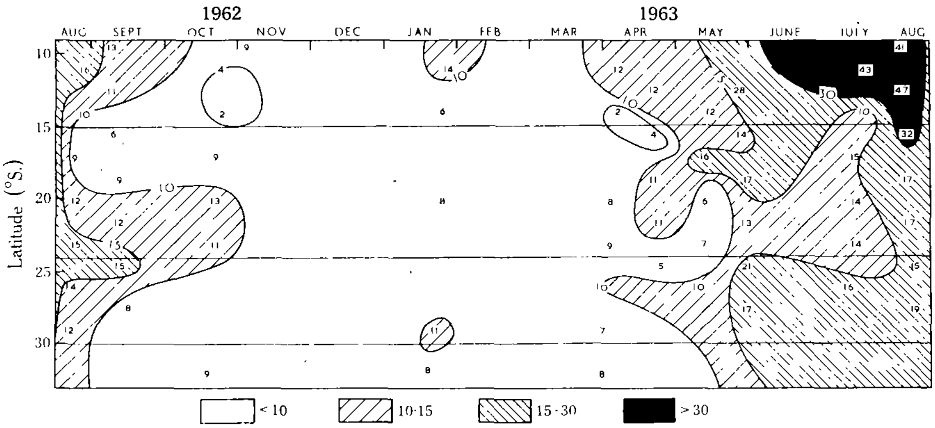

Fig. 7.—Seasonal variation with latitude of the daily rate of production, in 100 × g C/(day m^2), of the column under 1 m^2.

IV. Discussion

The earlier survey of 1959–1962 productivity data in the eastern Indian Ocean (Jitts, unpublished data) showed a mean *Ps* of 21 mg C/(hr m^2) in "summer" and 44 in "winter", giving an annual mean of 33. The annual mean along the 110°E. meridian, calculated from Figure 1, is 37 mg C/(hr m^2). However, Figure 1 suggests that the arbitrary division of the year into two seasons, "summer" from October to March, and "winter" from April to September, as used in the earlier survey, would be more valid if the seasons were from late November to early May and from late May to early November.

The low *Ps* found during January–February along the whole meridian in this study is consistent with the 1959–62 results, which showed the whole area to be occupied by waters of a mean *Ps* of 11 mg C/(hr m^2) originating in the centre of the south Indian Ocean. As stated in Section II(*a*), samples in this period were poisoned, and the mean value of 4 mg C/(hr m^2) given in Table 1 is probably too low. In December 1963–January 1964, along the 105°E. meridian, Saijo (1965) obtained values between 10 and 20 mg C/(hr m^2).

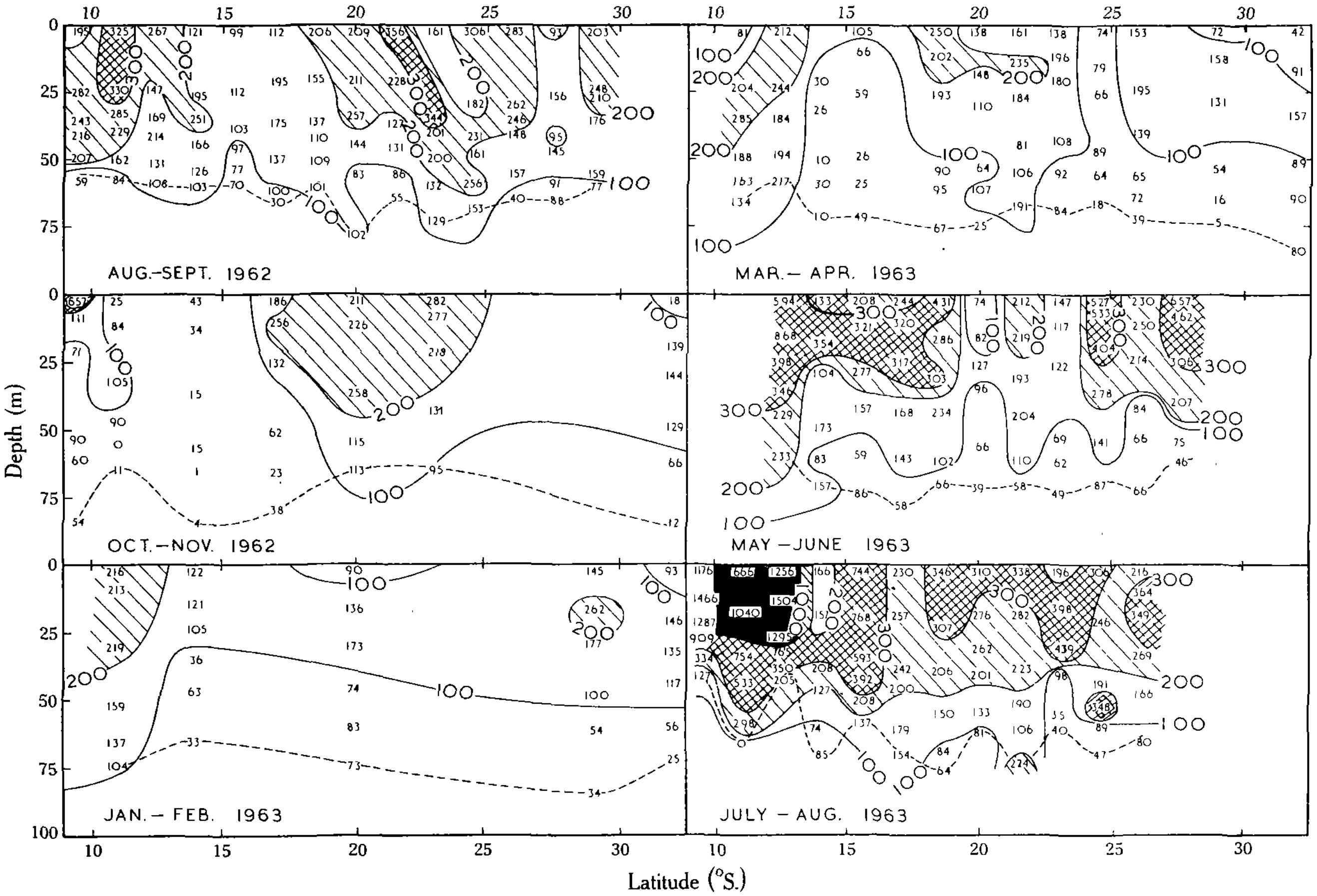

Fig. 8.—Vertical sections along the 110°E. meridian of the daily rate of production, in 100 × mg C/(day m³), for each of the six cruises. The depth of the deepest sample ——— is also contoured as an approximation to the depth of the euphotic layer.

TABLE 1

SCHEMATIC PRESENTATION OF THE SEASONAL VARIATION OF PRODUCTIVITY CHARACTERISTICS IN SELECTED PERIODS IN FOUR LATITUDINAL INTERVALS ALONG THE 110°E. MERIDIAN

"Mean" is the mean productivity of the column under 1 m^2 of all stations in the period. "Maximum" is the mean depth in the period where maximum productivity was found. "Stratification" is the mean depth at which a marked decrease in productivity was found

Latitude Interval	Characteristic	1962					1963							
		Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
9°S. to 15°S.	Productivity	High					Low			Moderate		High		
	Mean (mg C/(hr m^2))	69					4			24		69		
	Maximum (m)	0					25			0		0		
	Stratification (m)	50					75			75		50		
15°S. to 24°S.	Productivity			High			Low			Moderate		Moderate		
	Mean (mg C/(hr m^2))			60			4			24		32		
	Maximum (m)			0			25			0		25		
	Stratification (m)			100			75			75		75		
24°S. to 30°S.	Productivity	Moderate					Low			Moderate		High		
	Mean (mg C/(hr m^2))	42					4			24		58		
	Maximum (m)	0					25			0		25		
	Stratification (m)	100					75			75		100		
30°S. to 32°S.	Productivity		Moderate				Low			Moderate			High	
	Mean (mg C/(hr m^2))		42				4			24			70	
	Maximum (m)		75				25			0			25	
	Stratification (m)		100				75			75			100	

The waters of high *Ps*, mean 69 mg C/(hr m^2), found between 9 and 15°S. in the period May–October, have the same characteristics as those found south of Java in winter in the earlier survey. These waters were shown to be the result of upwelling in the area with possible advective contributions from enriched waters from further east. However, the present study shows that these highly productive waters occurred 5° of latitude further south than was evident in the earlier survey.

The 1959–62 survey gave no evidence of waters with the high *Ps* found in the present study between 15 and 24°S. during October–November and between 24 and 30°S. during May–July (Table 1). The shortness of the period (4–6 weeks) during which such waters were detected could have caused them to be missed in the earlier survey. An interesting feature common to both waters is that they have deep layers of photosynthetic organisms of over 100 m (Fig. 4, October–November 1962 and January–February 1963), while their euphotic layers in the corresponding periods are only about 60 and 70 m deep (Fig. 8, October–November 1962 and January–February 1963). Saijo (1965) found the same phenomenon in other parts of the Indian Ocean. The existence of significant quantities of phytoplankton capable of photosynthesis, but at depths well below the euphotic zone, explains some of the large variations found in the ratios of *Ps* to *Pa* shown in Figure 6.

In September 1951 at 10°S., Steemann Nielsen and Aabye Jensen (1957) measured a rate of production of 0·17 g C/(day m^2), whereas the value of 0·13 is given for *Pa* in Figure 7 for 9°30′S. in September 1962. Koblentz-Mishke and Kabanova (1964) measured surface *Pa* at 10 stations close to 110°E. between 15 and 25°S. with a mean of 4·1 mg C/(day m^3) in July 1962. This is similar to the mean of 3·5 mg C/(day m^3) of the surface values between the same latitudes given in Figure 8 for July–August 1963. Saijo (1965) gives 0·18 g C/(day m^2) for a station at 12°S. in December–January 1964, compared with 0·14 shown in Figure 7 for 11°S. in January 1963. It is interesting to note that, even though very different techniques were used, measurements of *Pa* in similar regions made at similar times of the year did not differ by a factor greater than 1·3.

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Reprinted from *Aust. J. mar. freshwat. Res.*, vol. 20, 1969, p. 77-84.

SEASONAL VARIATIONS IN THE INDIAN OCEAN ALONG 110°E.

III.* CHLOROPHYLLS *a* AND *c*

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[*Manuscript received July* 28, 1967]

Summary

The mean concentrations for all samples analysed were 0·17 μg/l. for chlorophyll *a* and 0·22 μg/l. for chlorophyll *c*; there were 27 mg/m^2 of *a* and 35 mg/m^2 of *c* in the water column to 150 m. June–August gave the highest values. The model depth at which concentrations were greatest was 75 m. Diagrams of regression surfaces fitted to the results are given. Regression analysis showed that depth, latitude, and season affected the concentration of chlorophylls; latitude and season affected the column amount of chlorophylls.

I. INTRODUCTION

A survey of the south-east Indian Ocean in 1959–62 (Humphrey 1966) showed that the greatest concentrations of chlorophylls *a* and *c* occurred at 75 m, that these maxima were often near density and temperature discontinuities, and that winter values were higher than summer values. However, the hour of sampling varied, sampling was spread over four years, and no samples were taken in January, April, or December.

Some of these deficiencies have been remedied by work carried out during the present series of cruises. The results are given in this paper.

II. METHODS

During the six cruises, 211 stations were sampled, almost always at 0, 25, 50, 75, 100, and 150 m. December was the only month in which no samples were taken. The chlorophyll concentrations given in the Oceanographical Cruise Reports were calculated using the equations of Richards and Thompson (1952), which give chlorophyll *c* in arbitrary units. The extinction coefficient of chlorophyll *c* is now known (Jeffrey 1963) and the concentrations in arbitrary units given in the Reports have been divided by 2 to give μg/l. before being used in the present paper. The average concentration of chlorophyll in the water column down to 150 m at each station was calculated according to Humphrey (1960).

The data were analysed by means of a non-orthogonal analysis of variance for possible relation to latitude, time of year, time of day, and depth. Sums of squares and *F*-tests were calculated for each factor as a main effect, and for each pair of factors in interaction. Interactions of higher order were not estimated. In the

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[*] Part II, *Aust. J. mar. Freshwat. Res.*, 1969, **20**, 51–4.

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Because of its finer mesh (0·26 mm), the CBS catches more zooplankton per volume filtered than does the IOSN (0·33 mm). An intercalibration experiment (Tranter 1963) suggested that values for CBS standard oblique hauls should be multiplied by 0·75 to give approximate IOSN equivalents.

The IOSN was assumed to filter 1 m^3 for each metre of wire paid out (mouth area = 1 m^2) and biomass values were calculated accordingly. The volume filtered by the CBS was measured with a calibrated flowmeter (Tranter 1966).

Tranter (1963) found that nine hauls with the IOSN at one station had a coefficient of variation of 15%. The coefficient of variation in the present investigation, calculated from 154 duplicates, was 31%. These estimates are of the same order as those of Motoda and Osawa (1964). Where the mean of two values was used, the effective coefficient of variation is reduced to 22% (C.V./$\sqrt{2}$). For CBS oblique hauls from cruises G 4/62 and Dm 4/62, the coefficient was 15% for single values and 11% for the means of duplicates.

King and Hida (1957) have shown the need to allow for diurnal variation in zooplankton biomass when drawing regional comparisons. As plankton sampling during the present series of cruises was generally at fixed times (0800–1200 and 2000–2400 hr), it was usually satisfactory to compare day values with day values, and night values with night values. However, enough samples were taken outside these standard sampling periods to establish the general nature of the diurnal variation present.

The data were analysed statistically to locate the main sources of variance. The technique used was regression analysis, biomass being the dependent variable. The transformation $\log_{10}$(biomass) was used so that the variance would be approximately independent of the mean and the residuals approximately normally distributed. The independent factors examined were time of day, season, latitude, depth (CBS horizontal hauls only), and bias in estimating volume filtered (IOSN hauls only). Linear and trigonometric functions were used to represent these factors and their interactions by pairs. An account of regression analysis is given in Williams (1959); Ch. 1–3.

The method of testing the significance of regression coefficients and deciding whether to omit them from the regression equation depends on the circumstances of the analysis. In this case the variables were arranged in groups so that each group corresponded to one factor or interaction. These groups were arranged in the order of their expected importance in the regression. The group considered least important was tested by calculating the ratio of its variance to the error variance, to see if it was significant at the 10% level. If so, the group was retained in the regression; otherwise it was dropped and the regression fitted to the remaining variables. Then the next least important group was tested and the process continued until only those groups which had been found significant at the 10% level were left in the model. The same (original) error variance was used in all tests of significance.

Biomass "estimates" were taken from the regression surfaces and used to represent, in graphical and contour form, the significant features of the data. The estimates are approximations to real but unknown values and are subject to the limitations inherent in the method of obtaining the regression equations.

TABLE 1

ZOOPLANKTON BIOMASS AT EACH STATION

Values for IOSN vertical hauls (200–0 m) and CBS oblique hauls (0–200–0 m) by day and night. Hauls usually in duplicate, CBS values in italics

Lat. S.	South–North		North–South		South–North		North–South	
	Day	Night	Day	Night	Day	Night	Day	Night
	August–September 1962				October–November 1962			
9° 30′		105 370	*129 190*			*40 66*	*81 100*	
11°	116 50			*212 194*				*43 47*
12° 30′		66 74	*104 88*			*47 68*	*18 24*	
14°	55 34			*68 62*				*32*
15° 30′		70 56	*100 64*			*50*	*36 39*	
17°	29 46			*34 47*				*46 36*
18° 30′		57 86	*40 48*				*40 51*	
20°	25 21			25 21				*64 55*
21° 30′		205 410	*72 78*			98	*153*	
23°	36 32			*41 58*	63 76			
24° 30′		73 65	*57 53*			30 61	*57 38*	
26°	52 64			*34 26*	30			*47 30*
27° 30′		72 56	*52 74*			100 75	*66 58*	
29°	34			*39*	21 18			*61 102*
30° 30′		26 31	*64 34*			162 95	*16 22*	
32°	19 23			*42 42*	17 19			*69*
	January–February 1963				March–April 1963			
9° 30′			34 19			48 49	60 55	
11°	21 21			186 160	64			42 165
12° 30′		37 64	38 35			65 39	51 43	
14°	26 22			68 41	45 45			135 93
15° 30′		50	40 30			67 49	29 32	
17°	40 55			111 105	33 44			58 35
18° 30′		48 43	57 64			68 114	119 35	
20°	28 46			62 75	31 176			59 45
21° 30′		44 71	25 37			79 61	40 35	
23°	57 54			31 77	51 34			76 35
24° 30′		71 65	53 36			60 42	39 53	
26°					33 33			42 34
27° 30′		41 37	48 54			53 70	32 40	
29°	32 35			29 51	27 26			57 55
30° 30′		54 35	33 43			40 23	23 21	
32°	14 13			30 46	17 17			30 27
	May–June 1963				July–August 1963			
9° 30′		62 82	85 85			112 118	129 192	
11°	42 39			137 164	36 45			182 525
12° 30′		29 37	47 50			42 44	103 131	
14°	20 24			53 45	20 26			65 62
15° 30′		55 33	19 19			31 34	18 15	
17°	40 39			23 30	23 15			51 39
18° 30′		36 43	17 17			35 34	19 30	
20°	19 26			26 35	85 29			44 59
21° 30′		40 27	21 21			28 83	38 30	
23°	28 24			33 32	13 17			30 114
24° 30′		30 28	27 19			54 31	19 40	
26°	24 15			32 71	22 20			78 99
27° 30′		18 12	41 49			48 109	36 33	
29°	14 15			19 96	21 22			73 88
30° 30′		28 30	13 18			27 5		
32°	3 10				16 11			

III. RESULTS

Table 1 lists the biomass values for the 200–0 m layer as determined by IOSN vertical hauls and CBS oblique hauls. The values are usually in duplicate and range from less than 25 mg/m^3 to more than 100 mg/m^3. The lowest was 3 mg/m^3, and the highest 525 mg/m^3.

TABLE 2

INFLUENCE OF VARIOUS EFFECTS ON ZOOPLANKTON BIOMASS

IOSN vertical hauls, 200–0 m

Effects in Order of Testing	Degrees of Freedom	Variance Ratio†	Action
Season × time of day	2	1·83NS	Omitted
Latitude × time of day	3	0·35NS	Omitted
Latitude × season	6	4·79***	Retained
Bias in estimating volume filtered	1	1·86NS	Omitted
Time of day	1	49·89***	Retained
Season	5	7·75***	Retained
Latitude	7	6·45***	Retained

† NS, Not significant (probability > 0·05). *** Significant (probability ⩽ 0·001). Error degrees of freedom: 114. Variance of $\log_{10}$(biomass): before regression, 0·0769; after regression, 0·0317. Percentage of crude variance ascribable to fitted variables: 50%.

Table 2 gives the results of the first analysis (IOSN data). Biomass varied systematically with time of day, season, and latitude. Variance associated with the volume filtered could have resulted from systematic error in the estimates with increasing wire angle. (It was assumed that 1 m^3 of water was filtered for every metre of wire out.) This effect has been described by Motoda *et al.* (1963), who advocated the use of a correction factor. The influence was not significant in the present data, probably because wire angle was seldon very great (mean wire angle = 20° from vertical).

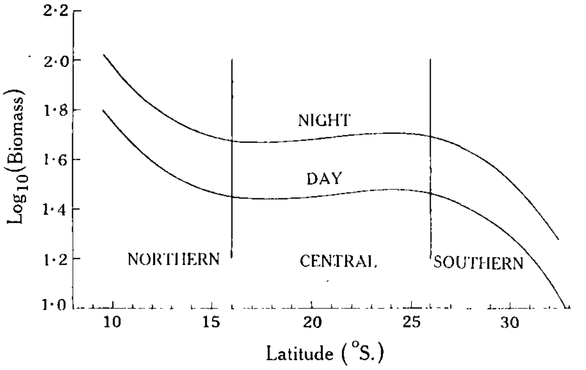

Fig. 1.—Biomass distribution along the section. Average for the year, as estimated from the regression of $\log_{10}$(biomass) (mg/m^3) on latitude. The S.D. varied between 0·19 and 0·23. IOSN vertical hauls, 200–0 m.

Day values were estimated to be 0·59 times the corresponding night values (95% confidence limits: 0·51, 0·69).

Of more direct interest is the variance associated with season and latitude. Figure 1 shows the biomass distribution along the section, averaged over the year, as estimated from the regression analysis of vertical hauls. In the region 16–27°S. (Central Region) biomass was fairly uniform (41 mg/m^3 by day; 68 mg/m^3 by night). North of this (Northern Region) the biomass rose to more than twice that in the Central Region; south (Southern Region) it fell to less than half the Central Region value.

Figure 2 shows the biomass distribution during the year, averaged over the section, as estimated from the regression analysis of vertical hauls. There were two peaks, one in September and one in March, separated by minima in December and June.

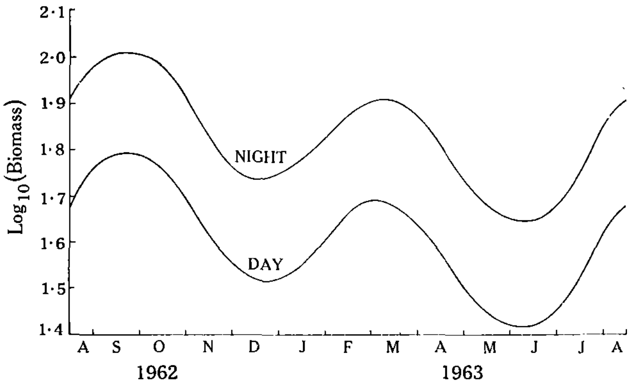

Fig. 2.—Biomass distribution during the year. Average for the section, as estimated from the regression of log$_{10}$(biomass) (mg/m^3) on season. The S.D. varied between 0·19 and 0·25 IOSN vertical hauls, 200–0 m.

Figures 3(*a*) (day) and 3(*b*) (night) show the distribution of biomass with respect to both latitude and season, according to regression estimates. The distribution by day was similar to that by night.

The September maximum had two latitudinal peaks with relatively high values in between. The greater peak lay at the far north of the section, the lesser at approximately 27°S. The March maximum covered a similar range of latitude but its peak lay at approximately 20°S. These seasonal maxima were also reflected in the biomass level of the Southern Region, but, by contrast with the regions further north, the general level there was low.

The June minimum dominated the whole section except in the far north where biomass was beginning to increase toward the September maximum. The December minimum was strongly developed both in the south and in the north and weaker in the centre.

The second analysis, comparing the results of CBS oblique hauls with IOSN vertical hauls, provided further evidence of a September maximum. However, the night values were generally lower than the day values (Table 1). This does not agree either with the results of the first analysis or with expectation. It is likely that the unusual sampling procedure adopted resulted in systematic bias.

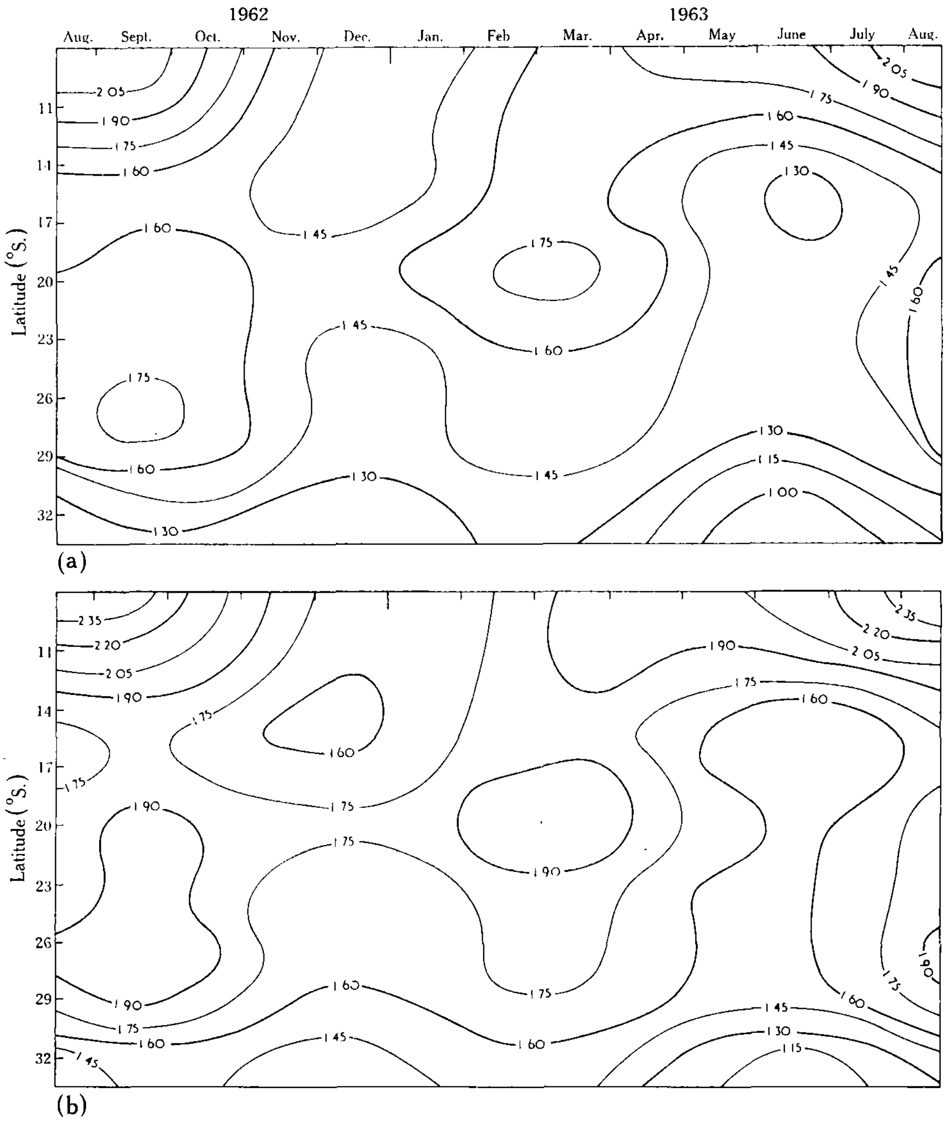

Fig. 3.—Biomass distribution with respect to both latitude and season, estimated from the regression; (*a*) by day, (*b*) by night. S.D. varied between 0·19 and 0·25. Contours, $\log_{10}(\text{mg/m}^3)$. IOSN vertical hauls, 200–0 m.

The third analysis (CBS horizontal hauls) confirmed the significance of season and latitude and their interaction in the overall variance, and established the significance of time of day, depth, and their interaction (Table 3). Figure 4 shows the mean biomass distribution with respect to depth and time of day. As would be expected, the biomass is concentrated in surface waters by night, and distributed more uniformly by day.

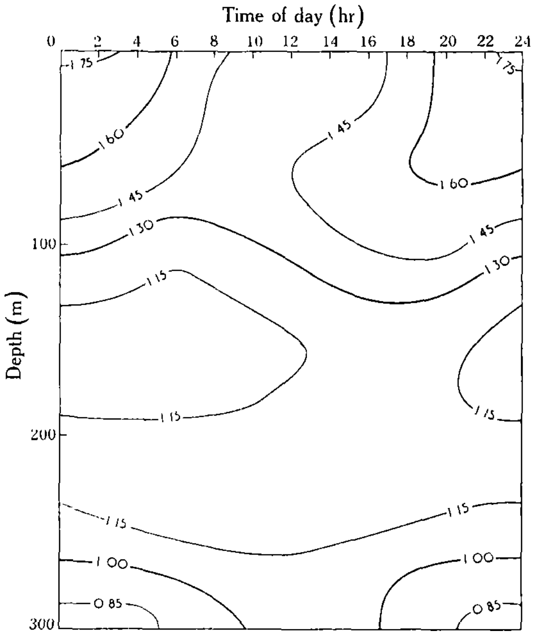

Fig. 4.—Average biomass distribution with respect to depth and time of day, estimated from the regression. S.D. varied between 0·28 and 0·30. Contours, $\log_{10}$ (mg/m^3).
CBS horizontal hauls at approx. 0, 50, 100, and 200 m.

TABLE 3

INFLUENCE OF VARIOUS EFFECTS ON ZOOPLANKTON BIOMASS

CBS horizontal hauls at approximately 0, 50, 100, and 200 m

Effects in Order of Testing	Degrees of Freedom	Variance Ratio†	Action
Time of day × depth	6	7·45***	Retained
Season × depth	6	0·91NS	Omitted
Season × time of day	4	1·42NS	Omitted
Latitude × depth	9	1·54NS	Omitted
Latitude × time of day	6	1·29NS	Omitted
Latitude × season	6	6·55***	Retained
Depth	7	18·53***	Retained
Time of day	2	8·30***	Retained
Season	5	17·84***	Retained
Latitude	7	3·28**	Retained

† NS, Not significant (probability $> 0·05$). ** Significant (probability $\leqslant 0·01$). *** Significant (probability $\leqslant 0·001$). Error degrees of freedom: 544. Variance of $\log_{10}$(biomass + 1): before regression, 0·157; after regression, 0·094. Percentage of crude variance ascribable to fitted variables: 34%.

IV. Discussion

The general distribution of zooplankton biomass in the area studied is the expression of a north–south gradient and a bimodal seasonal development. The factors which determine this pattern need to be investigated. It may now be accepted that the plankton development in the north during the South-east Monsoon is associated with the upwelling described by Wyrtki (1962). It needs to be established whether the secondary maximum during the late North-west Monsoon is a later stage of this, or the result of a separate enrichment. If continuous with the plankton development of the South-east Monsoon, it is necessary to determine the source of the interruption represented by the intervening minimum, and to establish the location of these plankton concentrations in the interval. Finally, an explanation is required for the spectacular June minimum.

The various phenomena may be due simply to horizontal water movements across the section, in which case the results need to be reconciled with the physical and hydrological evidence and with the plankton distribution in the surrounding area. The phenomena may be the result of local impoverishment and enrichment, in which case the results need to be reconciled with what is known about primary production and the distribution of phytoplankton. Finally, the phenomena may be a reflection of predation pressure from a higher trophic level, in which case the results need to be reconciled with the observations made on micronekton distribution along the section during the year.

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Part II

Physical oceanography and marine meteorology

Reprinted from *Deep-sea Res.*, vol. 15, 1968, p. 45-79

Hydrography of the Arabian Sea Shelf of India and Pakistan and effects on demersal fishes*

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(*Received* 18 *October* 1967)

Abstract—Time-series observations of temperature, salinity, and oxygen off Cochin between August 1958 and January 1960 are presented. Upwelling, which begins with the southwest monsoon, causes an uplift of the 20°C isotherm by 90–100 m. The Kerala Coastal Deep Water of earlier authors, a subsurface water peculiar to the upwelling season, is redefined by the shape of the *T–S* relation.

A comprehensive treatment is attempted of the hydrography in the area between Bombay and Karachi where time-series are not available from the open shelf. Mean sea level data suggest that during the southwest monsoon season cool subsurface water is always present on the entire shelf between Cochin and Karachi. Regular upwelling to the surface, however, is unknown north of 15°N. Probably June is the month this water usually appears on the middle of the shelf. All subsurface observations indicate that cool water is present from July onward below 50 m, sometimes even at shallower depths. Off Karachi, this situation may persist through November; off Bombay, through mid-December. Regional differences are pronounced, as are differences among years, in the period following the southwest monsoon. The cool water has a low oxygen content.

During December 1963, sinking in a very limited area near Karachi was observed. There is no upwelling from December through March between Bombay and Karachi. Atmospheric cooling seems to cause the seasonally low surface temperatures near land.

Away from the beaches the seasonal cycle of primary production is apt to be quite similar all along the west coasts of India and Pakistan. High photosynthetic rates can be expected during the southwest monsoon and later until the cool, deoxygenated subsurface water withdraws from the shelf. During the remainder of the year the density stratification in the surface layer will keep the photosynthetic rates low, near oceanic levels.

Catch per unit effort of commercially exploited fishes between Bombay and Karachi in November 1963 appeared to be related to the oxygen content of near-bottom water. During the southwest monsoon and postmonsoon seasons, the entire shelf off the west coasts of India and Pakistan, below about 50 m, may possibly be devoid of exploitable concentrations of the demersal fish species utilized so far. The distribution of prawns may also be affected. The catch of demersal fishes below the principal discontinuity layer cannot be predicted from temperature of the near-bottom water during this period.

INTRODUCTION

THIS paper amplifies an earlier report on large-scale upwelling off the southwest coast of India during the summer monsoon (BANSE, 1959). Seasonal trends of hydrography on the shelf of the northeastern Arabian Sea are described and the resulting trends of primary production outlined. The effect on catch of demersal fish of cool, poorly oxygenated bottom water present there during and after the southwest monsoon is discussed.

In utilizing data obtained before the Indian Ocean Expedition, many of them

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not readily available, as well as observations by the Expedition, it is hoped to provide background for future investigations on this shelf that extends for about 2400 km across about 18 degrees of latitude. Very much work, properly planned, remains to be done on regional differences—and explanation of the processes underlying them—for an understanding of the factors limiting the fisheries resources off the west coasts of India and Pakistan.

The study is based on subsurface time-series collections off Cochin by the author; on observations by expeditions available from the National Oceanographic Data Center/World Data Center A, Washington D.C., and from mimeographed or published data reports; and on an evaluation of previous publications and the data on

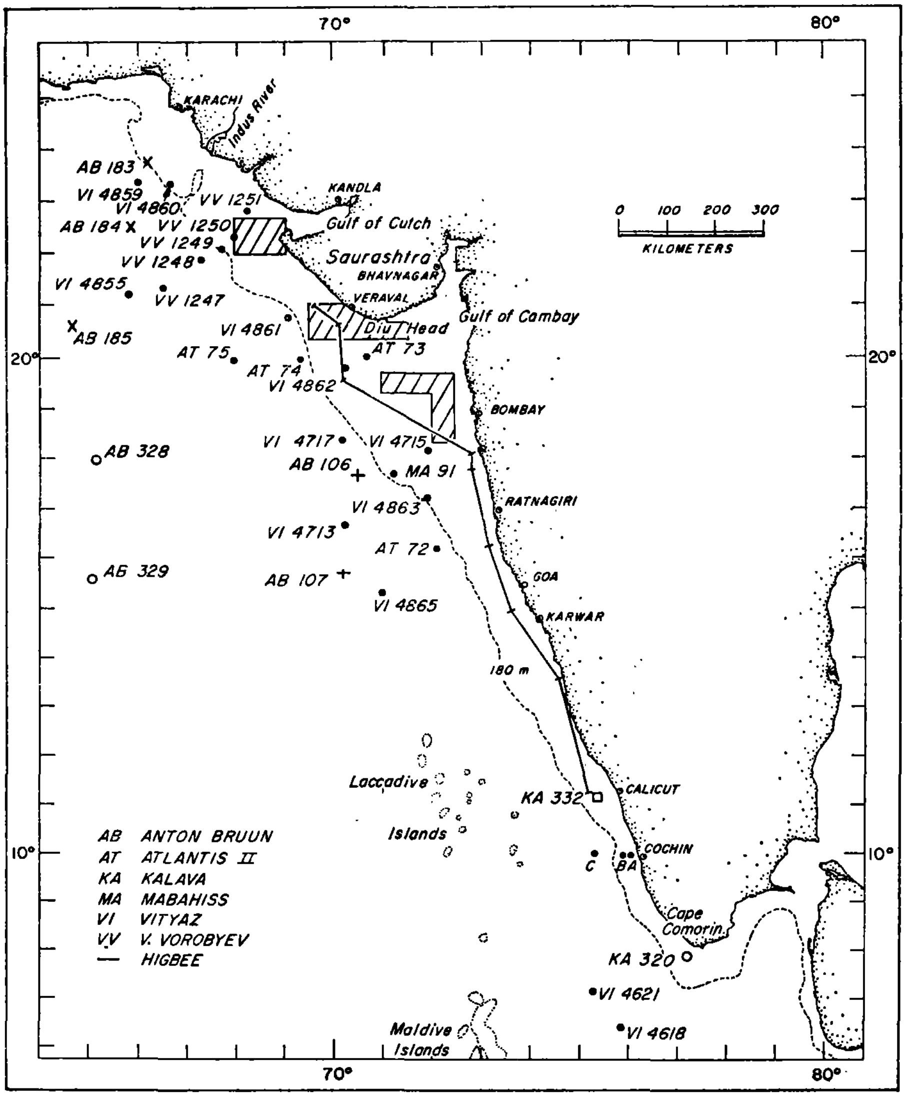

Fig. 1. Northeastern Arabian Sea. Station symbols, excepting solid circles, refer to Figs. 3 and 7. Hatched areas indicate Regions I (off Bombay), III (as in Table 2), and V of JAYARAMAN *et al.* (1959).

which they were based. Observations by *Atlantis II*, *Comdr. Robert Giraud*, I.N.S. *Kistna*, and *Meteor* have been used with restraint since little has yet been published by the investigators themselves.

METHODS

Measurements off Cochin

Time-series observations were made by the author from various vessels off Cochin (CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, 1964, and Fig. 1). Positions inshore at a depth of about 25 m (A), and approximately on the middle of the shelf at a depth of 55–60 m (B), were visited from August 1958 through January 1960. Most observations at B were made at about noon. A location (C), roughly 35 km beyond the break of the continental shelf and about 2000 m deep, was occupied from November 1958 through May 1959; observations were made to 500 m depth*.

The procedures described below also apply to the other data of 1958 to early 1960 in CENTRAL MARINE FISHERIES RESEARCH INSTITUTE (1964) :

Reversing thermometers with 0·2° or 0·1°C graduation were mounted on Nansen bottles, frequently in pairs. The instruments had been standardized a few years earlier, but the zero point had not been checked since then. Further, the thermometers were not kept in a water bath before reading but were adapted in air. A bathythermograph (range 0–135 m) was employed on most stations. Unprotected thermometers were not used for determination of sample depth, but wire angles, if any, were small.

The salinity was determined by titrating 10 ml of seawater with a Copenhagen burette, after measuring the seawater sample with an ordinary pipette, and using K_2CrO_4 as an indicator. Generally the $AgNO_3$ solution was standardized only once a day with Standard Sea Water from Copenhagen. Therefore an accuracy of ± 0·01 to ± 0·02‰ Cl generally was not attained, as shown by some duplicates.

The oxygen content was measured by the Winkler method in the laboratory after the reagents had been added at the stations. Subsamples of 50 ml were drawn for titration from the 150-ml sampling bottles. The 0·01 N thiosulfate solution was standardized against $K_2Cr_2O_7$/KI. Owing to the burette used, the precision of the results is considered to be ± 0·05 ml O_2/l. High nitrite values, up to 4 μg-atoms/l., occurred at a few intermediate depths during the southwest monsoon season; the corresponding oxygen values were not corrected for the error, which was in the order of the precision of the oxygen titrations. The saturation values of oxygen were taken from the nomograms by KALLE (1939), which are based on the tables of Fox.

The Taiyo Maru No. 17 *data*

From 1951 to 1953, temperatures of near-bottom water were routinely measured between Bombay and the Gulf of Cutch by the skipper of an exploratory fishing vessel, the *Taiyo Maru No. 17* (JAYARAMAN, SESHAPPA, MOHAMED and BAPAT 1959, Table XV and Fig. 16). The observations for December 1951 and November–December 1953 were not available; most of the other data are presented in Tables 1–4.

Temperatures were measured by a reversing thermometer lowered to near the bottom and triggered after 1–2 min of adaptation time; the auxiliary thermometer was not read (Messrs. R. JAYARAMAN and K. H. MOHAMED, personal communication). The records are in tenths of a degree. Surface temperatures were noted in full degrees for most of the observations.

The surface data are somewhat suspect, since during December–January through March of both years the means are about 1°C or more above the temperature means of the bottom water at the shallow

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*The approximate coordinates were : for position A, 9° 58′N, 76° 05′E through July 1959; 9° 54′N, 76° 07′E through October 1956; and subsequently 9° 57′N, 76° 07′E; for position B, 9° 58′N, 75° 50′E; 9° 48′N, 75° 59′E; and 9° 53′N, 75° 51′E, respectively. Position C was roughly at 10° 00′N, 75° 20′E.

Table 1. Temperature measurements by Taiyo Maru No. 17 *during 1952 and 1953 in Region I of* JAYARAMAN et al. *(1959) in °C. For location, see Fig. 1, southernmost cross-lined field. a, b, first and second halves of the months. S.D., standard deviations. Number of measurements in parentheses.*

	1952			1953					
Depth	*Feb.*	*March*		*February*		*April*	*June*	*Sept.*	*Oct.**
(m)	*b*	*a*	*b*	*a*	*b*	*b*	*b*	*b*	
Surface	26·1 (7)	28·7 (7)	27·6 (3)	26·4 (22)	26·3 (18)	28·0 (4)	29·7 (7)	28·0 (2)	
26–30	24·95 (2)								28·0 (11)
31–35	24·75 (4)	25·65 (3)		24·0 (1)	25·8 (1)				
36–40	25 (1)	25·40 (4)	25·10 (3)	24·60 (4)	25·6 (1)	27·0 (1)		27·65 (2)	
41–45					26·4 (1)	27·10 (3)	28·60 (3)		
46–50				25·75 (11)	26·20 (2)		28·60 (4)		
51–55				26·05 (10)	25·70 (6)				
56–60					26·00 (7)				

*From Tables X and XV of JAYARAMAN *et al.* (1959), including one depth in the range 31–35 m.

localities, at a time when all bathythermograph observations from the outer shelf and continental slope of the region show a deep isothermal surface layer. Therefore, the surface data have been lumped whereas the bottom water observations are presented as half-monthly means for depth increments of 5 m.

Because the temperature readings from the reversing thermometer were not corrected with the auxiliary thermometer, there may be a systematic error in the 1952 data. Often the half-monthly means of the surface water temperatures from January to April 1952 are about 1°C (maximally 3°C in March) higher on the deeper stations than inshore, as would be expected during this season (WARNERS, 1952). If the surface temperature records are accepted at face value, they would suggest thermal stratification (Tables 2 and 3a). Then, in the deeper part of the area the reversing thermometer would have been hauled through relatively warmer surface water than it would inshore. However, I estimate that, at worst, this would bias the deep observations by + 0·04°C.

Temperature gradients

Generally, temperature gradients, where given, were read from copies of original bathythermograph slides.

OBSERVATIONS OFF COCHIN

General hydrographic conditions off Cochin

The Laccadive Sea is characterized by a surface layer of variable temperature and salinity. The common salinity maximum of the tropical ocean is found in the upper part of the thermocline and seems to originate in the Northern Arabian Sea (Salinity Maximum D, or Arabian Sea High Salinity Water of ROCHFORD, 1964).

Generally, the coastal surface currents off the west coast of India set toward the south from February until late October or November and are reversed during the remainder of the year. The southward current is established north of about 20°N one or two months later than in the south. It gathers speed in May, and is strongest in July–August. The resultant speed of the current, calculated for 2-degree squares, is le 2. *Temperature measurements by* Taiyo Maru No. 17 *during 1952 and 1953 in Region III of* JAYARAMAN et al. (*1959; Areas 9–12 are included, see cross-lined field near Veraval, Fig. 1*). *Boldface means are significantly different. See also Table* 1.

Depth (m)	1952					1953										
	March			*April*	*May*	*February*		*April*		*May*		*June*		*September*		*October*
	a	S.D.	b	a	b	a	b	a	b	a	b	a	b	a	b	a
urface	26·4 (64)		25·5 (6)	28·2 (6)	29·3	25·2 (4)	24·7 (7)	26·7 (3)	28·0 (5)	28·5 (2)	28·8 (13)	30·0 (16)	29·5 (53)	27·9 (38)	28·1 (54)	28·6 (74)
26–30	23·7 (1)															
31–35	**23·90** (7)	0·48														27·85 (15)
36–40	**24·50** (18)	0·14	24·60 (2)	24·95 (4)	25·7 (1)	24·50 (4)	23·50 (6)	26·9 (1)	26·8 (1)	26·4 (1)	26·9 (1)				28·05 (35)	27·95 (59)
41–45	24·45 (13)	0·19	24·8 (1)	25·0 (1)	25·75 (18)	24·8 (1)		25·75 (2)	26·85 (4)	26·3 (1)	27·05 (11)	27·85 (7)	27·95 (11)	27·80 (12)	27·70 (19)	
46–50	24·70 (2)		24·60 (3)	26 (1)	25·8 (2)						26·6 (1)	27·65 (9)	28·05 (39)	27·90 (26)		
51–55							24·1 (1)						28·15 (2)			
56–60													28·2 (1)			

le 3*a*. *Temperature measurements by* Taiyo Maru No. 17 *during 1952 in Region V of* JAYARAMAN et al. (*1959*). *Northermost cross-lined field in Fig. 1. See also Table 2.*

Depth (m)	*January*				*February*			*March*	*April*		*May*	*June*	
	a	S.D.	b	S.D.	a	S.D.	b	b	a	b	a	a	b
urface	23·4 (23)		23·7 (75)		24·5 (42)		26·3 (16)	25·8 (74)	25·7 (48)	27·8 (49)	27·4 (48)	29·7* (29)	30·8* (14)
21–25			**22·10** (8)	0·21	22·10 (3)	0·31		24·20 (9)	25·5 (1)				
26–30	22·0 (1)		22·50 (34)	0·32	22·60 (17)	0·34	22·0† (5)	24·25 (27)	25·10 (10)				
31–35	23·2 (11)	1·4†	**22·75** (20)	0·45	22·65 (20)	0·26	22·5† (20)‡	24·30 (19)	25·25 (6)		28·0 (1)		
36–40	23·2 (11)	1·1†	22·60 (9)	0·77	22·8 (1)		22·2† (5)	24·20 (15)	25·20 (16)	25·45 (10)	25·80 (14)	25·60 (14)	28·1* (2)
41–45			22·9 (4)	0·6				24·60 (4)	25·30 (15)	25·55 (35)	25·70 (27)	25·45* (14)	27·55* (9)
46–50										25·05 (4)	25·85 (3)		27·90* (3)
51–55											25·4 (1)		
61–65													28·0 (1)

*Partly in Region IV, adjoining the upper shaded area in Fig. 1 in the south.
†Partly recorded in full degrees only.
‡Without three high values late in the month : 22·1 C.

le 3*b*. *Temperature measurements by* Taiyo Maru No. 17 *during 1952–1953 in Region V of* JAYARAMAN et al. (*1959*). *Northernmost cross-lined field in Fig. 1. See also Table 2.*

Depth (m)	*December*		*January*			*February*			*March*		*April*		*May*	
	b	S.D.	a	S.D.	b	a	S.D.	b	a	b	a	b	a	b
urface	23·0 (55)		22·8 (56)		23·0 (70)	24·1 (46)		24·4 (26)	25·9 (33)	26·2 (59)	26·2 (77)	27·2 (70)	28·6 (25)	28·3 (7)
16–20			21·7 (1)											
21–25	**22·15** (8)	0·40	22·00 (27)	0·36	21·90 (10)	**22·50** (11)	0·25	23·0 (2)	24·1 (1)		25·75 (8)	26·75 (9)		
26–30	22·50 (25)	0·39	22·15 (21)	0·84	21·95 (44)	22·75 (20)	0·45	23·30 (7)	25·50 (21)	24·90 (4)	25·80 (19)	26·45 (15)	27·5 (1)	
31–35	**23·00** (18)	0·53	22·05 (4)		21·85 (8)	**23·10** (12)	0·59	23·00 (5)	24·30 (6)	25·20 (14)	25·70 (11)	26·25 (9)		27·6 (1)
36–40	22·75 (5)	0·22	22·60 (3)		22·10 (8)	22·80 (3)		23·40 (12)	24·50 (4)	25·00 (26)	25·45 (22)	25·80 (34)	27·10 (7)	27·45 (3)
41–45					23·1 (1)			23·7 (1)	24·1 (1)	25·00 (13)	25·45 (17)	25·70 (3)	27·50 (15)	27·0 (3)
46–50								22·1 (1)		24·8 (1)			26·75 (2)	

Table 4. Temperature measurements by Taiyo Maru No. 17 *during 1951–1953 in various regions. See also Table 1. Region II includes only Areas 13 to 26.*

Date	*Region*	*Depth range* (m)	*Mean at depth*	*Mean at surface*
Dec. 1951*	II	36–40	25·8 (5)	
16 June 1952	II	41–45	27·2 (1)	31·5 (4)
		46–50	25·45 (3)	
June 1953 (b)	II	46–50	28·45 (2)	30·0 (2)
Nov. 1953*	II	31–35†	26·6 (12)	
May 1953 (a)	IV‡	36–40	26·95 (3)	28·0 (13)
		41–45	26·60** (10)	
May 1953 (b)	IV	36–40	27·40 (5)	28·7 (48)
prior to 21 May		41–45	27·60 (27)	
26–31 May			26·30 (16)	
1–9 June 1953§	IV	36–40	26·65 (6)	29·3 (38)
		41–45	27·10 (22)	
		46–50	27·95 (10)	
Dec. 1951*	V	36–45	24·2 (12)	

*From Tables XI, XIV and XV of Jayaraman *et al.* (1959).
†Including one at 26–30 m.
‡Mostly in Area E.
§Data in later part of period from deep water only, where water of about 26·5°C became replaced by water of ≧ 28·0°C.
**Below 26·0°C in the beginning, about 27·5°C late in the period.

below 20 km per day, except for the coast south of about Bombay where the speeds are greater during the southwest monsoon (Warners, 1952).

During the period of north-setting currents, water of relatively low salinity appears off Cochin (Fig. 2). Ramasastry (1959) named it Arabian Sea Surface Water, and Darbyshire (1967) called it Equatorial Surface Water. The latter term is used here. The annual salinity minimum usually occurs in January (Subrahmanyan, 1959) before the coastal current reverses; salinities below 33·0‰ were observed in January 1959 at the surface even beyond the continental slope. Concurrently a nearly isothermal layer develops which reached about 50 m depth in November 1958, and 75 or 100 m (i.e., almost down to the salinity maximum) in February and March 1959. The vertical salinity difference in the layer is 1–2‰ (almost 3‰ in December 1958, Darbyshire, 1967) so that the Equatorial Surface Water is not well mixed vertically. This is common in equatorial regions. The density stratification persists later in the premonsoon season (Fig. 2; Ramamirtham and Patil, 1966, for 1962); it was reinforced in 1959 by a secondary thermocline within the surface layer.

The temperature maximum occurs just before the onset of the southwest monsoon in surface water of high salinity advected from the north. The *T–S* relation of the Equatorial Surface Water then has the form found at Stas. 263–265 (Fig. 3). The highest subsurface salinities on the shelf are due to subsequent upwelling.

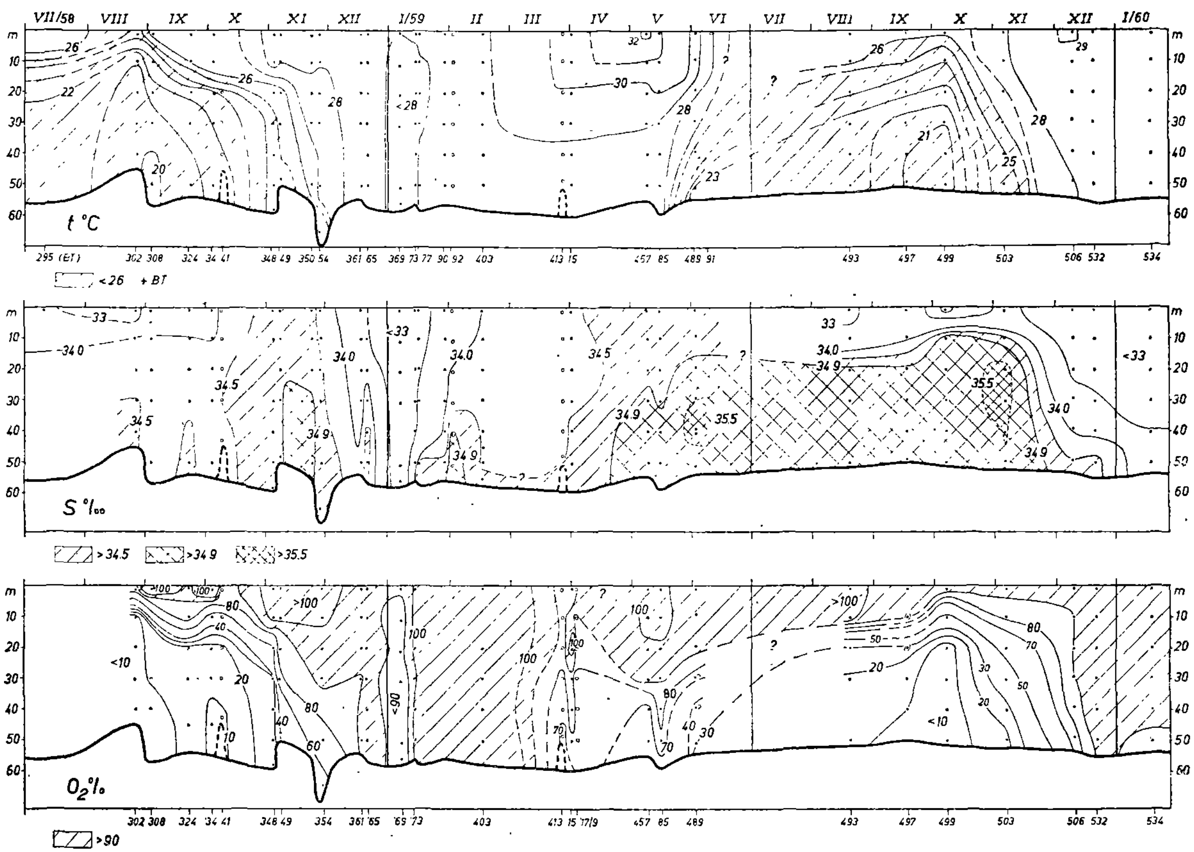

Fig. 2. Temperature, salinity and oxygen saturation at Position B off Cochin, 1958–1960. Station numbers at the bottom of the upper and lower panels. Open circles and broken bottom contours indicate stations occupied near Position B. Isotherms between standard depths from bathythermograph readings. The oxygen analyses for Sta. 390 are omitted; the difference between the surface and the bottom was about 10% in the saturation values.

The upwelling period

Upwelling off the southwest coast of India starts with the onset of the southwest monsoon. Cold water was found on the shelf off Cochin on 3 June 1959 (Fig. 2, Sta. 489; cf. Table 5, Stas. 490 and 491)*. In 1962, water colder than 27°C filled Cochin Harbor below 5 m between 9 and 30 May (RAMAMIRTHAM and JAYARAMAN, 1963; dates from Mr. K. C. GEORGE, personal communication). In May there is no surface source of cool water so that the upwelling of 1962 must have already begun at this time. Near Karwar (Fig. 1), upwelling in 1956 and 1957 seemingly started in June or early July (RAMAMURTHY, 1966). In the harbor of Karwar, which is greatly influenced by river runoff, the surface temperature fell rapidly from the annual maximum of 30°–31°C in April–May to 25°–26°C toward the end of June 1958 and the first week of July 1959 (original data, Survey of India, from World Data Center A). These values were at least 2°C lower than the mean temperature offshore (WARNERS, 1952). The lowest reading in the first week of July 1959 was 24·4°C. Again, upwelling was present. (For older observations see note added in proof, p. 79.)

The freshwater runoff apparently reaches the sea near Cochin before the actual upwelling occurs, thus setting up an estuarine circulation that favors the upsloping of dense deep water to shallow depths. This seems to hold also for other places along the southwest coast of India.†

The upwelling lasts through the southwest monsoon season as indicated by the upsloping of isotherm toward the coast (Table 5), although this trend cannot be demonstrated for late October and early November 1959, when the cool water had retreated below 20–30 m, the deepest observation at A (cf. Fig. 2). At the surface off Calicut, the upwelling effects are strongest during July and August (BANSE, 1959). Below the surface, on the shelf off Cochin, the coldest bottom water was present in August–September 1958 and in September–October 1959 (i.e. in the latter half of the southwest monsoon season when the winds tend to blow from the west or northwest). In 1962 the coldest water was observed in Cochin Harbor during early August and again during October (RAMAMIRTHAM and JAYARAMAN, 1963).

The geographical extent and the reasons for upwelling off southwest India have been discussed previously (BANSE, 1959) but the possible role of freshwater runoff was neglected. Even now, no quantitative treatment can be offered.

According to DARBYSHIRE (1967), who emphasized the advection processes, the surface temperature becomes low in the area when the warm Equatorial Surface Water that blankets the cool Arabian Sea Water retreats to the south. However, as seen from the I.N.S. *Kistna* observations near Cape Comorin in July 1963 (DARBYSHIRE, 1967, Fig. 23) showing upwelling on the northern end of the

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*The observations at Sta. 491, 10 June 1959, are not included in full in CENTRAL MARINE FISHERIES RESEARCH INSTITUTE (1964). The temperatures were read from the bathythermograph slide.

m	°C	*S* (‰)	m	°C	*S* (‰)
1	28·2	33·98	15	27·6	34·87
3	28·2	33·96	25	24·2	34·97

†The surface salinity off Cochin fell inshore, at A, by 0·6‰ between 15 May and 10 June 1959, whereas at B it did not change between 15 May and 3 June 1959. Observations by the Survey of India in inshore water off Calicut during 1959 showed a larger decline of salinity than at A from the middle of May onward, with a sharp drop between 4 and 8 June 1959. Similarly in 1962, the surface salinity in the innermost harbor of Cochin fell between 9 and 30 May from near 30 to below 10‰ (RAMAMIRTHAM and JAYARAMAN, 1963). In the mentioned observations in the harbor of Karwar, the surface salinity began to decrease from the annual maximum of almost 31‰ after the middle of April 1958, and reached 27‰ by the middle of June (data for 1959 are not available).

section, the surface temperature can be lowered to 26° in the absence of Arabian Sea Water. Rather, the dense, cool water approaches the surface because of the immediate interplay of the current with the tilting of the sea surface and the thermocline. The transport of entire water masses out of the area is a later consequence of the currents. Also contrary to Darbyshire's opinion, there may very well be wind-induced divergence off southwest India during the summer monsoon (BANSE, 1959).

Table 5. Subsurface temperatures in °C, at or near Positions A and B during the upwelling period.

Date	*Stations*	*Depth* (m)	*Temperature* (°C) A	B
1958				
25 Aug.	300; 302	20	20·85	20·70
2 Sept.	305; 308	20	23·96*	21·65
	306	20	20·53	
21 Sept.	325; 324	10	22·41	26·03
		20	22·05	21·85*
2 Oct.†	331; 332	20	21·27	22·72
7 Oct.	340; 341	20	22·68	23·13
3 Nov.‡	344; 348	20	27·62	25·82
1959				
3 June	490; 489	20/19	27·0 (BT)	29·12
10 June	491	20	25 (BT)	
19 Aug.§	494; 493	20	23·84	24·25
17 Sept.	498; 497	20	22·03	23·41
6 Oct.	500; 499	20	22·24	22·26
27 Oct.	502; 501	30	27·23	27·11
5 Nov.	504; 503	20	26·94	26·87

*Doubtful value.

†Off Calicut in corresponding situation.

‡Current setting north (beginning of sinking).

§These are the Stas. I and II of RAMAMIRTHAM and JAYARAMAN (1960). Contrary to the implication of the acknowledgment, their paper is based entirely on my observations. I had the company of Mr. O. J. Østvedt on 27 November 1958 and on 1–2 April 1959.

T–S *relations of the upwelling season*

The *T–S* relation of the water encountered on 3 June 1959 on the shelf off Cochin was quite similar to that of offshore water at other seasons, the intermediate salinity maximum being indicated at 40 m (Sta. 489, Fig. 3c). Before mid-August (possibly by 10 June, Sta. 491) a new subsurface water mass was formed by mixing of the upwelled water with low-salinity surface water. It persisted through the season as seen from the *T–S* relation for Stas. 493, 497, 499 and 500, occupied at B in August, September and early October 1959 (Fig. 3c). The water mass was characterized by a fairly constant, relatively low salinity through a range of several degrees of temperature, down to at least 20·5°C. Offshore the salinity in the temperature range of 19°–24°C increases with temperature, as shown by the heavy broken line in Fig. 3.

Subsurface water with similar properties is apparently formed each year. This feature was more obvious in 1958 than in 1957 and 1959 (Fig. 3a–c), because the salinity of the 1958 water mass was about 0·5‰ lower than that of offshore water with corresponding temperature during the premonsoon and postmonsoon seasons. In September–October 1958, the water mass had remarkably uniform properties between Cape Comorin and Calicut (Stas. 320, 324 [e.g., at B], and 332, Figs. 1 and 3b). The similarity of the shape of the *T–S* relation within the subsurface water in 1957, 1958 and 1959 and its variable average salinity suggest that the mechanics of its formation are similar from year to year but that in different years variable amounts of surface water are incorporated. The surface water component was particularly

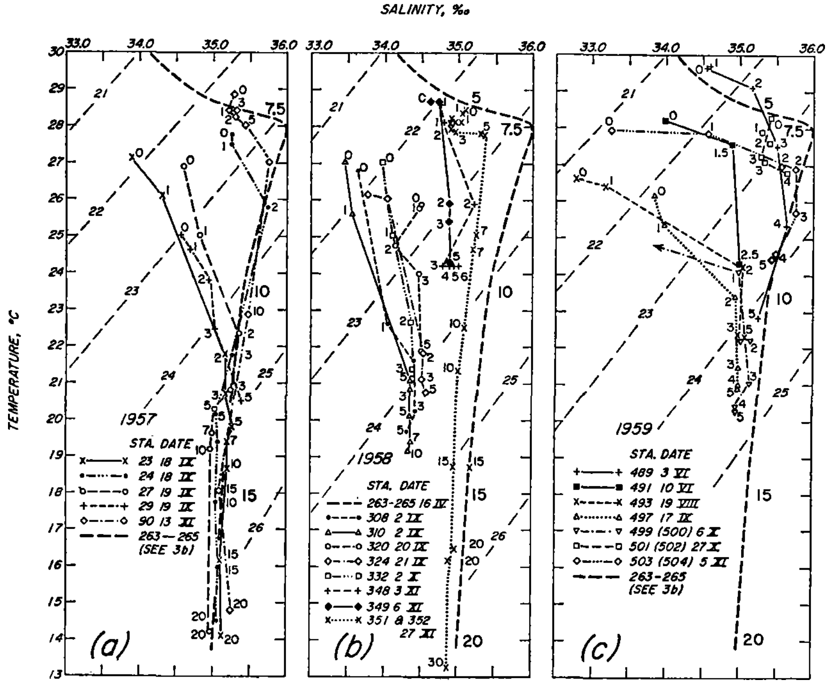

Fig. 3. Temperature–salinity diagram for stations off the southwest coast of India for 1957 (a), 1958 (b), and 1959 (c). Depth near station symbols in decameters. Heavy broken line, Stas. 263–265 (upper 200 m; Sta. 264, upper 100 m) at 10° 20′N. Data from Central Marine Fisheries Research Institute (1964).

high in 1958, compared with that in 1957 and 1959. The north–south extension of the water mass was larger in 1958 than in 1957, and its volume must have differed too. Ramasastry and Myrland (1959) and Ramasastry (1959) already have described the discontinuous nature of this water in 1957, on the basis of the vertical gradients of temperature*.

On the basis of their 1957 observations, Ramasastry and Myrland (1959) named the Kerala Coastal Deep Water, a fairly isothermal water layer occurring beyond the continental shelf, roughly between 50 and 100 m depth. This was contiguous with the equally isothermal bottom water on the shelf. Its appearance was believed to mark the end of the upwelling season (Ramasastry, 1959). In 1958, this layer was most conspicuous in the lower part of the subsurface water formed during the upwelling (see Sta. 310, Fig. 3b; no observations are available for 1959 from the area above the continental slope or beyond it). The formation of a nearly isothermal layer and of the *T–S* characteristics of the subsurface water described here is presumably due largely to the same mixing processes acting on the same water. The formation of isothermal bottom water is not peculiar to upwelling processes. Therefore the Kerala Coastal

*Contrary to September–October 1958, the core of the upwelling water ($t < 22{\cdot}5$°C) in September 1957 was essentially of the offshore type on sections at about 9°00′ and 9° 30′N; the salinity increased with temperature (Fig. 3a, Stas. 23, 27 and 29; above 20–30 m, mixing with surface water is indicated). However, on sections along 9° 10′N and 9° 20′N latitude (Stas. 12–14 and 16–20, not in Fig. 3a) again water of fairly uniform, low salinity (34·7–34·8‰ over the temperature range of 18·5° to about 23°C) was present. Farther away from the coast in these two sections, the *T–S* relation of the upwelled water was of the offshore type (particularly Sta. 24).

Deep Water might be defined by the shape of the *T–S* relation rather than by the vertical gradients of temperature. Contrary to RAMASASTRY (1959) this subsurface water is a feature of the entire upwelling season instead of its close.

It is debatable whether or not a special name is needed for the phenomenon, but certainly more than " only normal Arabian Sea Water " (DARBYSHIRE, 1967) is found above 100 m on and near the shelf off the southwest coast of India in late September and early October.

Toward the end of the upwelling period, water of almost offshore characteristics, similar to that found on the shelf during its inception, appears off Cochin (Stas. 348 and 349 for 1958, and Stas. 501 to 504 for 1959, Fig. 3b, c). The resulting increase in near-bottom salinity is also revealed by the data of SESHAPPA and JAYARAMAN (1956) at 15 m off Calicut.

Vertical extent of rise of isotherms due to upwelling

The lowest temperatures off Cochin, inshore at A at 20 m, were 20·9° and 22·0°C in 1958 and 1959, respectively (Table 5). The temperature of the coldest water observed at 50 m depth at B was 19·7°C in 1958 and 20·3°C in 1959 (Fig. 2). The greatest depth of the 20°C isotherm recorded off Cochin in the preceding northeast monsoon seasons was 140 m in December 1957 and 150 m in early April 1959. Thus the uplift of this isotherm was 90–100 m during 1958 and 1959. At the close of the upwelling season of 1957 it was 75–100 m (RAMASASTRY and MYRLAND, 1959; RAMASASTRY, 1959).

Oxygen content of subsurface water

About the turn of the year, well-aerated water extends down to the seabed at B (Fig. 2), as well as inshore. This is surprising because of the high vertical stability of the Equatorial Surface Water. After the establishment of the south-setting coastal current, the increasing stability due to the influx along the bottom of saline water from the north and to surface heating, leads to a marked lowering of the oxygen content near the seabed. Extrapolating from Secchi disc measurements in 1959, all of this water was in the photic zone. Thus oxygen removal (respiration) rates must have been quite high.

The upwelling water appearing subsequently is derived from within and below the thermocline and therefore has a low original oxygen content. It becomes further depleted when on the shelf (BANSE, 1959). At B, saturation values below 10% occurred in August, September, and October 1958, and in September and October 1959. In 1958 and 1959, saturation values of 50% prevailed for several months at about 15 m at this locality (Fig. 2). The conditions were more extreme inshore (at A) in both years, when at 20 m depth, 3–5 m above the bottom, the oxygen saturation was below 10% (mostly below 5%) from mid-August (no earlier observations were available) through October. Fifty per cent or less of saturation appeared to be the rule at 10 m there throughout the entire upwelling season.

For hydrographic reasons this oxygen regime should hold in principle for much of the southwest coast of India, at least to the latitude of Calicut. During the period of the north-setting current, shelf and offshore hydrography and water chemistry are similar because of the stability of the water column in the Equatorial Surface Water, which reduces the influence of the seabed on the upper water layers. The oxygen content seems to be high near the seabed in the middle and shallow parts of the shelf, and offshore almost down to the pycnocline (sections across the shelf off Cochin in 1958–1959; *Vityaz* Stas. 4618 and 4621 of January–February 1950, Fig. 1; PATIL and RAMAMIRTHAM, 1963, for December 1961). To the north of the area influenced by the Equatorial Surface Water, density gradients between the surface and the principal pycnocline are lower than in the south (RAMAMIRTHAM and PATIL, 1966), facilitating the supply of oxygen to the seabed by mixing and eddy diffusion.

The northward extension of the Equatorial Surface Water of DARBYSHIRE (1967) with which this oxygen regime appears to be related, is uncertain. In the available successive, geographically separate sections it is difficult to distinguish between persistent differences in space, and seasonal changes that occur between the times of occupation of the sections. Instead, time-series observations and quasi-synoptic (multipleship) surveys are needed.

A thermally uniform surface layer with a marked salinity gradient was absent on or near the shelf in November and December 1960 southwest of Bombay (*Vityaz* Stas. 4861–4865, Fig. 1 in part). It extended at least to 13°N in early February 1962 but only south of this latitude in late March 1962 (RAMAMIRTHAM and PATIL, 1966). The same hydrographic condition was found by *Meteor* off Goa in mid-February 1965, and off Bombay in early April 1960 by *Vityaz* (Stas. 4714 and 4717, Fig. 1) but was much less evident in April 1961 in this area (*Comdr. Robert Giraud*). A surface layer with a marked salinity gradient was also present although with a warmer upper horizon, on *Anton Bruun* Stas. 106 and 107 in May 1963 (Fig. 1). The salinities on these stations were above 34‰ or even 35‰, somewhat higher than off the southwest coast of India. Further the salinity maximum, found in the south at a density of slightly above σ_t of 23·0, occurred in the northern stations at slightly above σ_t of 23·5. It is not known whether the quoted observations represent advection (or absence thereof) of Equatorial Surface Water, or largely indicate changes *in situ* caused by the same processes acting all along the coast during this time of year.

In the period after the reversal of the coastal current, the oxygen content of the bottom water was reduced at shelf stations between 10° and 11°30′N in May 1959 when the salinity gradients in the bottom water were high (cf. Fig. 2). A few similar observations were made in the area in 1960 and 1961 (CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, 1964). Also farther north, oxygen concentrations in the near-bottom water must decline when the oxygen removal rate overtakes the rate of supply, which (neglecting horizontal gradients) is related to stability and, in shallow water, to photosynthesis.

During the summer monsoon, on the open shelf south of roughly 9°N upwelling and vertical instability may possibly always be so marked that the oxygen concentrations remain relatively large in the bottom water and conversely low at the surface throughout the season (BANSE, 1959). About 5 km off Calicut, with a bottom depth of 15 m, surface oxygen values are below 90% during much of the upwelling season despite strong phytoplankton development, and often fall to 70 or 60% (SUBRAHMANYAN, 1959). The lowest surface value reported by this author is 30% of saturation, in early September 1951. Surface upwelling occurs at least to Goa (BANSE, 1959). Conditions farther north, where the warm surface water is not removed during the southwest monsoon, ought to be similar to those off Bombay (p. 57).

SEASONAL CHANGES OF SEA LEVEL IN THE NORTHEASTERN ARABIAN SEA

No time series of subsurface temperature observations from the open shelf off the west coast of India and Pakistan have been published to prove that cold water is uplifted in the entire region during the southwest monsoon, as proposed by the present author in 1959. Since the upwelling off southwest India is ultimately due to divergence along the coast, which leads to a lowering of sea level there, sea level records were examined for indications as to whether hydrographic changes, similar to those observed off Cochin and Calicut, occur farther northward. Only long-term means were considered, which carry more weight than individual observations although the latter would illuminate extreme cases.

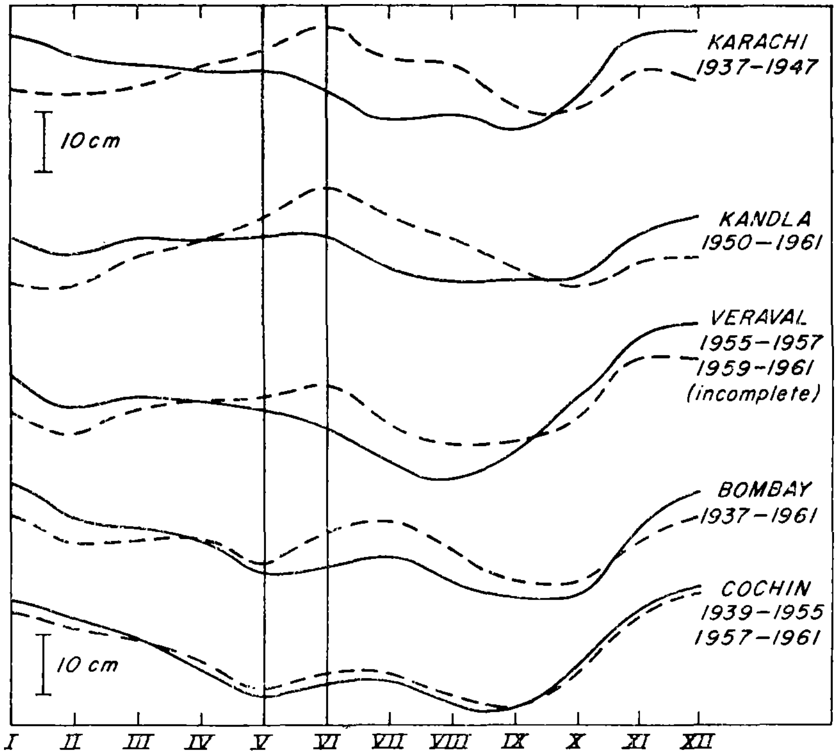

Fig. 4. Mean sea levels for Indian and Pakistani gages, above arbitrarily chosen datum levels (from ASSOCIATION D'OCÉANOGRAPHIQUE PHYSIQUE, 1958, 1959, 1963). Broken lines, actual observations; solid line, the former corrected for the effect of air pressure. For the correction, the deviation of the monthly means from the annual means of air pressure was estimated from the monthly charts in WARNERS (1952) and U.S. NAVY (1957). One millibar of pressure rise was considered to lower the sea surface by 1 cm (ROSSITER, 1962).
The records of the only remaining tide gage on the west coast of India, Bhavnagar in the Gulf of Cambay, seem to be dominated by local effects : the range of the corrected mean sea level curve is about 50 cm, with the maximum during August and September, possibly a result of runoff.

The annual maxima of corrected sea level, when corrected for the effect of atmospheric pressure, occur at all stations in December or January (Fig. 4). The minima are observed at all stations in August or September, that is, in the later part of the southwest monsoon season. River runoff possibly influences the water level means in June at Cochin and Bombay during the time of the secondary maxima. Otherwise the trend of the corrected mean sea level for Cochin, Bombay, Veraval and Karachi, situated at the open coast, agrees during April to October fairly well with the waxing and waning of the component of the current parallel to the coast estimated from WARNERS (1952).

The surface density in the open sea off Pakistan, Saurashtra and much of the west coast of the Indian peninsula is lower in May and August than in February (ISAKOV, 1953; JAYAMARAN and GOGATE, 1957; GOGATE, 1960; U.S. NAVY HYDROGR. OFFICE, 1960), except off the southwest coast, where the August values are higher than those for February. Despite this, the corrected sea level in August is lower than in February all along the coast (Fig. 4). Therefore, under the similar current and wind regimes prevailing off the west coasts of India and Pakistan, the fall in sea level during a period of increasing current velocity (p. 48) may well be indicative of a regular influx of dense (i.e., cool) water at depth, which overcompensates for the effect of the low surface density on mean sea level. This rising of dense water is to be expected on the left side (in the downstream direction) of a current in stratified water. The input of freshwater from rivers during the summer monsoon may further promote shoreward movement of bottom water.

EVIDENCE FOR COOL SUBSURFACE WATER ON THE INDO-PAKISTAN SHELF DURING THE SOUTHWEST MONSOON

The southwest monsoon season

The close similarity of the curves of corrected sea level for Cochin and the northern stations (Fig. 4) suggests that cool water may appear on the shelf off Bombay about as early as it does off Cochin, but somewhat later in the north, and that it may be present throughout the monsoon season. In all years, the monsoon is fully established by July; in fact, all observations made in July and thereafter demonstrate cool water at shallow depth on the shelf.

Three bathythermograph measurements by H.M.S. *Nubian* in July 1963, on the outer shelf west of the submarine canyon of the Indus as well as on the continental slope, showed an isothermal surface layer of 28·3°–28·4°C down to 25 m depth (35 m on the slope). The temperature gradients at the top of the thermocline were 3°–4°C over intervals of less than 5 m, suggesting active upward movement of deep water. The 23°C isotherm occurred on the shelf at roughly 40–45 m. In April and May this temperature is found off Bombay, and offshore slightly below 100 m.

One measurement by U.S.S. *Higbee* in August 1948, near the head of the Indus canyon, gave a temperature of 23·4°C at 20 m, the end of the trace, below a surface layer of 26·5°C. In subsequent observations by this vessel farther to the south (Fig. 5), the 23°C isotherm occurred at 30–35 m in the middle of the shelf north of about the latitude of Bombay. On the shelf south of Bombay, cold water reached even shallower depths than in the north. The depth of the isotherms was not clearly related to the distance of the section from the shore as one might expect, indicating geographic variation in the strength of upwelling. Some additional bathythermograph casts taken on the same days by U.S.S. *Chevalier* in about the same one-degree squares, and at about the same depths but without exact positions, support the *Higbee* observations.

In September 1962, the 25°C isotherm was observed on the outer shelf off Bombay at about 20 m below a shallow thermocline, and the 23°C isotherm at about 50 m (EDELMAN, 1965, Fig. 11). Likewise, the discontinuity layer was at about 30 m off Bombay and off Karachi in a section of I.N.S. *Kistna* of late September 1962; water of 23°C occurred west of the Indus canyon and southwest of Karachi between 30 and 40 m.

For the lightship off Bombay (about 10 km from the shore, 7 km from the Bombay

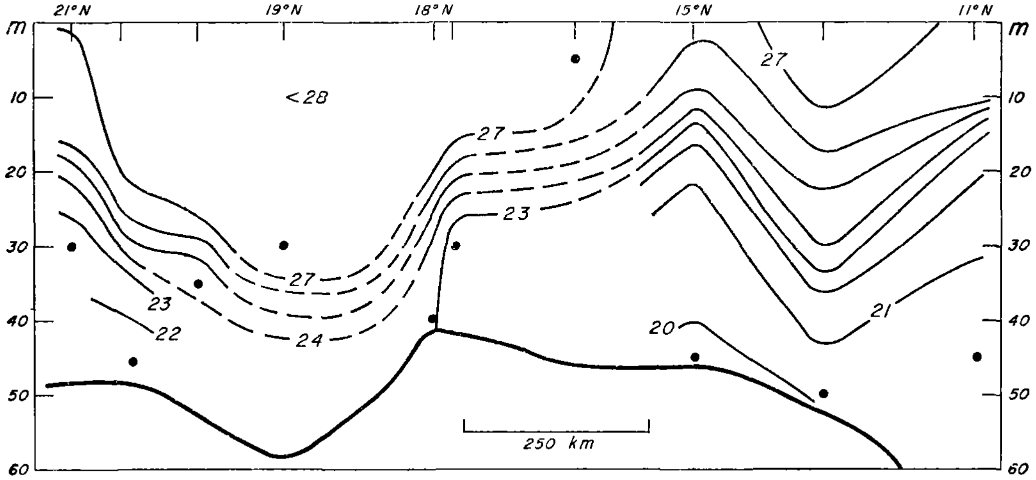

Fig. 5. Temperature section (°C) along the west coast of India (see Fig. 1) in August 1948, from digitized readings of bathythermograph slides by U.S.S. *Higbee*. Dots indicate the ends of the traces.

lighthouse; bottom depth, 18 m), the oxygen observations by GOGATE (1960)* suggest strongly that the discontinuity layer occurred near 10 m from the middle of September through October in 1959. In the middle of September there was no oxygen at 10 and 15 m, below a well-aerated surface layer†. The surface observations off the lighthouse for 1957–1959 likewise indicate that poorly oxygenated, nutrient-rich water may be present from May to July onward. The lowest surface oxygen values in 1957 were 2·2–2·5 ml/l. and occurred in May, September and October. There were marked drops of oxygen saturation (below 70%) in October 1958 and July 1959. The latter observation of 3·2 ml/l. (64% saturation) was well supported by temperature and phosphate data.

Other data from the open shelf, however, show a fairly deep surface layer overlying cool bottom water during the summer monsoon. In August 1963, *Atlantis II* found an isothermal surface layer of 40–55 or 60 m, at about 20°N (bathythermograph section, starting 60 km ESE of Sta. 73, Fig. 1). The 23°C isotherm occurred between 65 and 75 or 80 m. The temperature measurements by *Taiyo Maru No. 17* in September 1953 south of Veraval (Table 2, see also the October data and Table 1 for September 1953 off Bombay), likewise indicate a fairly thick surface layer.

In conclusion, all observations on deep parts of the shelf between Karachi and Bombay made after June indicate cool bottom water at least to about 50 m depth. Often, the thermocline is found at considerably shallower depths. It is not known

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*GOGATE gives a series of almost weekly subsurface observations of salinity and oxygen from December 1958 to the middle of May 1959, and from the middle of September through December 1959, with temperature and nutrient measurements at the surface; there is further a complete series of weekly measurements at the surface near the Bombay lighthouse, with a depth of bottom of about 5 m, from June 1958 through December 1959. The locality is strongly influenced by the outflow from the harbour as shown by the salinity data.

Mr. R. JAYARAMAN kindly provided the monthly ranges of the data from the station near the lighthouse for 1957, used by JAYARAMAN, VISWANATHAN and GOGATE (1962).

†The complete disappearance of oxygen from the subsurface water may have been an extreme case, not characteristic for the entire area near Bombay, since trawling has been successful to 30–40 m depth during the southwest monsoon of 1963, as well as during October–November of 1952, 1953, 1962 and 1963 (page 71).

what fraction of these differences reflects variations among years, or within years, or among localities.

The postmonsoon season

Upsloping isotherms during the postmonsoon period, before the onset of the northeast monsoon proper, have been reported from the northern region. Near Bombay water of 24°C occurred under much warmer surface water at 22 m depth in late October–early November 1958 (CARRUTHERS, GOGATE, NAIDU and LAEVASTU, 1959). The 23°C isotherm referred to earlier was slightly below 40 m, i.e., at about the depth shown in Fig. 5 for August 1948 or possibly somewhat deeper. The near-bottom current, at 43 m bottom depth, was setting toward the equator, rather than poleward as one might expect at this depth during the northeast monsoon proper (CARRUTHERS *et al.*, 1959). The wind speed was not more than 10 knots, and from the northeast and the northwest (BANSE, 1959). In October 1953, however, the surface layer off Bombay and south of Veraval was thicker than in 1958 (Tables 1 and 2). Similarly, in the middle of October 1962, on two *Kistna* stations, the thermocline was between 30 and 40 m and 40 and 50 m, respectively. The 23°C isotherm occurred between 40 and 50 m, and below 50 m depth.

On the continental shelf off the delta of the Indus, bathythermograph observations by *Anton Bruun* in October 1963 showed the thermocline at 30–40 m, and the 23°C isotherm at 50–65 m, in a section run from Sta. 183 toward Sta. 184 (Fig. 1), and in another one roughly parallel to it but about 40 km to the southeast.

Upsloping was similar during early November 1964 on the shelf between Karachi and the Gulf of Cutch (DOE, 1965). The top of the main thermocline was at 15–40 m depth. Temperature gradients in it were very steep over much of the area. The 23°C isotherm occurred inshore, on the middle of the shelf and in the submarine canyon of the Indus, at 30–40 m depth, and at about 55 m at the 180 m line, or slightly beyond. These conditions suggest active upsloping.* The wind was calm, or from the northeast (maximum, 8 knots), so that it is not likely to have been the main reason for the shallow thermocline.

Vertical extent of rise of isotherms

The extent of uplifting in the northeastern Arabian Sea may be estimated from the vertical shift of the 23°C isotherm. There are bathythermograph data for the second half of March 1961 by U.S.S. *Requisite* on sections across the Arabian Sea (cruise tracks in CHURGIN and SANGER, 1966) and offshore data from April to May (p. 65). Although there is some variability in the March data, and the trend to sinking in March 1961 makes comparison difficult, it appears that there may be an uplift of up to 75 m during the summer monsoon and postmonsoon seasons, although as a rule it is more likely to be 50 m (cf. Fig. 6). Thus, it is of smaller extent than that off southwest India.

In summation, the cool water rising regularly on to the shelf between Bombay and Karachi during the southwest monsoon, and most probably south of Bombay as well, is present at shallow depths at least until the onset of the northeast monsoon. During this period it seems to be effectively blanketed by warm surface water between about

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*The map of surface temperature (DOE, 1965, Fig. 3) points to upwelling to the surface at Sta. 11. However, there was no source of cool water on the neighbouring stations. Probably the marked salinity stratification (DOE, 1965, Fig. 6C) permitted the cooling of the surface water from the atmosphere. Observations by R.V. *Anton Bruun* in November 1963 likewise showed temperature inversions in the region.

Goa and Karachi, according to the available monthly charts of surface temperature which do not indicate regular and widespread upwelling to the surface in the north, as off the southwest coast of India. Exceptions to this statement are the charts for August–October of WOOSTER, SCHAEFER and ROBINSON (1967) showing slightly lowered temperatures inshore between about 66° and 70°E when the wind pattern of the southwest monsoon still obtains.

An investigation to explain the upsloping of cool water onto the shelf should include the open northernmost part of the Arabian Sea as well as the shelf and adjacent waters : On a section run across the Arabian Sea between about 22° and 20°N, in September 1962, the discontinuity layer was generally in the upper 25 m (EDELMAN, 1965). In the I.N.S. *Kistna* section of late September–early October 1962 along about 20°N, it was observed very close to a depth of 50 m depth east of 63°E, and at a much shallower depth west of this longitude. The 23°C isotherm was found roughly near 75 m (standard sampling depth) east of 63°E. A shallow thermocline occurs also in the open northern Arabian Sea in October–November (p. 62). The figure of the seasonal temperature distribution for 20°N 63°E of WOOSTER *et al.* (1967, p. TV 4) shows a situation similar to that observed by I.N.S. *Kistna*, for much of the premonsoon and southwest monsoon seasons. Thus, upsloping on to the shelf may be a consequence of changes affecting a large area, rather than merely of coastal divergence.

THE SHELF BETWEEN BOMBAY AND KARACHI DURING THE NORTHEAST MONSOON

Conditions during November and December

The air circulation pattern of the northeast monsoon season is established in the area in November; the wind off Bombay then blows almost from the north. The counterclockwise water circulation gains a hold in November, and the surface current off the Indian peninsula flows almost against the wind. The corrected mean sea levels along the coast rise strongly from October to November (Fig. 4), and one might expect sinking in November and December (the density of the surface water increases from August to November). However, all available observations show the continued presence of cool subsurface water at fairly shallow depths during November, and even early December. Later in the season, surface cooling begins to influence the vertical temperature distribution markedly.

Near Bombay cool water was present in shallow depths in 1958 at a time when it had receded off Cochin (CARRUTHERS *et al.*, 1959, for Bombay; Fig. 2 for Cochin). At the lightship off Bombay, low oxygenation persisted at 10 and 15 m depth through 24 November (GOGATE, 1960), i.e., longer than off Cochin in the same year (Fig. 2). Surface oxygen values were below 90% of saturation from the end of October to 24 November (down to 69% in early November). For 23 December, Gogate recorded 1·1, 2·5, and 3·1 ml O_2/l. at depths of 0, 5 and 10 m, respectively (no value for 15m), which is difficult to interpret. In any event, water of low oxygen content seems to have been present until that time at some depth.*

*Close to Bombay, the resultant surface current sets approximately west from October through February, requiring replacement at depth of the removed surface water, whereas on the outer shelf off Bombay and toward Saurashtra the main direction is to the northwest until the beginning of seasonal reversal of currents (WARNERS, 1952). Therefore the depth of the thermocline near Bombay in this period may not allow conclusions about the depth at the open shelf. But cold water at shallow depth near Bombay requires a source at the open shelf, and large-scale sinking there is not likely to prevail as long as upsloping and cool water can be observed near Bombay.

On the outer shelf off Bombay, the 23°C isotherm (offshore slightly below 100 m in April and May) was observed between 35 and 50 m (*Vityaz* Sta. 4863) and between 50 and 71 m (Sta. 4862) in early December 1960 (Fig. 1) below a sharp discontinuity layer at 30–50 m. It was also found between 50 and 60 m (*Mabahiss* Sta. 91) in mid-December 1933. SERYI and KHIMITSA (1963) mentioned upwelling in December 1961 on the outer shelf off Bombay. The bottom depth at the only shelf station by *V. Vorobyev* can be estimated to be 80–90 m (SERYI and KHIMITSA, 1963, Fig. 5); to judge from the oxygen distribution, the 23°C isotherm was at about 60 m depth. The surface current was setting to the south.

Between Bombay and Karachi, water of 26·6°C was observed at 31–35 m in November 1953 in Region II of JAYARAMAN *et al.* (1959 and Table 4). In late November 1960, the principal thermocline was between 30 and 40 m at *Vityaz* Stas. 4861 and 4862 (off Saurashtra, Fig. 1) and between 53 and 80 m at Stas. 4859 and 4860 (off Karachi). The 23°C isotherm occurred between 52 and 78 m (Sta. 4861) and between 76 and 110 m (Stas. 4859 and 4860). The surface temperatures were between 26° and 27°C. *Anton Bruun* found the top of the principal thermocline in the middle of November 1963 between 25 and 35 or 40 m depth on the middle and outer shelf southwest and northwest of Bombay, at ~ 30–40 or 45 m off Saurashtra, at ~ 45–65 m on the middle and outer shelf between the Gulf of Cutch and the submarine canyon of the Indus, and at ~ 65–75 m west of the canyon (late November). Considering the entire area in the fall of 1963, bottom water temperatures of 23°–24°C were observed at 66 and 71 m, and 22·3°–22·4°C down to 125 m. The water was poorly oxygenated (WOODS HOLE OCEANOGRAPHIC INSTITUTION, 1964).

During repetition of sampling northwest of Karachi in early December 1963 (until 8 December), new bottom water of 23·9°–24·9°C was present between 25 and 132 m (*Anton Bruun* Stas. 274–277). It had a high salinity and was well aerated, with an oxygen content of 1–2 ml/l. above that of offshore water with the same temperature (Figs. 6 and 7a, b, four samples; for location, see Fig. 6). Apparently there was deep convection but the area probably is not an important source of deep water (p. 66). During the same days, southwest of Karachi, *Anton Bruun* observed bottom water of 23·9°–24·0°C at 103 and 116 m of the ordinary oxygen content and salinity as met offshore, thus further suggesting that the source of deep water is a geographically small area.

About ten days later, on 17–18 December 1963, *V. Vorobyev* ran a section across the shelf, 250–300 km to the southeast (Fig. 1). The 23°C isotherm and the middle of the discontinuity layer were met between 75 and 90 m; apparently the cool bottom water observed by *Anton Bruun* had receded in the meantime. The surface temperature had not changed much, being 25·3°–26·3°C, which is about 2°C warmer than one might expect during this month. Except for the two innermost stations, vertical convection to about the depth of the 23°C isotherm could have set in had the surface water been cooled to normal temperatures.

Taiyo Maru No. 17 observations between Bombay and the Gulf of Cutch during November and December (Tables 3b and 4) show that on the average, the bottom water in the middle of the shelf off the tip of Saurashtra during December seems to be warmer than during January and February.

Reviewing these observations, a shallow surface layer between Bombay and Karachi during November and December seems particularly noteworthy because, on the average of many years, the corrected sea level attains its annual maximum during these months (Fig. 4). The shallow surface layer occurs likewise in the open northwestern Arabian Sea, off Arabia (GILSON, 1937; RYTHER and MENZEL, 1965; SERYI and KHIMITSA, 1963). An explanation may be found in the surface current pattern. Although the coastal current off the Indian peninsula is reversed by November and sets in a counterclockwise direction, the chart for November (U.S. NAVY HYDROGR. OFFICE, 1958) suggests drift in a clockwise direction on the entire ship track from Aden to Karachi, east of 50°E, as well as on the track from Karachi to Bombay, to about 69°E, that is, off Saurashtra. The drift along the track from Aden to the Persian Gulf is counterclockwise, that is, southwesterly. The number of observations per one-degree square is almost without exception below ten, and the constancy of the currents is not high, but a similar current pattern was present off Arabia in mid-October to early November 1963 and showed its effect on the thermocline (RYTHER and MENZEL, 1965). On the other hand, the November chart of WARNERS (1952) indicates a counterclockwise surface drift all along the coast between Bombay and Karachi. The counterclockwise surface circulation prevails in the entire area during December (WARNERS, 1952; U.S. NAVY HYDROGR. OFFICE, 1958).

The direction of the surface currents near Karachi and towards the Gulf of Oman may explain the transition of the hydrographic regime from that of the southwest monsoon to that of the northeast monsoon occurring as it does in November. Previously, it was believed that the change-over took place at the end of the southwest monsoon. The observations do not offer clues as to why the change-over near Bombay seems to take place later than off Karachi. The main difficulty in interpreting the temperature and salinity observations off Bombay is the lack of simultaneous current measurements. It may be significant that the two available statements about currents during this period (CARRUTHERS *et al.*, 1959, for early November; SERYI and KHIMITSA, 1963, for December) report southerly, i.e., clockwise currents, as mentioned earlier. Off Cochin, the establishment of a deep, warm surface layer is connected with the onset of the northward-setting current (BANSE, 1959).

In conclusion, marked sinking is evident nowhere between Bombay and Karachi during most of November and apparently does not occur off Bombay through the middle of December. Neither is there upwelling of deep water to the surface. The possible role of the northeast monsoon blowing essentially away from the shore is unclear.

Difference between areas and years in November and December

November 1963 with the variable depth of the thermocline and December 1963 with the discussed differences in hydrographic structure between Saurashtra and the area off Karachi demonstrate differences among areas within one year. Further, in late November 1960, essentially the same conditions prevailed on the continental slope off Saurashtra with the 23°C isotherm well above 75 m (*Vityaz* Sta. 4861), as near Bombay (Stas. 4862 and 4863; 23°C isotherm between 35 and 71 m). However, on the same day the depth of this isotherm south of Karachi and west of the Indus Canyon (Sta. 4860) was between 75 and 100 m, as it was to the west (Sta. 4859), beyond the continental slope. Therefore the present summary of the conditions on the shelf between Bombay and Karachi is only a preliminary one.

Similarly, there appear differences among years although no observations are available from the same stations. Whereas conditions favoring sinking were apparently established off Karachi early in December 1963, presumably because of the high surface salinity, a bathythermograph cast on 19 December 1956 off Karachi (U.S.S. *Soley*; bottom depth, 86 m) placed the 23°C isotherm at 35–40 m, below surface water of 23·6°C. One bathythermograph cast (U.S.S. *John Hood*) on 1 December 1957 in the submarine canyon off the Indus mouth showed the 24°C isotherm at 40 m below surface water of 25°C, and the 23°C isotherm between 50 and 55 m, slightly deeper than in early November 1964 (p. 59), but considerably shallower than on a line of stations by *V. Vorobyev*, about 130 km to the southeast, on 17–18 December 1963. In 1956 and 1957, the water at 80–90 m was just above 21°C, that is, large vertical temperature gradients were still present in December.

Water temperatures from January to March

Horizontal temperature gradients, with the warmer water offshore, prevail near the coasts of Saurashtra and West Pakistan from October to about April (WARNERS, 1952). They are strongest from November to February and may be taken as an indication of upwelling to the surface. JAYARAMAN and GOGATE (1957), CARRUTHERS *et al.* (1959), NEYMAN (1964), and GALLAGHER (1966) have in fact tentatively suggested upwelling in the northern Arabian Sea during the northeast monsoon. As shown, there is no regular upwelling reaching the surface in November and December. Neither is there evidence of cool, deep water reaching the surface in the first two months of the year. The temperature distribution may perhaps result from surface cooling by the dry and cool wind as in the northern Bay of Bengal during the northeast monsoon (BANSE, 1960).

One bathythermograph cast at about 80 m depth west of Bombay in early January 1963 (U.S.S. *Forrest Sherman*); two bottle casts in late February 1960, 140 km south of Diu Head, reaching 80 and 65 m, respectively (U.S.S. *Requisite*); and one bathythermograph cast on the outer shelf off Karachi in early February 1959, reaching 75 m (H.M.S. *Loch Alvie*), all showed more or less isothermal water to at least 50 m and mostly to 60 m, above the thermocline. Twenty bathythermograph casts of 75 m or deeper on the outer continental slope (about 2000 m depth) made by various ships during February off Bombay, Saurashtra, and Karachi also showed a deep surface layer roughly to 75 m, sometimes deeper. This is not to be expected during upwelling.

Further, in the case of upwelling, water temperatures would generally decrease with depth, and bottom water temperatures on the shelf would therefore decrease seaward. However, there is an increase of means toward intermediate depth between December and early March in the bottom water temperatures off Saurashtra during 1952 and 1953 (Tables 2 and 3). Using the normal approximation for the rank-sum test (DIXON and MASSEY, 1957), the differences between the means (in heavy print) in January, March and December 1952 are significant on the 1% level, and in the first half of February 1953 on the 5% level. This is not likely to occur in an upwelling area, and the conclusion is that during January and February deep water does not reach the surface by upwelling near the eastern end of the region of low surface temperatures shown by maps of monthly means. The fact that auxiliary thermometer readings were not recorded on the *Taiyo Maru No.* 17 does not introduce a marked bias in the data (p. 48).

The low surface temperatures off Saurashtra and West Pakistan may be caused by atmospheric cooling, because on the continental slope, where some bathythermograph observations are available for February, intermediate temperature maxima also occur. They are to be expected below the depth reached by convection induced by cooling. Of seven casts in February 1961 in the one-degree square north of 21°N and east of 67°E (U.S.S. *Requisite* and U.S.S. *Tanner*, outer continental slope), six showed inversions of 0·1°–0·5°C, between 45 and 100 m, the temperature maxima being between 23·8° and 24·8°C. All three observations in this square in March 1961 (U.S.S. *Requisite*) as well as five others in the two adjoining squares to the east (shelf proper), showed an uninterrupted decrease of temperature with depth (at this time the surface temperature begins to rise toward the annual maximum in May–June).

In the absence of upwelling in the northeastern Arabian Sea in the first quarter, the bottom water temperatures on the shelf off Bombay in February–March 1952, and 1953 (24°–26°C, Table 1) and in February 1960 (U.S.S. *Requisite*, close to 24°C, two stations), were higher than during the southwest monsoon (Fig. 5). This is presumably the rule in this region. The bottom water on the middle of the shelf of the Bombay region is 1°–2°C warmer than that near Saurashtra during February–March (cf. Tables 1–3).

For the shelf off Bombay and farther south where the isotherms of surface water during the first quarter do not run roughly parallel to the coast, one can assume that the hydrographic conditions are in principle similar to those off Calicut and Cochin. Of course, temperatures are lower, and salinities are higher than off the southwest coast (WARNERS, 1952; ISAKOV, 1953; JAYARAMAN and GOGATE, 1957; RAMAMIRTHAM and PATIL, 1966), and there may be differences in the timing or other details of the seasonal cycle.

Water temperatures in the transition period prior to the summer monsoon

At the time of the onset of surface heating, during the second half of March 1961, U.S.S. *Requisite* ran hydrographic sections across the Arabian Sea at roughly 20° 30′, 21° 30′, 22° 30′, 23° 30′ and 24° 30′N. On the Indian shelf, along the first three sections, a weak thermocline was present at 20–30 m depth. From the bathythermograph traces in late February 1961 (above), the thermal stratification appears to have been recent. The temperature of the bottom water at roughly 50 m was between 24° (or slightly below) and 25°C. In the two northernmost *Requisite* sections the water column was practically homohaline, but not homothermal. The salinities of the stations ranged between about 36·35 and 36·50‰ down to about 75 m depth, or roughly 23°C, with the exception of a shallow station off Karachi. On these stations, renewed cooling should have led to vertical convection at least to the mentioned depth, and produced water of about the same *T–S* characteristics as observed by *Anton Bruun* in early December 1963 off Karachi (p. 61).

Serial observations by the *Comdr. Robert Giraud* on the shelf break at about 19° and 22° 30′N in late April 1961, and at 24° 30′N in early May 1961 showed essentially the same situation as observed by U.S.S. *Requisite* 5 weeks earlier except that the seasonal thermocline, between 30 and 50 m (standard depths), had intensified.

Off the western tip of Saurashtra, water of 25°–26°C was found below 36 m, beneath a much warmer surface layer, through the first half of June 1952 (Table 3a; for similar observations near Veraval in May 1952, see Table 2; for June, Table 4). However, in the second half of June 1952, water of about 28°C reached 61 m off western Saurashtra. The observations terminated by June 20 after the surface temperature had fallen from between 30° and 35°C (mean, 31·5°C) to 28°–29°C, possibly indicating the onset of the monsoon. A similar increase of near-bottom temperatures occurred off the western tip of Saurashtra in May 1953 (Table 3). Near Veraval, water of 28°C was present to 60 m depth through late June 1953 (Tables 2 and 4).

Temperatures northwest of Veraval were between 26° and 27°C in May 1953 and rose in the days prior to 9 June to up to 28·5°C between 41 and 50 m (Table 4, Region IV). Both here and in the region south of Veraval (Table 2), water of almost 28°C had been present down to 45 m for a few days in the middle of May. Similar measurements are available from off Bombay for the second half of June 1953 (41–50 m, Table 1).

Serial observations of temperature and salinity were made in late March and April 1962 north of 13° 30′N (Ramamirtham and Patil, 1966), and between Ratnagiri and Veraval in May 1962 (Patil, Ramamirtham, Varma, Nair and Myrland, 1964). The sections showed marked temperature gradients near the surface but water of 25°C was found only at 75–100 m (see also *Anton Bruun* data from May 1963 and 1964, Fig. 7a, and *Vityaz* Sta. 4715 of early April 1960). There was a slight upsloping of isopycnals and isotherms noticeable off Bombay and farther north. However, off Veraval, water of 25°C occurred at 20 m depth. The last section, off Veraval, was occupied on 21 May (Mr. K. C. George, personal communication; in the same year, cold water entered the harbor of Cochin between 9 and 30 May, p. 51). If the 25°C water observed at 20 m off Veraval was connected with the water of 25°–26°C found during the same days along 71°E, it may have represented the beginning of upwelling of deep water, because along 71°E the salinity at 50 m apparently increased with temperature (Paitl *et al.*, 1964, Figs. 9 and 10). This is the case in this area below the salinity maximum, i.e., below the principal thermocline. Alternatively, it may have been cool subsurface water from the previous winter (see below).

Considering 1952, 1953, 1961 and 1962 together, it is remarkable that off Saurashtra, water of 25·0°–25·5°C, observed below warm surface water in all years, persisted in the depth interval of 36–40 m, and deeper, through June 1952 and into April 1953. Beyond the continental slope, this temperature occurs between about 75 and 100 m. Probably this water found in the transitional or premonsoon months below the shallow thermocline is the remnant of the strong winter cooling from the surface (see below). The warm water occurring from March to May above the shallow thermocline established in March seems to be continuous with the warm water off Bombay, where, however, it appears to reach a greater depth. There was thickening of the surface layer off Saurashtra just prior to the monsoon season, for which no reason is evident. The time of appearance of cool upsloping water on the shelf cannot yet be established, because of the uncertainty about the characteristics of the 25°C water off Veraval in May 1962, the fairly deep warm surface layer off Saurashtra in June 1952 and 1953, and the subsequent scarcity of data. Because all data for July show cool water on the shelf (p. 57), June is likely to be the usual time of upsloping.

The cool subsurface water of the premonsoon period off Saurashtra

Water of 25·0°–25·5°C on the shelf below a shallow thermocline after March 1952 and 1953 was probably a remnant of surface cooling during the previous months. In March 1961, the salinity decreased with rising temperature, or was fairly uniform, in a temperature range of 1°–2°C above about 24°C (Fig. 6). Five weeks later, the *Comdr. Robert Giraud* observed similar conditions below the meanwhile strengthened seasonal thermocline at 22° 30′N. Temperatures on the shelf off Saurashtra as

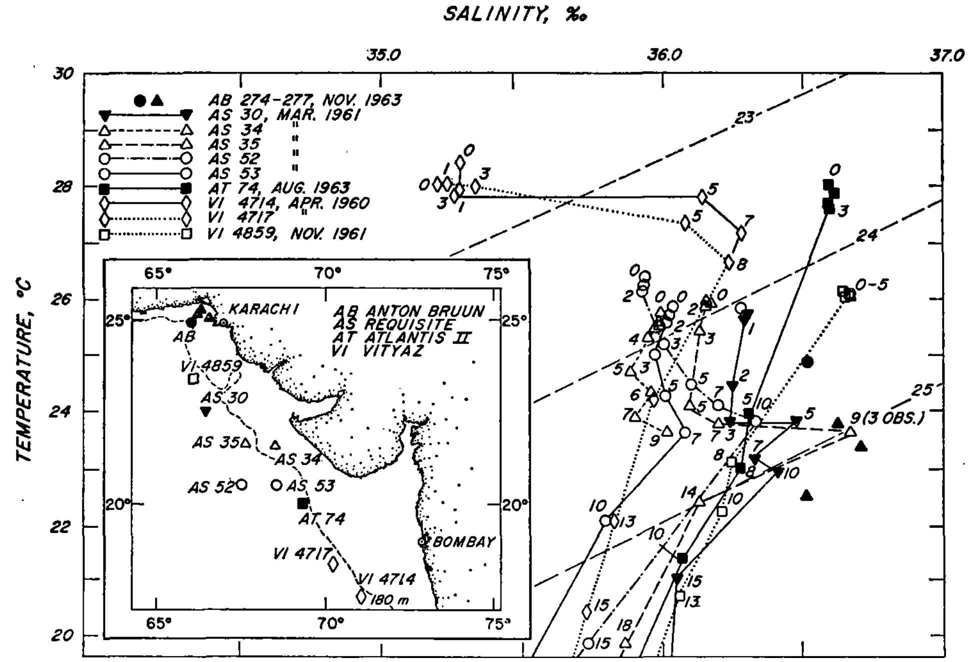

Fig. 6. Temperature–salinity diagram for stations in the northeastern Arabian Sea (see insert map; VI 4714 only to 80 m). Depth near station symbols in rounded-off decameters.

measured by *Meteor* in early March 1965 were between 24° and 25°C with small vertical gradients.

Below this water, an intermediate salinity maximum was present between 50 and 100 (150) m in 1961 (Fig. 6), and mostly between 100 and 150 m in 1965 on many stations of the three *Requisite* sections, and on some of the *Comdr. Robert Giraud* and *Meteor* stations. The density (σ_t) range was 24·5–25·1 in 1961 and 24·7–25·1 in 1965.* This salinity maximum occured at a lower temperature and higher density than that described by RAMAMIRTHAM and PATIL (1966) for the Indian shelf south of 16°N for April–May 1962. The southern maximum is situated at a temperature of 27°C or slightly above, and a σ_t of 23·7–24·0. It is present off Bombay in February–March 1965 (two *Meteor* sections), on *Vityaz* Stas. 4714 (40 km southwest of *Mabahiss* Sta. 91, Fig. 1) and Sta. 4717 of early April 1960, and *Anton Bruun* Stas. 106 and 107 of May 1963 (Figs. 6 and 7a). It is identical with the Salinity Maximum D (Arabian Sea High Salinity Water) of ROCHFORD (1964) that seems to occur also off Cochin, and is generated in the center of the northern Arabian Sea.

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*The highest salinities were 36·1 to above 36·6‰. Temperatures were 22·7°–24·5°C in 1961, and 23·0° to almost 25·0°C in 1965. Only *Meteor* measured the oxygen content. The oxygen saturation was slightly higher than in the overlying part of the surface water mass. The similarity of this maximum with the sinking water of December 1963 off Karachi (Figs. 6 and 7a, one dot at about 25°C, and three triangles to the right of the *T–S* curves, see p. 61) is obvious. Presumably the maximum is formed by convective sinking nearby. Surface water of adequately high density is present in the area (*Vityaz* Stas. 4859 of late November, Fig. 6, and 4860; *V. Vorobyev* of December, p. 61; northern *Requisite* stations of March, not in Fig. 6). Because of the high oxygen content in the salinity maximum (Fig. 7b and *Meteor* data), I doubt that the area near Karachi contributes much to Salinity Maximum C (ROCHFORD, 1964) of about the same density but with low oxygen concentrations. It is of somewhat unknown origin but must stem from the northwestern Arabian Sea or the surface of the Persian Gulf. The study by WOOSTER *et al.* (1967, p. 24) may be consulted.

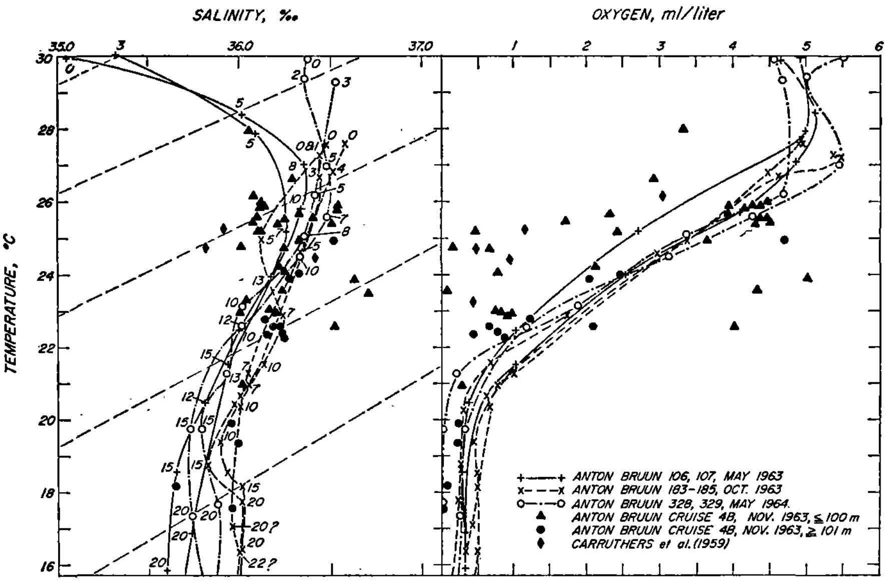

Fig. 7. Temperature–salinity diagram for offshore stations (see Fig. 1) and near-bottom water samples as indicated (a); temperature–oxygen diagram for the same observations (b). Depth near station symbols in rounded-off decameters. Filled *Anton Bruun* symbols for Stas. 201–237 and 274–281, all east of 65°E (from Woods Hole Oceanographic Institution, 1964).

The cool water present after March until shortly before the southwest monsoon on the middle of the shelf below the shallow thermocline but above the intermediate salinity maximum appears to be a regular feature because of the similarity of the temperatures in 1952 and 1953 with those of 1961 and 1965. The salinity of this water decreases with rising temperature in a small temperature range, or is fairly uniform, above about 24°C, depending on the situation of the intermediate salinity maximum. Thus this water mass is different from that uplifted shortly after the beginning of the southwest monsoon and present on the shelf at least until the reversal of the coastal current system, some time after the beginning of the northeast monsoon. In it, the salinity decreases with temperature over a wide range (Fig. 7). The former water mass, being above the principal discontinuity layer, is in contact with the atmosphere until the shallow thermocline is formed in March. The latter water mass occurs below the principal discontinuity layer and cannot have been in recent contact with the atmosphere. Probably the 25°C water at 20 m off Veraval in May 1962 came from below the principal thermocline, i.e., was uplifted water (p. 65), but the character of the 25·4°C water in Region II of Jayaraman *et al.* (1959) of June 1952 is uncertain (Table 4).

Nothing is known about the currents below the shallow seasonal thermocline, required to maintain the remnant water in the face of the general clockwise coastal currents. Possibly the warm water intrusion prior to the southwest monsoon (p. 65) signals the final removal of the cool water. The intermediate salinity maximum also disappears during the summer monsoon (Fig. 6). Stations by *Anton Bruun*, *Mabahiss* (Stas. 61 and 61A), *Vityaz* (Stas. 4859–4863) and *V. Vorobyev* show through the middle of December the same homogeneous surface layer as the summer monsoon and postmonsoon stations in Fig. 6, above a sharp thermocline.

TENTATIVE SEASONAL PATTERN OF HYDROGRAPHY OFF SAURASHTRA

During the southwest monsoon and postmonsoon seasons, cool water of low oxygen content covers much of the shelf off Saurashtra. Some time after this water has withdrawn, surface cooling sets in. Because of the shallowness of the surface layer, the water temperature may be lowered to 21°–22°C. The resulting convection is not very deep because of the relatively low salinity of the surface water that is advected along the coast from the southeast.

To the west where higher surface salinities prevail, deep convection sets in at 23°–24°C. Dense water generated there underlies the surface layer off Saurashtra and possibly also off the Gulf of Cambay during the first third of the year, forming an intermediate salinity maximum. With the warming during March, a thermocline is formed in the surface layer off Saurashtra that insulates water of normally 24°–26°C with high oxygen content on the shelf. This water disappears prior to the southwest monsoon, and for a short time a deep, warm surface layer is present. The summer monsoon season leads anew to an uplift of water of about 22°–25°C. The intermediate salinity maximum is absent during this period.

BIOLOGICAL EFFECTS OF SUBSURFACE WATER WITH LOW OXYGEN CONTENT

Oxygen content of the near-bottom water between Bombay and Karachi

Upwelling water off the southwest coast of India can be very low in oxygen. Concentrations below 0·25 ml O_2/l. (less than 5% of saturation) are common on the shelf (BANSE, 1959). In October 1958, oxygen was absent 5 m above the bottom on Sta. 332 off Calicut (Fig. 1) and Sta. 333, 60 km to the southeast; the bottom depth of both stations was 55 m. No oxygen was present in September 1959 near Bombay at 10 and 15 m (bottom depth, 18 m) (GOGATE, 1960). Since similar hydrographic conditions seem to prevail all along the west coast of India during the southwest monsoon, oxygen depletion may be widespread below the main thermocline. The distribution of bottom fauna, demersal fishes and prawns would be affected some time before the oxygen content a few meters above the seabed actually reached zero.

The maximum oxygen content in the subsurface water on entering the shelf between Bombay and Karachi is indicated by the offshore observations by *Anton Bruun* in 1963 and 1964 (Fig. 7b, open station symbols). Oxygen values from *Vityaz* Stas. 4713, 4855 and 4865 of April and November–December 1960 and of *Atlantis II* Stas. 72–74 of August 1963 (Fig. 1) are quite similar, and obvious differences between seasons or years seem to be absent below the surface layer.* Thus, water of 23°C present on the shelf during the entire southwest monsoon season cannot have a content above 2 ml O_2/l. Water of 22°C is likely to be close to 1 ml O_2/l. on entering the shelf.

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*Several *Vityaz* stations on the continental slope (partly in Fig. 1) tend to have oxygen values lower than those of the offshore stations in the intermediate temperature range, as is also the case of *Anton Bruun* Sta. 107.

On the shelf the oxygen in the water is further depleted by contact with the bottom, as off Cochin. Possibly also, the flux of organic matter from the surface layer is higher than in the open ocean, because of higher productivity. The degree of deoxygenation depends on the rate of oxygen removal, mixing, and the residence time of the water, and certainly varies in space and time. Therefore the oxygen content of the bottom water samples of October–November 1958 and of November–December 1963 from the shelf between Bombay and Karachi exhibit a great scatter when plotted against the corresponding temperatures (Fig. 7b). Many concentrations were half as high (or less) as those in offshore water of the same temperature. There was only moderate mixing, particularly below 24° (Fig. 7a); hence, the reduced oxygen content did reflect consumption *in situ.*

During the winter, when a deep isothermal layer of 22°–25°C is established off Saurashtra and Pakistan, the oxygen content of the bottom water is, of course, near saturation over wide areas. The changes *in situ* following re-establishment of stratification in March are not known.

Plankton production in the surface water

Because of the low oxygen content of cool water entering the entire shelf, off the west coast of India and Pakistan during the southwest monsoon, the nutrient content is high, and the effect on phytoplankton development is marked when the water reaches the euphotic zone (for Calicut see SUBRAHMANYAN, 1959; BANSE, 1959; and SUBRAHMANYAN and SARMA, 1967; for Karwar, see RAMAMURTHY, 1966). At A and B off Cochin during 1958–1959, concentration of more than 1 μg-atom PO_4^{3-}-phosporus/l. (up to 2 μg-atom/l.) and 10–20 μg-atom NO_3-nitrogen/l. were found within 10 m from the surface. Nitrate exhaustion usually prevailed at the surface, whereas phosphate was always present in appreciable amounts, as is true for the other seasons also. In spite of apparently active upwelling in July 1958 (Fig. 2), the Secchi disc could be seen to 30 m depth outside the muddy coastal waters, which was about the same as during November–December 1958–1959 when very low productivity rates (^{14}C uptake) of offshore levels were measured. During August–October 1958 and 1959, the Secchi disc disappeared at 5–10 m at B; the depth of the euphotic zone can be assumed to be twice or somewhat more than the Secchi disc readings. Concentrations of chlorophyll *a* during the periods with a shallow euphotic zone were above 1 μg/l. (up to 5 μg/l.).

On the shelf off Saurashtra concentrations of chlorophyll *a* at *Atlantis II* Sta. 73 of September 1963 (Fig. 1) were 0·4–0·5 μg/l., similar to the stations in the open ocean (YENTSCH, 1965). As off Cochin in July 1958, these measurements do not indicate a very shallow photic zone. However, observations in the northwestern Arabian Sea (RYTHER, HALL, PEASE, BAKUN and JONES, 1966) suggest that the rate of daily carbon uptake at the *Atlantis II* stations might have been as high as 1 g/m^2. The only other published biological observations from the southwest monsoon season, north of Karwar, were collected at Bombay, close inshore (GOGATE, 1960) and may not be representative of the open shelf. Concentrations of total phosphorus in coastal surface waters at and south of 18°N during July and August were high relative to the concentrations observed during January and February (JAYARAMAN and SESHAPPA, 1957).

During the postmonsoon season of 1963 at the end of October when cool water still covered much of the shelf, *Anton Bruun* made intensive studies of primary production in the northwestern Arabian Sea (including Stas. 183–185, Fig. 1) and toward the mouth of the Gulf of Oman and the Arabian coast. The concentrations of chlorophyll were usually well below 1 μg/l. (WOODS HOLE OCEANOGRAPHIC INSTITUTION, 1965). The daily rates of carbon uptake (RYTHER *et al.*, 1966) were mostly well above 1 gC/m^2 except on a line of stations running from 12° 15′N, 59° 42′E (Sta. 180, RYTHER and MENZEL, 1965, Fig. 1) towards Sta. 184, where they were lower. This line was just outside the large area off Arabia with a very shallow discontinuity layer that continued onto the shelf off Pakistan and western India. The rates in the section seem to represent a zone of transition between the area of high production and the open ocean where rates of daily carbon uptake lower by an order of magnitude prevail. Normal to the section and away from the Arabian coast, the sinking of the thermocline led to reduced production (RYTHER and MENZEL, 1965, Figs. 3–4).

The hydrographic evidence suggests that the time of withdrawal of the cool water from the shelf, in November or sometimes December, is a period of transition to low rates of primary production. From early November to early December 1933, the surface layer (defined by the vertical distribution of oxygen and nitrate) almost doubled in depth in the area between *Anton Bruun* Stas. 183–185 and the Arabian shelf (*Mabahiss* Stas. 60, 61, 65, 68, 76, 81 and 82, GILSON, 1937). Off Karachi in late October 1963, the 23°C isotherm near *Anton Bruun* Stas. 183 and 184 was at 50–65 m depth (p. 59), whereas in the last days of November 1960, on *Vityaz* Stas. 4859 and 4860, it occurred between 76 and 100 m. The daily rates of carbon uptake at the latter stations (KABANOVA, 1964) were almost an order of magnitude lower than those of late October 1963. In the open Arabian Sea far from divergences, the rates measured by the two ships were very similar (*Anton Bruun* sections along 65° and 70°E, RYTHER *et al.*, 1966, with Stas. 106, 107, 328 and 329, Fig. 1).

It is not known whether the deep convection on the shelf in the northernmost Arabian Sea during the winter leads to a marked increase of nutrient salts in the surface layer. The observations by *Anton Bruun* in November–December 1963 (WOODS HOLE OCEANOGRAPHIC INSTITUTION, 1964) do not suggest a marked change : The average phosphate content of surface water at the four stations off Karachi where convection prevailed (Fig. 6, Stas. 274–277) was 0·69 μg-atom P/l. and exactly that of the four following stations (278–281) where stratification obtained and the bottom water had a low oxygen content. The average of two groups of four roughly comparable stations, occupied about two weeks earlier in the same area, was 0·58 and 0·72 μg-atom/l., with considerable variation among stations.

There are eleven stations in the *Anton Bruun* material of November–December 1963 with a surface phosphate concentration $\geqq$ 0·99 μg P/l. Most stations are close to the coast, except off the Gulf of Cutch and toward the delta of the Indus; about half are in stratified water. Since the surface concentrations of phosphate on eight of these stations are higher (up to several times) than the bottom values, local upwelling or convection cannot be the cause of the high surface concentrations.

After the establishment of the thermocline off Saurashtra in March or April, the rate of nutrient supply from below must be cut down initially and phytoplankton production ought to be low. However, if the oxygen content of the cool water persisting there until shortly before the southwest monsoon is rapidly reduced, even a low rate of vertical mixing may provide significant amounts of nutrients to the lower part of the photic zone.

In conclusion, it would seem that the seasonal cycle of primary production on the middle and outer shelf off India and Pakistan must be fairly similar. The southwest monsoon season is the time of very high rates. Off the southwest coast these will fluctuate markedly when the upwelling water actually reaches the surface. Also north of about 15°N (or perhaps 18°N) where regular upwelling to the surface is not known, the rates will vary with changes in the depth of the thermocline and reduction of vertical stability, depending on changes of wind and currents. In all regions, a marked drop in photosynthetic activity is to be expected upon the receding of the upwelled water. Not only does the pycnocline become deep, but also the density stratification within the surface layer is not conducive to high production rates, particularly where the Equatorial Surface Water is present. Accordingly, the carbon uptake rates at B off Cochin in 1959 during this season were not much higher than those reported from the open Arabian Sea, and one might expect similar low primary production off much of the Indian west coast away from the beach. The average concentrations for seven years of plant pigment measurements off Calicut were roughly one-tenth of those of the upwelling season (SUBRAHMANYAN and SARMA, 1967) which was also true off Cochin at B in 1958/1959.

Oxygen and catch of demersal fishes

Off Cochin, the deoxygenation of the near-bottom water results in the regular disappearance of demersal fishes and in unprofitable trawling in a belt between the aerated water nearshore and the relatively new bottom water on the outer shelf. For the dominant fish, *Synagris japonicus*, oxygen concentrations of 0·25–0·50 ml/l. seemed to be critical (BANSE, 1959). Implicitly, the temperature of the bottom water can not be used for predicting the occurrence of demersal fishes because oxygen concentration in the near-bottom water is largely independent of temperature, as is true also in the northern region (Fig. 7b). The fact that off Bombay, as off Calicut, the oxygen content dropped to zero in near-bottom water (p. 68) suggests that there may possibly be a vast area on the outer shelf (and perhaps also on the middle shelf) approximately from Cochin to Karachi that is devoid of commercially exploitable concentrations of demersal fishes during the southwest monsoon. The fishes very likely disappear before the oxygen has completely vanished. There are scattered notes that this is true for the postmonsoon period (CARRUTHERS *et al.*, 1959; DOE, 1965) when poorly aerated water persists on the shelf between Bombay and Karachi.

There are three sets of extended observations. The hourly catch rates of the trawler *Jheenga* off Bombay, particularly in the ten-minute square north of 18° 50′N and east of 72° 30′E (depths between 20 and 40 m), increased markedly during the summer monsoon of 1963 over those of the first quarters of 1963 and 1964 (SUDARSAN, 1965). Since the summer monsoon of 1963 was weak (LARSSEN, 1964), the cool, deoxygenated water may not have reached as shallow depths as during 1959 when no oxygen occurred at 10 and 15 m depth in September (GOGATE, 1960). The increased catch rate might then be interpreted as caused by fishes crowding inshore when the conditions on the outer and middle shelf deteriorated, as happens off Cochin. However, oxygen-poor water is also observed near Bombay in November and December in shallow depths. Yet the catch rate of *Jheenga* as well as that of two other trawlers working in the same area was high during October–November 1962 and 1963, when compared with the rates for January to March 1963 and 1964 (SUDARSAN, 1965). No explanation can be offered.

The monthly averages of hourly catch rates of the *Taiyo Maru No. 17* during the summer monsoon and the postmonsoon time (JAYARAMAN *et al.* 1959) do not lend themselves easily to an analysis of depth dependence. Because the trawling effort was not spread evenly over all depths, excepting Region V, and because zero hauls are not clearly indicated in the tables, only positive evidence (e.g., a catch rate for a depth range that seems to be based on several hours of trawling) can be considered. During July through November of 1952 and 1953, 30 monthly means in Regions I–III, and about 12 monthly means plus July 1954 in Region I, can be used for evaluating trends : Six means in August and September represent average and above-average catch rates between 36–40 m and 46–50 m (emphasis was on the deeper part of this depth range). Six means in October and November represent about average or below-average rates between 21–25 m and 36–40 m. Thus the trawling in the last 2 months was definitely at shallower depth than during August and September. July is represented only once when average rates were obtained between 41 and 55 m. From Regions IV and V, observations are available only for June and July, and indicate average or above-average rates between 36 and 45 m. Because the thermocline is not always above 50 m at this time of the year, and hence aerated water may reach this depth periodically during the southwest monsoon and postmonsoon seasons, no conclusion can be drawn. The fishing of September 1953 was almost certainly in the surface layer (cf. Tables 1 and 2). It may be mentioned that most of the catch in earlier trawling attempts in Bombay waters came from depths shallower than 50–60 m (SPENCE and PRATER, 1931, 1932).

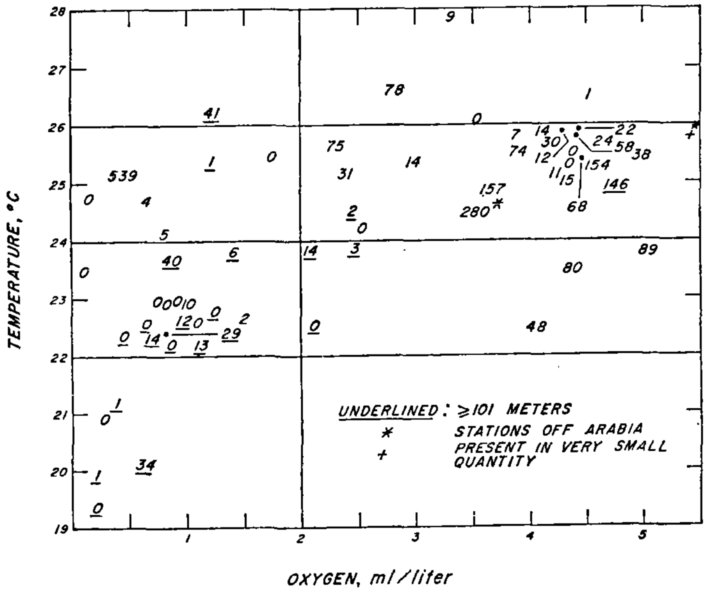

Fig. 8. Catch of commercially important fishes on *Anton Bruun* cruise 4B, November 1963, plotted into a temperature–oxygen diagram. Values in lb/45 min of trawling. To convert into kg/hr, multiply by 0·6.

The data from stations 202B and C, 203B and C, 238A, 239A, 249A, 254A, 256A, 257A, 262A, 271A, 273A, 279B, and 281A were incomplete so that the hauls have not been used.

Catch rates of selected fishes per unit effort from *Anton Bruun* cruise 4B of November–December 1963 in the northern Arabian Sea (Mr. A. T. Pruter, personal communication) were plotted against oxygen and temperatures (above 19°C) of the bottom water (Fig. 8).

The hydrographic data (Woods Hole Oceanographic Institution, 1964) east of 65° have been used in previous sections. A summary report on the material has been given by Hida and Pereira (1966). A nylon Gulf of Mexico shrimp trawl (mesh size, 3·8 cm stretch), measuring 13 m along the foot rope, was employed with otterboards of 0·8 by 1·5 m, of 73 kg weight. The averages given have been calculated on the basis of pounds adjusted to 45 min of trawling at 2·5–2·7 knots, since these were the units used in the log sheets, and have been converted to kg/hr. Considered is the catch of the families Ariidae (thus in the log sheets; = Tachysuridae), Sciaenidae, Pomadasyidae, Polynemidae, and Muraenesocidae, members of which are the important fishes trawled off Bombay (Spence and Prater, 1931, 1932; Jayaraman *et al.*, 1959). The various species involved are likely to differ in their reactions to the environment so that the following presentation is slightly nonbiological, but the raw data do not permit a detailed study. Catches of 5 lb/45 min (3 kg/hr) or less are regarded as insignificant in the following text.

Water of a temperature of 22°–26°C seemed to cover much of the shelf during the postmonsoon season. The poor hauls in this temperature range, at oxygen concentrations below 2 ml/l. (Fig. 8) were made predominantly on the middle and outer shelf between Bombay and Karachi, and suggest that in November 1963 fishing might have been poor on the entire shelf at depth greater than 40–45 m. In water of 22°–26°C, shallower than 100 m, with oxygen concentrations of more than 2 ml/l., 21 out of 25 hauls yielded catch rates of more than 5 lb (average of 25 : 52 lb, SD 65 lb, or 31–39 kg; without the two hauls off Arabia marked by * in Fig. 8, 44 lb, SD 45 lb, or 26·5–27 kg†).

Because warm aerated water occurs primarily at shallow depths, the distribution of catches might simply indicate a relation of fish abundance to depth rather than to oxygen. Neglecting the small catches from water deeper than 100 m, only the temperature range between 22° and 26°C above 100 m will be considered, and the rich catch at Sta. 204A discussed in footnote† and the hauls off Arabia (Stas. 270 A and 272 A) will be omitted. The rates at $\leq$ 100 m are divided into three groups (Table 6), assuming from the *Taiyo Maru* data that fishing for the species under consideration was good above 40 m during November 1963; Sudarsan's (1965) data support this for the area close to Bombay in 1963. In a normal approximation to the rank-sum test (Dixon and Massey, 1957), the first two means from water rich in oxygen just fail to be significantly different on the 20% level so that depth cannot be shown to be very important. The last two means from depth $>$ 40 m are different on the 5% level, thus oxygen is important. The first and the last means are different on the 0·1% level. A more refined statistical treatment has not been applied in view of geographic bias in the data, which could possibly affect the species composition of the catch and consequently the relation of catch rate to oxygen concentrations : 13 out of 15 samples of the first mean were collected east of 65°E, as well as 9 out of 11 samples of the last mean, whereas 5 out of

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†The analysis of the data in Fig. 8 is complicated by the fact that the largest catch was obtained at an oxygen concentration in the near-bottom water of 0·48 ml/l. (Sta. 204A), on apparently level bottom of 33 m depth, 20 km off Diu Head, about 10 km offshore of an area where the nautical chart (U.S. Hydrogr. Office, *H.O. No. 1589*, 7th Ed.) indicates strong current and eddies. The bathythermograph slide from this station suggested the top of the thermocline to be at about 18 m, but other casts within 80 km of station 204 A, between 30 and 45 m, showed a surface layer of 25–32 m. Thus, this very rich catch might have come from the border between the poor offshore zone and the aerated water inshore. Off Cochin, inshore trawling can be highly profitable in certain years, and the transition from the populated area to the barren one can be very sharp on particular days.

Table 6. Analysis of catch rates of commercially important fishes of Anton Bruun *(see text).*

Depth (m)	O_2 (ml/l.)	*Number of samples*	*Mean catch rate* lb/45 min (kg/60 min)
$\leqq 40$	$\geqq 2$	15	55, SD 49 (33–30)
> 40	$\geqq 2$	8	25, SD 29 (15–17·5)
> 40	< 2	11	2, SD 3 (1·2–1·8)

8 samples of the second mean came from west of 65°E. It is tentatively concluded that oxygen concentrations of roughly 2 ml/l. are likely to affect catch rates of the fishes under consideration. Of course, the critical concentration ought to vary from species to species.

There was no relation between temperature of the bottom water and total catch for the *Anton Bruun* data from the Arabian Sea, but there was a poor although significant correlation of catch to oxygen, and inverse correlation of the phosphate content of the bottom water (HIDA and PEREIRA, 1966). The average catch rate of all fishes in the Arabian Sea was quite differently distributed versus depth than was the case with the commercially important forms (as defined earlier) : The rate was about as high, or slightly higher in the depth intervals 74–110 m and 111–183 m, than in the interval 38–73 m (HIDA and PEREIRA, 1966, Fig. 6*). This was largely due to members of the family Nemipteridae which made up almost half of the catch between 74 and 183 m off India and West Pakistan. The catch rates grouped fairly arbitrarily according to temperature and depth (Table 7) indicate that Nemipteridae tended to avoid shallow water. On the deeper stations, there was no obvious relation between catch rate and oxygen or temperature.

Among other forms of the *Anton Bruun* material, Dasyatidae (stingrays) contributed a fair fraction of total trawl catches, as also found by earlier investigators. Omitting the catches of single large specimens, hauls yielding more than 5 lb/45 min (3 kg/hr) were made only in shallow (less than 30 m), warm (more than 22·5°C, mostly more than 24·5°C), and well-aerated water (more than 3·5 ml O_2/l.). The second richest haul, of 376 lb/45 min (226 kg/hr) was the exception, coming from water as characterized but at 132 m. Four other hauls in water warmer than 23°C, with more than 3·0 ml O_2/l. at 75–78 m depth (no other hauls in such water between 51 and 100 m)

Table 7. Distribution of Nemipteridae caught by Anton Bruun.

Temp. (°C)	*Depth* (m)	*Number of samples*	*Mean catch rate* lb/45 min (kg/60 min)
> 23	< 70	29	2, SD 3·5 (1·2–2·1)
< 23	< 70	2	12
> 23	$\geqq 70$	13	24, SD 24 (14·5–14·5)
< 23	$\geqq 70$	19	38, SD 48* (24–29)

*Without two large catches of 131 and 169 lb : 25, SD 29 (15–17·5).

*To obtain an undistorted picture of catch rates versus depth off West Pakistan, one specimen each of Dasyatidae of 170 kg and of Rhinobatidae of 182 kg ought to be omitted from the figure (cf. tables VI and VII of Hida and Pereira, for the necessary correction).

suggest that stingrays usually are rare in the northern Arabian Sea, during this season, at depths much greater than 30 m even if suitable water is found; hence, depth as such may be important also with these forms.

Other observations

When discussing absence of periodic large-scale mortality of fishes at the southwest coast of India during the southwest monsoon season in 1959, I had overlooked both the report by the port officer of Cochin that every year in August dead fishes float into the harbor of Cochin during flood tide, and observations of asphyxiated animals thrown onto the beach near Calicut; the deoxygenation of the water was said to be due to respiration during the night by masses of euglenoid algae (JACOB and MENON, 1951). SUBRAHMANYAN (1954) has further discussed the relation between flagellates and unperiodic fish kills in that region. I suggest that sometimes there might have been direct killing of fishes and Crustacea trapped in deoxygenated upwelled water, which is difficult to prove without subsurface measurements and after the fact. Regular fish kills during the upwelling period, other than off Cochin (which is not even well known locally), seem to be absent off the west coast of India.

Crustacea are in the same situation as are demersal fishes when the cool water is upsloping during the southwest monsoon. The data of GEORGE (1962) on prawn fisheries near Cochin suggests a relation of catch per man-hour to aeration of water although only surface observations of oxygen are available. At Alleppey, about 65 km south of Cochin, the catch rate became very high in May, June, and July 1956, when the average surface oxygen concentrations dropped (the trend did not hold in November). In contrast, at Narakkal north of Cochin, with well-ventilated surface water, the catch rates were low during the southwest monsoon of 1956 except during May, when the average oxygen content dropped. Possibly increased catch per man-hour was a consequence of prawns pushed toward the shore by poorly aerated water (cf. BANSE, 1959). However, the surface salinity, fairly stable off Alleppey during these months, fell to low average values in June and July off Narakkal. Thus we may possibly be concerned with a negative influence on the distribution of prawns off Narakkal, rather than the beneficial effects of the low oxygen content on the prawn fishery near the beach off Alleppey.

The prawn, *Penaeus indicus*, is fished off Bombay, and can contribute near Cochin one-fifth to three-fourths by weight of the total prawn catch in some months (GEORGE, 1962). SUBRAHMANYAN (1962), working at 28·2°C and about 14·5‰ S, the approximate salinity of the habitat of his specimens, found lethal oxygen concentrations between 1·5 and 3·8 ml/l. depending upon size, larger individuals being considerably more sensitive than smaller ones. Lethal concentrations were not studied for specimens acclimated to oceanic salinities; however, since *P. indicus* lives in oceanic as well as brackish ranges of salinities, the lethal levels in the open sea are not likely to be radically different from those observed by Subrahmanyan. Since oxygen concentrations of 1·5 ml/l. are practically absent below the thermocline over most parts of the shelf off the west coast of India during the southwest monsoon and shortly thereafter, the distribution of the species on the shelf may fluctuate seasonally.

SUBRAHMANYAN (1962) also recalculated older data on oxygen relations for *Metapenaeus monoceros* that dominates the commercial prawn catch near the Gulf of Cutch (GEORGE, GEORGE and RAO, 1963) but does not occur in significant numbers in inshore catches near Cochin (GEORGE, 1960). The respiration rate becomes affected at the relatively high level of " 125 mm Hg of oxygen " (SUBRAHMANYAN, 1962). Also these values suggest strongly an influence of the poor aeration of bottom water on the distribution.

Application of oxygen–catch relation

If the relation between oxygen content and fish catch, and consequently abundance, holds for the months of the summer monsoon, and the postmonsoon seasons, then, because of hydrographic conditions, fishing on the shelf below the discontinuity layer for the species hitherto commercially important off Bombay would be unprofitable near Bombay and toward Karachi. In terms of depth, fishing would be unprofitable between July and November–December at depth > 50 m in the earlier part of the period, and > 40 m in the later part. (The main discontinuity layer may be met at much shallower depths, i.e., 30 m, even in July, and also later). There are not yet enough data to discount the possibility that the oxygen content of the upsloping water, between 23° and 26°C, in the early part of the southwest monsoon season, is not depleted to a critical level; there was good fishing in water of 25·5°–25·8°C, below the thermocline, in Region V of JAYARAMAN *et al.* (1959) in May and June 1953. Also, water above 26°C but below the thermocline may always contain enough oxygen.

Because of the similarity in hydrography, including the oxygen regime, the above might hold in principle for the entire west coast of India and the coast of West Pakistan.

Where the distribution of fishes is affected by the oxygen regime in the bottom water when below the thermocline, the temperature of the bottom water is of little use for predicting catch. Since oxygen determinations by fishermen are impractical, a bathythermograph or a similar recording instrument might be employed to establish whether or not there is a thermocline. Fishes of the families reported by JAYARAMAN *et al.* (1959) can be expected when the surface water touches the bottom. Accordingly, the fishing area might be extended farther seaward than is the custom now, from December through March or April. Whether the catch rate on the outer shelf would be as high as on the established grounds during this season cannot be derived from the published material. The implication of the relation between catch rate of demersal fishes and aeration of the bottom water on the shelf is that in certain seasons these fish populations might not reach much farther seaward than is known already. Thus the resource might possibly be only of moderate size, and an extension of the fishery to the outer shelf in the good season would not draw on a hitherto untouched stock. Study of the catch data from the relatively intensive trawling off the Indian west coast during the past, including the original material of Spence and Prater, and of Sudarsan, may allow conclusions on this subject without much time spent at sea. Particular emphasis ought to be put on studying the distribution of unsuccessful hauls against depth and season.

Acknowledgements—The time series off Cochin was made possible by a fellowship from the Government of India under the Indo-German Industrial Cooperation Scheme, 1956–1957; by support from the German Research Association (Az. Ba 49/5, 49/8, and 49/9); by the hospitality and assistance from the former Central Marine Fisheries Research Station; by vessels, instruments, and logistic help from the Indo-Norwegian Project; and by vessels of the Offshore Fishing Unit, Cochin. The chlorinity and oxygen titrations were done by Mr. C. P. RAMAMIRTHAM; the computations of temperature, salinity, density, and oxygen saturation were made by Mr. C. P. A. NAIR. Original data were kindly provided by Dr. L. A. E. Doe, Mr. R. A. Miller, Mr. A. T. Pruter, Mrs. M. K. Robinson, the Central Marine Fisheries Research Institute, the National Oceanographic Data Center/World Data Center A, and the Woods Hole Oceanographic Institution. The study of the material was partially supported by the National Science Foundation, Grant No. GB-970. The main arguments were presented at the Second International Oceanographic Congress in Moscow in May–June 1966. A travel grant by the National Academy of Sciences allowed my attendance.

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Note added in proof:

During the preparation of the paper I had been unaware of some bathythermograph observations made during the early summer monsoon season on the shelf and the continental slope off the southwest coast of India. The U.S.S. *Fort Niagara* observed a temperature of 24·8°C at 25 m depth (below surface water of 28·3°C) on 12 June 1944 on a station with about 45 m bottom depth about 75 km northwest of Position B off Cochin (Fig. 1). Three stations by U.S.S. *Mispillion* on 7 June 1944, approximately along the 1000-m contour, between 12° 22′N and 13° 40′N, showed the 27°C isotherm close to 50 m depth. The surface temperature was 28·4°–29·7°C. *Anton Bruun* observed this isotherm on the same track in March and May 1963 between 70 and 150 m, and 70 and 80 m, respectively (cf. Fig. 3). In four observations by U.S.S. *Mispillion* on 23 July 1946 on the continental slope between 9° 30′N and 10° 41′N, the 25° isotherm was between 18 and 29 m depth (surface 25·6°–27·4°C). The 20°C isotherm occurred between 43 and 53 m depth (see Figs. 2 and 5 for the middle of the shelf, and page 54). These data further substantiate the early start of upwelling off the southwest coast of India.

Reprinted from *Deep-sea Res.*, vol. 15, 1968, p. 665-677

Comparison of near surface dynamic topography during the two monsoons in the western Indian Ocean*

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(*Received* 27 *June* 1968)

Abstract—The dynamic topography of the near surface water, 0–400 dbar, relative to 1000 dbar. is shown for the western Indian Ocean during both the southwest and northeast monsoon periods using data acquired during the recent International Indian Ocean Expedition. Seven zonal sections between 20°N and approximately 10°S allow seasonal comparison of essentiallly the same areas. The areas of greatest seasonal differences were off the Arabian coast and particularly the Somali coast where the large high (> 1·8 dy m) during the southwest monsoon was not evident during the northeast monsoon. The means of the surface topography in the northern ocean show that the winter values were greater by 0·04 dy m than summer. This is attributed to the increased cloudiness, evaporation and coastal upwelling during summer.

INTRODUCTION

THE SURFACE layers of the western Indian Ocean are exposed to severe seasonal changes in the prevailing winds. The southwest monsoon wind blows in strength from June through September and the weaker, somewhat shorter northeast monsoon period falls between December and the end of March. The seasonal differences in wind conditions are particulary noticeable off the Somali and Arabian coasts (U.S.N., 1957). With recent data obtained from hydrographic stations during the International Indian Ocean Expedition, near surface dynamic topography can now be calculated for each of the two seasons and is discussed here to ascertain the response to the monsoon winds.

TREATMENT OF THE DATA

The data (Table 1) were obtained between 1962 and 1965. There is always a need for a greater quantity of data than that on hand and this is certainly true here. The area considered is large (13 × 10^6 km^2) and each season of 3–4 months duration. Fortunately there are several tracks (mainly from *Atlantis II* Cruises 8 and 15) along approximately the same latitude in each of the seasons, thus allowing a comparison to be made of nearly the same area in both the southwest and northeast monsoons (Fig. 1). It should be understood that many of the small scale features depicted such as the small highs found off the Arabian coast in summer may not be common each year but may represent a certain amount of " noise " such as may result from internal waves at singular stations. Because of the absence of data over periods of several years it is difficult to know when to draw the line between topography that may occur seasonally and that which does not. Generally the larger features well-defined by

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*Contribution No. 2069 from the Woods Hole Oceanographic Institution.

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*Table 1. Cruises from which data was used listed by monsoon period.**

1. *Northeast monsoon*, northern winter, referred to as " winter " in this paper		
Atlantis II,	Cruise 15:	February 18 to May 29, 1965†
Discovery	Cruise 3:	February 29 to April 30, 1964
Argo,	Lusiad :	March 6 to May 10, 1963
Meteor,	Cruise 1:	December 17, 1964 to March 12, 1965 (Fig. 8 only)‡
Southwest monsoon, northern summer, referred to as " summer " in this paper		
Atlantis II,	Cruise 8:	August 7 to October 28, 1963†
Discovery,	Cruise 1:	June 25 to August 16, 1963
Discovery,	Cruise 3:	July 1 to September 10, 1964
Argo,	Lusiad :	July 8 to September 5, 1962
Argo,	DODO VI:	August 1 to September 7, 1964

*Station listings may be acquired from the National Oceanographic Data Center, Washington, D.C.

†Stations occupied during May and October were in the southern hemisphere and are included since they allow zonal comparison although unfortunately quite late in each monsoon season.

‡*Meteor* data are discussed separately to show the changes which may occur in winter as well as summer in the Somali coastal region.

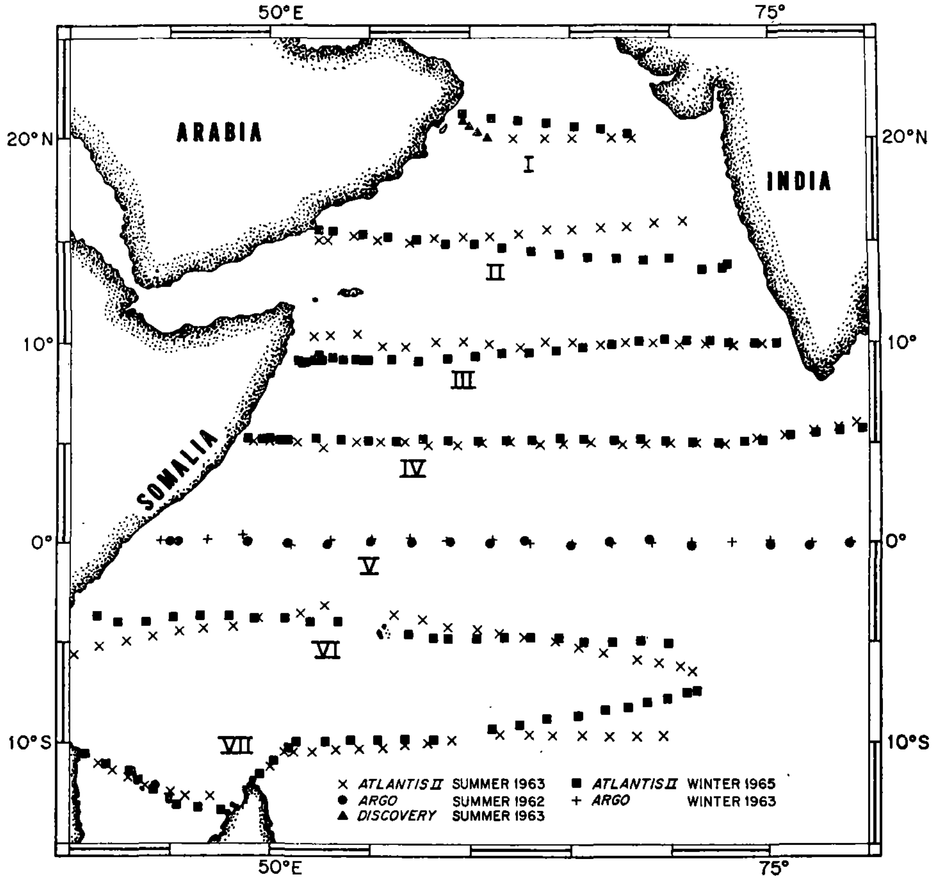

Fig. 1. Zonal sections (I–VII). These were occupied in the northwest Indian Ocean during the northern summer and winter monsoons. The 5°N, 10°N, 15°N, the two southern hemisphere sections, and part of the 20°N sections are *Atlantis* II (1963 and 1965) data, the equatorial section is from *Argo* (1962 and 1963) and a portion of the 20°N is from *Discovery* (1963) stations. Note that meridional coincidence between summer and winter sections is close along the 0°, 5°N, and eastern half of the 10°N section (the western portion lies near 9°N and merges into 10°N towards the east) and the western portion of 15°N. The remainder of the sections have departures as much as 180 km, particularly the eastern portion of the 15°N section.

a number of stations such as the Somali high, the pronounced meridional slopes north of Madagascar, or the winter high southwest of the Indian coast, may be expected to form seasonally.

The dynamic topography is referred to the 1000-dbar surface because numerous stations, especially during the winter season, are little deeper than this (average is about 1200 m). The circulation generally appears to be shallow (upper 200 m) and wind-driven, and there is reasonable agreement between the few direct measurements and geostrophic flow relative to this surface (Swallow and Bruce, 1966). Using the deeper stations the geopotential difference between the 1000- and 3000-dbar surfaces was calculated and the total range of variation was found to be 0·16 dy m, although the range of the 0/1000 dbar surface, as one might expect, was considerably greater, being about 5 times that of the 1000/3000 dbar surface. The topography of the Pacific has a similar range of variation (0·22 dy m) for the 1000/2000 dbar surface north of 50°S, but the range of the 0/1000 dbar surface was about 6 times greater (Reid, 1961).

Geopotential anomaly on zonal sections

The geopotential anomaly relative to 1000 dbar for the 0-, 100-, 200- and 400-dbar surfaces during summer and winter has been depicted in Fig. 2. The northern sections (I to IV) have two characteristics which seem to be common during the summer monsoon: (1) The zonal variations of geopotential anomaly, particularly on the upper pressure surfaces, tend to be larger along the western portion of the sections, some of the more marked variations being listed in Table 2. (2) There is a noticeable reduction in the amplitude of the zonal variations with increasing depth when the anomalies on the 0-dbar surface are contrasted with those on the 200- and 400-dbar surfaces. This reduction indicates that the baroclinic circulation responding to the monsoon winds tends to be relatively shallow, not extending much below 200 dbars. It should be noted that in some cases there were small variations on the 400-dbar surface such as the low of 0·54 dy m at Sta. 129 (Fig. 2, IV). There is in addition, reasonable agreement between direct current measurements and geostrophic

*Table 2. Zonal variations in surface geopotential anomaly during summer.**

Fig.	*Sect.*	*Approx. Lat.*	*Bracketing stations* (Atlantis II *except where noted*)	*Variation of geopotential anomaly*
2a	I	20°N	5063†–79	0·31‡
2b	II	15°N	57 –59	0·23
2c	III	10°N	89 –91	0·35
			93 –95	0·23§
2d	IV	5°N	129 –132	0·53
			124 –126	0·16

*Zonal winter variations are found, but to a lesser extent than in summer.

†*Discovery* station.

‡Difference may be function of time as there is interval of about a month between stations and rapid changes have been found to occur along the western region of this ocean during the southwest monsoon (Swallow and Bruce, 1966).

§Value probably low as minimum of anomaly between Stas. 92 and 93 is estimated as being $<$ 1·40 dy m (shown by dotted line, Fig. 2c) from bathythermograph data. Here a cold boundary of the type discussed by Stommel and Wooster (1965), Bruce (1965), and Warren *et al.* (1966) was found. The boundary probably extends north–south with minimum surface temperatures of 21·5°C (Stas. 92 and 93 are 24·3°C and 25·2°C respectively).

velocity relative to 1000 dbar off the Somali coast in summer (SWALLOW and BRUCE, 1966). With this exception off the Somali coast, there are no direct measurements known to the author of the 1000-dbar surface in the western Indian Ocean.

On Sect. V (equatorial), both summer and winter pressure surfaces, unlike the northern ones, had relatively small local variations of anomaly. During summer on the 0-dbar surface the anomalies tended to increase from 1·55–1·58 dy m in the west (45°–50°E) to 1·69–1·72 dy m in the east (75–78°E) with an overall slope (straight line fitted by eye) of approximately 4×10^{-8} (the slope down toward the west was given a positive sign, Fig. 2, V). At 100 dbar, however, it was $0 \cdot 8 \times 10^{-8}$ and was not measurable for the lower pressure surfaces. The surface slope is thus comparable in magnitude but opposite in sign to that in the Atlantic (-4×10^{-8}) (MONTGOMERY and PALMÉN, 1940) and to that in the Pacific (-5×10^{-8}) (AUSTIN, 1958). The mean wind stress of the easterly trades is believed to produce the upward slope to the west in these oceans (KNAUSS, 1963), but in the Indian Ocean the mean wind stress is westerly (HIKADA, 1958)) resulting in an upward slope to the east. Since the subsurface layers down to 100 dbar also exhibited a positive slope and resulted in a westward horizontal pressure force, an east flowing equatorial undercurrent (which would be associated with an eastward horizontal pressure force) probably was not present in the Indian Ocean during the summer (TAFT, 1965; 1967)*.

The surface slope of $0 \cdot 8 \times 10^{-8}$ during the winter was also positive but with considerably less magnitude than in summer. Between the surface and 100 dbar a reversal takes place, and at 100 dbar the slope is $- 1 \cdot 1 \times 10^{-8}$ producing an eastward component of pressure force. Similarly, there was an undercurrent at approximately 75–100 dbar in the winters of 1963 (TAFT, 1965) and 1964 (SWALLOW, 1964). The slopes at 200 and 400 dbar were very small as they were in summer.

Along both the southern sections (VI and VII) large variations in geopotential anomaly (order of 0·2 dy m) occurred during both seasons on the 0-dbar surface. As in the north, variations as well as large seasonal differences tended to be confined to the upper 200 dbar levels. On the 0-dbar surface (Sect. VII) the winter values were noticeably below those of summer, especially toward the east where there were differences of 0·1–0·2 dy m, but between the African coast and Madagascar these were about 0·2–0·3 dy m higher than for the eastern portion during both seasons.

Unfortunately there were few winter data (Fig. 2) for a seasonal comparison of the anomalies on the 1000-dbar surface relative to 3000 dbars on most sections.

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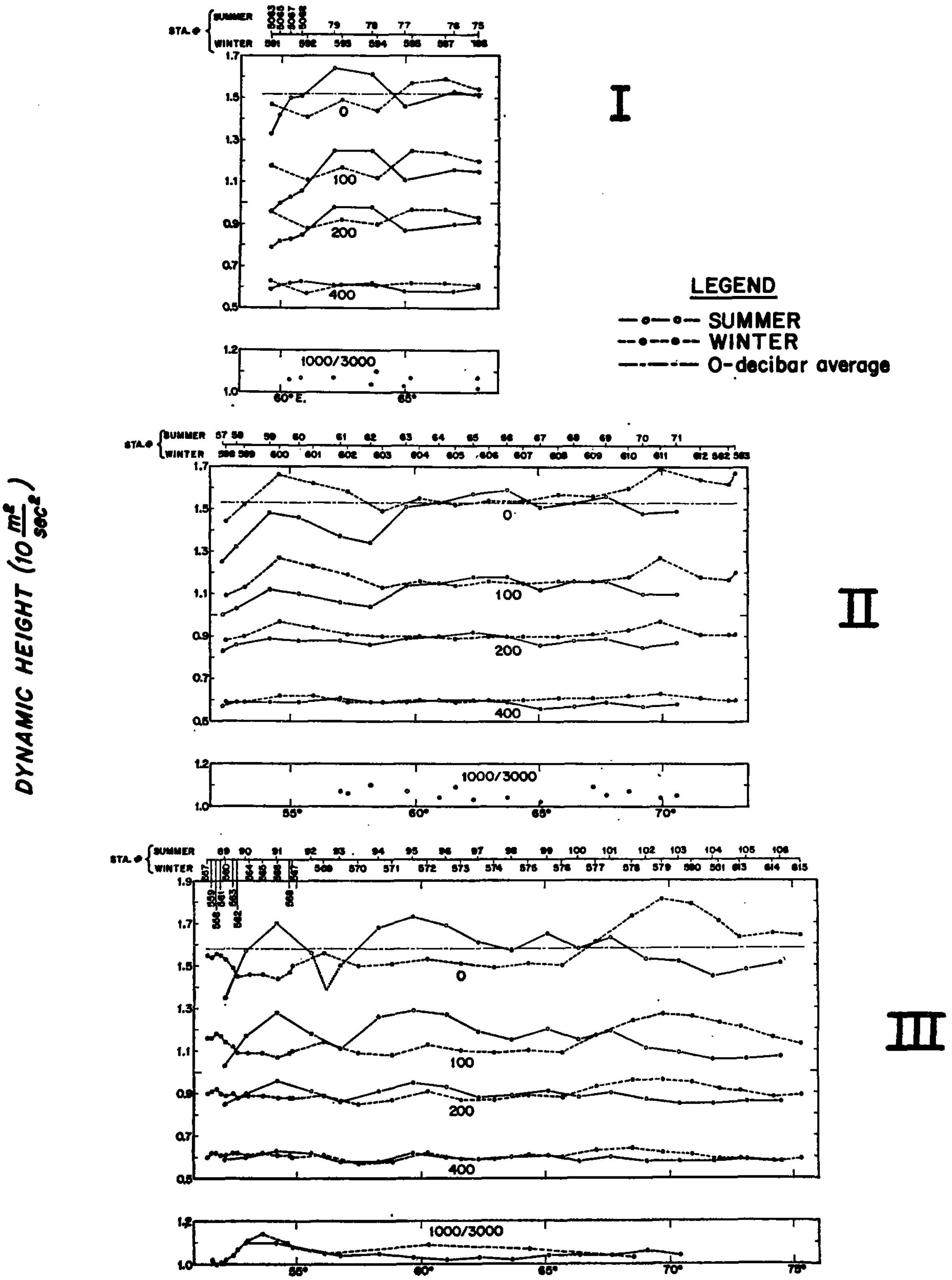
*Taft used *Argo* 1962 and 1963 data, selecting 400 dbar as the reference level for his hydrostatic computations with the assumption that the slope of the isobaric surfaces below 400 dbar relative to 1000 dbar is too small to be reliably estimated.

Fig. 2. (opposite) Geopotential anomaly on 0, 100, 200 and 400 dbar surfaces relative to 1000 dbar along zonal Sects. I-VII (Fig. 1) for northern summer and winter monsoons seasons. Sections I-V show both summer and winter anomalies together projected on the 20°N, 15°N, 10°N, 5°N parallels and the equator respectively. Sections VI and VII are near 5°S and 10°S respectively but some variations from the parallels (such as the stations near northern Madagascar) are large, thus it was decided to present the sections separately each along the station track. Long-short dashed line gives average of both seasons for 0 dbar. With each section are also shown values on 1000 dbar surface relative to 3000 dbar. Dotted lines in Sect. III, between Stas. 92 and 93, 0 dbar surface, gives best estimate across cold boundary using bathythermograph stations. Data are from *Atlantis* stations with exception of *Discovery* Stas. 5063, 5065, 5067 and 5068 in Sect. I and all *Argo* stations in Sect. V. During both *Atlantis II* surveys, the northern and equatorial sections were occupied about the middle of each monsoon, whereas the monsoons were nearly ended as the southern sections were completed. Thus Sect. I-V should be more representative of the seasonal topography and Sects. VI and VII of the interim between monsoons.


DYNAMIC HEIGHT (10 m²/sec²)
I
II
III
LEGEND
SUMMER
WINTER
O-decibar average
STA. #
SUMMER
WINTER
79
78
77
76
75
57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
598 599 600 601 602 603 604 605 606 607 608 609 610 611 612 582 583
89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106
569 570 571 572 573 574 575 576 577 578 579 580 581 613 614 615
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
0
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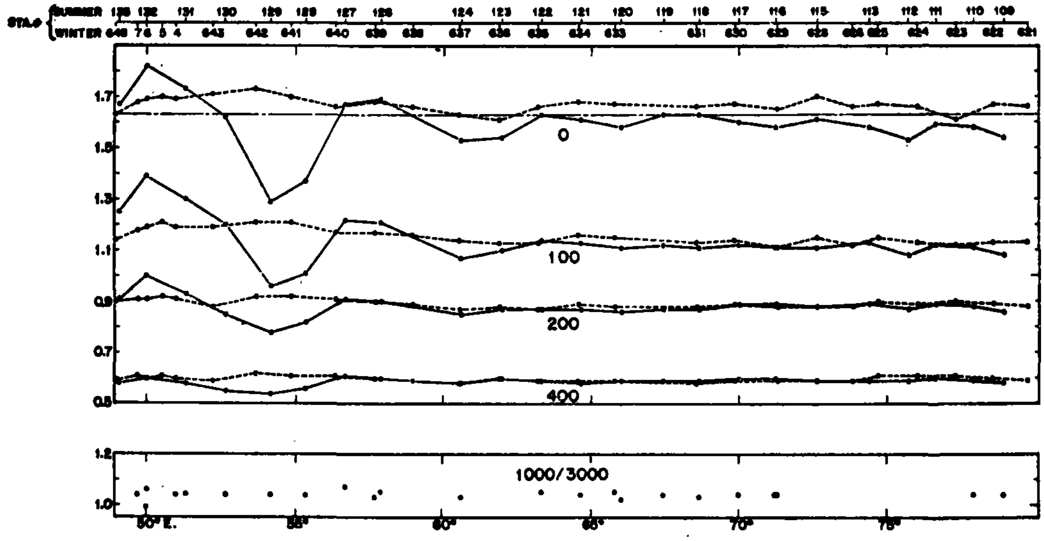
200
400
1.2
1.0
1000/3000
60° E.
65°
55°
60°
70°
75°


STA.#
SUMMER 133 132 131 130 129 128 127 126 124 123 122 121 120 119 118 117 116 115 113 112 111 110 109
WINTER 646 7 6 5 4 643 642 641 640 639 638 637 636 635 634 633 631 630 629 628 626 625 624 623 622 621
1.7
1.5
1.3
1.1
0.9
0.7
0.5
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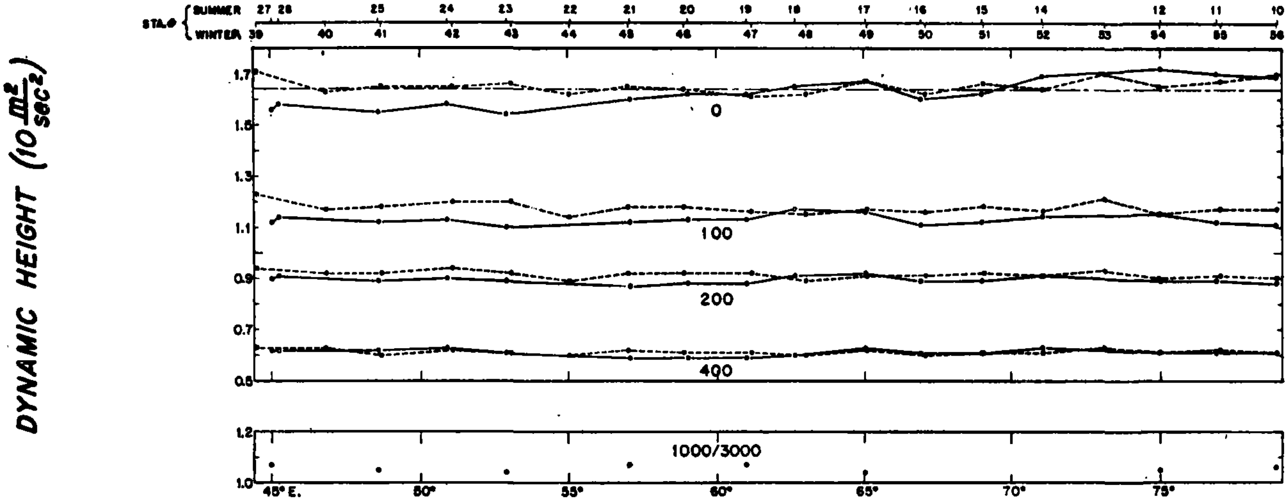
100
200
400
1.2
1.0
1000/3000
50° E.
55°
60°
65°
70°
75°

IV


DYNAMIC HEIGHT (10 m²/sec²)
STA.#
SUMMER 27 26 25 24 23 22 21 20 19 18 17 16 15 14 12 11 10
WINTER 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56
1.7
1.5
1.3
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0.9
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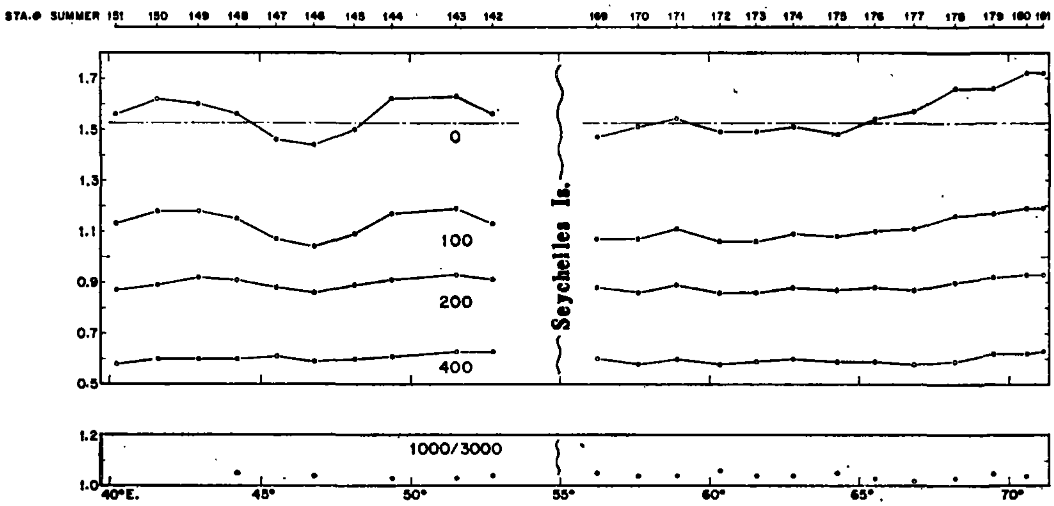
V


STA.# SUMMER 151 150 149 148 147 146 145 144 143 142 169 170 171 172 173 174 175 176 177 178 179 180 181
1.7
1.5
1.3
1.1
0.9
0.7
0.5
0
100
200
400
Seychelles Is.
1.2
1.0
1000/3000
40° E.
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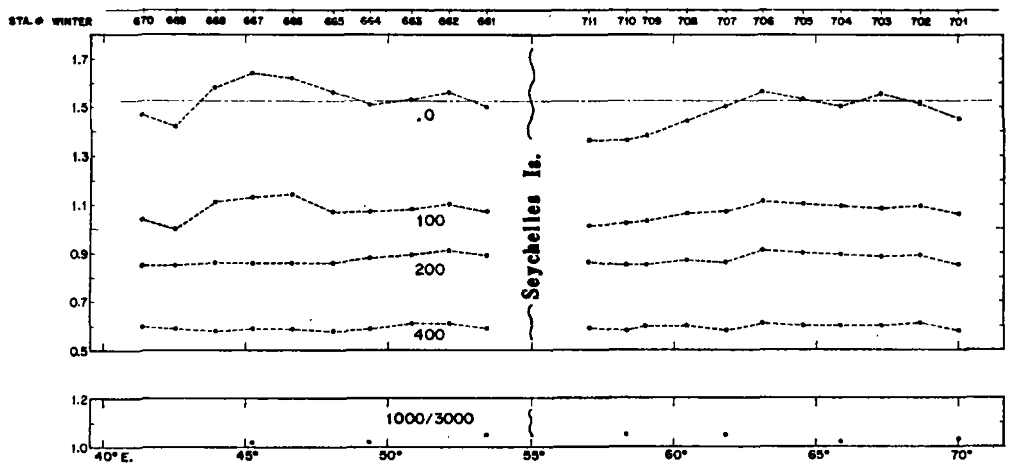
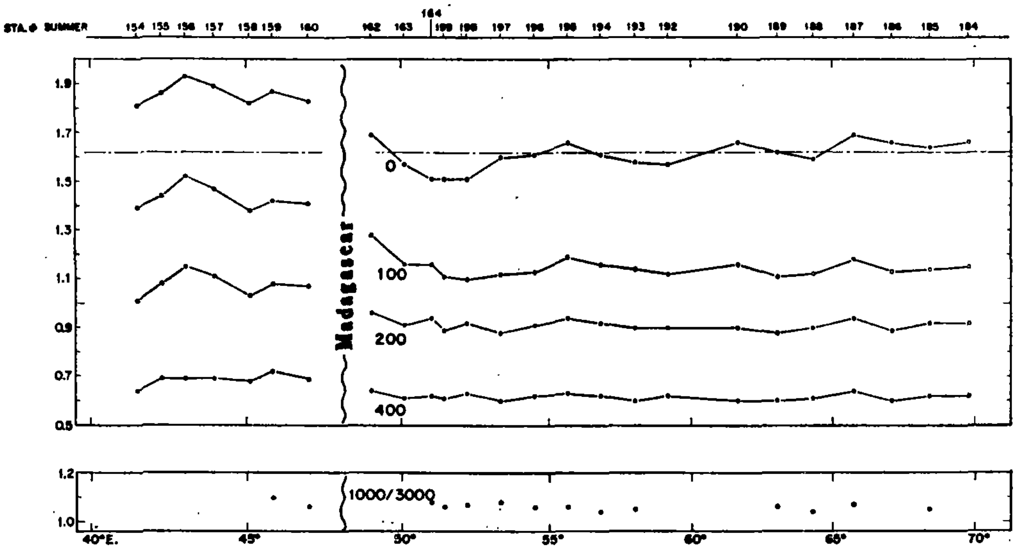
50°
55°
60°
65°
70°

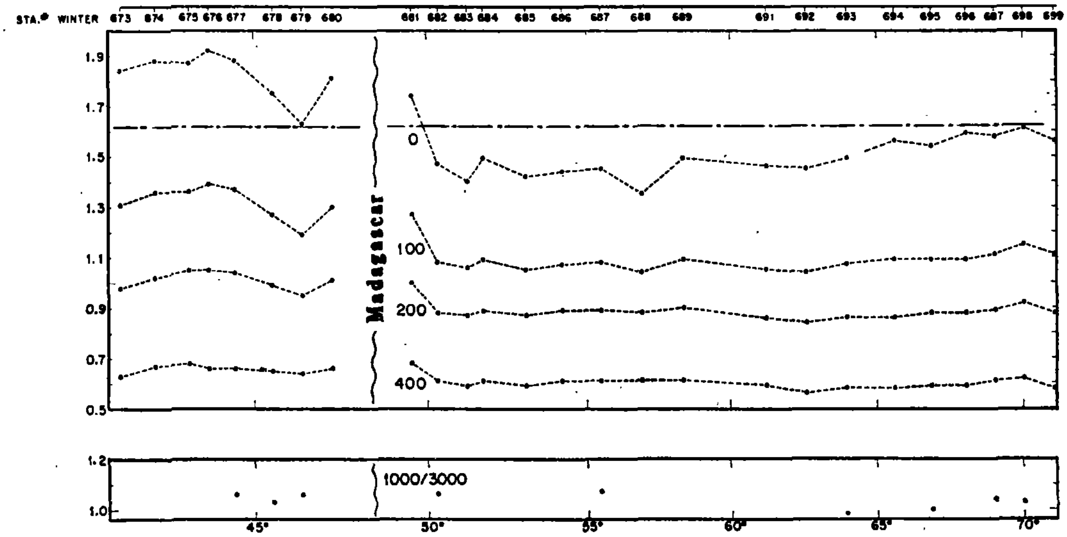
VI a



VI b



VII a



VII b

In general, there were differences of 0·03 to 0·05 dy m, except on the western edge of Sect. III in winter, where on the 1000-dbar surface between Stas. 558 and 565 there was a geostrophic flow to the north and between Stas. 565–569 to the south. West of Sta. 558 just off the coast there was also a weak southerly flow. There appears to be agreement with the geostrophic currents, adjusted to a level of no motion estimated from direct measurements using neutrally buoyant floats between 55°E and the Somali coast (Bruce and Volkmann, in preparation). Thus, west of Sta. 565 there were currents of 10–30 cm/sec toward the north (except for the weak southerly current just off the coast) at 1000 dbar and to the east there was a southerly flow of comparable magnitude.

Topography of the 0-*dbar surface*

The most obvious seasonal differences in the surface topography (Figs. 3 and 4) were along the northeastern Somali and Arabian coasts. In summer the Somali

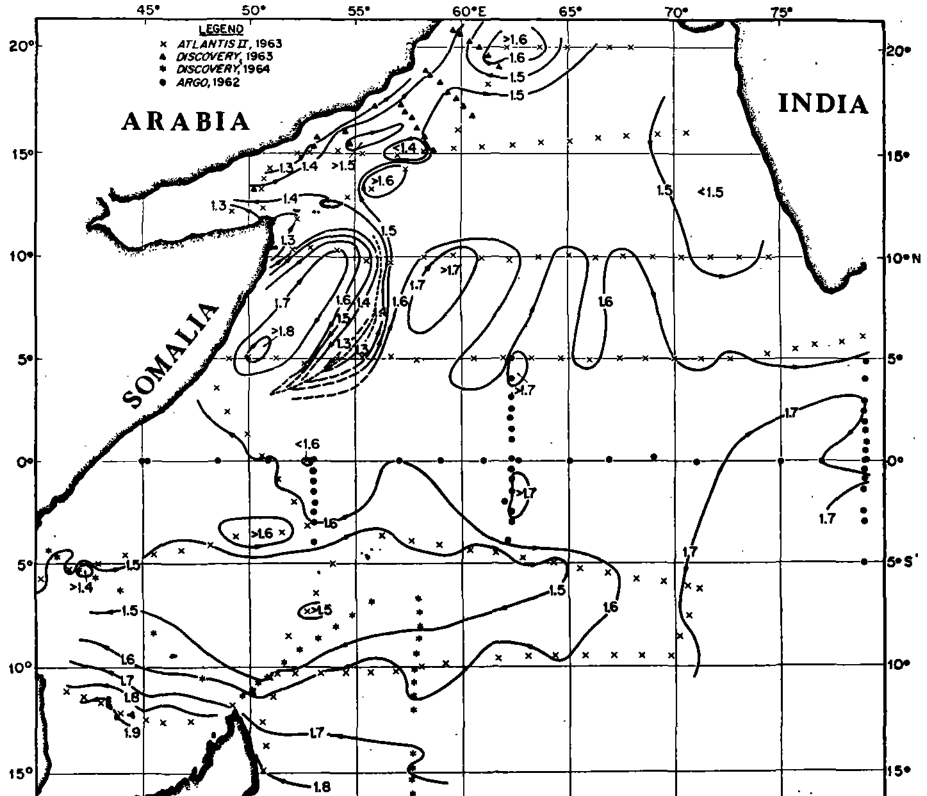


Fig. 3. Geopotential topography of the sea surface relative to 1000 decibars in the western Indian Ocean during northern summer (southwest monsoon). Units are in dynamic meters; contour intervals are 0·1 dy m. Short dashed line along eastern edge of Somali anti-cyclonic circulation is estimated position of cold boundary from bathythermograph stations. Long-dashed lines in same area are estimation of convergence of contours with cold boundary. The data used are from the cruises in Table 1 with the exception of those stations from *Argo*, *Discovery* and *Meteor* lying between the coast and 58°E and 0°–15°N, the topographies of which are shown separately in Fig. 7 and 8 because of extremely poor fitting with the *Atlantis II* 1963 and 1965 data in the Somali coast region.

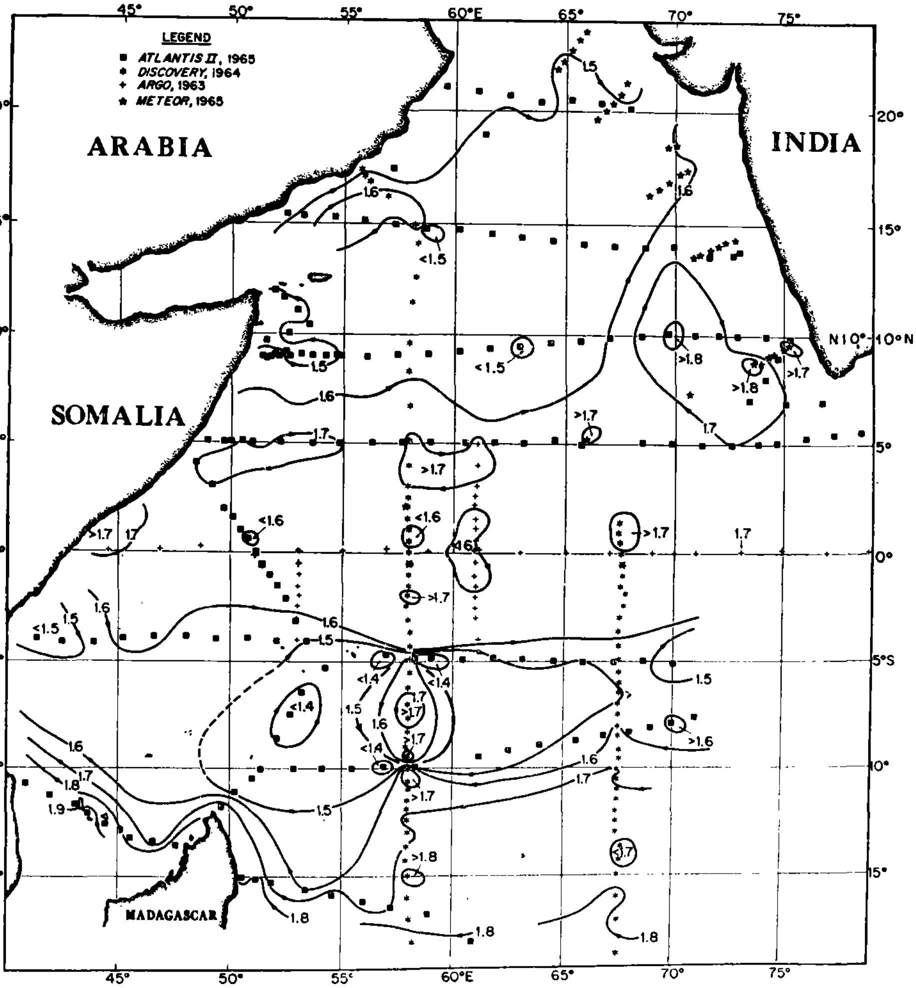


Fig. 4. Geopotential topography of the sea surface relative to 1000 dbar in the western Indian Ocean during northern winter (northeast monsoon). Units are in dynamic meters; contour intervals are 0·1 dy m.

coastal high and its bordering low trough were the dominant features between 3°N–12°N with a range of over 0·5 dy m from its northern edge to the centre. The circulation indicates a localized gyre (cf. Findlay 1866; Swallow and Bruce, 1966), rather than a trans-ocean current (Defant 1961, his Pl. 8a) continuing east toward the Indian coast. Current variations are known off the Somali coast in summer, i.e. during the peak of the monsoon a noticeable change in the current structure may occur within a two week period (Swallow and Bruce 1966). Because the sections in the Somali region were about 550 km apart and because three weeks elapsed between the 5°N and 10°N sections, it is uncertain how realistic the isopleths (Fig. 3) between Socotra and the northern part of the anticyclonic circulation may be, or the flow just south of 5°N. Estimates, however, of the ship's set (p. 671) tend to agree with this pattern. Leaving the coast the isopleths run nearly downwind then turn clockwise and proceed upwind to the southwest. Along the cold boundary (dashed line), a position estimated from bathythermograph observations spaced about 10–12 miles apart, the convergence of isopleths presumably is similar to that in the more detailed 1964 survey (SWALLOW and BRUCE, 1966)·

In winter off the Somali coast a small high (> 1·7 dy m) occurred near 5°N (Fig. 4) but the circulation was weaker than during the summer. Off the Arabian coast in summer (Fig. 3), there were three small highs, considerably weaker than the Somali high, the largest near 20°N (>1·6 dy m) (Fig 3), with a northeast flow along the coast, again considerably weaker than the Somali current. A weaker northeastward coastal flow in winter (Fig. 4) over a short section of the coast was part of the circulation of the high between 14°–17°N (> 1·6 dy m).

In general the surface topography of the central portion (north of 10°N) of the ocean fell between 1·5–1·6 dy m during both seasons. Between 5°–10°N there was considerable meridional variation of the 1·6 dy m isopleth in summer with weak highs to the east of the large Somali high. In this area data from ship's drift estimates are also indicative of weak currents and considerable variability in current direction (MICHAELIS, 1923). A low (< 1·5 dy m) (Fig. 3) existed west of the Indian coast during the summer. To its south the sea surface sloped upward to about 2°–3°N, indicating an eastward flow (Southwest Monsoon Current). The low did not exist in winter, but there was a high (to > 1·8 dy m) slightly farther south extending down to the latitudes (5°N) of the North Equatorial Current, only existing during winter in the Indian Ocean.

The South Equatorial Current indicated during both seasons by the closely spaced isopleths between 7°S–13°S in the central and western part of the ocean (Figs. 3 and 4) was particularly strong just north of Madagascar (150 cm/sec) and toward the African coast (50–100 cm/sec). During the southwest monsoon the current is believed to reach its greatest velocity (SVERDRUP *et al.*, 1942) being reinforced by water from the Pacific.

Somali coastal region: summer

Current estimates were determined from ship's set and direct measurements. The surface currents off the Somali coast during the summer of 1963 were estimated by the set of *Atlantis II* while underway between hydrographic stations. The set has been corrected for the effect of the wind and roughly represents the mean surface current within ± 15 cm/sec at that time between stations (Fig. 5). At two stations, a current meter was suspended from the ship while lying-to and referred to an anchored buoy (cf. SWALLOW and BRUCE, 1966). Large sets were also experienced on station within the high but are more difficult to estimate as the ship was often steaming on the wire at varying rates. At Sta. 89, for example, an entry on the hydrographic log sheet mentions that the ship was steaming about 7 knots, heading 225°T, while on station to maintain a minimum wire angle, yet during that station, *Atlantis II* (with allowances for wind) was set back at a rate of 3·0 knots towards 075°T. The set (Fig. 5; dashed arrow) is thus a very conservative estimate of the surface current.

Temperature–salinity distribution. There are too few stations to determine more than the general physical characteristics of the summer gyre off the Somali coast, although the topography and direct current observations give evidence for such a circulation. The near surface temperature–salinity distributions (Fig. 6) of the *Atlantis II* stations there during summer located within the gyre (west of the cold

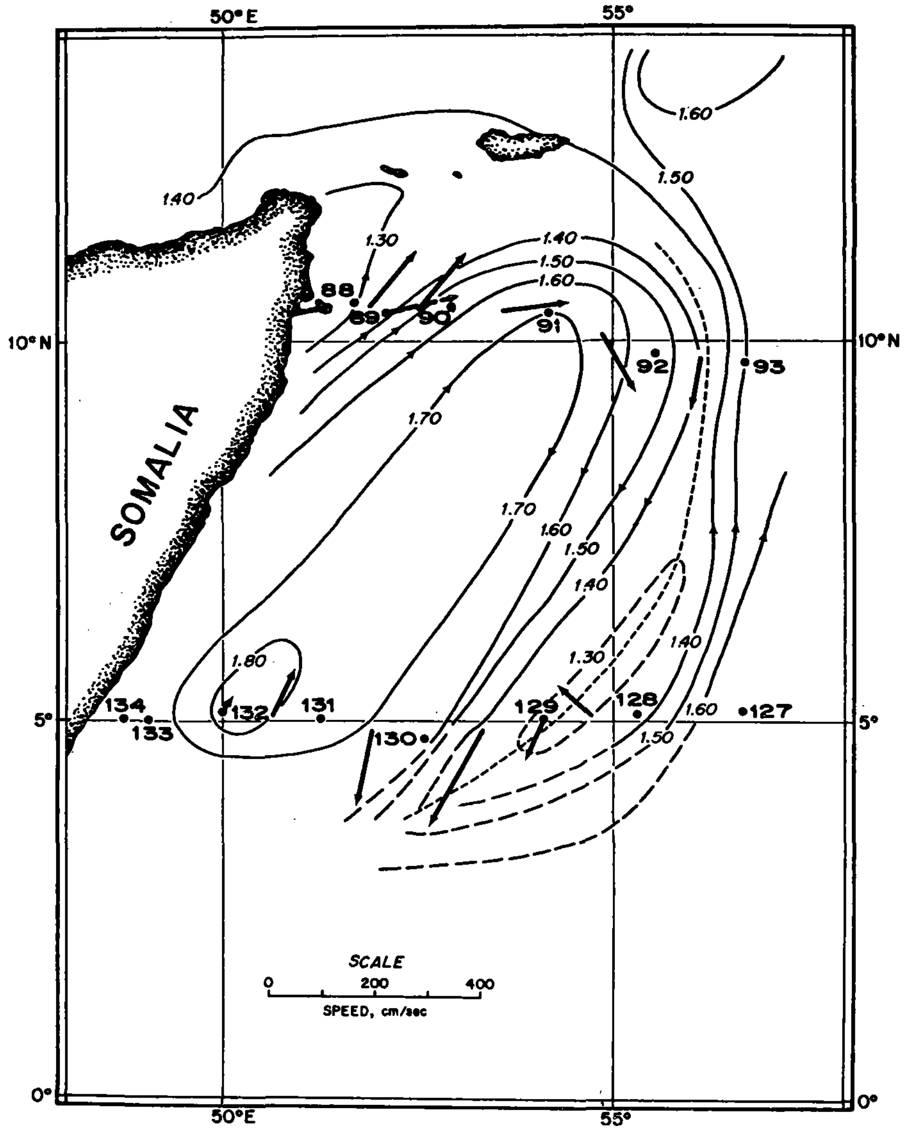


Fig. 5. Surface current vectors obtained from set of *Atlantis II* and direct measurements superimposed on detail of summer surface topography (Fig. 3). Solid arrows between stations show current determined from ship's set. Those at Stas. 129 and 132 are direct measurements referred to an anchored buoy. The dashed arrow estimates current while on Sta. 89

boundary) are generally fresher (35·1–35·4‰, above 15°C) and colder than those to the east of the boundary (>35·4‰, above 15°C). Two stations, 128 and 129 (see positions in Fig. 5), do not agree with the others: Sta. 128 east of the cold boundary has surface and subsurface salinities of <35·4‰ (open dots in Fig. 6) but Sta. 129, west of this boundary, with a high salinity only in the upper 30 m (solid dots in Fig. 6, 25–26°C, 35·60–35·75‰). These two stations are adjacent to the boundary, where mixing may account for such observations. Below 16–18°C (Fig. 6), about in the maxi-

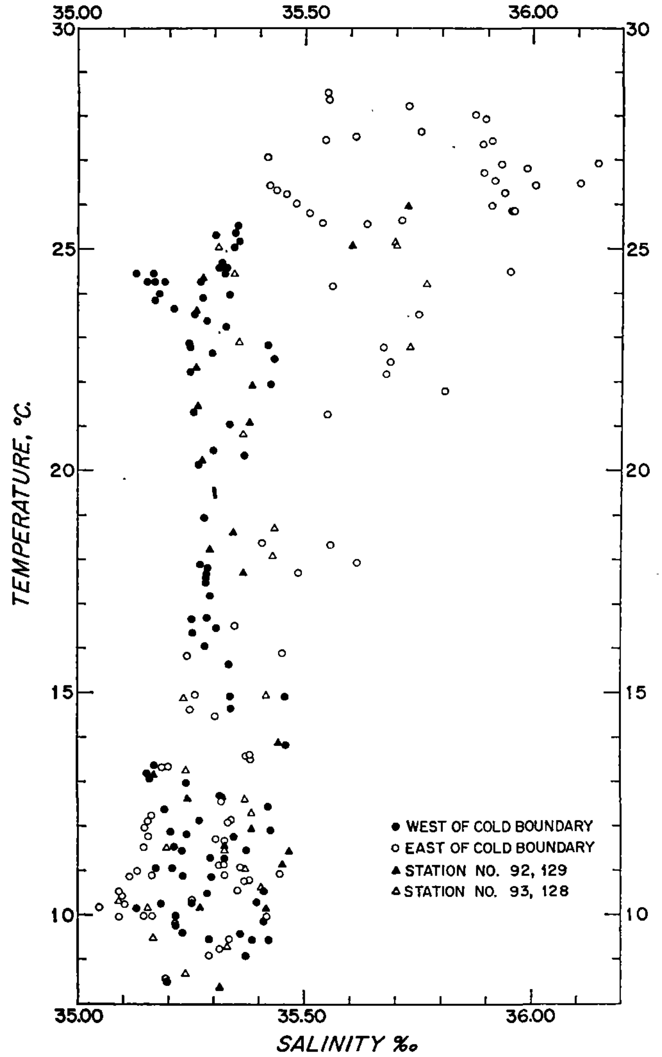


Fig. 6. Temperature–salinity distribution off Somali coast in summer from *Atlantis II*, Cruise 8 stations. Solid symbols are samples within anticyclonic circulation and open symbols lie to east of cold boundary.

mum gradient of the thermocline, between 175–225 m, water in the area of the high cannot be distinguished from that east of the boundary.

The Somali Current is sharply limited in depth (SWALLOW and BRUCE, 1966), the strong currents being generally above 200 m. The *T–S* distribution (Fig. 6) suggests that water above the thermocline in the rapidly moving current of the Somali high may be largely confined within the cold boundary. Thus, the *T–S* characteristics were essentially similar on both the 5°N and 10°N sections for the northeastward moving water just off the coast and for what appears to be the reversed current which has turned southwest and flows to the west of the cold boundary.

For the short period of the monsoon (3 months) the salinity of the near-surface

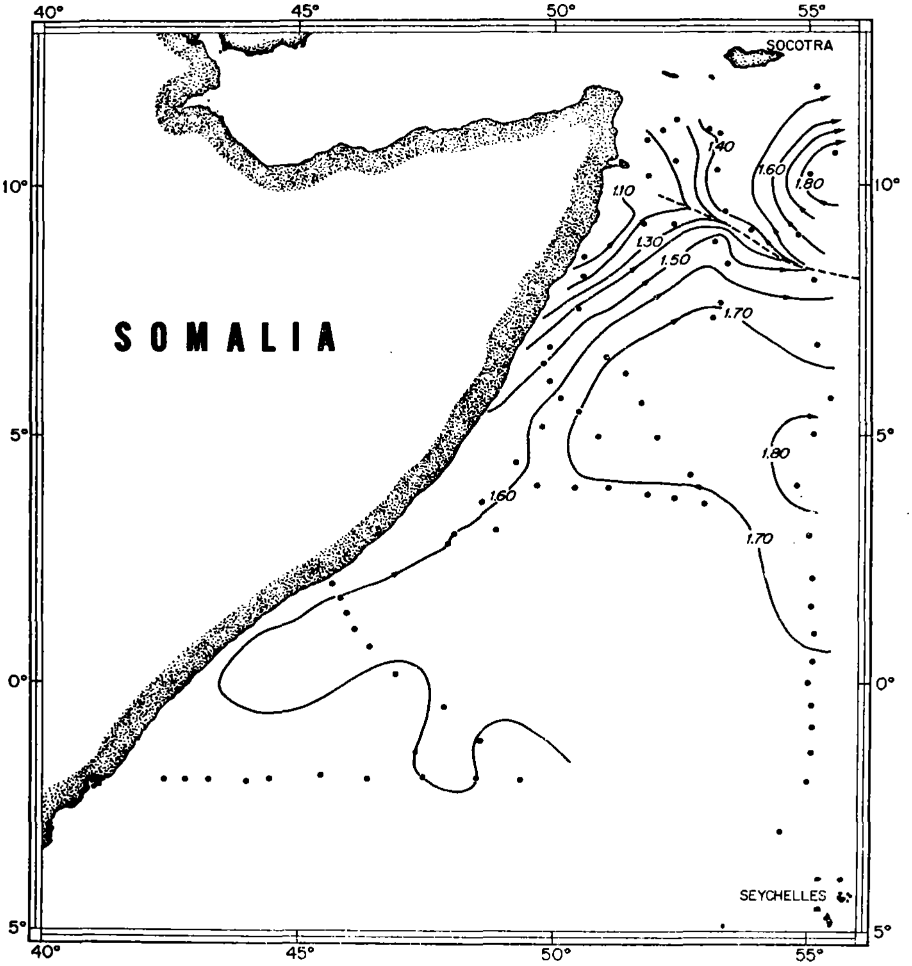


Fig. 7. Surface topography relative to 1000 dbar off Somali coast, summer 1964 (from Swallow and Bruce, 1966).

water perhaps may be considered as conservative relative to the differences of 0·3–0·4‰ found across the cold boundary. For such a difference to be caused by evaporation the area east of the boundary would have to have a much higher evaporation rate than the water in the Somali high which seems unlikely (Privett, 1959). If, however, the evaporative difference were as great as 120 cm/yr, and thorough mixing took place to 100 m in depth, then a salinity change of about 0·1‰ could take place over an entire monsoon period.

Year to year differences. Off the Somali coast, in summer, the surface topography during 1964 (not included in Fig. 3, but shown in Fig. 7) differed from that in 1963. Thus, the Somali Current turned east (1964) at about 8–9°N. The centre of the high ($>$ 1·8 dy m) was at about 5°N, 55°E (Fig. 7). Since there are no data east of about 55°E, the cold boundary could not be traced beyond this longitude. Hence it is not certain that the boundary did run south nor that a gyre was formed in 1964. In contrast during 1963 (Fig. 3) the coastal current flowed north of 10°N before

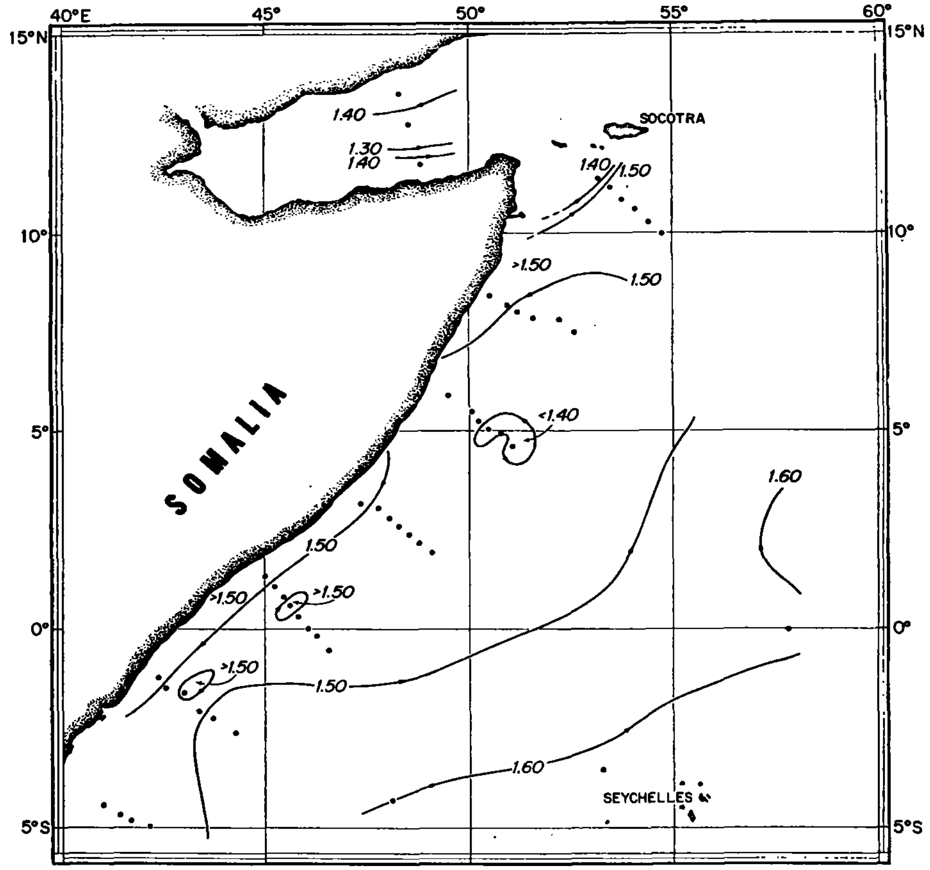


Fig. 8. Surface topography relative to 1000 dbar off Somali coast, December 1964–January 1965, from *Meteor*, Cruise 1.

turning east, and the trough of the cold boundary ($<$ 1·3 dy m) occurred near 5°N, 55°E where a high of 1·8 dy m existed in 1964. Southeast of Socotra near 10°N in 1964 there was a small, intense, and saline (to 35·6‰) high. This high was not revealed by the 1963 data. Possibly it was displaced by the Somali Current at 10°N. There are, however, general features of the Somali high during both 1963 and 1964 which are similar: in each the maximum elevation was approximately 1·8 dy m, and the meridional length was roughly 500 miles.

Somali coastal region: winter

Within the winter season changes in surface topography took place along the Somali coast (cf. Fig. 8 with Fig. 4). In general the *Meteor* anomaly values were between 1·4–1·5 dy m along the coast with a weak southwesterly coastal current between 2°S–5°N and 7°N–8°N. To the southwest of Socotra (11–12°N) a northeasterly flow was indicated. The *Atlantis II* data recorded generally higher anomalies: 1·5–1·6 dy m with a dynamic height of $>$ 1·7 dy m at 5°N and just off the coast at the equator. There was no indication of a southwesterly coastal current, but there was a weak northeast current off the coast at 5°N. Neither survey gave any evidence

Table 3. *Averages of geopotential anomaly* (0-*dbar surface relative to* 1000 *dbar*) (*in* dy m) *from data used in this paper of the Indian, Atlantic, and Pacific oceans by zonal bands from the African coast east to approximately* 78°E. *The zonal areas were taken into account in determining the averages.*

	Western Indian Ocean northern summer (southwest monsoon)	*Western Indian Ocean northern winter (northeast monsoon)*	*Northwestern Indian Ocean mean*	*Atlantic* (*from* REID, 1961)	*Pacific* (*from* REID, 1961)
10°–20°N	1·53	1·57	1·55	1·32	1·68
0°–10°N	1·60	1·64	1·62	1·27	1·68
0°–10°S	1·61	1·58	1·60	1·25	1·68

of the strong coastal currents at the surface characteristic of summer, but rather both indicated a weak, meandering surface circulation.

Zonal means on the 0-*dbar surface*

North of the equator the average of the geopotential anomaly of the zones (0°–10°N and 10°N–20°N) during the northern summer is slightly lower (0·04 dy m) than for the winter (Table 3). Because of the summer warming at the surface the reverse might be expected. In the northwest Indian Ocean, however, during the summer monsoon, there are three factors which tend to decrease the dynamic height relative to that in winter: (1) there is greater cloud cover (U.S. NAVY, 1957) and hence a reduction in the net absorbed radiation, particularly on the eastern side of the ocean (COLON, 1964); (2) the evaporation rate (PRIVETT, 1959) in the northwestern Indian Ocean reaches a maximum during June and July and tends to increase surface salinity; and (3) upwelling of cold water along the western coasts.

The Indian Ocean mean (Table 3) for both seasons in these latitudes is 0·23–0·35 dy m higher than the Atlanitc and 0·06–0·13 dy m lower than the Pacific (REID, 1961).

CONCLUSIONS

(1) The summer geopotential topography particularly off the Somali and Arabian coasts indicates that relatively small but intense anticyclonic gyres were formed during this period. Further evidence from ship's set, direct measurements, comparison with the 1964 topography, and *T–S* differences tend to substantiate the existence of the Somali gyre. A cold boundary was found to the north and east of the gyre although further evidence is needed to show continuity from 10°N to 5°N.

(2) The variations during a season as well as between seasons were considerably greater in the upper 200 m than at the 400 dbar level.

(3) In contrasting the summer and winter geopotential topography on the western side of the ocean, rather large changes occurred in the topography between seasons, particularly off the Somali coast at about 10°N where there were seasonal differences of 0·3 dy m. Changes were evident within the winter period as revealed by differences between the *Meteor* data from December and January and the *Atlantis II* data in March for the same winter.

(4) No pronounced southwestward current was observed along the Somali coast during winter.

(5) Toward the end of both seasons a well-defined South Equatorial Current was indicated which was especially strong just north of Madagascar.

(6) The mean dynamic height of the sea surface of the northwestern Indian Ocean was lower in summer than in winter by 0·04 dy m.

Acknowledgement—This research was sponsored by the National Science Foundation under Grant GP–870

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Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 163-176

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НЕКОТОРЫЕ ОСОБЕННОСТИ ТРОПОСФЕРНОЙ ЦИРКУЛЯЦИИ В ПРИЭКВАТОРИАЛЬНОЙ ЧАСТИ ИНДИЙСКОГО ОКЕАНА

С октября 1964 по март 1965 г. проходил 36-й специализированный геологический рейс и/с «Витязь» в Индийском океане. Попутно в рейсе выполнялись метеорологические наблюдения: приземные (через каждые три часа, а в интересных ситуациях через час), радиозондирование (два раза в сутки) и по возможности шаропилотные наблюдения с помощью ручного теодолита [1].

В настоящей статье мы рассмотрим результаты метеорологических наблюдений во время пересечения приэкваториальной зоны западных ветров в Индийском океане в ноябре 1964 г.

Распределение приземного ветра показано на рис. 1. Приэкваториальные западные ветры, как видим, отмечались в зоне между 8° с. ш. и 2° ю. ш.; к северу от этой зоны ветры были северо-восточными, к югу — сначала переменных направлений, а с 5,5° ю. ш.— юго-восточными. Такая картина близка к средней многолетней в ноябре [2]. Судя по синоптическим картам, составлявшимся в рейсе два раза в сутки, распределение приземного давления во время пересечения «Витязем» зоны западных ветров в большинстве случаев также было сходным со средним многолетним. Обычно вдоль экватора намечалась область повышенного давления, а к северу и к югу от нее — вытянутые с востока на запад ложбины (рис. 2). Все это дает основание предполагать, что и наблюдавшаяся в это время года картина в какой-то мере отражала средние ноябрьские условия.

ПРЕДШЕСТВУЮЩАЯ СИНОПТИЧЕСКАЯ ОБСТАНОВКА

Перед тем как описывать погоду, наблюдавшуюся при пересечении зоны западных ветров, несколько слов стоит сказать об интересной, на наш взгляд, схеме перестройки барического поля от летнего муссона к зимнему и об условиях погоды, наблюдавшихся в Бенгальском заливе в конце октября 1964 г.

20 октября, когда «Витязь» начал работы в Бенгальском заливе, над центральной частью залива наблюдалась область повышенного давления, а к северу и к востоку от нее полукольцом располагалась область низкого давления с двумя отдельными депрессиями: на востоке Индии (район Калькутты) и над Таиландом. Координаты центров давления, глубина и число депрессий в последующие дни несколько менялись, но вся эта область на севере Бенгальского залива продолжала существовать, занимая положение,

соответствующее в среднем положению ложбины на сентябрьской карте среднего многолетнего атмосферного давления [3]. На юге залива в это время (по нашим синоптическим картам, с 21 октября) намечалась еще одна область низкого давления, вытянутая в зональном направлении вдоль 7—11° с. ш., там, где располагается ложбина на ноябрьской карте среднего давления. Обе ложбины на севере и на юге Бенгальского залива существовали одновременно; перестройка барического поля давления от сентябрьского к ноябрьскому происходила не путем перемещения северной ложбины к югу, а в результате постепенного заполнения северной и углубления южной ложбины. К 29 октября северная ложбина окончательно заполнилась и над всем Бенгальским заливом и к северу от 10° с. ш., взамен наблюдавшихся ранее ветров переменных направлений, установился северо-восточный муссон.

С 30 октября до 3 ноября «Витязь» вел работы на станции ($\varphi = 11°08'$ с. ш., $\lambda = 85°37'$ в. д.), располагавшейся близ оси барической ложбины (чуть к северу от нее, так как ветры все время были северо-восточными), так что погода была обусловлена процессами, происходящими в этой ложбине. На оси ложбины северо-восточный муссон встречался (конвергенция) с приэкваториальными западными ветрами, что вело к образованию восходящих токов, развитию облачности и выпадению осадков. О ширине зоны, в которой происходила конвергенция ветра, в какой-то степени можно судить по ширине полосы с осадками, которая на наших синоптических картах на разных участках ложбины составляла 3—5° широты.

Вдоль оси ложбины в Бенгальском заливе (внутритропическая зона конвергенции) время от времени с востока на запад проходили отдельные депрессии, вызывающие на своем пути ухудшение погоды. Одна из них

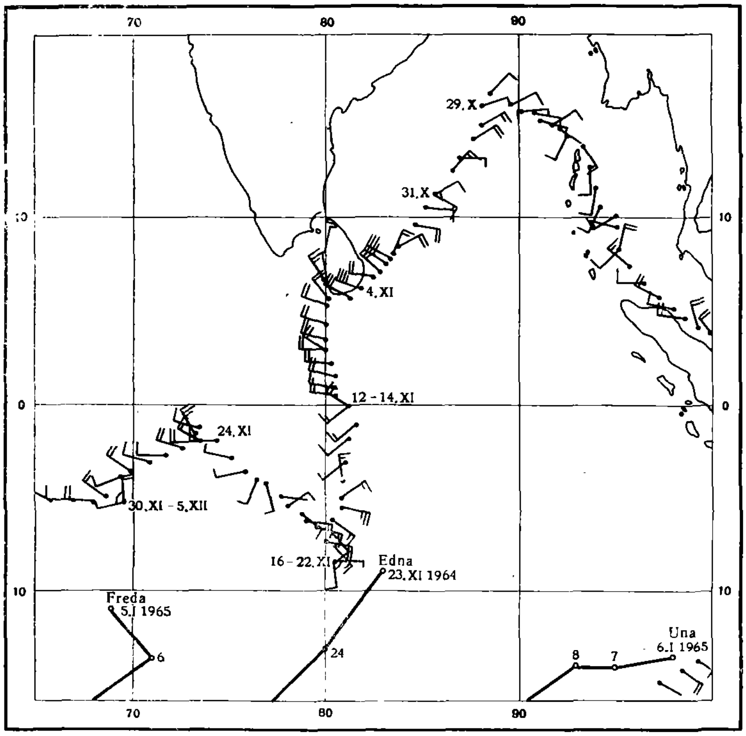

Рис. 1. Распределение приземного ветра по маршруту и/с «Витязь» в 1964/65 г.

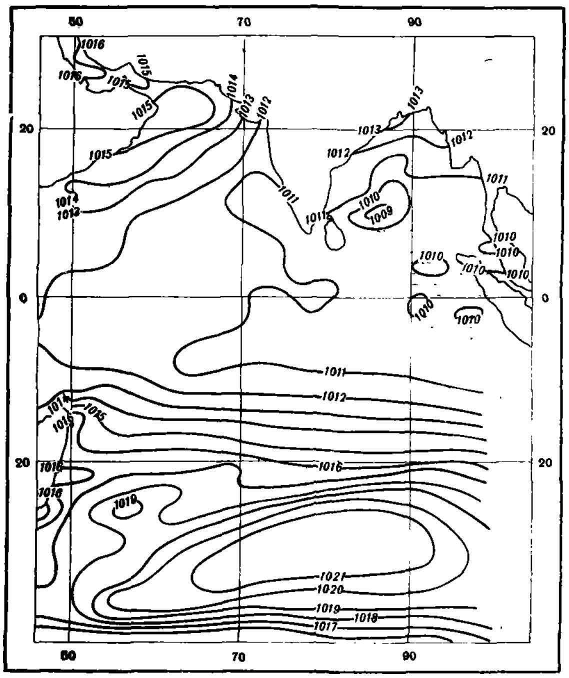

Рис. 2. Среднее многолетнее атмосферное давление в ноябре (по данным [15])

вечером 29 октября располагалась в Андаманском море. На следующий день она подошла к району работ «Витязя», расширилась и вызвала здесь сильнейший ливень (за 12 *час* выпало 56,6 *мм* осадков), правда, без заметного усиления ветра. После прохождения депрессий погода несколько улучшилась, однако вследствие близости корабля к оси зоны конвергенции ненамного и ненадолго.

ПОГОДА В ЗОНЕ ЗАПАДНЫХ ВЕТРОВ И НА ЕЕ ГРАНИЦАХ

3 ноября «Витязь» закончил работы на станции с координатами $\varphi = 11°08'$ с. ш., $\lambda = 85°37'$ в. д. и пошел на юго-запад в Коломбо. С утра была хорошая погода с небольшой облачностью и слабым (2—4 *м/сек*) восточным ветром. К вечеру атмосферное давление стало падать, ветер начал усиливаться, увеличилась облачность и пошел дождь. Судя по этим признакам, мы приближались к оси зоны конвергенции и для лучшего ознакомления с ее структурой с 20.00 3 ноября были начаты ежечасные метеорологические наблюдения (рис. 3). Данные о скорости и направлении ветра при пересечении границ зоны западных ветров помещены в табл. 1 и 2.

Ось внутритропической зоны конвергенции, как следует из табл. 1, мы пересекли в ночь с 3 на 4 ноября примерно на 8° с. ш. Здесь на отрезке всего лишь 7 миль направление ветра с северо-восточного резко сменилось на западное, скорость ветра увеличилась более чем в два раза и достигла 15,3 *м/сек*. Отметим, что резкий разрыв потоков на северной границе зоны западных ветров в районе Бенгальского залива наблюдался и рядом предыдущих экспедиций, проведенных в период зимнего муссона [4], и, по-видимому, является характерной чертой атмосферной циркуляции в этом районе океана.

Таблица 1

Ветер и атмосферное давление при пересечении северной зоны конвергенции

Дата	Время судовое, *час*	Широта сев.	Долгота вост.	Давление фактическое, *мб*	Давление приведенное, *мб*	Направление ветра, °	Скорость ветра, *м/сек*
3.XI	09	11°00′	85°32′	1008,6	1007,3	132	2,9
	12	10 30	85 12	1007,3	1006,5	95	4,4
	15	10 00	84 52	1004,2	1005,5	116	5,4
	18	9 37	84 35	1003,8	1004,6	97	6,9
	20	9 07	84 11	1005,1	1004,3	115	5,4
	21	9 04	84 09	1005,8	1004,5	66	6,8
	22	8 47	83 55	1005,8	1004,3	70	7,3
	23	8 36	83 50	1005,1	1003,6	62	7,4
4.XI	00	8 26	83 44	1004,3	1003,5	60	7,1
	01	8 15	83 36	1003,9	1003,9	45	6,5
	02	8 05	83 27	1003,7	1004,5	18	6,9
	03	7 58	83 23	1003,4	1004,7	288	15,3
	04	7 46	83 15	1004,1	1005,6	300	14,9
	05	7 35	83 05	1004,5	1006,0	303	12,7
	06	7 29	83 03	1005,1	1005,9	303	14,2
	07	7 17	82 55	1006,3	1006,3	310	11,0
	08	7 08	82 48	1006,9	1006,1	312	14,2
	09	7 00	82 40	1007,9	1006,6	309	13,0
	10	6 53	82 32	1007,9	1006,4	275	10,4
	11	6 46	82 25	1009,3	1008,0	278	8,8
	12	6 36	82 15	1008,5	1007,7	292	4,8
	15	6 20	81 53	1006,1	1007,4	262	14,6
	18	6 10	81 40	1007,1	1007,9	288	14,8
	21	5 48	81 14	1010,3	1009,0	297	11,7
5.XI	00	5 40	80 08	1010,3	1009,5	320	10,7

Таблица 2

Атмосферное давление, ветер, средняя для слоя 0—5 *км* влажность и температура воздуха при пересечении южной зоны конвергенции по меридиану 81° в. д.

Дата	Время судовое, *час, мин*	Широта южная	Давление фактическое, *мб*	Давление приведенное, *мб*	Направление ветра, °	Скорость ветра, *м/сек*	Средняя влажность слоя 0—5 *км*, %	Средняя температура слоя 0—5 *км*, ° С
14.IX	17,30	0°15′	1009,9	1011,0	235	5,9	56,2	11,73
	20.30	0 35	1011,8	1010,7	240	6,0		
	23.30	0 31	1011,7	1010,6	240	5,5		
15.XI	2.30	1 07	1010,6	1011,7	229	5,4		
	5.30	1 40	1011,0	1012,1	203	2,3	66,4	11,85
	8.30	1 56	1012,6	1011,5	232	3,6		
	11.30	2 36	1011,7	1010,6	167	1,7		
	14.30	3 07	1009,9	1011,0	230	2,5		
	17,30	3 41	1009,9	1011,0	8	2,1	83,6	11,03
	20.30	4 02	1012,2	1011,1	350	5,8		
	23.30	4 23	1021,8	1010,7	311	5,8		
16.XI	2,00	5 00	1010,1	1010,9	55	6,7		
	5.00	5 36	1010,7	1012,0	102	10,4	81,8	11,55
	8.00	6 20	1012,5	1011,7	124	6,0		
	11.00	6 52	1011,8	1010,5	138	4,3		
	14.00	7 35	1009,9	1010,7	150	6,1		

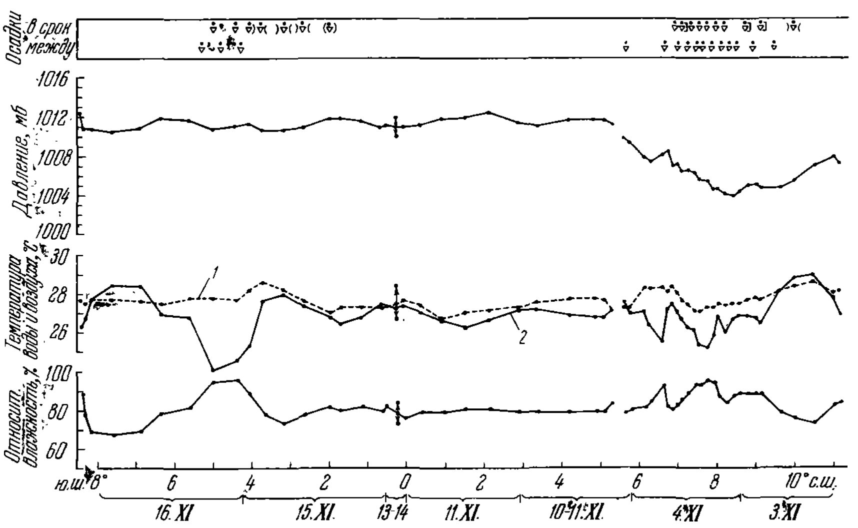

Рис. 3. Ход приземных метеоэлементов по маршруту и/с «Витязь» с 3.XI по 16.XI 1964 г.
1 — температура воды; 2 — температура воздуха

По мере удаления судна к югу от оси зоны конвергенции скорость ветра уменьшалась и в центральной части зоны западных ветров (1—5° с. ш.) составляла 6—9 *м/сек*. Атмосферное давление, приведенное к среднему суточному по методу Фурнье [5], на оси ложбины упало до 1003,5 *мб* (общий фон для соседних районов составлял 1010—1011 *мб*). Интересно, что широты, на которых наблюдалась смена направлений ветра (8° с. ш.) и минимальное атмосферное давление (8°26′ с. ш.), не совпали одна с другой. Расхождение между ними в 26′, на наш взгляд, может объясняться несинхронностью наблюдений, поскольку за время перехода судна от места к месту могло произойти смещение барических систем к северу или к югу. На рис. 3 видно, что градиент давления к югу от оси ложбины был несколько больше, чем к северу от нее. Это обстоятельство согласуется с соответствующими данными по скорости ветра.

Распределение осадков оказалось почти симметричным относительно положения оси разрыва в поле ветра. Общая ширина зоны с осадками составила здесь примерно 3,5° широты. Дожди были ливневого характера, интенсивные, лишь с небольшими перерывами. В нижнем ярусе преобладали мощные кучево-дождевые облака, в среднем — высоко-кучевые, образовавшиеся в результате растекания кучево-дождевых. Облачность верхнего яруса во время пересечения зоны конвергенции не просматривалась.

В районе этой зоны (7—9° с. ш.) наблюдалось небольшое (на 0,5—1,0°) понижение температуры воды и несколько большее — до 2—3° — воздуха. Причиной охлаждения воздуха, несомненно, явилось выпадение осадков, поскольку относительно низкая температура воздуха (до 25°) отмечалась здесь лишь во время дождя. В случае же, когда дождя не было, температура воздуха повышалась и становилась такой же, как и во всей зоне западных ветров. Охлаждение воздуха во время дождя приводило к образованию довольно большой (до 2,5°) положительной разности температур воды и воздуха и, следовательно, к усилению конвекции в зоне конвергенции.

На большей части зоны западных ветров разность температур воды и воздуха также была положительной, однако, как правило, не превышала 0,5°. Известно [6], что температура поверхности воды, измеренная обычным термометром, нередко отличается от температуры поверхностной пленки, где она вследствие испарения может быть несколько ниже, чем сразу под поверхностью. Учитывая это обстоятельство, разность температуры поверхности воды и воздуха в зоне западных ветров практически можно считать равной нулю.

Относительная влажность воздуха в зоне конвергенции достигала 90% и более, в то время как в зоне западных ветров она была около 80%.

За время стоянки «Витязя» в Коломбо с 5 по 9 ноября (разрыв в нанесении данных на рис. 3) каких-либо изменений в распределении ветра и состоянии погоды не произошло. 10 ноября «Витязь» вышел из Коломбо, направился на юг примерно по меридиану 80° и снова оказался в устойчивом западном потоке. До экватора ветры были западными и северо-западными, далее до 2° ю. ш. — юго-западными. Все время стояла хорошая погода, без осадков, с небольшой облачностью, в основном Cu hum и Cu med. Ухудшение погоды началось 15 ноября, когда на 2—3° ю. ш. мы подошли к южной зоне конвергенции. На небе начали расти Cu long, затем Cb, вокруг судна появились полосы дождей. Ветер ослабел до 2 *м/сек*, а направление его стало меняться, причем вначале без какой-либо определенной закономерности (табл. 2).

К вечеру 15 ноября, на 4° ю. ш., Cb закрыли все небо и разразился сильнейший ливень, продолжавшийся всю ночь, выпало 56,2 *мм* осадков. Направление ветра было юго-восточным, юго-западным, северо-восточным, затем северо-западным, и установить, в какую сторону происходил его поворот, по часовой стрелке или против нее, не удалось. Возможно, что мимо нас прошло несколько слабых циклонических вихрей, и мы оказывались то в передней, то в тыловой их части.

Лишь к утру 16 ноября на 5°36′ ю. ш. установилось юго-восточное направление ветра, что свидетельствовало о вхождении «Витязя» в зону юго-восточного пассата.

Температура и относительная влажность воздуха претерпевали на этом переходе такие же изменения, как и в северной зоне конвергенции. Во время дождя воздух становился холоднее на 2—3°, влажность с 80% поднималась до 90% и более.

Южная зона конвергенции, возникающая при встрече юго-восточных и экваториальных западных ветров, как и северная, связана с областью пониженного давления (см. рис. 2). Однако в ноябре 1964 г., как видим, она была выражена не так четко, как северная. Здесь и сдвиг ветра не такой резкий, и зона с дождем у́же, и ложбина давления выражена слабее. В частности, по данным, приведенным на рис. 3, не видно почти никакого падения давления на 3—5° ю. ш , но это, конечно, еще не доказывает, что его действительно не было, поскольку за время перехода судна через зону общий фон давления мог меняться и «смазать» закономерное изменение давления. Ведь по остальным признакам (особенно аэрологическим) зона конвергенции здесь намечается.

ВЕРТИКАЛЬНОЕ РАСПРЕДЕЛЕНИЕ ТЕМПЕРАТУРЫ И ОТНОСИТЕЛЬНОЙ ВЛАЖНОСТИ ВОЗДУХА НА РАЗРЕЗЕ ЧЕРЕЗ ЗОНУ ЭКВАТОРИАЛЬНЫХ ЗАПАДНЫХ ВЕТРОВ

Для характеристики вертикального распределения температуры и относительной влажности воздуха, наблюдавшейся при пересечении зоны западных ветров, нами по данным радиозондирования были построены соответствующие разрезы по 80° в. д. (рис. 4 и 5). К сожалению, в северной зоне конвергенции (7—10° с. ш.) из-за сильного ветра аэрологические наблюдения провести не удалось и наши разрезы начинаются лишь с 6° с. ш.

В распределении температуры отметим следующие особенности. На высотах от 5—6 *км* и до тропопаузы изотермы имеют довольно плавный ход, они почти горизонтальны и параллельны одна другой. Ниже, до высоты 1,5—2 *км*, отмечается прогиб изотерм в районе 4° ю. ш. К северу и к югу

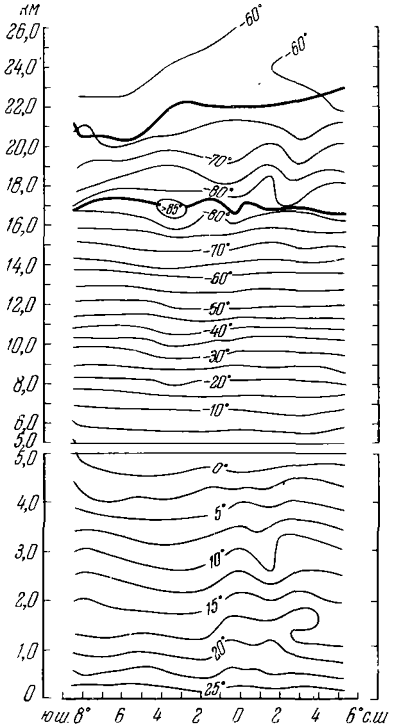

Рис. 4. Вертикальное распределение температуры воздуха на разрезе по 80° в. д.

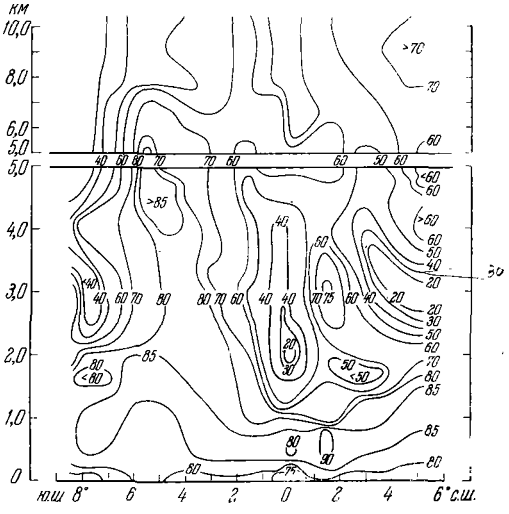

Рис. 5. Вертикальное распределение относительной влажности (в%) на разрезе по 80° в. д.

от него они «поднимаются». В соответствии с этим средняя температура нижнего 5-километрового слоя воздуха на широте 4° ю.ш. оказывается на 0,5—0,8° холоднее, чем в соседних районах (см. табл. 2). Несколько выпадает из общего хода распределение температуры на 1°30′ с. ш., где на высотах от 2,5 до 3,5 *км* изотерма резко изгибается.

Наиболее интересные особенности в распределении температуры относятся к нижнему двухкилометровому слою. Все выпуски радиозондов, произведенные в зоне западных ветров, зафиксировали наличие здесь задерживающих слоев. На 5° с. ш. с 1400 до 1800 *м* наблюдалась изотермия, на широте 3° — инверсия. Ближе к экватору и на экваторе изотермия была обнаружена на высотах от 800 до 1200 *м*. Южнее, в районе ветров переменных направлений, задерживающие слои исчезают и появляются вновь лишь на 8° ю. ш., т. е. в зоне юго-восточного пассата на высоте 1400—1700 *м*.

Судя по распределению относительной влажности (очень большие величины, порядка 80—85% под задерживающими слоями, и значительно меньше над ними, до 20% у экватора), образование задерживающих слоев связано с опусканием воздуха в этих районах, а следовательно, с дивергенцией потоков в нижних слоях.

Заметим, что задерживающие слои той или иной интенсивности наблюдались в этом районе приэкваториальной части Индийского океана рядом экспедиций и их существование здесь является, по-видимому, характерной особенностью этого района. Более подробно вопрос о задерживающих слоях над Индийским океаном разбирался нами в предыдущей работе [7].

Между 3 и 6° ю. ш., где по приземным данным намечается южная зона конвергенции, отмечается мощный «взброс» больших значений относитель-

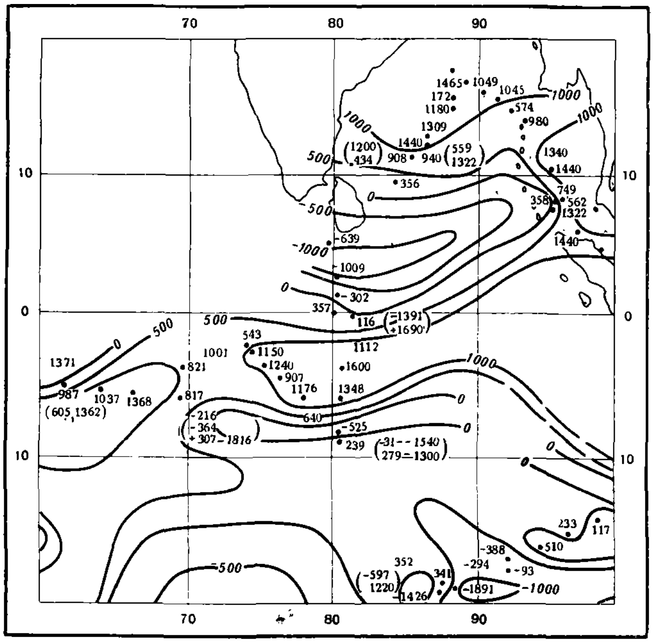

Рис. 6. Распределение величины энергии неустойчивости (в *дж·кг*$^{-1}$) в период зимнего муссона 1964/65 г. (до уровня поверхности 300 *мб*)

ной влажности (повышаются до 80—85%) до высоты 5—6 *км*, что свидетельствует о значительных восходящих потоках воздуха в этом районе. Судя по вертикальному распределению температуры и относительной влажности воздуха, восходящие токи поднимаются здесь до высот 6—7 *км*.

На рис. 6 представлено распределение энергии неустойчивости в период зимнего муссона 1964/65 г. по наблюдениям на и/с «Витязь». Величина энергии неустойчивости определялась в *дж/кг* до поверхности 300 *мб*. Как известно, отрицательные значения энергии неустойчивости характеризуют устойчивое состояние атмосферы; положительные значения — неустойчивую стратификацию, тенденцию к возникновению восходящих движений воздуха.

Общая картина распределения энергии неустойчивости неплохо согласуется с приведенными ранее данными. На 80° в. д. отрицательная и близкая к нулевым значениям величина энергии неустойчивости в юго-восточном пассате на 7—8° ю. ш. сменяется положительной в южной зоне конвергенции. Довольно большие положительные величины прослеживаются здесь до 1—2° ю. ш. К северу величина энергии резко убывает и вблизи от экватора она имеет уже отрицательное значение, т. е. стратификация атмосферы становится устойчивой.

Распределение энергии неустойчивости над остальными частями Индийского океана, построенное по редкой сетке наблюдений одного рейса, является, конечно, не более чем ориентировочной схемой.

РЕЗУЛЬТАТЫ НАБЛЮДЕНИЙ ЗА ВЕТРОМ НА ВЫСОТАХ ПРИ ПЕРЕСЕЧЕНИИ ЗОНЫ ЗАПАДНЫХ ВЕТРОВ

Для характеристики вертикального распределения ветра на разрезе через зону западных ветров удалось выполнить всего 6 шаропилотных наблюдений. Наблюдать за каждым выпускным радиозондом не удавалось то из-за темноты, низкой облачности и качки судна, то из-за частой смены курса и остановок судна при работах на геологических станциях. На экваторе и на широте 8° ю. ш. удалось провести по два наблюдения. В обеих точках первый и второй результаты отличались один от другого несущественно. Поэтому для построения разреза (рис. 7) использовались более высокие из этих пар.

На экваторе западный ветер отмечался до верхней точки наблюдений — 6255 *м*. Наибольшие скорости ветра (10—16 *м/сек*) были на высотах от 1,0 до 2,3 *км*. Интересно, что примерно на этих же высотах в температурной стратификации зафиксированы задерживающий малоградиентный слой и резкое уменьшение относительной влажности. Не исключена возможность, что струя сильного ветра, подсасывая сверху воздух, вызывает его оседание и, таким образом, участвует в образовании задерживающего слоя. На 3°41′ ю. ш. устойчивый западный ветер отмечался с высоты 700 *м* и до верхней точки наблюдений — 4330 *м*. В приземном слое дули очень слабые (1—3 *м/сек*) ветры различных направлений. На рис. 7 область ветров переменных направлений оконтурена штрихом. Несколько усилился западный ветер на высоте 3,0—3,7 *км*, однако без каких-либо особенностей в распределении температуры и влажности. На 7° ю. ш. на высотах примерно 3,5—5,5 *км* он был очень слабым, выше и ниже направление ветра было восточным и юго-восточным. Наконец, на 8°21′ ю. ш. западный ветер зафиксирован лишь один раз — на высоте 2470 *м*, причем, вероятно, случайно, так как при повторном наблюдении он уже не отмечался. Наиболее сильный дождь застал корабль, когда он находился между 4° и 5°30′ ю. ш. Нижняя граница западных ветров в этом месте располагалась, видимо, на высотах от 0,8 до 1,5 *км*.

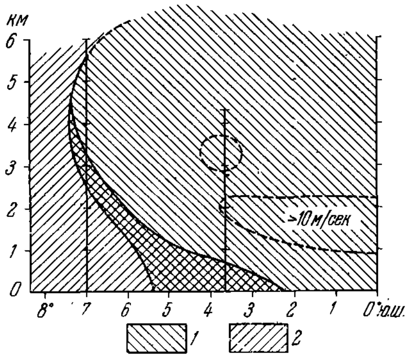

Рис. 7. Вертикальное распределение зональной составляющей ветра на разрезе по 80° в. д.

1 — западный ветер; 2 — восточный ветер

Заметим, что у Хоггарта [8], опубликовавшего единственный известный до последнего времени в литературе синоптический разрез ветра через южную границу зоны экваториальных западных ветров в центральной части Индийского океана (по 75° в. д.), наклон границы получился аналогичным нашему. С высотой область, занимаемая западными ветрами, расширялась, «находила» на область с юго-восточным пассатом, и сильный дождь прошел примерно в том же месте, как и у нас. Интересно, что по данным о вертикальном распределении температуры и влажности воздуха каких-либо существенных различий между экваториальными западными и юго-восточными пассатными ветрами выявить не удается. Зато зона конвергенции — зона встречи этих ветров — выражена достаточно резко (см. рис. 4, 5).

В районе северной границы зоны западных ветров шаропилотных наблюдений провести не удалось, однако судя по распределению осадков, симметричному относительно широты разрыва в поле приземного ветра, можно предположить наличие вертикальной границы между западными и северо-восточными потоками.

Естественно, что одного-двух наблюдений недостаточно для каких-либо обобщений относительно наклона границ зоны западных ветров в центральной части Индийского океана. Напомним, кстати, результат исследования Уоттса [9], который обнаружил, что над Малайзией наклон как северной, так и южной границ зоны западных ветров может быть самым разнообразным.

Как уже говорилось, западный ветер на экваторе отмечался до 6255 *м*. Судя по недавно опубликованным [10] климатическим картам ветров на разных уровнях над Индийским океаном, поворот ветра к восточному в ноябре должен начинаться выше 6255 *м*. Стоит отметить большую схематичность климатических карт ветра для акватории Индийского океана, что не удивительно, учитывая чрезвычайно редкую сеть станций в данном районе.

Весь ход изменения погоды на рассматриваемом разрезе очень интересен, особенно тот факт, что в полосе западных ветров была встречена ясная погода с задерживающими слоями. С чем это могло быть связано и чем объясняется возникновение экваториальных западных ветров? Прежде чем пытаться ответить на поставленные вопросы, скажем несколько слов об устойчивости и о границах распространения западных ветров в ноябре 1964 г. по данным наших синоптических карт.

Для полосы 0—5° с. ш. между 70 и 95° в. д. была подсчитана повторяемость ветров различных направлений. Из 49 случаев в 26-ти ветер оказался западным, в 12 — юго-западным, в 9 — северо-западным, один раз был штиль и один раз — северный ветер. Как видим, повторяемость западных ветров очень велика. Для такой же широтной полосы в южном полушарии из 58 в 49 случаях ветер дул с юго-запада до северо-запада, в четырех — с востока и в пяти — с юга. Причем в полосе 0—2° ю. ш. не было ни одного наблюдения с восточными ветрами. Между 3 и 5° ю. ш. западные и незападные ветры встречались примерно поровну, это говорит о том, что где-то здесь проходила граница между ветрами западных и восточных направлений.

О средних границах распространения западных ветров в ноябре 1964 г. в какой-то мере можно судить по средним положениям зон конвергенции (табл. 3).

Таблица 3

Зоны конвергенции в ноябре 1964 г.

Положение	Восточная долгота			
	60°	70°	80°	90°
	Северная зона, с. ш.			
Крайнее северное	6°	7°	7°	9°
Крайнее южное	1°	1°	1°	0°
Среднее	3,5°	4°	5,4°	5,3°
	Южная зона, ю. ш.			
Крайнее северное	4°	4°	4°	4°
Крайнее южное	7°	7°	7°	8°
Среднее	5,6°	5,4°	5,2°	5,4°

Как известно, проблема возникновения экваториальных западных ветров обсуждается уже очень давно. Высказано много догадок, гипотез [11—14], вокруг которых идут горячие споры, однако ни одно из высказываний еще не вылилось в убедительную теорию, способную увязать между собой все факты, связанные с приэкваториальными западными ветрами [15]. Можно сказать, что в рассматриваемом случае экваториальные западные ветры в ноябре 1964 г. неплохо объясияются распределением атмосферного давления. Как уже говорилось, в большинстве случаев изобары на наших ноябрьских картах можно было проводить аналогично тому, как это сделано на ноябрьской карте среднего многолетнего давления [2], на которой вдоль экватора с запада тянется небольшой гребень давления, а к северу и к югу от него располагаются ложбины (см. рис.2). Примерно для $^2/_3$ всех наших синоптических карт наблюдения за атмосферным давлением давали основания для подобного проведения изобар, причем иногда такая картина поля давления была очень отчетливой. Для большей части из оставшейся трети карт недостаток данных не позволял сколько-нибудь уверенно провести изобары тем или иным образом. И лишь в четырех-пяти случаях были основания для проведения изолиний в южном полушарии существенно иначе, чем показано на рис. 2.

Какие значения градиентов давления получены в приэкваториальных широтах? Для выяснения этого вопроса были подсчитаны градиенты давления тогда, когда на наших синоптических картах для последней декады октября и ноября имелись пары наблюдений за атмосферным давлением, ориентированные примерно в зональном или в меридиональном направлении, в полосах 0—5° с. ш. и 0—5° ю. ш. между 70 и 95° в. д.

Результаты получились следующие. Для полосы 0—5° с. ш. удалось рассчитать всего 25 значений меридиональных градиентов (в 21 случае градиент был направлен от экватора, в четырех — к экватору, средняя абсолютная величина градиента составляла 0,33 *мб/град*) и 22 значения зональных градиентов (в 18 случаях вектор был направлен на восток, в четырех — на запад, средняя абсолютная величина градиента равнялась 0,23 *мб/град*). Для полосы 0—5° ю. ш. из 25 случаев в 23-х градиент направлен от экватора, в двух — к экватору, средняя абсолютная величина — 0,26 *мб/град*. Из 22 наблюдений в 18 зональный градиент направлен к востоку, в четырех — к западу; средняя абсолютная величина градиента — 0,09 *мб/град*.

Как видно, в соответствии с распределением давления, указанным на рис. 2, в подавляющем большинстве случаев в исследованной полосе градиенты давления направлены от экватора и на восток. Средние абсолютные значения градиентов, особенно зональных, скорее несколько занижены из-за того, что расстояния между наблюдениями часто были слишком большими (4—5° широты для меридиональных пар и 8—10° широты для зональных). В общем они, однако, близки к статистическим средним величинам градиентов давления для экватора, полученным в работе [16].

Таким образом, в ноябре выявляется такое распределение атмосферного давления, при котором на некотором расстоянии от экватора и на самом экваторе поток воздуха направлен на восток. Гребень высокого давления на экваторе в совокупности с ложбинами к югу и к северу от него, вызывая возникновение западных ветров, обусловливает также процессы оседания, а следовательно, и малооблачную погоду в середине полосы западных ветров.

Интересно отметить, что малые зональные градиенты давления порядка 0,025 *мб/град*, возникающие из-за полусуточных колебаний атмосферного давления [17], по-видимому, никак не влияют на скорость ветра. По данным, полученным на экваторе, мы подсчитали средние скорости западных ветров для сроков, в которые градиент давления, возникающий из-за полусуточных колебаний давления, был направлен как на восток, так и на запад. Первая величина — 6,95 *м/сек* — оказалась даже несколько меньше второй — 7,19 *м/сек*.

Помимо сказанного остается, конечно, еще много нерешенных вопросов; главный из них — чем объясняется образование гребня высокого давления на экваторе, а также двух ложбин и двух зон конвергенции к северу и к югу от него?

На этот счет имеется гипотеза Флетчера [18], которая заключается в следующем. Он считает, что мощная облачность и осадки в зоне внутритропической конвергенции, вначале единой, должны создавать источник холода в нижней тропосфере с дивергенцией воздуха от экватора и с возникновением двух новых зон конвергенции на некотором расстоянии от экватора. Однако, как заметил Россби [19], причина, указанная Флетчером, может приводить лишь к периодическому образованию двойной зоны конвергенции. Дивергенция и нисходящие потоки у экватора способствуют разрушению облачности, а следовательно, и прогреванию района, ранее бывшего источником холода, что в конечном счете должно приводить к восстановлению единой зоны конвергенции. На это замечание, на наш взгляд очень важное, мы бы хотели обратить особое внимание. Судя по результатам отдельных синоптических исследований [7], на востоке Индийского океана в разное время действительно можно наблюдать как двойную, так и единую зону конвергенции, что свидетельствует в пользу гипотезы Флетчера. Вместе с тем в отдельные периоды, например в описываемом рейсе «Витязя», явно преобладала двойная зона конвергенции. Больше недели «Витязь» пересекал зону экваториальных западных ветров в ноябре 1964 г., и все это время отмечались две зоны конвергенции, а судя по консультациям метеорологического центра Коломбо, раздвоение зоны конвергенции наблюдалось и в отдельные дни ноября.

Посмотрим на вопрос с точки зрения климатологии. Если процесс раздвоения и восстановления единой зоны конвергенции периодичен, то при осреднении по времени поля всех метеоэлементов сгладятся и не будут иметь черт, присущих какой-либо из фаз этого процесса. В гипотезе Флетчера нет никаких предпосылок, из которых бы следовало, что одна из фаз рассматриваемого процесса должна преобладать по интенсивности или по продолжительности. Вместе с тем, анализируя распределение среднего многолетнего давления и ветра над Индийским океаном за отдельные месяцы [2, 20, 21], например за тот же ноябрь, можно обнаружить признаки явного преобладания раздвоения зоны конвергенции. У экватора здесь располагается область повышенного давления с ложбинами к северу и к югу от нее, тогда как при периодичности раздвоения и слияния зоны конвергенции вдоль всей приэкваториальной части океана должна была бы возникнуть единая «размытая» область пониженного давления. Во всей этой области следовало бы ожидать ветров переменных направлений, тогда как в действительности вдоль экватора в ноябре показаны устойчивые западные ветры, а переменные — в районах ложбин давления, к северу и к югу от экватора.

Как видим, гипотеза Флетчера не универсальна, и для объяснения раздвоения зоны конвергенции в Индийском океане в отдельные месяцы, во всяком случае в климатологическом аспекте, необходимо привлечь какой-то дополнительный механизм. В этой связи можно высказать некоторые соображения по поводу взглядов Фроста, Стефенсона [10] и Хромова [11]. Фрост и Стефенсон анализировали распределение среднего ветра на разных уровнях над Индийским океаном и пришли к выводу, что самое простое объяснение наблюдаемого пояса западных ветров на нижних уровнях и восточных ветров на высотах заключается в том, что они образуют часть простой циркуляционной ячейки с восходящей ветвью над нагретым массивом Индонезии и опускающейся ветвью над экваториальной частью Индийского океана около 60°в. д. Понятно, что вследствие опускания воздуха здесь появляются задерживающие слои и будет малооблачная погода.

Заметим, что объяснение Фроста и Стефенсона существенно включает в себя предположение об антитриптичности приземных ветров у экватора. Для переходных месяцев распределение давления и ветра у земли, по Фросту и Стефенсону, должно быть таким же, как на одной из схем Хромова [11], который также принимает гипотезу антитриптичности. На схеме (рис. 8) показаны экваториальные западные ветры, однако ложбины давления к северу и к югу от экватора отсутствуют. На наш взгляд, такая схема может быть отражением лишь первой стадии развития процессов. При любом нарушении стационарности режима, показанного на рис. 8, будь то расширение зоны западных ветров или отклонение ее в сторону от экватора, на границах между западными и восточными ветрами будет возникать резкая зона конвергенции. Если эта граница окажется на достаточном удалении от экватора, где начинает действовать сила Кориолиса, в поле давления, приспосабливающемся к циклоническому сдвигу ветра, должны образовываться циклонические структуры: вытянутые вдоль параллели ложбины или отдельные депрессии при вихреобразовании на границах потоков. Никаких термических факторов для возникновения таких ложбин не требуется. Происхождение их чисто динамическое.

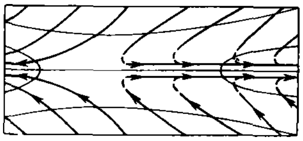

Рис. 8. Схема распределения атмосферного давления и линий тока (по С. П. Хромову)

Ложбины и депрессии, на наш взгляд, могут вносить определенный вклад в формирование среднего многолетнего распределения давления в приэкваториальной части Индийского океана в переходные месяцы. В остальные месяцы года в связи с муссонной перестройкой барического поля описанный эффект отходит на второй план, однако тенденция к образованию двойной зоны конвергенции может сохраниться, если останется некоторый градиент давления, направленный в приэкваториальный части Индийского океана на восток.

ABSTRACT

The paper analyses the results of meteorological observations carried out during the 36th cruise of the «Vityaz», when the expedition crossed the zones of equatorial western winds in the Indian Ocean in November 1964. At this time stable western winds up to about 6 km altitude were observed between 8°N and 2°S. The weather in the zone was almost cloudless without precipitation and at the altitudes of 0.8—1.8 km the arresting layers were observed. Rather clearly outlined zones of convergence with thick clouds, precipitation, wind shift and fall of pressure were observed between the near equatorial western winds and south-eastern trade-wind in the south and the north-eastern monsoon in the north. The paper discusses the current hypotheses as regards the formation of the western winds zone and two convergence zones on its boundaries. The paper also offers certain new conceptions in that respect.

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Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 177-179

К. А. Чекотилло

О МЕХАНИЗМЕ ЭКВАТОРИАЛЬНОГО ТЕЧЕНИЯ В ИНДИЙСКОМ ОКЕАНЕ

В целях исследования экваториального течения Индийского океана во время 36-го рейса и/с «Витязь» (ноябрь 1964 г.) были осуществлены следующие наблюдения. В точках с координатами 00°08′ ю. ш., 81°33′ в. д. и 00°19′ ю. ш., 81°36′ в. д. одновременно были поставлены два якорных буя с подвешенными к ним самописцами течений БПВ-2. Приборы располагались на горизонтах 50, 100, 150, 200, 500 *м* и работали с интервалом в 10 *мин*. Течения наблюдались в продолжение полутора суток. В то же время в исследуемом районе на трех гидрологических станциях проводились батометрические наблюдения для определения температуры и солености воды.

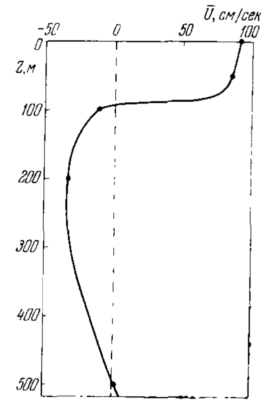

Рис. 1. Распределение осредненной зональной компоненты скорости течения с глубиной по данным измерений самописцами БПВ на якорной буйковой станции.

Положительные значения скорости соответствуют течению на восток; точки — положения приборов

По найденным модулю и направлению вектора скорости течения определялись зональная и меридиональная v составляющие скорости. Затем, чтобы исключить составляющие периодического течения, обе компоненты осреднялись за период 24 часа. Для получения данных о течении у поверхности моря определялся ветровой снос корабля при помощи прибора БПВ-2, спущенного с борта на глубину 15 *м*. После определения общего сноса дрейфующего судна при помощи астрономических обсерваций были найдены осредненные составляющие скорости течения близ поверхности моря.

На рис. 1 видно распределение осредненной зональной составляющей скорости течения $\bar{u}$ с глубиной по измерениям на одной из буйковых станций. Зональный поток имеет следующую вертикальную структуру: в верхнем слое течение направлено на восток (как и ветер), в слое 90—490 *м* —

на запад, а ниже 490 *м* — опять на восток. Другими словами, структура этого потока такая же, как и потока на экваторе в восточной части Тихого океана: в верхнем слое течение там направлено по ветру, ниже располагается противотечение Кромвелла, а еще ниже — течение, движущееся в направлении ветра. Разница между потоками состоит лишь в том, что в Тихом океане течение в верхнем слое следует на запад, а в Индийском — на восток.

Можно показать, что при соответствующих значениях ветрового напряжения и вертикального коэффициента турбулентности подобная трехслойная модель зонального течения на экваторе может быть получена и в том случае, когда в уравнении движения не учитываются эффекты инерции и горизонтальной турбулентности. Возьмем проекции упрощенного уравнения движения на оси x и z:

$$\frac{\partial p}{\partial x} = \frac{\partial T_{xz}}{\partial z}, \tag{1}$$

$$\frac{\partial p}{\partial z} = g\rho, \tag{2}$$

где оси x и z направлены на восток и вертикально вниз соответственно: $T_{xz} = -\rho\overline{u'w}$, u', w'— компоненты пульсационной скорости по осям x и z.

В уравнении движения для оси x отсутствует член ускорения Кориолиса, поскольку рассматривается движение на экваторе, а также члены инерции и горизонтальной турбулентности. Из (1) и (2) получаем

$$-(\rho g)_{-\zeta}\cdot \operatorname{tg}\gamma_x - \bar{\rho}\frac{\partial Q}{\partial x} = \frac{\partial T_{xz}}{\partial z},$$

где ζ — координата возмущенной поверхности моря, $tg\gamma_x$ — наклон поверхности моря в направлении x, $Q = \int\limits_{p_a}^{p_z} \alpha dp$, α — удельный объем морской воды; p_a — атмосферное давление, $\bar{\rho}$ — средняя величина плотности в пределах от $-\zeta$ до z. Интегрируя последнее уравнение от поверхности моря до z, находим

$$(T_{xz})_z = -(T_a)_x - (\rho g)_{-\zeta}\cdot \operatorname{tg}\gamma_x\cdot z - \bar{\rho}\int\limits_{-\zeta}^{z}\frac{\partial Q}{\partial x}dz,$$

где принято

$$(T_{xz})|_{z=-\zeta} = -(T_a)_x, \quad z \gg \zeta,$$

$(T_a)_x$ — касательное напряжение ветра на поверхности моря в направлении x.

Используя известное предположение

$$T_{xz} = A\frac{\partial \bar{u}}{\partial z},$$

где A — вертикальный коэффициент турбулентности, получаем

$$\frac{\partial \bar{u}}{\partial z} = -\frac{(T_a)_x + (\rho g)_{-\zeta}\cdot \operatorname{tg}\gamma_x\cdot z + \bar{\rho}\int\limits_{-\zeta}^{z}\frac{\partial Q}{\partial x}\partial z}{A}. \tag{3}$$

В (3) определим прежде всего величину $tg\gamma_x$. Как следует из рис. 1, кривая $\bar{u}$ имеет экстремум на горизонте $z_{\text{extr}} = 235$ *м*; тогда

$$\operatorname{tg}\gamma_x = -\frac{(T_a)_x + \bar{\rho}\int\limits_{-\zeta}^{z_{\text{extr}}}\frac{\partial Q}{\partial x}dz}{(\rho g)_{-\zeta}\cdot z_{\text{extr}}}. \tag{4}$$

Для получения величин Q, входящих в (3) и (4), по найденным на стандартных горизонтах значениям удельного объема строились графики вертикального распределения. Значения удельного объема снимались с графиков через 10 *м*, после чего производилось суммирование. При вычислении значений $\frac{\partial Q}{\partial x}$ величина шага бралась равной 74,3 *км*.

Расчеты по (3) и (4) производились при следующих значениях ветрового напряжения T_{ax}: 1, 5, 10, 15 $дн \cdot см^{-2}$. Коэффициент турбулентности A определялся таким образом: как показывают наблюдения, порядок величины вертикального градиента зональной скорости составляет 10^{-3}; порядок величины T_{xz} полагаем равным 1; отсюда порядок A должен составлять 10^3. Таким образом, при расчетах было принято, что $A = 10^3$ $г \cdot см^{-1} \cdot сек^{-1}$.

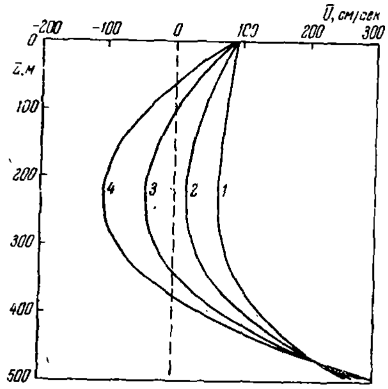

Рис. 2. Рассчитанное распределение зональной компоненты скорости течения с глубиной.

1 — $T_{ax} = 1$ $дн \cdot см^{-2}$; *2* — $T_{ax} = 5$ $дн \cdot см^{-2}$; *3* — $T_{ax} = 10$ $дн. \cdot см^{-2}$; *4* — $T_{ax} = 15$ $дн \cdot см^{-2}$

После проведения вычислений по (3) производная от $\bar{u}$ по z заменялась конечноразностным приближением; величина шага принималась равной 10 *м*. При значении компоненты $\bar{u}$ у поверхности моря, определенном по данным наблюдений, рассчитанные для четырех случаев эпюры зональной компоненты скорости выглядят так, как показывают кривые *1*, *2*, *3*, *4* на рис. 2.

Можно видеть, что при $T_{ax} = 10$ $дн \cdot см^{-2}$ и $T_{ax} = 15$ $дн \cdot см^{-2}$ рассчитанное зональное течение имеет ту же характерную структуру, что и реальное течение, т. е. в верхнем слое поток следует по ветру, далее располагается противотечение, и затем течение вновь идет на восток. Таким образом, проведенный расчет показывает, что трехслойное зональное течение на экваторе при известных условиях может формироваться и при отсутствии эффектов инерции и горизонтальной турбулентности. Надо сказать, что подобная модель зонального течения была предложена О. И. Мамаевым (1963 г.) в работе, посвященной исследованию течения Кромвелла [1].

ABSTRACT

The data of the instrumental current measurments at the anchored buoy stations which have been carried out in the Indian Ocean at the equator in November 1964, indicate that the zonal flow has the characteristic for the equatorial regions three-layers structure. It has been shown that under the corresponding values of the wind stress and the vertical turbulence coefficient the three-layers model of the zonal current can be built without taking into consideration the effects of the inertia and the horisontal turbulence.

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[1] О. И. Мамаев. К динамике течения Кромвелла. Океаны и моря.— В сб. «Вопросы географии», № 62, 1963.

Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 180-188

В. А. Химица

О ВОДНЫХ МАССАХ И ГИДРОХИМИИ МОЗАМБИКСКОГО ПРОЛИВА

В мае 1965 г. в Мозамбикском проливе проводила исследования 5-я научно-поисковая экспедиция АзЧерНИРО на э/с «В. Воробьев». За время работ на акватории пролива было выполнено 27 океанографических станций до глубины 1400 *м* по трем разрезам: Лоренцо-Маркес — мыс Сент-Мари, Бейра — Морондава и Мозамбик — мыс Сент-Андре (рис. 1). На станциях измерялись температура, соленость и окисляемость воды и определялось содержание растворенных в воде кислорода, фосфатного фосфора и кремнекислоты: соленость определялась титрованием на хлор по Кнудсену, кислород — по Винклеру, фосфаты — по Дениже — Аткинсу, кремнекислота — по Диэнеру и Ванденбульке и окисляемость в нейтральной среде — по Б. А. Скопинцеву. Степень насыщения воды кислородом вычислялась при помощи таблиц ВНИРО, рассчитанных по Трусдейлу; в результате определений фосфатов вводились солевые поправки по таблице С. В. Бруевича и В. С. Красновой, кремнекислоты — по таблице С. В. Бруевича и Л. К. Блинова.

Мозамбикский пролив—один из самых больших проливов мирового океана. Он протянулся с севера на юг почти на 900 миль, а ширина его составляет в среднем 400—450 миль. На севере водообмен с прилегающими частями океана затрудняет гряда Коморских островов, в то время как на юге водные массы Мозамбикского пролива широким фронтом контактируют с массами соседних районов Индийского океана.

Мозамбикский пролив до настоящего времени изучен очень слабо. Поэтому любые наблюдения над гидрологическими и химическими особенностями его вод представляют большой интерес, поскольку проливают свет на многие неясные стороны режима данного водоема. В настоящем сообщении производится анализ водных масс пролива и дается их комплексная физико-химическая характеристика.

В литературе [1] сведения о Мозамбикском проливе чрезвычайно скудны. Поэтому рассмотрим сначала различные классификации вод, предложенные для всего Индийского океана в целом.

Одна из первых подразделение вод Индийского океана осуществила Томсен [2]. Она выделила, в частности, в районе между 40 и 10° ю. ш. четыре водные массы (южную субтропическую, антарктическую промежуточную, глубинную и донную), но не дала подробного описания физико-химических их свойств и расположения границ по вертикали.

Свердруп [1] в этой области Индийского океана вместо южной субтропической выделил поверхностную центральную водную массу, оставив остальные типы вод такими же, как и у Томсен. Муромцев [3], на основании

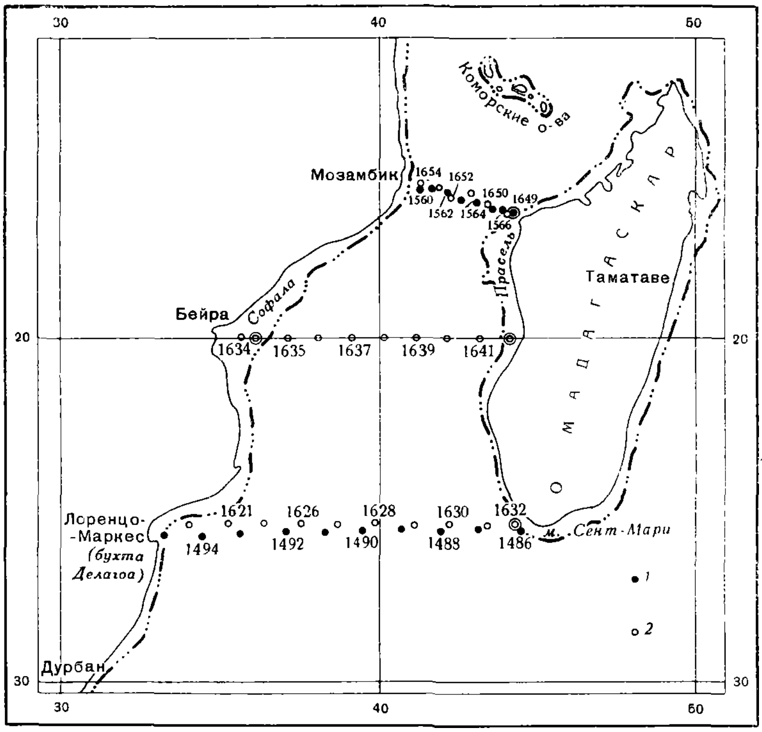

Рис. 1. Расположение океанографических станций в Мозамбикском проливе
1 — октябрь — ноябрь 1964 г.; *2* — май 1965 г.

сравнительно большого материала наблюдений пересмотрел типизацию вод, предложенную Томсен и Свердрупом, и выделил южнее 10° ю. ш. пять водных масс (поверхностную воду,подповерхностную субтропическую, промежуточную, глубинную и придонную антарктическую), указав при этом их границы по вертикали и основные характеристики температуры, солености и содержания кислорода.

Самая последняя и наиболее удачная (на наш взгляд) классификация водных масс Индийского океана была произведена в 1960 г. Иваненковым и Губиным [4]. Авторы разделили Индийский океан иа три зоны: тропическую (34—25° ю. ш.), южноэкваториальную (25—5° ю. ш.) и североэкваториальную (севернее 5° ю. ш.), выделив в каждой из них основные типы вод. Наш район исследований, согласно Иваненкову и Губину, расположен в южноэкваториальной зоне с шестью типами вод: поверхностной южноэкваториальной, подповерхностной южноэкваториальной, подповерхностной субтропической, промежуточной субантарктической, глубииной североиндийской и придонной антарктической.Самая южная часть Мозамбикского пролива примыкает к тропической зоие, где выделяются пять типов водных масс: поверхностная тропическая, подповерхностная субтропическая, промежуточная субаитарктическая, глубинная южноиндийская и придонная антарктическая. У южной границы Мозамбикского пролива водные массы обеих зон контактируют.

При выделении водных масс в том или ином районе океана обычно используют TS-кривые, карты, графики распределения температуры и солеиости. Нами также был применен этот метод. Однако в процессе анализа выяснилось, что, оперируя параметрами только солености и температуры,

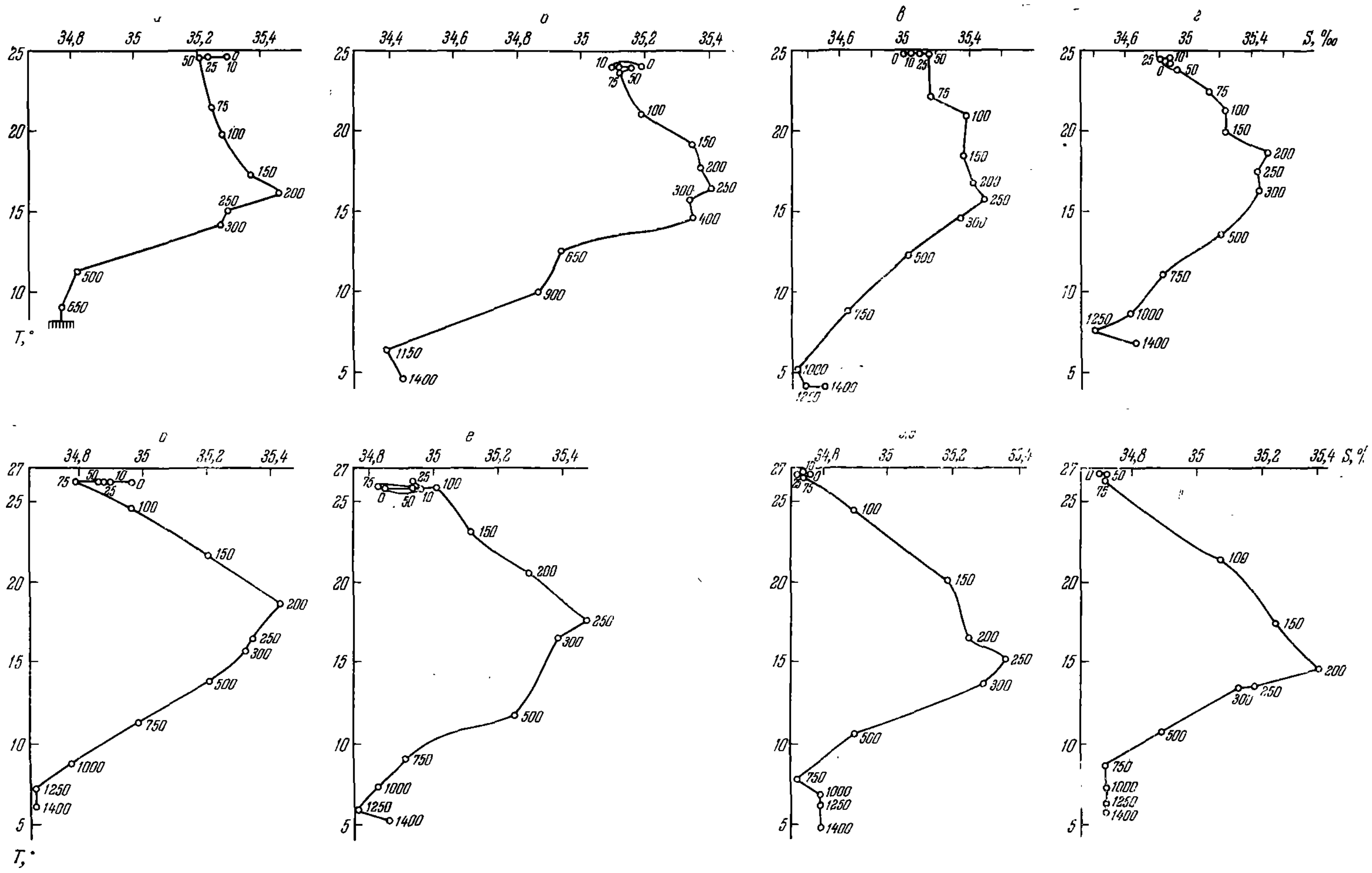

Рис. 2. *TS*-кривые, характерные для Мозамбикского пролива

а — 25°32′ ю. ш., 35°10′ в. д.; *б* — 25°32′ ю. ш., 37°30′ в. д.; *в* — 25°32′ ю. ш., 39°00′ в. д.; *г* — 25°32′ ю. ш., 41°00′ в. д.; *д* — 20°00′ ю. ш., 39°00′ в. д.; *е* — 20°00′ ю. ш., 40°01′ в. д.; *ж* — 15°37′ ю. ш., 42°08′ в. д.; *з* — 15°20′ ю. ш., 41°42′ в. д.

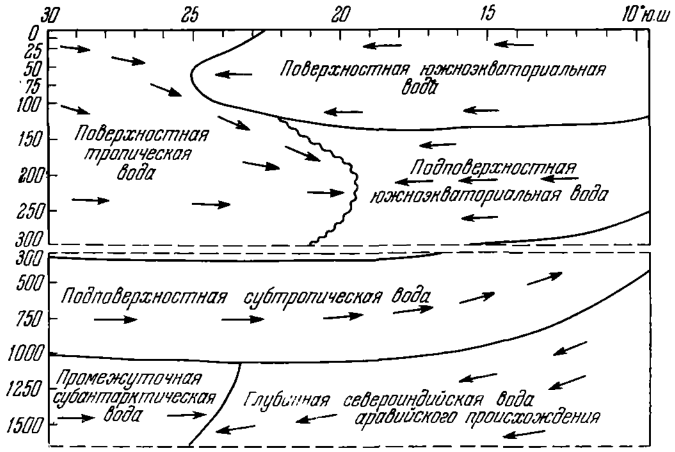

Рис. 3. Схема вертикальиой структуры вод Мозамбикского пролива

разобраться в типах вод,образующих водную толщу Мозамбикского пролива, очень трудно. Поэтому были привлечены также карты и графики распределения по вертикали содержания кислорода и биогенных элементов, что значительно облегчило решение поставленной задачи. Особенно показательны материалы по содержанию растворенного в воде кислорода при выделении тех типов вод, которые в районах формирования имеют высокие или низкие концентрации кислорода, а затем перемещаются на значительные расстояния от этих областей.

На рис. 2 приведены TS-кривые, наиболее характерные для водных масс Мозамбикского пролива. Следует отметить, что при выделении здесь типов вод за основу принималась классификация водных масс Индийского океана, предложенная Иваненковым и Губиным [4]. Из анализа кривых, а также графиков и карт океанологических характеристик следует, что на значительной части акватории пролива в пределах глубины наблюдений существуют четыре типа вод: поверхностная южно-экваториальная, подповерхностная южноэкваториальная, подповерхностная субтропическая и глубинная североиндийская. В юго-западной части пролива, кроме этого, выделяются водные массы, присущие тропической зоне: поверхностная тропическая и промежуточная субантарктическая. Общее представление о расположении типов вод в водной толще Мозамбикского пролива дает рис. 3. На схеме видно, что вертикальная структура вод Мозамбикского пролива очень сложна и поэтому естественно, что для более полного познания водных масс этой части океана необходимо привлекать как можно больше океанологических характеристик.

Поверхностная тропическая вода формируется в области Южно-индийского атмосферного максимума между 34 и 25° ю. ш. Этот район отличается относительно высокой температурой воздуха (22—32°), что способствует значительному испарению с поверхности океана: соленость на поверхности повышается до 35, 50—35, 90‰, а это в свою очередь приводит к развитию плотностной конвекции до 300—450 *м*.

Поверхностная тропическая вода в Мозамбикском проливе наблюдалась в мае в виде небольшого клина на юге, а также в районе бухты Делагоа. Она занимает здесь слой от 0 до 300—350 *м* и характеризуется соленостью 35, 25—35, 50‰ и температурой 24,5—16,0°. В западной части Мозамбикского пролива поверхностная тропическая вода подтекает под поверхностную южноэкваториальную. Эта вода в виде языка, вытянутого в направлений, обратном направлению Мозамбикского течения, прослеживалась до 22—20° ю. ш., причем в южной части пролива в более глубоких слоях (200 *м*) она распространялась по всей его площади.

Поверхностная тропическая вода отличается высокой концентрацией кислорода. В южной части пролива содержание его во всей толще не опускается ниже 4,40—4,80 *мл/л*, степень насыщения воды этим газом—ниже 80%. К северу концентрация кислорода постепенно понижается до 4,50—4,60 *мл/л*. Поверхностная тропическая вода в Мозамбикском проливе характеризуется невысокой концентрацией питательных солей. Количество фосфатного фосфора во всем ее слое не превышает 0,23—0,55 *мкг-ат/л* и лишь у северной границы оно возрастает до 0,65—1,00 *мкг-ат/л*. Подобная картина наблюдается и в распределении кремнекислоты: у южной границы пролива 7—11 *мкг-ат/л*, в районе 20° ю. ш. 11—18 *мкг-ат/л*.

Поверхностная южноэкваториальная вода образуется в восточной части Индийского океана под влиянием высоких температур воздуха и распреснения атмосферными осадками. Южным Пассатным (Экваториальным) течением эти воды переносятся на запад. К северу от о-ва Мадагаскар (11—9° ю. ш.), где Южное Пассатное течение разветвляется, образуется зона мощного подъема вод, и в формировании поверхностной южноэкваториальной воды принимают участие подповерхностная субтропическая, промежуточная субантарктическая и глубинная североиндийская водные массы. На акватории Мозамбикского пролива поверхностная южноэкваториальная вода занимает слой 0—100 *м* и выделяется высокой температурой (25,5—26,0°), пониженной соленостью (34,70—34,90‰) и несколько более низким по сравнению с поверхностной тропической водой содержанием кислорода (4,30—4,60 *мл/л*). Рассматриваемая вода занимала в мае почти всю акваторию пролива и лишь на юге, в узкой струе Мозамбикского течения, выносилась за его пределы.

Концентрация кислорода в поверхностной южноэкваториальной воде при перемещении ее с севера на юг постепенно возрастала. Так, если на разрезе Мозамбик — мыс Сент-Андре количество его во всем слое составляло 4,40—4,60 *мл/л*, а на разрезе Бейра — Морондава — 4,60—4,70 *мл/л*, то у южной границы распространения поверхностной южноэкваториальной воды содержание кислорода в ней возрастало до 4,80 *мл/л* (рис. 4). Это происходило вследствие понижения температуры воды, а также благодаря контакту с более богатой кислородом поверхностной тропической водой и более интенсивно протекающим на юге процессом фотосинтеза.

На всех разрезах толщина слоя воды, перенасыщенной кислородом, составляла 75—100 *м*, т. е. процессы созидания органического вещества здесь преобладали над процессами его распада, причем на юге степень насыщения воды кислородом была значительно выше (105—107%), чем на севере пролива (100—102%).

Интенсивное потребление фитопланктоном питательных солей повлияло на характер распределения биогенных элементов. Концентрация фосфатного фосфора колебалась во всем слое поверхностной южноэкваториальной воды в пределах 0,23—0,29 *мкг-ат/л*, кремнекислоты 6—11 *мкг-ат/л*, причем в южной части пролива, где, по-видимому, преобладали диатомовые водоросли, содержание кремнекислоты было более низким (5—9 *мкг-ат/л*), чем на севере, где оно возрастало до 9—14 *мкг-ат/л*.

Подповерхностная южноэкваториальная вода формируется из поверхностной тропической и подповерхностной субтропической водных масс, поднимающихся в зоне южноэкваториальной дивергенции. Частично принимает участие и глубинная североиндийская вода. Если первая придает подповерхностной южноэкваториальной воде повышенную соленость (в Мозамбикском проливе 35,40—35,50‰), а вторая — сравнительно низкую температуру (15—17°), то третья — значительно понижает в ней содержание кислорода (3,20—3,80 *мл/л*). В Мозамбикском проливе данная водная масса занимает слой 100—500 *м* и распространяется

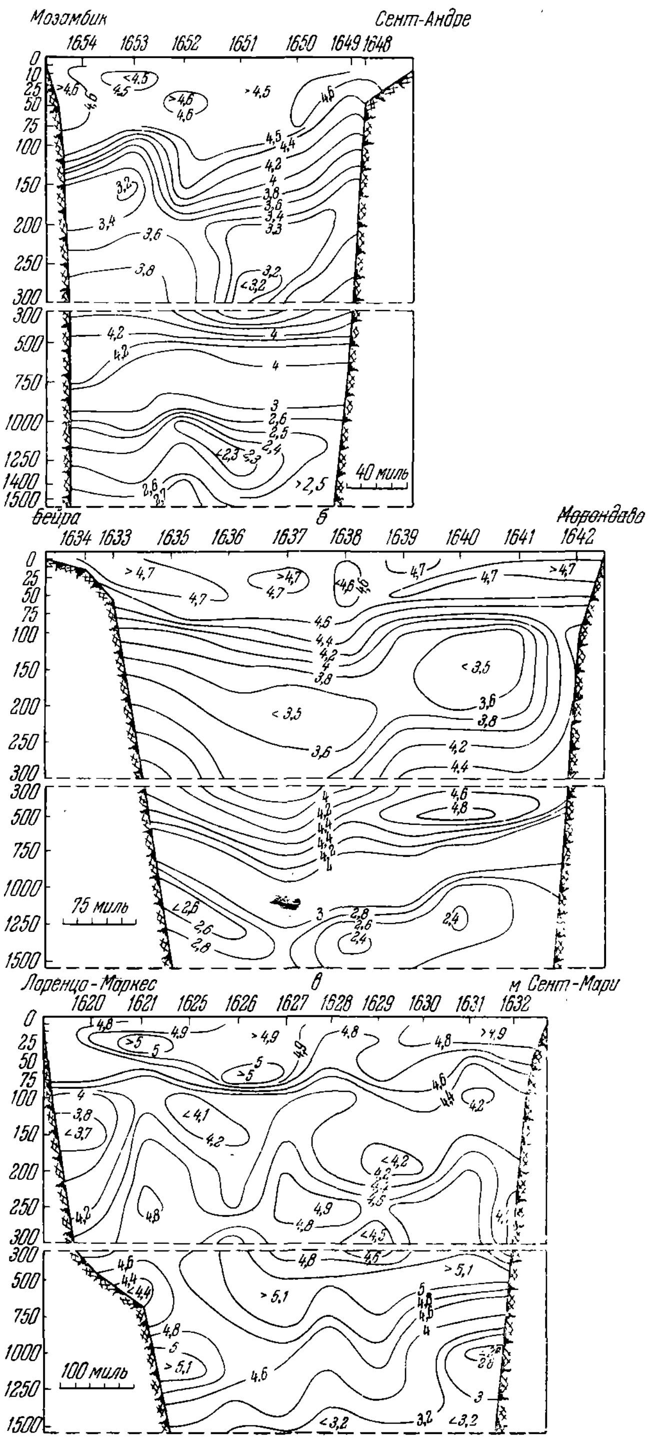

Рис. 4. Вертикальное распределение кислорода (в *мл/л*) на разрезах в Мозамбикском проливе

а — 20—22.V 1965 г.; *б* — 14—17.V 1965 г.; *в* — 4—9.V 1965 г.

с севера на юг. Ее легко можно обнаружить именно по пониженному содержанию кислорода, тогда как по солености она близка к поверхностной тропической водной массе.

Рассматриваемая водная масса отделяется от поверхностных слоев моря интенсивным пикноклином, что затрудняет проникновение кислорода сверху. В процессе движения концентрация O_2 в подповерхностной южноэкваториальной воде понижается вследствие затрат его на окисление органического вещества, в результате чего возрастают запасы питательных солей, а количество растворенной органики уменьшается (окисляемость воды в ней не превышает 0,15—0,30 *мл/л* O_2).

На всех разрезах (см. рис. 4) подповерхностная южноэкваториальная вода оконтуривается изооксигеной 4 *мл/л* и изолинией 70%. Наименьшее содержание кислорода (3,20—3,30 *мл/л*) отмечается на разрезе Мозамбик — мыс Сент-Андре. К югу оно постепенно возрастает в результате контакта с подповерхностной субтропической и поверхностной тропической водными массами (см. рис. 4).

Подповерхностная южноэкваториальная вода отличается богатством питательных солей. Больше всего фосфатов (1,00—1,60 *мкг-ат/л*) и кремнекислоты (14—28 *мкг-ат/л*) обнаружено на северном разрезе. Здесь у мадагаскарского побережья происходит подъем подповерхностной южноэкваториальной воды в верхние слои моря, что способствует обогащению их питательными солями. На разрезе Бейра—Морондава концентрация биогенных элементов в подповерхностной южноэкваториальной воде несколько уменьшается, но все же остается на достаточно высоком уровне. Здесь также есть выходы подповерхностных вод на шельф, причем не только у о-ва Мадагаскар, но и у африканского побережья. У южной границы распространения этого типа воды содержание биогенных элементов значительно понижается (фосфаты — 0,65 *мкг-ат/л*, кремнекислота — 14 *мкг-ат/л*), что является результатом обмена с поверхностной тропической водой, бедной питательными солями. Следует отметить, что вынос биогенных элементов с подповерхностной водой в верхние слои у африканского берега пролива в мае наблюдался повсеместно, в то время как у побережья о-ва Мадагаскар он происходил только в отдельных районах.

Подповерхностная субтропическая вода формируется в зоне субтропической конвергенции (40° ю. ш.) из поверхностной субтропической и поверхностной субантарктической водных масс [5]. Здесь она приобретает низкую соленость и повышенную концентрацию кислорода. В Мозамбикском проливе данная вода распространена в слое 500—1000 *м*. В процессе движения к северу толщина слоя подповерхностной субтропической воды постепенно уменьшается.

В южной части пролива соленость этого типа вод низка, а содержание кислорода высокое. К северу соленость возрастает, а концентрация кислорода уменьшается, в то время как температура не испытывает особых изменений и равна 6,0—8,0°.

Подверхностная субтропическая вода в Мозамбикском проливе легко обнаруживается по повышенному содержанию кислорода. На разрезе Лоренцо-Маркес — мыс Сент-Мари оно равно 5,00—5,20 *мл/л* (см.рис. 4). При перемещении подповерхностной субтропической воды на север, вследствие смешения ее с подповерхностной южноэкваториальной и глубинной североиндийской водными массами, а также вследствие затрат кислорода на окисление органического вещества, содержание кислорода в ней значительно уменьшается. Так, на разрезе Бейра—Морондава в ядре оно составляет 4,80—4,90 *мл/л*, а в среднем для всего слоя подповерхностной субтропической воды — 4,30—4,40 *мл/л*. На северном разрезе содержание кислорода в подповерхностной субтропической воде понижается до 4,20—4,30 *мл/л*. Так же как и поверхностная тропическая, подповерхностная субтропическая водная масса отличается низкой концентрацией биогенных элементов. Сформированная в основном из поверхностных вод с небольшим содержанием органического вещества, она в процессе перемещения на север мало пополняется питательными солями вследствие минерализации органического вещества. На входе в Мозамбикский пролив количество фосфатов в ней равно 0,65—1,00 *мкг-ат/л*, кремнекислоты—11—15 *мкг-ат/л*. Однако в результате обмена со слоями воды, лежащими выше и ниже, питательных солей в ней становится значительно больше и уже на разрезе Мозамбик — мыс Сент-Андре содержание фосфатов равно 1,60—1,90 *мкг-ат/л*, кремнекислоты — 28—36 *мкг-ат/л*.

Глубинная североиндийская вода, согласно В. Н. Иваненкову и Ф. А. Губину, формируется в Аравийском море, причем авторы считают, что большая роль в ее образовании принадлежит водным массам Красного моря и Оманского залива. Сохраняя ее название, мы не можем согласиться с такой версией происхождения.

Более поздние исследования [3, 6, 7] Индийского океана показали, что роль вод Красного моря и Оманского залива в формировании глубинных вод не столь уж значительна. Иванов-Францкевич [6], например, объясняет образование мощного слоя повышенной солености (200—2000 *м*) в Аравийском море без привлечения красноморских вод, выделяя его как более «старую» воду Аравийского моря. Заметим, что указанный слой отличается также очень низким содержанием кислорода (так называемый слой кислородного минимума).

Некоторые исследователи [6, 8] считают, что образование мощного слоя кислородного минимума в Аравийском море происходит в основном из-за выноса обедненных кислородом вод из Красного моря и Персидского залива. Однако, как показали исследования АзЧерНИРО [9], это не так. Наоборот, водные массы Красного моря и Персидского залива на выходе отличаются повышенным содержанием кислорода, а слой его дефицита формируется непосредственно в Аравийском море. Глубинные воды из Аравийского моря на значительном расстоянии от района формирования можно легко определить по низкой концентрации кислорода. В связи с этим следует остановиться на ошибочном мнении Свердрупа [1], который считал, что в красноморских водах мало кислорода, и по этому признаку прослеживал их вдоль восточного побережья Африки на глубинах 1250—1750—2000 *м* до 40° ю. ш. На самом деле на этих глубинах распространяется на юг глубинная североиндийская вода.

Таким образом, происхождение глубинной североиндийской воды не красноморское, как указывают Иваненков и Губин, а аравийское, в связи с чем мы называем ее глубинной североиндийской водной массой аравийского происхождения. Эта вода занимает слой от 1000—1250 до 2500—3000 *м* и отличается в Мозамбикском проливе несколько повышенной соленостью (34,70—34,85‰), низкой температурой (2,0—5,0°), а также невысокой концентрацией кислорода (2,30—2,70 *мл/л*). В Мозамбикском проливе она располагается почти у самого нижнего предела наших измерений и на разрезах выделяется по низкому содержанию кислорода и высокой концентрации питательных солей. В северной части пролива количество кислорода в ней равно 2,30 *мл/л*, фосфатов — 3,20—3,40 *мкг-ат/л*, кремнекислоты — около 110 *мкг-ат/л*; на юге соответственно 2,90—3,40 *мл/л*, 2,58 *мкг-ат/л*, 71 *мкг-ат/л*. Судя по окисляемости (0,20—0,30 *мл/л* O_2), глубинная североиндийская вода отличается низким содержанием растворенного органического вещества, поскольку в результате длительного движения вод это вещество минерализировалось, что сопровождалось также потерей кислорода.

Промежуточная субантарктическая водная масса формируется в области океана между антарктической и субтропической конвергенциями. Свердруп [1] называет ее промежуточной антарктической водой. Севернее 34° ю. ш. она занимает слой 800—2000 *м* и отличается низкой температурой (3,5—4,0°), пониженной соленостью (34.20—34,50‰) и высоким содержанием кислорода (6,50—4,50 *мл/л*). В Мозамбикском проливе промежуточная субантарктическая вода наблюдается у южной границы на глубинах ниже 1000 *м*. Соленость ее здесь равна 34,50—34,65‰, температура 4,0—5,0°, содержание кислорода 4,50—4,80 *мл/л*. Концентрация биогенных веществ более низкая, чем в глубинной североиндийской воде: фосфатов 1,29—2,00 *мкг-ат/л*, кремнекислоты — 28—50 *мкг-ат/л*. Вместе с этим в промежуточной субантарктической воде относительно много растворенного органического вещества (окисляемость воды 0,60—0,90 *мл/л* O_2). На севере эта водная масса подвергается интенсивной трансформации.

Анализ водных масс Мозамбикского пролива и их физико-химические характеристики, приведенные в настоящем сообщении, следует рассматривать как предварительные. При накоплении более обширного материала эти сведения будут значительно уточнены. Однако в настоящем виде полученные данные освещают некоторые стороны вертикальной структуры вод Мозамбикского пролива и их гидрохимические особенности.

ABSTRACT

The Mozambique Strait is a region of the Indian Ocean characterized by the distinctive oceanographic regime.The vertical structure of the waters in this Strait is complex.Itis defined by the nature of interaction of the water masses of different origin. Six types of waters occur in the water column of the Mozambique Strait within 1500 m: the surface tropical, surface south-equatiorial, subsurface south-equatorial, subsurface subtropical, intermediate subantarctic and the North-Indian deep water of the Arabian origin.

Being formed in different climatic regions of the Indian Ocean these water masses in the Mozambique Strait are distinguished not only by the temperature and salinity but also by the content of oxygen and biogenous elements. The water masses in the Mozambique Strait flowing from the South are characterized by the high concentration of oxygen and low concentration of biogenous elements, and on the contrary, the waters formed in the Northern part of the Indian Ocean are distinguished by abundance of nutrient salts and low concentration of oxygen.

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Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 195-200

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О ВОДООБМЕНЕ МЕЖДУ КРАСНЫМ МОРЕМ И АДЕНСКИМ ЗАЛИВОМ

В последнее время все большее внимание уделяется всестороннему изучению Индийского океана и его окраинных морей. Наибольший интерес представляют Красное море и Персидский залив, которые играют значительную роль в поддержании солевого баланса северной части Индийского океана.

По разным данным [1, 2], сток соленых вод только из Красного моря колеблется от 300 000 до 480 000 *м*^{3}/*сек*, что в среднем за год составляет около 12 500 *км*^{3}, т. е. 5% объема его вод. При отсутствии речного стока и ничтожном количестве осадков в Красном море этот объем воды, а также потери при испарении (более 1000 *км*^{3}/*год*) [3, 4] компенсируются только притоком вод из Аденского залива. Верселли (1925 г.) первый обратил внимание на многослойность структуры течений в Баб-эль-Мандебском проливе и высказал некоторые предположения относительно сезонных изменений режима течений в проливе [2]. Томпсон (1939 г.), а позднее и Нейман [4] пришли к выводу, что на циркуляцию вод в Красном море большее влияние оказывает испарение и плотностный обмен, чем ветер. Следует напомнить, что ветровой режим подвержен сезонной изменчивости только в южной части Красного моря, где с мая по сентябрь наблюдается северо-северо-западный ветер, а с октября по апрель — юго-юго-восточный, в то время как в северной половине моря постоянно господствуют ветры северных направлений. В последние годы инструментальные наблюдения за течениями в проливе были проведены только на и/с «Ю. М. Шокальский» и «А. И. Воейков» [1]. Все исследователи сходятся в том, что летом в проливе существуют трехслойные течения, а зимой — двухслойные, т. е. глубинное стоковое из Красного моря и промежуточное компенсационное течения действуют на протяжении всего года, меняется только поверхностное дрейфовое течение. Однако, учитывая как сгонно-нагонный характер поверхностной циркуляции вод, так и большие колебания в годовом ходе испарения Красного моря, можно предположить, что перечисленные факторы не могут не отразиться на интенсивности постоянных течений в Баб-эль-Мандебском проливе.

В данном сообщении делается попытка косвенным путем выявить характер сезонных изменений интенсивности глубинных течений в проливе и вызывающие их причины.

Первые шаги в этом направлении были предприняты Егоровым [3]. С учетом годового хода испарения и фактических колебаний уровня Красного моря (рис. 1, *а*) им сделан вывод, что летом превышение притока вод

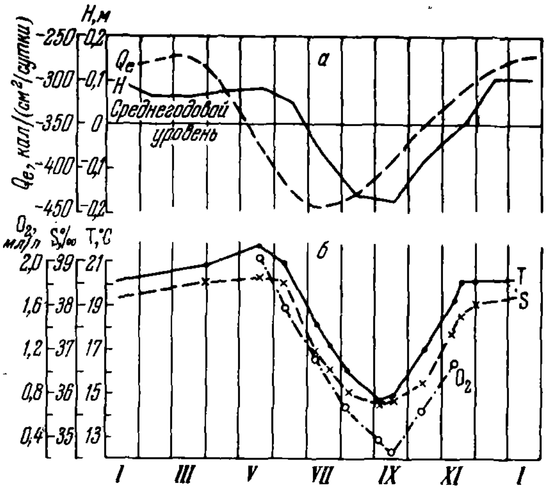

Рис. 1. Годовой ход уровня и потерь тепла на испарение в Красном море, по Н. И. Егорову (*а*), и сезонные колебания температуры, солености и кислорода красноморских вод на выходе из Баб-эль-Мандебского пролива (*б*)

в Красное море над стоком из него должно быть почти в два раза больше, чем зимой.

На рис. 1, *б* представлен годовой ход солености, температуры и содержания растворенного кислорода для глубинной красноморской воды, выходящей через Баб-эль-Мандебский пролив. Для построения кривых были привлечены материалы наблюдений трех экспедиций АзЧерНИРО на э/с «Владимир Воробьев» (1961—1964 гг.) на стандартном разрезе у юго-восточной границы Баб-эль-Мандебского пролива (всего 14 станций); кроме того, при анализе были использованы 24 станции, выполненные в этом районе с э/с «А. И. Воейков» (1959 г.), «Ю. М. Шокальский» (1960 г.), «Atlantis», «Owen» (1957—1958 гг.), «Ormonde», (1927 г.). Форма кривых свидетельствует о резко выраженной сезонности физико-химических характеристик стоковых вод Красного моря. Зимой и весной при выходе в Аденский залив красноморские воды почти полностью сохраняют свои характеристики: температура 21—23°, соленость 38,5—39,0‰, содержание кислорода 1,6—2,3 *мл/л*. В июле — сентябре, напротив, эти воды выходят уже значительно трансформированными: температура их не превышает 16—17,5°, соленость 36,0—36,5‰, количество кислорода 0,4—0,6 *мл/л*. Эти величины в какой-то степени отражают интенсивность глубинного стока вод Красного моря в течение года, поэтому можно заключить, что максимум стока приходится на зиму и весну, а минимум — на лето.

При сопоставлении этих характеристик с колебаниями уровня Красного моря обнаруживается синхронность в годовом ходе: наиболее низкому положению уровня соответствует минимальный сток и наоборот (см. рис. 1). Сам уровень Красного моря определяется в основном годовым ходом испарения, а также сгонно-нагонной циркуляцией в поверхностных слоях Аденского залива и южной половины Красного моря под действием муссонных ветров. Зимой вследствие интенсивного нагона воды из Аденского залива уровень в Красном море повышается (испарение в этот период минимальное).

Глубинным потоком избыток красноморской воды выносится через Баб-эль-Мандебский пролив в Аденский залив. Судя по температуре и солености (см. рис. 1), сток красноморских вод достигает максимума уже к концу ноября и держится на этом уровне вплоть до конца мая, когда он незначительно вторично повышается.

Основной причиной стокового глубинного течения в Баб-эль-Мандебском проливе считается значительная разность в плотности вод Красного моря и Аденского залива, которая остается на протяжении почти всего года постоянной. С другой стороны, не менее важную роль, по-видимому, играет сгонно-нагонная циркуляция, которая накладывается на плотностную и производит соответствующий эффект. В зимний период это выражается в том, что вследствие повышения уровня в Красном море увеличивается давление на глубинные слои, которые как бы выдавливаются по направлению к проливу. Подобное явление наблюдается на протяжении всего зимнего периода, когда юго-юго-восточный ветер очень устойчив, а дрейфовый поток, в основном осуществляющий нагон аденских вод, и высокое положение уровня в Красном море сохраняются вплоть до конца мая. Поверхность раздела между входящим и выходящим потоками в самом Баб-эль-Мандебском проливе находится в этом случае на глубине 75—100 *м*, понижаясь в направлении к выходу в Аденский залив. В последнем характеристики красноморской воды сохраняются на большом удалении от пролива. Так, по наблюдениям э/с «Atlantis» 10—12 июня 1958 г. в 60 милях от пролива температура этой воды, обнаруженной у аденского континентального склона на глубине 500—1000 *м*, была 21,8°, соленость $39{,}1^{0}/_{00}$ и содержание кислорода 1,61 *мл/л* [5].

Летом часть вод Красного моря сгоняется северо-западными ветрами в Аденский залив. Одновременно резко усиливается испарение, достигающее максимума в середине июля. В результате больших потерь воды уровень моря значительно понижается, что влечет за собой усиление промежуточного течения из Аденского залива. Дрейфовое течение, направленное в этот период из Красного моря в Аденский залив, захватывает поверхностные слои до 50 *м*. Нижняя граница промежуточного течения опускается до 150 *м*, т. е. поверхность раздела между ним и глубинным стоковым течением находится почти на уровне порога Баб-эль-Мандебского пролива. В этом случае порог, располагающийся со стороны Красного моря в 80 милях от узкой части пролива на глубине около 170 *м*, служит преградой нижнему течению, задерживая его и приводя в конечном счете к интенсивному перемешиванию вод на поверхности раздела. Чем сильнее потребность в компенсации вод Красного моря, тем больше мощность промежуточного течения. В результате придонное течение ослабевает и в отдельных случаях вообще может прекратиться. Часть красноморских вод увлекается промежуточным течением и возвращается вместе с ним в Красное море. Остальная часть значительно трансформируется, теряя свои первоначальные характеристики.

В самом проливе, например, соленость в придонных слоях в это время не привышает $36{,}5^{0}/_{00}$.

С сезонными колебаниями стока глубинных вод Красного моря через Баб-эль-Мандебский пролив связаны некоторые особенности и гидрохимического режима исследуемых водоемов. Так, содержание кислорода в трансформированной воде красноморского происхождения понижено летом до 0,6 *мл/л*. Это побудило Муромцева [1] охарактеризовать их как воды с минимальным запасом кислорода, что, по его мнению, приводит к крайне низкому содержанию кислорода в глубинных слоях Аденского залива и Аравийского моря. С таким мнением трудно согласиться: как известно, содержание кислорода в глубинной воде Красного моря вследствие хорошей и быстрой аэрации достигает 2,0—2,3 *мл/л*. Даже в западной части Аденского залива в красноморской воде оно в 2—3 раза больше, чем в аденской, и достигает 1,2 *мл/л*. В этом отношении показательно распределение температуры, солености и кислорода на разрезе Бербера — Аден (рис. 2). Минималь-

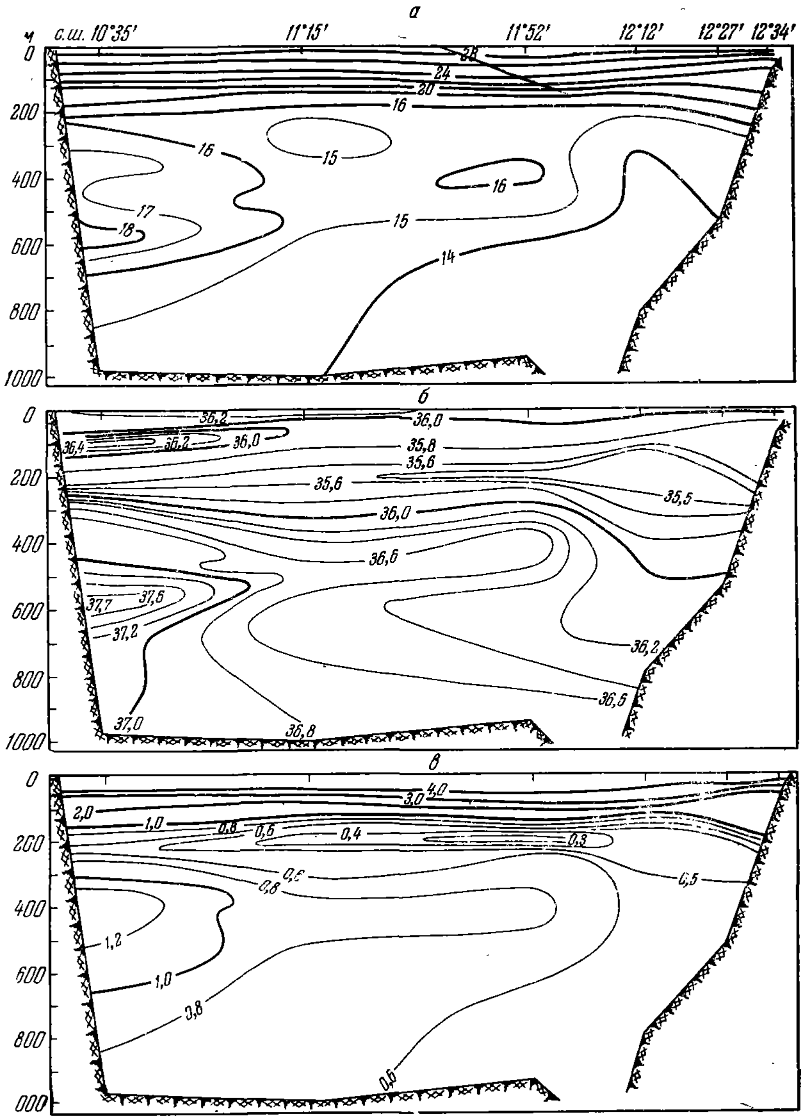

Рис. 2. Распределение температуры (*а*) (град.) солености (*б*) (‰) и содержания кислорода (*в*) (*мл/л*) на разрезе Бербера — Аден (по наблюдениям с э/с «В. Воробьев» 30—31.V 1963 г.)

ная концентрация кислорода (0,3—0,4 *мл/л*) на глубине 200 *м* отмечена в промежуточной воде, распространяющейся из Аравийского моря. Если перенос обедненных кислородом вод из него отрицательно сказывается на кислородном режиме Аденского залива и отчасти южной части Красного моря, то сток красноморской воды, сохраняющей запас кислорода при выходе в залив, в какой-то степени должен компенсировать этот недостаток.

Безусловно, сезонные изменения в водообмене между Красным морем, Аденским заливом и Аравийским морем будут сказываться и на кислородном режиме исследуемых водоемов. Летом, когда усиливается промежуточный поток из Аравийского моря, компенсирующий убыль воды в Аденском заливе и Красном море, слой минимума кислорода выражен сильнее и распространяется даже в Красное море. В связи с этим в Баб-эль-Мандебском проливе в июле — октябре содержание кислорода в трансформированных красноморских водах значительно понижено и мало отличается от содержания, типичного в этот период для промежуточных вод Аденского залива. Но с ноября по июнь красноморские воды сохраняют значительное количество кислорода даже при своем продвижении в западной части Аденского залива (см. рис. 2). Иными словами, концентрация кислорода в красноморских водах убывает пропорционально интенсивности их трансформации в Баб-эль-Мандебском проливе (см. рис. 1, *б*), что подтверждается прямолинейной связью, установленной нами между термохалинными характеристиками и содержанием кислорода в красноморской воде.

ВЫВОДЫ

1. Сток красноморских вод через Баб-эль-Мандебский пролив подвержен сезонным колебаниям и зависит не только от плотностной структуры вод, но и от ряда других факторов, определяющих аномалии в годовом ходе водообмена между Красным морем и Аденским заливом: сгонно-нагонных колебаний уровня и сезонного хода испарения в Красном море, а также от малых выходных глубин пролива.

2. В зимний и весенний периоды при наиболее высоком уровне Красного моря и наличии двухслойной структуры течений в проливе (дрейфовое — в Красное море и глубинное — из него), сток красноморских вод наиболее устойчив и интенсивен. Летом, когда потребность в компенсации вод Красного моря достигает максимума, входящий промежуточный поток преобладает и почти полностью подавляет стоковое глубинное течение.

3. С ноября до середины июня выходящие в Аденский залив красноморские воды в основном сохраняют высокие значения температуры и солености и отличаются повышенным содержанием кислорода, в то время как в июле — октябре они почти полностью трансформируются над Баб-эль-Мандебским порогом, смешиваясь с водами Аденского залива.

ABSTRACT

The paper uses the materials of observations conducted during a three-year period on board of the ets «Vladimir Vorobiew» (1961—1964) along the cross-section by the nerth-eastern boundary of the Bab-el-Mandeb Strait. Indirect methods have allowed to determine the character of sudden seasonal intensity variations of the deep water outflow from the Red Sea into the Gulf of Aden, and their causes.

Thermochaline and hydrochemical parameters of the Red Sea water change during the year in proportion to the process of its transformation in the Bab-el-Mandeb Strait. From November till May the Red Sea waters, flowing to the Gulf of Aden, retain the high temperature potential (21—23°), salinity (38.5—39.0%) and oxygen (1.6—2.3 ml/l), while in July — October these characteristics are considerably changed over the Bab-el-Mandeb sill; their temperature does not exceed at that time 16.0—17.5°, salinity 36.0—36.5% and oxygen 0.4—0.9 ml/l.

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Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 201-214

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ОСОБЕННОСТИ ГИДРОЛОГИЧЕСКИХ УСЛОВИЙ СЕВЕРНОЙ ЧАСТИ КРАСНОГО МОРЯ В ЗИМНИЙ СЕЗОН 1964/65 г.

Вследствие особенностей географического положения Красного моря, отсутствия речного стока и интенсивного испарения физико-химические характеристики его вод резко отличаются от характеристик вод других водоемов Мирового океана. Обладая очень большим запасом солей и тепла, красноморские воды оказывают определенное влияние на режим глубинной зоны Индийского океана, где они формируют промежуточный слой воды с максимумом солености.

Однако океанографический режим Красного моря и особенно его северной части изучен слабо. Сведения о его гидрологических условиях основаны в основном на материалах непродолжительных, зачастую эпизодических наблюдений, которые дают лишь общие, причем иногда не совсем верные, представления о распределении океанографических характеристик.

Наиболее полные исследования в северной части Красного моря были выполнены экспедицией АзЧерНИРО (ноябрь 1964 — апрель 1965 гг.) на э/с «Ихтиолог». Результаты экспедиции позволили подробно осветить гидрологические условия северной части Красного моря в зимний сезон, когда вследствие интенсивного развития зимней конвекции происходит формирование глубинной водной массы Красного моря. За это время были проведены три океанографические съемки моря к северу от тропика: в декабре, в январе и в конце марта — начале апреля. Наблюдения проводились на двух разрезах: от г. Хургада и от мыса Рас-Эгела.

Кроме того, для сбора данных о режиме моря в целом и для оценки влияния поступающих с юга вод Аденского залива на океанографические условия Красного моря в конце января — начале февраля нами была выполнена полная съемка моря. При проведении океанографических исследований помимо работ в открытом море на поперечных разрезах изучался режим вод в районах, представляющих интерес для развития рыболовства ОАР (Суэцкий залив, бухта Сафага, северная часть залива Фаул-Бей и др.). В этих районах выполнялись микросъемки, суточные станции и проводились наблюдения за течениями.

Всего за время экспедиции в Красном море было выполнено 110 гидрологических станций [1]. Наблюдения проводились на стандартных горизонтах до глубины 500—600 *м*, а на отдельных станциях — до 800—1000 *м*.

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[1] Карта океанографических станций, выполненных в Красном море на э/с «Ихтиолог», приведена в статье В. Н. Кочикова, которая публикуется в настоящем сборнике.

Помимо двух многосуточных буйковых постановок с самописцами течений Алексеева в открытом море были сделаны также 10 станций в прибрежной зоне, на которых производились непосредственные измерения течений с заякоренного судна до глубины 100 *м*.

Перечисленные материалы были использованы для написания настоящей статьи, в которой рассматриваются вопросы о сезонной изменчивости гидрометеорологических характеристик, движении красноморских вод, конвективном перемешивании и водных массах Красного моря.

СЕЗОННЫЕ ИЗМЕНЕНИЯ ГИДРОМЕТЕОРОЛОГИЧЕСКИХ ХАРАКТЕРИСТИК

Тепловой баланс, температура воздуха, а также температура, уровень и соленость воды имеют в Красном море, особенно в его северной части, хорошо выраженный сезонный ход.

Большой приток тепла в теплую половину года, несмотря на расход его на испарение, приводит к значительному повышению температуры воды. Испарение вызывает понижение уровня и осолонение воды [1, 2, 3, 4]. Напротив, в зимний сезон испарение уменьшается, уровень моря повышается и его воды охлаждаются до температуры, обеспечивающей развитие конвекции до больших глубин в северной части. Например, превышение среднего уровня Красного моря у г. Суэц зимой над средним его положением летом достигает почти 1 *м* [4].

Ветровой режим характеризуется четкой сезонной изменчивостью только в южной части Красного моря, где с октября по апрель преобладает юго-восточный ветер, а с мая по сентябрь — ветры северных направлений [5]. В северной части моря в течение всего года господствуют северные ветры, но повторяемость их зимой уменьшается, особенно в районе Суэцкого залива (см. таблицу).

Повторяемость ветров северной и южной четвертей и разность
(NW + N + NO) — (SW + S + SO), %

Месяц	Северная часть						Южная часть					
	Суэц			Хургада			о-в Камаран			о-в Перим		
	от NW до NO	от SW до SO	разность	от NW до NO	от SW до SO	разность	от NW до NO	от SW до SO	разность	от NW до NO	от SW до SO	разность
Январь	48	33	15	56	2	54	10	86	—76	6	75	—69
Февраль	51	30	21	57	10	47	14	76	—62	7	69	—62
Март . . .	62	26	36	81	4	77	10	81	—71	9	67	—58
Апрель	64	25	39	89	6	83	8	76	—68	8	80	—72
Май	78	16	62	94	4	90	18	44	—26	17	65	—48
Июнь . . .	88	8	80	99	0	99	26	27	—1	56	24	32
Июль . . .	90	6	84	99	0	99	58	10	48	66	11	55
Август . . .	93	4	89	99	0	99	40	25	15	66	16	50
Сентябрь	94	3	91	99	0	99	27	33	—6	47	36	11
Октябрь	82	10	72	94	0	94	11	65	—54	4	89	—85
Ноябрь	74	13	61	80	0	80	0	98	—98	0	96	—96
Декабрь	64	17	47	57	3	54	5	93	—88	0	94	—94

Общая циркуляция атмосферы над северной частью Красного моря в холодную половину года определяется взаимодействием трех барических систем — областями повышенного давления над северо-западной Африкой, Центральной Азией и Центрально-Африканской областью пониженного давления.

Зимний сезон 1964/65 г. характеризовался повышенной активностью атмосферной циркуляции над северной частью Красного моря. Особо повышенной ветровой деятельностью отличались март и первая декада апреля, когда повторяемость ветра силой 6—8 баллов составляла 15% общего числа наблюдений. В первой декаде февраля в южной части моря наблюдался устойчивый юго-восточный ветер в 4—5 баллов.

Сезонный ход ветров, уровня и других физических характеристик Красного моря определяет сезонную изменчивость дрейфового течения в Баб-эль-Мандебском проливе, а также отражается на интенсивности стокового и компенсационного течений на протяжении года. Как показали исследования [1, 2, 6], максимальный сток глубинных вод моря наблюдается в зимний период, минимальный — в летний. Но если в глубинных слоях пролива колебания течений синхронны с изменениями уровня, то в поверхностных слоях они синхронны с сезонной изменчивостью ветрового режима.

К сожалению, мы не располагаем достаточным количеством данных для анализа межгодовых изменений гидрологического режима Красного моря. Однако на основании наших материалов и материалов других экспедиций, выполнявших в нем кратковременные наблюдения («Atlantis», в 1958 г., «Shoyo-maru» в 1959 г., «Ю. М. Шокальский» в 1960 г., «Акад. А. Ковалевский» в 1961—1962 и 1963 гг., «К. Болдырев» в 1963 г., «Discovery» в 1964 г.), можно сделать вывод, что межгодовые колебания температуры и солености глубинных красноморских вод очень небольшие. Так, средняя соленость их изменялась от 40,4 до 40,7‰, а температура воды — в пределах 21,7 ± 0,1°. Вот почему вызывают сомнения результаты определения солености, выполненные в Красном море на э/с «А. И. Воейков» в сентябре 1959 г. По этим данным, средняя соленость глубинных вод составила около 42,2‰ [2]. Однако и в предшествующий, и в последующий годы в Красном море соленость глубинных вод была близка к 40,5—40,6‰.

По нашему мнению, такое полное обновление красноморских вод не могло произойти за столь короткий срок. В самом деле, легко убедиться, что на повышение солености с обычных ее значений до 42,2‰, даже если исходить из максимальных величин скорости испарения, потребуется значительно больше одного года. В 1959 г. была отмечена скорость испарения с поверхности моря, равная 1,14 *см/сутки* [2], которая почти вдвое выше величины, приведенной в работе Егорова [1]. Если допустить, что процесс испарения протекал с такой интенсивностью в течение всего года, то и тогда это привело бы к повышению солености водной толщи Красного моря всего на 0,3‰. Чтобы повысить соленость на 1,6‰, потребовалось бы полностью испарить в течение года слой воды толщиной более 20 *м*.

С другой стороны, также нереально понижение солености водной толщи с 42,2‰ в 1959 г. до 40,5‰ в 1960 г. [3] в результате выноса красноморских вод в Аденский залив, поскольку порог Баб-эль-Мандебского пролива служит серьезной преградой для свободного обмена между Красным морем и Аденским заливом [6]. По разным данным [1, 6, 7, 8], сток соленых красноморских вод в среднем за год составляет 12 500 *км*^{3}, т. е. 5% объема вод Красного моря. Даже если увеличить эту цифру вдвое, потребуется не менее 6—7 лет, чтобы полностью обновить глубинные воды моря.

Не исключено, что в многолетнем цикле изменений температуры и особенно солености воды возможны и более существенные отклонения от указанных средних величин. Однако вряд ли такое значительное повышение солености (на 1,6—1,7‰) могло быть во всей водной толще моря.

О ДВИЖЕНИИ ВОД КРАСНОГО МОРЯ

Циркуляция вод Красного моря (как поверхностного слоя, так и в еще большей степени глубинной толщи) изучена недостаточно.

Суммарные течения в Красном море возникают в результате одновременного действия нескольких факторов: ветра, горизонтального градиента давления, вызванного наклоном уровня моря и разностью плотностей воды в северной и южной частях моря, приливных сил и т. д. Эти факторы вызывают постоянные, периодические и другие течения. Однако роль каждой из перечисленных сил в формировании суммарного потока различна. В Красном море в суммарном потоке преобладают ветровые и постоянные течения; приливо-отливные течения имеют подчиненное значение, за исключением Суэцкого залива, где их роль более значительна.

Существенные различия в положении уровня и плотности вод между северными и южными районами моря (так, в январе 1965 г. разница в значениях условной плотности для верхних слоев на разрезах от Хургады и Ходейды составила 3,0) определяют перенос вод в глубинных слоях на юг и в поверхностных — на север.

Однако главной силой, формирующей систему поверхностных течений Красного моря, является ветер, который отличается большой устойчивостью по направлению, особенно в теплую половину года, и дует, как правило, вдоль продольной оси моря. В связи со сложным режимом ветров над Красным морем в холодный сезон (наличие северо-западных ветров на севере и южных, юго-восточных — на юге), циркуляция вод имеет более сложный, чем в летний сезон, характер. Господствующие ветры создают систему преобладающих поверхностных течений. Однако из-за ряда причин (рельеф дна, конфигурация берегов, влияние приливных колебаний и т. д.) эта система существенно отличается от системы ветров.

Результаты обработки наблюдений за течениями по способу АНИИ [9] показали, что скорости суточного, полусуточного и особенно четвертьсуточного приливо-отливных течений в открытой части Красного моря характеризовались небольшими значениями по сравнению со значениями скоростей остаточных течений. Так, на горизонтах 10 и 15 *м* скорость последних составляла около 1 узла (на горизонте 150 *м* — 0,6—0,7 узла), а средняя скорость полусуточного приливо-отливного течения — всего 0,1 узла. В отличие от приливо-отливного остаточные течения были более устойчивыми по направлению.

Материалы инструментальных наблюдений, собранные экспедицией АзЧерНИРО (рис. 1), и динамические карты, построенные относительно изобарической поверхности 500 *дб* по данным съемок в декабре и марте — апреле (рис. 2), дали возможность не только представить схему суммарных течений в северной части моря, но и проследить за ее изменениями в зимний сезон. Это позволило уточнить известную ранее схему движения поверхностных вод в холодную половину года [10], которая оказалась весьма приближенной. Согласно последней, система течений в поверхностном слое представлялась в виде двух встречных потоков вод, следующих в направлении господствующих ветров. В действительности циркуляция вод в Красном море имеет более сложный характер. Суммарный поток вод в верхних слоях образует в северной части моря систему циклонических и антициклонических круговоротов, которые подвержены существенным изменениям во времени. Так, в северной части моря в рассматриваемый период времени существовало два круговорота вод — устойчивый циклонический и неустойчивый антициклонический (см. рис. 1, 2). Вопреки мнению о том, что проникновение южного потока ограничивается северным тропиком [10], указанный поток в зимний сезон 1964/65 г. в сильно трансформированном виде прослеживался и в северной части моря, не проникая, однако, в декабре и январе севернее 27° с. ш. В районе мыса Абу-Дара поток занимал всю

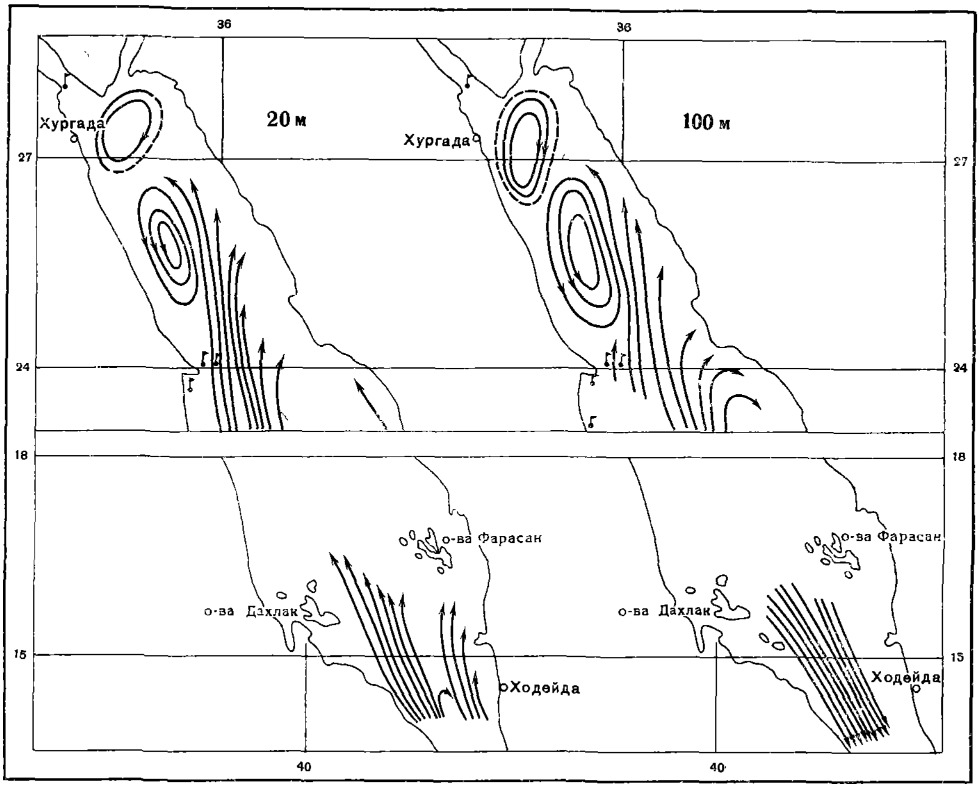

Рис. 1. Схемы циркуляции вод Красного моря (в январе 1965 г.)
Флажками показано положение буйковых станций

западную половину моря. При дальнейшем движении на север он постепенно смещался в центральную и восточную часть, существенно влияя на режим прибрежной зоны аравийского побережья.

Таким образом, на протяжении зимнего сезона в циркуляции вод поверхностного слоя моря к северу от тропика определяющую роль играли перенос трансформированных вод с юга на север вдоль аравийского побережья и два круговорота вод — циклонический и антициклонический.

Отмеченный характер циркуляции красноморских вод в северной части моря в целом сохранялся и в более глубоких слоях (по крайней мере до глубины 200 *м*). Напротив, в самой южной части уже на горизонте 100 *м* направление течения менялось на обратное. Как известно [6], в зимний сезон в Баб-эль-Мандебском проливе течение двухслойное: в верхних слоях наблюдается дрейфовый поток вод из Аденского залива, а в нижних — стоковое течение из Красного моря в Аденский залив.

Схемы, построенные по материалам трех океанографических съемок (см. рис. 1, 2), указывают на значительные изменения течений в северной части Красного моря с декабря по апрель. Они связаны прежде всего с колебаниями местоположения и интенсивности основных круговоротов вод. Так, антициклонический круговорот вод в декабре был выражен сравнительно слабо и занимал северо-восточную часть моря. В январе он значительно усилился и центр его переместился на запад. В начале апреля в связи с коренной перестройкой системы течений на севере моря антициклонический круговорот в пределах исследуемого района не обнаружен (см. рис. 2).

Еще в большей степени претерпел изменения циклонический круговорот вод. В декабре его центр занимал наиболее южное положение (25° с. ш.), а в апреле он находился почти на 2° севернее. Это смещение в конце зимнего сезона сопровождалось резким усилением притока вод с юга. Например, средние скорости циклонического круговорота в открытом море на траверсе мыса Рас-Бенас на горизонте 10 *м* превышали 1 узел (по данным буйковой постановки с 23 по 29 марта). Воды южного потока в конце марта проникали вдоль аравийского побережья вплоть дл залива Акаба (см. рис. 2).

Особый интерес в прибрежных районах Красного моря (в заливах Суэцком, Фаул-Бей и др.) представляют течения вращательного типа. Период вращения их менялся в зависимости от района и глубины наблюдений от 1 *час* 10 *мин* до 5 *час*, но направление (против часовой стрелки) оставалось всегда постоянным.

Поперечная циркуляция вод трофического слоя в северной части моря отличалась на протяжении зимы преобладанием нисходящих движений вод

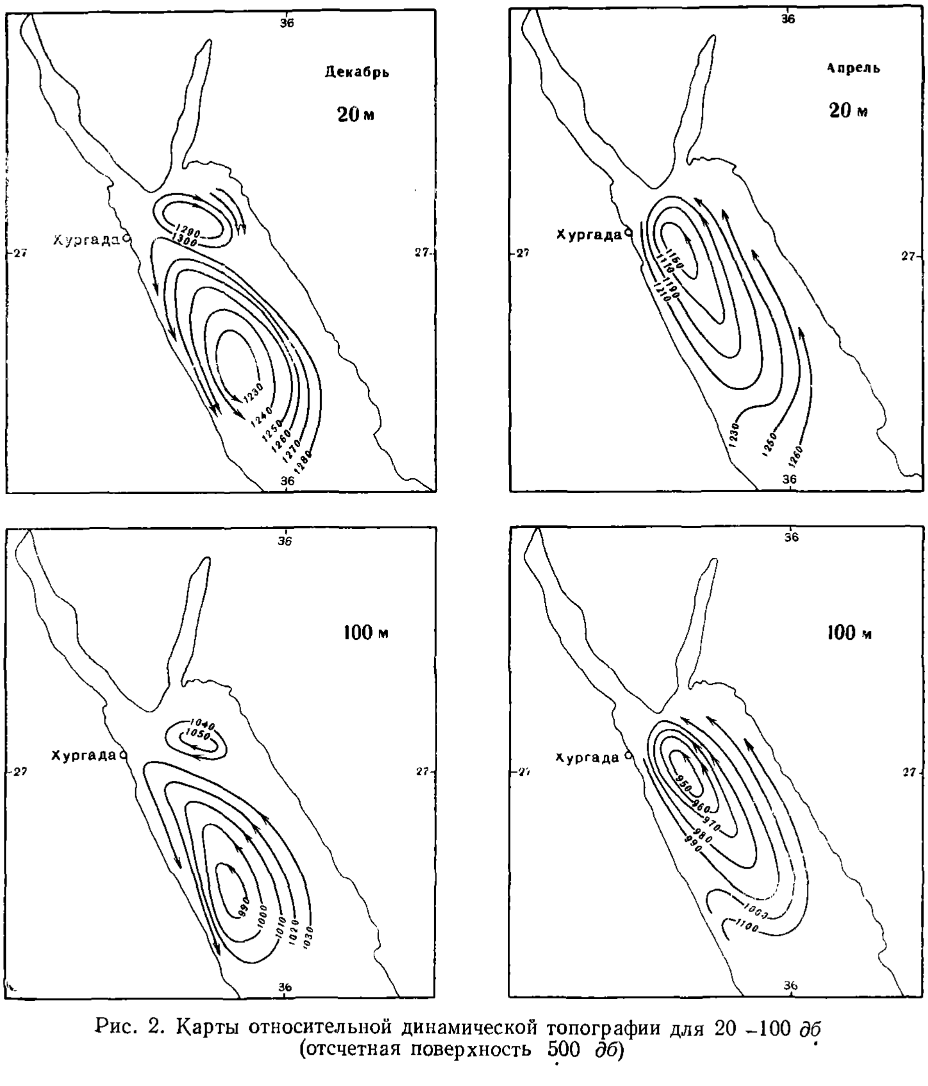

Рис. 2. Карты относительной динамической топографии для 20 –100 *дб* (отсчетная поверхность 500 *дб*)

у африканского берега и подъемом их в центральной области циклонического круговорота. В наиболее северной части аравийского побережья в декабре и январе преобладал подъем вод, а в более южных районах — опускание на протяжении всей зимы.

РАСПРЕДЕЛЕНИЕ ТЕМПЕРАТУРЫ И СОЛЕНОСТИ ВОДЫ

Поскольку Красное море (и особенно его северная часть) в значительной мере изолировано от других водоемов, термический режим его вод определяется главным образом местными факторами. В тепловом балансе северной части Красного моря в холодный сезон года важную роль играет перенос тепла морскими течениями из более южных его районов.

С октября до начала апреля температура воздуха на севере моря ниже температуры воды. Максимальная разность между значениями температур воды и воздуха наблюдалась в январе — феврале: 5—7° в районе Хургады и 3,5—4,0° на 25° с. ш.

Наиболее интенсивное понижение температуры воды отмечалось в ноябре и декабре; в дальнейшем темп охлаждения поверхностных вод замедлился. В результате к концу декабря 1964 г. температура воды в северной части моря понизилась до 24° на разрезе от Хургады и до 23,3—24,0° на разрезе от мыса Рас-Эгела (рис. 3, 4). Причем наиболее высокая температура и низкая соленость наблюдались в центральной части хургадинского разреза, где происходило опускание вод. Именно этот район моря в декабре характеризовался самым высоким запасом тепла (глубина залегания изотермы 24° составила здесь 120—150 *м*). Наиболее низкая температура (23,3—23,6°) и наиболее высокая соленость (40,25‰) были в средней и западной частях разреза от мыса Рас-Эгела, что связано с восходящим движением вод в центре расположенного здесь циклонического круговорота. Самая низкая соленость и самая высокая температура на указанном разрезе зафиксирована у аравийского побережья (см. рис. 3), где происходит приток вод из более южных районов Красного моря.

Дальнейшее усиление теплообмена с атмосферой вследствие увеличения разности между значениями температур воды и воздуха до 4—6° вызвало в январе 1965 г. значительное понижение температуры воды в северной части моря.

Уже в конце января в поверхностном слое на разрезе от Хургады она составила всего 22,5—22,8°. При этом, как и в декабре, наиболее высокая температура (22,7—22,8°) и самая низкая соленость (40,14—40,16‰) наблюдались в центральной части разреза — в области антициклонического круговорота, а наиболее высокая соленость (40,26‰) и наименьшая температура (22,5°)— у африканского и аравийского берегов. Однородность водной толщи на разрезе от Хургады до глубины 150 *м* — результат развития зимней конвекции.

Более сложным оказалось распределение температуры и солености воды с января на разрезе от мыса Рас-Эгела (см. рис. 3). Это обусловлено разной интенсивностью конвективного перемешивания на различных участках разреза: в западной части оно распространилось на значительно бо́льшую глубину, чем в центральной. Однако характер горизонтального распределения температуры и солености воды на разрезе остался прежним — наиболее высокая температура (23,2°) и самая низкая соленость (40,10‰) отмечались у аравийского побережья, а наименьшая температура (22,4—22,5°) и наибольшая соленость (40,30‰) — у африканского берега и в центральной части разреза.

В дальнейшем, несмотря на значительную теплоотдачу, благодаря огромному запасу тепла и поступлению более теплых вод с юга температура воды поверхностного слоя на севере Красного моря понизилась всего на 0,2—

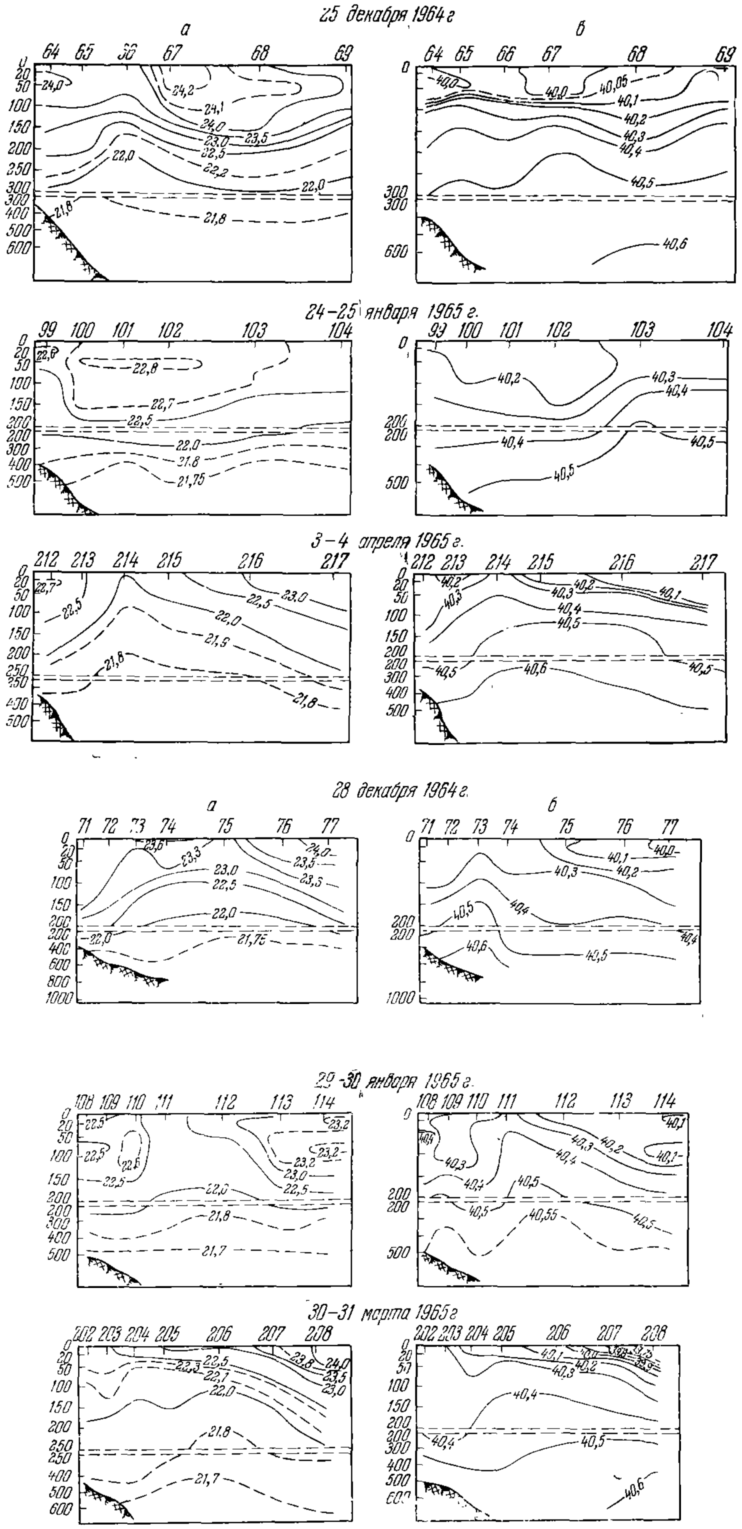

Рис. 3. Распределение температуры (*а*) и солености воды (*б*) на разрезах от г. Хургада и мыса Рас-Эгела

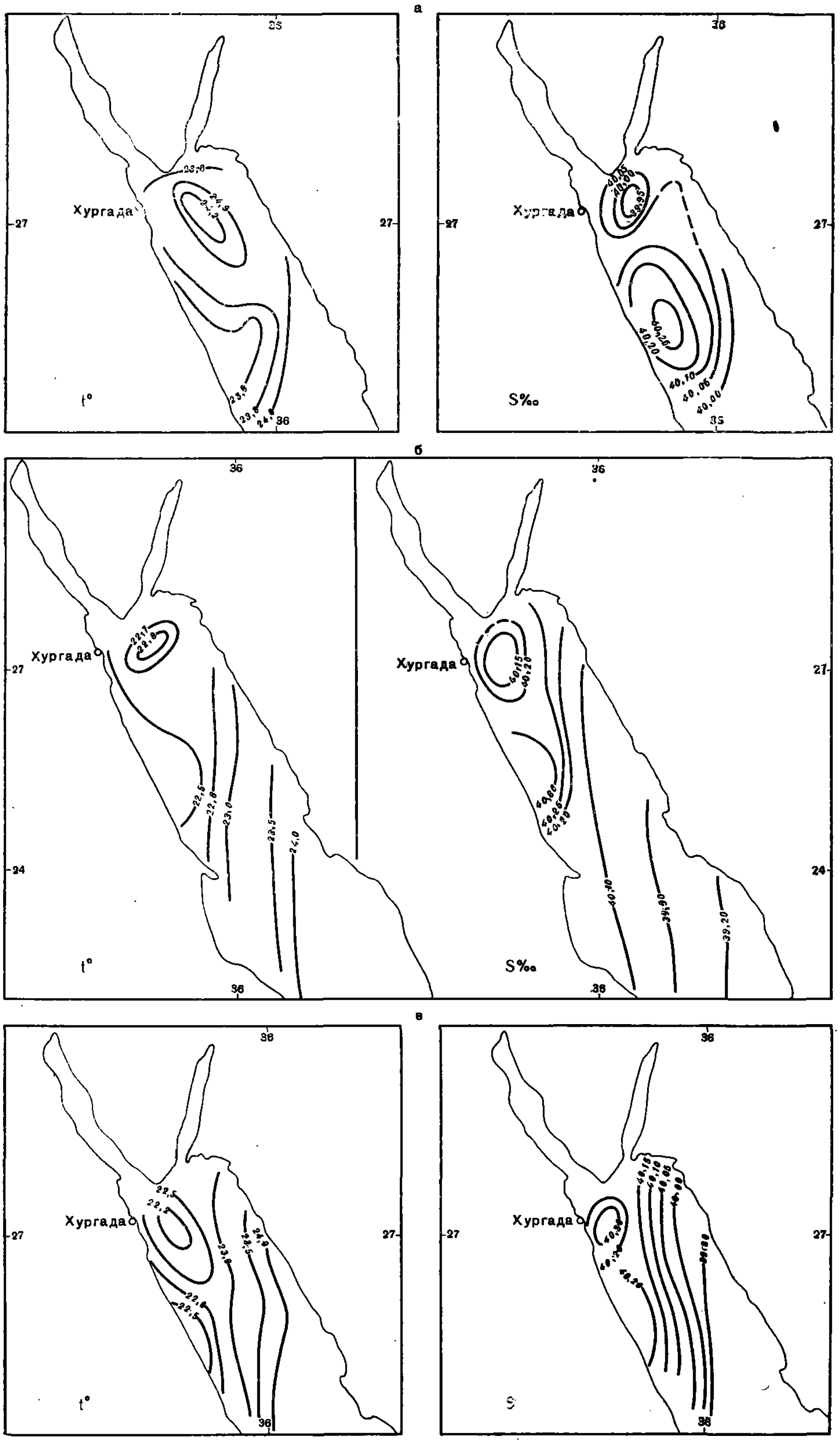

Рис. 4. Распределение температуры и солености воды на поверхности.

а — в декабре 1964 г., *б* — в январе 1965 г.; *в* — в марте — апреле 1965 г.

0,4°, достигнув своих минимальных значений к концу марта (см. рис. 4). Изменения в тепловом состоянии вод происходили в основном в более глубоких слоях воды под влиянием различных физических процессов, в частности в результате подъема более холодных глубинных вод. Последнее особенно характерно для самой северной части моря. Именно в этот период температура воды была наиболее низкой.

Значительное усиление интенсивности циклонического круговорота и смещение его центра на север в конце зимнего сезона привело к резкому изменению в распределении температуры воды и других характеристик на разрезе от Хургады в начале апреля (см. рис. 2, 3). Теперь наиболее высокая соленость (40,2—40,3‰) и минимальная температура (22,1—22,3°) наблюдались, наоборот, в центральной части разреза, а самая высокая температура (23,0°) и низкая соленость (40,01‰) — у аравийского побережья в связи с проникновением вод южного потока дальше на север (см. рис. 4).

На юге Красного моря распределение температуры и солености также хорошо согласуется с системой течений. Верхний слой воды до глубины 75—80 *м* на разрезе от Ходейды состоял из вод Аденского залива, которые в наименее трансформированном виде прослеживались в виде двух потоков — у аравийского берега и в центральной части разреза. Эти воды отличались от красноморских низкой соленостью и большим содержанием биогенных элементов. Более высокие значения солености в глубинных слоях у аравийского берега свидетельствуют о развитии циркуляции в нижних слоях южной части моря, в результате которой происходит опускание вод у африканского берега и подъем — у аравийского.

Вертикальное распределение солености в северной части моря в зимний сезон характеризовалось постепенным ее увеличением с глубиной. На юге моря, в зоне смешения аденских и красноморских вод, слой скачка солености, напротив, был выражен очень четко. Так, в феврале 1965 г. на разрезе от Ходейды значения градиентов солености в указанном слое составили 0,04—0,06‰ на 1 *м*.

Физические процессы (конвективное перемешивание, морские течения) определяли все существенные изменения в распределении океанографических элементов в Красном море в течение всего зимнего сезона, иногда искажая их сезонный ход. В частности, вместо понижения соленость верхнего слоя воды на крайнем севере моря непрерывно повышалась от декабря к апрелю (см. рис. 4).

Это повышение происходило в результате интенсивного перемешивания поверхностных вод с лежащими ниже слоями в течение большей части зимы и резкого подъема глубинных вод в конце зимнего сезона в связи с усилением интенсивности циклонического круговорота.

ОСОБЕННОСТИ ВЕРТИКАЛЬНОЙ СТРУКТУРЫ ВОДНОЙ ТОЛЩИ МОРЯ

В термодинамике вод северной части Красного моря большую роль играет зимняя конвекция, протекающая вследствие значительного охлаждения поверхностных вод. Понижение температуры воды в зимний сезон года на севере моря до 22,1—22,8° привело к увеличению условной плотности поверхностных вод на 1,5—2,0, что вызвало интенсивное развитие конвекции.

В летний сезон в северной части Красного моря на глубинах 50—75 *м* был хорошо выражен слой скачка температуры с вертикальными градиентами 0,2—0,3° на 1 *м*. Напротив, в зимний сезон 1965 г. этот слой располагался на значительной глубине, а градиенты в нем составляли всего 0,008—0,01° на 1 *м*. Вертикальные градиенты солености на севере моря также были незначительными. Уже в январе толща моря севернее 25° с. ш. была занята более или менее однородными водами до глубины 180—200 *м*. Так, на разрезе от Хургады слой скачка плотности располагался на глубинах 200—250 *м*. Причем значения вертикальных градиентов плотности в нем не превышали 0,006 v_t на 1 *м*, что свидетельствует о возможности дальнейшего развития зимней конвекции.

Глубина проникновения конвективного перемешивания в Красном море в зимний сезон 1964/65 г. уменьшалась с севера на юг и с запада на восток. На интенсивность развития конвекции большое влияние оказывали циркуляция вод и ее изменение во времени. Наибольшая глубина перемешивания на разрезе от Хургады в декабре 1964 г. (около 100 *м*) и январе 1965 г. (150—170 *м*) наблюдалась в центральной части разреза, в области антициклонического круговорота. У берегов (африканского и аравийского) в результате подъема вод она на указанном разрезе составляла в январе всего 75—90 *м*. На разрезе от мыса Рас-Эгела наиболее интенсивное перемешивание в течение всего зимнего сезона происходило в прибрежной части африканского берега, в зоне опускания вод. Наоборот, в открытых районах моря, где подъем вод в области циклонической циркуляции приводил к увеличению устойчивости слоев, глубина перемешивания была значительно меньше, чем в прибрежной зоне. Например, в декабре зимняя конвекция у мыса Рас-Эгела достигла глубины 120 *м*, а в центре разреза — всего 60—70 *м*. В январе слой перемешавшейся воды составил у африканского берега 150 *м* и у аравийского 100—120 *м*. Усиление интенсивности циклонической циркуляции в северной части моря и приток вод с юга в конце зимнего сезона привели к резкому уменьшению глубины перемешивания в центральной области северной части моря и у аравийского побережья. Однако процесс подъема вод в центре моря сопровождался активным опусканием охлажденных вод у африканского побережья (до глубины 130—140 *м* у Хургады и до 200 *м* и более у мыса Рас-Эгела).

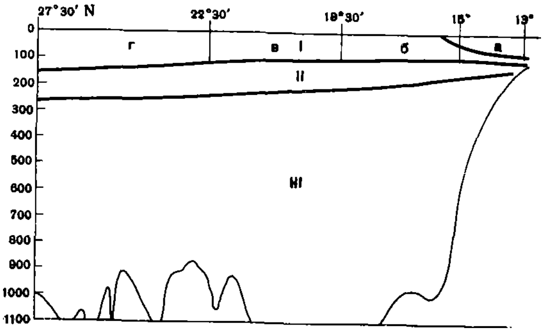

Рис. 5. Распределение водных масс в Красном море.

1 — поверхностные (а, б, в, г — разновидности водных масс); II — промежуточные ($t = 22,1°$; $S = 40,3-40,4‰$); III — глубинные ($t = 21,6-21,8°$; $S = 40,4-40,6‰$).

В процессе зимней конвекции на севере моря происходило формирование глубинной водной массы — основной водной массы Красного моря.

На основании анализа *TS* — кривых, для построения которых были использованы наблюдения на 60 станциях по всему морю, а также карт и графиков распределения гидрологических и гидрохимических характеристик, в Красном море выделяются три основных типа водных масс (рис. 5).

1. **Поверхностные воды**, которые вследствие существенных различий физико-химических характеристик можно подразделить на несколько подтипов, различных по происхождению и свойствам.

Трансформированные воды Аденского залива (см. рис. 5,Iа) характеризуются наиболее низкой соленостью (менее 38,5‰)

и сравнительно высокой температурой 24,0—24,8°. По химическим показателям они отличаются от красноморских вод более высоким содержанием биогенных элементов. К северу трансформированные воды все более смешиваются с водами Красного моря. При этом происходит повышение их солености и обеднение биогенными элементами. В результате в южной части Красного моря формируется *южная поверхностная водная масса*, соленость которой не более 39,5‰, температура выше 24,6° (см. рис. 5, Iб), в средней части моря — *центральная поверхностная вода*: соленость 39,5—40,2‰, температура выше 23,6° (см. рис. 5, Iв), а на севере — *поверхностная вода северных районов моря* (см. рис. 5, Iг). Соленость ее меняется от 40,0 до 40,4‰, температура воды — от 23,5 до 22,5°. В период наиболее интенсивного развития зимней конвекции эта вода по своим характеристикам приближается к глубинной. Наоборот, в летний сезон различия между поверхностной водой северных районов и глубинной очень значительны (особенно по температуре).

2. **Промежуточная водная масса** зоны смешения выделяется как переходная между поверхностными и глубинными водами. В направлении к югу мощность ее постепенно уменьшается.

3. **Глубинная красноморская водная масса** отличается высокой соленостью (свыше 40,4‰) и несколько меньшей температурой 22,0°. На ее долю приходится не менее 75% объема вод Красного моря. Глубинные воды не только играют большую роль в режиме Красного моря, но и оказывают определенное влияние на формирование промежуточных слоев Аденского залива и Индийского океана. Им свойственна большая однородность, что свидетельствует об их слабой трансформации при движении на юг.

Особый интерес в Красном море представляют воды глубоководных впадин, где водообмен с лежащими выше слоями протекает с очень незначительной скоростью. Так, «Atlantis II» в 1963 г. в средней части моря обнаружил в придонном слое (на глубине 2000 *м*) воду с соленостью 43,18‰ и температурой 25,76° [11, 12], а «Discovery» в 1964 г. примерно в том же районе зарегистрировал соленость 270‰ и температуру 44° [13]. Экспедицией на «Метеоре» в 1964 г. [14] также получены необычно высокие значения температуры (45°) и солености воды (300‰). Столь аномальное явление обусловлено, по-видимому, процессами, протекающими в пограничном слое вода — грунт. Таким образом, в Красном море можно выделить также **придонные воды** глубоководных впадин, исключительные по своим температурносолёностным характеристикам.

ВЫВОДЫ

1. В формировании океанографического режима вод северной части Красного моря большую роль играют течения и конвективное перемешивание. Суммарные течения Красного моря формируются под действием нескольких факторов. В открытых районах моря в них преобладают ветровые и постоянные течения, приливо-отливные имеют второстепенное значение. Основной поток, возбуждаемый на юге господствующим юго-юго-восточным ветром, по мере продвижения на север образует систему круговоротов циклонического и антициклонического характера. В северной части моря динамическая обстановка в течение большей части зимнего сезона определяется наличием двух основных круговоротов — антициклонического на севере и циклонического — на юге.

2. Система суммарных течений северной части Красного моря в зимний сезон подвержена существенным изменениям во времени, которые приводят к изменениям в распределении океанографических элементов.

3. В зависимости от интенсивности южного потока и местоположения основных круговоротов в северной части Красного моря в течение зимнего

сезона 1964/65 г. менялось и распределение температуры и солености воды. В декабре и январе воздействие южиого потока вод на характер распределения гидрологических элементов не прослеживалось севернее 27° с. ш. Усиление проникновения этих вод на север моря вплоть до залива Акаба привело в конце зимнего сезона к повышению температуры воды и существенному понижению солености в прибрежной зоне аравийского побережья.

4. В северной части Красного моря в зимний сезон 1964/65 г. большую роль играла конвекция, в результате которой происходило формирование глубинной водной массы и обогащение трофического слоя моря биогенными элементами. Наибольшая глубина распространения конвективного перемешивания (200 *м* и более) наблюдалась у африканского побережья и на крайнем севере моря.

5. Анализ *TS*-кривых, выполненный на основании данных 60 станций, позволяет выделить в Красном море три основные водные массы: поверхностную, промежуточную массу зоны смешения и глубинную. Первая из них включает несколько подтипов: трансформированные воды Аденского залива, южная поверхностная вода, центральная поверхностная вода, поверхностная вода северной части моря. Особый интерес в Красном море представляют придонные воды глубоководных впадин.

ABSTRACT

Some problems of seasonal changes of hydrometeorological characteristics, currents and their influence on the distribution of oceanographic elements, vertical structure of the water column of the Red Sea are considered.

On the basis of used materials the following is given in this article:

a. analysis of seasonal variability of the hydrometeorological elements;
b. characteristic of the dynamic processes, such as currents, winter convection;
c. classification of the water masses of the Red Sea.

The scheme of the currents in the surface layers in the north of the Red Sea was defined by the presence of two water circulations, i. e. steady cyclonic and unsteady anticyclonic, position of which undergoes considerable displacement during winter season. In the south of the Red Sea two-layered circulation of the waters of reverse nature was observed. The winter vertical circulation forming the deep water mass plays a great role in the water dynamis of the northern part of the Red Sea. Analysis of the TS curves allowed to mark out three main types of the water masses in the Red Sea:

deep;
intermediate,
surface.

The latter can be divided into the following subtypes: the winter surface water of the northern regions of the Sea; central surface water; south surface water, and transformed water of Aden Gulf.

The near-bottom waters of the deeps are of special interest in the Red Rea.

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Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 215-232

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ГИДРОХИМИЧЕСКИЕ УСЛОВИЯ КРАСНОГО МОРЯ В ЗИМНИЙ СЕЗОН 1964/65 г. И НЕКОТОРЫЕ ОСОБЕННОСТИ ИХ ИЗМЕНЕНИЙ

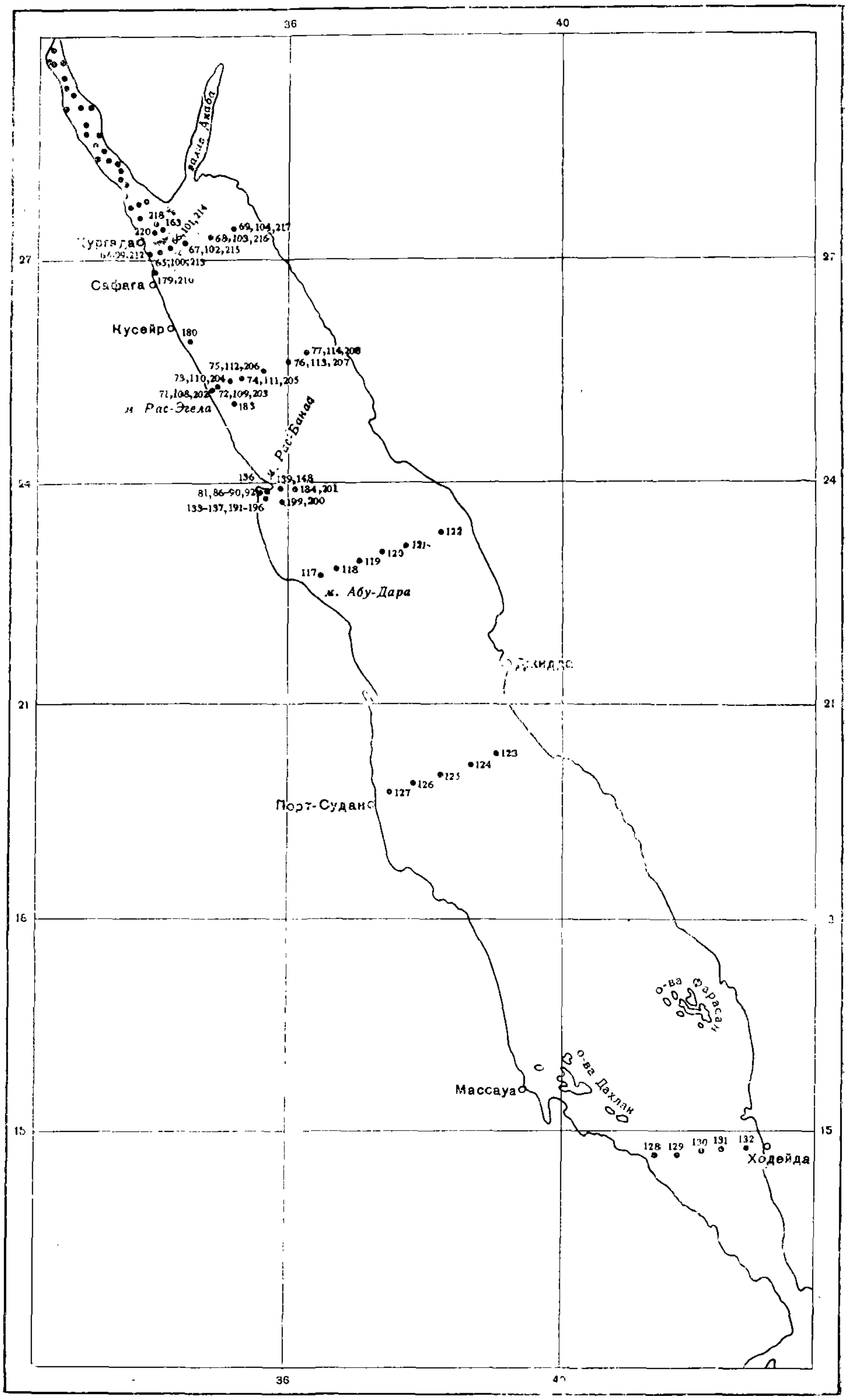
В данной статье излагаются результаты гидрохимических наблюдений 2-й Красноморской экспедиции АзЧерНИРО с ноября 1964 г. по апрель 1965 г., которые проводились на пяти поперечных разрезах; два из них выполнены по три раза (рис. 1). Пробы воды брались батометрами БМ-48; отбор проб из батометров начинался сразу же по поднятии их на борт.

В комплекс работ входило определение растворенного в воде кислорода по методу Винклера с расчетом процентов насыщения, по Трусдейлу; определение фосфатного фосфора, по Дениже—Аткинсу, и кремнекислоты, по Диэнеру и Ванденбульке. Определения осуществлялись в лаборатории при температуре воздуха 25°; при этом для фосфатов и кремнекислоты использовались стандарты на дистиллированной воде. В результате анализов вводились солевые поправки, полученные экстраполяцией табличных данных Бруевича и Красновой для фосфатов и данных Бруевича и Блинова для кремнекислоты [1, 2]. Для кремнекислоты приняты значения следующих поправочных коэффициентов: 1,75 при $S = 39‰$; 1,79 при $S = 40‰$; 1,83 при $S = 41‰$; для фосфатов при тех же значениях солености воды коэффициенты приняты равными 1,36; 1,37 и 1,38 соответственно. Калориметрирование производилось сериями (по 4—5 проб в каждой) визуально в цилиндрах Генера объемом 50 *мл* и высотой 25 *см*. Точность определений, естественно, несколько понижена. К сожалению, осуществить достаточно строгую и широкую проверку точности мы не имели возможности, однако двукратные анализы некоторых проб давали расхождения в отсчетах порядка 10%, что с учетом солевых поправок соответствует 15% для фосфатов и примерно 20% для кремнекислоты. Разумеется, эти цифры характеризуют лишь воспроизводимость результатов определений, а не их точность.

Кроме перечисленных анализов на большинстве станций определялись нитритный азот по методу Грисса-Илосвая со стандартами на морской воде, а также окисляемость морской воды на каждой третьей станции в нейтральной среде, по Б. А. Скопинцеву.

ДИНАМИКА ВОД КАК ОСНОВНОЙ ФАКТОР ФОРМИРОВАНИЯ РЕЖИМА КРАСНОГО МОРЯ

Гидрохимический режим Красного моря формируется динамикой его вод, а также его географическим положением. С одной стороны, в Красном море с его исключительно высокой температурой водной толщи [3] все биологические и биохимические процессы идут повсеместно и почти круглогодично с очень высокой скоростью. С другой стороны, это море полностью лишено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пополнения биогенными элементами, приносимого речным стоком. В таких условиях основную роль в пополнении биогенной базы продуктивного слоя моря играет водобмен через Баб-эль-Мандебский пролив [4] и конвективное перемешивание поверхностных вод с более богатыми биогенами глубинными водами. Обмен через Баб-эль-Мандебский пролив, без сомнения, полностью формирует биогенную базу продуктивного слоя в южной части Красного моря, особенно в период юго-восточных ветров с октября по апрель [5]. Северные районы моря лишены этого источника. Здесь большую роль играет водообмен с лежащими ниже слоями.

В зимний период объем вод, поступающих в Красное море из Аденского залива, несколько уменьшается, однако проникновение их на север идет более активно и достигает более высоких широт, поскольку в это время над южной частью моря господствуют юго-восточные ветры.

Наблюдения второй Красноморской экспедиции АзЧерНИРО дают возможность представить схему течений средней и северной частей моря рядом сопряженных круговоротов: антициклонических — между 20 и 25° с. ш. и в северо-восточном углу моря и циклонического круговорота, находящегося между ними [1].

Экспедиция работала в период охлаждения моря, во время усиления и максимального развития конвективного перемешивания. Естественно, что наиболее глубоко оно проникало в северной части Красного моря и особенно в северо-западной. В северо-восточном углу моря, защищенном Синайским полуостровом от сильных холодных ветров с севера и северо-запада, процессы зимней конвекции проникали менее глубоко (метров на 50 меньше, чем на северо-западе). В целом по морю перемешивание достигало несколько бóльших глубин у африканского берега, что вполне естественно при наличии здесь холодного северного потока. Далее к югу глубина перемешивания уменьшалась и уже на широте г. Порт-Судан не превышала 50 *м*, тогда как в северо-западной части моря она достигала 250 *м* и более.

РАСПРЕДЕЛЕНИЕ ГИДРОХИМИЧЕСКИХ ЭЛЕМЕНТОВ В КРАСНОМ МОРЕ В ЯНВАРЕ — ФЕВРАЛЕ 1965 г.

На рис. 2—4 представлены результаты гидрохимических наблюдений на пяти разрезах поперек Красного моря (см. рис. 1). Было выявлено распределение кислорода, фосфатов кремния, нитратов, а также определена окисляемость морской воды.

Кислород. Распределение кислорода в плоскости разрезов в верхнем пересыщенном слое довольно сложно. Общей особенностью всех разрезов является наличие «слоистого» распределения кислорода в 10-мильной прибрежной зоне. Здесь, как правило, на глубинах 20—30 и 60—80 *м* содержание его было пониженным. По нашему мнению, это вызвано повышенным расходом кислорода на окисление органического вещества. Именно на этих горизонтах отмечались небольшие скачки плотиости воды, способствовавшие накоплению органического материала.

Отдельные «пятна» в распределении кислорода вызваны определенными динамическими причинами. Так, максимум в средней части разреза от г. Хургада (см. рис. 2) и максимум у африканского берега на разрезе от

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[1] Более подробно вопрос о течениях Красного моря изложен в статье В. А. Бибика, опубликованной в настоящем сборнике.

Рис. 1. Схема расположения разрезов и станций 2-й Красноморской экспедиции АзЧерНИРО, ноябрь 1964 — апрель 1965 г.
В Суэцком канале выполнены станции 38—59, 152—161, 223—234

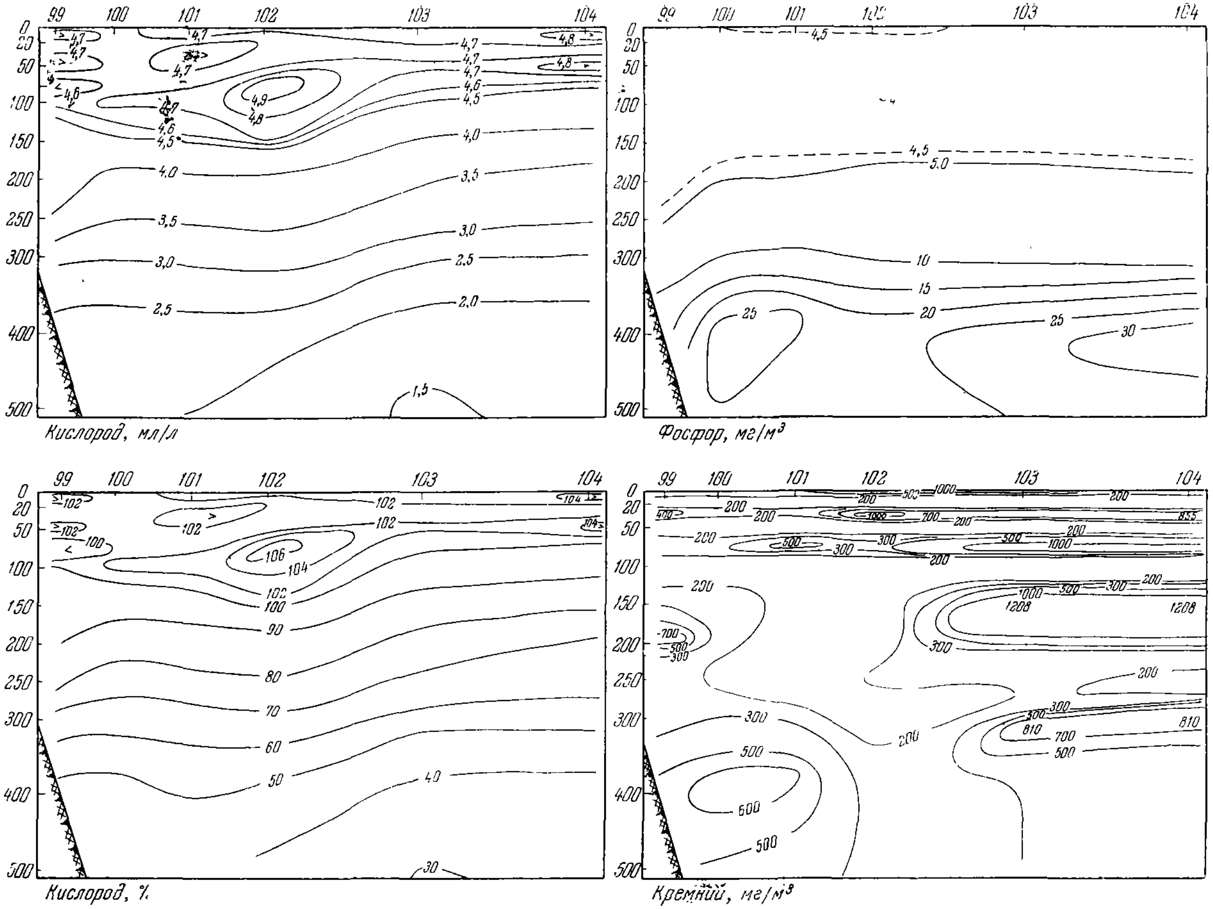


Рис. 2. Распределение гидрохимических элементов на разрезе от г. Хургада 24—25 января 1965 г.

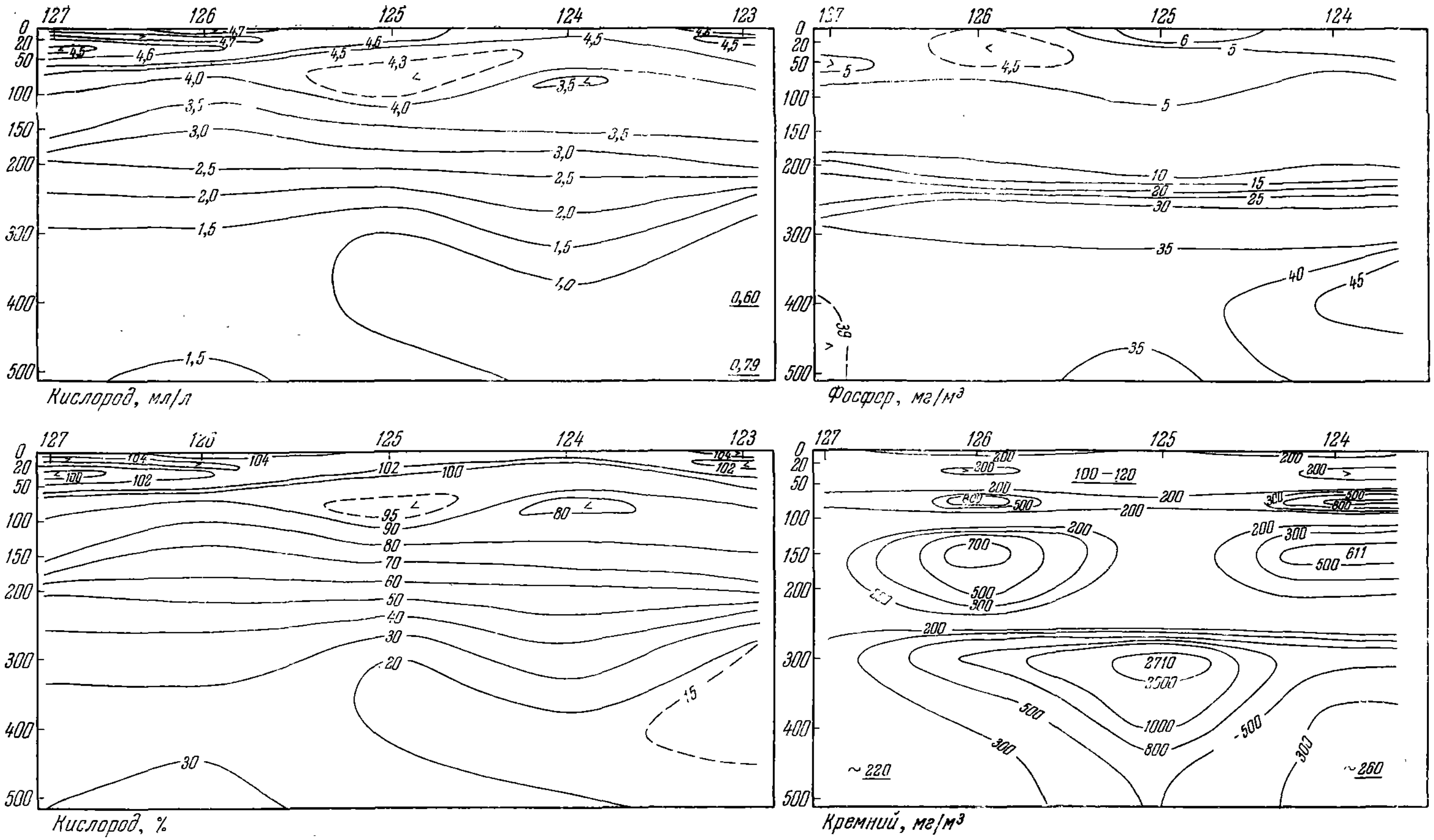
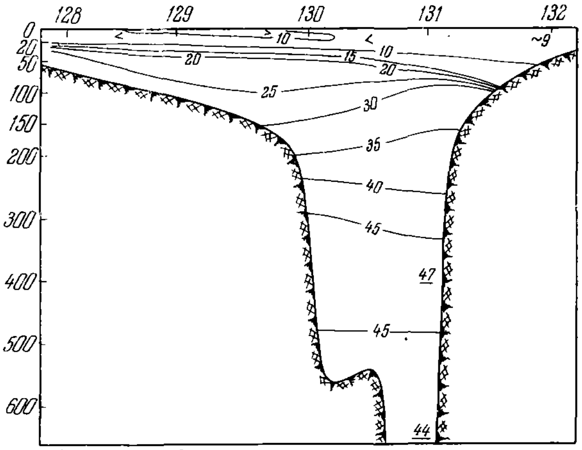
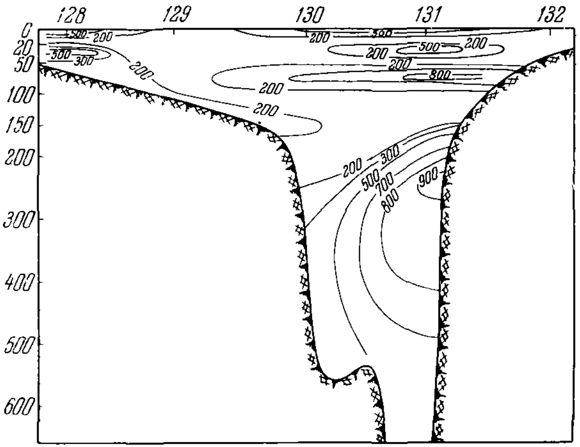


Рис. 3. Распределение гидрохимических элементов на разрезе от г. Порт-Судан 3—4 февраля 1965 г.



Фосфор, мг/м³

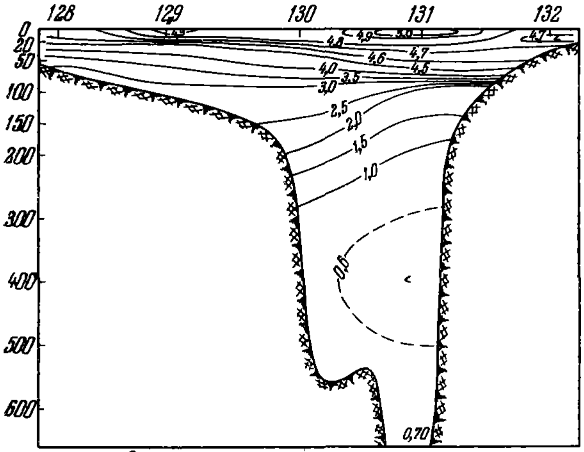


Кремний, мг/м³

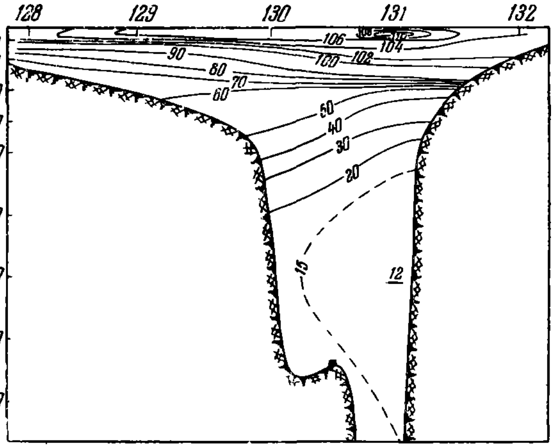
Рис. 4. Распределение гидрохимических элементов

мыса Рас-Эгела располагаются в центрах антициклонических круговоротов, где наблюдается опускание вод. В обеих зонах отмечались повышенные скопления планктона. Минимумы кислорода на разрезах от мыса Абу-Дара и от г. Порт-Судан (см. рис. 3) были в струе вод, идущей с юга. Максимум кислорода на разрезе Массауа — Ходейда (станция 131) имеет биологическое происхождение. Он вызван вспышкой развития фитопланктона на линии контакта вод различного происхождения.

Мощность слоя, пересыщенного кислородом, изменялась как от берега к берегу, так и с севера на юг. В приафриканской половине моря этот слой располагался на глубине 150—160 *м* у Хургады и мыса Рас-Эгела, на 100—110 *м* — у мыса Абу-Дара, на 65 *м* — у Порт-Судана и на 25 *м* у Массауа. В приаравийской части эти величины составляли 70—80 *м* на севере, 90—100 *м* — у мыса Абу-Дара, 50 *м* — у Порт-Судана и 60 *м* — у Ходейды. Наименьшая мощность продуктивного слоя отмечалась в удалении от берегов, в центральных участках моря: 50 *м* — у мыса Рас-Эгела, 40 *м* — у мыса Абу-Дара и всего 20 *м* — у Порт-Судана, что обусловлено динамическими причинами (подъемом вод в центрах циклонических круговоротов и в зонах дивергенции струй течений).



Кислород, мл/л



Кислород, %

на разрезе Массауа — Ходейда 6—7 февраля 1967 г.

Степень пересыщения вод кислородом (расчет насыщения осуществлялся по Трусдейлу) повсюду была небольшой. В большинстве случаев она составляла 2—3%. Максимальные величины отмечались в виде отдельных пятен (разрез от г. Хургад) или в виде тонких поверхностных и подповерхностных слоев (остальные разрезы). При этом степень пересыщения воды в «ядрах» максимумов составляла у Хургады и у мыса Рас-Эгела — 6%, у мыса Абу-Дара — 8%, у Порт-Судана — 5% (станции 126, 127) и на разрезе Массауа — Ходейда 10% (станция 131).

На всех разрезах пересыщение поверхностной воды в прибрежной зоне было несколько увеличенным, что, по-видимому, объясняется большей продуктивностью фитопланктона в этой зоне, поскольку скорости течения и степень волнения здесь меньше, чем вдали от берега.

Распределение кислорода ниже зоны пересыщения было более однообразным и полностью обусловлено структурой водных масс и активностью процессов вертикального перемешивания. Характерной особенностью распределения кислорода является его минимум на глубинах 300—500 *м* в приаравийской половине моря, причем глубина его залегания и величины концентраций на севере (разрезы от г. Хургада и мыса Рас-Эгела) значительно превосходили таковые на юге. Наименьшая концентрация отмечалась на горизонте 400 *м* (около 0,5 *мл/л*, или 15%) на последних станциях трех южных разрезов. Существование данного минимума в Красном море известно со времен экспедиции Джона Муррея. Томсон [6, 7] объясняла его существование вертикальной циркуляцией вод, которая зимой связана с опусканием поверхностных вод в северной части моря, и подъемом вод у порога на юге. По нашим материалам ясно видно, что слой с минимальным количеством кислорода наиболее развит у аравийского берега как на севере, так и на юге. Характер его залегания в плоскостях всех разрезов тоже одинаков. Разница заключается лишь в абсолютных значениях насыщения. Изоксигена 1,5 *мл/л* на севере появляется в плоскости разреза только в нижнем правом углу, у мыса Абу-Дара она очерчивает уже больше половины плоскости слоя в 250—500 *м*, а у Порт-Судана и южнее отсекает всю нижнюю часть графиков (см. рис. 2, 3). Такой характер залегания слоя минимума было бы правильнее объяснить различием в степени вентиляции вод в различных районах моря. Как уже упоминалось, глубина перемешивания уменьшается с севера на юг и достигает наибольших значений у африканского берега; это и обусловливает прогиб изолиний на западных половинах разрезов. Так что более логично объяснять различную глубину залегания слоя с минимальным содержанием кислорода различной интенсивностью вертикального перемешивания вод в отдельных районах, а также наличием поперечной циркуляции, включающей скопление и опускание охлажденных вод у африканского берега и перенос их на глубине 600—800 *м* на восток с постепенной потерей кислорода. Подъем глубинных вод у аравийского берега не вызывает размыва зоны минимума кислорода, так как концентрация кислорода в поднимающейся воде не превышает 1,0—1,5 *мл/л*. Кроме того, мы не исключаем и наличия круговорота вод, упоминаемого Томсон, однако считаем, что основным следствием круговорота являются особенности положения изолиний гидрохимических элементов в плоскости продольного разреза и, в частности, резкий подъем изолиний в южной части моря, перед проливом. Сам же слой минимума возник в связи с окислением остатков органического вещества, падающего сверху сквозь водную толщу. В тропических водах распад органического вещества заканчивается обычно в слое 600—1000 *м*, куда измельченные остатки организмов доходят со скоростью, не превышающей $^1/_{10}$ от скорости падения в начале пути [8]. В Красном море благодаря очень высокой температуре воды регенерация органики происходит, по всей вероятности, несколько быстрее, поэтому и слой минимума кислорода располагается на глубине около 400 *м*.

Наблюдавшиеся зимой 1964/65 г. концентрации кислорода в глубинах Красного моря, составлявшие в слое минимума около 0,6 *мл/л*, намного ниже тех, на которые указывала Томсон, считавшая, что к концу зимы концентрация кислорода на всех глубинах моря превышает 2 *мл/л*, а значения меньше 1 *мл/л* свойственны лишь концу летнего периода. Концентрация кислорода более 2 *мл/л* на глубинах 300—500 *м* не обнаружена нами даже в приафриканской части моря, где слой минимума кислорода был практически полностью размыт процессами перемешивания. Полученные нами данные в сопоставлении с результатами 1-й Красноморской экспедиции АзЧерНИРО в летне-осенний период 1963 г. и с материалами судов погоды за 1959 и 1960 гг. [9, 10] позволяют сделать предположение, что амплитуда годовых колебаний кислорода в слое минимума не превышает 0,3—0,5 *мл/л*. Эта величина в 2—3 раза меньше приводимой Томсон, что указывает на несколько меньшую, чем это предполагалось, роль зимней конвекции в обогащении кислородом нижних слоев воды. Однако с принципиальной точки зрения данное уточнение не противоречит существующим в настоящее время представлениям, согласно которым Красное море относится к морям тропических широт с достаточно хорошо аэрируемыми глубинами. Только благодаря интенсивному вертикальному обмену компенсируется активное биохимическое потребление кислорода в глубинах этого моря.

Распределение кислорода на глубинах 100—300 *м* характеризовалось довольно равномерным уменьшением его содержания с глубиной до 1,5—2,0 *мл/л*.

В плоскости разреза, идущего с севера на юг вдоль продольной оси моря, распределение кислорода аналогично распределению его в плоскости поперечных разрезов от мыса Абу-Дара и от г. Порт-Судан, если принять приаравийскую часть этих разрезов за юг, а приафриканскую — за север. Разница заключается только в том, что на южной части продольного разреза все изолинии резко поднимаются вверх, свидетельствуя о подъеме глубинных вод по мере приближения их к порогу перед Баб-эль-Мандебским проливом.

Фосфаты. Общий характер распределения фосфатов в Красном море ниже зоны активного фотосинтеза во многом схож с распределением кислорода. На глубинах более 300 *м* ход изолиний фосфатов на разрезах почти повторяет ход изоксиген. Столь разительное сходство возможно объяснить лишь единством причин, формирующих распределение кислорода и фосфатов в глубинах Красного моря.

Основным фактором, влияющим на распределение кислорода, является вертикальное перемешивание. Распределение фосфатов наряду с этим связано с характером распределения водных масс и степенью потребления фосфатов фитопланктоном. По распределению фосфатов на разрезах отчетливо выделяются три слоя. В верхнем, содержащем минимальное количество фосфатов, основным фактором, формирующим их распределение, является потребление их фитопланктоном. На разрезах (см. рис. 2, 3) этот слой обозначается величинами около 4,0—4,5 *мг*P/*м*^{3}. Мощность слоя малых концентраций фосфатов уменьшалась со 170 *м* на разрезе от г. Хургада до 130—120 *м* у мыса Рас-Эгела и мыса Абу-Дара и до 90 *м* — у Порт-Судана. На аравийской половине разреза от г. Порт-Судан содержание фосфатов в верхних слоях увеличивалось, что объясняется влиянием вод, пришедших с юга, из Аденского залива. Концентрация фосфатов в аденских водах у входа в Красное море (разрез Массауа — Ходейда) составляла 10 *мг/м*^{3} на поверхности и 30 *мг/м*^{3} на глубине 75—100 *м*.

Ниже слоя минимума залегали воды с содержанием фосфатов 5—10 *мг/м*^{3}. Увеличение его в этом слое с глубиной шло равномерно. Это слой залегания промежуточной водной массы. Она, как и глубинная вода, образуется в северной части Красного моря, но характеризуется меньшей степенью охлаждения и осолонения. От лежащих выше вод ее отличает отсутствие активного потребления фосфатов планктоном, а от лежащих ниже — наличие активного вертикального перемешивания, вызываемого течениями. Мощность данного слоя составляла 100—150 *м*. Некоторое уменьшение мощности промежуточных вод в районе мыса Абу-Дара было вызвано, по всей видимости, скоплением поверхностных вод в антициклоническом круговороте. Южнее 18° с. ш. промежуточные воды «выклинивались», вытесняемые поднимающимися глубинными водами, уходящими в Аденский залив. В нижних слоях промежуточной водной массы глубина залегания одноименных изолиний фосфатов уменьшалась с продвижением на юг на 100—120 *м*; одновременно уменьшалось и содержание кислорода на соответствующих горизонтах. Все это указывает на бóльшую аккумуляцию фосфатов в глубинах южной части моря и на «старение» промежуточных вод по мере распространения на юг, вызываемое потерей кислорода на биохимические процессы.

На нижней границе слоя промежуточных вод отмечался резкий скачок содержания фосфатов с 10 *мг/м*^{3} до 20,25 и даже 30 *мг/м*^{3}. Здесь промежуточные слои соприкасаются с глубинными водами.

Значения концентрации фосфатов в глубинной воде составляли более 20 *мг/м*^{3} с максимумами в слоях минимального содержания кислорода (до

30, 40 и 45 *мг*P/*м*^{3}), причем больше всего фосфатов было в южной половине моря. Приведенные цифры несколько ниже значений концентрации фосфатов, обычных для тропических вод на глубинах залегания слоя минимума кислорода. Данный факт следует объяснить большей степенью вентиляции глубин Красного моря по сравнению с другими морями тропического пояса. Возможно, что некоторую роль играет здесь и вынос наиболее богатых фосфатами глубинных вод через порог в Аденский залив.

Кремний. Характер распределения кремния в Красном море в осенне-зимний период 1964/65 г. был наиболее сложным и отличался от характера распределения кислорода или фосфатов. Наиболее существенной деталью при этом явилось наличие «слоистости». На соседних горизонтах одной и той же станции наблюдались величины концентраций кремнекислоты менее 200 *мг/м*^{3} и более 1000 *мг/м*^{3}. При внимательном рассмотрении графиков (см. рис. 2—4) обнаруживается, что максимальные концентрации кремния на станциях отмечались обычно на одних и тех же горизонтах, будь то станция в прибрежной зоне или же в центральных частях моря. Такая закономерность является, с одной стороны, следствием дискретности наших наблюдений, с другой — указывает на то, что мощности слоев максимальных содержаний кремнекислоты не превышают расстояния между стандартными горизонтами. Сохранение аналогичного характера распределения во всех частях моря заставляет предположить наличие одних и тех же причин возникновения таких слоев.

Первый максимум отмечался в поверхностном слое моря. Он, без сомнения, связан с выносом материковой пыли, содержащей кремнекислоту.

Появление максимума кремнекислоты на глубине 30 *м* вызвано, вероятно, наличием небольшого скачка плотности на нижней границе слоя активного ветрового перемешивания, усиленного конвективными токами. Здесь существенно замедляется скорость падения наиболее мелких отмерших организмов, а также некоторых фракций пыли, что и приводит к повышению концентрации растворенной кремнекислоты. Разрывы в слое максимума (разрезы от мыса Абу-Дара и от г. Порт-Судан) следует отнести за счет активного потребления кремнекислоты фитопланктоном.

Нижняя граница слоя активного фотосинтеза, характеризующаяся прежде всего интенсивным распадом органического вещества и подстилаемая слоем максимальных вертикальных градиентов плотности (связанных, по нашему мнению, с резким затуханием скоростей дрейфового потока) является одновременно и верхней границей третьего по счету максимума в распределении кремнекислоты. Данный максимум выражен наиболее отчетливо и повсеместно. Наибольшие концентрации кремнекислоты в нем, как правило, отмечались на некотором удалении от берега (станции 101, 126, 131).

Следующий по глубине максимум кремнекислоты приходится на довольно мощный слой на глубинах 130—220 *м*. Характер и глубина залегания слоя максимума позволяют объяснить его образование ограниченностью глубины проникновения конвективно-турбулентного перемешивания.

В зоне контакта промежуточной и глубинной водных масс существует еще один максимум кремнекислоты на глубине около 300 *м*. Он отчетливо выражен во всех районах моря, хотя и с некоторым ослаблением на центральных участках, но характер его залегания на севере и на юге был различным. Если в северной части (см. рис. 2) толщина этого слоя не более 100 *м*, то южнее Порт-Судана он занимал глубины от 250 до 500 *м* и больше. В том же направлении увеличивались и концентрации кремнекислоты в «ядрах» слоя.

Нитриты. Являясь промежуточным звеном в цепи перехода соединений азота органического вещества к потребляемой планктоном форме соединений — нитратам, нитриты могут служить косвенным показателем продукции планктона. Как правило, они встречаются ниже слоя активного фотосинтеза на глубинах с высокими значениями вертикального градиента плотности воды.

В январе — феврале 1965 г. нитриты в Красном море обнаружены в слое 50—100 *м*. Величины концентраций их обычно составляли 1—2 *мг/м*^{3}, лишь редко достигая 5 *мг/м*^{3}, за исключением района Массауа — Ходейда (30 *мг*N/*м*^{3}). В приафриканской части разреза воды, идущие из Аденского залива, имели аномальное количество нитритов в слое 10—120 *м*. В направлении к Ходейде мощность слоя вод с нитритами и их концентрация быстро уменьшались и на станции 131 они отмечались лишь на горизонте 75 *м*. Высокое содержание нитритов в морях встречается довольно редко, обычно в период массовых вспышек развития планктона, образующего большие скопления минерализующегося органического вещества ниже зоны активного фотосинтеза. Принесено ли в данном случае органическое вещество из Аденского залива или же его происхождение связано с местными биологическими процессами — ответить пока трудно. По нашему мнению, более правильным следует считать первое предположение. Относительно моря в целом следует заметить, что, хотя небольшая концентрация нитритов и обычна для слоя, лежащего ниже зоны фотосинтеза, все же в зимний период они, как правило, не наблюдаются. По этой причине Красное море следует отнести к таким морям, в которых продуцирование планктона происходит в течение всего года. В январе — феврале мощность слоя воды с нитритами в северной части моря была больше, чем в средней его части. Возможно, что это связано с меньшей скоростью минерализации органического вещества и более активными вертикальными потоками вод, размывающими слой интенсивного окисления органики.

Окисляемость морской воды. Одной из отличительных особенностей вод Красного моря является низкое содержание органического вещества [6, 7]. Такое положение вполне объяснимо очень высокой температурой воды, способствующей быстрому распаду органического вещества. Наши исследования в зимний период 1964/65 г. подтверждают это мнение. Ни на одном разрезе нами не отмечались значения окисляемости более 0,6 *мл*O$_2$/*л*, в основном они колебались около 0,40 *мл*O$_2$/*л*. Наибольшей она была в прибрежном районе мыса Абу-Дара. Здесь окисляемость всего слоя воды до 150 *м* составляла более 0,50 *мл*O$_2$/*л*, а выше 100 *м* — более 0,60 *мл*O$_2$/*л*. В этом районе величины порядка 0,45 *мл*O$_2$/*л* наблюдались нами до глубин 500 *м*, тогда как южнее и севернее — не ниже 100 *м*. В центральных участках моря довольно отчетливо прослеживалось увеличение окисляемости на горизонте 30 *м* до 0,46—0,49 *мл*O$_2$/*л*, совпадающее с одним из максимумов в распределении кремнекислоты.

Глубинная водная масса обычно характеризовалась величинами окисляемости менее 0,30 *мл*O$_2$/*л*, а на самом юге моря — даже менее 0,20 *мл*O$_2$/*л*. В то же время в приафриканской половине северной и средней частей моря окисляемость глубинной воды менее 0,30 *мл*O$_2$/*л* встречалась сравнительно редко. Для промежуточной водной массы наиболее характерны значения 0,30—0,35 *мл*O$_2$/*л*, с некоторым повышением в прибрежных участках в средней и северной частях моря.

ИЗМЕНЕНИЕ ГИДРОХИМИЧЕСКИХ УСЛОВИЙ СЕВЕРНОЙ ЧАСТИ КРАСНОГО МОРЯ В ЗИМНИЙ СЕЗОН 1964/65 г. В СВЯЗИ С ИЗМЕНЕНИЯМИ ДИНАМИКИ ВОД

Объектом наиболее тщательного исследования 2-й Красноморской экспедиции АзЧерНИРО была северная часть Красного моря. В этой части моря экспедиция неоднократно повторяла комплекс своих работ. Гидрологический и гидрохимический режим контролировался работами на двух разрезах: от г. Хургада и от мыса Рас-Эгела. Разрезы выполнялись 25—28 декабря 1964 г., 24—30 января и 30 марта — 4 апреля 1965 г. Полученные данные позволяют проследить изменения океанологических условий северной части Красного моря с начала и до конца зимнего периода 1964/65 г.

Как показывает предварительный анализ результатов наблюдений, динамическая обстановка в районе не только обусловливает общий характер распределения гидрохимических элементов, но и в значительной степени определяет все основные изменения в этом распределении. Наиболее отчетливо такая зависимость проявляется на глубинах более 200 *м*. Некоторым подтверждением данного положения могут служить изменения в структуре вод на разрезе Массауа—Ходейда, вызываемые сменой ветровой деятельности. Летом 1963 г. [11] максимум фосфатов 40—45 *мг/м*^{3} отмечался лишь в слое 50—150 *м* на приаравийской половине разреза. В основной же массе вод на глубине было не более 10—20 *мг*P/*м*^{3}. Зимой 1964/65 г. вся толща вод ниже 250 *м* содержала более 40 *мг*P/*м*^{3}. Такая перестройка в распределении фосфатов связана со значительным уменьшением подъема и выхода глубинных вод из Красного моря в летне-осенний период, из-за усиления притока аденских вод, вызываемого повышенным испарением в Красном море и выносом его вод в Аденский залив с дрейфовым потоком.

Изменение динамической обстановки на глубине 300—500 *м* в период работы экспедиции характеризовалось прежде всего постепенным усилением циклонического круговорота в северо-западном углу моря. В соответствии с этим происходило накопление глубинных вод в северной части Красного моря. Если в декабре вода, содержащая менее 2,0 *мл/л* кислорода, около Хургады встречалась в среднем лишь на глубине 450 *м*, а у мыса Рас-Эгела — на глубинах более 400 *м*, то в апреле — на 350 и 300 *м* соответственно (рис. 5). В результате глубины северной части моря в зимний период 1964/65 г. не только не обогатились кислородом, что должно было бы произойти вследствие усиления вертикальной конвекции, а даже «потеряли» 1 *мл/л* в южной половине района и 1,0—1,5 *мл*O_2/*л* (до 1,8 *мл/л*) — в северной. Параллельно снижению концентраций кислорода шло увеличение содержания фосфатов. На севере оно составляло 5—10 *мг/м*^{3} и даже более, а у мыса Рас-Эгела — не превышало 5 *мг/м*^{3}. Циклонический характер движения вод на глубине обусловил куполообразную форму верхней границы глубинной водной массы в центральной части моря. Этому способствовало направление идущих вблизи от берегов течений верхних слоев моря. В связи с этим содержание кислорода в глубинных слоях прибрежной зоны возросло с декабря по апрель в среднем на 0,5—0,8 *мл/л*, а фосфатов — понизилось примерно на 5—7 *мг/м*^{3}.

Одновременно с описанными крупномасштабными изменениями в структуре глубинных водных масс происходили изменения океанологических условий и в верхних слоях моря. Выше глубины 200 *м* они были более сложными в основном вследствие более сложного характера динамической обстановки, а также вследствие интенсивности развития фитопланктона. Так, в январе 1965 г. из-за мощного развития антициклонического круговорота на севере моря произошел прогиб изоксиген в центральной части разреза от г. Хургада (см. рис. 2). Скопление пришедших с юга поверхностных вод в центре вихря вызвало вспышку развития планктона в слое 75—150 *м*, обнаруживающуюся по высокому проценту (до 106) содержания кислорода.

Все изменения гидрохимических условий большей части акватории района (ее центральных и западных участков) связаны с изменениями в динамике циклонического круговорота. Так, на разрезах от мыса Рас-Эгела в прибрежной части отмечалось опускание изолиний кислорода и фосфатов, вызванное сначала усилением циклона, а затем его смещением на север. С декабря по январь «опускание» одноименных изолиний O_2 и P составило 60 *м*, а к апрелю оно увеличилось еще на 80 *м*. Одновременно с этим степень пересыщения воды кислородом возросла на 3—4%. В то же время в центре моря происходил подъем вод, выразившийся в уменьшении глубин залегания изолиний кислорода и фосфатов на 50 *м* в январе и 20 *м* в апреле, наряду с уменьшением степени пересыщения верхних слоев за указанный период примерно на 4%. В районе Хургады этот процесс отчетливо проявлялся в резком подъеме вод в центре моря и у египетского берега, достигшем с января по апрель 90 *м* при одновременном снижении пересыщения воды на 2—4%.

Поток вод с юга вдоль аравийского побережья с декабря по апрель усиливался, причем направление движения его основиых струй несколько менялось. Эти изменения определяли гидрохимическую обстановку в верхних слоях приаравийской части района. Наличие указанного потока достаточно отчетливо сказалось на прогибе изолиний кислорода и фосфатов в приаравийских участках разрезов. В январе у мыса Рас-Эгела усиление потока привело к углублению изолиний фосфатов почти на 70 *м*; на разрезе от г. Хургада изолинии O_2 и Р в апреле опустились на 100 *м* по сравнению с январем.

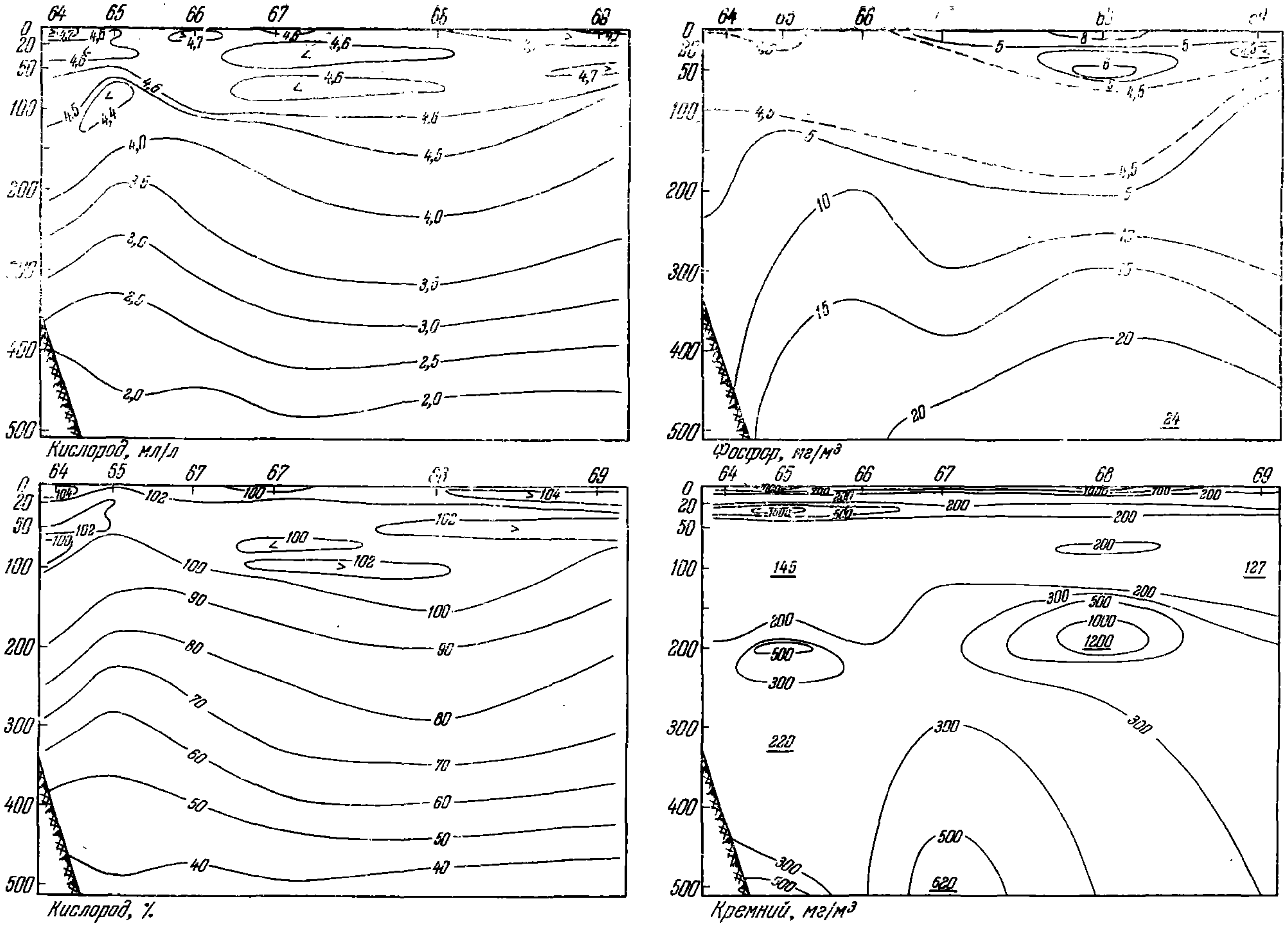
Вторжение южных вод вызвало вспышку развития планктона на глубинах 100—200 *м*, в результате насыщение воды растворенным кислородом увеличилось до 99%, в то время как обычно на этих глубинах оно не превышает 95% (см. рис. 5). Аналогичный эффект отмечался и на разрезе от мыса Рас-Эгела в декабре, с той только разницей, что здесь слой контакта располагался в зоне активного фотосинтеза и вторжение южных вод сказалось в увеличении насыщения вод до 104%.

В заключение необходимо указать, что фосфор в воде Красного моря является основным лимитирущим элементом в развитии фитопланктона. Небольшие концентрации фосфатов в довольно мощном верхнем слое (отмеченные в зимний период, когда обогащение биогенами продуктивного слоя моря идет наиболее интенсивно) указывают на возможность полного потребления фосфатов с началом летнего прогрева вод и возникновения заметного скачка плотности. Такую картину и констатировала в летне-осенний период 1963 г. 1-я Красноморская экспедиция АзЧерНИРО на разрезах от мыса Абу-Дара, от г. Порт-Судан и от г. Тринкитат (18°40′ с. ш.).

Почти до начала декабря (экспедиция работала с июля) в верхнем 50-метровом слое воды между 18 и 22° с. ш. фосфаты отсутствовали. На разрезе Массауа—Ходейда подобная картина наблюдалась и в конце декабря.

ИЗМЕНЕНИЯ В РАСПРЕДЕЛЕНИИ КРЕМНЕКИСЛОТЫ

В ряду обсужденных изменений гидрохимических условий в северной части Красного моря совершенно особое место занимают изменения в содержании растворенной в воде кремнекислоты. Как уже отмечалось, в распределении кремнекислоты выявлен ряд максимумов, расположенных в слоях повышенных градиентов плотности. В декабре наиболее отчетливо они прослеживаются на поверхности и на глубине 30 *м*. В январе, сначала на юге района, начался их «размыв» с одновременным увеличением максимума на глубине 75 *м*, который в декабре был почти незаметным. В это же время произошло увеличение максимумов на глубинах 150—200 и 300 *м*. Таким образом, период с декабря по январь следует определить как время активного накопления растворенной кремнекислоты в глубинах северной части Красного моря и понижения ее содержания в зоне активного фотосинтеза. Подобное положение можно было бы объяснить усилением вертикальных токов в верхних слоях моря и некоторым уменьшением скорости минерализации органических остатков. Тогда январь следует принять за срок максимального зимнего содержания кремнекислоты в глубинах северной части моря. В этой связи абсолютно неожиданными являются результаты наблюдений в конце марта — начале апреля 1965 г., указывающие на резкое изменение не только количества кремнекислоты, но и на полную перестройку характера ее распределения. Причинами столь разительных перемен наряду с перераспределением водных масс между отдельными районами


Кислород, мл/л
Фосфор, мг/м³
Кислород, %
Кремний, мг/м³
64
65
66
67
68
69
0
20
50
100
200
300
400
500

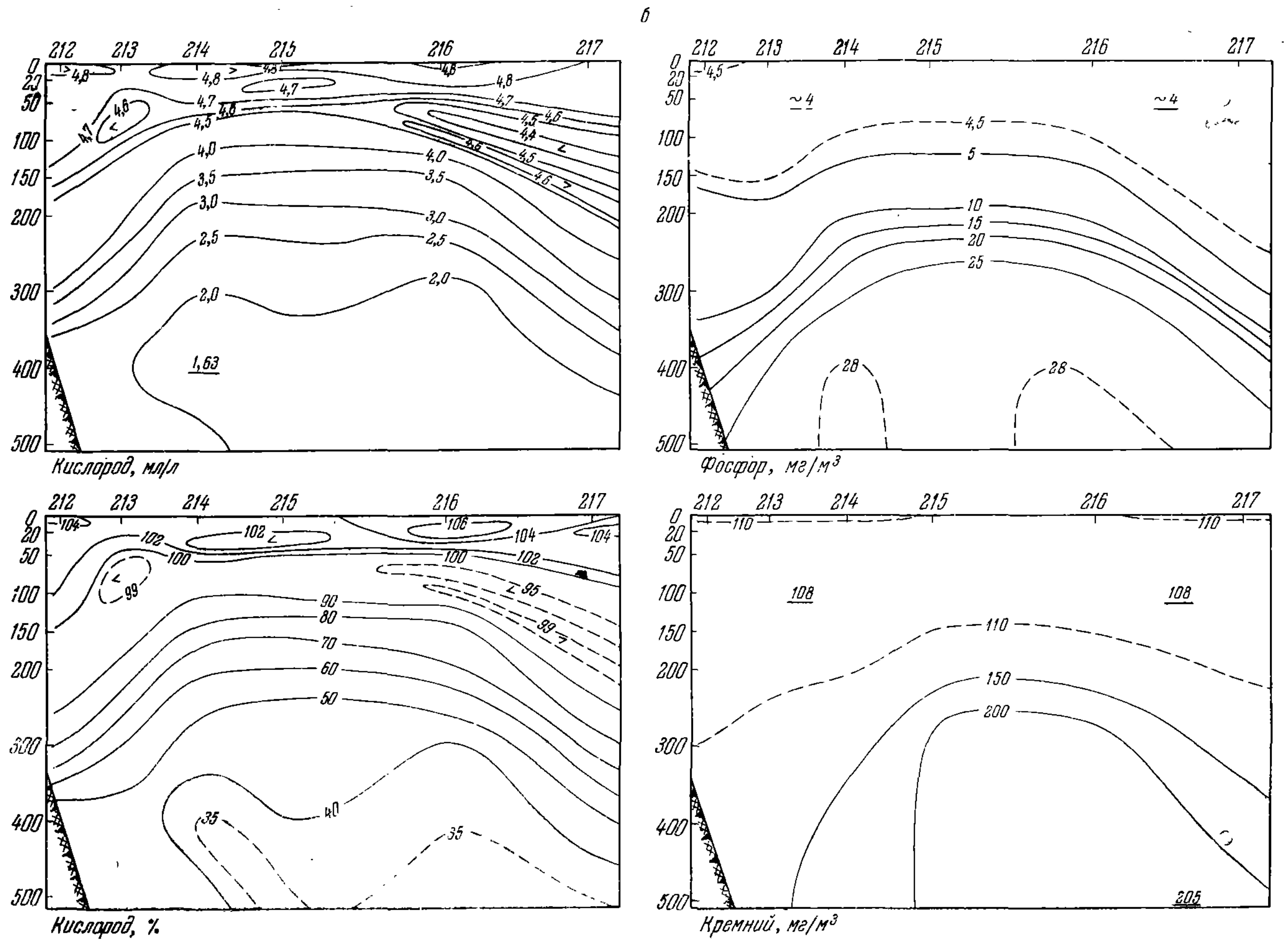


Рис. 5. Распределение гидрохимических элементов на разрезе от г. Хургада

а — 25 декабря 1964 г.; б — 3— 4 апреля 1965 г.

моря могут быть как интенсивное потребление кремнекислоты фитопланктоном, так и вполне вероятный переход раствора ее в коллоид. К сожалению, в настоящее время мы не располагаем необходимыми материалами для определения истинной из возможных причин, поэтому и ограничимся здесь лишь их перечислением.

ОКИСЛЯЕМОСТЬ МОРСКОЙ ВОДЫ

Количество органического вещества в верхних слоях северной части моря (по данным окисляемости) несколько колеблется. Окисляемость воды изменялась в пределах 0,40—0,50 *мл/л* O_2. Наибольшие значения на разрезах от г. Хургада наблюдались в апреле (0,50—0,53 *мл/л* O_2), а на разрезах от мыса Рас-Эгела — в январе и апреле (0,48—0,50 *мл/л* O_2). В нижних слоях моря, особенно в районе Рас-Эгела, величины окисляемости значительно уменьшались, захватывая все более верхние горизонты. Если в декабре значения менее 0,40 *мл/л* O_2 встречались только ниже 250—300 *м*, то в апреле они отмечались уже на глубинах около 50 *м*, а на глубине 300 *м* они снизились до 0,10 *мл/л* O_2. Вне всякого сомнения, это было вызвано накоплением глубинных вод в северной части моря. В районе Хургады глубинные воды с окисляемостью менее 0,40 *мл/л* O_2 «поднялись» в январе до горизонта 100 *м*, в то время как в декабре окисляемость на глубине 500 *м* составляла 0,43 *мл/л* O_2. К апрелю значения более 0,40 *мл/л* O_2 вновь наблюдались на глубинах 200—250 *м* вместо 0,20—0,30 *мл/л* O_2 в январе. Описанные изменения в районе Хургады, как нам представляется, можно объяснить возрастанием интенсивности продуцирования органического вещества от декабря к апрелю.

Материалы 1963 г. позволяют предположить, что величины окисляемости воды Красного моря бывают максимальными в летний период. Так, 2—3 августа 1963 г. в средней части моря в 2—3-мильной прибрежной полосе моря они достигали 1,40 *мл/л* O_2. При этом окисляемость воды почти 20-мильной прибрежной зоны была более 0,6 *мл/л* O_2 до глубины 100—130 *м*. Не меньшие значения в летний период отмечались и на разрезе Массауа — Ходейда, где на глубинах менее 150 *м* окисляемость составляла 0,75—1,25 *мл/л* O_2 против 0,30—0,40 *мл/л* O_2 в феврале 1965 г. Более всего изменяется она, по-видимому, в глубинной части района, так как величинам 0,08—0,16 *мл/л* O_2, наблюдавшимся зимой 1965 г., здесь противостоят значения 0,75—1,00 *мл/л* O_2, зафиксированные в августе 1963 г. Все эти данные свидетельствуют об активизации продуцирования органического вещества в южных и прибрежных частях моря в весенне-летнее время. О том же свидетельствует и несколько больший процент насыщения вод кислородом (до 106—110% против 102—104% в зимний период).

ВЫВОДЫ

1. Характер распределения гидрохимических элементов в Красном море зависит в основном от динамических причин: движения вод и интенсивности процессов вертикального перемешивания.

2. В верхних слоях моря содержание гидрохимических элементов определяется интенсивностью развития фитопланктона. Установлено, что мощность слоя воды с активно развивающимся фитопланктоном уменьшается с севера на юг и от побережья к центру моря от 100 до 50, а местами до 20 *м*. Потребление фосфатов фитопланктоном поддерживает очень низкую концентрацию их в верхних слоях Красного моря. В зимний период 1964/65 г. она не превышала 3—4 *мг/м*^{3}. Лишь в южной части моря благодаря приходу вод из Аденского залива количество фосфатов приблизительно равно 10 *мг/м*^{3}. В слое воды ниже зоны активного фотосинтеза и до глубины при-

мерно 200 *м* концентрация кислорода равномерно падает до 1,5—2,0 *мл/л*, содержание фосфатов повышается до 10 *мг/м*^{3}.

3. Характерной особенностью распределения кислорода и фосфатов на глубинах 300—500 *м* является наличие минимума кислорода и максимума фосфатов на глубине около 400 *м* в приаравийской половине моря. Такое распределение связано с поперечной циркуляцией, обусловливающей опускание охлаждающихся поверхностных вод у африканского берега и перенос этих вод на глубинах 600—800 *м* на восток с постепенной потерей кислорода на окислительные процессы.

4. Зимой в Красном море отмечается ряд слоев с повышенной концентрацией кремнекислоты (до 3000 *мг/м*^{3}), происхождение которых объясняется наличием повышенных вертикальных градиентов плотности воды. Интересен факт исчезновения слоев высоких концентраций кремнекислоты в водной толще северной части моря, наблюдавшийся в конце зимы 1964/65 г. Эти изменения могли произойти в результате оттока вод поверхностного слоя на юг в связи с активным накоплением глубинных вод, а также вследствие усиленного развития фитопланктона. Не исключена также возможность перехода части растворенной кремнекислоты в коллоидную форму.

5. Количество органического вещества в воде Красного моря в зимний период 1964/65 г. было небольшим. Величины окисляемости воды держались на уровне 0,40—0,50 *мл/л* O_2, а в глубинных слоях не превышали 0,20 *мл/л* O_2. Это является следствием не только малой продукции планктона, но и высокой скорости окисления органического вещества. Присутствие нитритов, как косвенного показателя продукции органического вещества, отмечалось на всех разрезах на нижней границе слоя пересыщения воды кислородом. Концентрации нитритов измерялись единицами *мг/м*^{3}, что для зимы является достаточно высоким содержанием. На разрезе Массауа—Ходейда на африканском шельфе наблюдались концентрации нитритов до 40 *мг/м*^{3} N, что характерно для районов массового цветения фитопланктона.

6. Продукция фитопланктона отмечается в Красном море круглый год, но держится примерно на одном и том же невысоком уровне с некоторым возрастанием в весенне-летний период вблизи от берегов. Невысокий уровень обусловливается недостаточным количеством биогенных элементов (особенно фосфора) в верхних слоях моря.

ABSTRACT

In the paper results of the hydrochemical investigations are given. They can be cummarized as follows: the character of the distribution of the hydrochemistry elements in the Red Sea depends mainly on the dynamics factors: the water movements and the intensity of the vertical mixing processes. The value of the hydrochemistry elements content in the upper layers of the Sea is determined by the intensity of phytoplankton development. The water column layer of active photosynthesis observed during Expedition was decreasing from the North to the South, and from the coast to the central part of the Sea, its fluctuation being within the limits of 100—50 m, and sometimes 20 m. Phosphate content in the surface waters of the Red Sea is very low due to consumption of it by phytoplankton and its value in winter season of 1964—1965 was not higher than 3—4 mg P/m^3. Only in the southern part of the Sea increasing to 10 mg P/m^3 occured due to the inflow of the surface waters from the Gulf of Aden. At the depths about 200 m decreasing of the dissolved oxygen content to 1.5—2.0 ml/L and increasing phosphate content to 10 mg P/m^3 was observed. The water layer at a 300—400 m depth is characterized by minimal content of oxygen, less than 1. Oml/L in the region along the Arabian coast, and by increased phosphate content about 30—40 mg P/m^3. The distribution of silicon is characterized by layering with maximum about 3.000 mg Si/m^3. The disappearance of the layers of silicon maximum was observed in the Northern part of the Red Sea by the end of the winter.

As oxidation data show the quantity of organic matter is low in winter season. The value of oxidation is 0.40—0.50 mg 02/L in the surface layer, and does not exceed 0,20 mg 02/L in the deep layers. The high nitrite content was observed at the low boundary of the layer of oxygen oversaturation. The nitrite content reached 40 mg N/m^3 in the regions of intensive

photosynthesis, in particular, on the Massaua-Hodeida section. On the grounds of the results of the hydrochemistry analysis it can be considered that the Red Sea is characterized by low content of biogenous matter, in particular, in the upper water column. Mineral phosphate is the most deficient. By the end of winter phosphates and silicon are almost completely consumed by the first spring phytoplankton outburst. The income of biogens from the deep waters of the Sea decreases abruptly with the advent of the spring heating of the surface waters. The production of phytoplankton is relatively low during the whole year.

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Reprinted from *Aust. J. mar. freshwat. Res.*, vol. 20, 1969, p. 1-50

SEASONAL VARIATIONS IN THE INDIAN OCEAN ALONG 110° E.

I. HYDROLOGICAL STRUCTURE OF THE UPPER 500 M

By D. J. Rochford*

[*Manuscript received July* 28, 1967]

Summary

Tropical and subtropical water masses at surface and subsurface depths were separated by their salinity, temperature, oxygen, and nutrient characteristics. The annual mean depths and latitudinal extent of these water masses were determined. Annual changes in the upper 50 m were generally so small relative to those found in other oceans that advection and mixing must have been less important in their genesis than local climatic changes. There was a barely significant seasonal rhythm in surface phosphate and nitrate, with peak occurrences of each some 6 months apart. At each latitude the permanent thermal discontinuity centred around a particular isotherm varied little in intensity during the year, but rose and fell in accordance with surface currents. The thermocline south of *c.* 18° S. varied little in depth but greatly in intensity during the summer.

The depth of the mixed layer was much less in summer and at all times shallower in the tropics. The depth of this layer was governed more by the accumulation of surface waters by zonal currents and eddies, than by wind stress or convective overturn. Therefore there was little difference from south to north, or month to month, in average nutrient values of this mixed column. The movement of the various surface waters, deduced from salinity and temperature changes during the year, usually agrees with geostrophic currents across 110° E. and ships' observations of surface currents in the south-east Indian Ocean.

I. Introduction

Data collected on Indian Ocean cruises between 1959 and 1962 have been published in a series of Oceanographical Cruise Reports (CSIRO Aust. 1962*a*, 1962*b*, 1962*c*; 1963*a*, 1963*b*, 1963*c*; 1964*a*, 1964*b*, 1964*c*; 1966*a*; 1967), and discussed in scientific papers (Hagmeier 1964; Hamon 1965; Humphrey 1966; Rochford 1961, 1962, 1963*a*, 1963*b*, 1964, 1965, 1966*a*; Tranter 1962; Tranter and Newell 1963; Wood 1963*a*, 1963*b*; Wyrtki 1962*a*, 1962*b*).

In 1962–63, this Laboratory, with the collaboration of the Oceanographic Laboratory, Centre O.R.S.T.O.M., Nouméa, New Caledonia, undertook the "Seasonal Biological Cruises", a series of six cruises at two-month intervals, along the 110° E. meridian between 32 and 9° S. The main aim of the series was to assess the effects of seasonal and latitudinal changes in the hydrological environment, on primary production, and on standing stocks at various trophic levels. The 110° E. meridian was chosen because it passes through both relatively stable, nutrient-poor,

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subtropical waters, and equatorial waters enriched by upwelling. Enough data had previously been collected in this region to allow predictions of probable values and trends, and to aid planning of the sampling programme.

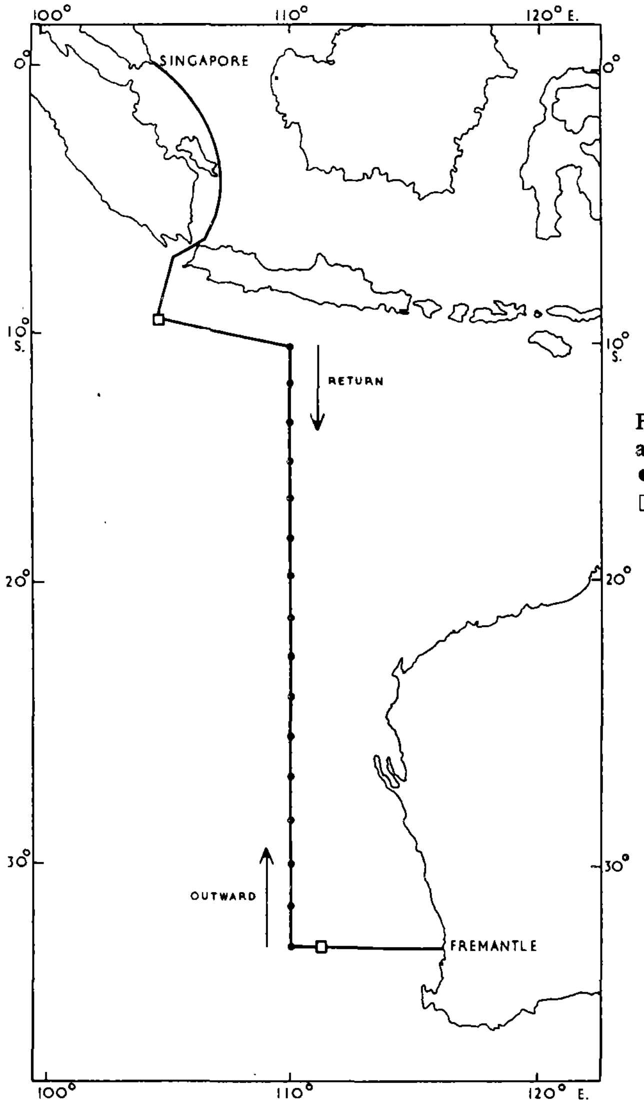


Fig. 1.—Track chart and station positions.
● Position station.
□ Reference station.

On each of the six cruises in the series (August–September and October–November 1962; January–February, March–April, May–June, and July–August 1963), sampling was undertaken for each of six fields of study: hydrology, particulate carbon, chlorophylls, primary production, zooplankton, and midwater trawl organisms. The midwater trawling programme was planned and carried out by O.R.S.T.O.M., Nouméa.

Sixteen stations were worked at 90 mile (1·5°) intervals along the cruise track (Fig. 1). On each cruise, on the outward and return legs, two stations per day were worked at fixed times. At the morning station (0800–1230 hr) sampling was carried out for hydrology (surface to bottom), particulate carbon, chlorophylls, primary production, and zooplankton. Hydrology samples (taken using an electric oceanographic winch of 10,000 m wire capacity), were analysed for salinity, oxygen, inorganic phosphorus, total phosphorus, and nitrate nitrogen. At the same time a smaller winch was used to collect water samples for particulate carbon, chlorophyll, and primary production determinations. When hydrology sampling had been completed, the oceanographic winch was used for plankton net vertical hauls and light penetration measurements. The ship then got under way and plankton net tows were made from a stern davit. From noon to sunset, while the ship was under way, a simulated *in situ* measurement of primary production was made. At the evening station (2000–2400 hr) a similar procedure was adopted except that, because midwater trawling took about 2 hr, hydrology sampling was restricted to a cast from the surface to 500 m for salinity analysis only; no light penetration measurements were made. The midwater trawl was towed from the stern davit before the evening plankton tows.

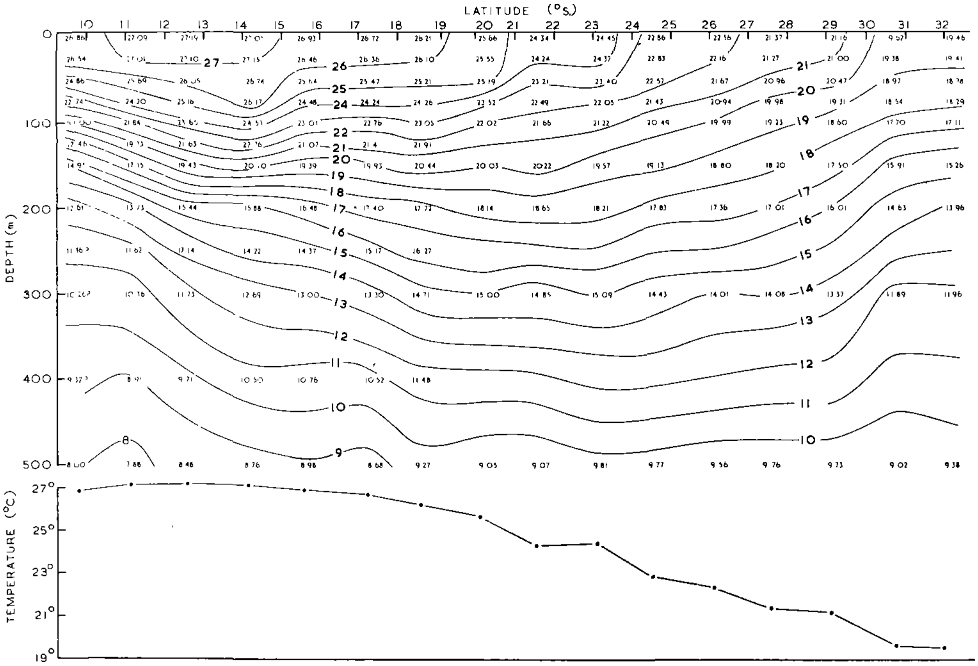


Fig. 2.—(Above) Mean distribution of temperature (°c); (Below) changes in mean surface temperature as a function of latitude.

Thus sampling for particulate carbon, primary production, chlorophylls, zooplankton, and some hydrology, was carried out twice at each station on each cruise; on the outward and return legs. There was an interval of 28 days between the first and last stations on each cruise, and of 12 days between the end of the outward leg and the start of the return leg. Two SCOR–Unesco Reference Stations (Fig. 1) were worked twice on each cruise but data for these stations have not been used in this series of papers.

Details of work accomplished, sampling and analytical methods, and all data, are in the relevant Oceanographical Cruise Reports (CSIRO Aust. 1965*a*, 1965*b*, 1965*c*, 1965*d*; 1966*b*, 1966*c*). The programme of Seasonal Biological Cruises was more comprehensive and rigorous in its approach to the problem of seasonal variations in the ocean than any previous study. Moreover, the 110° E. meridian cuts through a region which is hydrologically diverse. There is, in the region, a confluence of waters from a number of different sources. In many cases these waters have markedly different characteristics (Rochford 1961, 1962, 1964). The situation is further complicated by the occurrence, between May and September, of an area of upwelling between Java and the north-west coast of Australia (Wyrtki 1962*a*).

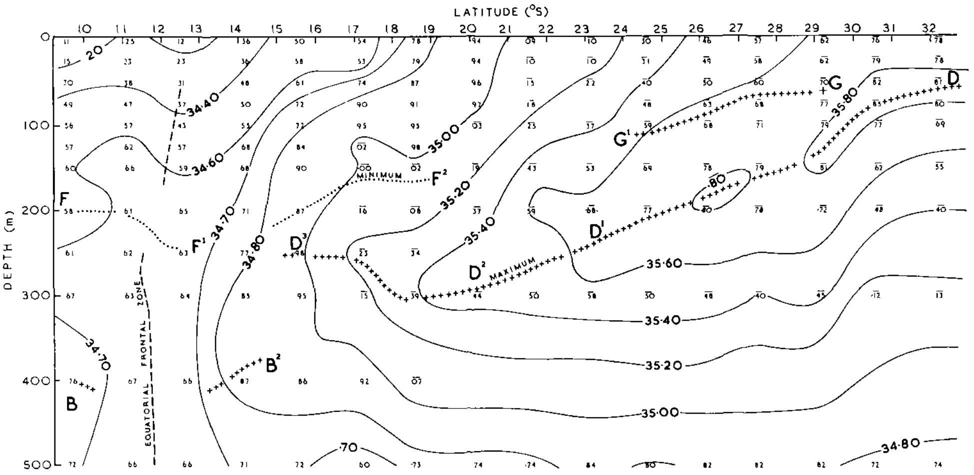


Fig. 3.—Mean distribution of salinity (barred values+35·00 and unbarred+34·00‰). - - - - Vertical column of low salinity.

This paper discusses the general features of the hydrological structure, water mass composition, and changes in properties of the waters of the upper 500 m. It is the first of a series of six papers giving analyses of the results for each discipline. These will be followed, at a later date, by the more detailed and synthetic papers necessary to fulfil the main aim of the programme.

II. Data and Methods

Analytical methods and all data are given in the Oceanographical Cruise Reports. Where no evidence is presented, the identification of the water masses in this paper is based upon the characteristic properties established by Rochford (1964).

Vertical temperature gradients (Section VI) are based upon temperatures at water bottle sampling depths. These were 0, 25, 50, 75, 100, 125, 150, 200, 250, 300, 400, and 500 m.

III. The Mean Meridional Distribution of Hydrological Properties

Seasonal changes in properties along 110° E. have been eliminated by averaging the hydrological data for each station. When sampling was not at standard depths, linearly interpolated values were used. This averaging procedure draws attention to those features of the hydrological structure that persist throughout the year and which are, therefore, of the greatest importance in the maintenance of the year by year hydrological regime along 110° E.

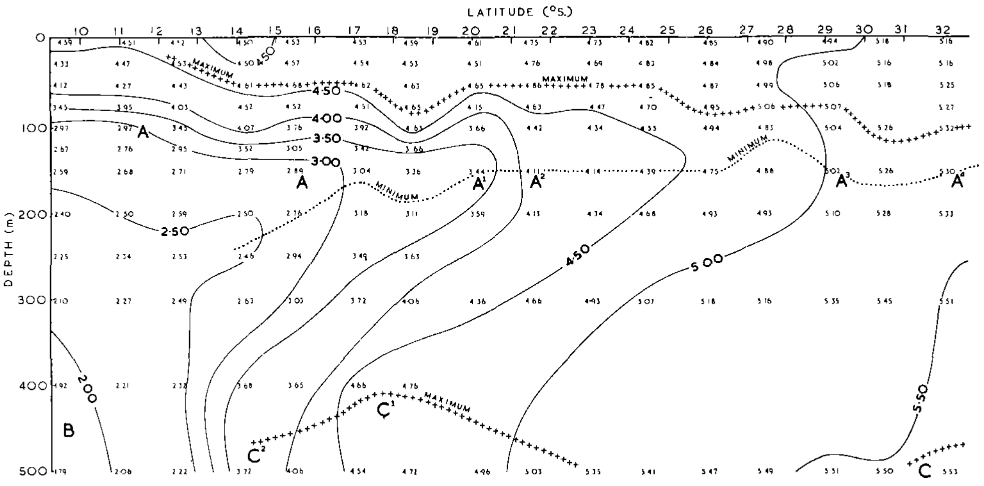


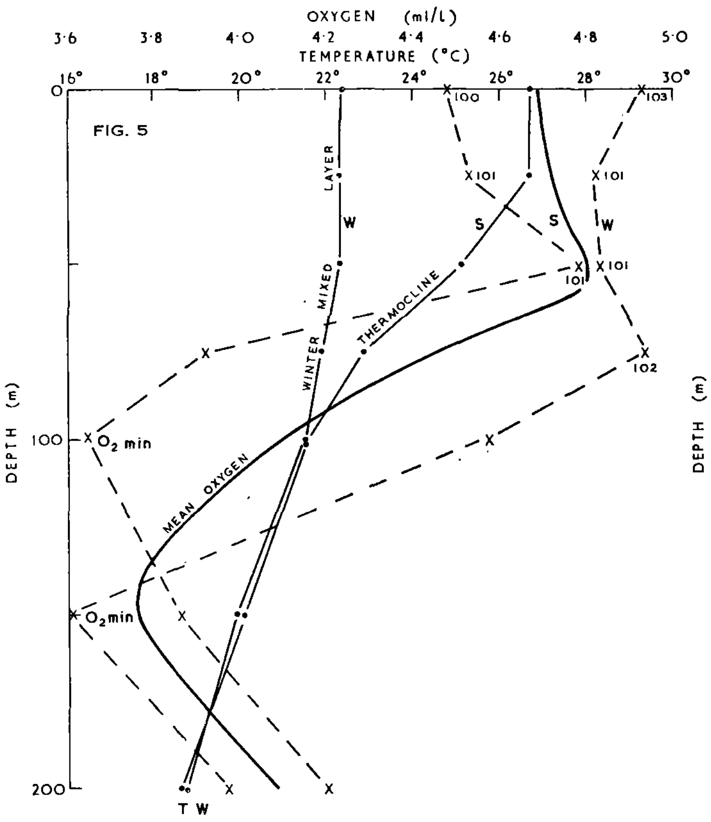
Fig. 4.—Mean distribution of oxygen (ml/l.).

(*a*) *Temperature*

Surface temperatures increased steadily from south to north (to *c.* 20° S.) at *c.* 0·7 degc per degree of latitude (Fig. 2). Thereafter the increase was much slower. Around 12–13° S. surface temperatures were at their maximum. Further north, temperatures decreased by some 0·3 degc towards the Java coast. The warmest water at 75 m (26°c) was found at 14° S. (Fig. 2), denoting the mean position of the southern boundary of the west-flowing South Equatorial Current. The decrease in temperature north of 14° S., at all depths to 300 m and at greater depths, was caused by dynamic uplift along the northern boundary of the same current. The 10°c isotherm occurred at greatest depths between 18 and 29° S., caused principally by the accumulation of subtropical waters (South Indian Central and subtropical oxygen maximum water masses) (Section IV).

(*b*) *Salinity*

Highest salinities occurred near the surface in the south, but at progressively greater depths towards the north (Fig. 3). At *c.* 15° S. this layer of high salinity disappeared. North of *c.* 13° S. salinity values were very similar between 150 and 500 m, except at 9°30′ S. near the Java coast. This vertically homogeneous zone forms part of the Equatorial Frontal Zone extending across the south Indian Ocean as a



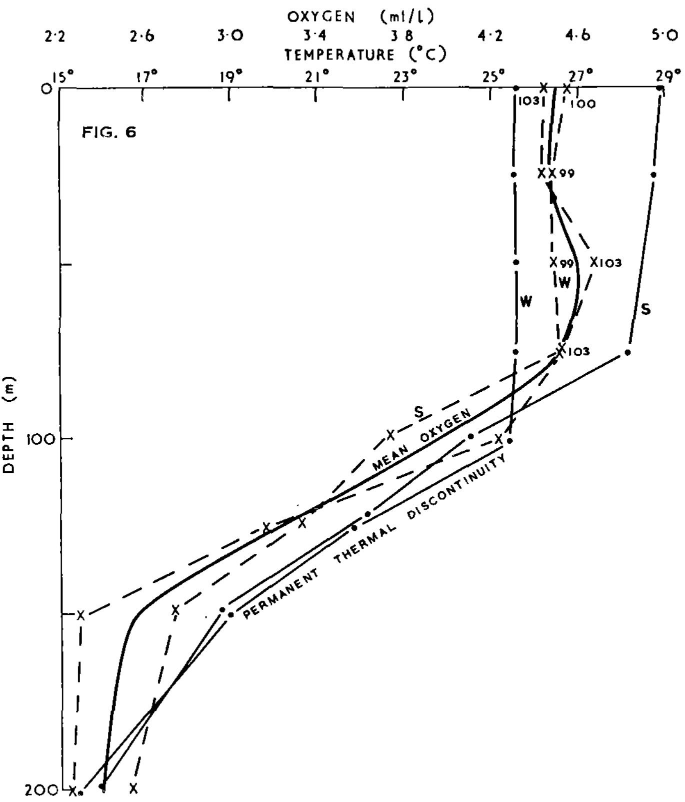


Fig. 5.—Typical winter (W) and summer (S) profiles of temperature (———), and oxygen (– – – –), and the resultant annual mean curve (———) of oxygen at 21°30′ S.

Fig. 6.—Typical winter (W) and summer (S) profiles of temperature (———), and oxygen (– – – –), and the resultant annual mean curve of oxygen (———) at 14° S.

structural feature of the South Equatorial Current (Rochford 1966*a*). An associated feature is the accumulation of low salinity water in the upper 150 m at 12°30′ S. (Fig. 3).

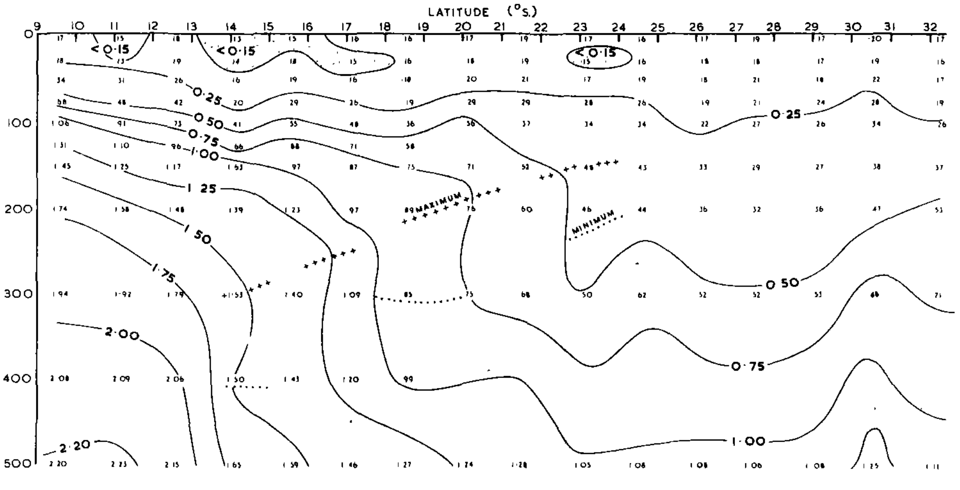


Fig. 7.—Mean distribution of inorganic phosphate (μg-atom/l.).

A low salinity layer F^1–F^2 occurred at around 200 m above the high salinity layer D^2–D^3 (Fig. 3). This layer is maintained by southward spreading of low salinity tropical waters (Section IV). A layer G–G^1, discernible as a weak salinity maximum on the mean salinity–temperature curves (Section IV), shows the extent of northward drift of high salinity waters of the West Australian Current.

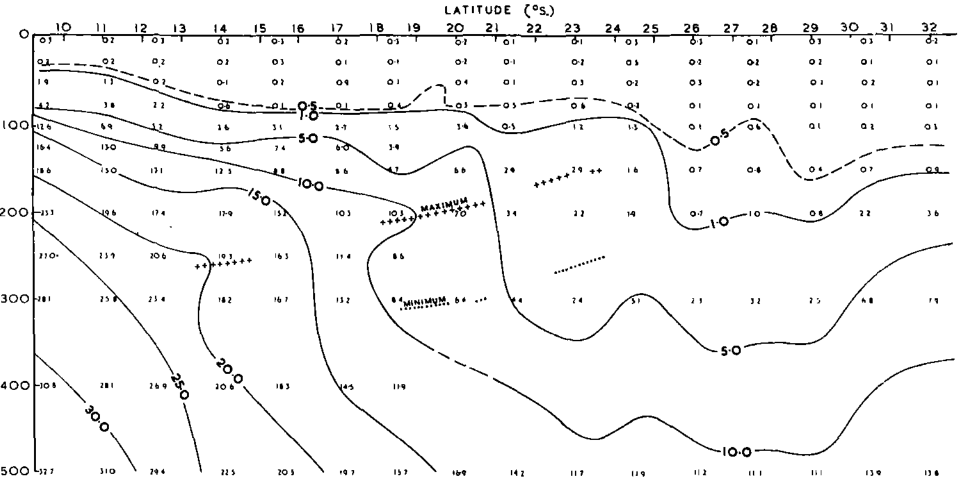


Fig. 8.—Mean distribution of nitrate nitrogen (μg-atom/l.).

(*c*) *Oxygen*

South of 12° S., oxygen values increased from the surface downwards to form an upper oxygen maximum at each latitude (Fig. 4). South of 20° S., this was associated with the summer thermocline within which oxygen is conserved throughout the year

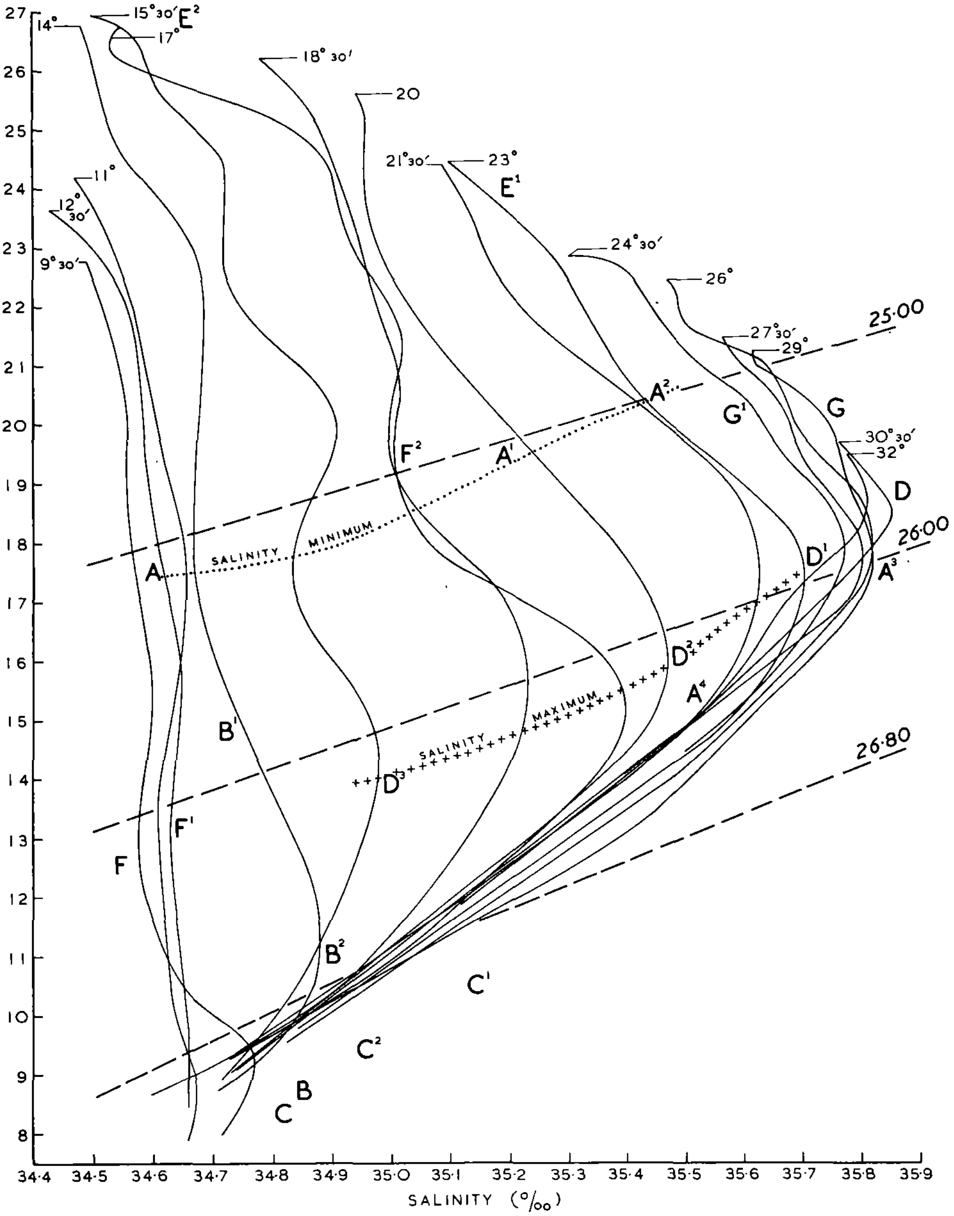


Fig. 9.—Mean temperature–salinity relations of waters (0–500 m) at various latitudes. ---- Sigma-*t*. Letters correspond to regions of Figures 3 and 4.

at the value that it had in the winter mixed layer (Fig. 5). Above the thermocline, oxygen values decreased by atmospheric loss as summer heating proceeded. Below the thermocline, because the transfer downwards of well-oxygenated surface waters was stopped by the thermocline during summer, oxygen values decreased by mixing

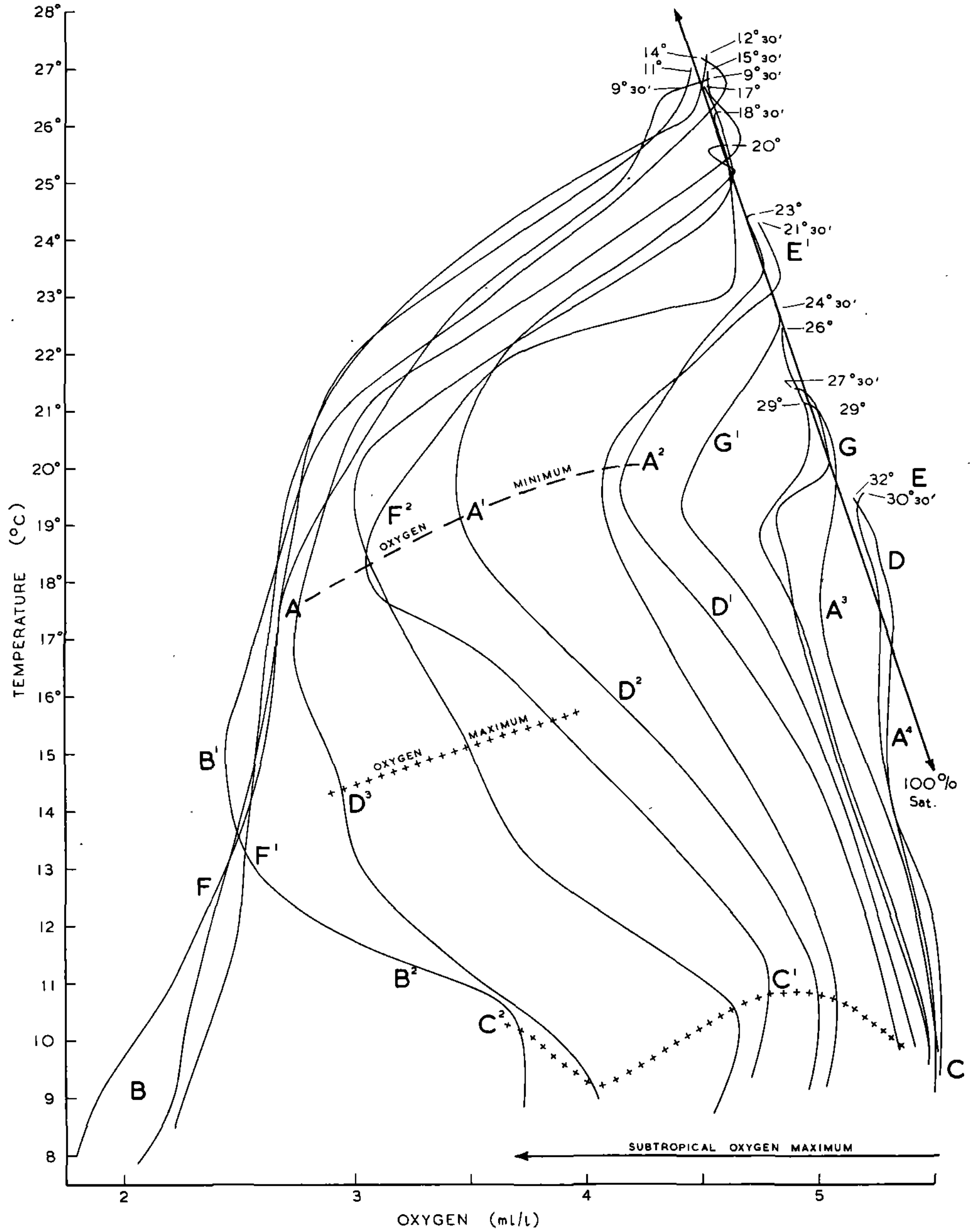


Fig. 10.—Mean temperature–oxygen relations of waters (0–500 m) at the same latitudes as Figure 9. Letters correspond to regions of Figures 3 and 4.

of winter waters of near saturation oxygen content with increasing amounts of deeper, oxygen-poorer waters. Thus, above and below the depth of the thermocline, oxygen values decreased during summer, forming an oxygen maximum within the thermocline. North of 20° S., where a summer thermocline rarely formed, this upper oxygen maximum was found near the bottom of an isothermal layer of fairly constant depth, lying above the permanent thermal discontinuity (Fig. 6). At this mean depth, oxygen values were greater in summer than winter. The maximum north of 20° S. cannot be

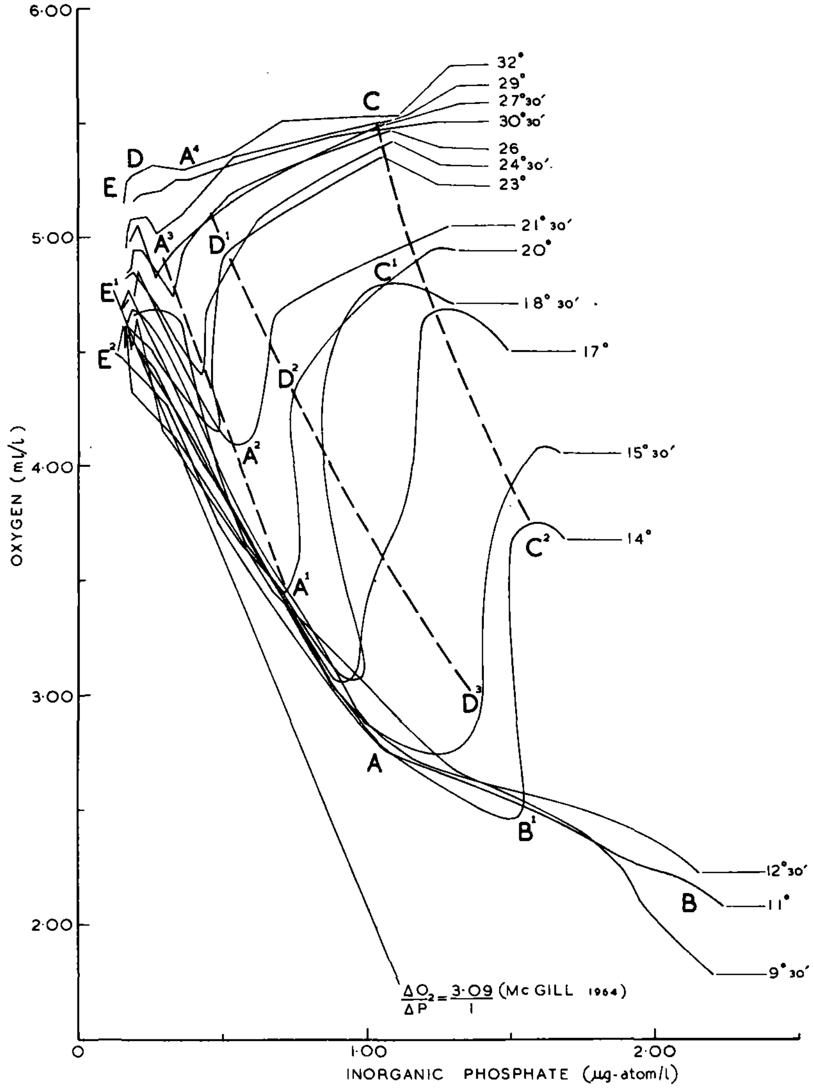


Fig. 11.—Mean oxygen-phosphate relations of waters (0–500 m) at the same latitudes as Figure 9. Letters correspond to regions of Figure 3.

formed, therefore, by the same physical processes of seasonal mixing and heat and gaseous exchange that were effective south of 20° S. In this northern region, therefore, the maximum could be the result of biological production of oxygen in summer.

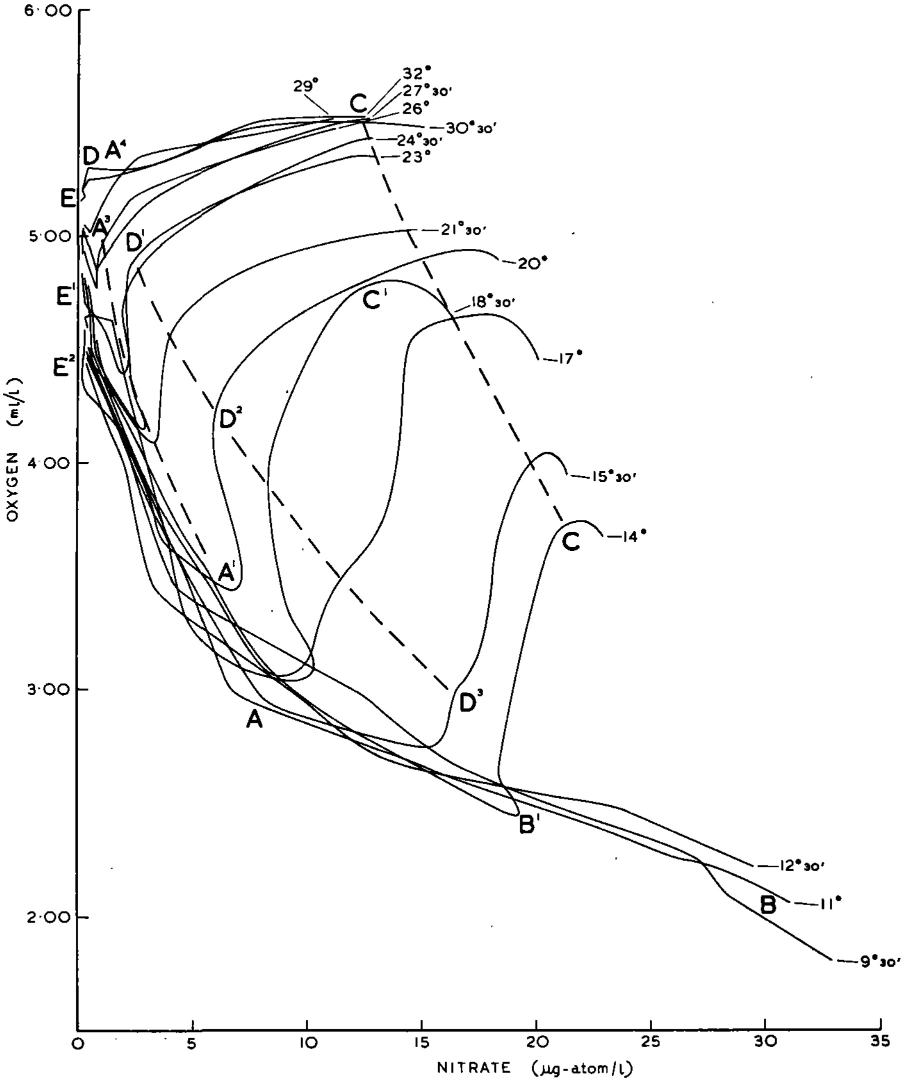


Fig. 12.—Mean oxygen–nitrate relations of waters (0–500 m) at the same latitudes as Figure 9. Letters correspond to regions of Figure 3.

Below this upper oxygen maximum, an oxygen minimum (A–A^4, Fig. 4) was found around 150–200 m at all latitudes south of 14° S. Oxygen values of this minimum increased southward, and by 29–32° S. the differentiation of this minimum in the mean oxygen profiles was less than 0·10 ml/l. (A^3–A^4, Fig. 10) (Section IV). Around 13° S. there was a transition region where oxygen values decreased rapidly from south to

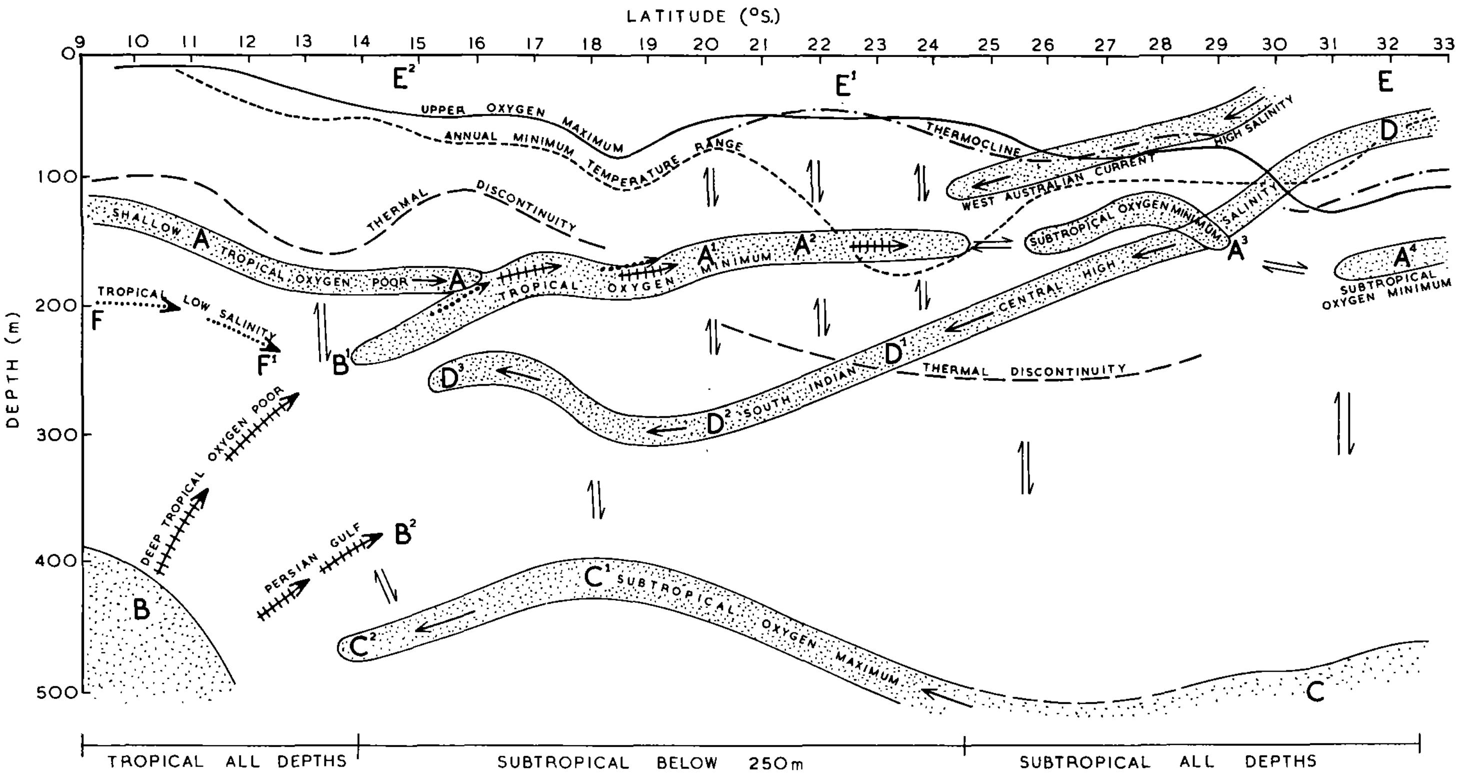


Fig. 13.—Mean positions of the principal water masses, and other structural features along 110° E. Depth of the thermocline and thermal discontinuity from Section VI. Depth of the upper oxygen maximum from Figure 4. Depth of the minimum annual temperature range from Figure 14. A–G explained in text.

north at depths below 300 m (Fig. 4). This was formed by the mixing of oxygen-rich waters of the subtropical oxygen maximum (C–C^2, Fig. 4), and the tropical oxygen-poor waters of the Equatorial Frontal Zone and the Persian Gulf water mass (B, Fig. 4). Oxygen values within this tropical region north of 13° S. were less than 3·00 ml/l. at all depths below the mean depth of the thermal discontinuity (100–150 m). Below this mean depth of the thermal discontinuity, vertical mixing was considerably reduced (Section VI).

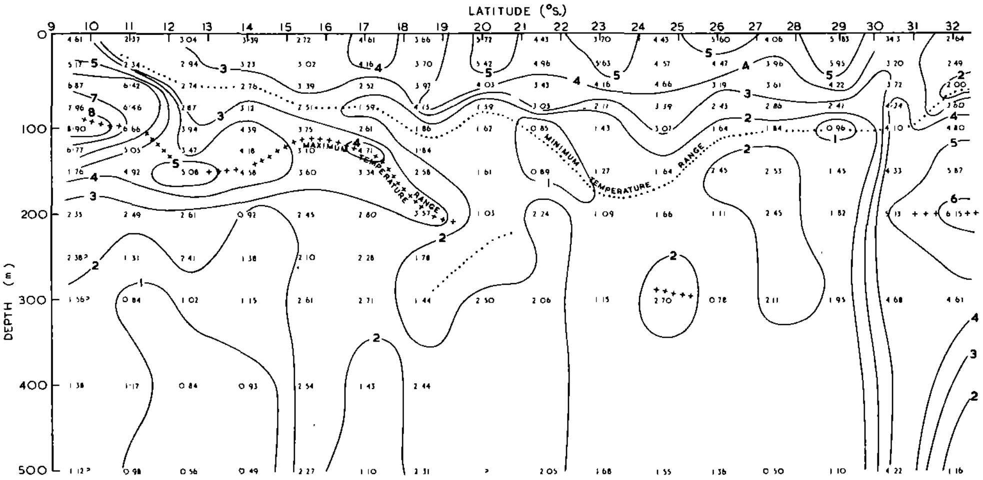


Fig. 14.—Isopleths of the annual temperature range (degc).

(*d*) *Inorganic Phosphate*

Surface phosphate decreased slightly northward with the lowest value (0·13 μg-atom/l.) at around 14° S. (Fig. 7) in the centre of the high-temperature (Fig. 2), low-salinity (Fig. 3) accumulation of South Equatorial Current water. The relatively low phosphate values south of 20° S., at all depths, resulted from the accumulation of high-salinity (Fig. 3), well-oxygenated (Fig. 4), but phosphate-poor subtropical waters in the same region. Despite dynamic uplift of deeper waters near the coast of Java (Fig. 2), no appreciable increase was found in the phosphate of the upper 25 m compared with other latitudes along 110° E. (Fig. 7). A phosphate maximum at 150–300 m between 14 and 23° S. was caused by the southward spreading of low salinity (F^1–F^2, Fig. 3), oxygen-poor (A–A^2, Fig. 4), but phosphate-rich tropical waters.

(*e*) *Nitrate Nitrogen*

The nitrate distribution (Fig. 8) closely paralleled that of phosphate (Fig. 7). The nitrate maximum at around 150–300 m in the region 14–23° S. was caused by southward spreading of tropical waters of high nitrate content at these depths. All surface waters, to depths of 30 m in the north, and 125 m in the south, had nitrate values less than 0·5 μg-atom/l., as determined by the strychnidine method. Comparison of the strychnidine and hydrazine methods at low nitrate concentrations (Dal Pont *et al.* 1963) has shown that the strychnidine method, in coastal waters of relatively high organic content, can underestimate by *c.* 1·00 μg-atom/l. It is probable, therefore, that the lowest nitrate value of waters along 110° E. lay between 0·50 and 1·00 μg-atom/l. As for phosphate, surface nitrate was no greater north of 11·0° S. (Fig. 8) than south.

IV. The Major Water Masses

Figures 2–4 and 7–8, together with the mean annual curves of temperature–salinity (Fig. 9), temperature–oxygen (Fig. 10), oxygen-phosphate (Fig. 11), and oxygen–nitrate (Fig. 12), show consistent evidence throughout the year of a number of water masses. Temperature–salinity relations (Fig. 9) show that the oxygen minimum (A–A^2, Fig. 10) was also a salinity minimum of nearly constant sigma-*t* (25·00). In this oxygen minimum, phosphate (Fig. 7), and to a greater extent nitrate (Fig. 8), were both at a maximum. The layer A–A^2 at depths around 100 m (Fig. 13) is called the tropical oxygen minimum. North of *c.* 16° S. this layer assumed more and more the properties of the deep water (B, Fig. 13), so that by 13° S. it cannot be distinguished as an oxygen minimum.

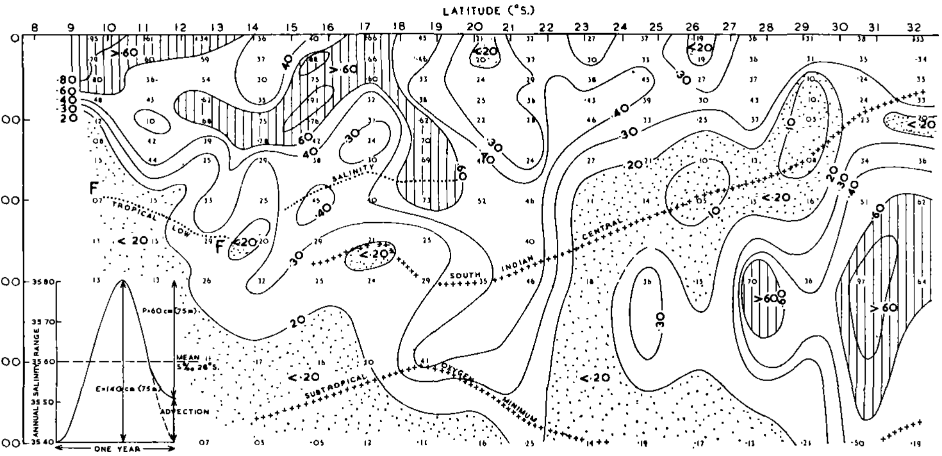


Fig. 15.—Isopleths of the annual salinity range (‰). Depths and lettering of the various water masses from Figure 13. Inset: Annual cycle of salinity in an upper 75 m mixed layer at 28° S.

The oxygen–phosphate curves (Fig. 11) show that the ratio of oxygen decrease to phosphate increase, from the surface to the depth of the oxygen minimum, was not markedly different from 3·09 : 1, the ratio that would result from the decomposition of plankton of average carbon to phosphorus composition (McGill 1964). It is considered likely, that north of about 15° S., the well-developed temperature discontinuity found throughout the year just above the layer A (Fig. 13) accumulated organic detritus which by oxidative decomposition kept oxygen values low within this layer. South of 15° S., it is possible that the oxygen minimum layer (A^1–A^2, Fig. 13) was formed principally by a similar process of local oxygen consumption. However, this does not explain the salinity minimum in this layer (A^1–A^2, Fig. 9). To a large extent, therefore, the oxygen minimum south of 15° S. is formed by the southward advection of low-salinity, low-oxygen, tropical water.

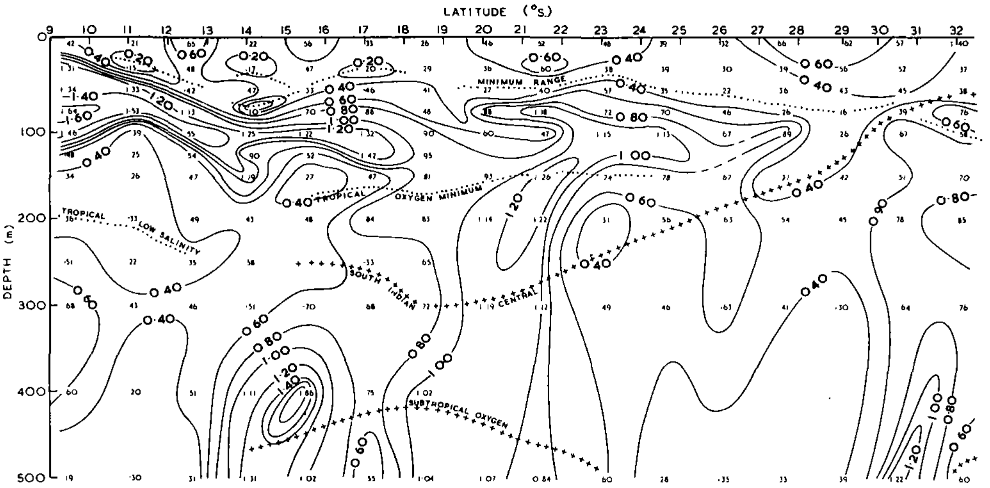


Fig. 16.—Isopleths of the annual oxygen range (ml/l.). Depths of various water masses from Figure 13.

South of *c.* 23–29° S. however, the oxygen minimum (A^3, Fig. 10) was much weaker, was associated with a salinity maximum rather than a minimum (A^3, Fig. 9),

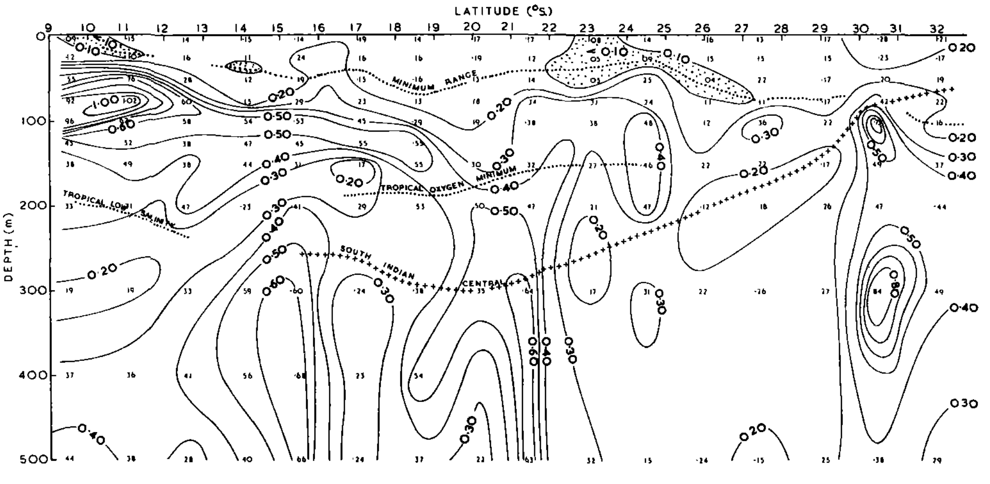


Fig. 17.—Isopleths of the annual phosphate range (μg-atom/l.). Depths of various water masses from Figure 13.

and had a greater sigma-*t* than at 23° S. (Fig. 9). South of 31° S., the oxygen minimum (A^4, Fig. 13) lay below the salinity maximum and was only just discernible on the temperature-oxygen curve of the region (Fig. 10). Therefore, the oxygen minimum south of 23° S. is not considered an extension of the tropical oxygen minimum further to the north, and is called the subtropical oxygen minimum. This minimum occurred *c.* 50 m below the depth of the summer thermocline (Fig. 13), and *c.* 100 m above the depth of the permanent thermal discontinuity. It is not likely therefore, that this minimum is formed by the same localized biological processes as are thought to occur north of 15° S. More probably it is formed outside the 110° E. region and carried north and east through 110° E. by the drift of subtropical high salinity water masses. Two such high salinity water masses occurred along 110° E. South Indian Central water (D–D^3, Fig. 13) on about the 26·00 sigma-*t* surface (Fig. 9) originates in winter at *c.* 35° S. (Rochford 1967). The shallowness of this layer around 32° S. (Fig. 13) is not indicative of its formation in these latitudes but is indicative rather of localized dynamic elevation by the eddies which are a common feature of this region (Hamon 1965). In the absence of such eddies it is believed that this high salinity layer would lie below the thermocline at around 200 m. The very small annual change in salinity of this South Indian Central water between 23 and 30° S. indicates that there is either very little advection of this central water from the south during the year, or, if there be such advection, the rate of mixing across and into this layer must be proportional to the advection in order to maintain this near steady state of salinity. As it spreads north the depth of the core of this water mass deepens. However, its mean salinity–temperature relations indicated (Fig. 9) that its flow remained nearly isentropic on the 26·00 sigma-*t* surface. At its northern extremity (D^3, Fig. 13) the centre of this water mass ascended and merged into the tropical low salinity layer (F–F^1, Fig. 13) of the same sigma-*t* (F–F^1, Fig. 9).

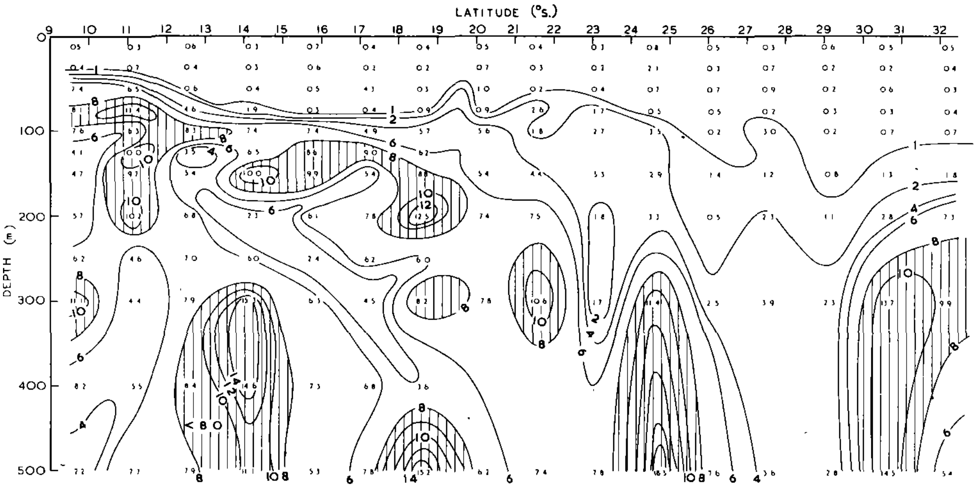


Fig. 18.—Isopleths of the annual nitrate range (μg-atom/l.).

Above D–D^3, a warmer high salinity water mass occurred within the thermocline region to the south of 24° S. (Fig. 13). This layer was formed by the northward spreading of waters with a sigma-*t* value of around 25·20 (G–G^1, Fig. 9) of the West Australian Current (see Section VIII). Water of this current has the lowest phosphate content in the south Indian Ocean (Rochford 1967), and is the principal cause of the very low nutrient levels, especially nitrate (Fig. 8), in the upper 150 m south of 25° S. Around 500 m in the south, but shallowing to near 400 m in the north (Fig. 13), occurred a water mass distinguished by its high oxygen content (Fig. 10). Spreading of this water mass occurred on about the 26·80 sigma-*t* surface and it is therefore identical with the subtropical oxygen maximum (Rochford 1966*b*). Mixing of this water mass with South Indian Central water at depths above it increased its salinity in the region northward (C–C^1, Fig. 9). Northward again, however, the subtropical oxygen maximum decreased in salinity (C^1–C^2, Fig. 9) by mixing with a southward extension of Persian Gulf waters (B^2, Figs. 10 and 13).

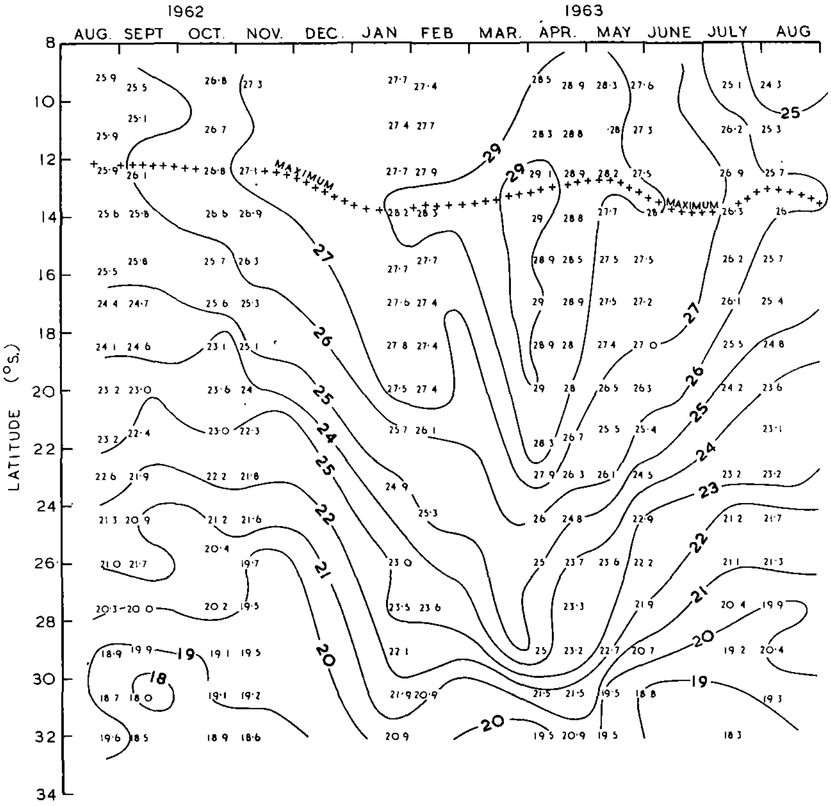


Fig. 19.—Changes in surface temperature with time and latitude.

V. The Annual (August 1962–August 1963) Variation in Hydrological Properties

(*a*) *Annual Range with Respect to Depth and Latitude*

(i) *Temperature*

The annual temperature range decreased with depth (Fig. 14), reaching a minimum at the depth of summer heating and winter cooling of the water column, assuming the thermal structure is largely unaffected by mixing or advection. North of *c.* 18° S., this minimum in the temperature range does show the vertical extent of the seasonal heat exchanges, since the vertical flux of heat is limited by the permanent thermal discontinuity (Fig. 13), and the largely zonal movements of water do not transport waters of very different temperatures through the region. South of 18° S., however, at various depths, there is a net annual flow to the north of subtropical, and to the south of tropical waters (Section IV). Because of this, the minimum in the temperature range (south of 18° S.) cannot be interpreted solely in terms of heat exchange with the surface. However, the similarity in depths (within 25 m) of this minimum in the temperature range, and of the mean summer thermocline (Fig. 13) at 20° S. and 26–32° S., shows that heat exchange with the surface was a major factor at these latitudes. Between 21 and 26° S., however, this minimum in the temperature range occurred some 50–150 m below the mean depth of the summer thermocline, and at these latitudes therefore, vertical mixing and advection must also be important factors. The annual range of surface temperatures increased southward, from around 3 degc per year at 11° S. to nearly 6 degc at 29° S. (Fig. 14). Southward again, however, the annual range of surface temperatures decreased to less than 3 degc. At comparable latitudes of the North Pacific unaffected by the Kuroshio or California currents, the annual range of surface temperature varied from about 1 degc at 10° N. to 4 degc at

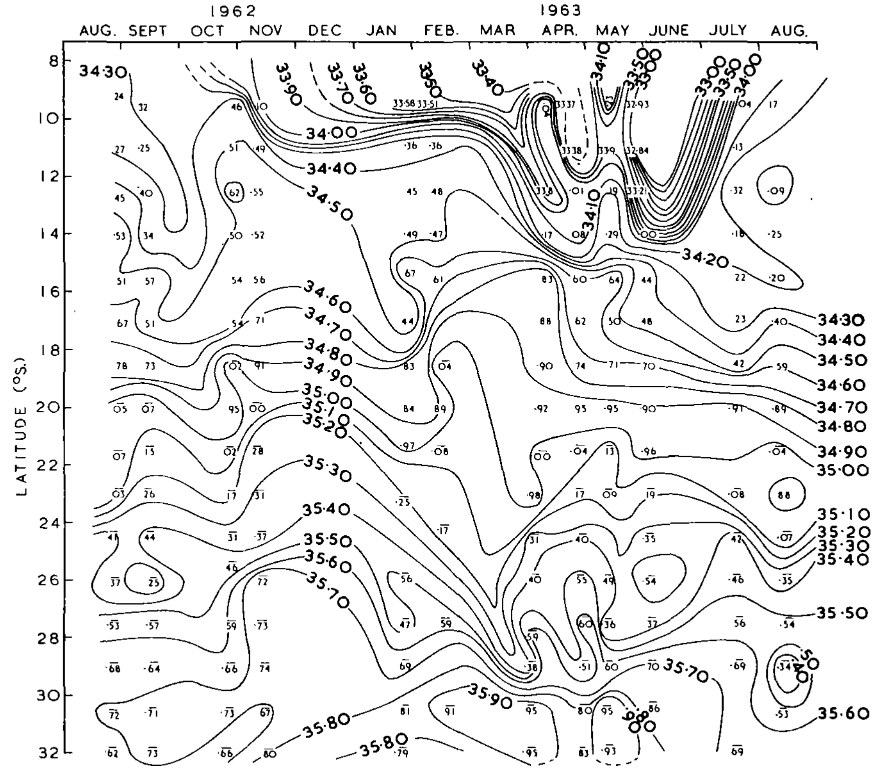


Fig. 20.—Changes in surface salinity with time and latitude. For salinity coding see Figure 3.

30° N. (Wyrtki 1965). Generally therefore, the annual surface temperature range along 110° E. was greater than at comparable latitudes in the North Pacific. However, the extent of this increase caused by greater north–south exchange of waters of different temperatures or greater vertical mixing along 110° E. cannot be decided. The annual temperature variations at 100–200 m between 9 and 18° S. (Fig. 14) were caused by vertical oscillations of water of a particular temperature, in response to changes in intensity of the Java and South Equatorial Currents (Hamon 1965).

The large annual variations in temperature at 200–500 m between 30 and 32° S. (Fig. 14) were the result of eastward movement of eddies through this region (Hamon 1965).

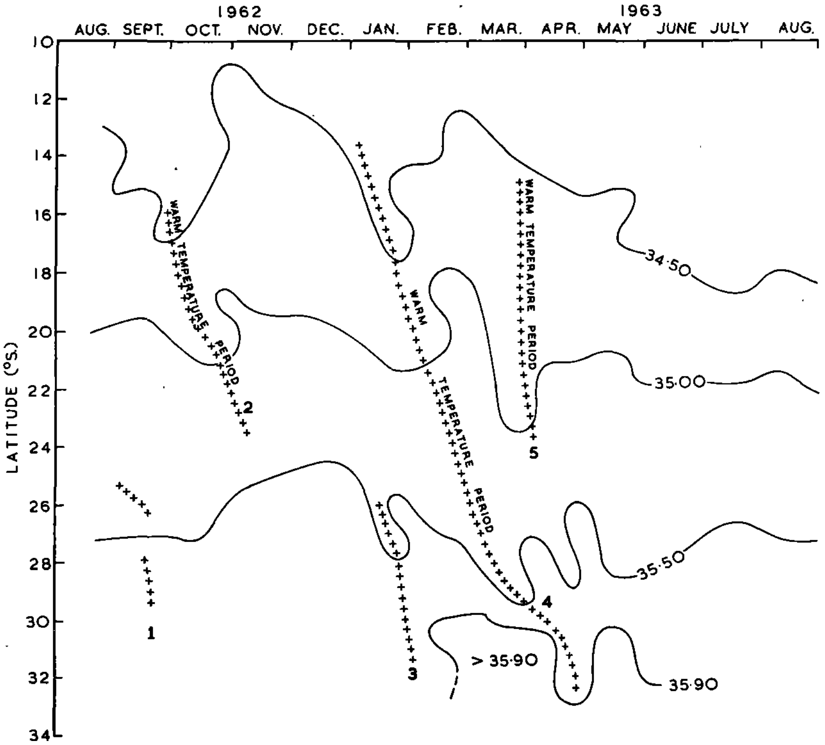


Fig. 21.—Comparison of changes in position of selected isotherms (Fig. 19) and isohalines (Fig. 20).

(ii) *Salinity*

The largest annual range of salinity (greater than 0·60‰) within the upper 50 m occurred around 17° S. near the boundary of low salinity tropical and higher salinity subtropical waters (Fig. 15), and in the region north of 13° S. These latter variations in salinity were caused principally by the seasonal drift southward, in summer and autumn, of water of very low salinity from the Java and Banda Seas, and by the east-flowing Java Current. The former variations in surface salinity were caused by north–south shifts in position of tropical and subtropical waters. Within the zone of warm water accumulation by the South Equatorial Current at 14° S. (Fig. 2), salinities remained relatively constant during the year (less than 0·40‰ annual range). South of 20° S. the annual range of salinity in the upper 75 m was less than 0·40‰ (Fig. 15). This is within the range of salinity transformation that the annual evaporation of 140 cm of this region (Dietrich and Kalle 1957) would cause within a mixed layer of 75 m (Fig. 15, inset). However, to maintain the steady state salinity each year, a supply of low salinity water as well as the annual precipitation of 60 cm (Dietrich and Kalle 1957) would be required (Fig. 15). This low salinity water is probably supplied by a combination of surface advection of tropical water (Section VIII), and deeper, southward spreading of waters of the tropical oxygen minimum (Fig. 13).

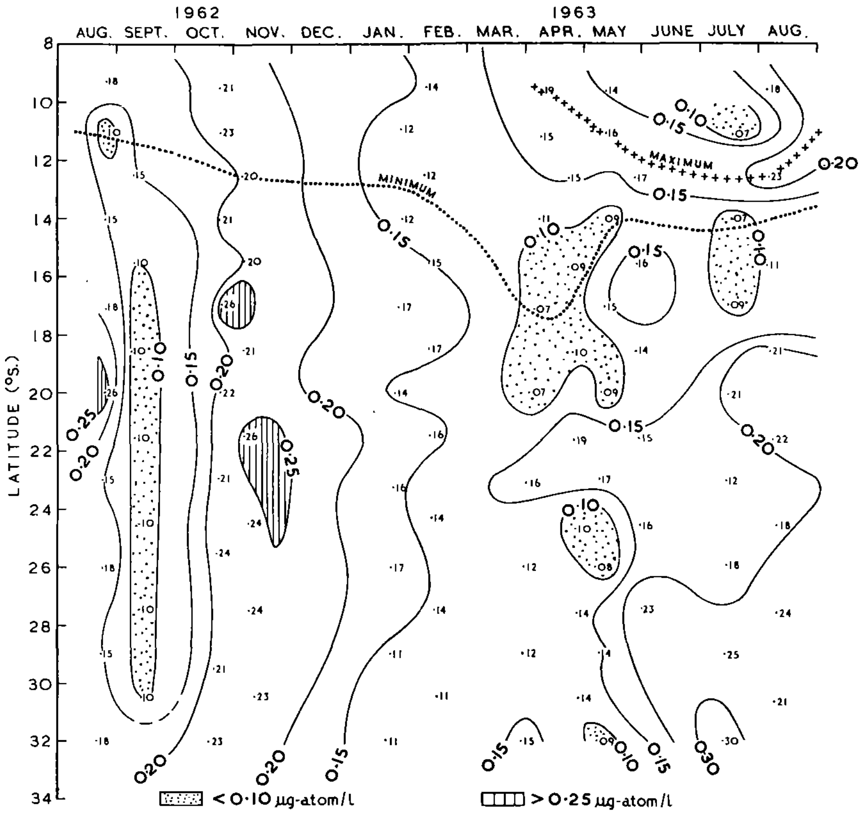


Fig. 22.—Changes in surface inorganic phosphate with time and latitude.

The large annual range in salinity at 200–400 m, south of 27° S., was caused by oscillation in the depth of accumulation of high salinity waters within the anticyclonic eddies that occur periodically in this region.

(iii) *Oxygen*

In a region of strong mixing and horizontal advection within the Kuroshio Current off south-east Japan, Uda (1964) found an annual variation in surface oxygen of 2·12 ml/l. This variation is very large when compared with that along 110° E. (Fig. 16), where the highest was 0·66 ml/l. It is thought therefore, that along 110° E. most of the annual surface change in oxygen concentration was caused by changes in the solubility of oxygen in response to surface temperature changes. For example, at *c.* 28° S., the annual changes in temperature and salinity of surface waters (Figs. 14 and 15) would cause the oxygen concentration to vary by 0·50 ml/l., which is very similar to the observed range of about 0·60 ml/l. (Fig. 16). South of 20° S., a layer of minimum annual change in oxygen was found at depths of 25–75 m (Fig. 16).

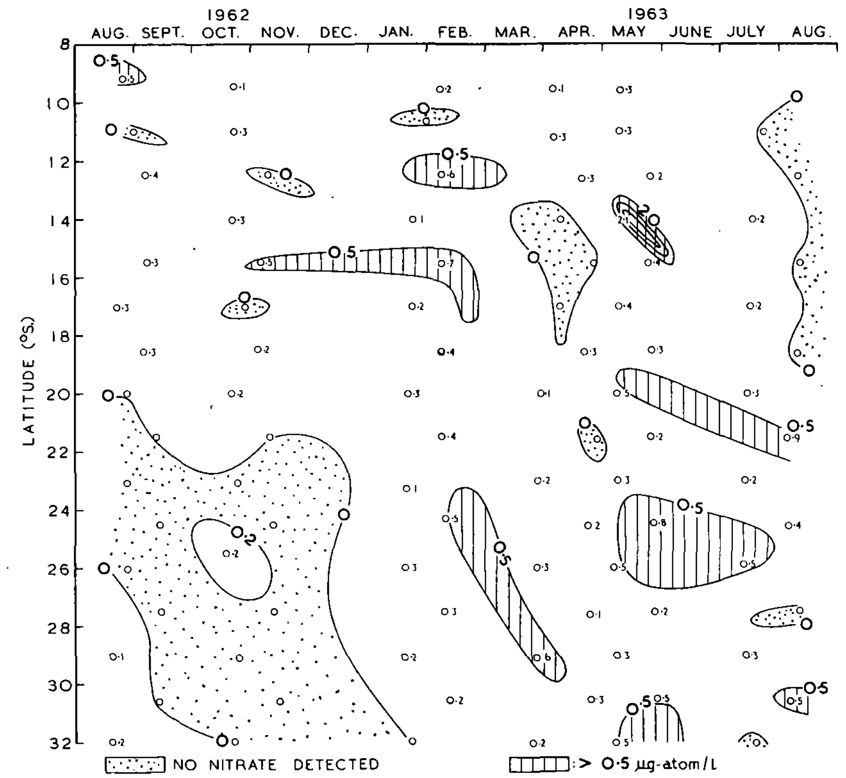


Fig. 23.—Changes in surface nitrate nitrogen with time and latitude.

This minimum was caused by retention, within the summer thermocline, of winter well-oxygenated water (Section III) also forming a maximum in oxygen concentration at the same depth (Fig. 4). Below this layer of minimum annual change, however, the annual changes in oxygen were much greater than at the surface (Fig. 16). Generally, the largest of the annual changes occurred in the boundary regions separating the horizontal circulation paths of the major water masses, and were caused by seasonal changes in the horizontal and vertical extent of these water masses.

(iv) *Inorganic Phosphate*

In temperate waters Armstrong and Butler (1962) observed annual changes of some 0·5 µg-atom/l. in the phosphate of the surface waters of the English Channel, whilst Rakestraw and Carritt (1948) found an annual change of 1·10 μg-atom/l. in surface waters between New York and Bermuda. In the tropics George (1953) found an annual variation of some 0·50 μg-atom/l. in surface phosphate off the Malabar coast of India. In comparison, the annual changes in surface phosphate along 110° E. were very small, rarely exceeding 0·20 μg-atom/l. (Fig. 17). In regions where the surface change was less than 0·10 μg-atom/l. (e.g. 10 and 23° S., Fig. 17) it is impossible to separate real variations in phosphate from those caused by experimental error in the analyses. It is probable that in these latitudes the phosphate content remained constant during the year. Below the surface the annual range generally decreased to a minimum value (Fig. 17) at a depth which corresponded closely to that of the minimum range in oxygen (Fig. 16). Below this minimum value of phosphate, the annual variation in phosphate paralleled that of oxygen (Fig. 16) and was caused by the same changes in mixing.

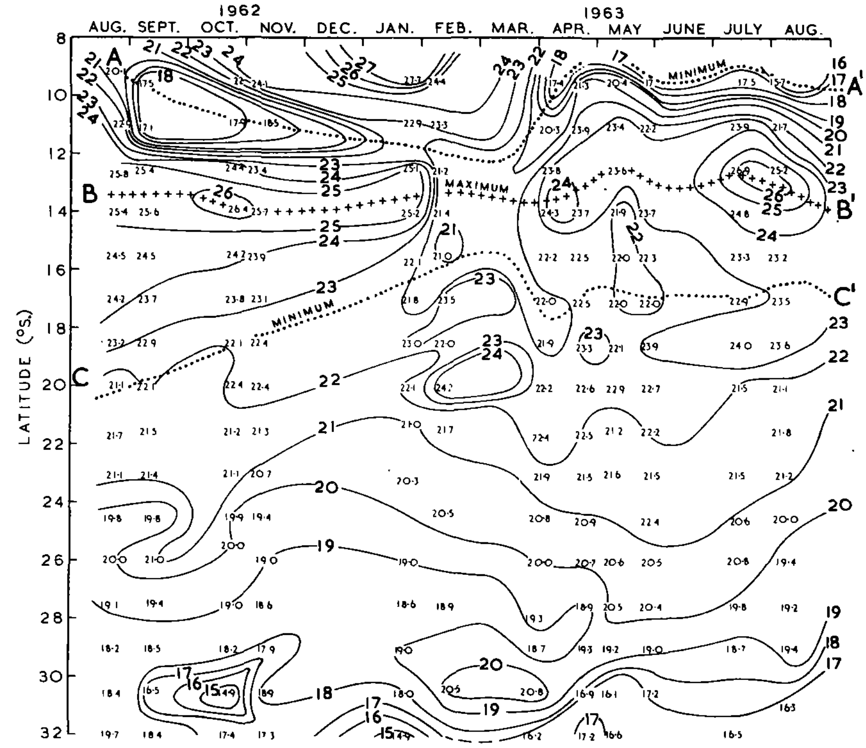


Fig. 24.—Changes in temperature at 100 m with time and latitude.

(v) *Nitrate Nitrogen*

Taking into account the sensitivity of the strychnidine method at low nitrate concentration (Section III), it is probable that the annual range in nitrate at the surface along 110° E. was less than 1·00 μg-atom/l. (Fig. 18). This was less than the annual variation of 2·0 μg-atom/l. observed by Rakestraw and Carritt (1948) in the Gulf

Stream off New York, and very much less than the annual variation of *c*. 7 μg-atom/l. observed by Cooper (1933) in the English Channel. This constancy of surface nitrate is in agreement with low annual variability of phosphate (Fig. 17) and oxygen (Fig. 16). Along 110° E., much larger annual variations occurred in the deeper waters than at the surface. The largest of these were found at latitudes and depths shown by other properties (Figs. 14–17) to be caused by vertical and horizontal movements of different water masses during the year.

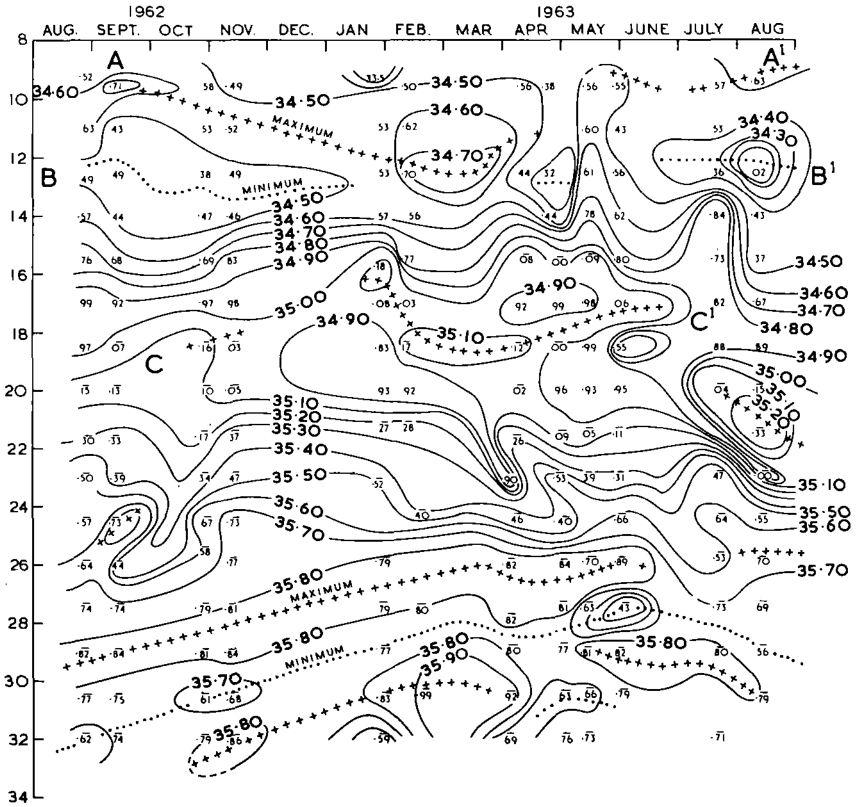


Fig. 25.—Changes in salinity at 100 m with time and latitude.

(*b*) *Time and Latitude at Selected Depths*

(i) *Temperature* (*0 m*)

Temperatures ranged from 18°c in the south in September 1962, to 29·1°c around latitude 12° S. in April 1963 (Fig. 19). Maximum temperatures for the period were found between March and April at all latitudes except south of 30° S. Here, January temperatures were equal to, or greater than, those in April. The temperature pattern showed periods of warm water (V, Fig. 21: (*b*)(ii) below) alternating with colder water. South of 28° S. much of this colder water was formed by mixing during the movement of eddies through the region. The warmer periods are therefore considered normal for this region. However, between 15 and 28° S. it is thought that the warmer water periods are caused by advection of warm water from the north while the colder periods are normal for the region.

(ii) *Salinity* (*0 m*)

Salinities ranged from 32–84‰ in the north in late May 1963, to 35–95‰ in the extreme south in April–May 1963 (Fig. 20). The lowest salinities of the year for the latitudes 24–32° S. were generally found in the summer–autumn period (January–May). North of 24° S., however, and north of 14° S. in particular, the lowest annual salinities occurred in the autumn–winter period (April–July). Generally, periods of lowered salinity coincided with periods of increased temperature (1–5, Fig. 21). The most likely explanation of these drops in surface salinity is advection of low salinity tropical water (see also Section VIII).

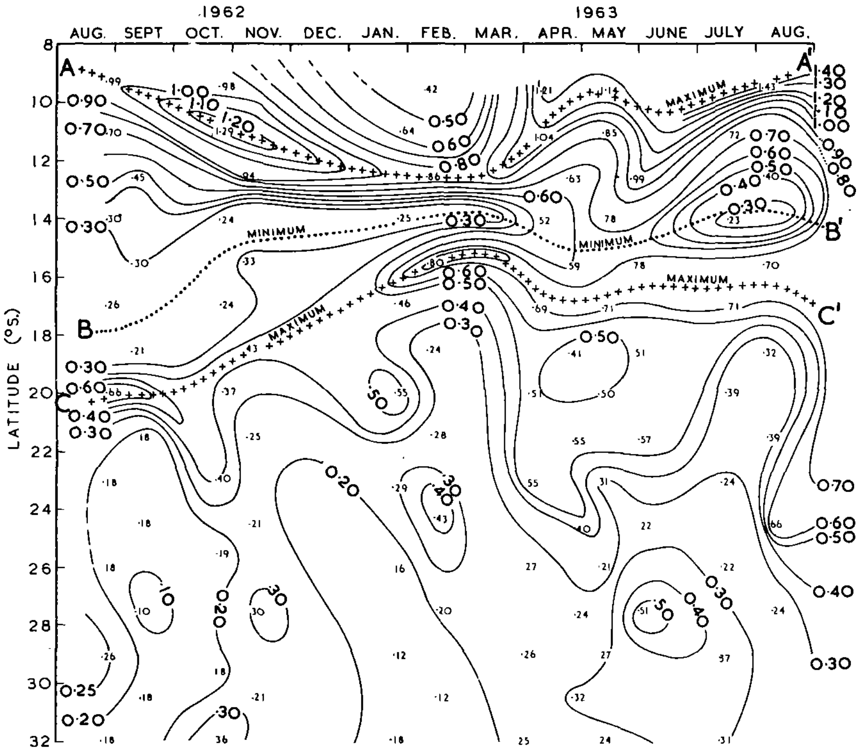


Fig. 26.—Changes in inorganic phosphate at 100 m with time and latitude.

(iii) *Inorganic Phosphate* (*0 m*)

Values ranged from 0·07 to 0·30 μg-atom/l. (Fig. 22). The lowest values of this range were found in April–May throughout most of the region south of 15° S., and in July largely between 11 and 17° S. The highest values for the period were mostly found in October–November when the thermocline structure indicated (Section VI) maximum vertical mixing. Increased phosphate around 12° S., particularly in August

1963, occurred within a region of lowered surface temperatures (Fig. 19) and was caused by upwelling or uplift and mixing of deeper waters into the surface layer.

(iv) *Nitrate Nitrogen* (*0 m*)

Values ranged from 0 to 2·1 μg-atom/l. (Fig. 23). Values greater than 0·5 μg-atom/l. were largely confined to the period January–May and to the region south of 12° S. Nitrate did not increase during the period of phosphate enrichment in August 1963 (Fig. 22). During the period of increased vertical mixing in October–November 1962, when phosphate increased (Fig. 22), nitrate was at about its lowest value for the year (Fig. 23). Considering the experimental error of these nitrate values (Section III), it is possible that these discrepancies were of no significance, but if real, they imply that nitrate was being utilized more rapidly than phosphate.

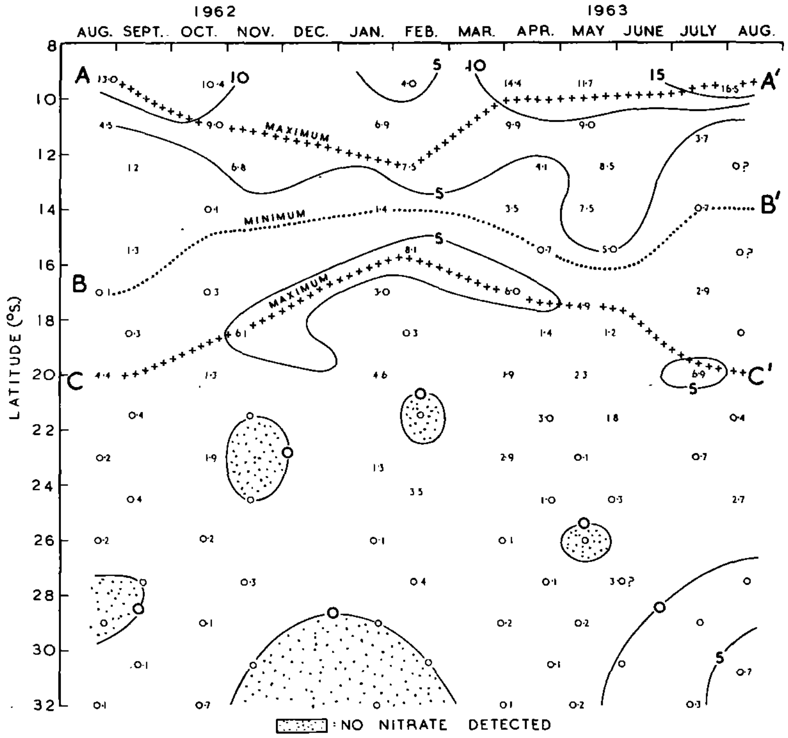


Fig. 27.—Changes in nitrate nitrogen at 100 m with time and latitude.

(v) *Temperature* (*100 m*)

The most rapid changes in temperature within the period of one cruise, or from one cruise to the next, occurred around 9–12° S. (A–A^1, Fig. 24). These rapid changes were brought about by short period uplift and sinking of colder water. The band of increased temperatures between 12 and 14° S. (B–B^1, Fig. 24) was caused by warm water accumulation within the South Equatorial Current.

(vi) *Salinity (100 m)*

North of 20° S. the position of bands of higher salinity (A–A^1 and C–C^1, Fig. 25) coincided with those of zonal bands of lower temperature (A–A^1 and C–C^1, Fig. 24). The zonal band of lower salinity (B–B^1, Fig. 25) and the zonal band of higher temperature (B–B^1, Fig. 24) occupied much the same position each month.

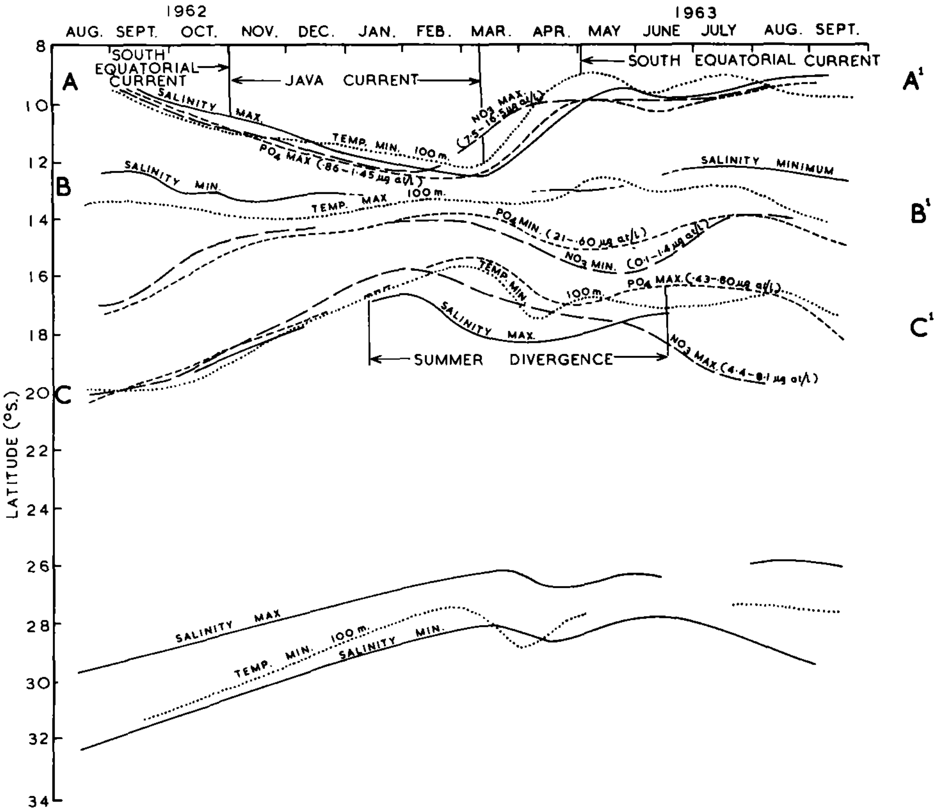


Fig. 28.—Comparison of changes in position with time and latitude of selected features of Figures 24–27. A–A^1, B–B^1, and C–C^1 explained in text.

(vii) *Inorganic Phosphate (100 m)*

Meridional maxima (A–A^1 and C–C^1, Fig. 26) and minima (B–B^1, Fig. 26) of phosphate were found during the year at about the same latitude as corresponding zones of salinity (Fig. 25) and temperature (Fig. 24).

(viii) *Nitrate Nitrogen (100 m)*

Bands of maxima (A–A^1 and C–C^1, Fig. 27) and minima (B–B^1, Fig. 27) in the meridional nitrate values corresponded fairly well with similar bands of phosphate at about the same positions (Fig. 26).

(ix) *Significance of Zones of Higher and Lower Temperature and Associated Properties*

Zone A–A[1] (Fig. 28), with a constant meridional maximum in salinity and nutrients, and a minimum in temperature at 100 m, forms the northern boundary of the west-flowing South Equatorial Current from April to September, and the southern boundary of the east flowing Java Current from about November to February.

Zone B–B[1] (Fig. 28), with a meridional maximum in temperature and a minimum in salinity and nutrients at 100 m, was not found throughout the year. When developed, this zone was formed by accumulation of warm water around the southern boundary of the South Equatorial Current. Zone C–C[1] was characterized by a meridional temperature minimum and a slight salinity and nutrient maximum at 100 m (Fig. 28).

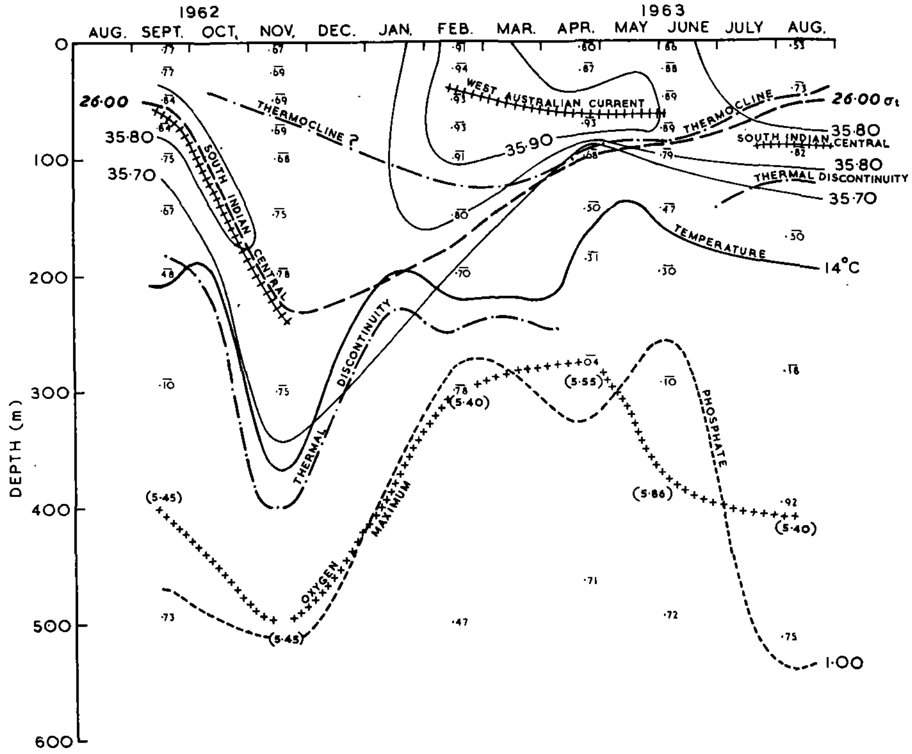


Fig. 29.—Changes in salinity, water masses, and selected structural features with time and depth at 30°30′ S. Barred values, salinity less 35·00‰. Unbarred values, salinity less 34·00 ‰.

During the winter and spring, Hamon (1965) found easterly currents in the region of this zone (18–20° S.). Zone C–C[1], during these months, is therefore formed by dynamic uplift along the southern margin of these currents. In summer however, easterly currents were either absent, or very weak (less than 5 cm/sec) in the region of zone C–C[1] (Hamon 1965). A temperature minimum cannot therefore be formed by the same dynamic uplift in summer as in winter. However, Wyrtki (1962*b*) postulated that north-flowing currents, which would not be detected in Hamon's geostrophic currents, diverge in the region around 20° S. during summer. It is possible therefore, that zone C–C¹ is the result of this divergence in summer. If this is so, such a divergence had no effect on surface nutrients (Figs. 22 and 23).

(*c*) *Time and Depth at Selected Latitudes*

The monthly cycles of the appearance and disappearance of the major water masses and other features at selected latitudes along 110° E. are shown in Figures 29–35.

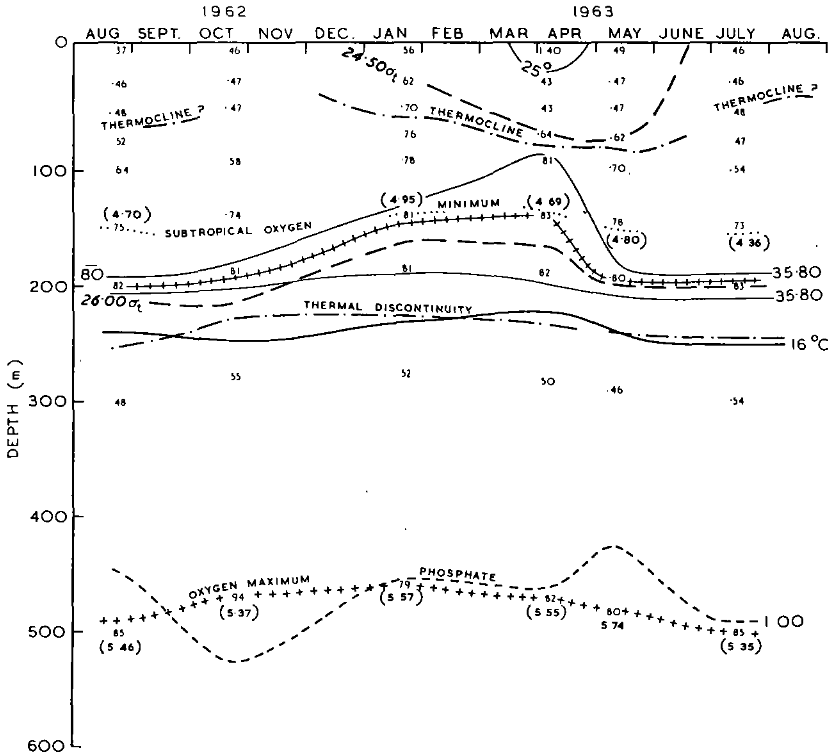


Fig. 30.—Changes in salinity, water masses, and selected structural features with time and depth at 26° S.

(i) *30°30′S.*

South Indian Central water on the 26·00 sigma-*t* surface occurred as a recognizable salinity maximum from July to November (Fig. 29). Between November and February, South Indian Central water lost its identity by mixing. From February to April–May, the upper salinity maximum at shallow depths (50 m) was formed by the ingress of high salinity water of the West Australian Current. The increase in depth of the thermal discontinuity, the 1·00 μg-atom/l. phosphate isoline, the 14°c isotherm, and the core of the subtropical oxygen maximum during October–November, were caused by the accumulation of subtropical surface waters in eddies. The disappearance of the thermal discontinuity from April to July was caused by the ingress of relatively cold waters of the subtropical oxygen maximum, elevating the 14°c isotherm almost to the depth of the summer thermocline.

(ii) *26° S.*

At 26° S. only one high salinity layer was clearly recognizable. This was South Indian Central water (with almost constant salinities throughout the year), on about the 26·00 sigma-*t* surface (Fig. 30). Lying just above or within this layer was the subtropical oxygen minimum. The increase in salinity at 100 m in April 1963 was caused by waters of the West Australian Current, distinguishable as a salinity maximum only on a salinity–temperature diagram. The thermal discontinuity centred about the 16°C isotherm occurred at around 250 m, and the subtropical oxygen maximum centred about the 1·00 μg-atom/l. isoline of phosphate at 450–500 m.

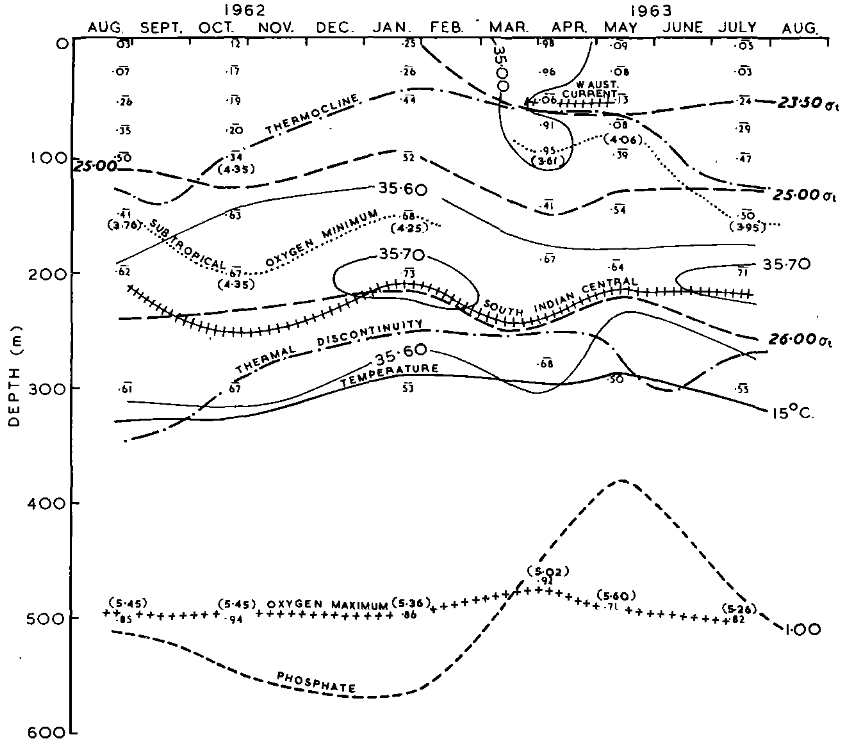


Fig. 31.—Changes in salinity, water masses, and selected structural features with time and depth at 23° S.

Within this latter layer, oxygen values were at their lowest in October when the salinity was highest and phosphate at its lowest for the year. This is the period of maximum accumulation of shallower subtropical waters within this layer.

(iii) *23° S.*

The salinity of the South Indian Central water mass varied more at 23° S. although the sigma-*t* and depth of this layer were fairly constant (Fig. 31). Highest salinities, indicative of increased flow, occurred in January and July. A summer thermocline persisted at least until October. Below this thermocline the tropical

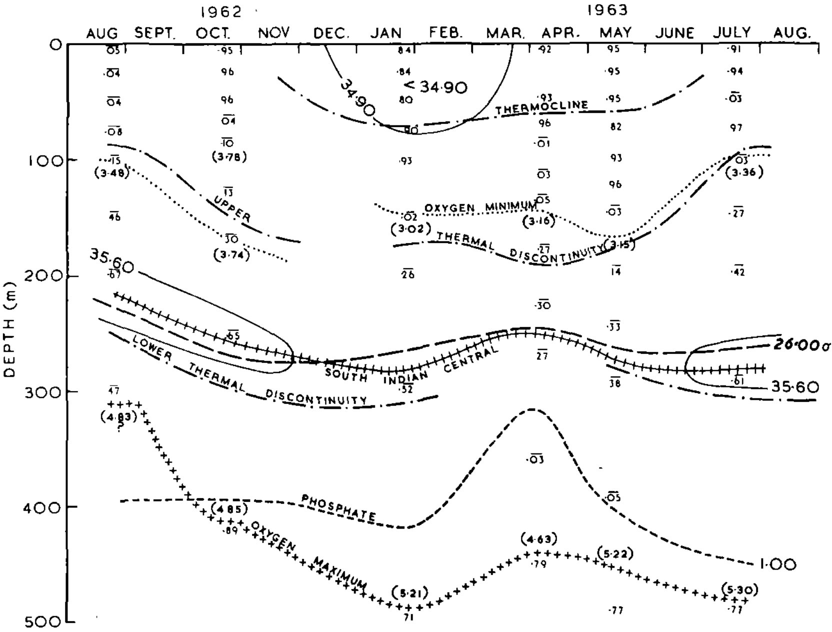


Fig. 32.—Changes in salinity, water masses, and selected structural features with time and depth at 20° S.

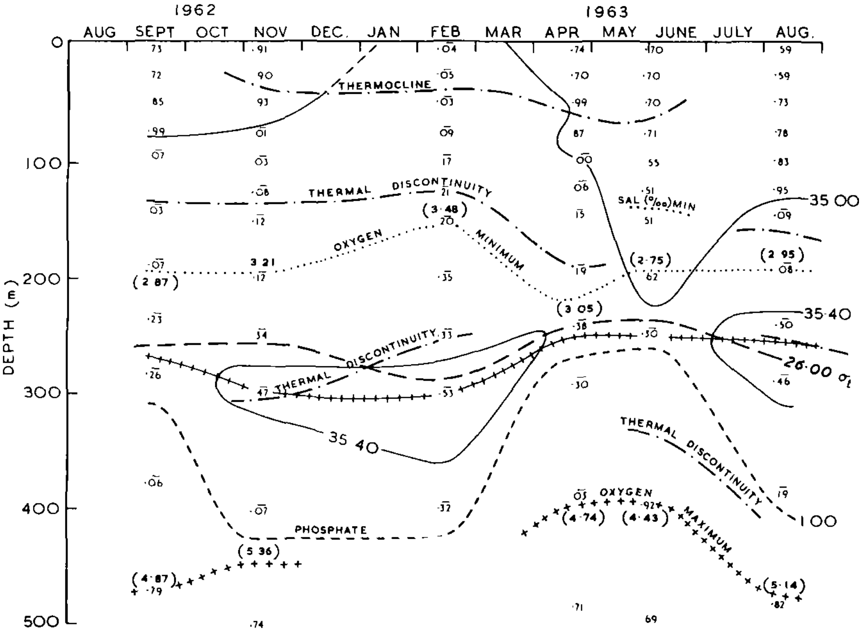


Fig. 33.—Changes in salinity, water masses, and selected structural features with time and depth at 18°30′S.

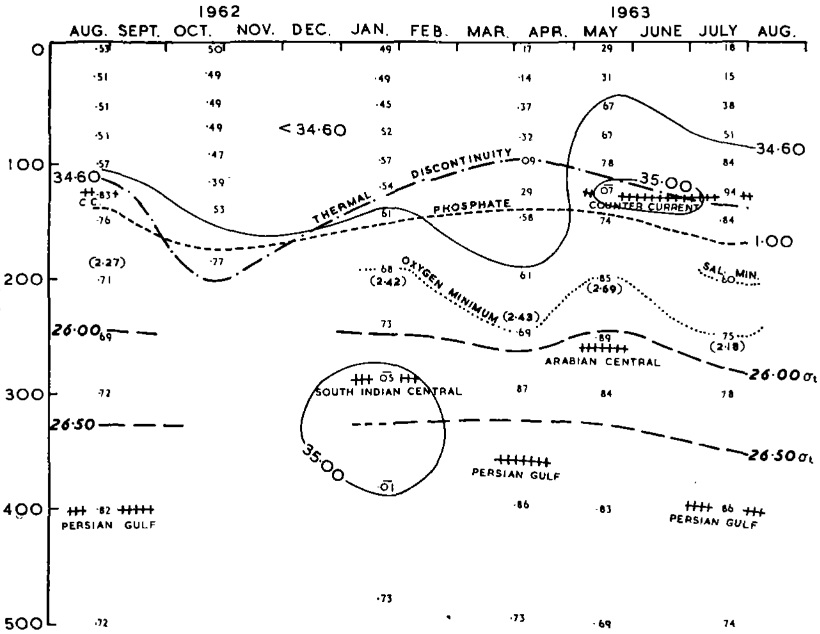


Fig. 34.—Changes in salinity, water masses, and selected structural features with time and depth at 14° S.

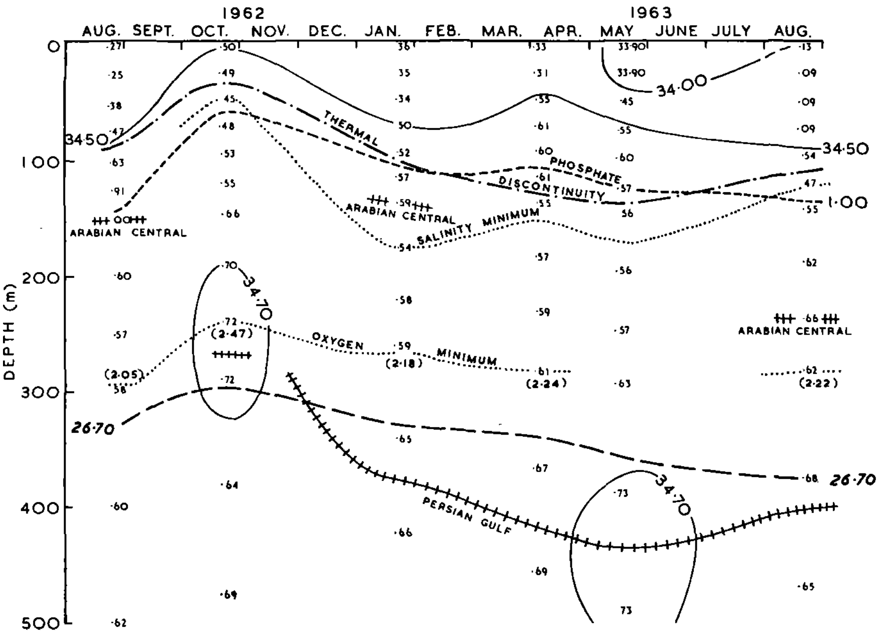


Fig. 35.—Changes in salinity, water masses, and selected structural features with time and depth at 11° S.

oxygen minimum layer first occurred in March–April, with the lowest oxygen content of the year. From then on, this layer deepened and increased its oxygen content until by January the oxygen saturation was as high as 83%, and its identity as an oxygen minimum was almost lost. The salinity maximum on the 23·5 sigma-*t* surface during April–May, centred on the thermocline, was formed by mixing of low salinity waters into the layers above and below the thermocline during the ingress of waters of this tropical oxygen minimum. The thermal discontinuity, and the 15°c isotherm with which it was associated, varied little in depth during the year. Below this stable zone, however, there was considerable variation in the extent of waters with a phosphate content greater or less than 1·00 μg-atom/l., and in the salinity and oxygen values of the subtropical oxygen maximum. Oxygen and salinity values, without making any allowance for variations in mixing, indicate that more of the waters of this maximum occurred at 23° S. in May–June than in other months of the year.

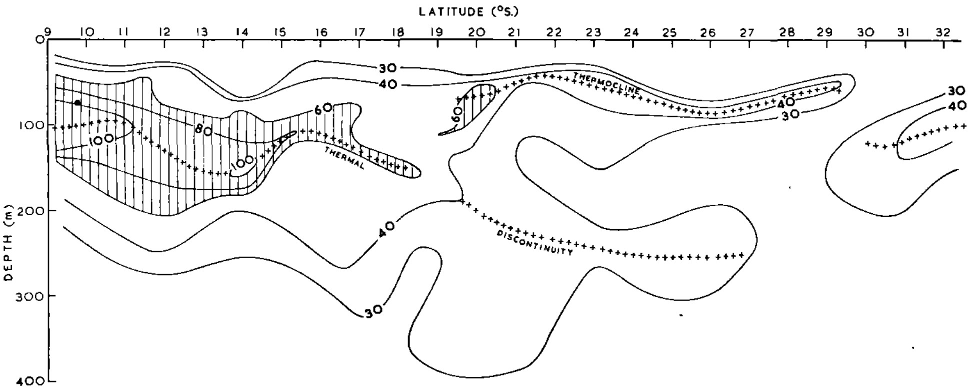


Fig. 36.—The mean annual vertical temperature gradients in degc per m multiplied by 10^3. + + + + Maximum indicative of the mean depth of the thermal discontinuity and thermocline.

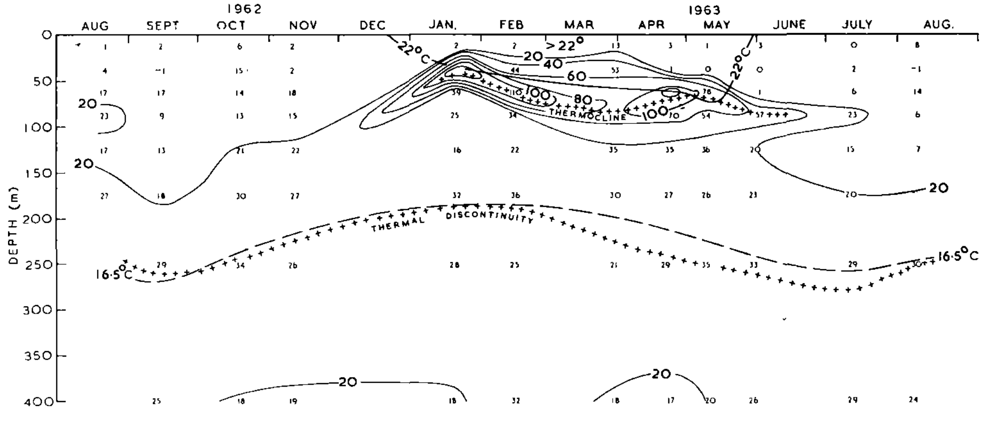


Fig. 37.—Changes in vertical temperature gradients (degc × 10^3/m) with time and depth at 27°30′ S. + + + + Maxima in the vertical gradients. Depths of the 16·5 and 22°c isotherms are shown.

(iv) *20° S.*

At 20° S. waters above 200 m were largely of tropical origin. The ingress of tropical water was greatest in January–February, as evidenced by the decrease in salinities of the upper 50 m and by the oxygen minimum around 150 m (Fig. 32).

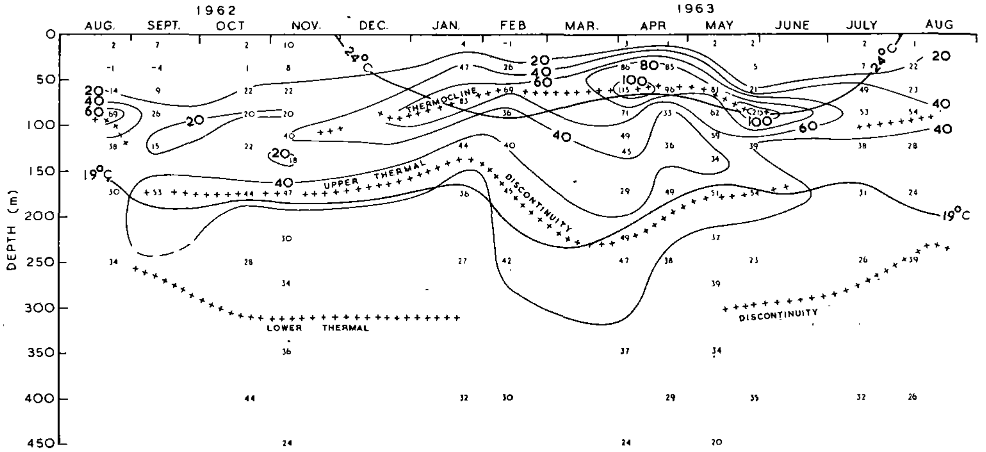


Fig. 38.—Changes in vertical temperature gradients (degc × 10^3/m) with time and depth at 20° S. Depths of the 19 and 24°c isotherms are shown.

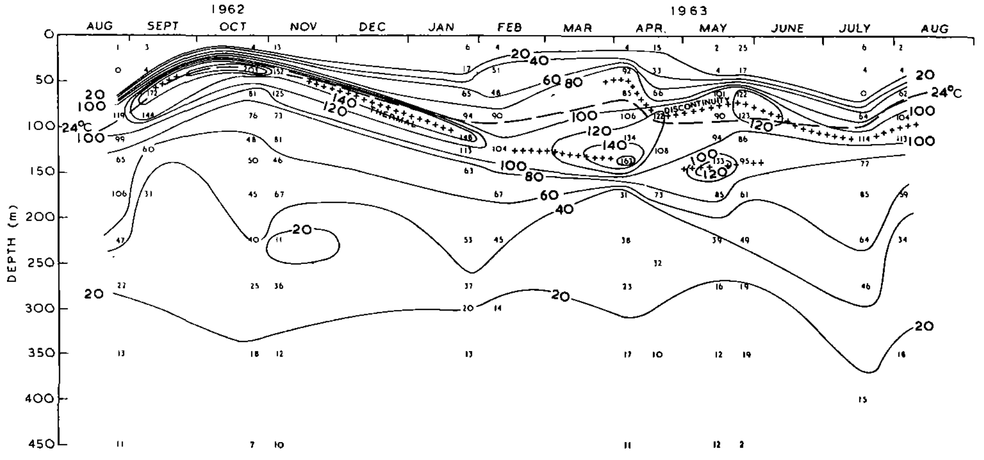


Fig. 39.—Changes in vertical temperature gradients (degc × 10^3/m) with time and depth at 11° S. Depth of the 24°c isotherm shown.

Below 200 m however, waters were largely of subtropical and southern origin. This was caused by advection of South Indian Central water on the 26·00 sigma-*t* surface around 250 m, and of subtropical oxygen maximum water at deeper levels. The salinity of the South Indian Central water was at its lowest for the year in March–April, when a marked diminution in the oxygen of the subtropical oxygen maximum below also occurred. However, since this diminution in oxygen was accompanied by an increase in phosphate (Fig. 32), its cause must have been an influx of waters of northern origin, rather than mixing of subtropical waters to the depth of this subtropical oxygen maximum. The northward spread of South Indian Central and subtropical oxygen maximum waters for most of the year at 20° S. appears therefore to be reduced in late summer by a counter-flow of tropical waters. Associated with the tropical oxygen minimum and South Indian Central water, were two separate thermal discontinuities formed by advection of waters of a different temperature structure and not, as occurs to the north (Section VI), by vertical displacement of a temperature layer.

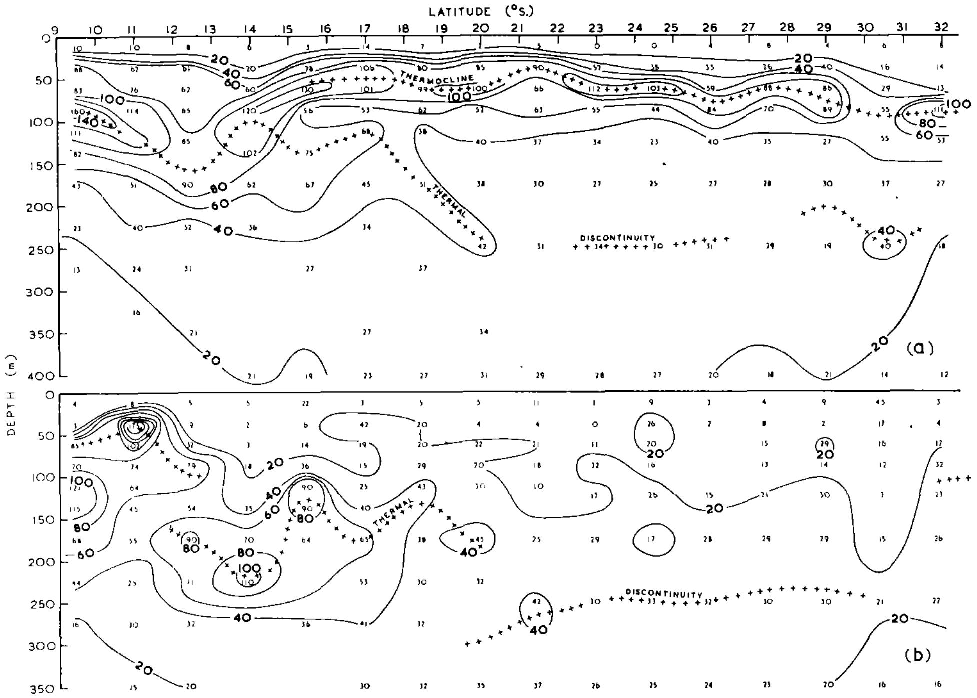


Fig. 40.—Changes in vertical temperature gradients (degc × 10^3/m) with latitude and depth. (*a*) March–April 1963, (*b*) October–November 1962.

(v) *18°30′S.*

The tropical oxygen minimum was well developed throughout the year but the greatest influx of waters of this minimum occurred in May–June when its oxygen and salinity were at their lowest values (Fig. 33). A thermal discontinuity was associated with this minimum at some 50 m above it. During the May–June influx, however, this thermal discontinuity disappeared because of vertical mixing. This vertical mixing occurred at a time when the salinity of the South Indian Central water mass was lowered, and the oxygen and phosphate content of the subtropical oxygen maximum indicated (as at 20° S., Fig. 32) an increase in the influx of tropical water. In May–June therefore, the 500 m column was strongly influenced by tropical waters. A thermal discontinuity was found at about the same depth as the South Indian Central only during periods when its salinity suggested the strongest influx.

(vi) *14° S.*

At 14° S., South Indian Central water occurred only in January–February and on about the 26·30 sigma-*t* surface at *c.* 300 m (Fig. 34). High salinity waters at about this depth at other times of the year were identified as Arabian Central and Persian Gulf (Rochford 1964), but these also did not occur all the year round. The constancy in depth of the 26·00 and 26·50 sigma-*t* surfaces showed that mixing did not extend to sufficient depths at 14° S. to destroy the identity of these high salinity layers at certain times of the year. These bolus type intrusions must therefore be formed outside the 14° S. region. Above 250 m the tropical oxygen minimum showed by its oxygen values that the greatest influx of this water occurred in July–August. This was also the period when so-called counter-current water (Rochford 1964) of the north Indian Ocean was found within the thermal discontinuity layer. This discontinuity layer was at maximum depth in October when the South Equatorial Current was flowing most rapidly (Hamon 1965), and at minimum depth in March–April when this current was weakest.

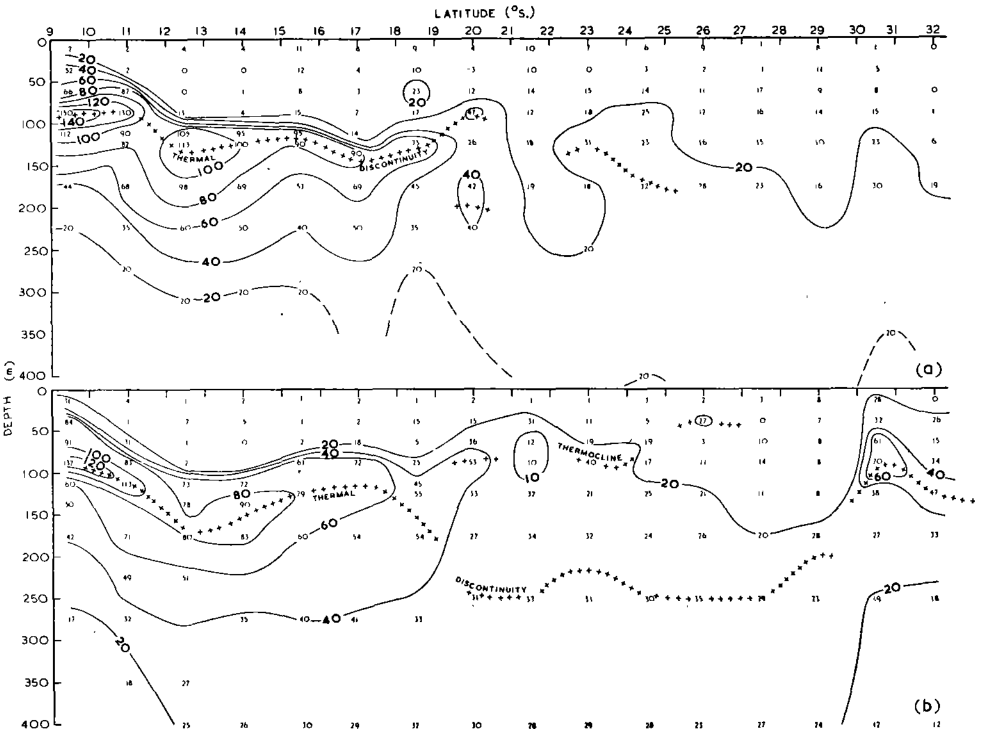


Fig. 41.—Changes in vertical temperature gradients (degc × 10³/m) with latitude and depth. (*a*) August–September 1962, (*b*) July–August 1963.

(vii) *11° S.*

All the selected features of the hydrological structure (thermal discontinuity, salinity, density, phosphate, and oxygen) were closest to the surface in October

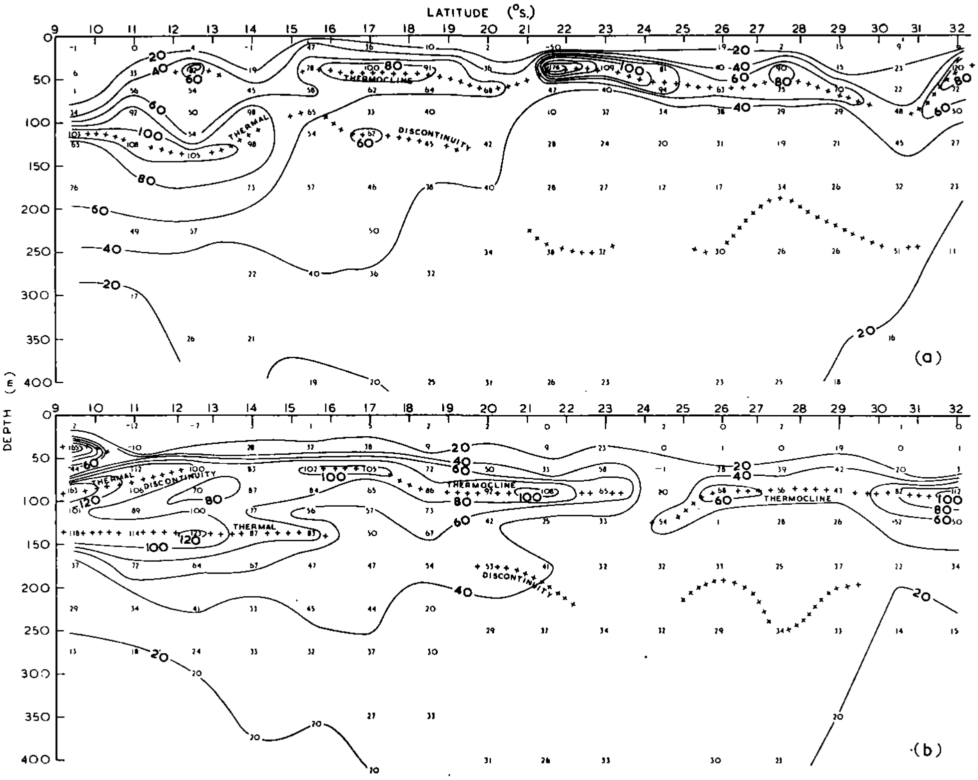


Fig. 42.—Changes in vertical temperature gradients (degc × 10³/m) with latitude and depth. (*a*) January–February 1963, (*b*) May–June 1963.

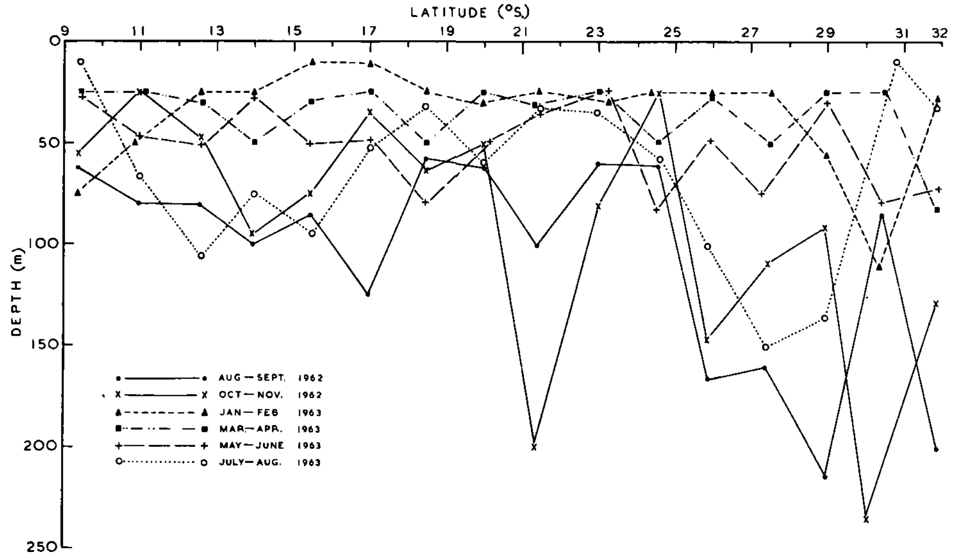


Fig. 43.—Variations in the depth of the mixed layer (degc/m less than 0·02).

(Fig. 35). This elevation, which was brought about by dynamic uplift along the northern boundary of the South Equatorial Current, affected the hydrological structure to at least 400 m.

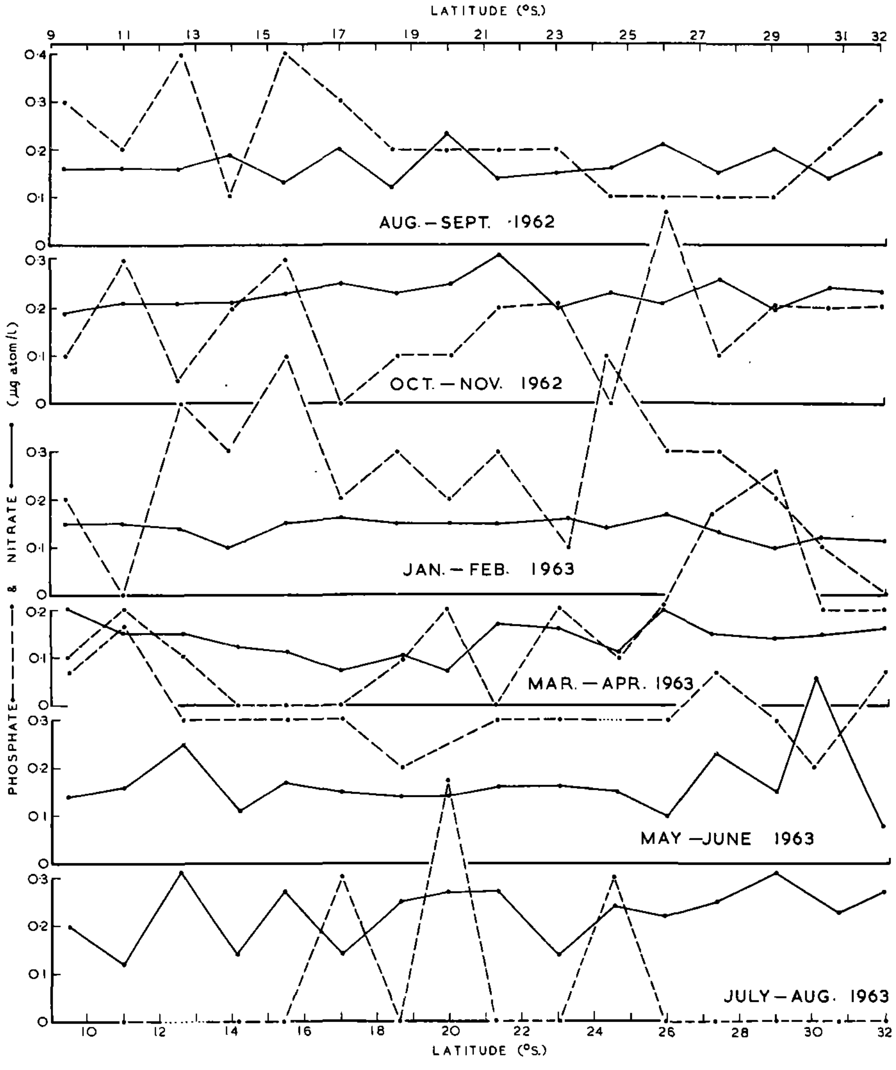


Fig. 44.—The column averages of phosphate and nitrate to the bottom of the mixed layer (Fig. 43).

VI. Seasonal and Latitudinal Changes in the Vertical Temperature Gradients

Temperatures decrease non-uniformly with depth in the upper layers of the south-east Indian Ocean and this gives rise to one or more maxima in the vertical temperature gradients. The mean annual vertical temperature gradients at each latitude (Fig. 36) show that, north of *c.* 18° S., there was only one maximum of this gradient throughout the year. South of 20° S., however, two such maxima occurred (Fig. 36). In this southern region the deeper maximum in the temperature gradient separated colder, deeper water, of near uniform temperature, from warmer, shallower water of more variable temperature, and was permanently centred about a particular temperature band (Fig. 37) which ascended and descended according to the surface circulation. This maximum in the temperature gradient is called the thermal discontinuity, in preference to the term "permanent thermocline" introduced by Wyrtki (1964). The term thermocline is reserved for the maximum in vertical temperature gradient, found much nearer the surface, and restricted to the summer period when a shallow heated layer forms above the thermal discontinuity (Fig. 37). Thus, at 27°30′ S., the thermal discontinuity occurred all year round at 200–250 m, and was centred on the 16·5°C isotherm, whilst the thermocline occurred only from January to May, then disappeared, and reformed only when surface temperatures exceeded 22°C (Fig. 37). At 20° S. the thermocline and thermal discontinuity tended to coalesce but were still clearly differentiated, the former appearing only when surface temperatures exceeded 24°C and the latter almost permanently centred about the 19°C isotherm, which ascended and descended some 100 m in the year (Fig. 38).

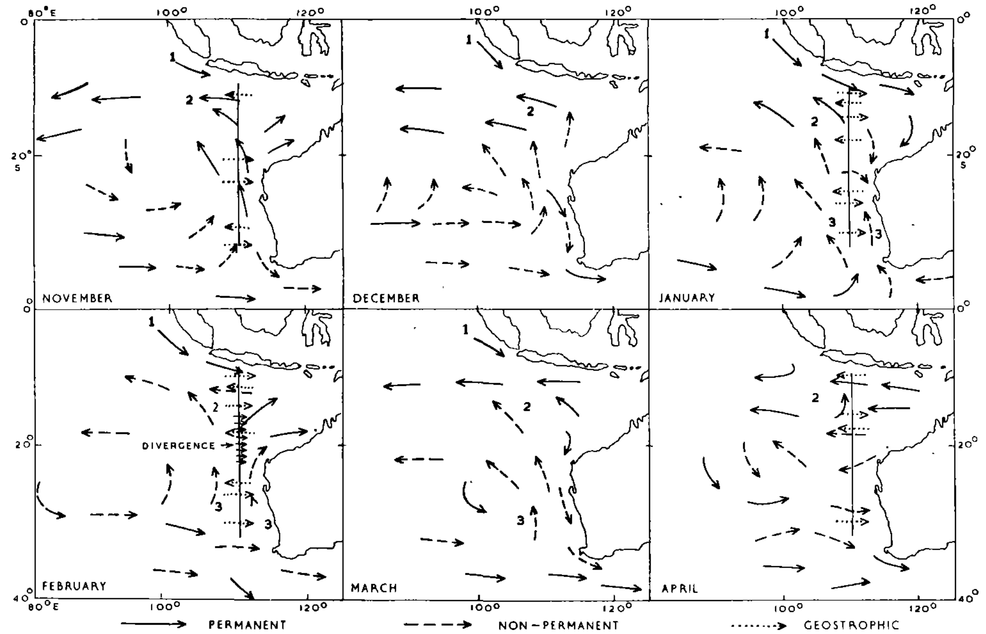


Fig. 45.—Surface currents November–April. Only those surface ship drift currents (Deutsches Hydrographisches Institut 1960) greater than 20 cm/sec are shown. These currents have been divided into permanent (persistent drift in one direction for more than 50% of the month) and non-permanent (persistence less than 50%). Surface geostrophic currents across 110° E. (Hamon 1965) with velocities greater than 15 cm/sec are shown for comparison. For 1, 2, and 3 see text.

At 11° S. only one maximum in the vertical temperature gradient was found for most of the year (Fig. 39). This was centred about the 24°C isotherm and was therefore the equivalent of the thermal discontinuity of southern latitudes, rather than the true thermocline (Fig. 37). This thermal discontinuity occurred nearest the surface (30–40 m), and at maximum intensity, in late October when Hamon (1965) found the South Equatorial Current at near maximum strength just south of 11° S. The uplift and intensification of the thermal discontinuity were principally caused, therefore, by upthrust of the deeper, colder water. During the summer, when the South Equatorial Current lies more to the south and is much weaker (Hamon 1965), this thermal discontinuity weakened considerably, but its intensity was still as strong as the summer thermocline south of 20° S. (Figs. 37 and 39).

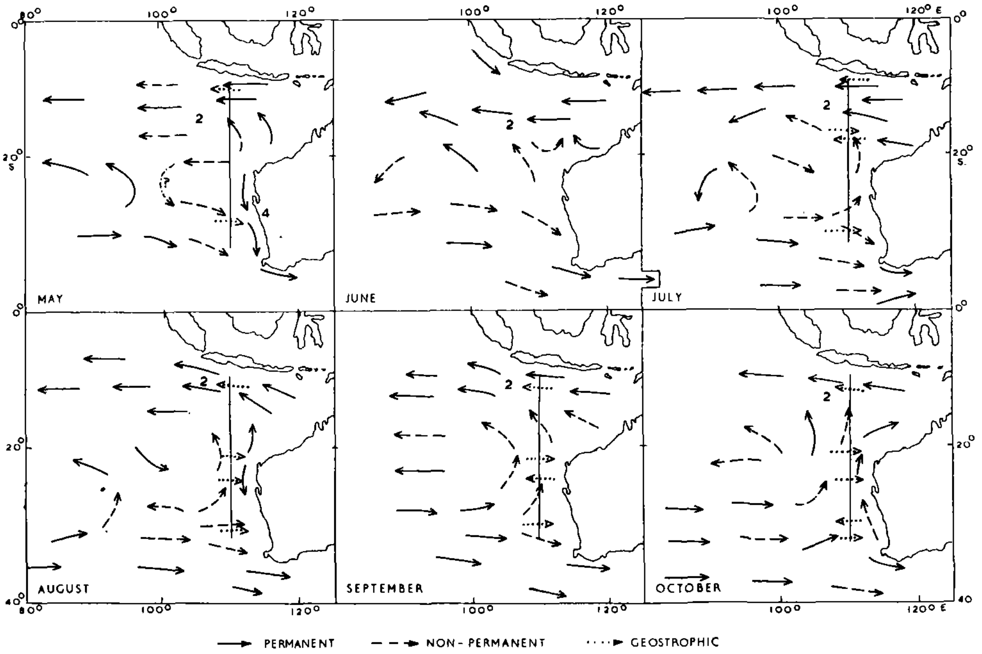


Fig. 46.—Surface currents May–October. For 2 and 4 see text. Other symbols, see Figure 45.

During late summer (March–April), a thermocline with a vertical temperature gradient of more than 2 degc in 25 m (80 units, Fig. 40(*a*)) occurred from *c*. 15–32° S. at depths of 50 m in the north to around 100 m in the south. North of 15° S., a thermal discontinuity of about the same intensity, but at a deeper level (100–150 m), was found. South of 17° S., this thermal discontinuity weakened and its centre deepened to around 250 m.

In late spring (October–November) no thermocline with an intensity greater than 0·75 degc per 25 m (30 units, Fig. 40(*b*)) was in evidence. The thermal discontinuity was very strongly developed in the extreme north and nearer to the surface than elsewhere. The deepening of this discontinuity around 14° S. occurred in the region of maximum accumulation of warm water (Fig. 2) by the South Equatorial Current. The thermal discontinuity south of *c*. 20° S. varied little in depth or intensity from late summer to late spring (Fig. 40), except in the far south where the thermal structure is complicated in the late spring by eddy disturbances. The depths and intensities of the thermocline and thermal discontinuity at other times of the year varied within these two extreme conditions (Figs. 41 and 42).

VII. SEASONAL AND LATITUDINAL CHANGES IN THE MIXED LAYER AND NUTRIENT COLUMN AVERAGES

The mixed layer was defined by Defant (1936) as that part of the temperature profile, from the surface downwards, in which the temperature gradient did not exceed 0·02 degC/m. More recently Wyrtki (1964) used a value of 0·03 degC/m. Defant's value of 0·02 degC/m is used in this paper to determine the depth of the mixed layer in which no physical boundaries exist to impede the vertical mixing of nutrients and biota. The depth of this mixed layer varied, from extreme values of more than 200 m in the south during winter and spring, to around 10 m in latitudes 15–17° S. in summer (Fig. 43). Between 11 and 15° S. the depth of the mixed layer increased to 80–100 m during the period of strongest flow of the South Equatorial Current, and decreased during the counter-flow of the Java Current and weakest flow period of the South Equatorial Current (Fig. 43). The depth of the mixed layer in these latitudes was governed, therefore, by the varying depth of accumulation of warm water in response to geostrophic balance, and not directly by seasonal changes in wind stress and convective overturn.

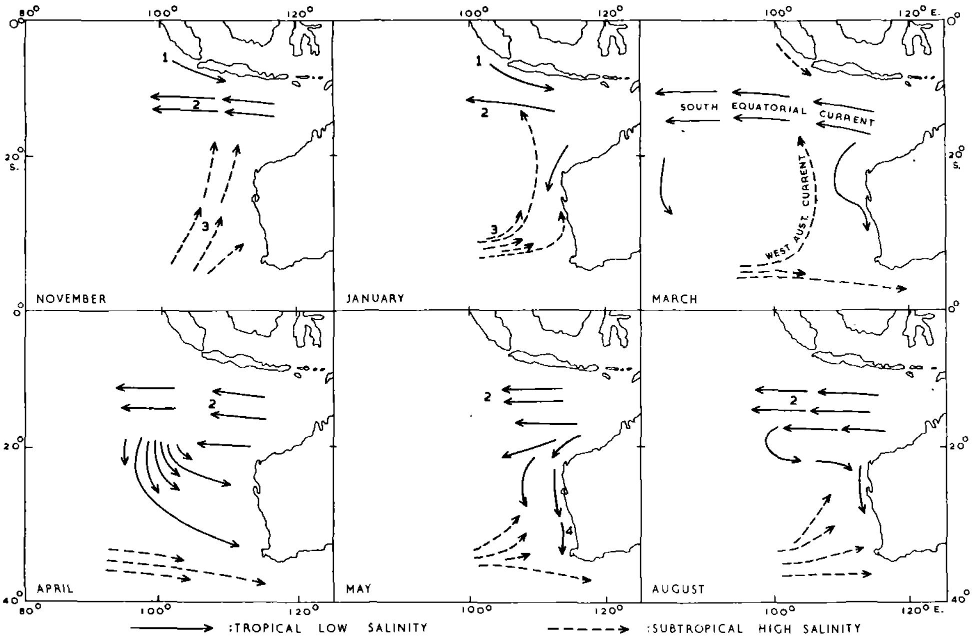


Fig. 47.—Changes in the direction of drift of tropical low salinity and of subtropical high salinity waters across and along 110° E. For 1, 2, 3, and 4 see text.

South of *c*. 17° S. the depth of the mixed layer remained nearly constant throughout the year at certain latitudes (19 and 24° S., Fig. 43) but fluctuated considerably at others (17, 21, and 26–32° S., Fig. 43). It is considered most unlikely that the mean wind stress and convective overturn could vary so much from one latitude to another as to create, for example, a deep mixed layer to near 170 m at 26° S. on August 22, 1962 (Fig. 43), but to only 60 m at 23° S. some 24 hr later. It is thought more probable therefore that the deepening of the mixed layer at 17, 21, and south of 25° S. (Fig. 43) was a consequence of the eastward passage of eddies during winter and spring (Fig. 43). Without this augmented mixing it is doubtful whether the mixed layer south of 20° S. would extend much below 75 m, the depth of the near constant mixed layer at 24° S.

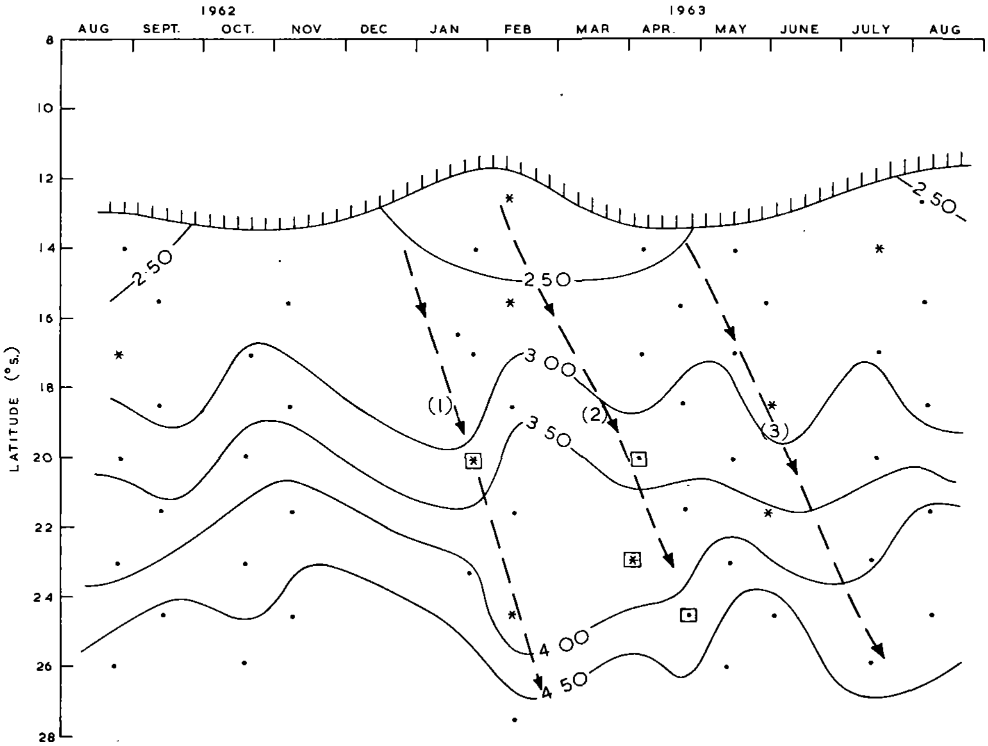


Fig. 48.—Changes with time and latitude of oxygen content (ml/l.) of the tropical oxygen minimum (sigma-*t* 25·00–26·00). For (1), (2), and (3) see text. * Minimum value for the year at the particular latitude. □ Sigma-*t* less than 25·00.

The column average of nutrients in this mixed layer was not significantly greater at latitudes where this pronounced deepening of the mixed layer occurred in winter and spring (17, 21, and 25–32° S., Fig. 44). This stability in nutrients also favours eddy accumulation of surface waters and not wind stirred mixing and convective overturn as the explanation of the deep mixed layer south of 20° S.

The latitudinal variation in the mixed column averages of inorganic phosphate was not very great (Fig. 44) and in most cases was within the experimental error of the analysis. Similarly, with nitrate, it is doubtful whether any significance can be attached to the latitudinal variation. It is probable that all column averages of nitrate can be accepted as less than 1·0 μg-atom/l., but variations from 0 to 0·5 μg-atom/l. have doubtful significance. The seasonal variations in the mixed column averages of inorganic phosphate from one cruise to another indicate that, on the average, there was slightly more phosphate in this column in winter and spring than in summer and autumn (Fig. 44). However, the range of variation was quite small (less than 0·15 in summer and autumn to more than 0·20 in winter and spring; Fig. 44).

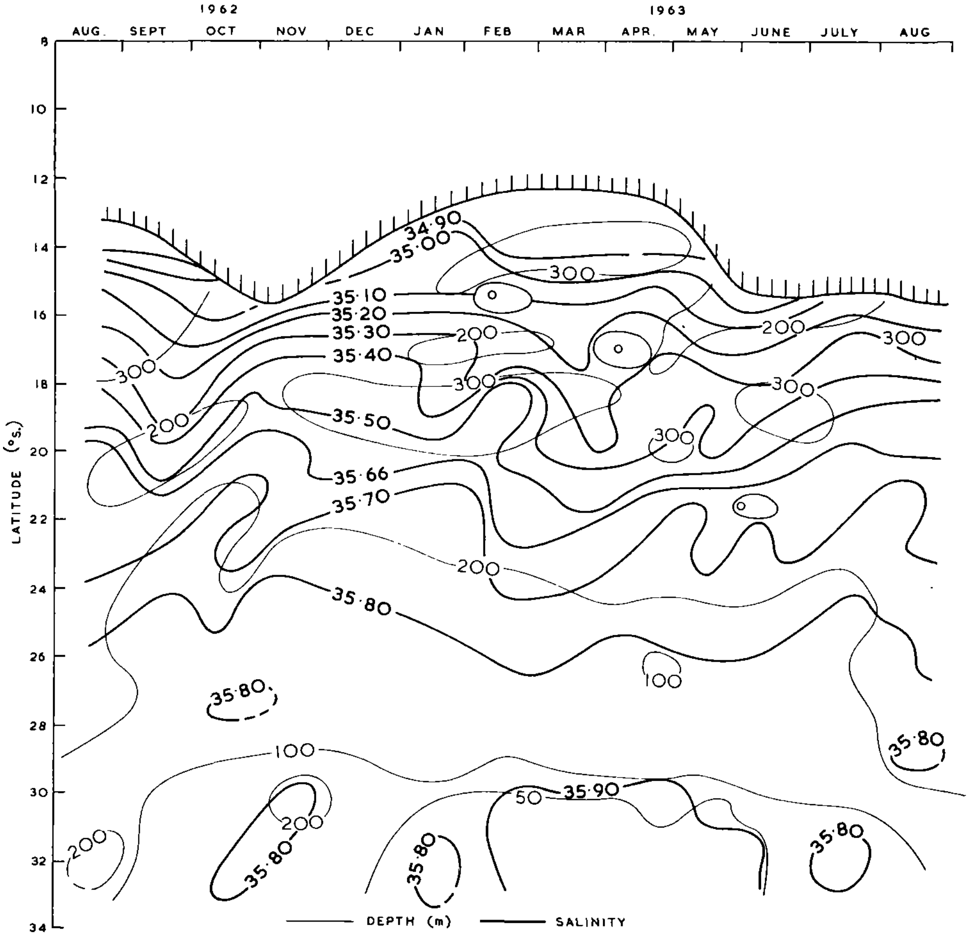


Fig. 49.—Changes with time and latitude of the salinity (‰) (thicker lines) and depth (m) (thinner lines) of South Indian Central water.

VIII. Surface Currents of the 110° E. Region

Wyrtki (1962*b*) and Hamon (1965) have described the geostrophic currents of the south-east Indian Ocean. Hamon (1965) also indicated the zonal components of geostrophic flow across 110° E. during this present series of cruises. Surface currents from ships' observations (Deutsches Hydrographisches Institut 1960), whilst more extensively charted, are quantitatively much less reliable than these limited geostrophic current measurements. However, by collation of the results from both these sources of information, charts of the monthly changes in surface circulation in the vicinity of 110° E. have been prepared (Figs. 45 and 46).

In the summer months (November–March) the Java Current (1, Fig. 45) flows east across the northern end of 110° E. This current had a geostrophic velocity of only *c.* 3 cm/sec in January 1963 (Hamon 1965), but its velocity at other times and places (Soeriaatmadja 1957) was around 15–25 cm/sec. South of the Java Current the west flowing South Equatorial Current occurs between 11 and 13° S. throughout the year (2, Fig. 45) with velocities according to Hamon (1965) of 30–100 cm/sec.

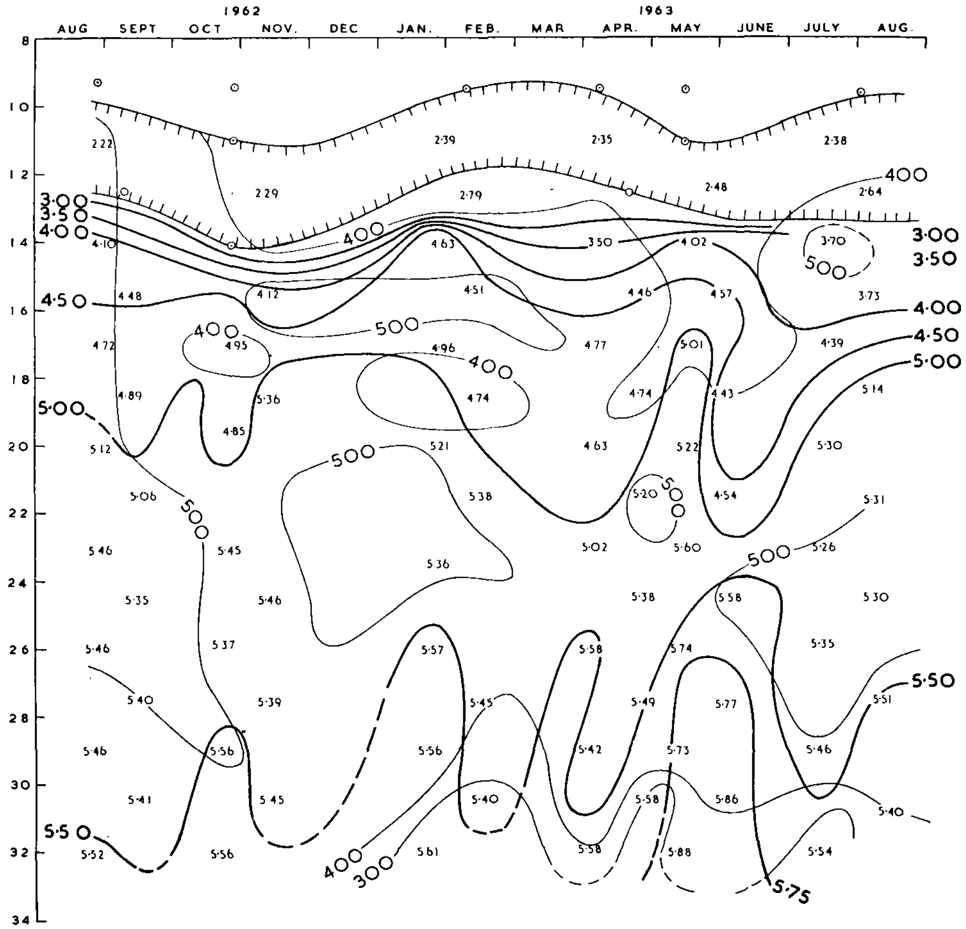


Fig. 50.—Changes with time and latitude of the oxygen (ml/l.) (thicker lines) and depth (thinner lines) of the subtropical oxygen maximum.

South of this Equatorial Current, from November to March, north setting currents are generally found in the region from 110° E. to West Australia. In early summer (January) these north setting currents coalesce into the West Australian Current (3, Fig. 45), whose zonal geostrophic component (Hamon 1965) has a velocity of less than 15 cm/sec. After March these north setting currents veer to the east and by May have developed into a strong (15–40 cm/sec) south-flowing current between 110° E. and the Australian mainland (4, Fig. 46). Between June and September the east-flowing currents across 110° E. continue but veer more and more to the north, so that by October, the general drift to the north (which by January coalesces into the West Australian Current) begins.

It is believed (Section V) that some of the annual changes in surface salinity along 110° E. were caused by the movement of low salinity, high temperature, tropical waters, and of high salinity, low temperature, subtropical waters across or along 110° E. Schematic charts based upon the evidence of the monthly changes in salinity (Fig. 21), and of the changes in surface circulation (Figs. 45 and 46) show the most probable seasonal changes in the movements of these two kinds of water (Fig. 47).

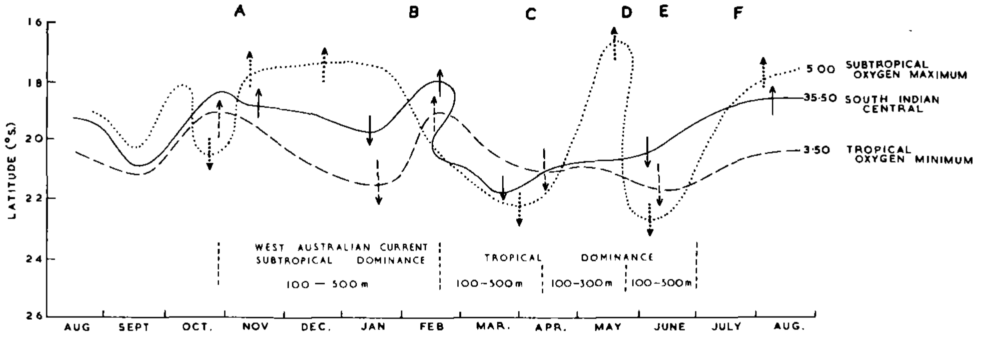


Fig. 51.—Changes with time and latitude of positions of the 3·50 ml/l. oxygen isoline (tropical oxygen minimum—Fig. 48), of the 35·50‰ isoline (South Indian Central—Fig. 49), and of the 5·00 ml/l. oxygen isoline (subtropical oxygen maximum—Fig. 50). Arrows show the periods of maximum meridional displacement. A–F explained in text.

The November chart (Fig. 47) is typical of the early summer pattern, with high salinity water drifting north along 110° E. to about 15° S. This is the period when surface salinities north to at least 15° S. reach their highest value in the year (Fig. 11). By midsummer (January) this high salinity drift separates into a southern component close to the coast, and a northern component to the west of 110° E. By autumn (March–April) the high salinity water has been diverted to the south and west of 110° E. and replaced largely by low salinity tropical water. This is the period when surface salinities south of 20° S. decrease to their lowest annual value (Fig. 21). From May onward, however, these low salinity waters gradually decrease in area, particularly south of 25° S. and west of 110° E., and higher salinity waters begin to drift north and east again (August, Fig. 47).

IX. SUBSURFACE WATER MOVEMENTS

The geostrophic currents of the upper 500 m of the south-east Indian Ocean are not detailed enough in time and space to corroborate directions of movement inferred from monthly changes in water mass distribution along 110° E. However, such changes in water mass distribution can show only meridional components of the change in movement and not necessarily, therefore, the true subsurface currents.

(*a*) *Tropical Oxygen Minimum*

This oxygen minimum first occurred along 110° E. at 12–14° S. (Fig. 48) as a minimum within the sigma-*t* range 25·80–26·00 at depths of around 200 m. The oxygen minimum at greater sigma-*t* values and at deeper levels further to the north was not a continuation of the tropical oxygen minimum (Section III). Southward, the sigma-*t* of this minimum decreased to about 25·20 around 26° S. Further south the oxygen minimum increased its sigma-*t* (25·90–26·00) and was not therefore a southward continuation of the tropical oxygen minimum (Section III.) The limits of the tropical oxygen minimum are therefore 12–26° S. (Fig. 48). Within the region 18–26° S. the oxygen values of this minimum changed as much at adjoining stations in a period of about half a month as they did within the whole year. Moreover, during February–April, when the oxygen values indicated a southward extension of this water mass, its sigma-*t* values decreased to less than 25·00 (Fig. 48), this being caused by mixing with surface waters. It is not possible, therefore, to decide with certainty that any seasonal changes in its distribution occurred. However, since the lowest oxygen values of the year occurred in January–May (shown by asterisks in Fig. 48), it is likely that more of this tropical water mass accumulates in the region 18–26° S. during this period of the year. In these months the oxygen contours indicate that such accumulation occurred predominantly during two smaller periods ((1) and (3), Fig. 48) and possibly during a third ((2), Fig. 48).

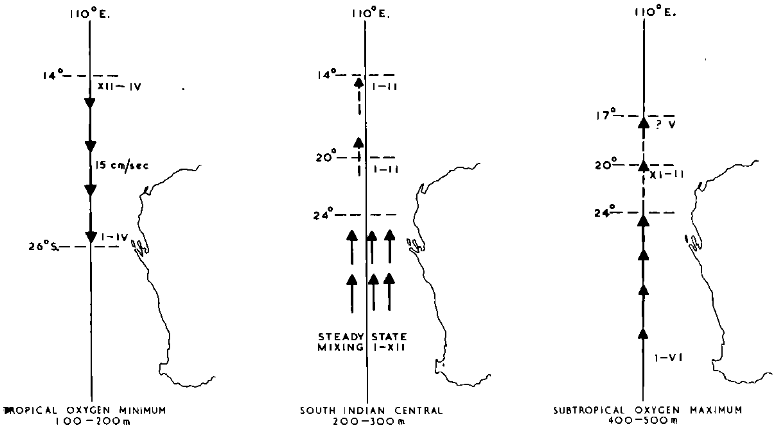


Fig. 52.—Schematic representation of the meridional components of drift of the three principal subsurface water masses. Roman numerals, months.

(*b*) *South Indian Central*

North to about 24° S., the core of South Indian Central water retained much the same salinity (35·80–90‰), sigma-*t* (25·90–26·00), and depth (100–200 m) during the year (Fig. 49). The major exception to this was in February–March, south of 30° S. This exception was caused by advection and mixing of high salinity waters by the West Australian Current nearer the surface, and not by large changes in the characteristics of the South Indian Central water. North of 24° S., the salinity often changed as much in a period of several weeks at the same latitude, as it did in the whole year. It is difficult, therefore, to distinguish seasonal changes in meridional drift of this water mass. However, in summer (January–April), the northern limit of this water mass occurred some 150 miles further to the north than at other times of the year. This is interpreted as a real component of drift northward, although seasonal variations in mixing at these latitudes might equally as well provide the explanation.

(*c*) *Subtropical Oxygen Maximum*

South of 24° S., waters of this oxygen maximum had their highest oxygen content of the year for each latitude in May–June (Fig. 50). For an oxygen maximum, such an increase in oxygen can be caused directly by advection of more waters from nearer the source region, or indirectly by reducing the oxygen values by greater vertical mixing in months other than May–June. However, the latter explanation should cause greater changes than were found in the salinity of the South Indian Ocean Central water mass above it (Fig. 49). It is thought therefore, that greater advection of waters of the subtropical oxygen maximum was the reason for the higher oxygen values south of 24° S. in May–June. However it was only in May, during the north bound leg of Cruise Dm2/63, that an accompanying increase in oxygen values north of 24° S. occurred (Fig. 49). Also, the highest oxygen value of the year for a particular latitude of this region generally occurred in months other than May–June.

(*d*) *Variations in Tropical and Subtropical Dominance North of 24° S.*

The changes in seasonal distribution along 110° E. of the two subtropical and the one tropical water mass have previously been considered in isolation from one another. However, a comparison of the simultaneous changes in position along 110° E. of selected isolines of their characteristic core property (Fig. 51) shows to what extent the upper 500 m was affected by such changes. For example, from July to February, the northward extension of the three isolines at A, B, and F (Fig. 51) can be interpreted only as an increase in the subtropical dominance within the whole 100–500 m column. From January, the isolines of the tropical oxygen minimum and of the South Indian Central waters, and from February that of the subtropical oxygen maximum also, retreated southward so that by April all three isolines were at their southernmost limit (C, Fig. 51). By April, therefore, tropical water had accumulated to depths of 500 m in the region north of 24° S. From April to June this tropical water dominance continued in the upper 100–300 m. However, large variations in the position of the selected isoline of the subtropical oxygen maximum show that this dominance was rapidly weakening below 300 m.

The principal conclusions about the movements of subsurface water masses along 110° E. are schematically represented in Figure 52. The arrows show the direction of drift of the limit of detectability of these water masses but do not necessarily show the direction of movement of the water mass itself.

X. CONCLUSIONS

The following kinds of water were responsible for the changes in hydrological characteristics along 110° E. in 1962–63:

(1) Surface (0–50 m), low salinity (less than 35·00‰), high temperature (greater than 25°c), tropical waters which spread south of 20° S. in autumn and winter.

(2) Surface (0–50 m), high salinity (greater than 35·90‰), lower temperature (20–22°c), subtropical waters carried north to about 25° S. in summer by the West Australian Current.

(3) Subsurface (100–150 m), low salinity (less than 35·00‰), low oxygen (less than 3·50 ml/l.), tropical water spreading south to about 26° S. on the 25·00 sigma-*t* surface in late summer and autumn.

(4) Subsurface (200–300 m), high salinity (greater than 35·80‰), subtropical waters of the South Indian Central region, spreading north on about the 26·00 sigma-*t* surface to about 12° S. in summer, and to about 16° S. in winter.

(5) Subsurface (400–500 m), low salinity (less than 35·00‰) waters of the subtropical oxygen maximum (greater than 4·50 ml/l.) drifting north on about the 26·80 sigma-*t* surface to about 12° S. in summer, and to about 14° S. in winter.

(6) West-flowing surface (0–50 m) waters of the South Equatorial Current with salinities around 34·50‰, and temperature greater than 26°c, between latitudes 10 and 14° S. Near the northern boundary of the South Equatorial Current an accumulation of low salinity water (less than 35·00‰) formed the Equatorial Frontal Zone extending to depths of around 400 m. This Frontal Zone generally formed a southern limit to the spread of north Indian Ocean water masses.

(7) However, Persian Gulf waters spread south below the Frontal Zone to *c.* 15° S. where mixtures of Persian Gulf and subtropical oxygen maximum waters occurred during the whole of the year.

(8) North Indian Ocean water masses at depths less than 400 m (e.g. countercurrent (100 m) and Arabian Central (200 m)) occurred south of this Zone only in summer to about 15° S. At other times of the year these water masses were absorbed by mixing with waters of the Equatorial Frontal Zone.

(9) Waters of the east flowing Sumatra–Java Current (salinity less than 34·00‰, temperature greater than 27·5°c) were detected only in January 1963 at around 9°30′ S.

(10) Very low salinity (less than 33·00‰) surface waters in May–June around 10° S. were carried by currents out of the Java and Banda Seas and were not a result of the Sumatra–Java Current.

All the surface water masses (viz. 1, 2, 6, 9, and 10) were low in nutrients (phosphate generally less than 0·15 and seldom greater than 0·20 μg-atom/l.; nitrate generally less than 0·50 μg-atom/l.). No significant enrichment of waters at the surface occurred during the year even in the extreme north during the maximum spring uplift of deeper waters.

Annual changes in temperature, salinity, and oxygen at the surface were mostly within the range that heating and cooling, evaporation and precipitation, and gaseous exchanges with the air could cause. Changes in surface phosphate and nitrate were so small as to be inseparable in many cases from the experimental error of the analyses. A subsurface minimum in the annual temperature range showed that surface heat exchanges extended to about 25–50 m in the north, and to about 100–150 m in the south. This zone of heat exchange was generally deeper by 25–50 m than the mean depth of the thermocline or of the upper oxygen maximum conserved within the thermocline.

Below this zone changes in hydrological characteristics were very variable during the year but, generally, were smallest in deep tropical waters and greatest in the boundary layers separating water masses or separating cold and warm water which rose and fell in response to surface currents in the north or eddies in the south. The stability of much of the deep hydrological properties during the year was such as to imply very much a steady state mixing condition.

Only south of about 18° S. was a true thermocline formed near the surface (25–75 m) as the result of summer heating. Generally this thermocline disappeared in winter. North of 18° S., a permanent tropical thermal discontinuity was found centred about a particular isotherm which rose and fell (50–150 m) during the year. Below the thermocline south of 18° S. a permanent subtropical thermal discontinuity also occurred at depths of 200–300 m. However, the intensity of this discontinuity was much weaker than its tropical counterpart.

The mixed layer (temperature gradients less than 0·02 degC/m) was shallowest (10 m) in the north in summer, and deepest (200 m) in the south in winter and spring. Most of this deepening of the mixed layer during winter in the south was the result of accumulation of surface waters within eddies, not solely by vertical overturn. This accumulation of surface waters also accounted for the very small increase in nutrient column averages of this winter mixed layer in the south.

In general, the surface currents of the south-east Indian Ocean confirm the time table of tropical and subtropical water movements based upon changes in salinity and temperature.

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Reprinted from *J. geophys. Res.*, vol. 74, no. 8, 1969, p. 1958-1967

Some Measurements of Current off the Somali Coast during the Northeast Monsoon

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Geostrophic and direct current measurements off the Somali coast during the northeast monsoon of 1964–1965 indicate a large subsurface north-going current across a 9°N section between 52° and 53°30′E and a south-going current of similar characteristics between 53°30′ and 55°30′E. The characteristics of the flow suggest the existence of an anticyclonic gyre having a transport of approximately 70×10^6 m^3/sec, the center being near that of the gyre found during the southwest monsoon.

INTRODUCTION

It is known that off the Somali coast during the northern summer southwest monsoon the current is very strong. A description of its velocity (up to 350 cm/sec) and transport (approximately 70×10^6 m^3/sec near 8°N) between the coast and 55°E was given by *Swallow and Bruce* [1966] and its properties by *Warren et al.* [1966]. On the other hand, the winter circulation during the northeast monsoon is not well understood. Surface current estimates from ship's drift [*K. Ned. Meteorol. Inst.*, 1952] indicate a southward current along the coast south of 8°N from December through February although surface topography [*Bruce*, 1968] suggests that the currents are weak and irregular relative to the summer current.

The measurements discussed here, obtained off the Somali coast during the winter of 1964–1965, are mainly those from *Atlantis II* cruise 15, consisting of serial hydrographic stations and, along 9°N, a number of direct current measurements. A number of hydrographic stations from *Meteor* cruise 1, augment those of *Atlantis II*. All of the station data are available from NODC. Station positions are shown in Figure 1.

METHOD

Along the section 9°N, the general procedure on *Atlantis II* between stations 555 and 568, February 28–March 10, 1965, was to obtain direct measurements of current by a meter suspended from the ship [*Swallow and Bruce*, 1966] and by neutrally buoyant floats [*Swallow*, 1955]. In each case the measurements were referred to the sea bottom by anchored buoys or, as in the case of station 555, to a point on the coast by ship's radar. The positions of the buoys and checks for possible buoy drift were obtained by satellite and celestial navigation. Satellite navigation was performed using the AN/SRN-9 integral Doppler equipment [*Guier*, 1966] developed and installed on *Atlantis II* by the Applied Physics Laboratory of the Johns Hopkins University. Fixes could be obtained a few minutes after the passage of a satellite, as the data were processed on the shipboard computer (Digital Equipment Corporation, PDP-5) using a program furnished and adapted by the Applied Physics Laboratory. Fourteen standard hydrographic stations (all to the bottom) were positioned as shown in Figure 1 approximately along 9°N and bracketing the positions of direct current stations near the anchored buoys A to F. From these stations geostrophic flow, adjusted where possible to the velocity indicated by the neturally buoyant floats, was determined.

The relative accuracies of and comments on the various 'links' in the current measuring system are briefly discussed here:

1. The satellite navigation appeared to be comparable to that reported by *Talwani et al.* [1966], who used similar equipment aboard the *Robert D. Conrad*. Position checks while the *Atlantis II* was in port are listed in Table 1.

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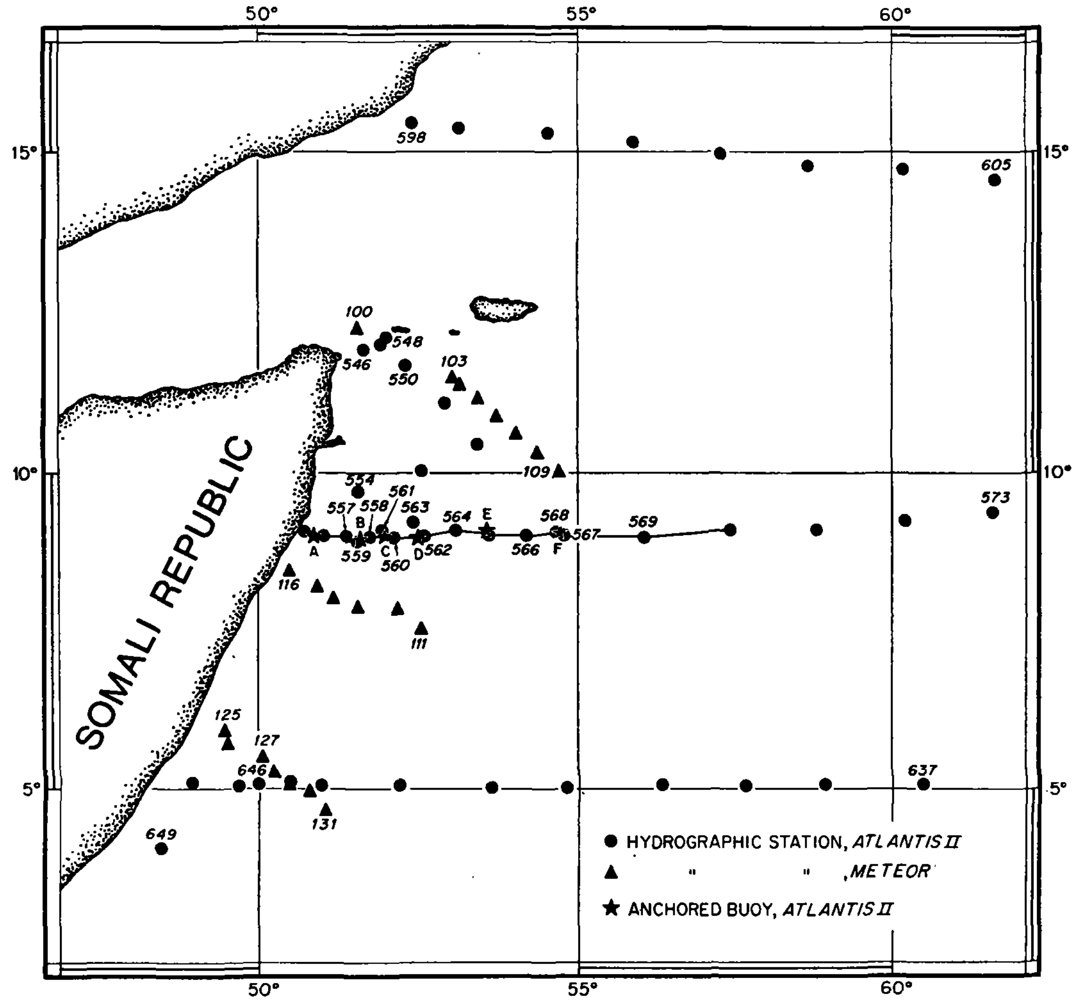

Fig. 1. Positions of *Atlantis II* and *Meteor* hydrographic and anchored buoy stations. Most of the work discussed in this paper concerns the 9°N section as shown by the solid line connecting stations from the Somali coast east to station 570.

TABLE 1. Position Checks by AN/SRN-9 Satellite Navigation while *Atlantis II* Was at Fixed Location in Port

Port	Date	Number of Observations	Percentage of Observations within Distance from Mean		
			≤ 0.1 n.mi.	≤ 0.2 n.mi.	≤ 0.3 n.mi.
Aden	Feb. 21–24, 1965	10	60	80	90
Seychelles	May 24–27, 1965	13	15	69	85
Mauritius	June 7–10, 1965	15	60	100	
Durban	June 21–27, 1965	15	33	73	93
				All observations <0.5 n.mi	

At sea there was doubtless greater error in the fixes due to many changes in speed and direction during the various current measurements. It is estimated that fixes are probably good to 0.8 n. mile.

2. The usual star and sun sights for celestial navigation were possible for almost the entire period of the current measurements, as there was little cloud cover. It is estimated that the celestial and satellite fixes generally agreed within 1 n. mile.

3. It was planned to set the anchored reference buoys on very short scope (A through F, Figure 1) with radar reflectors on a mast to give ranges of 5–7 n. miles, but it was found that bottom irregularity made this difficult, and scope ranged between about 2% and 10%, with the exception of buoy D, the anchor of which did not quite reach bottom. Position fixes on buoy D showed a reasonably steady drift toward 295°T at 16 cm/sec, and thus, since its drift rate was known, it could be used also as a reference. By observing the buoys after launching it could be noted whether full freeboard was retained after the anchor reached bottom. In the case of buoy D the float remained partially submerged. The wind speed (average force 3) and direction (NE) were steady, and the yaw of the floats at mooring was slight. An estimate of float movements, shown in Table 2, indicates a negligible error in the current measurements.

4. Error introduced by radar fixes on the anchored buoy during direct measurements should be an order of magnitude less than actual buoy float movement. A fix was obtained every 5–10 minutes during suspended meter stations, and the range and direction data were smoothed.

5. Use of the suspended current meter is discussed by *Swallow and Bruce* [1966] and by *Bruce* [1965]. The meter used for this work had a savonius rotor, a direction vane (Braincon, model 252), and an additional stabilizing vane (area approximately 0.3 m^2). The unit was suspended on a conducting cable and the output was recorded aboard ship. Procedure at each station was to lower the meter, stopping at fixed depths between 0 and 1000 m, for 3–5 minutes at each depth. On ascent the meter was again stopped at several of the same fixed depths. A smooth curve was fitted to averages of speed and direction of current relative to the ship versus depth. Current relative to the bottom was obtained by removing drift of the ship relative to the anchored buoys obtained from radar fixes (taken every 5 min during lowering). Accuracy of this type of meter should be within ±3% [*Richardson et al.*, 1963], but the overall accuracy is certainly considerably reduced by other factors, such as vertical motion of the ship, variation of inclination of the meter, and movement of reference buoys, and is probably closer to ±15–20%. Weather conditions during the northeast monsoon were considerably more favorable for current measurements than during the southwest monsoon, as the ship's drift while lying-to on current meter stations was reasonably steady in direction and speed.

6. The position fixes relative to the ship for the neutrally buoyant floats were obtained using suspended hydrophones [*Swallow*, 1955] and also using two pairs of towed hydrophones, the output of which was displayed on the ship's precision graphic recorder [*Knott and Witzell*, 1960] while the ship was underway.

Discussion and Results

The meridional component of geostrophic current was adjusted to neutrally buoyant float observations (Table 3) through 9°N section

TABLE 2. Estimate of Maximum Possible Movement of Anchored Reference Buoys Determined from Scope of Each Buoy and From Satellite and Celestial Position Fixes

Anchor Buoy	Period in Use, hours	Maximum Possible Movement (360° yaw), n.mi.	Maximum Drift Rate, cm/sec
A	4	0.13	Period too short for fixes
B	41	1.3	< 2
C	48	1.2	< 3
D	38	12.	16 (295°T)
E	12	2.3	< 2
F	24	2.1	< 2

TABLE 3. Observations of Neutrally Buoyant Floats

Buoy	Depth, meters	Duration, hours	Mean Speed, cm/sec	Azimuth, degrees
B	2190	35.4	5.3	281
	2580	12.5	4.3	331
C	2000	18.5	3.5	323
	2000	25.0	5.0	331
	2500	32.5	4.4	320
D	1900	23.0	10.8	321
	1960	4.5	15.	337
	3030	4.5	15.	325
E	2000	Lost	(no measurements)	
	2000	Lost	(no measurements)	
	3425	20.5	4.8	213

(Figure 2). Adjustments were similar to those discussed by Swallow and Bruce, the geostrophic velocity-depth curve being shifted along the velocity axis to give best agreement with velocities indicated by the float observation. A large north-going core is indicated approximately between 52° and 53°30′E with a current maximum at 600–700 m, and to the east between 53°30′ and 55°30′E a core with similar distribution of speed but flowing southward is indicated. The two cores are roughly symmetrical about station 565. The volume transport of the northward current was calculated to be 76×10^6 m^3/sec, and the southward transport was 71×10^6 m^3/sec. By adjusting the velocity-depth curves to float velocities the near-bottom current

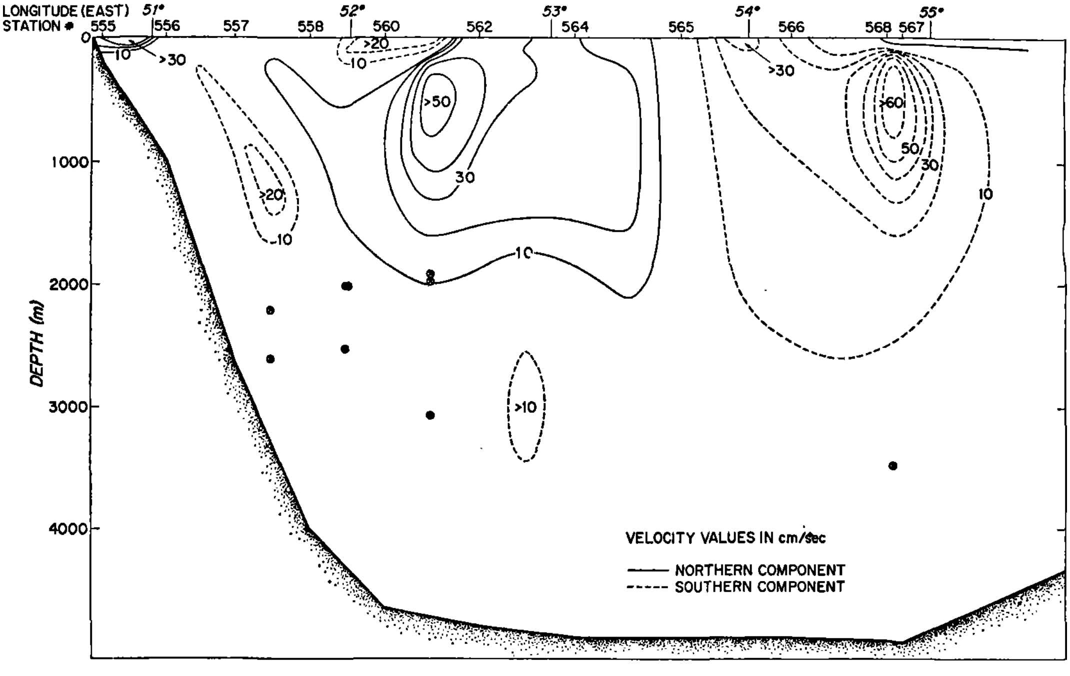

Fig. 2. Distribution of meridional geostrophic current across 9°N section, *Atlantis II*, February 28–March 9, 1965. Velocities are adjusted to best fit with neutrally buoyant float values (Table 3) where floats were near station pairs; otherwise geostrophic bottom velocity was used as level of zero motion. Float positions are shown by small circles with enclosed × to indicate northward flow and with enclosed dots for southward flow.

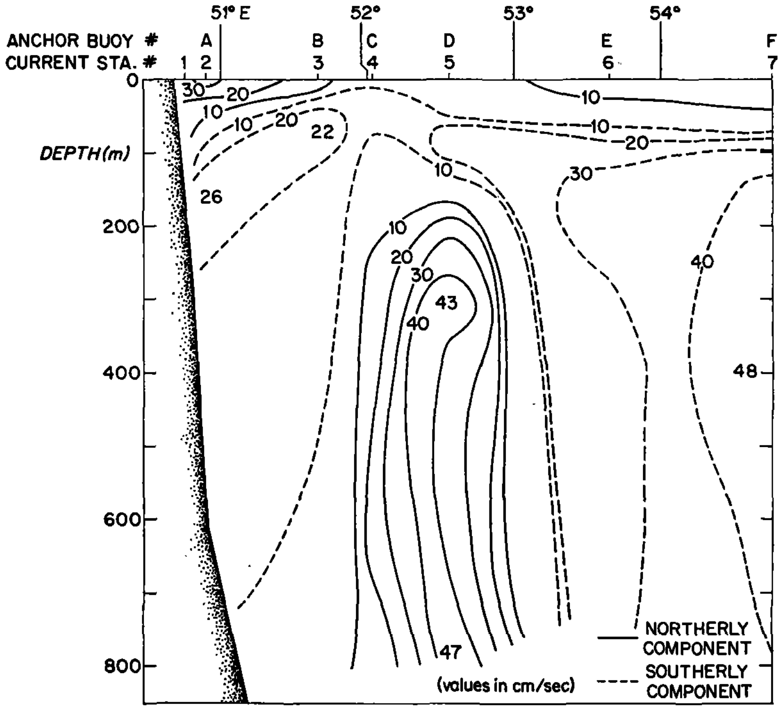

Fig. 3. Meridional velocity component from direct measurements by suspended current meters referred to anchored buoys.

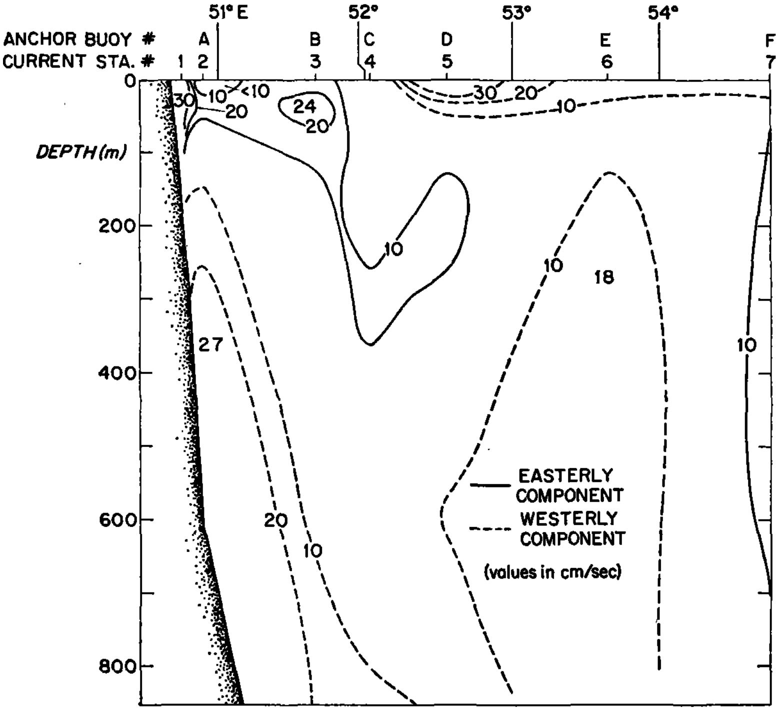

Fig. 4. Zonal velocity components from direct measurements by suspended current meters referred to anchored buoys.

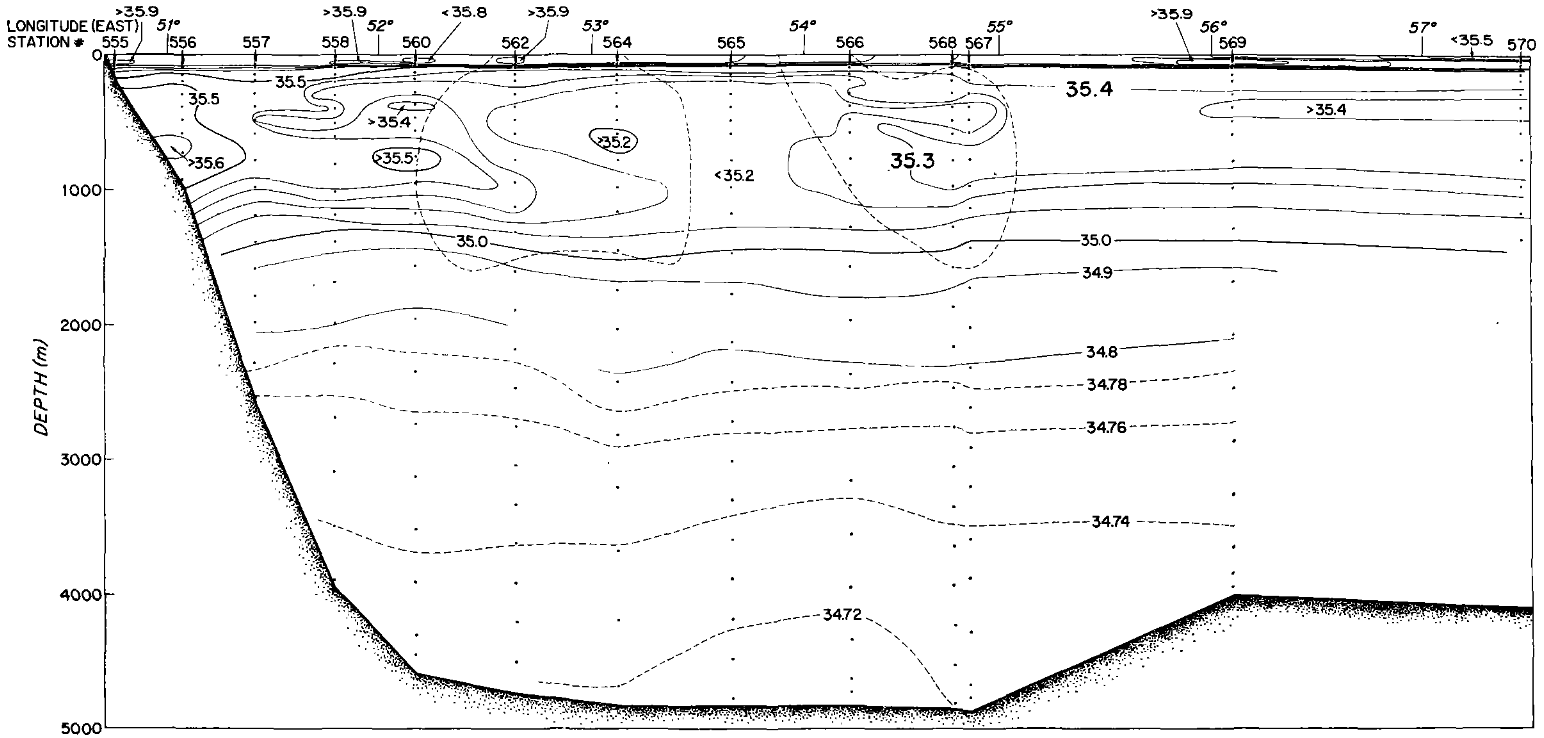

Fig. 5. Salinity distribution in ‰ on 9°N section. Dashed loops are 20 cm/sec velocity contours from Figure 2 superimposed to show relative position of north- and south-going cores of water.

indicated is 2 cm/sec north between stations 557 and 558, 3 cm/sec south between stations 558 and 560, 5 cm/sec south between stations 560 and 562, 15 cm/sec north between stations 558 and 567. By using other levels of no motion for the section (2400 m, 3600 m, or the bottom) shown in Figure 2, the velocity distribution is found to be quite similar and transports are not changed more than about 10%.

An independent series of measurements (Figures 3 and 4) of current velocity with the suspended current meter to 800 m depth on 9°N obtained concurrently with the geostrophic section of Figure 2 shows reasonable agreement between the two methods as to location, speed, and direction of the north- and south-going cores. The geostrophic core centers were near anchor buoys D and F. Both methods also indicate a weaker subsurface southward flow along the slope of the Somali coast which is comprised in part of Red Sea water flowing to the southwest [*Rochford*, 1964]. The zonal components of directly measured current contoured in Figure 4 were weak in the region of the two cores (10 cm/sec or less) although appreciable on the coastal slope and near the surface (upper 50 m).

The charts for February and March [*K. Ned. Meteorol. Inst.*, 1952] indicate that surface currents are variable in speed and direction in the vicinity of the 9°N section. Our direct measurements also show that movement of the surface water (upper 100 m) is variable (11–47 cm/sec) and does not appear to reflect the flow of the subsurface cores of north- and south-moving water.

In the upper 1500 m between stations 560 and 567 the distribution of salinity (Figure 5) indicates a dome of relatively fresh water (<35.2‰ at the center) nearly symmetrical about station 565, the east and west edges of the dome lying in the regions of the north- and south-going cores (the 20-cm/sec velocity contours are shown as dashed lines in Figure 5). The salinity maximum of the Red Sea water (700–800 m depth) is found to extend from the coast with salinity 35.6‰, and it becomes fresher toward the east until the salinity maximum vanishes between stations 564 and 565. A somewhat weaker Red Sea maximum is found to the east of the fresh dome at stations 567 and 568.

The water types comprising the north- and south-going cores are similar in temperature-salinity characteristics (Figure 6), suggesting they are perhaps part of the same circulating system. Since the relatively fresh water of the dome is most noticeable at the levels of the adjacent Red Sea water, $\sigma_t \simeq 27.2$ [*Rochford*, 1964], by contouring salinity on this density surface with winter 1964–1965 hydrographic station data (Figure 7), an approximation of the horizontal distribution of the fresher water is obtained. Because of data lacking in the region to the southeast of the low-salinity cell at 9°N, 53°E, it is of course not certain whether the 35.3‰ isohaline around the cell should be contoured as a closed curve or as a loop extending up from the 35.3‰ isohaline at about 7°N, 54°–55°E. Thus it is not impossible

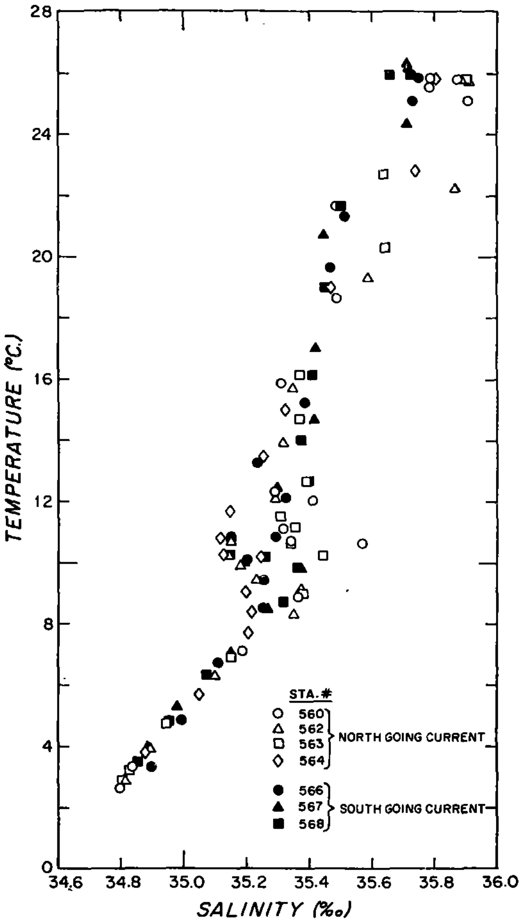

Fig. 6. Temperature-salinity distribution of samples from stations along 9°N within north- and south-going core.

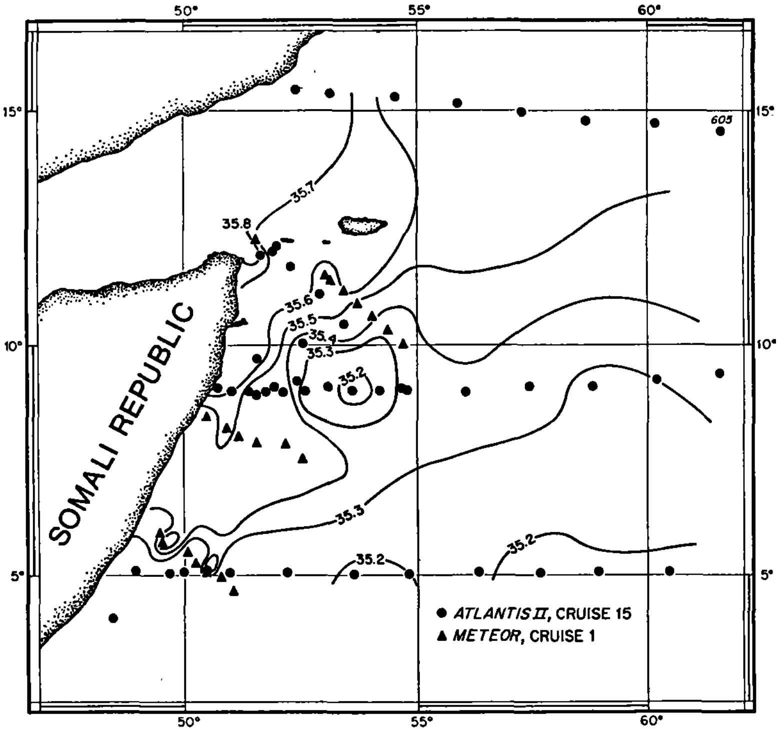

Fig. 7. Distribution of salinity on isopicnal surface, $\sigma_t = 27.2$.

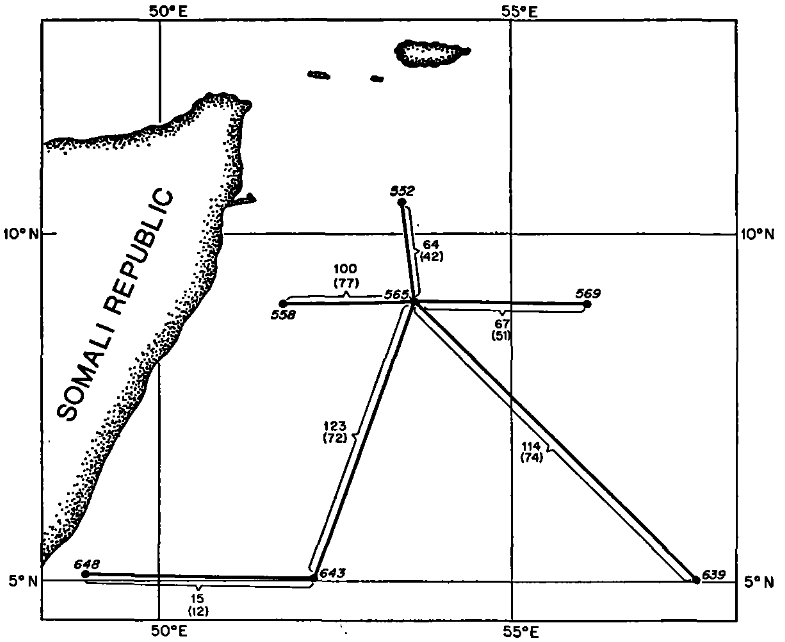

Fig. 8. Volume transport in 10^6 m^3/sec between *Atlantis II* stations. Values are relative to 3600 and 2400 decibars (in parentheses). Point on bracket shows direction of flow.

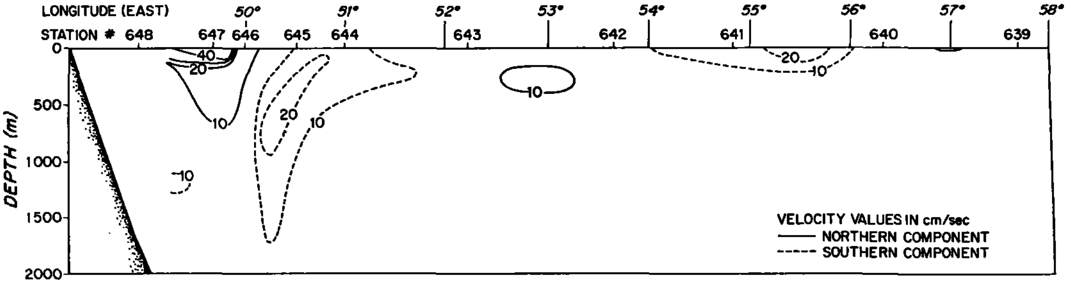

Fig. 9. Distribution of geostrophic velocity across *Atlantis II* section along 5°N, April 19–21, 1965. Stations 643–647 relative to 2400 decibars, stations 647–648 relative to 1600 decibars, stations 639–643 relative to 1200 decibars.

for the fresh water to be continuous on the $\sigma_t = 27.2$ surface toward the SE to 5°N. To the west of the low- salinity cell the penetration of Red Sea high-salinity water is particularly noticeable moving southward along the Somali coast. It should be noted further that although the *Atlantis II* and *Meteor* stations are plotted together in Figure 7 and were occupied during the same winter (1964–1965), the *Meteor* stations were two months in advance of those of the *Atlantis II*, and possible changes may have occurred.

A rough estimate of the geostrophic transport around station 565 was made using *Atlantis II* cruise 15 stations (Figure 8), and these further suggest an anticyclonic circulation around the low-salinity cell using two reference levels (2400 and 3600 decibars). A relatively small flow (15×10^6 m^3/sec relative to 3600 decibars, 12×10^6 m^3/sec relative to 2400 decibars) passed south through the 5°N section between stations 643 and 648. The velocity distribution (Figure 9) through the section shows the southward flow confined to a tongue centered near station 645 and weak flow off the coastal slope. The salinity distribution (Figure 10) shows areas of relatively high salinity (>35.3‰) in the regions of southward flow, this water being probably of Red Sea origin. *Rochford* [1964] has indicated a flow along the African coast of water with a salinity maximum near the surface $\sigma_t = 27.2$. It is clear that the flow across the 5°N section shown here is considerably less than that through the 10°N section.

CONCLUSIONS

It is interesting to note that the position off the Somali coast of the winter gyre-like circulation discussed in this paper is roughly that of the Somali gyre found in summer during the opposite monsoon. The summer circulation during 1963 was mentioned by *Bruce* [1968] and that during 1964 by *Swallow and Bruce* [1966]. It was suggested that during the period of strong summer southwest monsoon winds an anticyclonic gyre or cell might be formed off the Somali coast, the Somali current itself constituting the western part of the circulation. There is a possibility that the anticyclonic cell found in

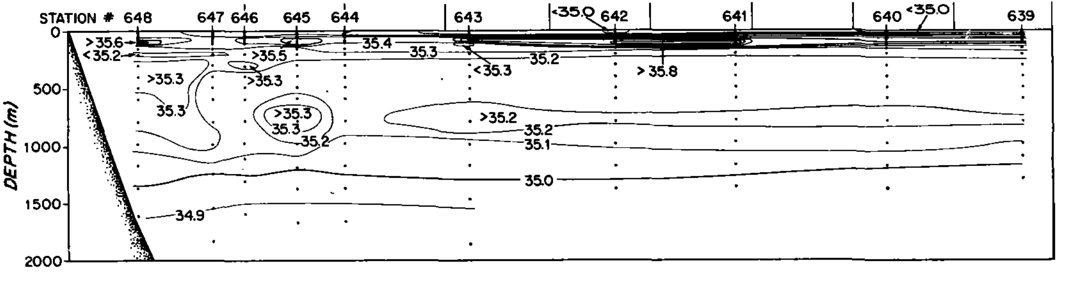

Fig. 10. Distribution of salinity on *Atlantis II* section along 5°N, April 19–21, 1965.

the winter of 1964–1965 might have been initiated the previous summer and might have continued its rotation for a number of months after the cessation of the southwest monsoon. The transport found in winter was approximately the same as that in summer, although the summer circulation was confined mostly to the upper 400 m and was of high velocity (over 300 cm/sec at the surface) [*Swallow and Bruce*, 1966] whereas the winter flow extended to below 1500 m depth. It should be noted that measurements of current during the summer monsoon are difficult because of strong winds and current and probably are not so accurate as winter measurements. Thus the details of the relatively slower portion of the flow in summer in water below 400 m (say, <20 cm/sec) are not delineated so clearly as for winter and actually may extend deeper than has been indicated by Swallow and Bruce. In fact, a deep flow in summer has been suggested [*Warren et al.*, 1966] from an examination of salinity on potential temperature surfaces below 2500 m depth. The pattern of this flow appears to be similar in shape to that of the near-surface water in summer during 1964.

The symmetry of the distribution of salinity and the meridional flow across the 9°N section about the low-salinity cell centered near station 565 suggests an anticyclonic circulation with a rather large transport $\simeq 70 \times 10^6$ m^3/sec. Whether the flow constitutes a loop or a gyre is not known, but evidence such as the distribution of salinity on the $\sigma_t = 27.2$ density surface, the similarity of the *T-S* distribution of the north- and south-going currents, and the apparent anticyclonic flow from transport considerations (Figure 8) suggests a gyre.

Acknowledgments. This research was sponsored by the National Science Foundation under grant GA-870. Special thanks from the authors are due A. R. Miller for the use of *Atlantis II* hydrographic data and for ship time for obtaining current measurements.

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(Received September 20, 1968;
revised November 15, 1968.)

Part III

Marine geology and geophysics

Reprinted from *Cahiers ORSTOM - Océanographie*, vol. IV, no. 2, 1966, p. 49-130

ÉTUDE DYNAMIQUE DE LA SÉDIMENTATION AU LARGE DE L'ESTUAIRE DE LA BETSIBOKA

par L. BERTHOIS[*] et A. CROSNIER[**]

ENGLISH ABSTRACT

The river Betsiboka is the largest river in Madagascar. Its discharge can vary from 400 m^3 / *sec to more than* 4500 m^3 / *sec.*

In low stage its estuary belongs to the river mouths in which the equilibrium zone is situated at the coastline, whereas during the floods the equilibrium zone moves out of the coastline (L. Berthois, 1965).

The study of sediment transportation, as well as the grainsize analysis of coarse sediments, and the mineralogical study of fine sediments (thermal differential analysis and X rays), show that the coarse sediments found on the continental shelf are not supplied presently by the river, which only carries a large amount of fine particles. This fine material settles principally at the river mouth in low stage and spreads on the shelf during floods.

As a consequence of low salt content and occurrence of suspended matter in water, the corals which live on the outer edge of the shelf have difficulties to thrive.

Measurements of Potassium, Calcium and Magnesium in fresh and in brackish waters showed that cation percentages are a function of chlorinity and follow linear relations in their variation.

INTRODUCTION

C'est en survolant en avion l'estuaire du fleuve Betsiboka et le canal de Mozambique que nous est venue l'idée de ce travail ; les eaux sortant de l'embouchure du fleuve étendaient vers le large, leur coloration rouge, puis verte tranchant sur le bleu intense des eaux de l'Océan Indien, formaient une admirable et immense palette aux couleurs vives.

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Mais nous avions à ce moment un objectif bien défini qui était l'étude du lagon de Mayotte et, à la fin de cette campagne Comorienne, il nous était impossible d'entreprendre un autre travail.

C'est pourquoi cette étude à laquelle nous avions songé en 1959 n'a pu être entreprise qu'en 1961 et achevée sur place en 1962. Il était indispensable d'exécuter deux séries de mesures, l'une en étiage et l'autre en crue du fleuve. — A. Crosnier, Biologiste à l'O.R.S.T.O.M. qui était alors attaché au laboratoire de Nosy-Bé a dirigé les deux campagnes et récolté tous les échantillons. Les dosages de salinité et les calculs de correction de température ont été exécutés au laboratoire de l' O.R.S.T.O.M. à Nosy-Bé sous la direction de M. Menaché auquel nous adressons nos très vifs remerciements. Enfin, les échantillons récoltés ont été examinés au laboratoire de sédimentologie de l'E.N.S.A. à Rennes.

PREMIÈRE PARTIE

1o MORPHOLOGIE DU PLATEAU CONTINENTAL

Le plateau continental qui s'étend au nord de l'embouchure du fleuve Betsiboka est de largeur restreinte :

en face l'embouchure de la rivière d'Andranolava elle est d'environ 10 milles jusqu'aux accores nord des bancs du Mariner et du Forfait (voir fig. 24).

en face l'embouchure du fleuve Betsiboka le plateau continental atteint 20 milles de largeur, mais en allant vers l'Est sa largeur se réduit à nouveau à environ 10 milles en face de l'embouchure de la rivière Marovandy.

La morphologie de ce plateau continental a été dessinée à l'aide des sondes de la carte ne 4852 – de la Pointe Komany au Cap Tanjona — du Service Hydrographique de la Marine, complétées par un profil de sondage exécuté au cours de cette étude, entre les postes 6 et 23 (voir fig. no 1).

Le bord externe du plateau continental est jalonné d'une série de « bancs » dont les sommets sont le plus souvent recouverts par moins de 10 mètres d'eau ; en allant d'Ouest en Est on rencontre aux abords de l'embouchure de la Betsiboka : le Banc de la Thétis, le Banc de la Turquoise, le Banc de l'Euryalus, le Banc du Mariner, le Banc du Forfait, le Banc du Vaudreuil, le Banc de la Romanche. Entre ces principaux bancs s'échelonnent des hauts fonds de moindre importance qui complètent la bordure du plateau continental.

Cette série de crêtes sous-marines est échancrée de passes parfois profondes et bien développées, les plus importantes sont, en allant de l'Ouest vers l'Est : la passe de Tanjona, la passe de Makamby la passe de Katsepe, la passe d'Ampajony, la passe d'Andranolava, la passe du Tsimanénoakoho.

Les passes qui existent aux abords immédiats de l'embouchure du fleuve Betsiboka sont orientées suivant des directions rayonnantes autour de celle-ci :

La passe de Makamby possède une digitation Est orientée à 282° ; la passe de Katsepe pénètre sur le plateau continental suivant une direction de 330°, la passe d'Ampajony a une direction de 25°, sur le prolongement de laquelle se trouve un bas-fond de 24 mètres à l'Ouest du banc du Nacrissus. Enfin, la petite fosse Est située à proximité de la côte possède la même direction.

Une série de « hauts fonds » achèvent de donner à ce plateau continental une morphologie compliquée, ce sont :

le Banc de Narcissus culminant à la côte 2,7 m ; trois bancs aux abords du Poste no 12 dont les sommités atteignent respectivement 3,70 m au Sud de ce poste, 5 m à l'Ouest et 6,20 m au Nord. Enfin, au Sud-Est du Poste no 8, il existe un dernier haut fond dont le sommet est à la côte 9,2 m. Ainsi les hauts fonds paraissent d'autant moins élevés dans la zone étudiée, qu'ils sont plus éloignés vers le Nord.

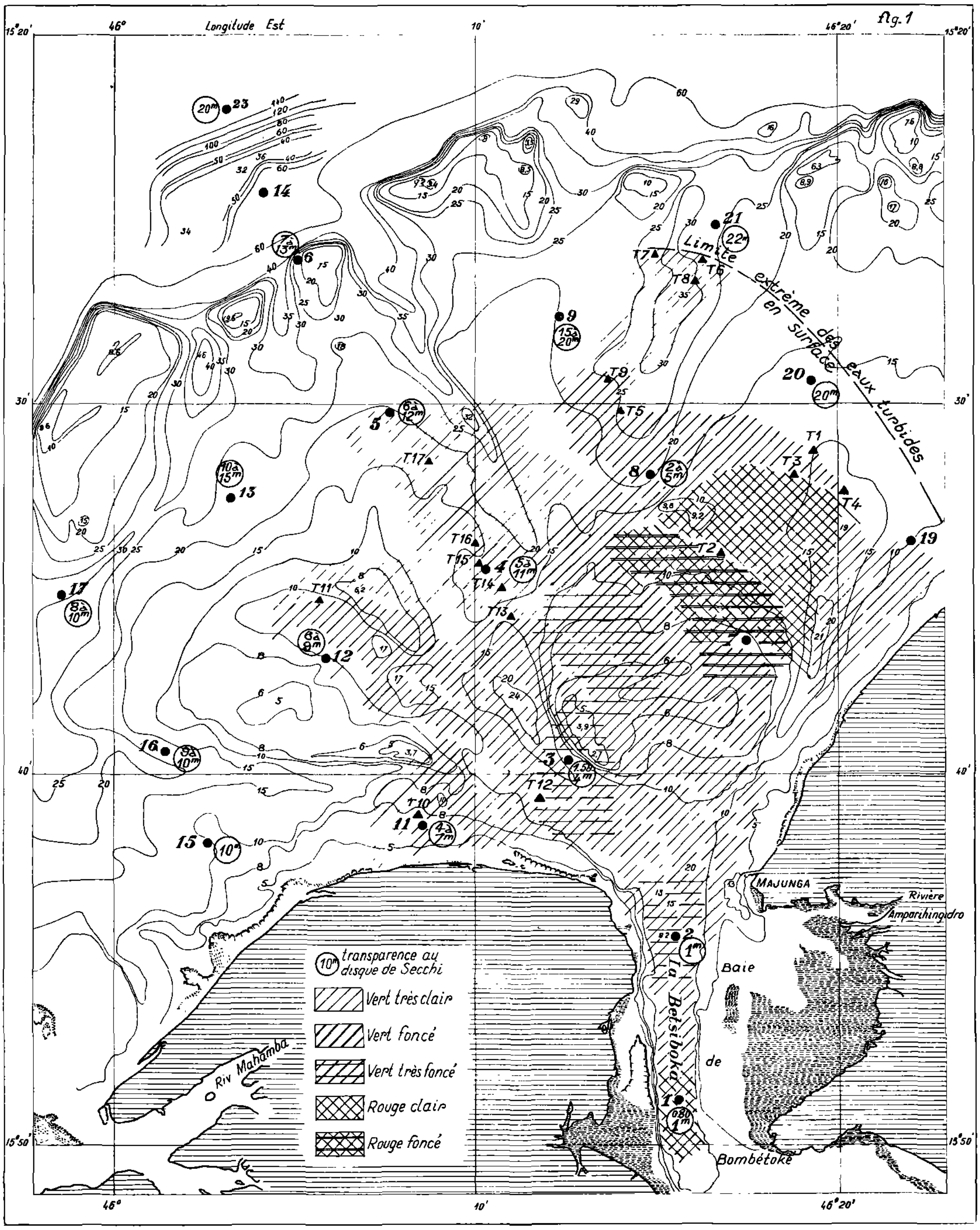

Fig. 1. — Plateau continental aux abords de l'embouchure du fleuve Betsiboka.

Les points noirs accompagnés d'un chiffre désignent les emplacements des postes de mesure et de prélèvements. Les triangles noirs accompagnés de « T » suivi d'un chiffre filiforme désignent les emplacements des stations de mesure de transparence des eaux au disque de Secchi.

La couleur de l'eau est représentée par des hachures suivant les conventions portées dans la légende.

En résumé l'estuaire de la Betsiboka se prolonge sur le plateau continental par trois chenaux divergents ; l'un vers l'Ouest, le second vers le N-N-O et le troisième vers le N-N-E. Ces chenaux sont séparés par des plateaux dont la pente générale irrégulière est dirigée vers le large, leurs surfaces sont accidentées de hauts fonds décrits précédemment.

Les bancs qui jalonnent le rebord extérieur du plateau continental sont corralliens. Ils paraissent principalement formés de corail mort ou de récifs coralliens dont la vie est extrêmement ralentie actuellement. Ces formations s'apparentent donc à celles qui ont été précédemment décrites sur les côtes Malgaches par A. Guilcher (1954-1958) par R. Battistini (1964) et par L. Berthois, R. Battistini et A. Crosnier (1964) ; cette question sera examinée à nouveau dans le chapitre consacré à la sédimentologie.

2° RÉGIME FLUVIAL DE LA BETSIBOKA

Les débits fluviaux de la Betsiboka sont mesurés à la station d'Ambodiroka où sont enregistrés par conséquent les débits de ce fleuve et de tous ses affluents de la rive droite.

Les eaux des affluents de la rive gauche sont amenées à la Betsiboka par l'Ikopa qui est jaugé à la Station d'Antsarana située en amont de son confluent avec la Betsiboka. C'est pourquoi il est nécessaire, pour obtenir la valeur du débit fluvial total en estuaire, de réunir les évaluations provenant des deux stations de mesures précitées. Malgré cela, il subsiste une zone aval de la Betsiboka qui n'est pas incluse dans les mesures effectuées, elle est comprise entre les deux stations de dosage et l'embouchure du fleuve. En conséquence, les débits qui seront mentionnés plus loin sont un peu trop faibles mais nous n'avons pas voulu apporter de correction arbitraire aux débits mesurés, la majoration serait sans doute assez faible puisqu'il n'existe aucun affluent important dans la zone négligée.

Le bassin versant de la Betsiboka à la station d'Ambodiroka est de..........	11 800 km^2
Celui de l'Ikopa à la station d'Antsatrana est de..............................	18 550 km^2
	30 350 km^2

Des relevés journaliers de débits sont faits dans ces deux stations de mesure, les renseignements nous ont été aimablement communiqués par le Service Hydrologique de l'Institut de Recherche Scientifique de Madagascar auquel nous tenons à exprimer notre gratitude.

A l'aide de ces renseignements, nous avons construit un graphique du débit global journalier des deux cours d'eau, représenté en m^3 / sec (fig. n° 2).

Ce graphique couvre la période du 1er juillet 1961 au 30 juin 1962. Entre le début de juillet et la fin de novembre les fleuves sont en étiage et leur débit total est presque constamment inférieur à 400 m^3 / sec.

La période de crues importantes commence au début de décembre et s'achève vers la mi-avril. Ces cours d'eau ont des débits de crue extrêmement variables pendant de courtes durées, les augmentations sont très brutales elles peuvent atteindre plus de 1000 m^3 / sec. entre deux journées consécutives, mais les décrues sont presque aussi rapides bien qu'en général un peu plus amorties que les crues, ce qui se conçoit aisément par un étalement plus marqué de la période de ruissellement.

De la deuxième quinzaine d'avril à la fin de juin le débit fluvial décroît sans fluctuation notable.

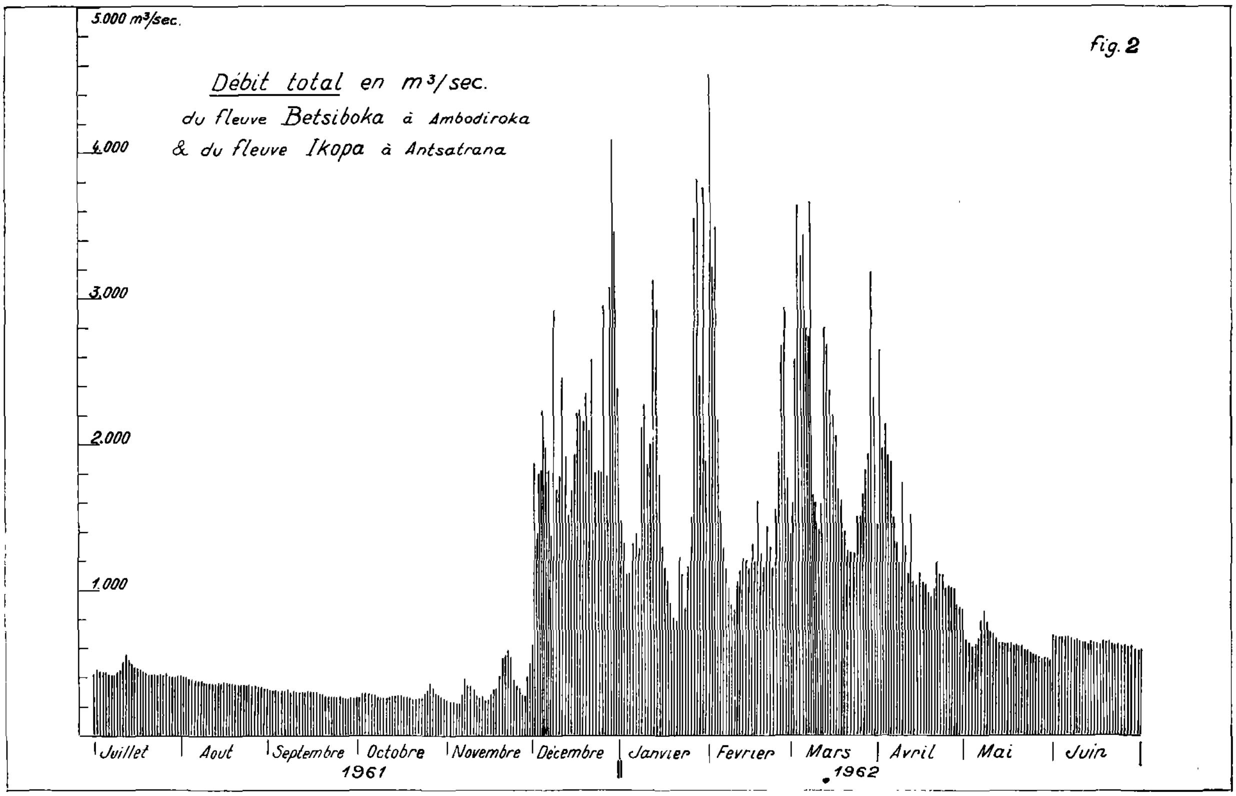

Fig. 2.

Au cours des mesures dont les résultats sont exposés plus loin, les débits fluviaux ont été les suivants :

TABLEAU N° 1

DÉBITS FLUVIAUX PENDANT LES OPÉRATIONS

de juillet 1961 5 — 423 m³ / sec.
6 — 429 m³ / sec.
7 — 424 m³ / sec.
8 — 424 m³ / sec.
9 — 433 m³ / sec.
10 — 457 m³ / sec.
11 — 509 m³ / sec.
12 — 562 m³ / sec.
13 — 531 m³ / sec.

de mars 1962 7 — 2742 m³ / sec.
8 — 3665 m³ / sec.
9 — 1651 m³ / sec.
10 — 1598 m³ / sec.
11 — 1427 m³ / sec.
12 — 1596 m³ / sec.
13 — 2810 m³ / sec.
14 — 2680 m³ / sec.
15 — 2378 m³ / sec.
16 — 2190 m³ / sec.
17 — 2050 m³ / sec.

DEUXIÈME PARTIE

ÉTUDE DYNAMIQUE DE LA SÉDIMENTATION

1o REMARQUES PRÉLIMINAIRES

L'étude dynamique de la sédimentation dans un estuaire ou sur le plateau continental, au large de cet estuaire, doit comprendre au moins deux séries de mesures : une première campagne en étiage du fleuve et une deuxième pendant une crue.

Dans les régions tropicales où l'on dispose rarement de l'équipement nécessaire, les mesures en période d'étiage permettent une mise au point du matériel et l'entraînement de l'équipage et des aides, mais elles apportent souvent peu de renseignements sur la sédimentation. La période des crues permet en général, de faire les observations les plus importantes, car les apports sédimentaires continentaux atteignent à ce moment leur intensité maximale, mais l'exécution du programme rencontre fréquemment de très grosses difficultés, notamment à cause de la vitesse élevée du courant qui gêne considérablement l'immersion des appareils de mesure.

L'exécution d'une série d'observations doit être faite à poste fixe pendant la durée d'une marée complète, c'est-à-dire environ 12 heures, mais dans les pays tropicaux notamment, il est impossible de faire des observations de cette durée à cause du décalage des marées par rapport à la période diurne et de l'insuffisance du balisage lumineux qui rend difficile les sorties nocturnes. C'est pourquoi certaines observations à poste fixe ont été notablement plus brèves que la durée idéale.

Les mesures effectuées à chaque poste fixe sont réitérées à intervalles de 2 heures ; elles comportent :

Mesures du courant de surface au bâton lesté mêmes mesures à mi-profondeur et au fond à l'aide d'un courantomètre Ekmann. — Mesure de la transparence de l'eau au disque de Secchi.

Les prélèvements d'eau à la bouteille à renversement, munie de thermomètres à renversement ont été effectués en surface puis aux profondeurs de 1 m, 2 m, 3 m, 5 m, puis à proximité du fond, un prélèvement supplémentaire a été fait à 10 m lorsque la hauteur d'eau était importante. Sur ces prélèvements d'eau on a dosé en laboratoire : la salinité, la turbidité, les teneurs en potassium, calcium et magnésium.

2o CHOIX DES EMPLACEMENTS DES POSTES D'OBSERVATION

Le but essentiel de ce travail était l'étude du transport des sédiments à la sortie de l'estuaire et leur répartition sur le plateau continental au large de celui-ci.

C'est pourquoi nous avons placé les postes 1 et 2 (voir fig. 1) à l'embouchure de la Betsiboka. La recherche de la répartition des sédiments sur le plateau continental posait un problème quasi insoluble quant à la répartition des postes d'observation ; en effet, les mesures devaient d'abord être faites en période d'étiage du fleuve. puis réitérées aux mêmes postes pendant une crue fluviale. Or, pendant la première série de mesures, faite en étiage, les eaux turbides n'auraient sans doute qu'une faible extension sur le plateau continental ; et seraient incluses dans le damier des postes d'observations. Mais, nous savions qu'au cours des mesures faites pendant la crue fluviale, la nappe d'eau turbide s'étendait plus loin vers le large et elle risquait alors de déborder le damier des postes où les observations seraient réitérées.

Cependant, nous savions aussi que les crues peuvent être violentes et très courtes et qu'en conséquence le nombre des postes devait être assez restreint, qu'enfin ils ne devaient pas être éloignés de plus de 5 milles. C'est en tenant compte de toutes ces considérations que nous avons fixé la position des postes d'observations telle qu'elle est indiquée sur la figure 1.

Initialement, nous avions prévu 4 postes supplémentaires au bord externe du plateau continental ; ils portaient des numéros 10 au large du n° 9, n° 22 au large du 21, n° 14 au large du n° 13 et n° 18 au large du n° 17. Ils n'ont pu être stationnés comme prévu, mais leur abandon n'a pas eu de conséquences fâcheuses ainsi que nous le verrons plus loin.

3° REPORT DES RÉSULTATS, ÉTABLISSEMENT DES PROFILS

L'un de nous (L. Berthois 1965) a montré les avantages offerts par l'établissement de profils instantanés dans l'étude de la sédimentation estuarienne. Nous avons tenté d'utiliser cette méthode pour l'étude du déplacement des eaux et du dépôt des sédiments sur le plateau continental.

Lorsqu'on travaille, comme c'est le cas ici, dans une région où la marée est semi-diurne, l'échelonnement idéal dans le temps consiste à établir un profil instantané toutes les heures en prenant la basse mer ou la pleine mer comme origine des temps. Mais cela suppose une réitération fréquente de toutes les observations et un stationnement de 12 heures à chaque poste ; de telles conditions d'exécution sont pratiquement irréalisables dans les pays tropicaux où il faut opérer dans des conditions difficiles.

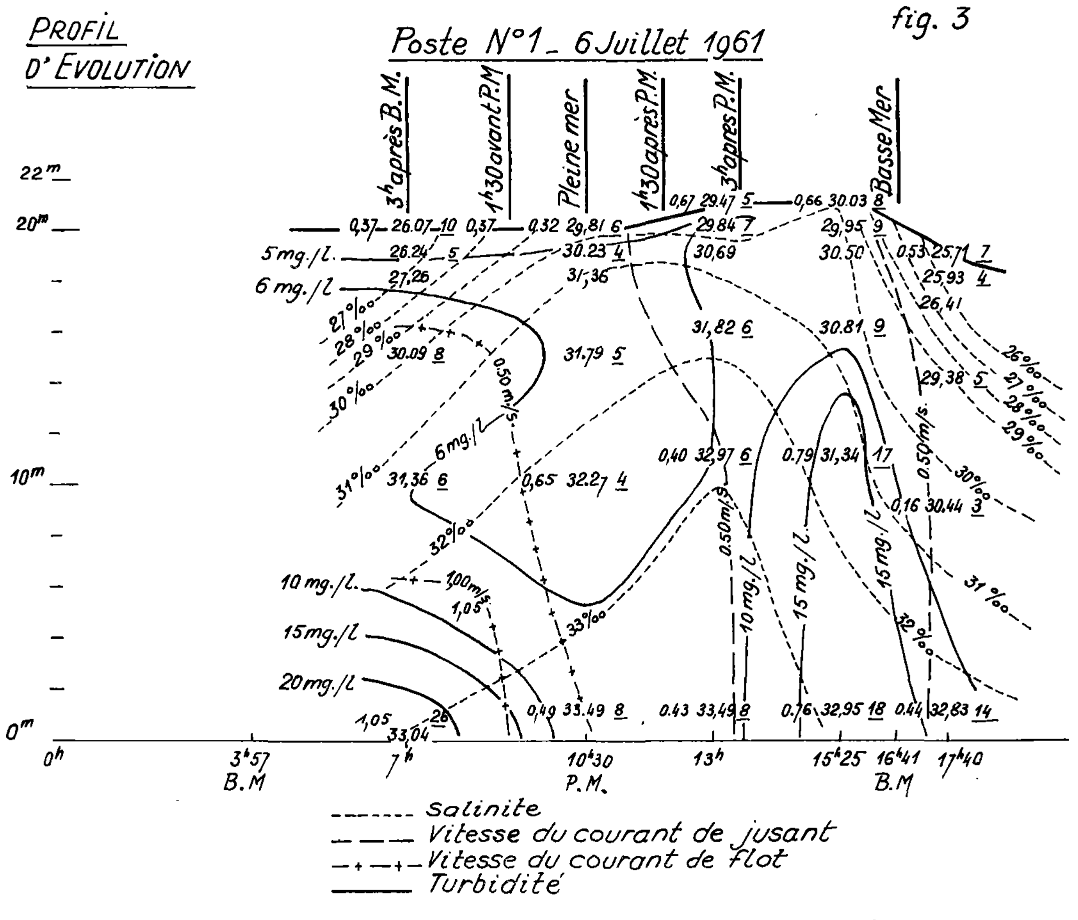

Fig. 3. — Profil d'évolution au poste n° 1 en période d'étiage du fleuve. Les courbes qui relient les valeurs identiques de salinité, turbidité, etc., n'ont pas de signification intrinsèque, elles matérialisent l'évolution et permettent des interpolations plus rapides.

C'était le cas ici où deux postes voisins devaient être stationnés à tour de rôle avec des décalages horaires inévitables. Cette manière d'opérer, imposée par les circonstances et les conditions de travail, oblige à calculer ensuite des interpolations entre les séries de mesures. Pour exécuter des calculs aussi exactement que possible, il est préférable de construire pour chaque poste un profil d'évolution qui représente les états successifs au cours de la marée (voir fig. 3).

Nous avons donc construit, pour chacun des postes de mesures, un profil d'évolution du même type que celui de la figure 3, mais pour ne pas allonger démesurément ce travail les autres profils d'évolution n'ont pas été reproduits, ils n'ont servi qu'à la construction des profils instantanés qui vont être étudiées en détail.

Cependant, pour permettre un contrôle de nos mesures et éventuellement, leur utilisation pour une autre étude, nous avons donné en annexe, à la fin de ce travail, des tableaux de tous les résultats obtenus.

4^o DYNAMIQUE DE LA SÉDIMENTATION EN ÉTIAGE DE FLEUVE

Les mesures ont été exécutées du 6 au 13 juillet 1961, les débits fluviaux n'ont subi que de faibles variations pendant cette période (voir tableau n° 1) ; les conditions océaniques étaient également stables.

Les positions des postes d'observation sont indiquées sur la fig. n° 1. Il nous a paru inutile de donner une réprésentation du fond à cause de l'énorme distorsion des graphiques (plus de 1000 fois) ; la complexité de ceux-ci nous a également conduit à supprimer toutes les valeurs mesurées et à ne représenter que les courbes isohalines, d'isoturbidité et d'isocélérité, puisque les valeurs exactes sont données en annexe.

Profil transversal du plateau continental dans l'axe de l'embouchure du fleuve (Postes 1 à 6).

a) **Basse-Mer.**

Au poste 1, la salinité est abaissée à 27 ‰, cette forte réduction est de faible amplitude puisqu'au fond la salinité dépasse 32 ‰ et qu'elle atteint déjà 30 ‰, un peu en aval du poste n° 2; cependant, sur tout le plateau continental la salinité est abaissée, elle n'atteint 35 ‰ qu'aux abords du poste n° 6, situé près de la limite extérieure du plateau continental.

La vitesse du courant de jusant est encore importante, près de la surface, au poste n° 2, mais elle s'atténue rapidement en profondeur, elle n'est plus que de 0,40 m / sec. à 9 m au-dessus du fond où les eaux se déplacent très lentement ; entre les postes 3 et 6 la vitesse du courant est de 0,20 m / sec. à 5-6 m au-dessus du fond où les eaux sont immobiles.

La turbidité atteint 8 mg / l. dans les eaux de surface au Poste 1, les eaux de la tranche médiane sont moins turbides, les eaux du fond contiennent 10 à 15 mg / l. de sédiments en suspension entre les postes 1 et 4, mais cette quantité se réduit à 2 mg / l. entre les postes 5 et 6.

b) **3 heures après la Basse-Mer** (période de Flot).

La salinité a faiblement augmenté dans les eaux estuariennes profondes des postes 1 et 2 mais elle est restée stationnaire en surface, elle a légèrement augmenté au poste n° 3 où la courbe de 34 % englobe une plus grande épaisseur d'eau profonde.

Le courant de flot se fait intensément sentir, il atteint 1 m / sec. dans les eaux profondes du P. 1. Aux postes 4 à 6 le courant de flot atteint 0,20 m / sec. au fond et 0,30 m / sec. dans les eaux médianes.

Sous l'effet de ce courant de flot, les sédiments qui étaient restés en suspension sont refoulés vers l'estuaire et se concentrent vers les postes 2 et 1 où la turbidité a augmenté.

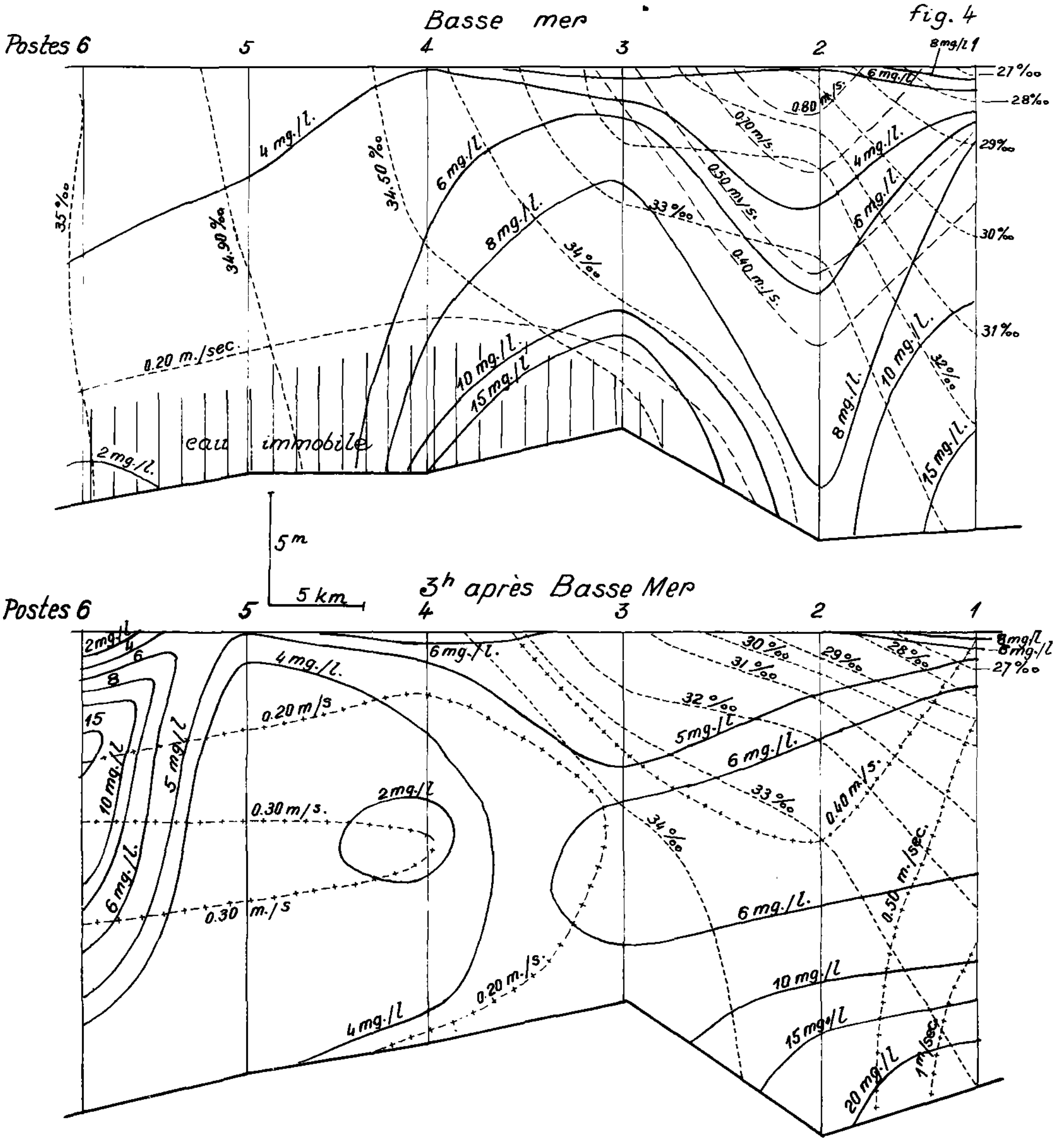

Fig. 4. — Coupe axiale. Profils instantanés en étiage du fleuve.

A ce moment, il apparaît au Poste 6 une couche d'eau médiane dont le maximum de turbidité 15 mg / l. se situe à près de 6 m de profondeur, cette petite lentille d'eau turbide est allongée verticalement et les sédiments qu'elle renferme tendent à gagner le fond.

c) **1 h 30 avant la Pleine-Mer** (période de flot).

La salinité a augmenté au poste 1 où les eaux de surface atteignent 29 $^0/_{00}$; tandis que les eaux du fond dépassent 33 $^0/_{00}$. En outre, l'isohaline de 34 $^0/_{00}$ passe à 5 m au-dessous de la surface au P. 3, et atteint le P. 2 à 7 m au-dessus du fond ; enfin, l'isohaline de 35 $^0/_{00}$ dépasse le P. 6 et atteint le P. 5 à 2 m au-dessus du fond.

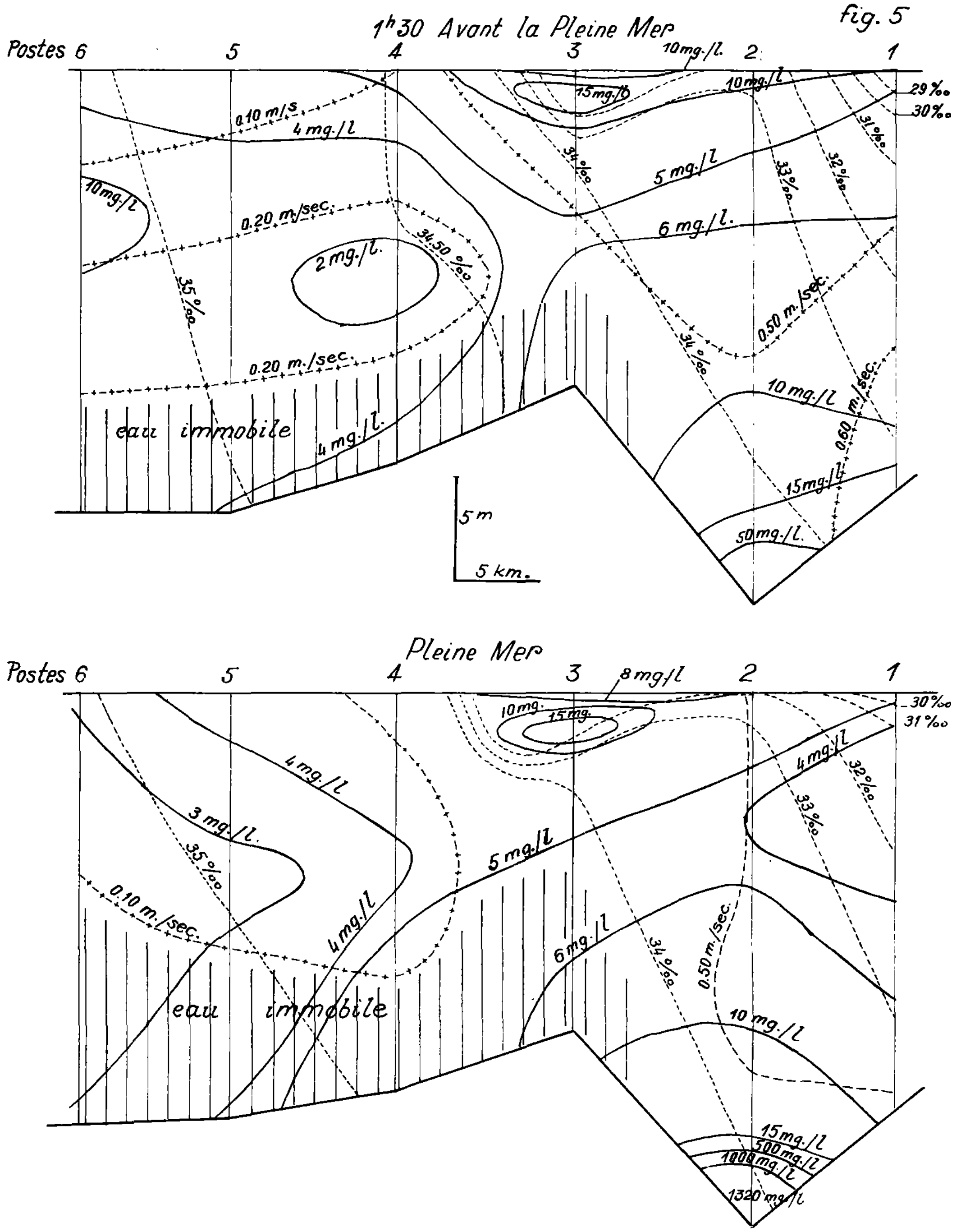

Fig. 5. — Profils instantanés en étiage du fleuve.

La vitesse du courant a notablement diminué : elle n'est plus que de 0,60 m / sec. au poste 1 et de 0,20 m / sec. à 5-6 m au-dessus du fond aux postes 6-5 et 4 où les eaux profondes sont immobiles.

Sous l'effet de ce ralentissement du courant, les sédiments en suspension se concentrent et les eaux se décantent. La turbidité a diminué dans la tranche d'eau médiane du poste 6. Une lentille d'eau turbide apparaît à 1-2 m de profondeur au P. 3, ces sédiments proviennent sans doute de la remise en suspension d'un dépôt sur le haut fond du banc du Narcissus. Enfin, la turbidité a notablement augmenté au P. 2.

d) **Pleine-Mer** (début du courant de jusant en amont).

La salinité a légèrement augmenté dans l'ensemble du profil, mais cette progression est plus apparente en surface (augmentation de 1 $^0/_{00}$ au P. 1) qu'en profondeur ou la progression de l'isohaline de 35 $^0/_{00}$ est la plus marquée.

Le courant de jusant apparaît déjà aux postes 1 et 2 avec une vitesse de 0,50 m / sec., tandis que le courant de flot est encore sensible aux postes 6-5 et 4, mais sa vitesse est seulement de 0,10 m / sec. à une distance du fond comprise entre 7 m et 12 m, si bien qu'on peut en inférer que les eaux sont immobiles à proximité du fond.

Sous l'effet du courant de jusant existant en amont (P. 1 et 2), les sédiments se concentrent au P. 2 où nous avons dosé 1 gr / l. mais à la faveur de la très faible mobilité des eaux aux postes 4, 5 et 6, les particules en suspension se sédimentent : on remarque notamment une nette diminution de la turbidité au poste 3 et la disparition de la lentille d'eau turbide au poste 6.

e) **1 h 30 après la Pleine-Mer** (période de Jusant).

La répartition et le tracé des courbes isohalines n'ont subi que de faibles modifications, on note seulement, l'étirement des isohalines en surface, entre les postes 3 et 4, et la régression très marquée de la courbe de 35 $^0/_{00}$ vers le large.

Les vitesses du courant de jusant sont encore fluctuantes et mal définies, cependant le courant oblique du profil précédent a fait place à un courant bien orienté vers l'embouchure, mais moins rapide, au-delà du P. 3 jusqu'au P. 6 les courants sont très lents. A l'aplomb du P. 3 les eaux sont immobiles, c'est ce qui permet la sédimentation des particules qui étaient en suspension à 1 m-1,50 m au-dessous de la surface ; cette lentille d'eau turbide qui s'est appauvrie pendant sa descente est maintenant à 11 m de profondeur. Enfin les eaux des postes 4, 5 et 6 sont elles-mêmes en cours de décantation.

f) **3 heures après la Pleine-Mer** (Période de Jusant).

La salinité a très peu varié pendant la période d'1 h 30 qui vient de s'écouler ; entre les P. 1 et P. 2 les isohalines se sont étirées vers le large ; la courbe de 34 $^0/_{00}$ est en légère régression, mais celle de 35 $^0/_{00}$, qui est également en régression dans sa partie profonde, paraît au contraire avoir légèrement avancé vers la surface.

Le courant de jusant s'est précisé et intensifié depuis les observations précédentes en surface et 0,50 m / sec. à 3 m du fond au P. 2 au P. 4 ; il existe encore un courant de 0,20 m / sec. à 1 m du fond, mais entre le P. 4 et le P. 6 la vitesse du courant n'atteint que 0,10 m / sec. à 13 et 15 m. au-dessus du fond, ce qui implique l'immobilité d'une épaisse tranche d'eau profonde.

La turbidité des eaux a évolué entre les deux observations : elle a notablement augmenté aux postes 1 et 2, où elle atteint 10 mg / l. près du fond. Dans la tranche d'eau médiane du P. 3 apparaît une longue lentille d'eau à 4 mg / l. de turbidité qui s'étend jusqu'au P. 6 où elle atteint presque la surface, cette localisation de la turbidité matérialise la décantation des eaux qui se poursuit en l'absence quasi totale de courant.

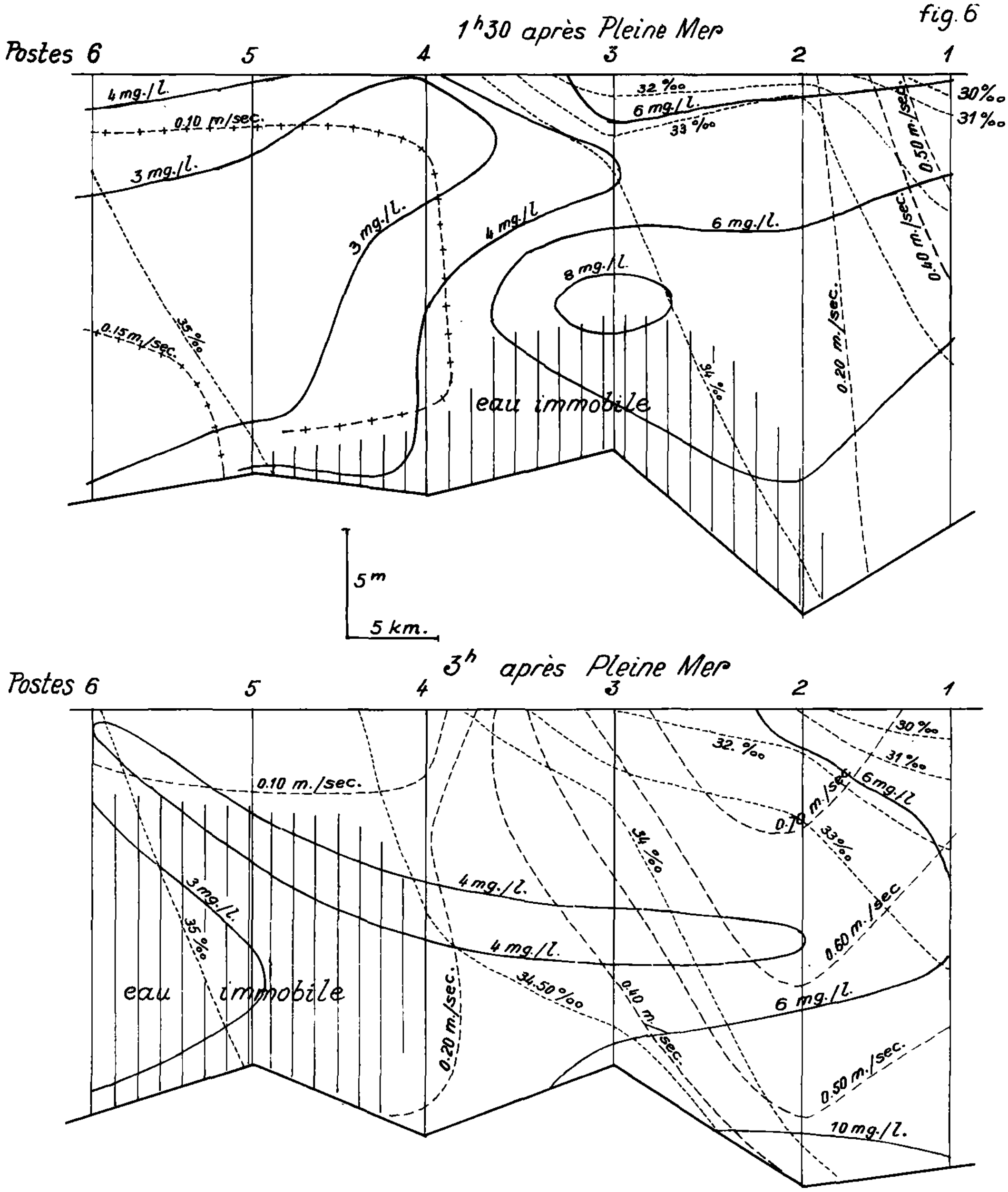

Fig. 6. — Profils instantanés en étiage du fleuve.

En résumé.

Ces profils instantanés qui partent de l'estuaire du fleuve et traversent la totalité du plateau continental pour aboutir à son bord extérieur, mettent en évidence les faits suivants :

La sédimentation est intimement liée aux conditions dynamiques et en conséquence la turbidité des eaux peut être momentanément élevée à l'embouchure de l'estuaire ; elle reste toujours faible sur le plateau Continental où les eaux profondes sont immobiles pendant de très longues périodes entre lesquelles les courants sont toujours animés de faibles vitesses. Il apparaît que les matières en suspension sont amenées par les eaux de surface qui se décantent lentement. Les sédiments fraîchement déposés sur les hauts fonds sont probablement remaniés partiellement, c'est ce qui expliquerait l'apparition de lentilles turbides isolées à faible profondeur aux postes 3 et 6.

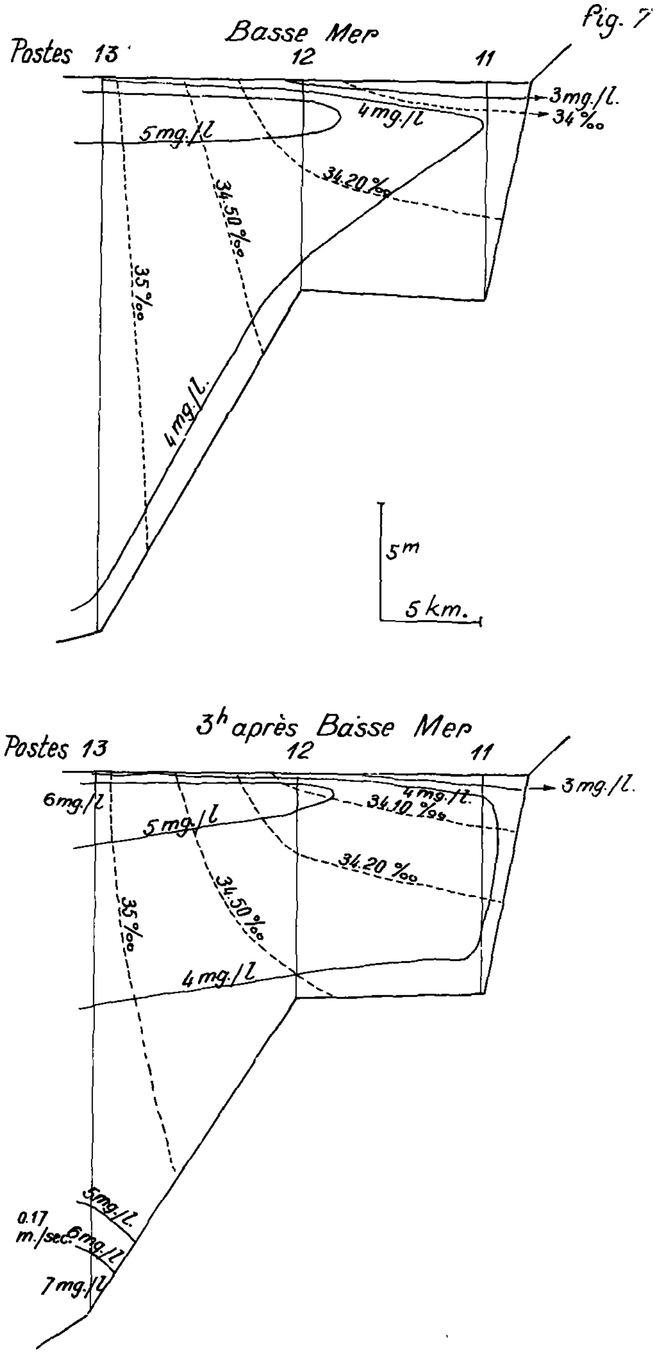

Fig. 7. — Première transversale Ouest. Profils instantanés en étiage du fleuve.

Premier profil transversal à l'ouest du profil axial (Postes 11 à 13).

a) **Basse-Mer** (voir fig. 7). (Période de flot).

La salinité est plus élevée au P. 11 qu'au moment de la Basse-Mer au P. 3 où elle était supérieure à 31 $^0/_{00}$ (fig. 6), elle augmente assez régulièrement vers le large et atteint 35 $^0/_{00}$ avant la verticale du P. 13.

La turbidité est faible : 3 à 4 mg / l. en surface, 4 mg / l. près du fond et 5 mg / l. dans une lentille d'eau s'étendant de 0,75 m à 1,50 m entre les postes 12 et 13.

b) **3 heures après la Basse-Mer** (Période de flot).

La salinité n'a pas subi de modification notable pendant la période écoulée, aussi, malgré l'absence de mesure de vitesse de courant, on peut en inférer un très faible mouvement des eaux sur le plateau continental.

A la faveur de cette quasi-immobilité des eaux la décantation s'est amorcée, la courbe d'isoturbidité de 4 mg / l. s'est éloignée du fond du poste 13 où l'on observe des teneurs en suspension atteignant 7 mg / l. Un courant de 0,17 m / sec. à 4 mètres au-dessus du fond ne peut s'opposer à ce dépôt.

c) **1 h 30 avant Pleine-Mer** (Période de flot, fig. 8).

La salinité a légèrement augmenté : l'isohaline de 34,5 $^0/_{00}$ atteint le fond à l'aplomb du poste 11 et celle de 35 $^0/_{00}$ s'est rapprochée du P. 12.

La vitesse du courant a augmenté légèrement, elle est maintenant de 0,24 m / sec. à 1 m du fond au P. 13.

Sous la poussée du flot, la turbidité en surface au P. 11 est passée de 3, à 4 mg / l. et la teneur de 6 mg / l. des eaux, situées à 2 m. de profondeur au P. 13, atteint maintenant le P. 12.

Cependant, au P. 11 la turbidité s'est abaissée à 3 mg / l. et au P. 13, la turbidité au fond, n'a augmenté que d'1 mg / l. malgré l'accélération de la vitesse du courant.

d) **Pleine-Mer.**

A la pleine-mer, la salinité n'a pratiquement pas varié depuis les précédentes observations ; il en est de même de la turbidité en surface et dans la tranche d'eau médiane.

Dans la zone profonde du P. 13, la turbidité a augmenté de 2 mg / l., il s'est donc probablement amorcé une concentration des matières en suspension qui peut être attribuée à la réduction de la vitesse du courant passée de 0,24 m / sec. à 0,20 m / sec.

e) **1 h 30 après Pleine-Mer** (période de Jusant).

Les observations sont incomplètes, elles ne permettent pas l'établissement d'un profil instantané.

f) **3 heures après la Pleine-Mer** (Période de Jusant, fig. 9).

La salinité n'a pas subi de profondes modifications mais elle a augmenté légèrement aux postes 11 et 12 tout en restant pratiquement inchangée entre les postes 12 et 13.

La vitesse du courant n'est plus que de 0,11 m / sec. à 2 m du fond du P. 13 ; à la faveur de cette perte de vitesse des eaux, les sédiments se sont déposés : il ne reste que 3 mg / l. en suspension.

Les courbes d'isoturbidité font apparaître une augmentation de la turbidité vers le large, ce qui montre que les sédiments transportés en suspension tendent à s'écarter du littoral.

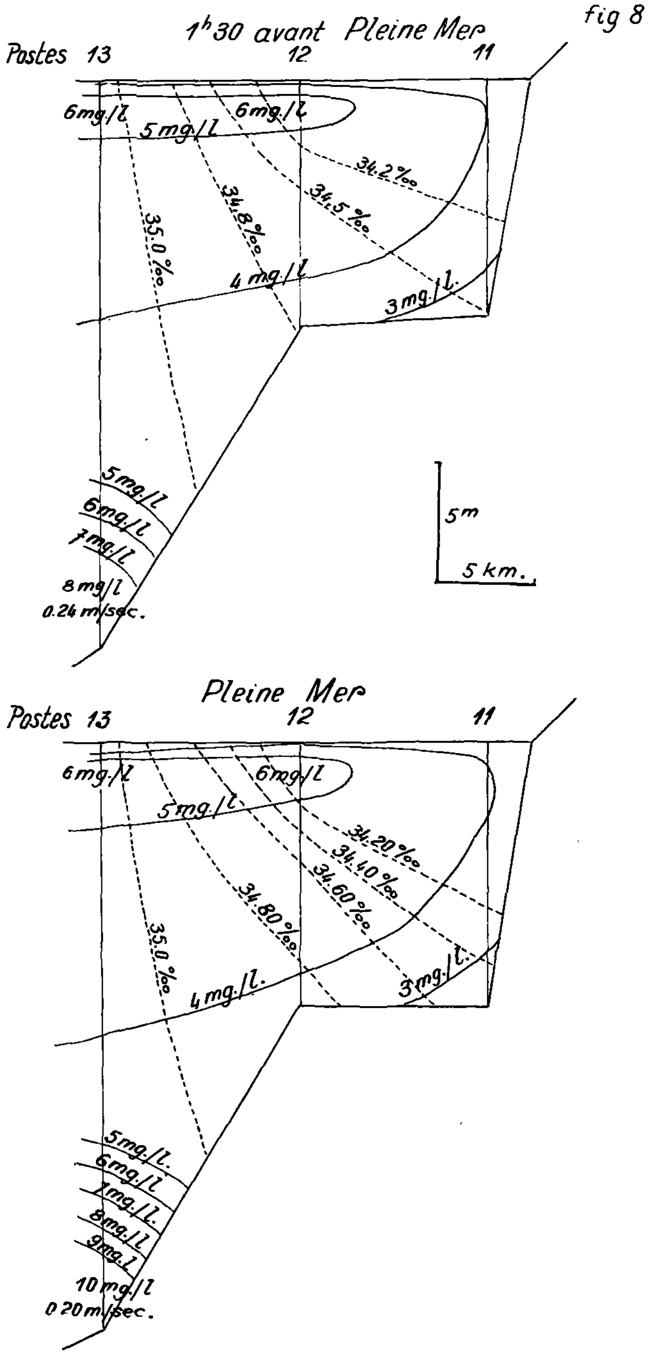

Fig. 8. — Profils instantanés en étiage du fleuve.

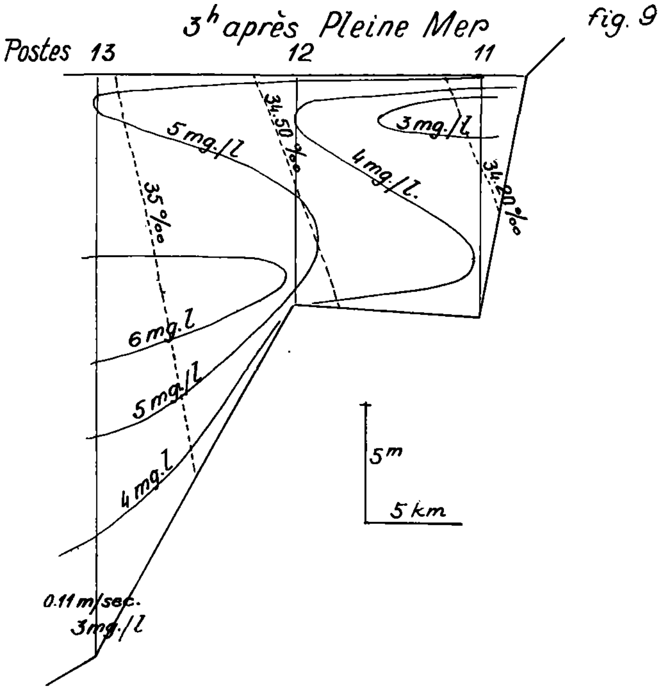

Fig. 9. — Profil instantané en étiage du fleuve.

En résumé.

L'étude des états successifs du premier profil transversal à l'ouest du profil axial a montré que :

la salinité subit des modifications sensibles mais peu importantes qui décroissent rapidement vers le large, sur la verticale du P. 13 la salinité reste pratiquement inchangée.

La turbidité est plus importante vers le large qu'à proximité du littoral, les courants de surface, que nous étudierons en détail ultérieurement, étant orientés vers l'extérieur dans ce secteur du plateau continental.

Cette répartition sédimentaire de la fraction fine apparaît dans la composition granulométrique des dépôts. En effet, les sédiments qui ont été dragués renferment des fractions de diamètres inférieurs à 0,080 m qui sont le suivantes :

Poste n° 11 - - 0,7 % de grains < 0,080 mm.
n° 12 — 0,6 % de grains < d.
n° 13 — 45,1 % de grains < d.

Cette répartition sédimentaire sera examinée à nouveau dans une étude d'ensemble.

Deuxième profil transversal à l'Ouest du profil axial (Postes 15 à 17).

Pour des raisons de navigation le poste 15 n'a pu être stationné au point initialement prévu, il a du être reporté vers le large d'environ 1 mille ½. Cependant, les postes 16 et 17 ont été stationnés, comme prévu par le travers des postes 12 et 13.

a) **Basse-Mer** (fig. 10).

La salinité est plus élevée qu'aux postes 11 et 13 pendant la même période : la courbe isoha-

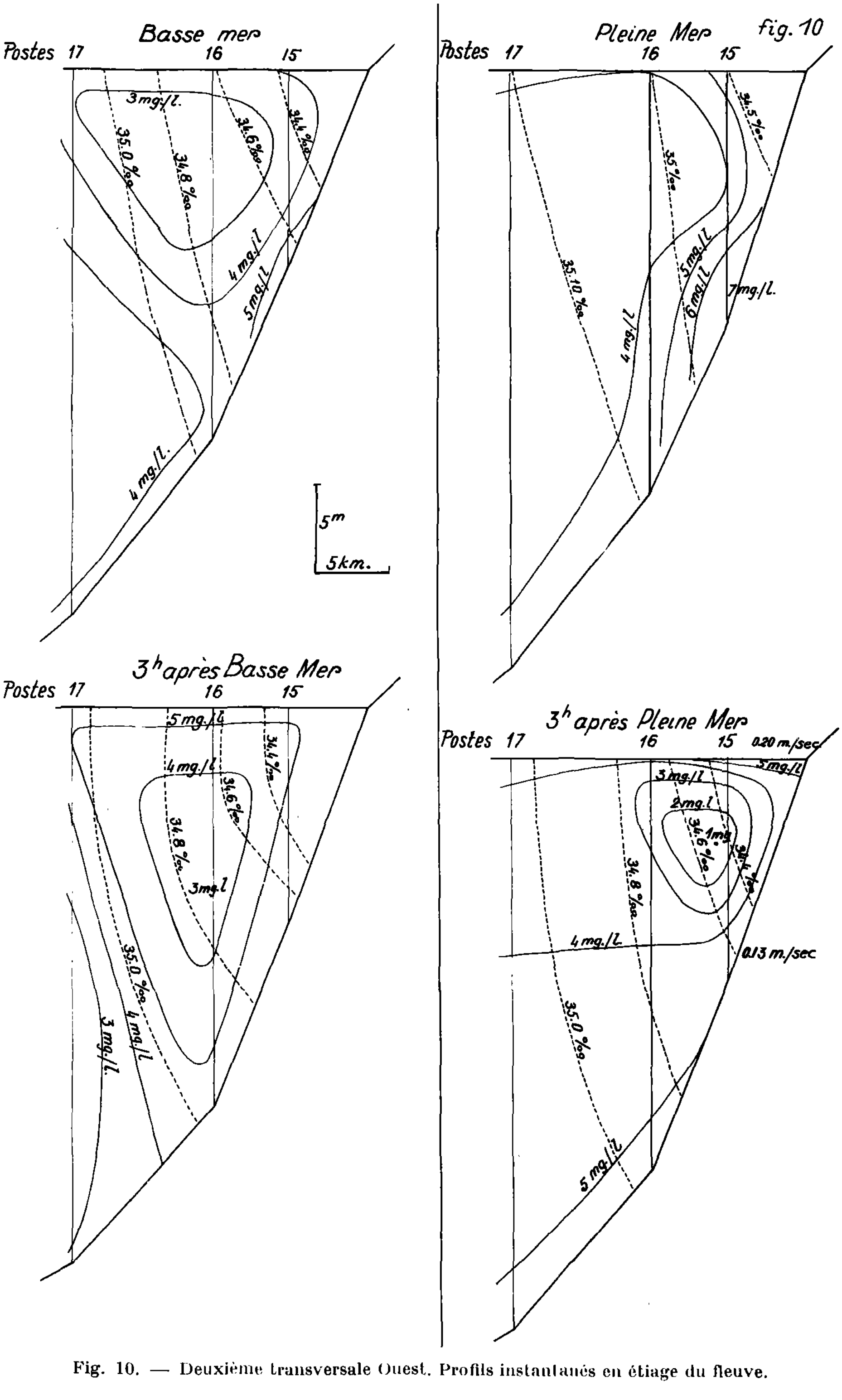

Fig. 10. — Deuxième transversale Ouest. Profils instantanés en étiage du fleuve.

line de 35 $^0/_{00}$ est voisine du poste 16, en profondeur et il n'y a, dans l'ensemble du profil, qu'un abaissement de 0,6 $^0/_{00}$ de la salinité au P. 15.

La turbidité est faible : 3 mg / l. dans la partie médiane de la tranche d'eau, 5 mg / l. près du fond au P. 15 et 4 mg / l. au P. 17.

b) **3 heures après la Basse-Mer** (Période de flot, fig. 10).

La salinité est restée pratiquement inchangée depuis les précédentes observations.

La turbidité est toujours faible mais elle présente une évolution intéressante : les eaux de la tranche médiane tendent à se décanter, par conséquent, il y a un abaissement de la teneur en suspension dans les zones où elle était de 4 mg / l (Poste 17).

Il y a régularisation ou augmentation de la turbidité à proximité du fond aux postes 15 et 16 où la courbe d'isoturbidité de 5 mg / l. s'allonge vers le fond. Mais corrélativement, un nouvel apport de sédiments s'effectue dans les eaux de surface refoulées par le courant, la turbidité y atteint 5 mg / l.

c) **Pleine-Mer** (fig. 10).

Les eaux plus salées du large sont repoussées vers le littoral, cependant la salinité n'a augmenté que de 0,1 $^0/_{00}$ au profil 15. Toutefois la courbe isohaline de 35 $^0/_{00}$ est maintenant située entre les postes 16 et 15 et celle de 35, 10 $^0/_{00}$ atteint presque la verticale du poste n° 16.

Les eaux turbides ont suivi ce mouvement vers le littoral : la teneur en suspension est de 7 mg / l. près du fond au P. 15 puis, elle diminue vers le large pour être comprise entre 4 et 5 mg / l. au P. 16, au P. 17 elle est encore de 4 mg / l. au fond. Les eaux de surface ont des turbidités comprises entre 5 et 4 mg / l., elles paraissent se décanter avec une extrême lenteur.

d) **3 heures après la Pleine-Mer** (Période de Jusant, fig. 10).

La salinité est en régression au P. 15 nous retrouvons sensiblement l'état initial de la Basse-Mer et il en est à peu près de même aux postes 16 et 17.

On observe entre les postes 15 et 16 un noyau à très faible turbidité, il est entouré d'une couche d'eau plus turbide, à la base elle est due à la décantation et en surface aux nouveaux apports sédimentaires.

Entre les postes 16 et 17 la courbe d'isoturbidité à 4 mg / l. se relève à cause de la décantation des eaux qui atteignent 5 mg / l. de suspension à proximité du fond à ces deux derniers postes.

RÉSUMÉ.

La salinité varie très peu et la turbidité également, les vitesses des courants sont faibles et ne se prêtent pas à des déplacements importants des sédiments du fond. Les sédiments en suspension sont plus aisément transportés. La comparaison des teneurs en fraction fine ($<$ 0,080 mm) montre que :

Au P. 11 de la première transversale ouest la fraction fine représentait............. 0,7 %
au poste 15 de la 2^e transversale elle est de.. 5,8 %

Cependant, il est important de noter qu'au poste 15 la teneur en suspension des eaux est toujours inférieure à celles qui ont été observées au poste n° 13.

Les sédiments du P. 16 sont difficilement comparables à ceux du P. 12 car les premiers peuvent être enrichis, en fraction fine, par les apports de la Rivière Mahamba.

Premier profil transversal à l'est du profil axial (Postes n^{os} 7 et 9, fig. 1).

Les postes n^{os} 7-8 et 9 ont été placés par le travers des postes n^{os} 3, 4 et 5 du Profil axial, ils sont donc comparables à ces derniers.

a) **Basse-Mer** (fig. 11).

La salinité est notablement plus élevée au poste 7 qu'au poste nº 3, mais la quantité d'eau douce qui parvient, en surface, au P. 7 est plus importante que celle qui franchit le P. 11 où l'abaissement du taux de salinité est faible, on peut donc en déduire que l'écoulement des eaux estuariennes s'oriente vers le N.-E. à l'embouchure du fleuve. Au poste nº 8 la salinité est comparable à la valeur trouvée au P. 4 de la transversale axiale et au poste 9 elle est un peu plus élevée qu'au poste 5.

La turbidité est répartie autour de deux maxima : le premier au P. 7 (8 mg / l.) avec une décroissance régulière des teneurs en suspension en allant vers le P. 8 et des valeurs constantes de la surface au fond.

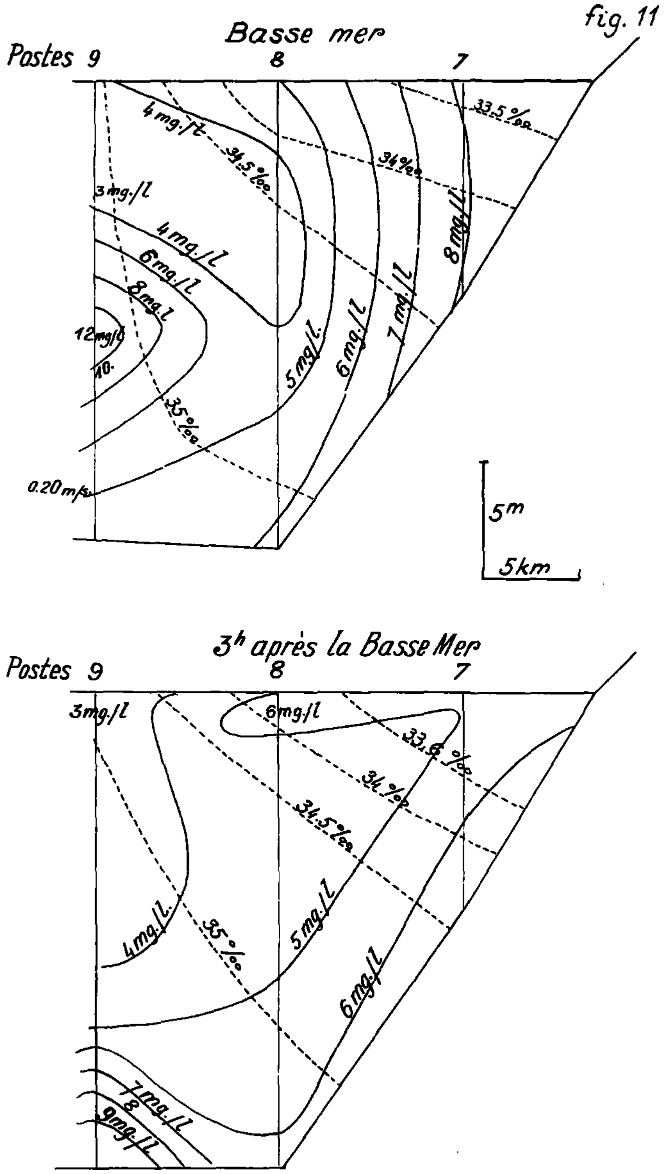

Fig. 11. — Première transversale Est. Profils instantanés en étiage du fleuve.

Le deuxième maximum est situé à 11 m. de profondeur à l'aplomb du P. 9, il est représenté par une lentille d'eau turbide, de faible étendue, avec une teneur maximale de 12 mg / l.

b) **3 heures après la Basse-Mer** (Période de flot, fig. 11).

La salinité a très légèrement augmenté depuis les dernières observations.

La turbidité a notablement décru entre les postes 7 et 8. Il en est de même au P. 9 où les eaux sont décantées d'une notable partie des matières en suspension qui sont maintenant à proximité immédiate du fond.

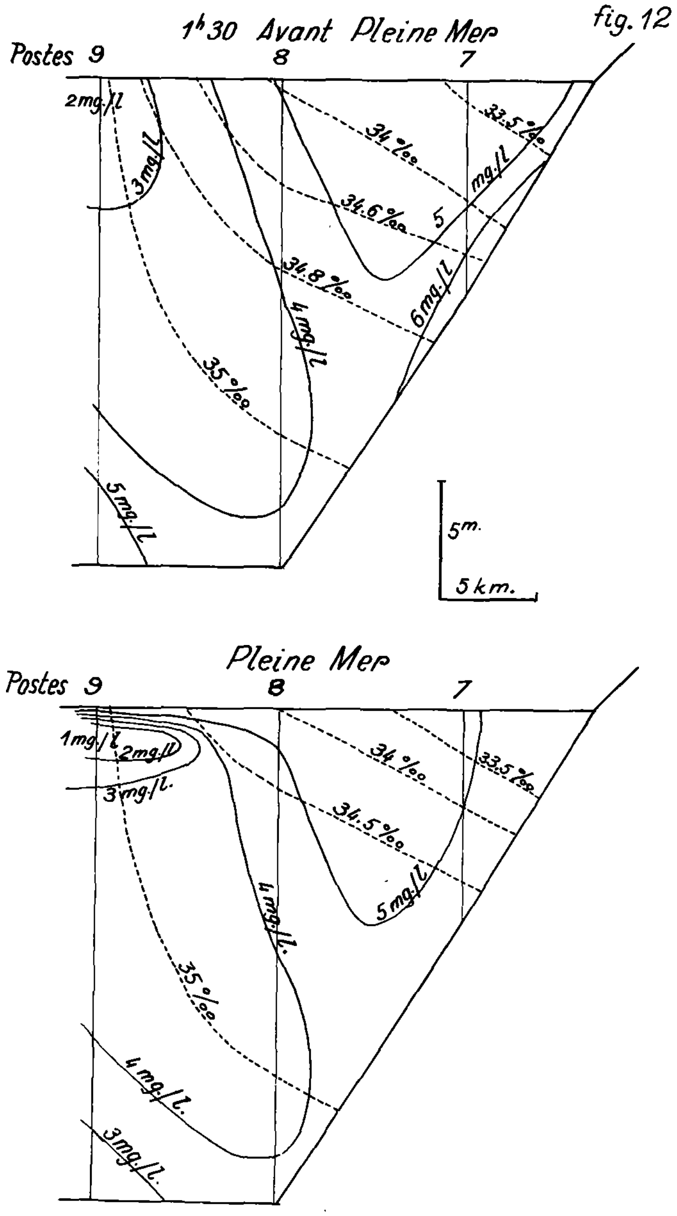

Fig. 12. — Profils instantanés en étiage du fleuve.

c) **1 h 30 avant la Pleine-Mer** (Période de flot, fig. 12).

La salinité a encore très légèrement augmenté et la turbidité a diminué, il ne subsiste plus qu'une petite lentille d'eau chargée de 6 mg / l. de suspension au P. 7, et une autre avec 5 mg / l. de suspension au P. 9.

d) **Pleine-Mer** (fig. 12).

Le taux de salinité est toujours stationnaire, mais la turbidité a encore diminué dans l'ensemble du profil, il apparaît même, à faible profondeur, au P. 9 une lentille d'eau très claire (1 mg / l).

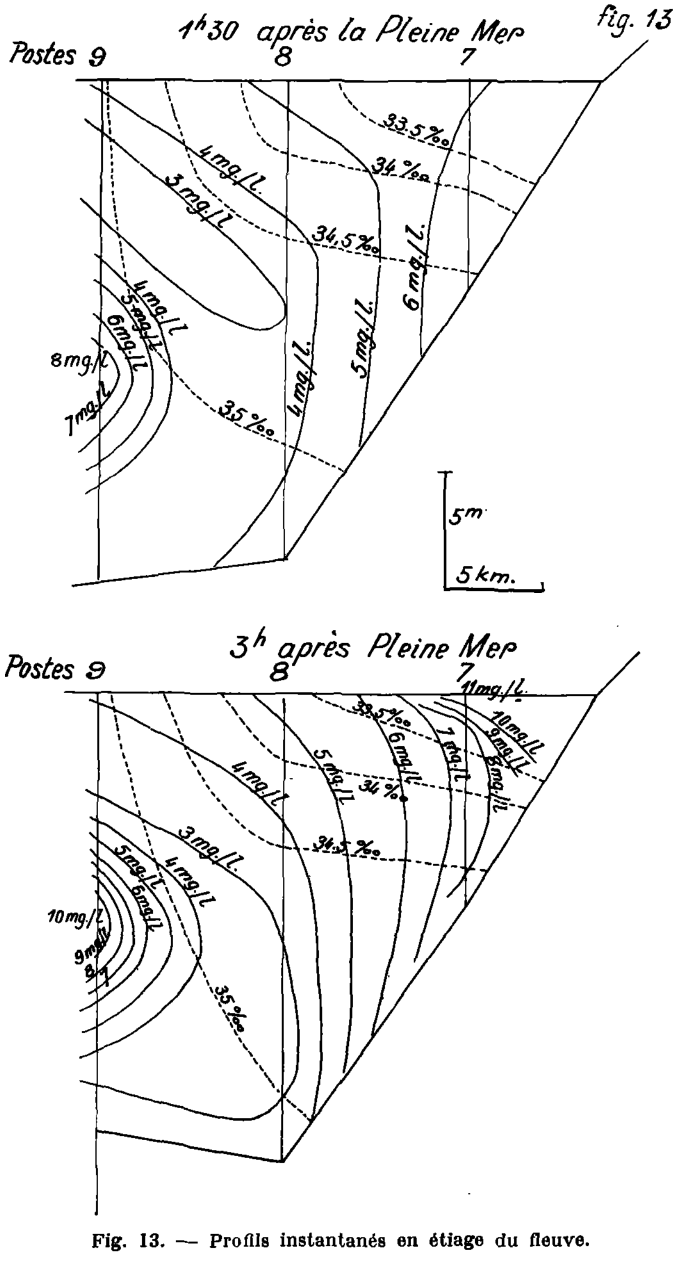

Fig. 13. — Profils instantanés en étiage du fleuve.

e) **1 h 30 aprés la Pleine-Mer** (Période de Jusant, fig. 13).

La salinité est en légère régression aux postes n^os^ 7 et 8 mais elle est restée pratiquemment stationnaire au poste 9.

La turbidité a augmenté depuis la pleine mer :
au poste 7 les eaux contiennent plus de 6 mg / l. et il apparaît à nouveau,
au P. 9, une lentille d'eau turbide (8 mg / l.) à la profondeur de 12 m.

f) **3 heures après la Pleine-Mer** (Période de Jusant, fig. 13).

La salinité est en légère régression au P. 7, elle est pratiquement inchangée aux postes 8 et 9.

La turbidité a notablement augmenté dans l'ensemble du profil surtout par un apport des eaux de surface au P. 7 où nous observons une augmentation de 5 mg / l.

D'autre part, la lentille d'eau turbide du P. 9 s'est légèrement renforcée par des apports nouveaux, elle atteint maintenant 10 mg / l.

RÉSUMÉ.

L'étude de ce profil transversal montre une remarquable stabilité du taux de salinité aux postes 8 et 9, c'est seulement au poste 7 que des fluctuations peuvent être observées. Il apparaît donc que le dessalement n'affecte qu'une mince tranche d'eau superficielle.

La localisation des eaux turbides explique la séparation verticale des matières en suspension.

Le courant orienté N.E.-S.O. qui, d'après la carte marine, longe la bordure du plateau continental, contribue sans doute au maintien des matières en suspension aux postes situés vers le large (ici le poste 9) et à leur répartition le long de cette bordure. Aucun poste n'ayant pu être stationné au large du P. 9, la limite nord des eaux turbides qui apparaissent parfois dans la tranche médiane n'a pu être fixée.

L'étude des sédiments qui sera développée ultérieurement confirme cette répartition de la turbidité; les teneurs en fraction fine ($<$ 0,080 mm) sont les suivantes :

station n° 7 — fraction fine — 99,7 %
n° 8 — fraction fine — 99,1 %
n° 9 — fraction fine — 10,5 %

Deuxième profil transversal à l'est du profil axial (Postes n^os^ 19 à 21, fig. 1).

Les postes n^os^ 19, 20 et 21 ont été stationnés aux emplacements prévus, par le travers des postes 7, 8 et 9 qui viennent d'être étudiés.

a) **Basse-Mer** (fig. 14).

La salinité la plus basse est observée au poste 20 où les eaux les moins salées paraissent s'écouler comme dans un chenal délimité par la teneur de 34 $^0/_{00}$; toutefois, il ne faut pas oublier que par suite de l'énorme distorsion de ces profils, il ne s'agit que d'une mince tranche d'eau s'étendant sur une dizaine de kilomètres de largeur. Il faut encore noter que l'abaissement de la salinité est moins important que dans le premier profil transversal.

La turbidité atteint son maximum dans les eaux superficielles mais elle est peu élevée ; les eaux de la tranche médiane et les eaux profondes sont les moins chargées de sédiments.

b) **3 heures après la Basse-Mer** (Période de flot, fig. 14).

La salinité a légèrement augmenté, principalement vers le fond. La turbidité évolue dans le sens de la décantation des eaux ; la comparaison avec le profil 7 à 9 de la même période (fig. 11). montre que la turbidité décroît très nettement lorsqu'on passe de la 1^re^ transversale Est à la deuxième. En particulier les eaux turbides qui existaient au fond, au profil n° 9, n'atteignent pas le P. 21.

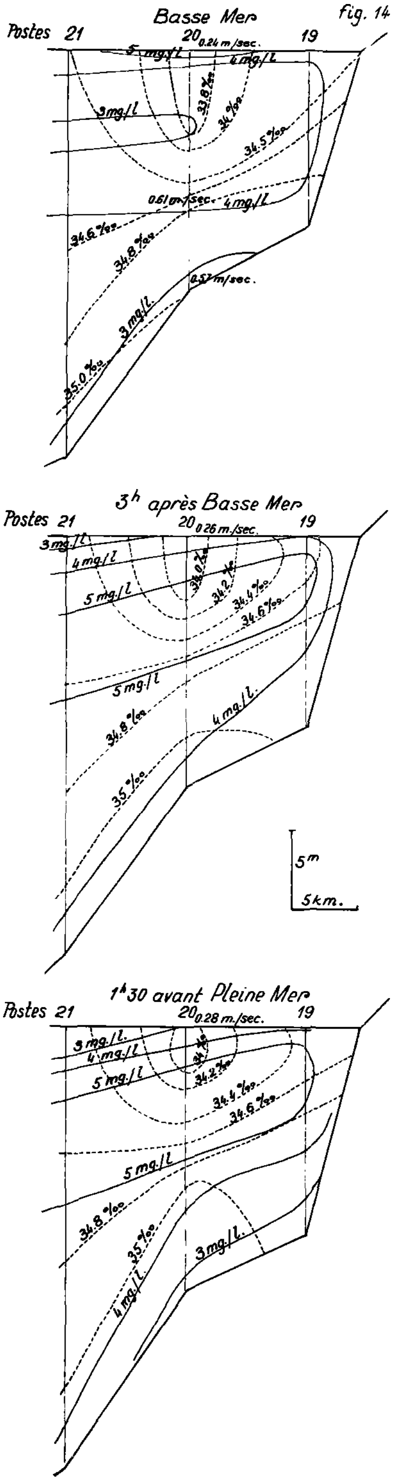

Fig. 14. — Deuxième transversale Est. Profils instantanés en étiage du fleuve.

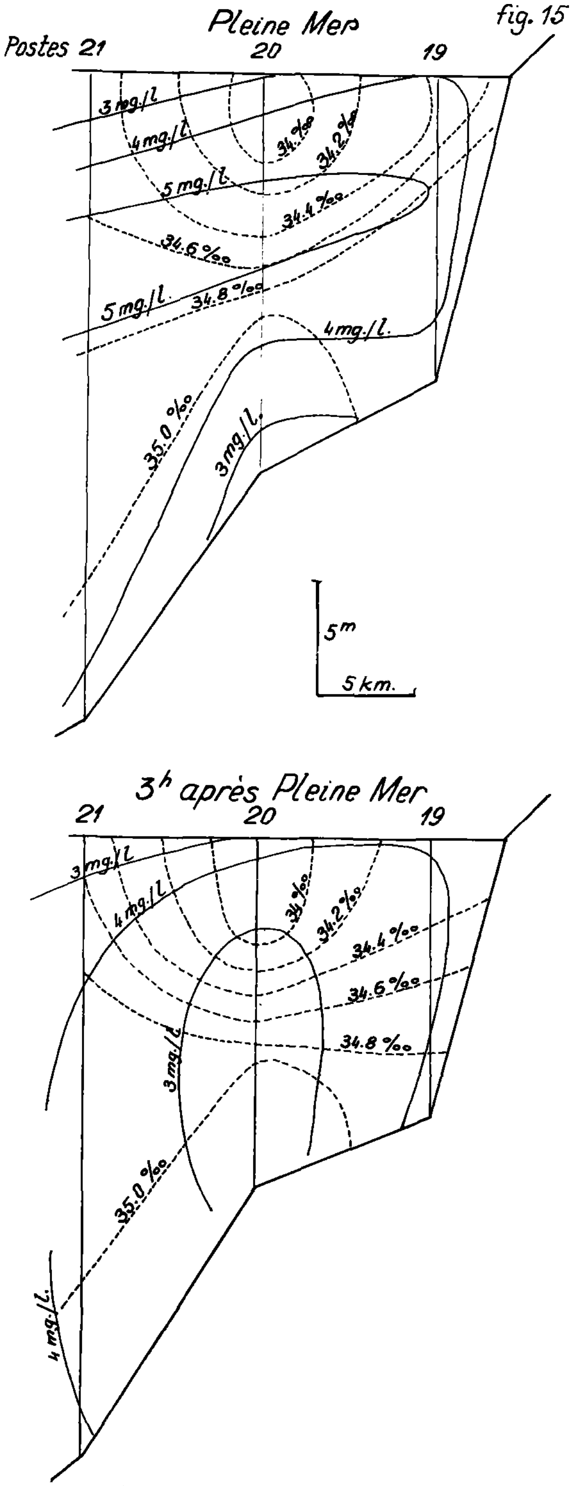

Fig. 15. — Profils instantanés en étiage du fleuve.

c) **1 h 30 avant la Pleine-Mer** (Période de flot, fig. 14).

La salinité a faiblement augmenté depuis les observations précédentes et la turbidité est restée pratiquement inchangée, on note seulement une zone légèrement moins turbide que précédemment, à proximité du fond aux postes 19 et 20.

La comparaison avec le profil 7 à 9, de la première transversale Est, montre que les teneurs en suspension ont, dans les deux cas, des valeurs sensiblement identiques.

d) **Pleine-Mer** (fig. 15).

La salinité n'a pas varié sensiblement depuis les dernières mesures, il en est de même pour la turbidité.

La comparaison avec le profil 7 et 9 de la première transversale Est montre que les teneurs en suspension sont du même ordre de grandeur dans les deux cas.

e) **3 heures après la Pleine-Mer** (fig. 15).

La salinité s'est abaissée au P. 19 depuis les dernières observations.

La turbidité a également diminué pendant la même période, la lentille d'eau contenant 3 mg / l. s'est considérablement développée.

La comparaison avec les profils 7 et 9, de la première transversale Est, permet de constater un abaissement très net de la turbidité lorsque les eaux atteignent la deuxième transversale.

EN RÉSUMÉ.

L'examen des profils de la deuxième transversale Est montre qu'il y existe une stabilité notable de la salinité, le dessalement des eaux de surface est un peu plus important au P. 20 que dans les deux postes latéraux, mais la stratification des eaux reste pratiquement constante.

On observe également une diminution des teneurs en suspension qui ne présentent plus de maximum bien défini. Ainsi, des deux comparaisons latérales qui viennent d'être faites, avec la ligne du Profil Axial traversant le plateau continental, il apparaît que les déplacements sédimentaires sont plus importants, à l'est qu'à l'ouest de l'axe choisi.

D'autre part, il semble que les transports importants de sédiments ne dépassent pas sensiblement, en régime d'étiage du fleuve, la deuxième transversale Est. Pour examiner cette question plus en détail, nous avons construit une série de profils spéciaux qui vont être examinés ci-dessous.

Établissements de profils pour la recherche de l'évacuation des sédiments sortant de l'estuaire du fleuve en période d'étiage.

a) **Basse-Mer** (fig. 16).

Le dessalement des eaux a, bien entendu, son maximum dans les deux postes estuariens et les courbes isohalines s'incurvent vers les postes extérieurs ; celle de 33 $^0/_{00}$ atteint en surface le P. 7.

Le maximum de turbidité au fond est situé au P. 1, ensuite la turbidité au fond diminue progressivement jusqu'au P. 2 ; elle reste quasi stationnaire au fond entre les postes 2 et 7 où elle est égale sur toute la hauteur de la tranche d'eau. Enfin, la turdibité diminue entre les P. 7 et 19.

Les eaux de surface, en provenance de l'estuaire, renferment 8 mg / l. de sédiments en suspension, mais elles ont déjà abandonné une portion des particules transportées avant d'atteindre le P. 2. Entre les P. 2 et P. 7 la décantation paraît se poursuivre, mais il y a une augmentation de teneur au P. 7.

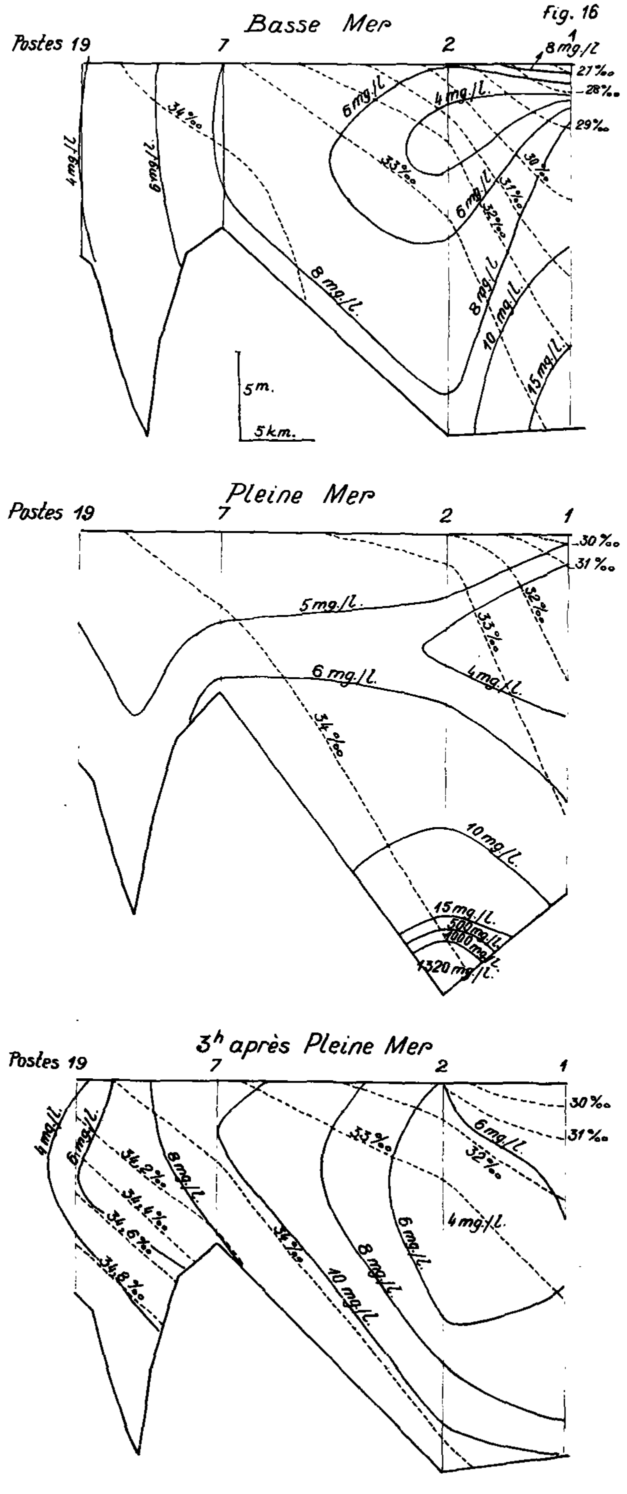

Fig. 16. — Profils pour l'étude de l'évacuation des sédiments de l'estuaire du fleuve.

b) **Pleine-Mer** (fig. 16).

A la pleine-mer la salinité augmente d'une manière très sensible.

Sous la poussée du courant de flot les sédiments en suspension sont refoulés vers l'entrée de l'estuaire où ils sont bloqués. On observe alors une concentration de plus d'un gramme par litre d'eau près du fond au P. 2 mais il y a déjà moins de 10 mg / l. au P. 1. Il apparaît donc que l'importante masse sédimentaire de l'entrée n'est pas déplacée vers l'amont du fleuve.

En surface et jusqu'à la tranche d'eau médiane la turbidité s'est abaissée et régularisée.

c) **3 heures après la Pleine-Mer** (Période de Jusant, fig. 16).

La salinité s'abaisse dans la partie amont du profil où la courbe isohaline de 33 $^0/_{00}$ atteint presque le P. 7 tandis que celle de 32 $^0/_{00}$ dépasse largement de P. 2. L'isohaline de 34 $^0/_{00}$ reste inchangée.

Une partie des sédiments précédemment concentrés au P. 2 est refoulée par le jusant et remise en suspension ; il en résulte un accroissement de la turbidité au fond et en surface aux postes 7 et 19.

En résumé.

La comparaison des deux profils transversaux Est (Postes 7 et 9 et Postes 19 à 21) avec le profil axial (Postes 1 à 6) avait montré que les eaux fluviales s'orientaient de préférence au N.-N.-E. à leur sortie de l'estuaire ainsi qu'on pouvait s'y attendre.

Il était en outre apparu que le courant de flot, dirigé vers le littoral, pouvait peut-être provoquer une concentration des sédiments vers les postes côtiers 7 et 19. Il était donc nécessaire d'étudier sur des profils spéciaux, les conséquences de ces deux actions dynamiques sur la répartition des sédiements.

L'examen détaillé qui vient d'être fait montre, qu'en période d'étiage du fleuve, la masse sédimentaire importante qui se concentre au P. 2 à la pleine-mer ne progresse pas vers l'amont.

La fraction fraîchement déposée paraît être remise en suspension et partiellement dispersée au cours du jusant suivant, mais les eaux assez fortement turbides qui atteignent le P. 7 sont notablement moins riches en sédiments lorsqu'elles atteignent le P. 19 où le dépôt paraît être beaucoup moins actif.

5e DYNAMIQUE DE LA SÉDIMENTATION EN PÉRIODE DE CRUE DU FLEUVE

Les mesures ont été exécutées du 8 au 17 mars 1962. Les débits fluviaux ont subi des variations importantes pendant cette période, notamment le 8 mars, mais justement la brusque augmentation du débit qui était passé à 3.665 m³ / sec. n'a pas permis de poursuivre les observations qui ont du être interrompues et reprises le lendemain 9 mars.

Ainsi donc, les mesures ont été faites pour des débits fluviaux variant de 1427 m³ / sec. à 2.810 m³ / sec. L'écart est important, mais il ne paraît pas possible, à l'examen de la courbe des débits totalisés (fig. 2), de découvrir une période de 8 à 10 jours durant laquelle le débit fluvial soit stabilisé. Cela est d'autant plus irréalisable qu'en commençant une campagne de mesures, il est impossible de connaître comment évoluera la crue qui va être étudiée.

Cependant, les variations, dans les évolutions dynamiques ou sédimentaires devront être interprétées en tenant compte de ces fluctuations du débit fluvial au cours des mesures.

Les conditions océaniques ont également subi des fluctuations assez importantes pour cette région du globe où les marnages sont modérés. Les hauteurs des basses-mers ont varié de 0,60 m à 2,50 m, celles des hautes-mers de 3,40 m à 5,20 m.

Profil tansversal du plateau continental dans l'axe de l'embouchure du fleuve (Postes 1 à 6 et 23).

a) **Basse-Mer** (fig. 17).

La salinité est fortement abaissée, elle est inférieure à 2 $^{0}/_{00}$ aux postes 1 et 2 et les eaux superficielles n'atteignent que 15 à 20 $^{0}/_{00}$ sur toute la longueur du profil. La courbe isohaline de 30 $^{0}/_{00}$ apparaît seulement au 1/3 de la hauteur d'eau et près du fond on observe seulement 33 $^{0}/_{00}$.

Les vitesses de courant de surface varient de 0,42 à 1 m / sec., mais il y a une disproportion énorme entre ces vitesses superficielles et celles près du fond qui sont comprises entre 0, 09 et 0,20 m / sec.

La turbidité des eaux de surface est supérieure à 10 mg / l. jusqu'au-delà du P. 3, puis elle est comprise entre 4 et 6 mg / l. aux postes 4-5 et 6.

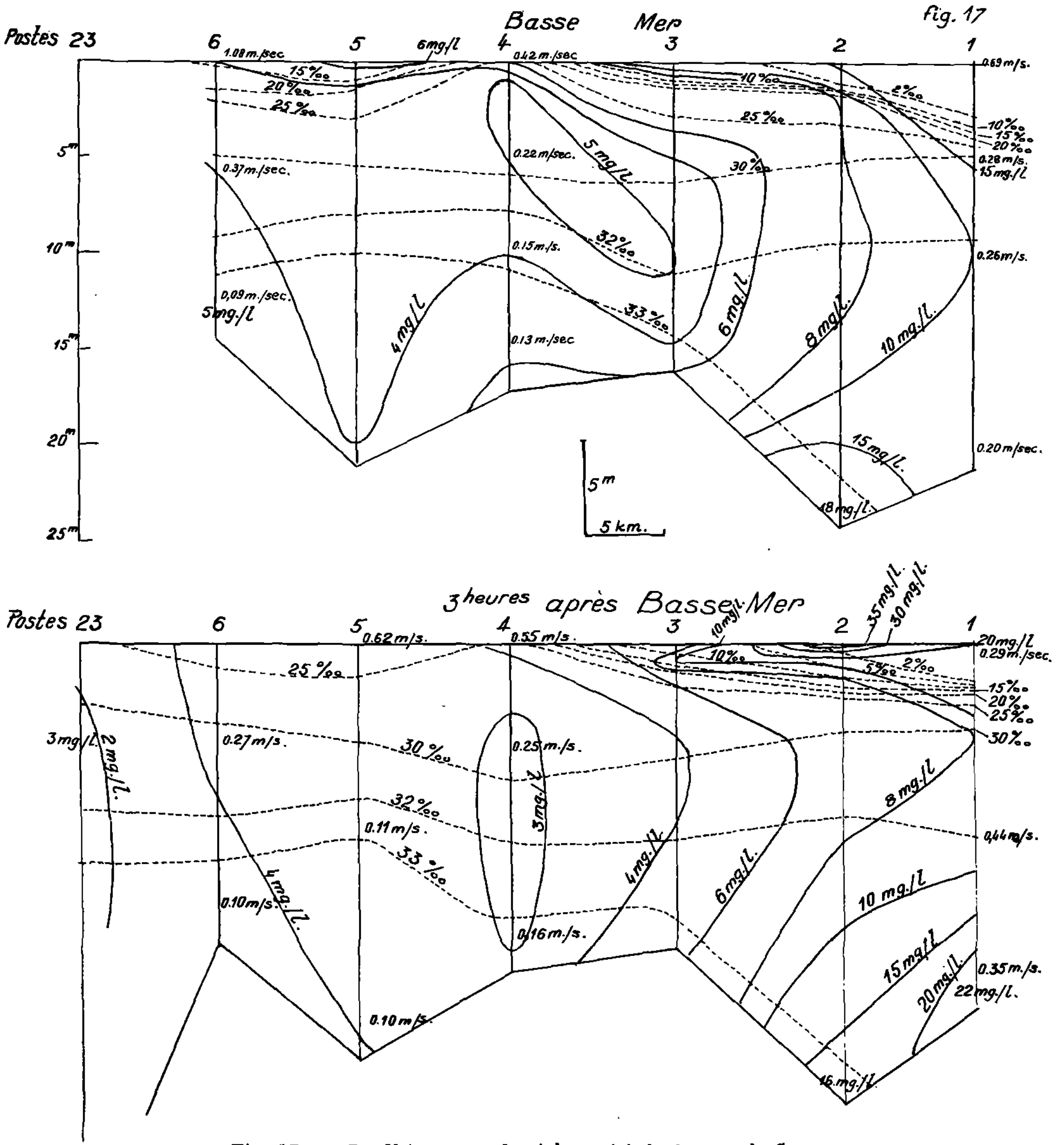

Fig. 17. — Profil transversal axial en période de crue du fleuve.

La turbidité près du fond varie de 6 à 18 mg / l. pour les 3 premiers postes, le maximum étant situé au P. 2. Entre postes 3 et 6, la turbidité près du fond varie de 4 à 6 mg / l.

b) **3 heures après la Basse-Mer** (Période de flot, fig. 17).

La salinité est restée quasi stationnaire près du fond dans la tranche d'eau médiane. Par contre, les eaux très dessalées de la surface sont en régression très nette puisqu'on observe 25 $^0/_{00}$ de salinité du P. 23 au P. 4.

Les vitesses des courants de surface sont comprises entre 0,29 et 0,62 m / sec. ces vitesses s'atténuent vers le fond puisqu'à mi-profondeur elles varient de 0,25 à 2,27 m / sec. sur le plateau continental et 0,44 m / sec. dans le fleuve. Près du fond, les vitesses sont encore plus réduites 0,10 à 0,16 m / sec. sur le plateau continental et 0,35 m / sec. en estuaire ; avec d'aussi faibles courants près du fond, il est impossible d'assurer d'importants transports de sédiments grossiers

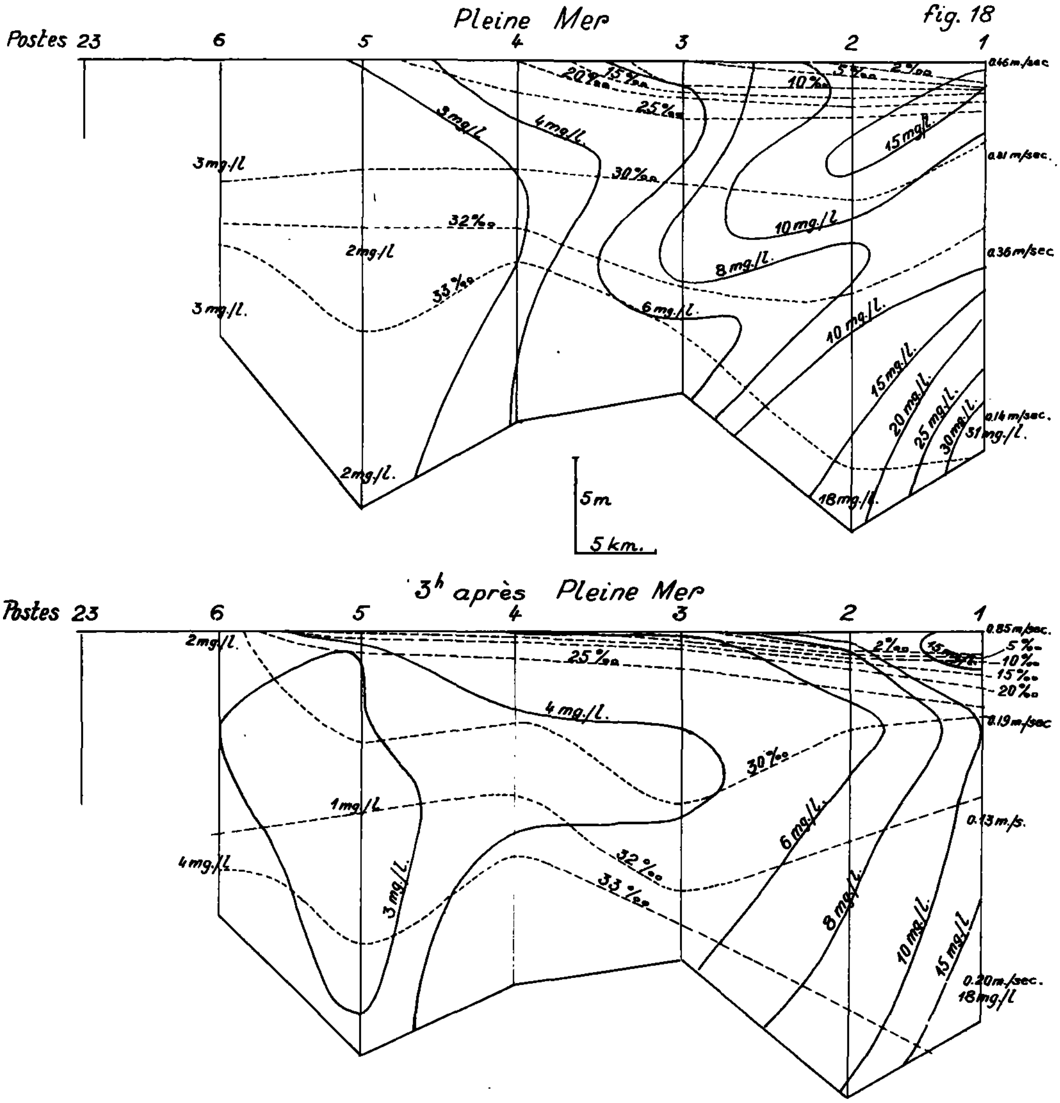

Fig. 18. — **Profil instantané en période de crue du fleuve.**

et même de sédiments fins. Le transport sédimentaire intéresse donc surtout les particules fines qui sont abondantes dans les eaux de sub-surface : 35 mg. à 10 mg / l. entre les postes 1 et 3.

Près du fond, on observe des teneurs de 10 à 20 mg / l. aux P. 1. et P. 2 mais ensuite la turbidité des eaux se réduit vers le large.

c) **Pleine-Mer** (fig. 18).

A la Pleine-mer, la salinité a un peu augmenté depuis les dernières observations ; ceci se traduit par une épaisseur un peu plus grande de la couche d'eau à 33 $^0/_{00}$ et un léger recul des couches d'eau à très faible salinité.

Les mesures de vitesses de courant sont limitées au poste 1 mais elles sont cependant intéressantes avec 0,46 m / sec. en surface et seulement 0,14 m / sec. en profondeur.

Les eaux fortement turbides qui existaient en surface, lors des dernières observations, se sont décantées et l'on observe maintenant 15 mg / l. à des profondeurs comprises entre 1,50 m. et 5 m ; corrélativement, la turbidité a augmenté en profondeur aux postes 1 et 2 où l'on observe maintenant deux maxima de 18 et 31 mg / l.

La turbidité diminue rapidement vers le large, elle est seulement de 2 à 3 mg / l. à partir de la mi-distance entre les postes 4 et 5.

d) **3 heures après la Pleine-Mer** (Période de Jusant, fig. 18).

La salinité a diminué dans la tranche superficielle où les eaux à 15 $^0/_{00}$ s'étendent jusqu'au-delà du P. 5. Par contre, les eaux profondes ne sont pratiquement pas modifiées depuis les précédentes observations.

Les vitesses de courant n'ont été mesurées qu'au poste 1, leur répartition verticale est très caractéristique ; nous avons enregistré 0,85 m / sec. en surface et 0,19 m / sec. à 4 m. de profondeur, ce qui souligne la stratification des eaux.

La turbidité des eaux superficielles a augmenté depuis les dernières observations, les eaux à 6 mg / l. de suspension atteignent maintenant le poste n° 4.

Les teneurs en suspension près du fond ne sont importantes qu'aux postes 1 et 2, elles sont cependant moins élevés qu'à la Pleine-Mer. La faible vitesse des courants près du fond n'autorise pas à supposer une dispersion importante des sédiments en suspension, c'est plutôt une décantation des eaux et un dépôt des sédiments qui doit être envisagé.

EN RÉSUMÉ.

L'examen de ces profils transversaux qui s'étendent jusqu'à la limite nord du plateau continental met en évidence les faits suivants :

1° Il existe une stratification extrêmement serrée des eaux sortant de l'estuaire du fleuve. Le dessalement qui est presque total à l'embouchure s'atténue vers le large mais il est encore extrêmement marqué et abaisse la salinité de 10 $^0/_{00}$ jusqu'à la limite du plateau.

2° les vitesses de courant sont elles-mêmes fortement stratifiées, elles se réduisent au 1/3 ou au 1/4 de leur valeur en surface, à 4 ou 5 m de profondeur. Il en résulte que les courants, à proximité du fond, sont toujours de faible intensité, et qu'il n'existe pas de transport important de sédiment sur le fond. Ce sont les particules transportées en suspension qui constituent l'essentiel de la sédimentation sur le plateau continental.

Premier profil transversal à l'ouest du profil axial, période de crue du fleuve (Postes 11 à 13).

Les mesures qui ont été effectuées en Mars 1962 n'ont permis que la construction de deux profils complets.

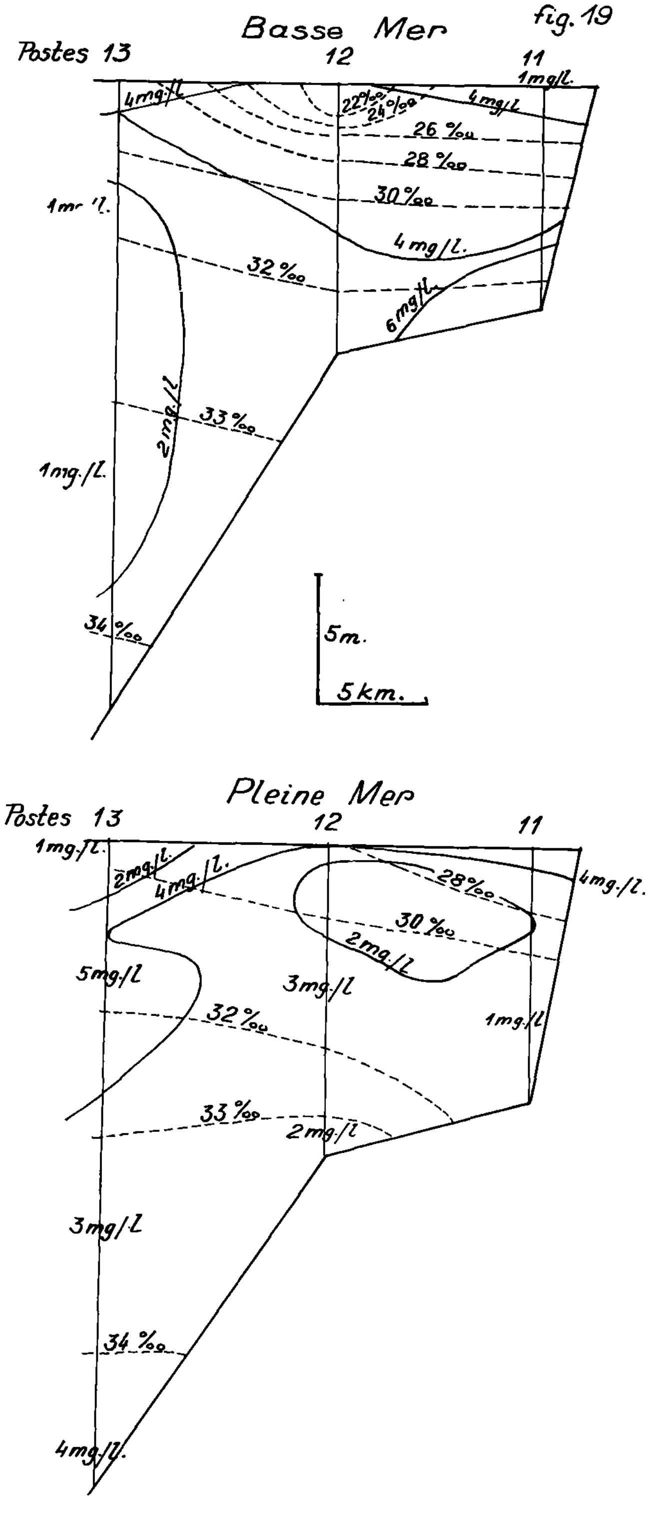

Fig. 19. — Première transversale Ouest, en période de crue du fleuve.

Basse-Mer (fig. 19).

Le dessalement des eaux de surface est beaucoup moins important ici que sur la transversale axiale. En effet, au P. 3 situé en face du P. 11, nous avions observé (fig. 17) moins de 10 $^0/_{00}$ de salinité, tandis qu'au P. 11 la salinité était supérieure à 25 $^0/_{00}$. C'est au P. 12 qu'est observé le dessalement le plus important, mais il est beaucoup moins marqué au P. 4 du profil axial.

La turbidité des eaux superficielles et médianes est faible (4 mg / l.), elle augmente seulement jusqu'à 6 mg / l. près du fond, au P. 11. Sur la verticale du P. 13, la turbidité est faible : elle varie de 1 à 2 mg / l.

Pleine-Mer.

La salinité a nettement augmenté depuis la Basse-Mer ; en particulier dans la tranche d'eau de surface qui est passée d'un minimum de 22 $^0/_{00}$ à près de 28 $^0/_{00}$.

La turbidité a diminué à l'aplomb des postes 11 et 12, mais elle a augmenté au P. 13 de 3 à 5 mg / l. dans les eaux médianes et profondes tandis qu'elle a diminué dans les eaux superficielles qui semblent s'être décantées.

Deuxième profil transversal à l'ouest du profil axial (Postes 15 à 17) **en période de crue.**

Les mesures qui ont été effectuées en mars 1962 n'ont permis que la construction de deux profils complets.

Basse-Mer (fig. 20).

La salinité est plus élevée que dans le premier profil transversal, sauf au P. 13 où elle dépassait 28 $^0/_{00}$. Il en résulte que la stratification des eaux est nettement moins serrée ici que dans le premier profil transversal.

La turbidité est faible dans la tranche d'eau supérieure (2 à 3 mg / l.) mais elle augmente sensiblement au P. 16 où elle atteint 10 mg / l. à proximité du fond.

Pleine-Mer (fig. 20).

La salinité a augmenté, les eaux à 28 $^0/_{00}$ se trouvent cantonnées dans une étroite zone superficielle près du P. 15, mais les eaux à salinité plus élevée n'ont pas beaucoup évolué et leurs isohalines ne subissent que des modifications de détail.

Les sédiments qui étaient en suspension près du fond au cours des mesures faites en Basse-Mer se sont probablement déposés, car cette anomalie a totalement disparu. Dans le profil établi pour la Pleine-Mer la turbidité décroît en allant vers le large, elle est toujours assez faible.

EN RÉSUMÉ.

L'étude des deux transversales Ouest, en période de crue du fleuve montre que l'abaissement de la salinité des eaux superficielles, y est considérablement moins marqué que sur la transversale axiale. En conséquence, la stratification des eaux est signalée par les courbes isohalines peu serrées et une salinité plus élevée des eaux profondes.

La turbidité y est modérée, elle paraît s'accentuer vers le poste n° 13 au moment de la Pleine-Mer, mais pendant la même période elle s'amoindrit en P. 17.

Premier profil transversal à l'est du profil axial (Postes 7 à 9) Période de crue du fleuve.

Les mesures effectuées sur place en mars 1962 ont permis la construction de 3 profils.

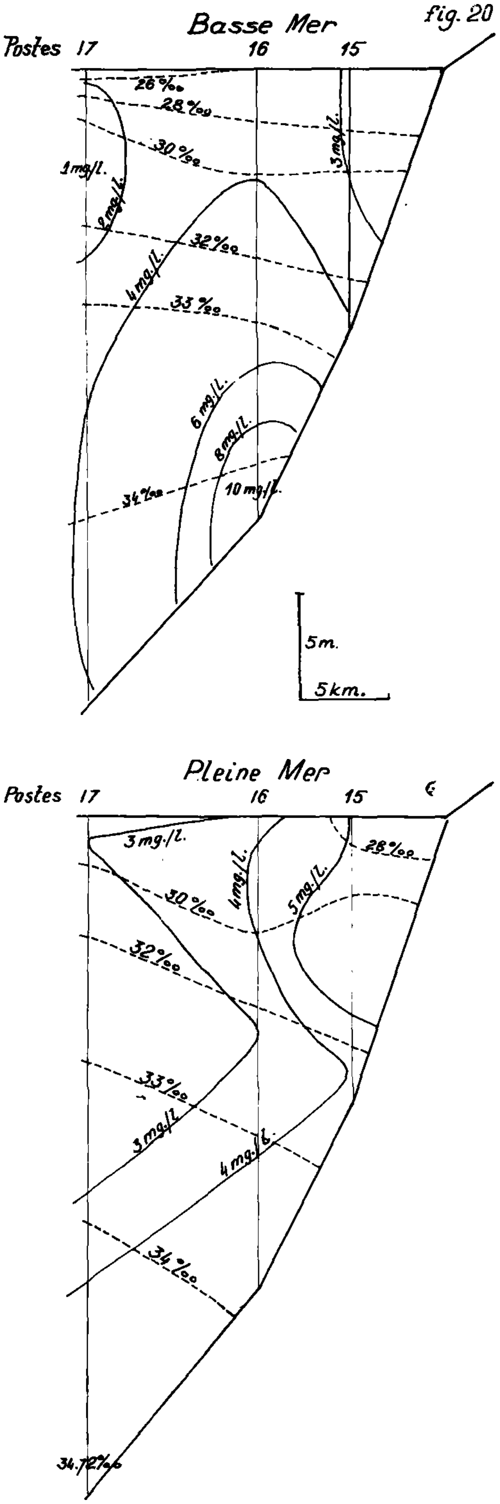

Fig. 20. — Deuxième transversale Ouest, en période de crue du fleuve.

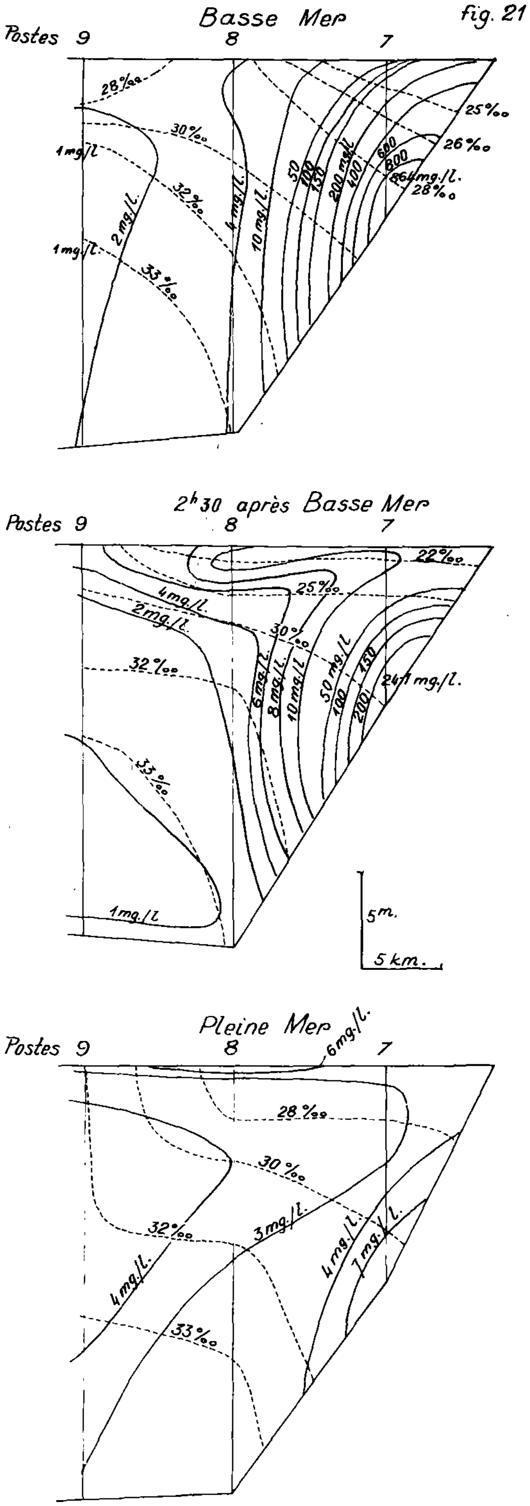

Fig. 21. — Première transversale à l'est du profil axial en période de crue du fleuve.

Basse-Mer (fig. 21).

La comparaison avec les salinités observées sur la transversale axiale (fig. 17) notamment aux postes 3, 4 et 5 par le travers desquels sont situés les postes 7, 8 et 9 montre que les eaux de surface dont le dessalement est très marqué n'atteignent pas le profil Est. En effet, la salinité ne s'abaisse pas au-dessous de 25 $^0/_{00}$ au poste 7.

Par contre la turbidité est extrêmement élevée au Poste 7 presque aussi élevée qu'au poste 2 des profils pour l'étude de l'évacuation des sédiments en période d'étiage. Elle décroît très rapidement vers le large, elle ne s'élève plus qu'à 4 mg / l. au P. 8 et 1 à 2 mg / l. au P. 9.

2 h 30 après la Basse-Mer (fig. 21).

La salinité des eaux de surface s'est abaissée à 32 $^0/_{00}$ mais dans les eaux moyennes et profondes la salinité est pratiquement inchangée.

La turbidité des eaux profondes a considérablement diminué au P. 7, et, corrélativement, elle a également diminué légèrement à l'aplomb. du P. 8 ; cependant les eaux de surface contiennent une plus grande quantité de sédiments en suspension que précédemment et la couche d'isoturbidité de 6 mg / l. atteint presque le P. 9. Il est à noter que les eaux profondes de ce poste sont très faiblement turbides.

Pleine-Mer (fig. 21).

La salinité a notablement augmenté dans la tranche d'eau supérieure puisque l'isohaline de 25 $^0/_{00}$ est remplacée par celle de 28 $^0/_{00}$. Dans la partie médiane et profonde des eaux, la salinité ne subit que de faibles variations.

La turbidité a considérablement évolué, la masse de sédiments en suspension près du fond au P. 7 est pratiquement déposée, il ne subsiste plus que 7 mg / l. en suspension. Vers les P. 8 et P. 9 les teneurs en suspension varient de 3 à 4 mg / l.

EN RÉSUMÉ.

En période de crue importante du fleuve, la salinité est plus fortement abaissée dans le profil transversal 7-8-9 à l'est du profil axial. que dans le profil transversal 11-12-13 situé à l'ouest de ce même profil axial.

La masse de sédiments transportés en suspension à proximité du fond s'étend jusqu'aux abords du profil 7 en période de crue et paraît s'y déposer.

Deuxième profil transversal à l'est du profil axial (Postes n^{os} 19-20-21) Période de crue du fleuve.

Les mesures effectuées sur place en Mars 1962 n'ont permis que la construction de deux profils.

Basse-Mer (fig. 22).

La salinité est notablement moins abaissée qu'à la même période dans le premier profil transversal à l'est du profil axial (Postes n^{os} 7, 8 et 9). On observe cette fois 28 $^0/_{00}$ dans les eaux de surface des postes 19 et 20 tandis qu'il existait moins de 25 $^0/_{00}$ au P. 7.

Les eaux sont stratifiées obliquement (mais avec une très faible déclivité si l'on tient compte de la distorsion qui est considérable).

La turbidité est faible : 4 mg / l. en surface au P. 19, puis dans tout le reste du profil, de la surface au fond, les teneurs en suspension sont comprises entre 1 et 2 mg / l., notamment dans les eaux profondes du P. 19 et dans toute la hauteur d'eau des postes 20 et 21.

Pleine-Mer (fig. 22).

La salinité a légèrement augmenté depuis les observations précédentes.

La turbidité atteint 9 mg / l. dans les eaux profondes du P. 19 mais elle s'abaisse à 3-4 mg / l. dans la tranche d'eau supérieure jusqu'à la surface. Aux postes 20 et 21 la turbidité est comprise entre 1 et 2 mg / l.

EN RÉSUMÉ.

L'étude du deuxième profil transversal à l'est du profil axial montre que le dessalement y est faible en surface, les eaux sont encore stratifiées, mais les courbes isohalines sont largement écartées et leurs positions respectives ne subissent que des modifications de détail au cours d'une marée.

La turbidité est considérablement moins élevée qu'au poste 7 du premier profil transversal est, le P. 19 paraît bien constituer la limite est du dépôt des sédiments fins.

Pour étudier plus efficacement cette question de limite sédimentaire actuelle et pour préciser les données qui viennent d'être acquises nous avons établi un profil comprenant les postes n^{os} 1-2-7 et 19.

Établissement de profils pour la recherche de l'évacuation des sédiments sortant de l'estuaire du fleuve en période de crue.

Basse-Mer (fig. 23).

La salinité est extrêmement faible dans la couche de surface des postes 1 et 2, c'est pratiquement de l'eau douce qui s'écoule et la stratification est extrêmement serrée dans les premiers mètres au-dessous de la surface. Mais cet abaissement important de la salinité n'atteint pas le P. 7 où l'on observe de l'eau à 25 $^0/_{00}$.

La turbidité est assez réduite aux Postes 1 et 2 mais elle est considérable au P. 7 où l'on observe 200 mg / l. à 1 m. de la surface et 864 mg / l. au fond. Cette masse de matériaux en suspension n'atteint pas le P. 19 où la turdidité est seulement de 1 à 3 mg / l.

Pleine-Mer (fig. 23).

La salinité a légèrement augmenté mais la stratification des eaux de surface aux postes 1 et 2 et 7 est quasi inchangée.

La turbidité est élevée aux P. 1 et 2 où les sédiments en suspension gagnent le fond ; au P. 7 la presque-totalité de la masse de sédiments en suspension a été déposée. la turbidité est toujours faible au P. 19.

3 heures après la Pleine-Mer (fig. 23).

La salinité s'est abaissée mais le schéma de répartition des isohalines est resté inchangé.

La teneur en suspension est peu élevée aux postes 1 et 2 à cause de l'entraînement dû au courant de Jusant.

Par contre, la turbidité est à nouveau très élevée au P. 7, à cause des nouveaux apports sédimentaires auxquels s'ajoutent sans doute des éléments fraîchement déposés qui sont remis en suspension.

La turbidité est restée faible au P. 19.

EN RÉSUMÉ.

En période de crue les sédiments en suspension peuvent être transportés en masses importantes sur le plateau continental, ils paraissent se déposer en majeure partie aux abords de la station n^0 7 dans les conditions fluviales et océaniques de nos expériences.

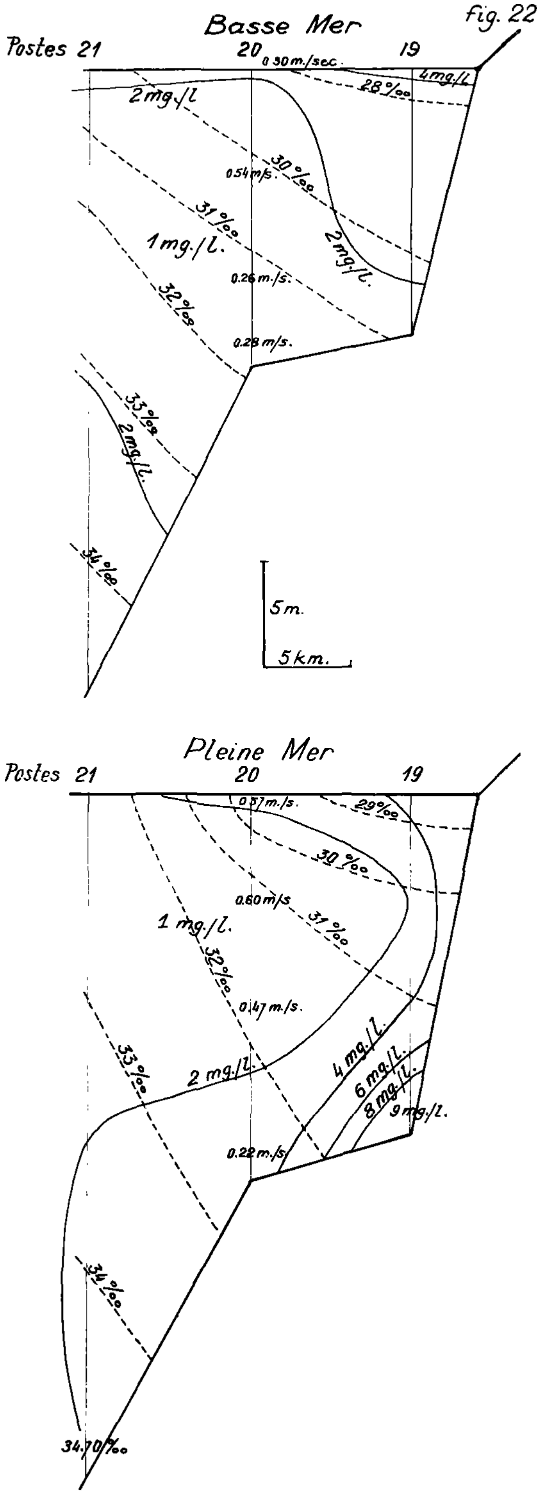

Fig. 22. — Deuxième transversale à l'est du profil axial en période de crue du fleuve.

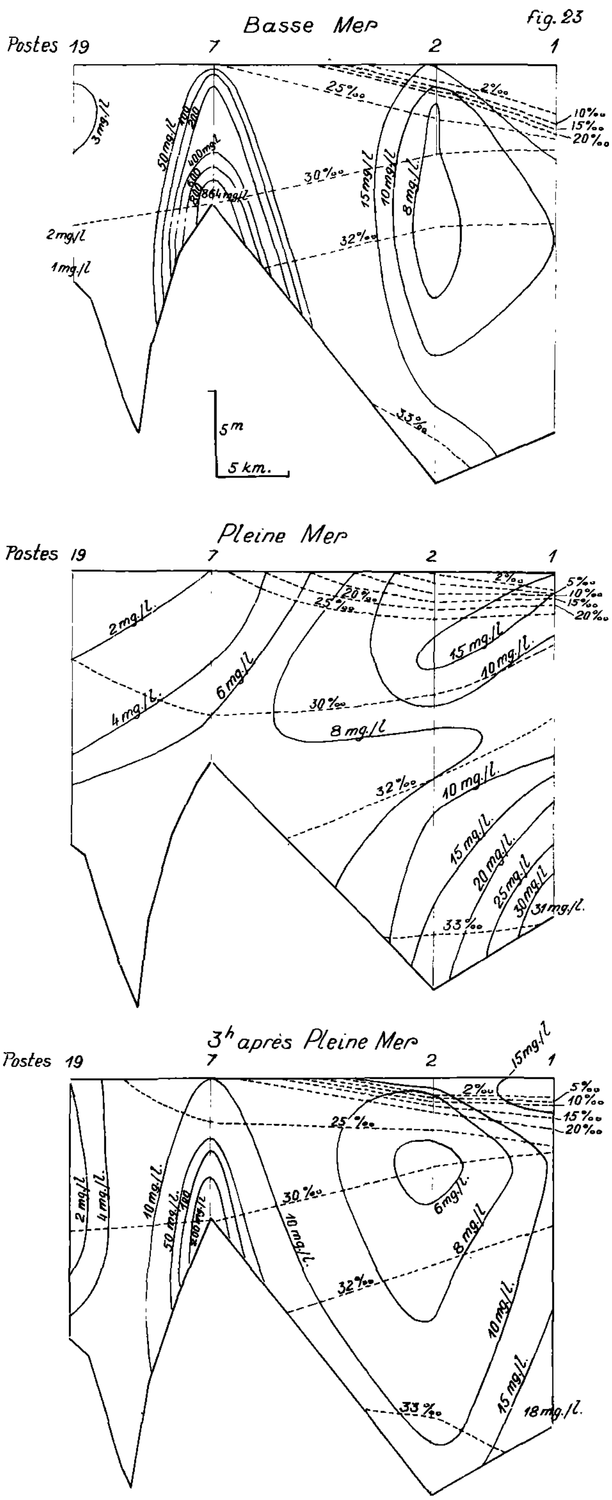

Fig. 23. — Évacuation des sédiments sortant de l'estuaire en période de crue.

TROISIÈME PARTIE

SÉDIMENTOLOGIE

1re ÉTUDE DES SÉDIMENTS FINS TRANSPORTÉS EN SUSPENSION

L'étude du transport sédimentaire en suspension comprendra deux parties :

a) l'étude de la transparence des eaux ;

b) l'étude de la répartition des sédiments fins ($< 0{,}080$ mm) qui peuvent être transportés en suspension dans la tranche d'eau superficielle.

a) *Étude de la transparence des eaux.*

La transparence des eaux a été mesurée par M. A. Crosnier, au disque de Secchi au cours des observations faites pendant la crue fluviale de mars 1962.

Ces mesures sont extrêmement intéressantes à la condition d'en bien définir la portée et d'en préciser la signification.

Des observations de coloration des eaux de surface ont été faites aux stations représentées sur la figure 1 par un triangle noir accompagné de l'indication T1, T2, etc...

A l'aide de ces remarques nous avons représenté la coloration par une série de hachures d'autant plus serrées que la teinte des eaux était plus accusée.

On remarquera immédiatement que les eaux rouge foncé ont été observées aux abords du poste n° 7 où l'étude des profils de turbidité signale justement une concentration importante des sédiments en suspension.

Mais la répartition des couleurs dessinée sur la figure 1 ne représente qu'un schéma approximatif, car les observations ne pouvaient pas être faites au même instant à tous les postes (elles ont eu lieu les 9-10-12-13-16 et 17 mars) et d'autre part, elles ont été faites à des heures différentes à chacun des postes considérés ; elles concernent par conséquent des périodes distinctes de l'évolution océanique et non tel moment caractéristique par rapport à la basse mer ou la pleine mer.

Malgré ces imperfections, dont il est indispensable de tenir compte, cette répartition, même schématique, est fort intéressante car elle matérialise la répartition des eaux renfermant des matières en suspension, sur le plateau continental.

Les mesures de la transparence des eaux au disque de Secchi ont été exécutées au cours des stationnements de l'embarcation aux postes successifs, les résultats de ces mesures sont portés sur la figure 1, où la profondeur d'immersion du disque de Secchi est entouré d'un cercle.

Il faut faire ici la même restriction qu'en ce qui concerne les mesures de coloration, car les mesures de transparence n'ont pas été simultanées sur l'ensemble du plateau continental ; mais, elles ont été répétées au cours de chaque station et c'est pourquoi il existe fréquemment deux indications de profondeur à l'intérieur du cercle : elles représentent le minimum et la maximum d'enfoncement du disque de Secchi pendant la durée du stationnement. Lorsqu'il n'y a qu'une valeur c'est parce que la profondeur d'immersion est restée inchangée.

Les deux résultats des mesures peuvent être voisins mais ils peuvent aussi être très différents ; par exemple au P. 4, l'enfoncement du disque a varié de 5 à 11 m, au poste 5 de 6 à 12 m. au poste 6 de 7 à 13 m.

L'étude des profils instantanés, qui a été developpée précédemment nous a appris que cette augmentation de la transparence était en majeure partie attribuable à la décantation des eaux. En effet, les faibles variations de salinité qui ont été observées dans la plupart des postes, au cours de l'évolution de la marée, ne nous autorise pas à envisager un remplacement complet des eaux turbides par des eaux claires venues du large.

Cette interprétation est confirmée par la faible amplitude des écarts de transparence dans les postes de l'extrême périphérie, par exemple.

Tableau n° 2

Transparences mesurées au disque de Secchi

Poste		Hauteur		différence	
Poste	n° 15	Hauteur	10 m	différence	0 m
—	n° 16	—	9 à 10 m	—	1 m
—	n° 17	—	8 à 10 m	—	2 m
—	n° 23	—	20 m	—	0 m
—	n° 21	—	22 m	—	0 m
—	n° 20	—	20 m	—	0 m

Aux trois derniers postes, les mesures ont été faites constamment en eau claire.

Aux trois premiers postes, les eaux sont turbides, mais la quasi stabilité de la turbidité montre que, ces eaux se décantent lentement et très faiblement au cours des observations. Nous noterons en passant que la sédimentation aux trois premiers postes (n^{os} 15, 16 et 17) est probablement influencée par les apports de la rivière Mahamba dont l'embouchure est voisine, cette question sera examinée à nouveau dans le paragraphe consacré à l'étude des sédiments grossiers.

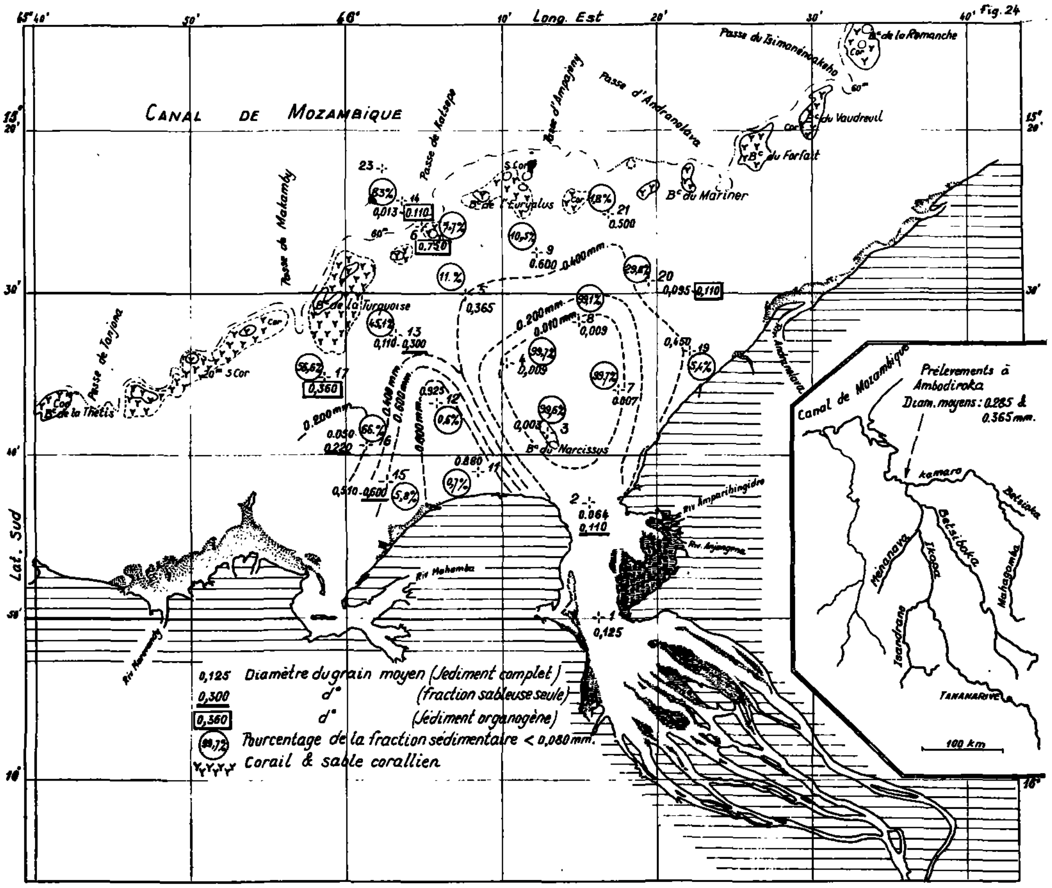

Fig. 24. — Sédimentologie de l'embouchure de la Betsiboka et du Plateau Continental.

b) *Étude de la repartition des sediments fins (diamètres inférieurs à 0,080 mm) qui peuvent être transportés en suspension dans la tranche d'eau superficielle.*

Nous avons choisi arbitrairement le diamètre de 0,080 mm :

1° Parce qu'il correspond à la limite inférieure des grains qui peuvent être tamisés à sec.,

2° A cause de la facilité avec laquelle on isole cette fraction d'un ensemble sédimentaire complexe, par un tamisage sous l'eau,

3° Parce que cette dimension correspond sensiblement au diamètre maximum des particules susceptibles d'un transport de longue durée par un cours d'eau à l'étiage.

Sur la figure 24, nous avons reporté les pourcentages de cette fraction fine dans le dépôt dragué au fond (ces pourcentages sont entourés d'un cercle).

On constate que les sédiments fins se déposent dans une aire assez restreinte englobant les postes n^{os} 3, 4, 7 et 8, et nous noterons que l'étude des profils instantanés a montré que, dans les conditions fluviales et océaniques de nos observations, la sédimentation de la fraction fine était particulièrement active aux abords de la station n° 7.

Mais le dépôt des sédiments fins n'est pas limité à cette zone priviligiée et dans les stations extérieures, c'est-à-dire voisines de la bordure nord du plateau continental les proportions suivantes ont été décelées :

TABLEAU n° 3

POURCENTAGES DES SÉDIMENTS FINS DANS LES STATIONS EXTERNES

	% de sédiments < 0,080 mm
Poste n° 17	56,6 %
Poste n° 13	45,1 %
Poste n° 5	11,0 %
Poste n° 9	10,5 %
Poste n° 21	1,8 %
Poste n° 6	1,7 %
Poste n° 14	83,0 %

Nous ne prenons pas en considération le poste n° 14 dans la suite de cet exposé ; il est en effet situé dans les conditions très différentes des 6 premiers. Son emplacement dans une dépression allongée entre deux abrupts du plateau continental n'autorise pas une assimilation complète aux autres postes situés sur le plateau continental.

Mais ce qu'il est important de retenir de la lecture de ce tableau, c'est la proportion, parfois très importante, de sédiments fins apportés par les eaux de surface, ainsi que les profils instantanés l'ont montré, et déposés sur le fond jusqu'au bord du plateau continental.

Pour terminer ce paragraphe consacré à l'étude des sédiments transportés en suspension, nous allons rechercher l'influence de ce facteur sur le développement des récifs coralliens.

Influence de la sédimentation fine sur le développement des récifs coralliens.

Les auteurs qui ont étudié les récifs coralliens de la côte ouest de Madagascar, en particulier A. Guilcher (1954-1958) et R. Battistini (1964) ont signalé que la bordure externe du plateau continental était constituée par de très nombreuses protubérances coralliennes ; elles sont indiquées sur les cartes marines du Service Hydrographique et désignées sous le vocable général de « bancs ». Nous en avons mentionné quelques-uns dans la description morphologique de la première partie de ce travail, elles sont constamment immergées sous 6 à 10 mètres d'eau R. Battistini (*loc. cit.* p. 448) a signalé la présence de bourrelets coralliens sous-marins, dans le sud de Madagascar et il a parfois constaté, avec quelque surprise, l'indigence de la vie corallienne dans un certain nombre d'endroits.

Tenant compte de la basse latitude (25° sud) des lieux d'observation et de la découverte par M. Ménaché (1961) d'un phénomène de remontée d'eau profonde au sud du Canal de Mozambique, R. Battistini s'est demandé si le ralentissement de la vie des coraux ne pouvait pas s'expliquer par le refroidissement des eaux.

Dans la région que nous avons étudiée, les bancs coralliens ont une vie très ralentie ; un dragage au poste n° 6 a rapporté une quantité importante de débris de corail, mais presque exclusivement du corail mort.

Pour examiner ce problème en détail, nous avons recherché une comparaison avec les conditions océaniques des récifs coralliens de Mayotte où la vie est intense. Les termes de comparaison sont réunis dans le tableau suivant.

Comparaison des conditions océaniques à Mayotte et en Bordure du Plateau Continental au large de l'embouchure de la Betsiboka.

TABLEAU n° 4

Lagon de l'Ile Mayotte (Comores)				Plateau Continental Malgache			
Profondeur m	Salinité °/oo	Température °C	Turbidité mg/l	Profondeur m	Salinité °/oo	Température °C	Turbidité mg/l
Ouest des Iles Ajangua (Lagon Est)				POSTE N° 6 (8 h 10 le 17-3-62)			
0	35,24	27°00	0,3	0	14,36	28°18	4,4
10	35,03	25°01	0,6	5	30,95	28°97	3,6
20	35,04	24°88	0,4	13	33,68	28°37	5,3
30	35,01	24°78	0,7				
40	35,03	24°69	0,8				
Lagon Sud				POSTE N° 6 (10 h 40 à 11 h)			
0	35,16	25°00	0,4	0	20,25	29°20	5,7
5	35,07	24°98	0,4	5	30,77	29°14	5,0
10	35,04	24°40	0,0	14	33,68	28°45	4,1
20	35,06	23°99	0,5				
30	35,04	23°91	0,0				
Lagon S.-W.				POSTE N° 9 (11 h 20 le 10-3-62)			
0	35,20	25°40	0,9	0	27,07	30°31	4,5
5	35,07	25°52	1,0	1	27,09	29°51	2,9
15	34,78	24°15	1,1	5	32,25	28°75	0,8
25	35,04	23°96	0,8	10	33,08	28°45	0,9
35	35,06	23°74	1,5	19	33,77	28°21	1,6
Lagon Ouest				POSTE N° 13 (15 h 15 le 13-3-62)			
0	35,32	26°10	3,1	0	29,63	29°51	3,3
10	35,04	24°87	1,6	1	29,63	29°48	4,4
20	35,06	24°68	0,8	5	31,94	28°96	0,9
30	35,06	24°08	0,7	15	33,51	28°07	0,7
40	35,05	23°87	0,9	23	34,14	27°52	3,3
				POSTE N° 17 (13 h 55 le 13-3-62)			
				0	25,15	29°34	2,8
				1	27,27	29°18	1,0
				5	31,55	28°79	0,8
				15	33,51	27°99	4,4
				29	34,45	26°99	4,5

La comparaison des deux parties de ce tableau met en évidence les faits suivants :

1° Les températures des eaux du plateau continental sont plus élevées que dans le lagon de Mayotte. Lors des mesures effectuées en juillet 1961 (Période d'étiage du fleuve) les températures des eaux du plateau continental malgache étaient moins élevées, mais cependant elles ne descendaient guère au-dessous de 25° C c'est-à-dire qu'elles étaient au moins égales à celles du lagon de Mayotte.

2° En période de crue du fleuve la salinité des eaux de surface sur le plateau continental malgache, est beaucoup trop basse pour être favorable à la vie corallienne.

3° Dans le lagon de Mayotte, sauf à proximité du petit port de Dzaoudzi où les eaux sont polluées, la turbidité est presque toujours inférieure à 1,5 mg / l. Exceptionnellement il a été observé 3,1 mg / l. dans les eaux de surface du lagon ouest.

Sur le bord externe du plateau continental malgache la turdibité des eaux atteint fréquemment 3 mg / l. et dépasse parfois 5 mg / l. l'abondance des particules en suspension dans l'eau s'oppose certainement à la prolifération d'organismes constructeurs de récifs. D'après M. M. Sachet (1962) on sait que les conditions satisfaisantes de développement des coraux sont les suivants :

a) la température ne doit jamais descendre au-dessous de 20° C la température optima se situant entre 25° et 30° C ;

b) l'eau doit être suffisamment salée, l'optimum étant 36 ‰.

c) l'eau doit être très limpide. Dans une île corallienne la croissance des coraux est toujours amoindrie là où la circulation de l'eau est ralentie et la sédimentation importante.

On peut donc conclure que l'abaissement de la salinité et la turdibité relativement élevée des eaux, du bord externe du plateau continental malgache, ne permettent pas une vie corallienne intense.

2° ÉTUDE DES SEDIMENTS GROSSIERS

1° Étude des courants.

Avant d'étudier la granulométrie des sédiments et leur répartition sur le plateau continental, il nous paraît important d'étudier les conditions de répartition de sédiments par les courants.

Période d'étiage du fleuve.

a) *courants de Jusant* (fig. n° 25).

A la sortie de l'estuaire de la Betsiboka, les courants de Jusant mesurés aux postes 1 et 2, sont rapides en surface et au fond, il faut toutefois remarquer qu'au poste n° 1, la mesure a été faite à 4 m du fond et en conséquence, la vitesse à proximité du fond doit être réduite d'environ 2/3.

Sur le plateau continental, les vitesses de courants de surface sont très faibles, dirigées dans des directions voisines du Nord.

Les vitesses des courants mesurées près du fond sont faibles, surtout si nous tenons compte de la hauteur au-dessus du fond des mesures faites au moulinet.

Les vecteurs des courants de fond et de surface portent parfois, à la suite de la vitesse de courant, mesurée pendant la période considérée, l'indication d'une vitesse maximale qui a été mesurée soit en jusant, soit en flot, mais avec un certain décalage horaire par rapport à la période étudiée.

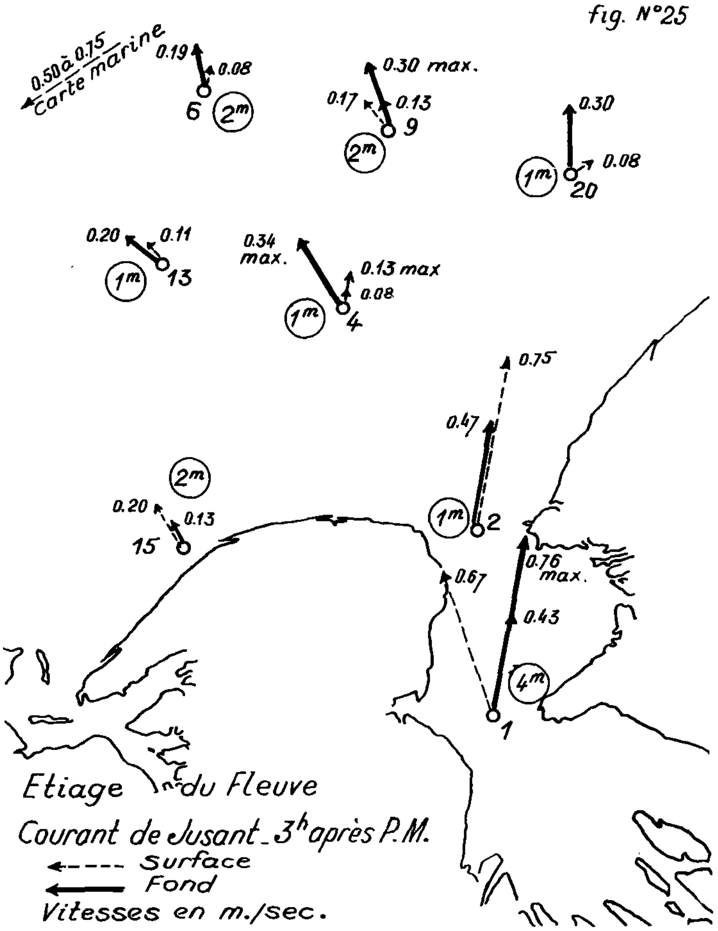

Fig. 25. — Les cotes entourées d'un cercle indiquent la hauteur du moulinet au-dessus du fond pendant la mesure de la vitesse du courant.

b) *Courants de flot* (voir fig. 26).

Les courants de surface sont moins rapides qu'en Jusant aux postes 1 et 2, ce qui est conforme à ce qu'on sait de l'équilibre estuarien.

Sur le plateau continental, les vitesses des courants de surface sont un peu plus élevées que pendant la période de jusant.

Les courants de flot sont très rapides à l'entrée de l'estuaire. Sur le plateau continental, compte tenu des hauteurs auxquelles ont été faites les mesures au moulinet au-dessus du fond, les vitesses du courant de flot sont sensiblement équivalentes à celles du courant de Jusant.

Ces vitesses atteignent au maximum 0,34 m / sec., à 1 m. au-dessus du fond ce qui correspond à une vitesse qui est certainement inférieure à 0,15 m / sec. à proximité du fond dans de telles conditions l'abaque de Hjulström (L. Berthois, *loc. cit.* 1965, p. 3) montre qu'un sédiment composé de grains de 0,5 mm. peut être transporté par ce courant, mais il ne peut pas être érodé dans un dépôt préexistant.

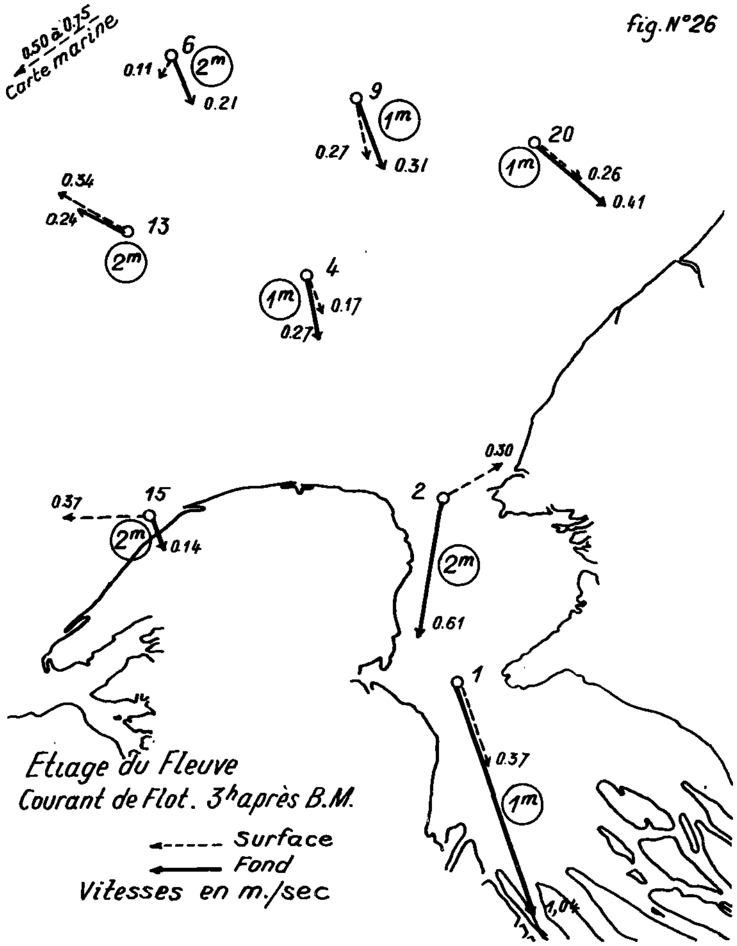

Fig. 26. — Les cotes entourées d'un cercle indiquent la hauteur du moulinet au-dessus du fond pendant la mesure de la vitesse du courant.

Période de crue du fleuve.

a) *Courants de Jusant* (fig. 27).

Les courants de surface sont extrêmement rapides aux postes 1 et 2 situés à l'embouchure de la Betsiboka.

Sur le plateau continental, les courants de surface sont moins rapides mais ils atteignent encore des vitesses relativement considérables ; ils sont tous dirigés vers le secteur N.O. à N.N.O. Ces directions et les vitesses élevées dont ils sont animés justifient pleinement le dessalement important de l'eau de mer que nous avons observé jusqu'à la crête du talus du plateau continental (voir tableau n° 4, poste 6 à 8 h 10) où la salinité est abaissée à 14,36 ‰.

Les courants de flot ont des vitesses extrêmement réduites et cependant, aux postes n^os^ 4 et 12 les mesures ont été faites à 2 mètres du fond et au poste n° 6 à 2,50 m et 4 m du fond, ce qui signifie qu'à proximité du fond les eaux sont pratiquement immobiles. Ceci est confirmé par le très faible abaissement de la salinité dans les eaux profondes (voir tableau n° 4, poste n° 6) ainsi pour un abaissement de salinité à 14,36 ‰ en surface, la salinité à 13 m est de 33,68 ‰.

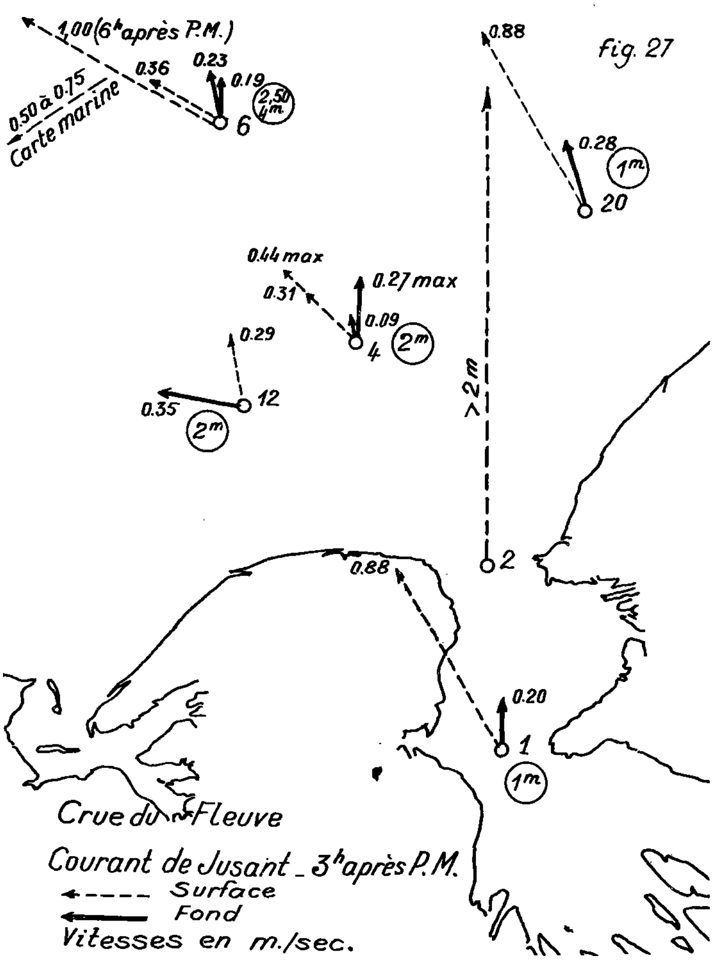

Fig. 27. — Les cotes entourées d'un cercle indiquent la hauteur du moulinet au-dessus du fond pendant la mesure de la vitesse du courant.

b) *Courants de flot* (voir fig. 28).

A la sortie de l'estuaire, les courants de surface dirigés vers le Nord sont très rapides (2,37 m / sec. au P. 2), sur le plateau continental les courants de surface sont fortement atténués mais surtout, ils ont des directions désordonnées qu'on peut attribuer à la poussée vers le large des eaux continentales. La persistance de la direction ouest au poste 4 et d'une direction N.-O. au poste n° 6, 3 heures après la Basse-Mer, est le facteur dominant qui justifie du dessalement des eaux de surface sur le plateau continental au large de l'embouchure de la Betsiboka.

Les vitesses des courants mesurés à 1 m ; 2 m et 4 m au-dessus du fond sont extrêmement réduites. En rapprochant ces observations de celles concernant la salinité au fond qui accuse des variations extrêmement faibles en période de flot, comme en période de Jusant, nous pouvons en conclure, que les eaux profondes sont animées de mouvements très lents ou même pratiquement immobiles sur le plateau continental.

Ces observations conjuguées sur la stabilité de la salinité au fond, et sur la quasi-immobilité des eaux profondes sur le plateau continental permettent d'établir une liaison entre l'équilibre estuarien et la sédimentation.

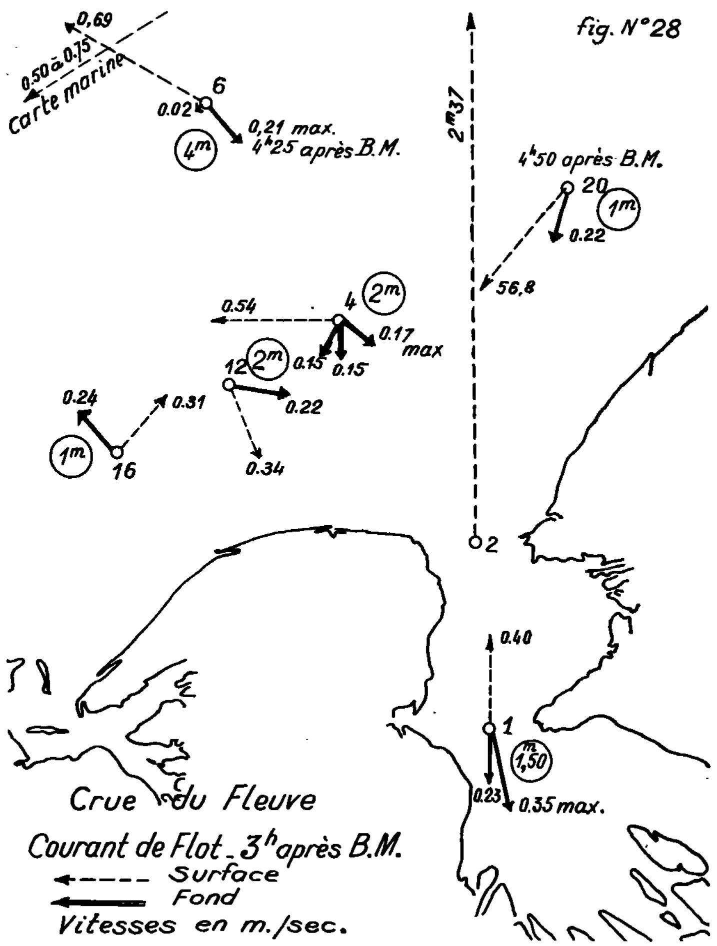

Fig. 28. — Les cotes entourées d'un cercle indiquent la hauteur du moulinet au-dessus du fond pendant la mesure de la vitesse du courant.

En période d'étiage les sédiments grossiers qui peuvent arriver jusqu'à l'embouchure du fleuve par roulement ou saltation sur le fond ne peuvent pas parvenir jusqu'au plateau continental où il n'existe pas de courant de vitesse suffisante pour les transporter en masse importante sur le fond (voir les figures 4, 5 et 6).

Les sédiments transportés en suspension se déposent dans la zone estuarienne d'équilibre qui est, à ce moment, en amont de l'embouchure.

En période de crue du fleuve.

L'équilibre fluvio-océanique profond est reporté sur le plateau continental mais les vitesses du courant au fond sont insuffisantes pour y apporter les sédiments grossiers (voir les fig. 17, 18, 27 et 28).

Par contre, les courants de surface qui sont très rapides transportent des quantités importantes de sédiments en suspension, ils se déposent en majeure partie aux abords des stations 3, 4, 7 et 8 et une fraction non négligeable atteint le bord externe du talus continental.

Ainsi, l'apport de la Betsiboka dans la sédimentation actuelle sur le plateau continental est essentiellement contitué par des sédiments fins apportés, en suspension par les eaux superficielles. Les sédiments qui peuvent être déplacés par des courants dont la vitesse est le plus souvent inférieure à 0,15 m. seconde ont des diamètres atteignant au maximum 0, 500 mm. d'après Hjulström.

2e Granulométrie des sédiments dragués.

a) *travaux antérieurs.*

Dans un travail fort documenté L.R. Lafond (1957) a distingué les variétés sableuses suivantes dans la région occupée par l'estuaire de la Betsiboka. Ses observations sont résumées ci-dessous :

1o *Sables de plage* (autour de Majunga) à granulométrie assez grossière, l'arrière-plage est très souvent formée de dunes, cependant ni la granulométrie ni la morphoscopie ne permettent de déceler une évolution poussée du sédiment sous des actions éoliennes.

2o *Sables continentaux* ce sont des sables éoliens, formés de grains de quartz fins recouverts d'une mince pellicule d'oxyde de fer. Ils recouvrent les formations anciennes dans l'intérieur du pays.

3e *Sables fluviaux de la Betsiboka.* Ils sont essentiellement quartzeux, les grains sont anguleux, leur granulométrie varie suivant les conditions locales de dépôt.

TABLEAU no 5

Caractéristiques granulométriques des sables étudiés par L.R. Lafond (*loc. cit.* d'après la fig. 3, p. 428).

	Diamètres en mm.	
	maximum	moyen
M. 503. — Ambato. — Boeni. — Confluent de la Betsiboka et du Kamoro (en étiage)	2,00	0,500
M. 115. — Sable de dune. — Ambovory	1,20	0,600
M. 516. — Haut fond sableux au voisinage de l'île verte	5,00	0,750
M. 114. — Sable de la plage d'Ambovory	3,00	1,250

b) *Granulométrie des sédiments récoltés aux postes d'observation.*

Observation : Les remarques qui ont été faites précédemment sur les apports de sédiments fins sur le plateau continental nous ont conduit, dans certains cas, à calculer un diamètre moyen de la fraction sableuse associée, dans le dépôt, à la fraction fine apportée en suspension.

Les modes de transport étant différents pour les deux fractions sédimentaires, il importait donc de les séparer granulométriquement comme elles l'avaient été hydrauliquement.

Dans le tableau suivant, la composition minéralogique a été mentionnée lorsqu'elle pouvait être déterminée par observation directe à la loupe binoculaire, c'est-à-dire jusqu'au diamètre minimum de 0,360 mm. La composition minéralogique des sédiments fins a été étudiée par analyse thermique différentielle et diffraction X, elle sera décrite ultérieurement.

TABLEAU n° 6

GRANULOMÉTRIE ET COMPOSITION MINÉRALOGIQUE

N° du Poste	DIAMÈTRE EN MM			POURCENTAGES				
	Maximum	Diamètres moyens		Quartz	feldspath	Mica	Débris organogènes	Observations sur la composition de la fraction sableuse
		Sédiment complet	fraction sableuse seule					
1	0,510	0,125		18,7	3,2	78,1		
2	0,510	0,064	0,110					non déterminé
3	0,003	0,003						non déterminé
4		0,009						non déterminé
5	>2,18	0,365		99,5	0,5			
6	>10,0	0,750					100,0	Sable corallien et coquillier.
7		0,007						non déterminé
8		0,009						non déterminé
9	>2,18	0,600		98,0			2,0	
11	>3,0	0,880		99,0			1,0	
12	>3,0	0,925		99,0			1,0	
13	>2,18	0,110	0,300	75,0			25,0	foraminifères et débris coquilliers.
14	>2,18	0,013	0,110					-d°-
15	>3,0	0,510	0,600	95,0			5,0	
16	>2,18	0,050	0,220	95,0			5,0	débris coralliens
17	>2,18	0,070	0,360	25,0			75,0	foraminifères
19	>2,18	0,450		98,0			2,0	
20	>2,18	0,095	0,110	80,0			20,0	foraminifères
21	>2,18	0,500		99,0			1,0	

c) *morphoscopie du quartz.*

L'examen morphoscopique du quartz a été fait à la loupe binoculaire en utilisant la méthode de A. Cailleux (1943) et A. Cailleux et J. Tricart (1949) nous avons examiné séparément chaque résidu de tamisage jusqu'à la dimension de 0,360 mm.

Les résultats sont exposés dans le tableau n° 7.

TABLEAU n° 7

MORPHOSCOPIE DU QUARTZ EXPRIMÉE EN POURCENTAGES

symboles
N.U. = non usé
E.L. = émoussé luisant
R.L. = rond luisant
R.M. = rond mat
E.M. = émoussé mat

N° du Poste	Symboles	DIAMÈTRES EN MM					
		> 2,18	2,18 1,48	1,48 1,09	1,09 0,75	0,75 0,51	0,51 0,36
1	N.U.						61,5
	E.L.						38,5
5	N.U.	29,1			2,6	16,0	
	E.L.	67,3	98,6	100	97,4	84,0	97,1
	R.L.	3,6	1,4				2,9
9	N.U.	3,0	50,0	30,0	30,0	40,0	55,0
	E.L.	96,0	30,0	50,0	50,0	50,0	40,0
	R.L.	1,0	10,0	10,0	15,0	5,0	4,0
	R.M.	0	10,0	10,0	5,0	5,0	1,0
11	N.L.			3,6	2,1		
	E.L.	100,0	100,0	96,4	97,9	100,0	100,0
12	E.L.	99,0	100,0	96,4	98,1	96,9	98,0
	R.L.	1,0		3,6	1,9	3,1	2,0
13	E.L.		64,0	19,7	47,0	88,5	88,5
	R.M.		36,0	80,3	53,0	11,5	11,5
15	N.U.			10,0	10,0	15,0	25,0
	E.L.	100,0	100,0	85,0	85,0	80,0	70,0
	R.L.			5,0	5,0	5,0	5,0
16	E.L.	corail	corail	corail	98,6	95,2	94,2
	R.L.				1,4	4,8	5,8
19	E.L.		88,9	93,2	95,8	99,3	100,0
	R.M.		11,1	6,8	4,2	0,7	
21	E.L.			5,8	42,0	92,8	97,3
	E.M.	100,0	98,3	94,2	57,0	7,2	
	R.M.		1,7		1,0		2,7

Pour compléter ce tableau dans lequel sont réunis les principaux éléments d'observation concernant le quartz, nous exposerons les résultats des observations faites sur les organismes et débris organogènes du plateau continental.

Poste 6. — (Profondeur 20 m). — Les débris coralliens sont fréquemment roulés.

Poste 9. — (Profondeur 18 m). — Malgré l'usure accentuée du quartz, il existe des débris coquilliers anguleux, des foraminifères à coquille mince portant des ornementations sans trace d'usure, de très petits lamellibranches : Mye striée, bucarde épineuse, sans aucune trace d'usure.

Poste 13. — (Profondeur 23 m.). — Les foraminifères, qui sont abondants possèdent des coquilles gris très foncé portant de fines ornementations sans trace d'usure.

Poste 17. — (Profondeur 30 m.). — Les foraminifères sont abondants quelques-uns portent des traces d'usure.

Poste 20. — (Profondeur 15 m.). — Le sédiment est presque exclusivement composé de foraminifères discoïdes et de débris anguleux avec de très petits lamellibranches : tapes et cardiites sans aucune trace d'usure, tant sur les côtes que sur les ornementations de la charnière.

RÉSUMÉ ET CONCLUSION.

Nous avons montré, dans le tableau n° 6, qu'il existe sur le plateau continental, des sédiments quartzeux grossiers dont la répartition est représentée fig. 24.

Ces sables composés de grains quartzeux façonnés par le transport dans l'eau ont parfois conservé leur faciès éolien ; ils alternent ou coexistent dans les gisements avec des organismes fragiles, le plus souvent dénués de traces d'usure ou ne portant que de faibles stigmates de transport.

Nous avons antérieurement montré que, même en période de crue fluviale importante, les eaux marines recouvrant le plateau continental sont quasi immobiles ou animées de courants très faibles incapables de déplacer les sédiments grossiers qui gisent au fond.

La répartition des sédiments fins (fig. 24) au large de l'embouchure de l'estuaire de la Betsiboka montre que ce fleuve dépose, principalement en période de crue, des sédiments apportés en suspension qui recouvrent les dépôts grossiers mis en place à une époque antérieure.

3° **Minéralogie des sédiments fins.**

Les sédiments dragués contenant une fraction fine importante ont été étudiés par l'analyse thermique différentielle et par diffraction aux rayons X (raie Kα du Cobalt).

a) *analyses thermiques différentielles.*

Les analyses ont été faites sur une fraction brute de l'échantillon, sans aucune concentration des parties les plus fines. Les courbes des analyses thermiques différentielles sont groupées sur la fig. 29.

Commentaires.

L.R. Lafond (*loc. cit.* p. 428) a signalé que les sédiments rouges renferment du quartz, des minéraux argileux (essentiellement de la Kaolinite) et de l'oxyde de fer colloïdal. D'après cet auteur, la teneur en $Fe^2 O^3$ atteint en moyenne 5 % du poids sec de la partie fine du sédiment.

L'examen des courbes portant les n^{os} P. 2, 3, 4, 5, 8, et 7 de la fig. 29 confirme pleinement cette composition minéralogique.

fig. 29

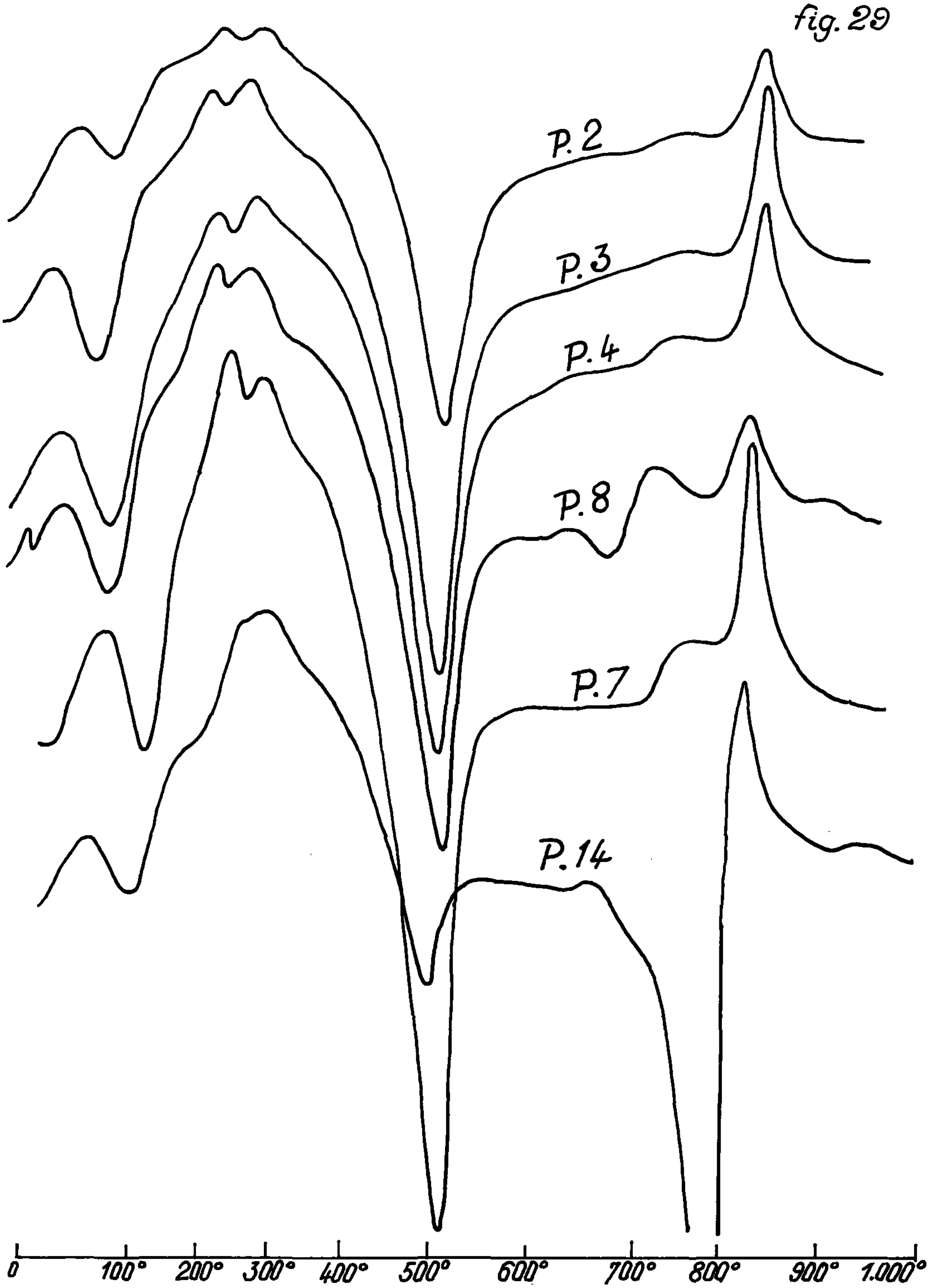

Fig. 29. — Courbes d'analyses thermiques différentielles des échantillons bruts, les courbes portent les numéros des postes où ils ont été dragués.

Dans les courbes obtenues par analyse thermique différentielle, les accidents endothermiques et exothermiques sont signalés par des crochets dont le développement n'est pas rigoureusement proportionnel au pourcentage du minéral responsable de leur production ; mais, il est certain que l'abondance ou la rareté d'un minéral influe considérablement sur l'importance de l'accident thermique qu'il provoque. Ce fait a été mis en évidence au cours des recherches faites que J. Orcel (1924) sur les mélanges artificiels de montmorillonite et de kaolinite (J. Orcel et S. Caillère 1933).

La courbe du sédiment du poste 2, correspondant à un lieu de dépôt des sédiments fins en période d'étiage, montre des crochets très nets mais assez peu développés, et on peut en inférer que le pourcentage d'argile est relativement peu élevé parce que les apports sédimentaires fins ne sont pas abondants en période d'étiage du fleuve.

La comparaison des courbes des sédiments dragués aux postes 3, 4, 7 et 8 montre que les trois premières courbes présentent des crochets endothermiques et exothermiques qui sont pratiquement d'importance semblable. On peut en déduire que les sédiments déposés dans ces trois stations au cours des crues du fleuve possèdent des teneurs en argile à peu près identiques.

Le sédiment récolté au poste 7, se différencie nettement des trois premiers : les crochets endothermique et exothermique de la Kaolinite (520° et 850°) y sont beaucoup plus développés, nous pouvons donc en conclure que les sédiments fins se déposent de préférence aux abords du poste 7.

Nous rappellerons que l'étude dynamique de la sédimentation en période de crue fluviale nous a justement conduit à cette même conclusion.

La courbe des sédiments du poste 14 diffère notablement des 5 courbes précédentes, elle présente en effet, entre 700 et 850°, un grand crochet endothermique dû à la présence d'aragonite.

L'énorme développement de ce crochet montre que la sédimentation n'est plus en majorité argileuse, car le crochet de la kaolinite est peu marqué, mais qu'elle est au contraire à dominance organogène.

Les conclusions de l'étude dynamique sont donc à nouveau confirmées puisque l'examen des profils instantanés (fig. 17 et 18) nous avait conduit à conclure qu'il n'y avait qu'une faible fraction, des apports fluviaux en suspension, qui étaient suceptibles d'atteindre les postes 6 et 23 entre lesquels se trouve le point de dragage n° 14.

b) *analyses par diffraction aux rayons X.*

De même que pour les analyses thermiques différentielles, les analyses aux rayons X ont été exécutées sur des échantillons bruts.

Les résultats sont groupés dans le tableau n° 8.

TABLEAU n° 8

ANALYSE PAR DIFFRACTION AUX RAYONS X

Symboles	5	très abondant
	4	abondant
	3	peu abondant
	2	rare
	1	très rare

Nº du Poste	quartz	kaolinite	palygorskite	goethite	feldspath	chamosite (type kaolinique)	Cordiérite	Illite	chlorite	aragonite	pyrophyllite
2	3	3		2				2	1		
3	3	5			1			2	1		
4	2	5		2		1	1	2			
7	2	5		2		1		3			
8	2	4		2				2	2		
14	1	1				1				3	1
16	1	3		1				1	1		1
20	3		3								1

Commentaires.

L'examen de ce tableau confirme les analyses thermiques différentielles dont les résultats ont été discutés précédemment et il complète les déterminations minérologiques. En outre, ces analyses apportent deux renseignements complémentaires importants :

Sédiment du poste nº 16.

On y observe une diminution très nette de la teneur en Kaolinite confirmant la moindre abondance des apports en suspension qui avait déjà été mise en évidence par l'étude dynamique de la sédimentation.

Sédiment du poste nº 20.

L'étude de la répartition dynamique des sédiments sur le plateau continental, nous avait conduit à penser que les sédiments apportés actuellement pendant les crues du fleuve Betsiboka n'atteignaient pas le poste nº 20. L'étude aux rayons X confirme cette interprétation puisque, dans la fraction fine, la kaolinite, qui existe dans les dépôts actuels, manque totalement ici où elle est remplacée par une Palygorskite.

Sédiments des postes nºs 14, 16 et 20.

Dans ces trois sédiments, où la Kaolinite devient rare, ou même fait totalement défaut, apparaissent des traces de Pyrophyllite. Ce silicate d'alumine fait probablement partie du dépôt ancien, au même titre que la palygorskite du sédiment nº 20.

4º **Étude chimique des eaux.**

L'étude chimique entreprise a principalement porté, à l'origine, sur les eaux fluviales douces ou faiblement salées, puis, le caractère très particulier des résultats obtenus nous a incité à analyser les eaux de chlorinité plus élevée.

Malheureusement, un incident regrettable s'est produit ; après la deuxième campagne de mesures, une partie des eaux récoltées n'est pas parvenue en France et l'étude chimique n'a pas pu être entreprise sur ces échantillons.

Nous avons dosé le calcium et le magnésium par la méthode au Versenate. Le potassium a été dosé au photomètre à flamme.

Les résultats de ces dosages sont donnés dans les tableaux annexes à la fin de ce travail, nous les avons utilisés pour construire un graphique en fonction de la chlorinité (voir fig. n° 30).

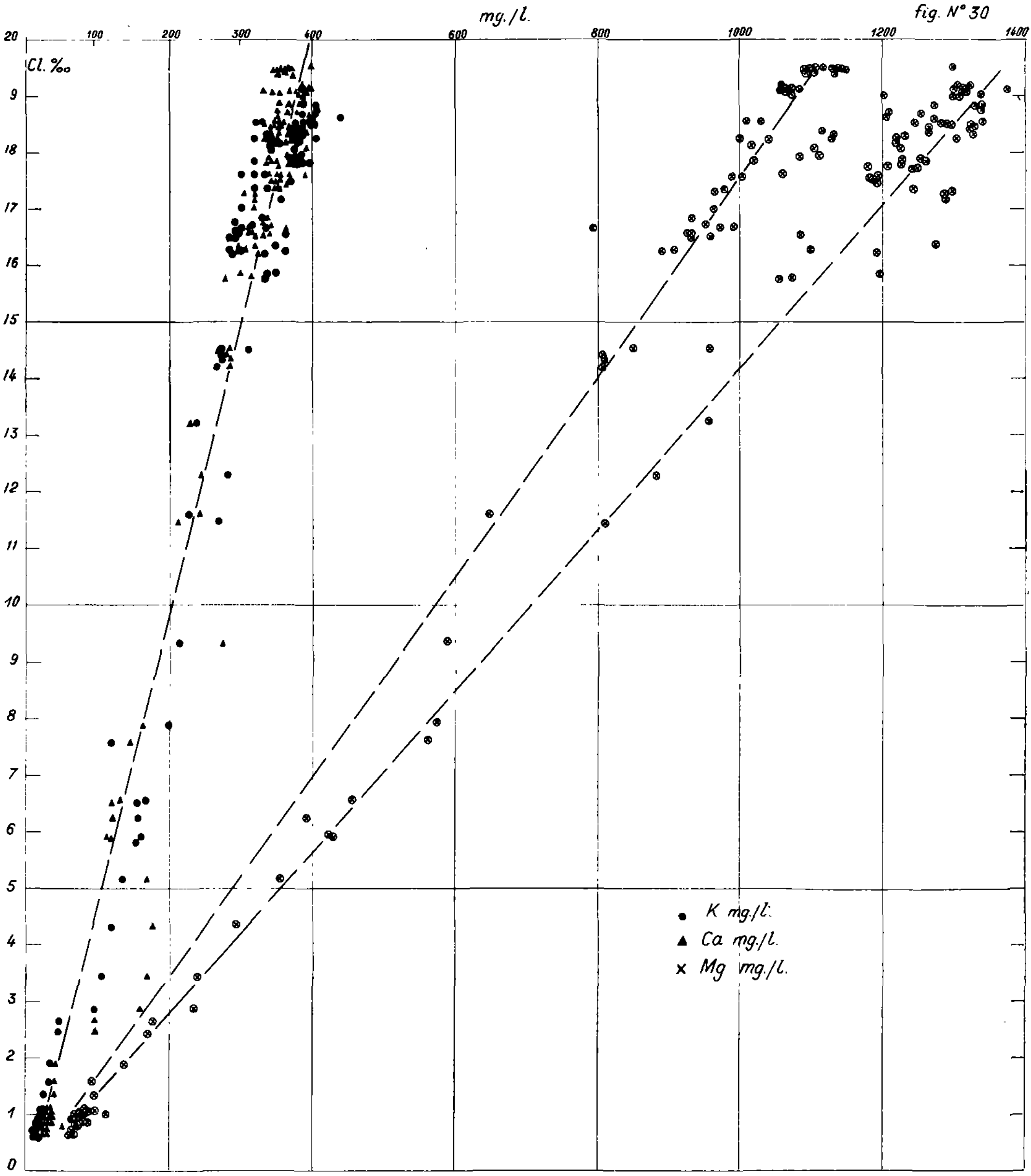

Fig. 30. — Teneurs des eaux en Potassium, Calcium et Magnésium (exprimées en mg/l) en fonction de la chlorinité.

Il apparaît, sur ce graphique, que les teneurs en Potassium et en Calcium se groupent sensiblement suivant une droite dont l'équation est

$$X = 20\ y$$

Par conséquent, pour des chlorinités comprises entre 0,5 et 20 $^0/_{00}$, les teneurs en Potassium et calcium, exprimées en mg / l. sont voisines de 20 fois le taux de chlorinité.

En ce qui concerne le magnésium les résultats des dosages offrent une dispersion plus accusée que pour le Potassium et le Calcium, ils répondent à deux équations :

$$X = 57\ Y$$
$$X = 70\ Y$$

Ainsi, pour des chlorinités comprises entre 0,5 et 20 $^0/_{00}$l es teneurs en magnésium, exprimées en mg / l. sont approximativement comprises entre 57 et 70 fois le taux de chlorinité.

Ces résultats diffèrent profondément de ceux qui ont été obtenus dans le lagon de l'Ile Mayotte (Comores) et à l'extérieur de ce lagon, par L. Guilcher, L. Berthois, Y. Le Calvez, R. Battistini et A. Crosnier (*loc. cit.* 1964, pp. 55-57) où ces auteurs ont observé qu'à l'intérieur du lagon les sneurs en Ca^{++}, K^{+} et Mg^{++} peuvent varier de 10 à 20 % dans d'étroites limites de chlorinité, tandis qu'à l'extérieur du lagon des variations peu importantes des mêmes cations s'accompagnent de fluctuations étendues de la chlorinité.

Par contre, des relations linéaires du type de celles qui viennent d'être décrites, aux abords de l'embouchure de la Betsiboka, ont été observées récemment par Taizo Okuda (1964) au Vénézuela.

La continuité et l'échelonnement des résultats sur une gamme aussi étendue des valeurs de chlorinité est une manifestation de l'influence des eaux fluviales sur une aire étendue du plateau continental.

RÉSUMÉ ET CONCLUSIONS

Des conclusions partielles ont déjà été formulées à la fin de chaque chapitre, nous nous bornerons ici à les rappeler et à les relier entre elles pour constituer un ensemble plus cohérent.

Le fleuve Betsiboka est le plus important de Madagascar tant par sa longueur et celle de ses affluents, que par la surface de son bassin versant ; son embouchure est située sur la côte ouest de l'île qui est bordée par un plateau continental étroit, dont le bord extrême est jalonné par une série de « bancs » qui sont des formations d'origine corallienne, à vie très ralentie, immergés sous 7 à 10 mètres d'eau.

Le régime fluvial de la Betsiboka et de son principal affluent, l'Ikopa, est sujet à d'importantes variations saisonnières, le débit total journalier en 1961-1962 a été inférieur à 400 m^3 / sec. pendant 5 mois, puis il a parfois dépassé 4500 m^3 / sec. au cours de la saison des pluies qui dure de décembre à la mi-avril, en mai et juin le débit est voisin de 700 m^3 / sec.

Deux séries de mesures et de prélèvements d'eau ont été faites ; la première en période d'étiage de juillet 1961, la deuxième pendant la crue de mars 1962.

L'étude dynamique de la sédimentation a été conduite en construisant d'abord des profils d'évolution à chaque poste d'observation, puis en utilisant ces profils pour la construction de profils instantanés, de l'estuaire du fleuve et de coupes transversales sur le plateau continental, aux abords de l'embouchure.

L'étude des profils instantanés construits avec les données recueillies en période d'étiage fluvial montre qu'il s'établit à l'embouchure du fleuve une lentille d'eau profonde immobile ou animée de mouvements très lents, qui se maintient sur toute l'étendue du plateau continental et ne permet pas aux sédiments grossiers d'y pénétrer par roulement et saltation sur le fond.

Les sédiments fins, transportés en suspension, peuvent seuls atteindre puis dépasser légèrement l'embouchure du fleuve.

En période de crue fluviale, les faibles vitesses des courants animant les eaux profondes sur le plateau continental, ne permettent pas aux sédiments grossiers actuellement apportés par le fleuve d'y parvenir, la comparaison des faibles vitesses des courants voisins du fond avec la granulométrie des sables recouvrant le plateau continental, confirme cette manière de voir, cette interprétation est consolidée par la répartition des sédiments quartzeux grossiers, qui alternent ou coexistent avec des foraminifères et de très petits lamellibranches dont les ornementations ne portent aucun stigmate d'usure.

Les eaux fluviales qui s'étendent à la surface des eaux marines sur le plateau continental provoquent un dessalement très important qui peut atteindre le bord externe du plateau continental.

Ces eaux fluviales transportent, en suspension, une masse considérable des sédiments fins qui se déposent dans la zone d'équilibre fluvio-océanique, notamment aux abords du poste 7.

Il se constitue ainsi, au cours d'une crue, un dépôt extrêmement important de sédiments fins (plus de 99 % d'éléments inférieurs à 0,80 mm) qui recouvrent une aire ayant approximativement 10 milles dans le sens Nord-Sud et 8 milles dans le sens Est-Ouest.

Ainsi, l'estuaire de la Betsiboka constitue un type intermédiaire dans la classification établie par l'un de nous (L. Berthois 1965, *loc. cit.* p. 77) en période d'étiage du fleuve, cet estuaire est une embouchure fluviale à zone « d'équilibre littoral » tandis qu'en période de crue importante il possède une embouchure dont la zone d'équilibre est située un peu « au-delà du littoral » il s'apparente donc au fleuve Konkouré de la côte Ouest africaine (République de Guinée) décrit par l'un de nous (L. Berthois 1963).

L'étude minéralogique des sédiments fins par l'analyse thermique différentielle et l'analyse aux rayons X, a fourni d'autres arguments en faveur de cette interprétation : elle a montré que la plus grande concentration de kaolinite dans les sédiments du fond se trouvait justement aux abords du poste d'observation (Poste 7) où la décantation des eaux atteint sa valeur maximale.

Elle a montré, en outre, que les postes du plateau continental qui n'étaient pas atteints par les dépôts actuels du fleuve ne contenaient pas de kaolinite, mais une palygorskite. Que les postes qui n'étaient que faiblement atteints par ces matériaux transportés en suspension contenaient moins de kaolinite mais de petites quantité de pyrophyllite.

Tout ce faisceau d'observations a permis de conclure que les sédiments grossiers du plateau continental ont été mis en place au cours d'un épisode sédimentaire antérieur à l'époque actuelle pendant laquelle le fleuve Betsiboka n'y apporte que des éléments fins en suspension, les sables grossiers apportés par les crues ne progressant pas sensiblement au-delà de l'embouchure.

L'étude du dessalement des eaux marines et de l'apport de matériaux fins en suspension, a montré que l'abaissement de la salinité et l'augmentation de la turbidité, à la limite externe du plateau continental, constituaient des conditions très défavorables à la vie des récifs coralliens qui est extrêmement ralentie dans la zone que nous avons étudiée.

Enfin, les dosages de potassium, calcium et magnésium exécutés sur des eaux douces et saumâtres ont montré que les pourcentages de ces cations varient en fonction de la chlorinité suivant des relations simples de type linéaire, l'étendue des valeurs des chlorinités observées est liée à la pénétration des eaux douces dans le domaine maritime du plateau continental.

ANNEXE

a) Tableaux des heures des marées et hauteurs d'eau

b) Mesures et dosages d'Hydrologie
- température
- Salinité
- Turbidité
- dosage des Cations K+, Ca++, Mg++

c) Mesures des vitesses du courant.

MESURES EN PÉRIODE D'ÉTIAGE DE LA BETSIBOKA

TABLEAU n° 9

Heures et hauteurs de la marée au cours des observations en Juillet 1961.

Date	Basse Mer		Pleine Mer		Basse Mer		Pleine Mer	
	heure	hauteur en m	heure	hauteur en m	heure	hauteur en m	heure	hauteur en m
6 Juillet	3 h 57	1,8	10 h 25	4,0	16 h 41	2,1	22 h 47	3,7
7 Juillet	5 h 10	1,9	11 h 45	3,9	18 h 10	2,2		
8 Juillet							0 h 14	3,6
8 Juillet	6 h 32	2,0	13 h 07	4,0	19 h 34	2,1		
10 Juillet							2 h 40	3,8
10 Juillet	8 h 42	1,8	15 h 05	4,3	21 h 27	1,7		
11 Juillet							3 h 29	3,9
11 Juillet	9 h 28	1,6	15 h 46	4,5	22 h 07	1,5		
12 Juillet							4 h 08	4,1
12 Juillet	10 h 06	1,5	16 h 22	4,6	22 h 41	1,4		
13 Juillet							4 h 41	4,2
13 Juillet	10 h 41	1,5	16 h 53	4,6	23 h 11	1,3		

TABLEAU n° 10

HYDROLOGIE EN PÉRIODE D'ÉTIAGE DE LA BETSIBOKA

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
				POSTE N° 1 6 JUILLET 1961				
—1—	0	24,87	14,42	26,07	10,6	277,0	279	807,5
7 h à	1	24,97	14,52	26,24	5,4	277,0	285	849,0
7 h 30	2		15,08	27,26			—	—
	5	25,49	16,65	30,09	8,4	301,5	309	794,5
	10	25,61	17,35	31,36	6,0	320,0	351	977,0
	20	25,68	18,29	33,04	25,8	339,0	339	1132,0
—2—	0	25,59	16,50	29,81	6,0	294,0	333	960,0
10 h 30	1	25,69	16,73	30,23	3,8	294,0	331	951,5
à	2		17,36	31,36				
10 h 55	5	25,51	17,59	31,79	5,2	320,0	351	1005,0
	10	25,60	17,86	32,27	4,2	320,0	352	1010,0
	20	25,67	18,53	33,49	8,0	330,0	354	1030,0
—3—	0	26,19	16,31	29,47	4,6	286,0	312	907,8
13 h 00	1	26,25	16,51	29,84	7,2	286,0	321	932,5
à	2		16,98	30,69				
13 h 20	5	25,59	17,61	31,82	5,7	301,5	339	989,0
	10	25,62	18,25	32,97	5,6	320,0	352	1000,0
	21	25,59	18,54	33,49	8,0	320,0	359	1009,5
—4—	0	25,67	16,62	30,03	8,4	294,0	311	928,5
15 h 25	1	25,47	16,57	29,95	8,8	294,0	318	929,0
à	2		16,88	30,50				
15 h 45	5	25,62	17,05	30,81	9,0	301,5	319	963,5
	10	25,63	17,34	31,34	17,4	339,0	347	966,0
	21	25,71	18,23	32,95	17,8	339,0	347	1042,0
—5—	0	26,51	14,22	25,71	6,7	268,5	287	808,0
17 h 40	1	26,12	14,35	25,93	3,7	277,0	287	808,0
à	2		14,61	26,41				
17 h 55	5	25,87	16,26	29,38	4,8	301,5	303	890,0
	10	25,74	16,84	30,44	3,2	330,0	338	932,0
	19	25,70	18,17	32,83	14,0	358,6	347	1017,0
				POSTE N° 2 6 JUILLET 1961				
—1—	0	25,50	18,04	32,60	3,8	377,5	344,0	1228,5
9 h 30	1	25,48	18,30	33,13	4,1	388,5	352,0	1329,0
à	2		18,35	33,16				
9 h 50	5	25,74	18,38	33,22	4,2	377,5	352,0	1329,0
	10	25,68	18,38	33,22	7,9	377,5	368,0	1296,0
	21	25,83	18,86	34,03	11,6	409,0	364,0	1332,5
	23	—	—	—	1320,0	409,0	368,0	1342,0
—2—	0	25,96	18,43	33,30	5,1	388,5	340,0	1266,0
11 h 40	1	25,82	18,40	33,24	3,8	377,5	340,0	1266,0
à	2		18,43	33,30				
11 h 55	5	25,70	18,44	33,32	3,5	377,5	356,0	1326,5
	10	25,72	18,54	33,49	4,1	388,5	348,0	1342,0
	22	25,83	18,87	34,09	7,2	388,5	356,0	1360,5

Nº de Station et heure	Profondeur en m	Températ. ºC	Cl º/ₒₒ	S º/ₒₒ	Turbidite mg/l.	K mg/l.	Ca mg/l.	Mg mg/l. c
suite du POSTE Nº 2								
—3—	0	26,41	17,16	31,00	5,7	358,5	320,0	1290,0
13 h 55	1	25,91	17,81	32,19	6,2	388,5	344,0	1263,5
à	2		17,65	31,89				
14 h 15	5	25,74	18,25	32,98	5,0	377,5	336,0	1303,5
	10	25,70	18,49	33,41	3,9	398,0	348,0	1284,0
	18	25,79	18,76	33,90	8,8	409,0	352,0	1340,0
—4—	0	25,71	16,33	29,52	5,6	350,0	320,0	1278,0
16 h 25	1	25,53	16,53	29,87	5,1	—	—	—
à	2	—	16,82	30,39	—	—	—	—
16 h 45	5	25,61	17,89	32,33	3,2	377,5	340,0	1254,0
	10	25,69	18,49	33,40	5,8	398,0	336,0	1291,5
	18	25,71	18,58	33,57	7,3	398,0	352,0	1271,0
—5—	0	25,81	15,84	28,63	4,2	350,0	300,0	1197,0
19 h 05	1	25,57	15,87	28,69	4,2	339,0	316,0	1072,7
à	2		16,95	30,63	—	—	—	—
19 h 25	5	25,69	17,81	32,19	3,4	377,5	332,0	1230,0
	10	25,69	18,48	33,39	4,3	398,0	354,0	1245,5
	19	25,78	18,70	33,79	16,6	409,0	380,0	1207,0
POSTE Nº 3 7 JUILLET 1961								
—1—	0	25,19	17,50	31,63	27,9		356,0	1187,5
7 h 30	1	25,03	17,37	31,39	28,0		356,0	1244,5
à	2		17,59	31,78				
7 h 45	5	25,61	18,35	33,15	26,0		368,0	1237,0
	10	25,96	19,09	34,50	33,0		384,0	1378,5
	14	25,99	19,11	34,52	30,0		368,0	1319,0
—2—	0	25,71	17,51	31,65	4,7		344,0	1182,5
10 h 30	1	25,54	17,56	31,74	19,3		356,0	1198,5
à	2		17,60	31,81				
10 h 55	5	25,87	19,01	34,34	3,3		384,0	1309,5
	10	25,91	19,13	34,56	7,1		384,0	1314,5
	13	25,93	19,16	34,61	5,2		384,0	1320,5
—3—	0	26,82	17,25	31,17	7,2		304,0	1310,5
12 h 50	1	26,30	17,30	31,26	7,3		320,0	1301,0
à	2		18,02	32,57				
13 h 10	5	25,95	19,02	34,37	4,3		392,0	1339,0
	10	26,05	19,15	34,61	9,0		388,0	1318,0
	15	26,00	19,16	34,62	6,0		396,0	1302,0
—4—	0	26,18	17,80	32,17	3,7		354,0	1210,5
15 h 10	1	25,69	17,84	32,24	5,1		380,0	1230,0
à	2		17,91	32,37				
15 h 25	5	25,88	19,02	34,36	4,7		388,0	1302,0
	10	25,99	19,10	34,51	3,5		388,0	1318,0
	14	25,99	19,55	34,61	4,7		400,0	1295,0

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 3								
—5—	0	26,09	17,72	32,01	7,7		368,0	1249,0
17 h 30	1	26,01	17,58	31,76	5,3		372,0	1224,0
à	2		17,54	31,70				
17 h 45	5	25,89	18,21	32,91	7,9		380,0	1219,0
	10	25,81	18,83	34,02	8,7		384,0	1274,5
	14	25,97	19,14	34,58	19,0		396,0	1302,0
POSTE N° 4 7 JUILLET 1961								
—1—	0	25,71	19,10	34,52	6,9			
9 h 10	1	25,55	19,07	34,45	4,8			
à	2		19,06	34,43				
9 h 25	5	25,79						
	10	26,01	19,14	34,59	1,2			
	16	26,29	19,27	34,81	3,6			
—2—	0	26,09	19,04	34,41	4,3			
11 h 45	1	25,93	19,04	34,41	3,3			
à	2		19,03	34,39				
12 h 05	5	25,89	19,04	34,41	3,0			
	10	25,96	19,11	34,52	4,6			
	18	26,26	19,25	34,79	4,8			
—3—	0	26,47	19,05	34,42	2,8			
13 h 55	1	26,26	19,06	34,43				
à	2		19,05	34,42				
14 h 10	5	25,92	19,06	34,43	3,1			
	10	25,91	19,10	34,52	4,2			
	17	26,22	19,23	34,75	4,1			
—4—	0	26,39	18,98	34,30	4,2			
16 h 15	1	26,26	18,99	34,31	4,2			
à	2		18,98	34,30				
16 h 30	5	25,90	19,05	34,42	3,0			
	10	25,97	19,13	34,57	3,4			
	17	26,11	19,22	34,73	16,6			
—5—	0	25,99	18,95	34,24	3,1			
18 h 40	1	25,80	18,96	34,26	4,8			
à	2		18,96	34,25				
19 h 00	5	26,00	19,00	34,33	6,7			
	10	26,14	19,23	34,75				
	16	26,16	19,22	34,72	5,0			
POSTE N° 5 8 JUILLET 1961								
—1—	0	26,03	19,29	34,85	4,4			
7 h 00	1	25,88	19,29	34,86	3,6			
à	2		19,28	34,84				
7 h 15	5	26,23	19,28	34,84	3,5			
	10	26,34	19,33	34,92	2,9			
	17	26,36	19,34	34,95	3,2			

N° de Station et heure	Profondeur en m	Températ. °C	Cl ‰	S ‰	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l
suite du POSTE N° 5								
—2—	0	26,18	19,35	34,97	5,1			
9 h 10	1	26,02	19,34	34,94	3,8			
à	2		19,33	34,83				
9 h 30	5	26,32	19,34	34,94				
	10	26,34	19,33	34,93	3,4			
	18	26,36	19,35	34,96	3,1			
—3—	0	26,48	19,38	35,01				
11 h 25	1	26,29	19,34	34,95				
à	2		19,33	34,93				
11 h 45	5	26,34	19,32	34,91				
	10	26,26	19,33	34,92				
	20	26,34	19,35	34,97	4,0			
—4—	0	26,79	19,32	34,91				
13 h 50	1	26,77	19,34	34,94	3,9			
à	2		19,32	34,91				
14 h 05	5	26,26	19,32	34,90	3,3			
	10	26,23	19,31	34,89	3,3			
	18	26,34	19,36	34,98	4,2			
—5—	0	26,70	19,33	34,92	6,1			
15 h 50	1	26,41	19,28	34,84	3,1			
à	2		19,25	34,86				
16 h 05	5	26,16	19,28	34,84	3,8			
	10	26,16	19,28	34,84	3,1			
	15	26,22	19,30	34,88	3,4			
POSTE N° 6 8 JUILLET 1961								
—1—	0	26,11	19,39	35,03	4,0			
5 h 15	1	25,86	19,37	34,99	5,0			
à	2		19,36	34,98				
5 h 45	5	26,38	19,36	34,97				
	12	26,42	19,36	34,98	4,4			
—2—	0	26,34	19,38	35,02	4,0			
8 h 00	1	26,15	19,38	35,01				
à	2		19,39	35,03				
8 h 20	5	26,51	19,37	34,99	4,4			
	10	26,52	19,38	35,01	2,0			
	20	26,51	19,39	35,03	2,2			
—3—	0	26,51	19,42	35,08	4,2			
10 h 20	1	26,46	19,41	35,07	1,7			
à	2		19,42	35,08				
10 h 40	5	26,53	19,39	35,03	2,8			
	10	26,54	19,39	35,04	15,0			
	20	26,26	19,41	35,08	3,2			

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 6								
—4—	0	26,99	19,42	35,09	3,3			
12 h 40	1	26,71	19,40	35,06	3,0			
à	2		19,39	35,03				
13 h 00	5	26,68	19,39	35,04	3,0			
	10	26,56	19,40	35,06	3,1			
	20	26,44	19,44	35,12	3,0			
—5—	0	27,02	19,38	35,01	2,8			
14 h 50	1	26,80	19,40	35,06	3,8			
à	2		19,38	35,02				
15 h 10	5	26,64	19,37	35,00	3,0			
	10	26,60	19,39	35,04	2,2			
	18	26,52	19,44	35,13	3,4			
POSTE N° 7 10 JUILLET 1961								
—1—	0	25,48	18,30	33,07	10,7			
6 h 50	1	25,32	18,31	33,08	8,2			
à	2		18,30	33,07				
7 h 00	5	25,96	18,87	34,09				
	8	26,04	18,93	34,20	8,0			
—2—	0	25,93	18,60	33,61	5,2			
11 h 00	1	25,87	18,58	33,58	5,0			
à	2		18,58	33,57				
11 h 10	5	25,97	18,61	33,62				
	8	26,11			8,0			
—3—	0	26,03						
14 h 40	1	26,12	18,52	33,46	5,4			
à	2		18,53	33,48				
14 h 50	5	26,14	18,55	34,06	4,9			
	8	26,30	19,22	34,73	6,3			
POSTE N° 8 11 JUILLET 1961								
—1—	0	25,53	18,60	33,60	3,8			
6 h 55	1	25,54	18,60	33,60	4,7			
à	2		18,64	33,69				
7 h 05	5	26,01	19,00	34,34	3,7			
	10	26,31	19,25	34,79	3,0			
	19	26,36	19,39	35,04	3,2			
—2—	0	26,16	18,65	33,70	5,3			
11 h 10	1	26,20	18,64	33,68	7,1			
à	2		18,82	34,01				
11 h 20	5	26,28	19,13	34,56	3,8			
	10	26,38	19,29	34,86	5,0			
	19	26,38	19,41	35,07	7,4			

N° de Station et heure	Profondeur en *m*	Températ. °C	Cl ‰	S ‰	Turbidité *mg/l.*	K *mg/l.*	Ca *mg/l.*	Mg *mg/l.*
suite du POSTE N° 8								
—3—	0	26,30	18,81	33,99	4,8			
15 h 15	1	26,21	18,85	34,05	4,5			
à	2		18,99	34,31				
15 h 25	5	26,26	19,20	34,69				
	10	26,35	19,31	34,89	3,7			
	19	26,43	19,42	35,08	4,4			
POSTE N° 9 11 JUILLET 1961								
—1—	0	26,09	19,39	35,03				
8 h 10	1	26,19	19,39	35,03	3,6			
à	2		19,38	35,01				
8 h 25	5	26,42	19,38	35,02	3,4			
	10	26,38	19,38	35,02	16,8			
	18	26,42	19,39	35,03	3,1			
—2—	0	27,21	19,39	35,04	3,2			
12 h 10	1	26,71	19,39	35,04	3,1			
à	2		19,37	35,00				
12 h 30	5	26,53	19,39	35,04	2,8			
	10	26,45	19,37	35,00	3,3			
	18	26,45	19,38	35,01	9,2			
—3—	0	26,61	19,38	35,01	6,2			
16 h 25	1	26,64	19,37	35,00	0,93			
à	2		19,37	35,00				
16 h 40	5	26,50	19,37	35,00	3,5			
	10	26,49	19,40	35,05	4,5			
	18	26,49	19,40	35,06	3,1			
POSTE N° 11 13 JUILLET 1961								
—1—	0	25,92	18,84	34,04	5,3			
8 h 45	1	25,96	18,83	34,02	3,2			
à	2		18,84	34,05				
8 h 55	5	26,27	18,99	34,32				
	8	26,29	19,03	34,39	4,1			
	8				4,4			
—2—	0	26,30	18,75	33,88	1,5			
11 h 55	1	26,22	18,76	33,89	6,6			
à	2		18,86	34,07				
12 h 05	5	26,31	18,79	33,96	5,5			
	7,5	26,28	18,94	34,23	6,8			
—3—	0	26,00	18,87	34,10	4,2			
15 h 25	1	26,07	18,87	34,09	5,6			
à	2		18,88	34,11				
15 h 40	5	26,27	18,92	34,18				
	8	26,27	19,03	34,38	4,7			

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
POSTE N° 12 12 JUILLET 1961								
—1—	0	25,81	19,07	34,45	7,0			
6 h 20	1	25,81	19,06	34,43	6,2			
à	2		19,05	34,42				
6 h 40	5	26,08	19,05	34,42				
	9	26,08	19,06	34,44	9,5			
—2—	0	26,29	18,89	34,13	4,2			
10 h 55	1	26,19	18,87	34,09	7,5			
à	2		18,87	34,10				
11 h	5	26,02	18,87	34,10				
	8	26,02	18,88	34,12	6,2			
—3—	0	26,43	18,83	34,03	5,6			
14 h 10	1	26,43	18,84	34,05	9,7			
à	2		18,86	34,07				
14 h 25	5	26,26	19,17	34,63				
	8	26,26	19,17	34,64				
POSTE N° 13 12 JUILLET 1961								
—1—	0	26,30	19,45	35,15	4,7			
8 h 00	1	26,30	19,45	35,15				
à	2		19,46	35,17				
8 h 15	5	26,48	19,45	35,15				
	10	26,48	19,45	35,15	5,5			
	23	26,48	19,45	35,15	3,1			
—2—	0	27,08	19,46	35,16	3,8			
11 h 55	1	26,71	19,45	35,15	5,5			
à	2		19,45	35,14				
12 h 10	5	26,65	19,46	35,16				
	10	26,54	19,46	35,17	3,9			
	22	26,54	19,46	35,16	3,6			
—3—	0	26,64	19,45	35,14	3,0			
16 h 20	1	26,55	19,45	35,14	5,8			
à	2		19,44	35,12				
16 h 45	5	26,49	19,44	35,12				
	10	26,47	19,44	35,12				
	23	26,46	19,43	35,11	10,3			
POSTE N° 15 13 JUILLET 1961								
—1—	0	25,82	18,99	34,31	5,2			
7 h 35	1	25,82	18,99	34,31	3,1			
à	2		19,00	34,34				
7 h 50	5	26,16	19,05	34,42	0,9			
	10	26,29	19,16	34,62	4,0			

N° de Station et heure	Profondeur en m	Températ. °C	Cl ‰	S ‰	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 15								
—2—	0	26,00	18,98	34,30	4,5			
10 h 55	1	26,03	18,98	34,30	2,2			
à	2		18,99	34,31				
11 h 05	5	26,31	19,01	34,34				
	10	26,34	19,18	34,65				
—3—	0	26,15	18,99	34,32	3,1			
14 h 10	1	26,15	19,00	34,33	4,5			
à	2		18,99	34,32				
14 h 20	5	26,41	18,99	34,31	4,4			
	11	26,41	19,17	34,63	7,2			
			POSTE N° 16	13 JUILLET 1961				
—1—	0	25,71	19,24	34,76	3,8			
6 h 30	1	25,72	19,20	34,69	3,2			
à	2		19,19	34,68				
6 h 40	5	26,16	19,19	34,68				
	10	26,16	19,20	34,69	3,6			
	22	26,36	19,38	35,01				
—2—	0	25,91	19,16	34,62	4,5			
9 h 55	1	25,98	19,13	34,57	3,1			
à	2		19,14	34,58				
10 h 05	5	26,17	19,14	34,59				
	10	26,21	19,19	34,67	3,4			
	20	26,31	19,35	34,97				
—3—	0	26,11	19,18	34,65	4,5			
13 h 05	1	26,23	19,16	34,61	5,0			
à	2		19,16	34,61				
13 h 15	5	26,42	19,16	34,61				
	10	26,35	19,21	34,70	3,2			
	20	26,41	19,35	34,97	4,7			
			POSTE N° 17	12 JUILLET 1961				
—1—	0	26,38	19,44	35,19	3,8		361	1094,0
9 h 25	1	26,36	19,44	35,13	3,2		363	1144,5
à	2		19,45	35,14				
9 h 40	5	26,44	19,47	35,17				
	10	26,36	19,45	35,15	3,6		375	1140,5
	30	26,31	19,45	35,15	3,6		364	1108,5
—2—	0	26,91	19,46	35,16	5,5			
13 h 05	1	26,83	19,46	35,17	4,8		373	1118,0
à	2		19,45	35,15				
13 h 15	5	26,48	19,45	35,15				
	10	26,48	19,45	35,15	3,6		359	1150,2
	30	36,41	19,45	35,14	3,0		355	1107,0

N° de Station et heure	Profondeur en m	Températ. °C	Cl ‰	S ‰	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 17								
—3—	0	26,33	19,43	35,10	4,4		355	1132,0
16 h 40	1	26,32	19,45	35,14	3,6		357	1090,8
à	2		19,44	35,13				
16 h 55	5	26,66	19,44	35,12				
	10	26,48	19,46	35,17	4,1		347	1097,0
	30	26,31	19,45	35,14	3,7		357	1100,8
POSTE N° 19 10 JUILLET 1961								
—1—	0	25,91	19,00	34,33	3,8			
8 h 10	1	25,52	18,99	34,31	4,2			
à	2		18,97	34.27				
8 h 20	5	26,02	19,18	34,66	4			
	10	26,06	19,31	34,89				
—2—	0	26,41	19,14	34,58	4,0			
12 h	1	26,26	19,08	34,48	5,2			
à	2		19,09	34,49				
12 h 15	5	26,14	19,25	34,79	4,9			
	11	26,14	19,34	34,94	2,9			
—3—	0	26,22	19,04	34,40	3,8			
15 h 55	1	26,14	19,04	34,41	4,1			
à	2		19,04	34,40				
16 h 10	5	26,21	19,35	34,96	4,5			
	11	26,21	19,34	34,95	3,5			
POSTE N° 20 10 JUILLET 1961								
—1—	0	25,61	18,62	33,65	5,2			
9 h 05	1	25,69	18,62	33,64	4,1			
à	2		18,59	33,59				
9 h 20	5	22,85	18,66	33,72	3,2			
	10	26,23	19,29	34,86	3,9			
	14	26,26	19,36	34,98	3,2			
—2—	0	26,49	18,82	34,01	2,5			
13 h 00	1	26,48	18,68	33,75	3,8			
à	2		18,76	33,90				
13 h 20	5	26,13	18,99	34,32	3,3			
	10	26,44	19,40	35,05	3,6			
	15	26,44	19,41	35,08	2,6			
—3—	0	25,89	18,69	33,78	3,2			
17 h 25	1	25,91	18,69	33,78	4,0			
à	2		18,70	33,79				
17 h 40	5	25,96	18,83	34,02	3,0			
	10	26,36	19,38	35,01	3,2			
	15	26,36	19,38	35,01	3,5			

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
POSTE N° 21 11 JUILLET 1961								
—1—	0	25,66	19,11	34,53	3,2		357	1075,0
9 h 55	1	25,76	19,11	34,52	4,0		383	1050,0
à	2		19,11	34,52				
10 h 05	5	25,91	19,11	34,53	3,1		331	1071,5
	10	25,91	19,10	34,52	3,6		343	1064,0
	24	26,41	19,42	35,08	3,1		375	1060,5
—2—	0	26,41	19,09	34,49	3,0		343	1084,0
13 h 40	1	26,41	19,08	34,47	2,8		347	1067,0
à	2		19.09	34,50				
13 h 50	5	26,06	19,09	34,50	6,0		347	1067,0
	10	26,11	19,18	34,65	5,0		349	1071,0
	24	26,38	19,43	35,10	3,8		359	1135,2
—3—	0	25,77	19,11	34,52	3,2		343	1104,0
17 h 50	1	25,73	19,12	34,54	3,5		355	1057,0
à	2		19,11	34,53				
18 h 10	5	26,26	19,23	34,75	3,7		369	1078,0
	10	26,34	19,31	34,88	4,0		375	1065,5
	26	26,39	19,41	35,08	4,2		373	1066,0

TABLEAU n° 11

MESURES DES VITESSES DU COURANT EN PÉRIODE D'ÉTIAGE DE LA BETSIBOKA

Station et heure	Profondeur *en m*	Vitesse en *m/sec.*	Direction	*Station* et heure	Profondeur en m.	Vitesse en m/sec.	Direction
POSTE N° 1 6 JUILLET 1961							
—1—	0	0,37	160°	—4—	0	0,67	350°
7 h 45	15	1,05	160°	15 h 30	10	0,79	10°
à	20	1,04	160°	à	20	0,76	10°
8 h 20	21	fond		15 h 45	24	fond	
—2—	0	0,32	160°	—5—	0	0,53	50°
10 h 40	10	0,65	180°	17 h 40	10	0,16	230°
à	20	0,49	190°	à	20	0,44	170°
10 h 55	23	fond		17 h 55	21	fond	
—3—	0	0,67	340°				
13 h 00	10	0,40	10°				
à	20	0,43	10°				
13 h 15	24	fond					

Station et heure	Profondeur en m	Vitesse en m/sec.	Direction	*Station* et heure	Profondeur en m.	Vitesse en m/sec.	Direction
			POSTE N° 2	6 JUILLET 1961			
—1—	0	0,62	160°	—3—	0	0,75	10°
9 h 35	10	0,61	185°	13 h 55	10	0,66	5°
à	24	0,32	195°	à	20	0,47	0 à 10°
9 h 45	26	fond		14 h 10		0,41	
					21	fond	
—2—	0	0,17	90°	—4—	0	0,83	30°
11 h 45	10	0,06	80°	16 h 30	10	0,50	0 à 10°
à	—	0,09	345°	à	20	0,28	10°
12 h	22	0,14	345°	16 h 45	21	fond	
	25	fond					
				—5—	0	0,30	60°
				19 h 00	10	0,53	190°
				à	20	0,61	190°
				19 h 15	22	fond	
			POSTE N° 4	7 JUILLET 1961			
—1—	0	0,17	160°	—4—	0	0,12	340°
9 h 15	10	0,31	170°	16 h 15	10	0,41	335°
à	18	0,27	170°	à	18	0,34	325°
9 h 30	19	fond		16 h 30	19	fond	
—2—	0	0,12	160°	—5—	0	0,15	130°
11 h 45	10	0,21	140°	18 h 45	10	0,13	250°
à	18	0,05	140°	à	15	0,17	230°
12 h	21	fond		19 h	16	fond	
—3—	0	0,05	10°				
14 h 00	10	0,23	350°				
à	18	0,28	340°				
14 h 15	19	fond					
			POSTE N° 6	8 JUILLET 1961			
—1—	0	0		—4—	0	0,03	220°
5 h 30	12	0,09	170°	12 h 30	10	0,18	150°
à	14	fond		à	20	0,12	130°
5 h 45				12 h 45	22	fond	
—2—	0	0,13	200°	—5—	0	0,08	10°
8 h 00	10	0,36	120°	15 h	10	0,14	350°-0
à	20	0,24	160°	à	20	0,19	350°-0
8 h 15	21	fond		15 h 15	22	fond	
—3—	0	0,08	220°				
10 h 15	10	0,27	130°				
à	20	0,19	160°				
10 h 30	22	fond					

Station et heure	Profondeur en m	Vitesse en m/sec.	Direction	*Station* et heure	Profondeur en m	Vitesse en m/sec.	Direction
POSTE N° 9 11 JUILLET 1961							
—1—	0	0,17	320°	—3—	0	0,18	115°
8 h 10	10	0,20	350°	16 h 30	10	0,26	20°
à	18	0,13	340°	à	—	0,35	0°
8 h 25	19	fond		16 h 45	18	0,30	10°
					20	fond	
—2—	0	0,27	170°				
12 h 15	10	0,37	160-180°				
à	18	0,31	160°				
12 h 30	19	fond					
POSTE N° 13 12 JUILLET 1961							
—1—	0	0,20	310°	—3—	0	0,29	170°
8 h 10	10	0,17	340°	15 h 30	10	0,29	200°
à	24	0,11	320°		24	0,20	220°
8 h 25	26	fond			25	fond	
—2—	0	0,34	210°				
12 h	10	0,36	210°				
à	22	0,24	210°				
12 h 15	24	fond					
POSTE N° 15 13 JUILLET 1961							
—1—	0	0,20	330°	—2—	0	0,37	270°
8 h 00	10	0,13	330°	11 h	10	0,14	160°
	12	fond		à	12	fond	
				11 h 15			
POSTE N° 20 13 JUILLET 1961							
—1—	0	0,24	110°	—3—	0	0,08	55°
9 h 15	10	0,61	125°	17 h 30	10	0,39	0°
à	15	0,57	125°	à	15	0,30	0°
9 h 30	16	fond		17 h 45			
—2—	0	0,28	160°	—4—	0	0,02	20°
13 h 00	10	0,36	130°	19 h 45	10	0,23	340°
à	15	0,26	130°	à	15	0,17	340°
13 h 15	16	fond		20 h			

MESURES EN PÉRIODE DE CRUE DE LA BETSIBOKA

TABLEAU n° 12

Heures et hauteur de la marée au cours des observations en Mars 1962

Date	Basse Mer		Pleine Mer		Basse Mer		Pleine Mer	
	heure	hauteur en m	heure	hauteur en m	heure	hauteur en m	heure	hauteur en m
8 mars			5 h 35	5,2	11 h 47	0,6	17 h 55	5,2
9 mars	0 h 03	0,7	6 h 10	5,1	12 h 22	0,7	18 h 30	5,1
10 mars	0 h 39	0,9	6 h 45	4,9	12 h 55	0,9	19 h 05	4,9
11 mars								
12 mars	1 h 54	1,5	7 h 56	4,2	14 h 06	1,5	20 h 21	4,3
13 mars	2 h 38	1,9	8 h 37	3,8	14 h 49	1,9	21 h 10	3,9
14 mars								
15 mars	5 h 33	2,5	11 h 35	3,2	18 h 01	2,5		
16 mars							0 h 45	3,5
16 mars	7 h 47	2,4	13 h 56	3,4	19 h 57	2,4		
17 mars							2 h 17	3,7
17 mars	8 h 47	2,1	14 h 56	3,7	20 h 54	2,1		

TABLEAU n° 13

HYDROLOGIE EN PÉRIODE DE CRUE DE LA BETSIBOKA

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
			POSTE N° 1	15 MARS 1962				
—1—	0	28,65	1,00	1,84	20,8	20,8	32,0	68,8
7 h 00	1	28,63	0,93	1,71	10,9	18,3	28,0	68,7
à	2	28,64	1,12	2,05				
7 h 10	3	28,87	1,43	2,61				
	5	28,97	14,97	27,05	6,8			
	10	28,55	17,98	32,48	17,3			
	18	28,41	18,16	32,81	15,0			
	19	fond						
—2—	0	28,75	0,65	1,20	19,6	16,0	24,0	62,1
9 h 20	1	28,68	0,65	1,20	15,8	12,4	24,0	48,1
à	2	28,75	0,88	1,62				
9 h 30	3	29,01	13,05	23,59				
	5	28,82	16,67	30,12	7,6	337,0	384,0	991,0
	10	28,72	17,62	31,83	7,0	337,0	392,0	1060,0
	18	28,54	18,09	32,68	22,2	343,0	392,0	1104,0
	19	fond						

N° de Station et heure	Profondeur en m	*Températ.* °C	Cl ‰	S ‰	*Turbidité* mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 1								
—3—	0	29,68	0,85	1,56	14,2	19,2	28,0	86,2
11 h 40	1	29,41	0,84	1,55	16,7	17,0	28,0	70,9
à	2	29,10	10,31	18,64				
11 h 50	3	28,97	15,10	27,29				
	5	28,77	17,33	31,31	9,3			
	10	28,64	17,91	32,36	9,3			
	19	28,39	18,24	32,95	31,0			
	20	fond						
—4—	0	30,80	1,05	1,93	13,7	23,2	32,0	87,3
13 h 45	1	30,00	1,10	2,02	13,6	20,6	34,0	82,6
à	2	29,28	11,19	20,23				
14 h 05	3	29,15	15,28	27,61				
	5	28,71	17,57	31,74	7,2			
	10	28,57	18,01	32,54	12,3			
	19	28,43	18,22	32,92	21,4			
	20	fond						
—5—	0	30,09	0,65	1,20	17,1	17,4	22,0	63,3
16 h 15	1	29,71	0,67	1,24	16,9	13,5	22,0	63,3
à	2	28,98	0,97	1,78				
16 h 35	3	28,84	1,16	2,12				
	5	28,84	17,01	30,73	16,0			
	10	28,59	17,86	32,27	10,5			
	20	28,55	18,07	32,65	11,9			
	21	fond						
POSTE N° 2 8 MARS 1962								
—1—	0	28,44	14,21	25,68	142,0			
6 h 25	1	28,60	14,19	25,64	177,0			
à	2	28,60	14,13	25,53	144,0			
6 h 55	5	28,83	14,50	26,20	270,0			
	10	28,86	15,19	27,45	1062,0			
	25	28,86	16,62	30,03	1248,0			
Aucune prise d'échantillon de fond n'a pu être faite au cours de cette station, le courant étant trop rapide								
NOUVELLES STATIONS LE 15 MARS 1962								
—1—	0	29,20	0,80	1,47	36,0	18,8	52,0	72,8
8 h 10	1	28,94	1,37	2,50	9,0	25,7	40,0	96,0
à	2	29,02	6,41	11,60				
8 h 20	3	29,05	15,59	28,17				
	5	28,92	16,70	30,17	7,1			
	10	28,55	17,95	32,43	7,6			
	23	28,27	18,41	33,26	16,0			
	24	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 2								
—2—	0	29,28	1,01	1,85	10,8	22,2	30,0	97,5
10 h 20	1	29,08	2,63	4,78	14,6	46,4	96,0	177,5
à	2	29,08	7,40	13,39				
10 h 30	3	29,02	13,45	24,31				
	5	29,02	15,87	26,68	10,7			
	10	28,77	17,62	31,83	5,7			
	23	28,27	18,41	33,26	17,8			
	24	fond						
—3—	0	30,17	1,02	1,87	13,4	22,8	30,0	85,0
12 h 40	1	30,08	6,25	11,31	7,8	157,0	120,0	394,0
à	2	29,71	10,13	18,31				
12 h 50	3	29,47	14,88	26,89				
	5	29,16	16,57	29,94	21,0			
	10	28,82	17,52	31,65	7,9			
	23	28,25	18,42	33,28	17,1			
	24	fond						
—4—	0	30,58	0,99	1,83	13,2	23,3	26,0	111,4
15 h	1	30,25	1,02	1,87	3,4	22,2	26,0	78,9
à	2	29,68	11,32	20,46				
15 h 15	3		13,97	25,35				
	5	29,22	16,77	30,30	5,3			
	10	28,77	17,69	31,96	6,9			
	23	28,30	18,41	33,26	9,9			
	24	fond						
—5—	0	30,02	0,86	1,58	14,7	20,0	24,0	80,1
17 h 30	1	29,85	0,90	1,65	7,9	19,3	24,0	66,3
à	2	29,24	11,89	21,49				
17 h 40	3	29,37	14,04	25,37				
	5	28,97	16,68	30,14	8,2	337,0	362,0	974,0
	10	28,67	17,84	32,23	7,1	370,0	370,0	1083,0
	23	28,31	18,36	33,17	17,9	370,0	392,0	1115,0
	24	fond						
POSTE N° 3 16 MARS 1962								
—1—	0	27,79	1,90	3,46	9,1	37,0	40,0	138,0
6 h 05	1	28,61	7,59	13,73	5,8	119,8	144,0	562,6
à	2	29,20	12,23	22,11				
6 h 20	5	29,00	16,79	30,34	5,8			
	10	28,53	18,19	32,86	3,9			
	15	28,29	18,45	33,33	4,1			
	16	fond						
—2—	0	28,33	2,43	4,42	7,0	46,4	96,0	169,4
9 h 05	1	28,49	3,43	6,22	10,6	105,6	164,0	239,6
à	2	29,40	12,38	22,38				
9 h 15	5	29,26	16,24	29,34	3,7			
	10	28,85	17,59	31,78	5,5			
	15	28,09	18,63	33,66	3,9			
	16	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 3								
—3—	0	29,75	5,16	9,34	7,1	134,5	168,0	357,3
11 h 55	1	29,46	9,34	16,89	7,7	216,0	276,0	587,5
à	2	29,48	14,01	25.32				
12 h 05	5	29,37	16,21	29,29	3,1			
	10	28,83	17,70	31,98	3,7			
	15	27,97	18,75	33,87	4,6			
	16	fond						
—4—	0	30,30	2,83	5,14	6,8	99,0	160,0	237,0
14 h 20	1	30,20	4,28	7,76	6,5	119,0	178,0	293,2
à	2	29,62	12,31	22,25				
14 h 30	5	29,47	16,41	29,65	5,5			
	10	29,05	17,29	31,24	8,9			
	16	28,05	18,69	33,77	4,6			
	17	fond						
—5—	0	30,23	1,62	2,95	6,4	35,2	36,0	92,4
17 h 00	1	29,71	11,61	20,99	5,0	228,0	244,0	648,0
à	2	29,75	13,87	25,07				
17 h 10	5	29,45	16,22	29,31	4,0	333,0	324,0	1181,0
	10	29,37	16,68	30,14	4,4	380,5	332,0	1187,0
	16	28,39	18,36	33,17	5,5	380,5	374,0	1136,0
	17	fond						
			POSTE N° 4		16 MARS 1962			
—1—	0	29,10	15,21	27,48	3,7			
7 h 25	1	29,11	15,27	27,59	5,0			
à	2	29,14	15,29	27,63				
7 h 40	5	29,20	16,01	28,93	5,4			
	10	28,65	18,24	32,95	4,4			
	16	28,29	18,49	33,40	6,1			
	17,5	fond						
—2—	0	29,47	15,30	27,65	3,6			
10 h 05	1	29,37	15,31	27,66	3,6			
à	2	29,33	15,30	27,65				
10 h 25	5	29,37	15,50	28,01	2,7			
	10	28,69	18,22	32,92	2,7			
	16	28,18	18,61	33,62	3,1			
	17	fond						
—3—	0	29,80	11,82	21,37	4,6			
12 h 50	1	29,68	12,79	23,12	3,8			
à	2	29,59	14,40	26,02				
13 h 05	5	29,49	15,66	28,30	2,4			
	10	28,68	18,23	32,94	3,3			
	17	28,23	18,59	33,58	5,1			
	18	fond						
—4—	0	30,10	10,73	19,40	5,5			
15 h 20	1	29,90	12,97	23,44	5,8			
à	2	29,73	15,11	27,30				
15 h 35	5	29,32	15,50	31,62	3,6			

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/₀₀	S °/₀₀	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 4								
fin du	10	28,59	18,30	33,06	3,4			
—4—	18	27,97	18,78	33,93	4,4			
	19	fond						
—5—	0	30,09	5,89	10,66	5,7	161,0	116,0	430,5
18 h	1	29,68	13,20	23,86	5,2	238,0	230,0	962,0
à	2	29,63	14,14	25,55				
18 h 15	5	29,55	16,26	29,38	4,0	363,0	298,0	1102,0
	10	28,78	18,17	32,83	3,6	380,5	364,0	1327,0
	17	28,08	18,68	33,75	5,8	387,0	368,0	1254,0
	18	fond						
POSTE N° 5 17 MARS 1962								
—1—	0	27,92	6,53	11,82	6,6	167,0	130,0	457,0
7 h 15	1	28,40	7,90	14,29	4,4	200,0	162,0	578,5
à	2	29,12	13,35	24,13				
7 h 25	5	29,12	16,54	29,88	2,9	363,0	340,0	1103,0
	10	28,97	17,77	32,10	0,8	399,0	378,0	1178,0
	20	28,27	18,64	33,68	4,6	445,0	392,0	1205,0
	21	fond						
—2—	0	29,21	9,47	17.12	5,0			
9 h 45	1	29,13	10,07	18,21	5,4			
à	2	29,15	12,51	22,61				
9 h 55	5	29,27	16,46	29,74	4,0			
	10	28,62	18,31	33,08	3,8			
	20	28,15	18,63	33,66	3,6			
	21	fond						
—3—	0	30,80	14,37	25,97	4,0			
14 h 10	1	29,82	14,71	26,58	2,3			
à	2	29,75	14,79	26,73				
14 h 20	5	29,39	16,39	29,61	3,3			
	10	28,79	18,22	32,92	3,0			
	22	28,12	18,68	33,75	2,6			
	23	fond						
—4—	0	30,61	15,50	28,01	2,9			
16 h 10	1	30,45	15,53	28,06	2,5			
à	2	29,82	15,67	28,31				
16 h 20	5	29,57	15,99	28,89	2,7			
	10	29,07	17,70	31,98	2,2			
	22	27,97	18,76	33,89	1,0			
	23	fond						
POSTE N° 6 17 MARS 1962								
—1—	0	28,72	17,24	31,15	2,1			
5 h 35	1	28,77	17,28	31,22				
à	2	28,88	17,28	31,22				
6 h 00	5	28,87	17,28	31,22	2,8			
	10	28,99	17,62	31,83				
	12,5	28,69	18,34	33,13	4,1			
	14,5	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl ‰	S ‰	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 6								
—2—	0	28,18	7,94	14,36	4,4			
8 h 10	1	28,45	9,99	18,06				
à	2	28,84	15,52	28,04				
8 h 30	5	28,97	17,13	30,95	3,6			
	10	28,88	18,13	32,75				
	13	28,37	18,64	33,68	5,3			
	14	fond						
—3—	0	29,20	11,20	20,25	5,7			
10 h 40	1	29,14	11,44	20,68				
à	2	29,30	15,86	28,66				
11 h	5	29,14	17,03	30,77	5			
	10	28,88	18,00	32,52				
	14	28,45	18,64	33,68	4,1			
	15	fond						
—4—	0	30,55	14,34	25,91	3,9			
12 h 55	1	29,58	14,46	26,13	3,2			
à	2	29,59	14,63	26,44				
13 h 15	5	29,14	16,79	30,34	3,2			
	10	28,87	18,15	32,79	5,9			
	15	28,29	18,81	33,98	5,5			
	16	fond						
—5—	0	30,63	15,72	28,40	3,1			
15 h 05	1	30,35	15,64	28,26				
à	2	29,58	15,80	28,55				
15 h 25	5	29,51	15,96	28,24				
	10	28,94	18,39	33,22				
	13	28,87	18,77	33,91	3,2			
	14	fond						
POSTE N° 7 9 MARS 1962								
—1—	0	28,81	15,14	27,36	2,2			
6 h 45	1	28,90	15,13	27,34	2,6			
à	2	28,97	15,23	27,52				
7 h	5	28,99	16,34	29,52	3,2			
	10	28,99	16,76	30,28	7,0			
	11	fond						
—2—	0	30,01	13,86	25,05	46,5			
11 h 10	1	29,47	13,69	24,74	202,0			
à	2	29,13	14,22	25,70				
11 h 20	5	29,05	14,71	26,58	400,0			
	7	29,05	15,69	28,35	864,0			
	8	fond						
—3—	0	30,78	11,33	20,48	10,2	257,0	244,0	727,5
14 h 40	1	30,40	12,28	22,20	9,2	282,0	244,0	848,5
à	2	29,31	13,37	24,16				
14 h 50	5	29,17	16,35	29,54	155,0	363,0	344,0	1084,0
	7	29,12	16,50	29,81	241,0	363,0	352,0	1079,0
	8	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
POSTE N° 8 10 MARS 1962								
—1—	0	29,00	14,89	26,91	8,3			
8 h 45	1	29,00	14,87	26,87	0,9			
à	2	28,94	14,98	28,07				
9 h 00	5	29,07	16,66	30,10	4,5			
	10	28,65	17,94	32,41	3,1			
	21	28,07	18,63	33,66	1,7			
	22	fond						
—2—	0	32,00	15,89	28,71	2,8			
12 h 30	1	30,14	15,87	28,68	4,6			
à	2	29,69	15,85	28,64				
12 h 40	5	29,25	16,60	29,99	3,1			
	10	28,86	17,69	31,96	3,7			
	18	28,47	18,26	32,99	4,1			
	19	fond						
—3—	0	30,80	5,82	10,54	8,8	157,0	93,5	426,5
16 h 05	1	29,66	12,31	22,25	13,9	282,0	244,0	883,5
à	2	29,95	11,83	21,38				
16 h 15	5	29,07	17,48	31,58	3,8	370,0	356,0	1192,0
	10	28,80	17,94	32,41	2,4	387,0	364,0	1112,0
	20	28,53	18,23	32,94	0,9	407,0	370,0	1218,0
	21	fond						
POSTE N° 9 10 MARS 1962								
—1—	0	28,61	17,71	32,00	2,1			
7 h 20	1	28,58	17,73	32,03	4,9			
à	2	28,58	17,74	32,05				
7 h 30	5	28,58	17,84	32,23	2,0			
	10	28,52	18,08	32,66	4,8			
	21	28,09	18,77	33,91	3,2			
	22,5	fond						
—2—	0	30,31	14,98	27,07	4,5			
11 h 20	1	29,51	14,99	27,09	2,9			
à	2	29,30	15,04	27,18				
11 h 30	5	28,75	17,85	32,25	0,8			
	10	28,45	18,31	33,08	0,9			
	19	28,21	18,69	33,77	1,6			
	20	fond						
—3—	0	32,30	15,47	27,95	4,8			
14 h 55	1	29,79	15,91	28,75	4,4			
à	2	29,52	16,54	29,88				
15 h 05	5	29,07	17,39	31,42	1,4			
	10	28,57	18,28	33,03	0,8			
	19	28,17	18,74	33,86	0,8			
	20	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
POSTE N° 11 12 MARS 1962								
—1—	0	29,50	14,85	26,83	4,1			
6 h 50	1	29,53	14,87	26,87	4,1			
à	2	29,52	14,93	26,98				
7 h 00	5	29,17	16,88	30,50	0,8			
	9	29,15	17,19	31,06	1,0			
	10	fond						
—2—	0	30,08	11,45	20,70	5,7	269,0	212,0	813,0
11 h 15	1	29,92	13,70	24,76				
à	2	29,90	12,83	23,19				
11 h 25	5	29,85	14,54	26,27	5,2	315,0	268,0	959,0
	8	29,62	15,78	28,51	6,2	337,0	276,0	1054,5
	9,5	fond						
—3—								
15 h 10	0	30,20	14,40	26,02	1,1			
à	1	30,10	14,43	26,08	4,5			
15 h 20	2	30,08	14,39	26,00				
	5	29,05	16,96	30,64	1,7			
	7	28,77	17,69	31,96	7,1			
POSTE N° 12 13 MARS 1962								
—1—	0	28,62	15,73	28,42	3,6			
8 h 30	1	28,83	16,32	29,49	1,3			
à	2	28,87	16,38	29,60				
8 h 50	5	28,87	17,20	31,08	2,7			
	11	28,27	18,36	33,17	1,8			
	12	fond						
—2—	0	29,45	16,57	29,94	0,9			
12 h 05	1	29,35	16,57	29,94	1,0			
à	2	29,28	16,59	29,97				
12 h 20	5	28,97	17,41	31,46	3,0			
	10	28,54	18,09	32,68	4,0			
	11	fond						
—3—	0	29,88	11,72	21,18	4,2			
16 h 10	1	29,82	12,15	21,96	4,7			
à	2	29,43	15,28	27,61				
16 h 30	5	29,39	17,06	30,82	4,2			
	9	28,68	18,14	32,77	4,8			
	10	fond						
POSTE N° 13 13 MARS 1962								
—1—	0	28,72	16,24	29,34	1,0			
7 h 25	1	29,00	16,61	30,01	0,8			
à	2	29,07	16,77	30,30				
7 h 35	5	28,85	17,50	31,62	4,7			
	15	28,22	18,57	33,55	3,1			
	24	27,27	19,00	34,33	4,0			
	25	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
Suite du POSTE N° 13								
—2—								
11 h 05	0	28,95	16,61	30,01	4,5			
à	1	28,98	16,62	30,03	4,5			
11 h 15	2	29,00	16,69	30,16				
	5	28,88	17,53	31,67	1,4			
	15	28,15	18,59	33,58	2,5			
	24	27,42	18,90	34,14	1,7			
	25	fond						
—3—								
15 h 15	0	29,51	16,40	29,63	3,3			
à	1	29,48	16,40	29,63	4,4			
15 h 25	2	29,17	16,50	29,81				
	5	28,96	17,68	31,94	0,9			
	15	28,07	18,55	33,51	0,7			
	23	27,52	18,90	34,14	3,3			
	24	fond						
POSTE N° 15 12 MARS 1962								
—1—	0	29,50	15,37	27,77	5,5			
8 h 40	1	29,47	15,35	27,74	5,5			
à	2	29,40	15,71	28,39				
8 h 50	5	29,35	17,30	31,26	6,7			
	12	28,79	17,80	32,16	4,4			
	13,5	fond						
—2—	0	30,02	15,49	27,99	3,5			
12 h 25	1	29,95	15,50	28,01	3,0			
à	2	29,74	15,73	28,42				
12 h 35	5	29,67	16,54	29,88	3,4			
	11	29,09	18,00	32,52	4,2			
	12	fond						
—3—	0	29,67	16,03	28,96	1,4			
17 h 20	1	29,68	16,03	28,96	3,2			
à	2	29,68	16,08	29,05				
17 h 30	5	28,82	17,79	32,14	4,4			
	12	27,48	18,35	33,15	1,4			
	13	fond						
POSTE N° 16 12 MARS 1962								
—1—	0	29,34	15,14	27,36	3,5			
9 h 15	1	29,33	15,15	27,38	3,0			
à	2	29,37	15,15	27,38				
9 h 40	5	29,35	15,43	27,88	3,3			
	10	29,15	17,05	30,81	3,5			
	22	27,90	18,47	33,37	3,9			
	23	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 16								
—2—	0	29,91	14,92	26,96	4,2			
13 h	1	29,90	14,94	27,00	5,2			
à	2	29,90	14,95	27,01				
13 h 45	5	29,45	16,69	30,16	3,9			
	10	28,62	18,14	32,77	5,2			
	20	27,14	18,94	34,22	10,0			
	21	fond						
—3—	0	29,45	16,15	29,18	3,0			
18 h 20	1	29,50	16,09	29,07	4,0			
à	2	29,50	16,13	29,14				
18 h 30	5	29,43	16,52	29,85	3,6			
	10	28,82	17,96	32,45	3,2			
	20	27,97	18,61	33,62	5,0			
	22	fond						
POSTE N° 17 13 MARS 1962								
—1—	0	28,70	16,25	29,36	0,8			
6 h 30	1	28,70	16,25	29,36	1,1			
à	2	28,80	16,39	29,61				
6 h 40	5	28,58	17,69	31,96	3,3			
	15	28,04	18,56	33,53	0,8			
	31	26,47	19,22	34,72	0,9			
	32	fond						
—2—	0	28,82	16,58	29,96	3,0			
10 h 05	1	28,80	16,55	29,90	4,0			
à	2	28,81	16,47	29,76				
10 h 15	5	28,87	17,27	31,20	0,9			
	15	27,65	18,75	33,87	2,7			
	31	26,55	19,11	34,52	5,4			
	32	fond						
—3—	0	29,34	13,90	25,15	2,8			
13 h 55	1	29,18	15,09	27,27	1,0			
à	2	29,00	16,33	29,51				
14 h 15	5	28,79	17,46	31,55	0,8			
	15	27,99	18,55	33,51	4,4			
	29	26,92	19,07	34,45	4,5			
	30	fond						
POSTE N° 19 9 MARS 1962								
—1—	0	28,88	15,56	28,12	2,2			
7 h 50	1	28,94	15,58	28,15	1,1			
à	2	29,14	15,98	28,87				
8 h	5	29,16	16,57	27,94	1,1			
	10	29,13	16,67	30,12	0,8			
	15	29,09	16,82	30,39	3,7			
	16	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl °/oo	S °/oo	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du POSTE N° 19								
—2—	0	30,11	14,84	26,82	5,5			
12 h 00	1	29,71	15,25	27,56	3,3			
à	2	29,64	15,66	28,30				
12 h 10	5	29,46	16,36	29,56	3,3			
	10	29,25	16,70	30,17	2,2			
	12	29,02	17,05	30,81	0,7			
	12,5	fond						
—3—	0	30,19	15,74	28,44	3,3			
15 h 45	1	29,91	15,93	28,78	4,1			
à	2	29,78	16,13	29,14				
15 h 55	5	29,15	16,73	30,23	1,6			
	10	28,99	17,19	31,06	4,4			
	14	28,99	17,20	31,08	9,4			
	15	fond						
POSTE N° 20 9 MARS 1962								
—1—	0	29,08	16,13	29,14	1,4			
9 h 05	1	29,15	15,72	28,40	3,4			
à	2	28,99	16,24	29,34				
9 h 30	5	28,97	16,60	29,99	2,1			
	10	28,86	17,26	31,18	1,0			
	15	28,67	17,70	31,98	1,4			
	16	fond						
—2—	0	30,08	15,71	28,39	3,3			
13 h 00	1	29,63	15,78	28,61	1,4			
à	2	29,48	16,05	29,00				
13 h 15	5	29,06	16,89	30,52	1,1			
	10	28,86	17,33	31,31	0,6			
	13	28,76	17,64	31,87	1,1			
	14	fond						
—3—	0	30,09	16,44	29,70	3,5			
17 h 00	1	30,11	16,45	29,72	1,5			
à	2	29,76	16,68	30,14				
17 h 15	5	29,07	17,64	31,69	1,0			
	10	28,85	17,60	31,80	1,0			
	17	28,57	18,00	32,52	2,7			
	18	fond						
POSTE N° 21 10 MARS 1962								
—1—	0	28,40	18,13	32,75	1,5			
6 h 20	1	28,43	18,12	32,74	0,6			
à	2	28,44	18,13	32,75				
6 h 30	5	28,47	18,13	32,75	1,0			
	15	28,37	18,43	33,30	2,5			
	31	28,43	19,21	34,70	1,9			
	32	fond						

N° de Station et heure	Profondeur en m	Températ. °C	Cl ‰	S ‰	Turbidité mg/l.	K mg/l.	Ca mg/l.	Mg mg/l.
suite du	POSTE N° 21							
—2—	0	29,12	17,61	31,82	0,8			
10 h 20	1	29,08	17,55	31,71	0,7			
à	2	29,02	17,82	32,20				
10 h 30	5	29,05	17,96	32,45	3,0			
	15	28,43	18,44	33,31	3,0			
	31	27,37	19,12	34,54	0,6			
	32	fond						
—3—	0	31,32	16,82	30,39	1,0			
13 h 55	1	29,92	16,77	30,30	2,1			
à	2	29,50	16,86	30,46				
14 h 05	5	28,97	17,56	31,73	1,5			
	15	28,45	18,41	33,26	2,5			
	28	27,62	19,17	34,63	3,3			
	29	fond						
			POSTE N° 23		17 MARS 1962			
—1—	0	29,28	14,30	25,84	0,8			
11 h 45	5	29,02	17,22	31,11	2,6			
à	10	29,07	18,09	32,68				
11 h 50	20	29,15	19,13	34,56				
	150 (environ)		fond					

TABLEAU n° 14

MESURES DES VITESSES DU COURANT EN PÉRIODE DE CRUE DE LA BETSIBOKA

Station et heure	Profondeur en m	Vitesse en m/sec.	Direction	*Station* et heure	Profondeur en m	Vitesse en m/sec.	Direction
		POSTE N° 1		15 MARS 1962			
—1—	0	0,39	0°	—4—	0	0,88	330°
7 h 10	5	0,07	0°	14 h 00	5	0,15	0°
à	10	0,18	180°	à	10	0,07	0°
7 h 20	18	0,23	180°	14 h 20	19	0,20	0°
	19,5	fond			20	fond	
—2—	0	0,29	340°	—5—	0	0,69	
9 h 20	5	0.40	170°	16 h 00	5	0,28	0°
à	10	0,44	170°	à	10	0,26	340°
9 h 32	18	0,35	170°	16 h 28	19	0,20	330°
	19,50	fond			20	fond	

Station et heure	Profondeur en m	Vitesse en m/sec.	Direction	*Station* et heure	Profondeur en m	Vitesse en m/sec.	Direction
suite du POSTE N° 1							
—3—	0	0,45					
11 h 45	5	0,31	170°				
à	10	0,36	180°				
11 h 49	19	0,14	180°				
	20	fond					
		POSTE N° 2		8 MARS 1962			
—1—	0	0,14	35°	—2—			
6 h 00	5	0,37	130°	9 h 30	0	2,37	0°
à	10	0,17	90°	10 h 00	0	2,37	0°
6 h 30	25	0,27	90°	10 h 30	0	2,05	0°
	27	fond		11 h 00	0	1,55	0°
		POSTE N° 4		16 MARS 1962			
—1—	0	0,42	270°	—4—	0	0,44	315°
7 h 30	5	0,22	0°	15 h 25	5	0,20	310°
à	10	0,15	10°	à	10	0,10	350°
7 h 45	15	0,13	10°	15 h 37	16	0,09	350°
	17,5	fond			18	fond	
—2—	0	0,54	270°	—5—	0	0,31	315°
10 h 10	5	0,25	250°	18 h 03	5	0,08	290°
à	10	0,13	305°	à	10	0,27	0°
10 h 30	16	0,15	195°	18 h 11	16	0,27	0°
	18	fond			18	fond	
—3—	0	0,56	290°				
12 h 55	5	0,31	180°				
à	10	0,33	130°				
13 h 05	16	0,17	130°				
	18,5	fond					
		POSTE N° 6		17 MARS 1962			
—1—	0	0,36	300°	—3—	0	0,67	300°
5 h 32	5	0,28	0°	10 h 40	5	0,23	320°
à	12	0,19		à	8	0,11	235°
5 h 48	14,5	fond		10 h 55	12	0,02	
					14	fond	
—2—	0	1,00	300°	—4—	0	0,62	260°
8 h 17	5	0,38	350°	13 h 00	5	0,32	290°
à	8	0,23	350°	à	8	0,10	135°
8 h 30	12	0,10	130°	13 h 15	12	0,21	135°
	14	fond			16	fond	
—5—	0	0,50	260°				
15 h 11	5	0,39	300°				
à	8	0,12	270°				
15 h 19	12	0,10	270°				
	15	fond					

Station et heure	Profondeur en m	Vitesse en m/sec.	Direction	*Station* et heure	Profondeur en m	Vitesse en m/sec.	Direction
POSTE N° 12 13 MARS 1962							
—1—	0	0,37	40°	—3—			
8 h 35	5	0,12	110°	16 h 25	0	0,34	160°
à	11	0,09	110°	à	5	0,29	100°
8 h 45	12	fond		16 h 30	9	0,22	100°
—2—	0	0,29	350°				
12 h 20	5	0,37	320°				
à	9	0,35	280°				
12 h 35	11	fond					
POSTE N° 16 12 MARS 1962							
—1—	0	0,31	40°				
9 h 20	5	0,12	35°				
à	10	0,05	300°				
9 h 45	—	0,12	100°				
	21	0,24	320°				
	22	fond					
POSTE N° 20 9 MARS 1962							
—1—	0	0,88	330°	—3—	0	0,57	220°
9 h 15	5	0,40	300°	17 h	5	0,60	200°
à	10	0,49	320°	à	10	0,47	200°
9 h 35	15	0,27	340°	17 h 15	17	0,22	200°
	16	fond			18	fond	
—2—	0	0,30	250°				
13 h 05	5	0,55	230°				
à	10	0,26	210°				
13 h 30	13	0,28	180°				
	14	fond					

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Reprinted from *Proceedings. Seminar on Geomorphological Studies in India 1965*, 1967, p. 114-120

17-11-1965 Session 9 Chairman : **Prof. V. S. Gananathan**

SUBMARINE CANYONS OFF THE EAST COAST OF INDIA

M. Subba Rao †, K. Venkata Ratnam ‡, and P. R. Chandra §

INTRODUCTION

Except for the submarine canyons around Ceylon, the trough-like valley off the Ganges delta (Hayter, 1960) and the suspected north-south running turbidity channels (Dietz, 1953), the deep floor of the Bay of Bengal was believed until recently to be a monotonous plain gently sloping southwards into the Indian Ocean (Dietz, 1953). Its surrounding shelves and slopes too were thought to be devoid of any notable features. But as a result of the current intensive exploration of the Bay of Bengal in connection with the International Indian Ocean Expedition Programme, its oceanography is now better understood and many physiographic features of the sea-floor such as mountain chains, submarine canyons, deep channels, etc., have been brought to light. It is the purpose of this paper to describe mainly the submarine canyons discovered along the shelf and continental slope between Visakhapatnam and Madras during the 18th Scientific Cruise of INS Kistna (August 2-9, 1964) organized by the Indian National Committee on Oceanic Research, New Delhi (INCOR).

Even though the British Hydrographic charts have suggestively shown some canyons along the east coast of India, La Fond (1964) was the first to establish their existence on the east coast of India. The canyons discovered by La Fond are located E.N.E of Visakhapatnam (Krishna, Mahadevan, and Andhra canyons between lat. 17°54′ O N. : long 84°16′ 2 E. and lat 17°44′ O N. : 84 01′ O E.). These canyons cut into the continental slope. During the 15th Cruise of INS Kistna two sets of canyons have been reported off the Pondicherry coast between latitudes 11°30′ N and 12°10′ N (Setty, 1964). In fact, there is a suggestion of these canyons in the British Admiralty chart No. 71 itself for here the 100 fathoms isobath bends near the coast in several places. During the 16th Cruise one canyon off the Penner confluence and another off the Gautami Godavari confluencce were discovered (Varadachari, 1964). The 18th Cruise was devoted mainly to geological work when a number of canyons have been identified off the Kakinada-Madras coast. Balarama Murty (1965) has since reported a canyon south of Puri (Lat. 19°30′ N : Long. 85°50′ E *)

Description of the Canyons :

The location of all the canyons and canyon-like features hitherto reported to exist along the east coast of India are shown in Fig. 1. Transverse profiles as obtained by the Edo Echosounder of some of the canyons are presented in Figs. 3, 5, and 6. Depth values of the canyon-floors at different points as obtained from the echogram traces have been transferred on to the Hydrographic charts. Utilizing these depth values together with those already available on the chart, an approximate contouring of such canyons as have

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* International Indian Ocean Expedition - *Newsletter*, India, Voll. II, No. 5.

traversed 3-4 times during the 18th Cruise has been attempted. The different canyons are given identifying names : a majority of them have been named after those rivers in the vicinty of whose confluences they are located.

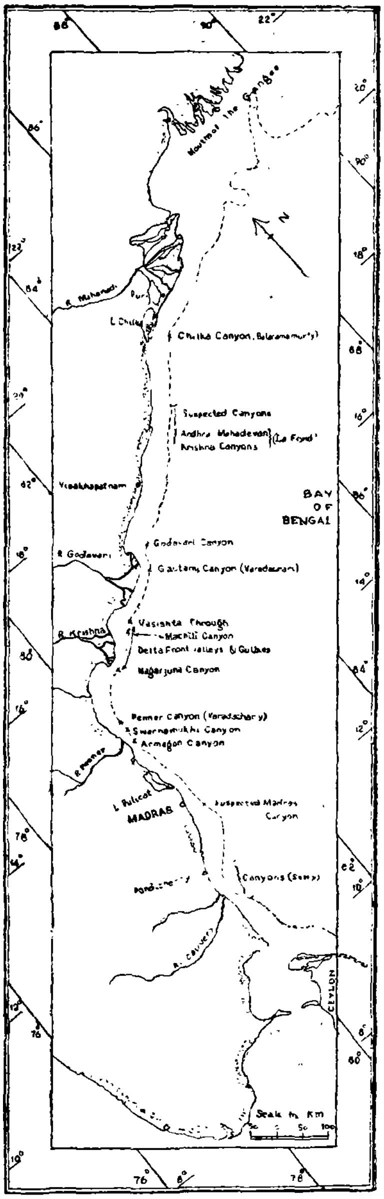

Fig. 1

The East Coast of India

(Locations of submarine canyons)

Swarnamukhi canyon :

Four traverses were made across the Swarnamukhi canyon (Fig. 2). The one running near the coast at depths of around 25 fathoms has not revealed any topographic feature while the other three have revealed the canyon aspects in the echo profiles. It is presumed that the valley heads in around 30-35 fathoms depth. Toward the headward portion the profile (Fig. 3 A) shows a number of valleys marked *a, b, c, d* & *e*. The inter-valley crests are all very sharp except the one between *a* and *b* which is broad showing a notch marked *x*. The second traverse does not appear to have crossed the canyons at right angles to their trend for the profile shows unequally sloping walls and also the floors are somewhat broader probably because of the meandering nature of the canyons (Fig. 3 B). But for the valleys incised in the deep central portion, the profile presents a U-shape in the most-seaward traverse (Fig. 3 C). At this crossing the valleys *a*, *b*, & *c* reach a depth of 700, 500, and 540 fathoms respectively. The intervening sharp crests rise to 430 fathoms. The sharp pinnacles that show up on the northern wall of valley *d* are smoothened out in the profile II while they make their appearance again in the profile III. The southern wall of the valley *a* which is smooth in the profile I develops irregularities towards the east. The ridge between *a* and *b* become sharp in the profile II. Most of the smaller valleys are in general confined to the northern side of the topographic depression. While moving up the shelf from traverse III to traverse I, a valley having a crossing depth of 200 fathoms is encountered (Fig. 3 D). This is obviously a tributary valley running into the major system from the south.

Penner canyon :

The Penner canyon was approached from the southern side during the 16th Cruise. The profile (not shown) shows many valleys and terrace-like features of the continental slope towards the south. In the upper portion the feature consists of five valleys which are all typically V-shaped and the

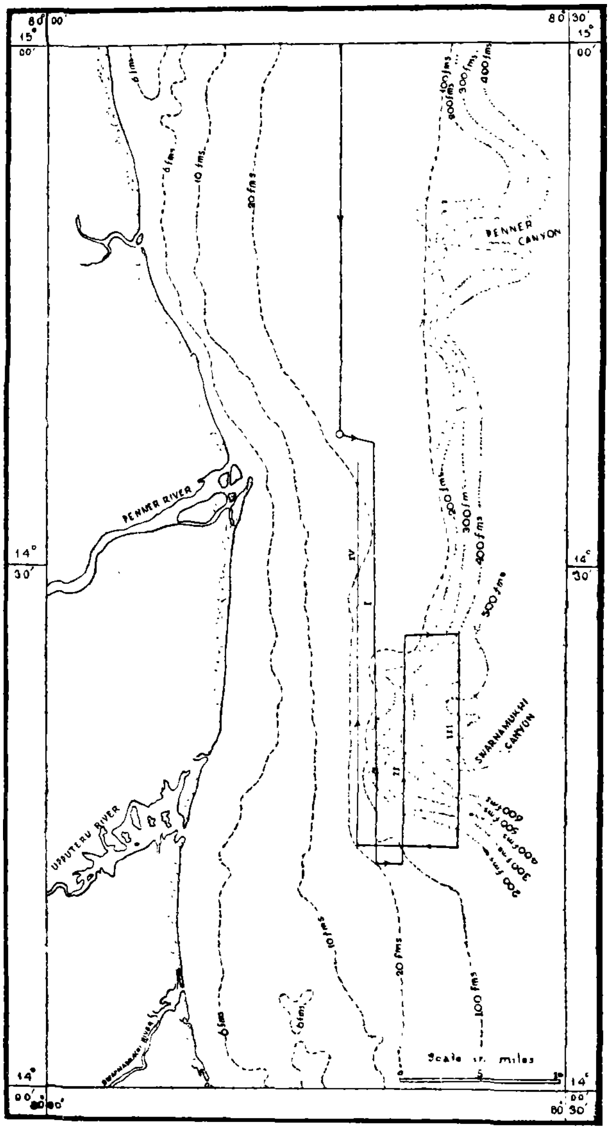

Fig. 2

Swarnamukhi and Penner Canyons

intervening ridges are quite sharp. The deepest valley has a crossing depth of 450 fathoms. The profile shows that the northernmost wall is more rugged.

Nagarjuna canyon :

Three traverses were made across the Nagarjuna canyon (Fig. 4). The canyon commences its course at about 25 fathoms depth. The bottom of the canyon is narrow and V-shaped at its head (Fig. 5 A). It has a depth of 240 fathoms at this crossing; the canyon becomes broader seaward. The profile of traverse II (Fig. 5 B) indicates a smaller southern valley and a larger northern valley with crossing depths of 200 and 350 fathoms respectively. Between traverses I and II as the ship moved down the slope, a small valley of 25 - 30 fathoms depth was encountered. It is possibly a tributary and a landward extension of the smaller valley that appeared in the profile of traverse II. Both the walls of the bigger valley are irregular either because of tributaries or of slump structures. Four valleys are revealed in the profile of traverse III (Fig. 5 C). From north to south these valleys have depths of 400, 470, 370 300 fathoms respectively at this crossing. The two northern crests are sharp while the southern crest rising to 160 fathoms is broad with slump structures. The tributary valleys that are only present as minor features in the central profile are well shaped into imposing valleys in the profile of traverse III. The major trend of the valley is towards the south-east.

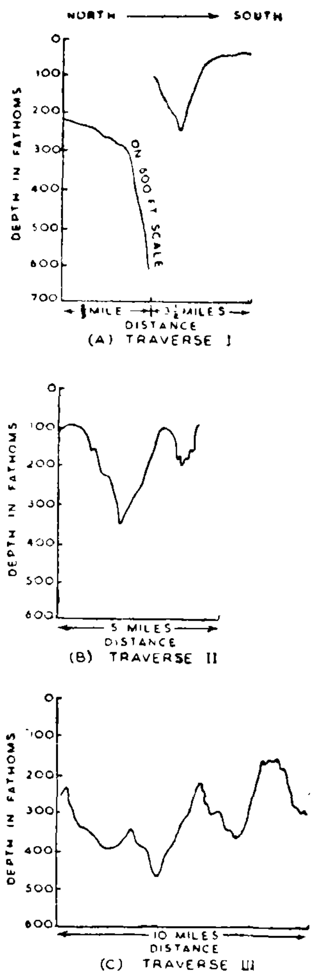

Fig. 5

Echo-profiles of Nagarjuna Canyon

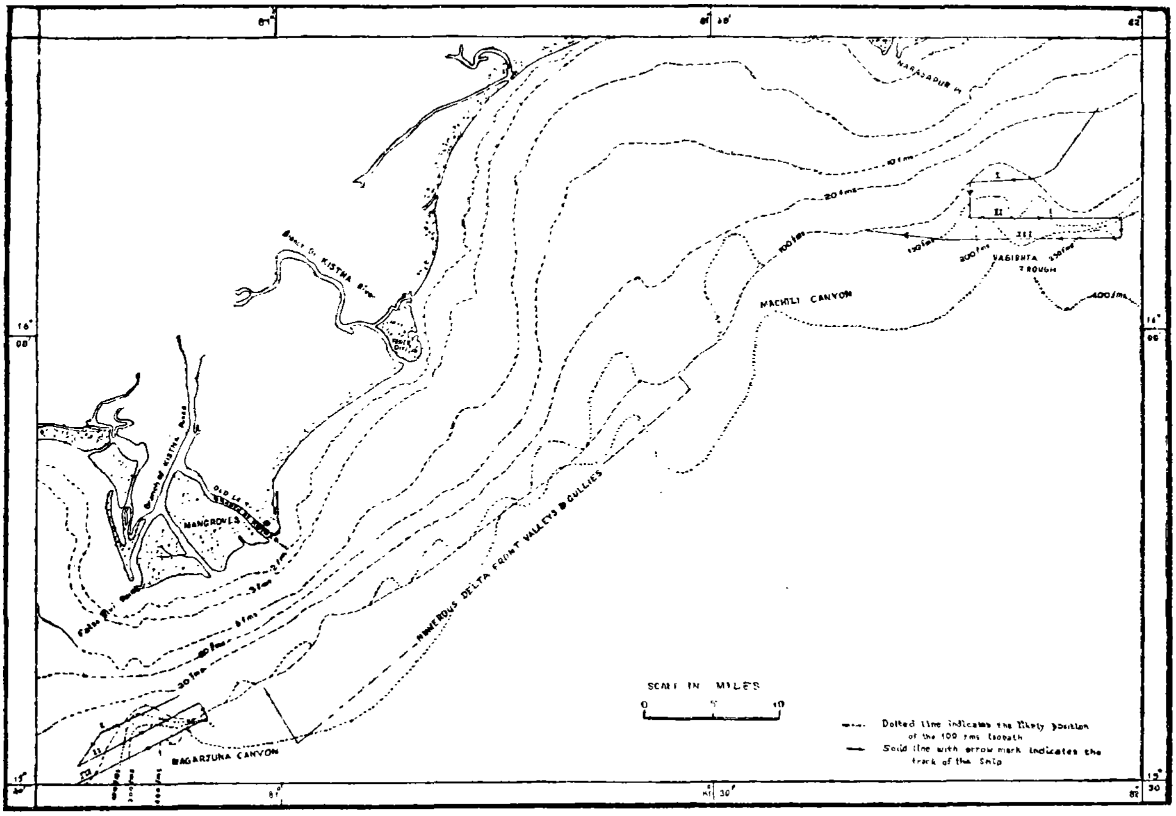

Fig. 4
Nagarjuna Canyon (bottom left)

Valleys between Krishna and Vasishat-Godavari Confluences :

The entire continental slope between False Divi Point and Narsapur Point (Fig. 4) is indented by numerous valleys and trough-like features. These may aptly be described as delta-front troughs or valleys and they are of much bigger dimensions than the valleys and gullies which have been described by Shepard (1955) off the Mississippi delta and by Mathews and Shepard (1962) of the Fraser river delta, British Columbia, Canada. The Vasishat trough across which three traverses were made and the Machili canyon may be relegated to the category of delta-front valleys while the others may be described as delta-front gullies.

Godavari Canyon :

The Godavari canyon crossed in the 16th Cruise is made up of five valleys. The deepest of them is 275 fathoms deep (not shown).

Gautami Canyon :

The traverse across the Gautami canyon shows in the echo profile four valleys designated as *p*, *q*, *r*, & *s*, which reach respectively depths of 205, 230, 250 and 155 fathoms at this crossing (Fig. 6 D). They are all V-shaped except *r* which shows conspicuous breaks in the slopes of its walls. The inter-valley ridge-crests are all sharp except the one between *r* and *s* which is broad and flat-topped.

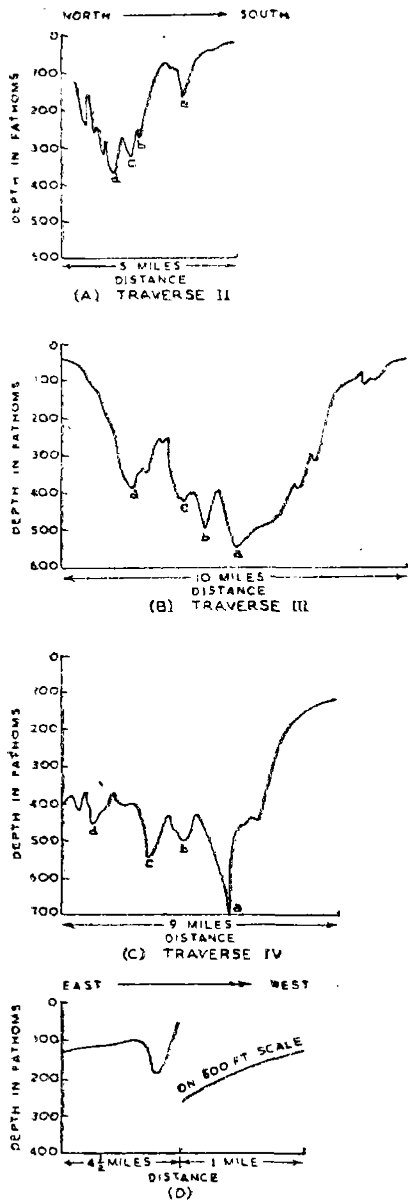

Fig. 3

Echo-profiles of
Swarnamukhi Canyon

Other canyons :

Form the sparingly distributed soundings recorded on the Admiralty charts the likely existence of the following canyons is inferred :

Directly off Madras there appears to be a small canyon on the continental slope, tentatively named the *Madras canyon*. Between the Pulicat Lake and the Swarnamukhi canyon there is a possibility of three or more canyons of which the Armagon canyon has been traversed by the authors. To the north of the Andhra, Mahadevan, and Krishna canyons as far as 18° 30′ N latitude and again off the Orissa coast north of Puri, a large number of canyons of impressive dimensions can be expected.

DISCUSSION

Shepard (1993, p.238) has generalised that the shelf edge of the east coast of India is around 50-70 fathoms except off the deltas where it shoals to 20 fathoms. But there are a few departures from this generalised picture. Between Visakhapatanm and Kakinada the continental slope commences around 90-100 fathoms as shown by the profiles of the shelf off Visakhapatnam (Kukkuteswara Rao, and La Fond, 1954). Also to the north of latitude 18° 30′ N as far as Puri the shelf-break occurs around 120 fathoms as indicated in the profiles of La Fond (1664). On the other hand, the break in slope in other parts occurs around 50-70 fathoms. From the available data, it is noted that it is exactly in the areas where the break in slope occurs at or below 50-70 fathoms that the canyons are numerous. While we do not venture to suggest that there are no canyons where the slope commences around 100 fathoms it is likely that the canyons in such areas may not have attained the dimensions of those discovered off the narrow shelves.

It is significant to note that on such coastal strips off which the shelves are relatively narrow and the cnyons are numerous, a number of rivers, large and small, youthful and old, debouch into the sea. Thus, the Palar, Varahanadi, Ponnaivar, Gadilam, Vellar, Coleroon and a number of small streams empty into the sea on the Pondicherry coast; the Kottalaiyar, Arani, Swarnamukhi, Upputeru, Penner and other smaller rivers on the Madras-Nellore; the Krishna and Godavari and their distributaries on the Central Andhra coast; Vamsadhara, Langulya and many other smaller streams on the Northern Andhra coast; and the Mahanadi and its distributaries on the Orissa coast. Also bigger valleys occur in the proximity of smaller rivers and vice versa with the exception of "Swatch of no ground". But in no case do the trends of the present river channels appear to lead into the heads of the submarine canyons. A possible explanation would be that the seaward ends of the river-valleys as well as the headward portions of the submarine canyons are obscured since the end of the Pleistocene glacial stages or even earlier. Or the canyon heads did not cut across the shelf because they lacked the sediments necessary for submarine erosion since the rapid rise of sea-level during the Pleistocene.

Submarine valleys which have been classified into seven types by Shepard (1963, p. 311-312) might originate in a variety of ways. But in recent years most of the hypotheses explaining the canyons as the products of artesian springs coming out along the continental slopes, tsunamis, diastrophic movements, land slides etc., "have been gradually discarded, leaving only the turbidity current hypothesis and another which combines subaerial erosion with drowning and maintenance of the canyons by turbidity currents, submarine slides, and sand flows." (Shepard, 1963, p. 337). With the investigation of the canyons off the east coast of India still at the nascent stage it is far premature to ascribe a definite mode for their origin. However, one is tempted to explain some of these canyons as having been produced by subaerial erosion by rivers much earlier than the Pleistocene, for the east coast of India is said to have taken its present configuration as early as in the Upper Jurassic (Krishnan, 1960, p. 76). The other smaller canyons located in the vicinity of the active rivers may owe their origin to the submarine processes such as those of the turbidity currents.

The Krishna and Godavari deltas are advancing seaward in an eastern direction much more rapidly than in the other directions. During the high flood stages in the Godavari and Krishna rivers (July-September), the winds are predominantly south - westerly over the region where these rivers join the sea. The surface currents of July-August in the Bay of Bengal are directed in the area north and north-east. Consequently the fine detritus delivered to the sea by the rivers will be transported in a north-east direction into the deeper waters. In the post-south-west monsoon period, when the winds are light and variable the transport direction is influenced much by the surface currents in the ocean. Currents as deduced from the thermal field studies (Ramasastry, and Balaramamurty, 1957) are directed southwards below a depth of 100 feet in the entire region. But in the surface layer of 100 feet they are directed northwards towards the coast north of the Godavari confluence and south of the Goadavari confluence they are directed southwards It may be surmised that the net effect of these current systems aided by other hydrodynamical factors will be such as to trigger off mudflows and landslides that produce south-east-trending delta- front valleys.

CONCLUSION :

The authors are deeply aware that "in spite of the amount of writing on the subject, the origion of canyons remains shrouded in mystery" (Guilcher, 1958). And yet they are inclined to believe that some of the canyons off the east coast of India were formed in the remote past, while some others have originated during the Pleistocene and have been maintained since then by progressive slumps, density flows, and slow creep.

ACKNOWLEDGEMENTS :

The authors are thankful to Dr N. K. Panikkar for allowing them to participate in the 18th Cruise of INS Kistna. They are particularly indebted to the Commanding Officer of INS Kistna, J. N. Maitra, his Officer colleagues and the crew for their whole-hearted co-operation during the cruise.

* * * *

During the discussion that followed, Dr. J. P. Mishra remarked that while accounting for the origin of these canyons, the speaker had overlooked the role of sea level changes just after the Pleistocene glacial period. At least some of the canyons, which crossed the continental shelf and existed off the rivers of the Indian land, he felt, had been carved out by rivers and were only drowned river-valleys.

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Reprinted from *Okeanol. issled.*, no. 18, 1968, p. 156-174

Е. И. Гордеев

ГРАНУЛОМЕТРИЧЕСКИЙ СОСТАВ ВЗВЕСИ ИЗ ПОВЕРХНОСТНЫХ ВОД СЕВЕРНОЙ И ЦЕНТРАЛЬНОЙ ЧАСТЕЙ ИНДИЙСКОГО ОКЕАНА

Широкий комплекс исследований, проводившихся в Индийском океане на э/с «Витязь» [1, 2], включал значительные работы по изучению взвешенного вещества в морской воде. Количественное распределение взвеси в поверхностном слое вод северной части океана рассматривалось ранее [4]. Представляется интересным выяснить особенности распределения взвешенного вещества в зависимости от крупности частиц. Этот вопрос имеет большое значение для выяснения закономерностей современного осадконакопления, а также гидрохимии, гидрооптики и других разделов океанологии [7].

Для проведения гранулометрического анализа взвеси обычно требуется несколько граммов сухого вещества. Получение такого количества взвеси стало возможным лишь после внедрения в практику океанологических работ новой методики сбора взвеси, в первую очередь высокопроизводительных промышленных сепараторов [6, 8].

На э/с «Витязь» в 33-м рейсе для сбора взвешенного материала использовалась сепарационная установка, состоящая из пары сепараторов двух типов шведской фирмы Де Лаваль. Камерный сепаратор типа К-212-35S имеет барабан из нержавеющей стали с 5000 *об/мин*. Тарельчатый сепаратор типа Vib 1929 С имеет также барабан из нержавеющей стали с 6000 *об/мин*. Подача воды в сепараторы осуществлялась из носовой части судна при помощи насоса ВЦН-65у по полиэтиленовому шлангу, что предохраняло пробы от попадания в них грязи и ржавчины. Этому же способствовал режим работы установки — пробы отбирались только на ходу судна, а на станциях сепараторы выключались.

Камерный сепаратор разделяет взвешенное вещество в зависимости от гидравлической крупности на четыре фракции, тарельчатый дает одну фракцию.

Сепарационная установка работала по схеме последовательного включения, т. е. вода сначала поступала в камерный сепаратор, где отделялись четыре фракции взвеси, затем в тарельчатый, где улавливались более мелкие частицы, не осевшие в камерном сепараторе. В итоге мы получали пять фракций. Кроме этого, после съема взвеси из сепараторов, все детали барабанов, с которых не удалось собрать взвесь механически, тщательно обмывались чистой водой, которая затем для отделения оставшейся взвеси пропускалась через лабораторный сепаратор Lab-202 с числом оборотов барабана 15 000 в 1 *мин*. Таким образом, взвесь из сепараторов практически извлекалась полностью.

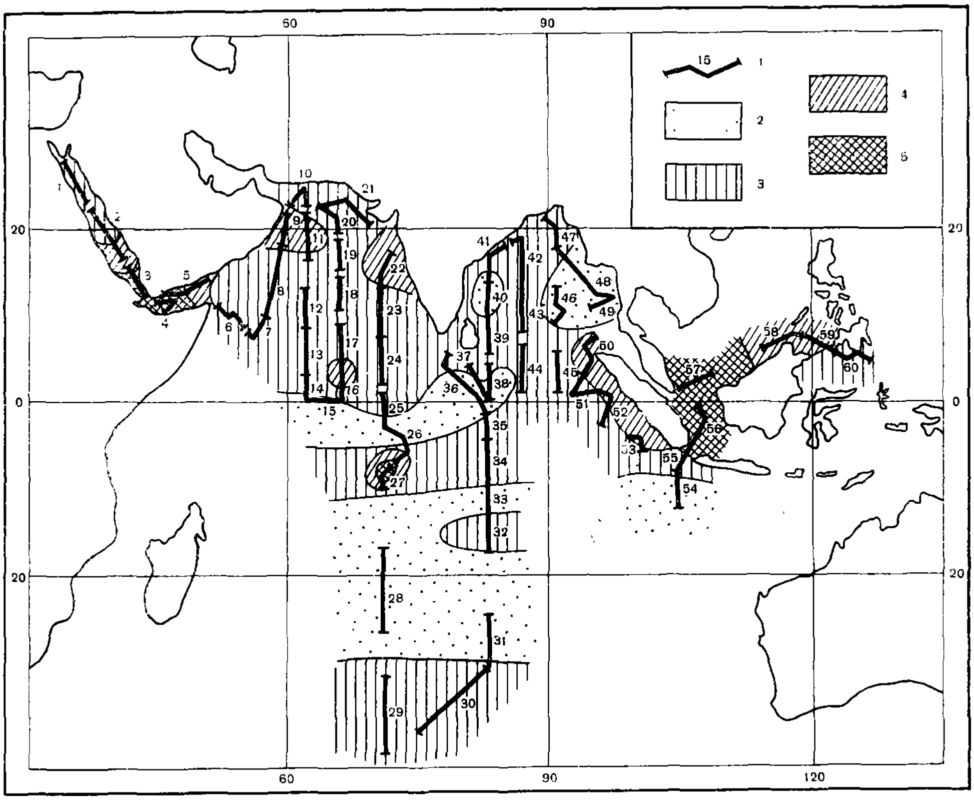


Рис. 1. *Схема расположения сепарационных проб и концентрация взвеси в поверхностном слое воды*

1 — места взятия пробы и ее номер; концентрация (в *г/м³*): 2 — меньше 0,1; 3 — 0,1—0,2; 4 — 0,2—0,3; 5 — больше 0,3

Опытным путем было установлено, что наиболее полно взвесь в сепараторах отделялась при производительности их 2,5—3 *м³/час*. Обычно для получения одной пробы установка работала непрерывно на ходу судна в течение 20—30 *час* и перерабатывала 70—100 *м³* воды, т. е. в одну пробу попадал взвешенный материал, собранный с отрезка пути в 250—300 миль (450—550 *км*). Глубина забора воды равнялась 0—5 *м*.

Всего за рейс было получено 66 проб взвеси (из них 55 непосредственно в Индийском океане) из 5500 *м³* поверхностной воды. Схема расположения проб показана на рис. 1.

Параллельно с отбором проб методом сепарации на каждой станции (а на переходах без станций) три раза в сутки производился отбор проб воды для определения содержания взвеси методом мембранной ультрафильтрации. Это давало надежные данные о концентрации взвеси в каждой отдельной точке, в то время как сепарационные пробы являлись суммарными и характеризовали участки океана большой протяженности.

Пробы взвеси, полученные методом сепараций, сразу после получения высушивались при температуре около 70°. Гранулометрический анализ взвеси производился по методу Института океанологии [9, 10], разработанному для осадков. Применимость его к анализу взвеси была убедительно показана на материалах 2-го рейса Морской Антарктической экспедиции на д/э «Обь» [7].

Местоположение, концентрация и гранулометрический

№ пробы	Часы и дата работы сепараторов		Координаты участков работы		Средняя концентрация взвеси, г/м³
	начало	конец	начало отбора	конец отбора	
1	12.X 60 г. 08^h00^m	13.X 60 г. 08^h00^m	27°11′ 9″ с. ш. 34 05 1 в. д.	21°36′ 0″ с. ш. 34 05 0 в. д.	0,144
2	13 11 00	15 08 00	21 50 37 20	16 00 41 20	0,183
3	15 11 20	16 13 00	15 30 41 50	12 30 44 20	0,340
4	21 01 10	21 12 20	12 17 45 06	10 59 45 43	0,329
5	24 17 00	25 20 00	12 34 45 11	14 44 50 02	0,256
6	28 15 00	31 13 15	11 06 52 14	8 20 55 50	0,189
7	31 15 45	2.XI 08 45	07 34 55 57	11 10 57 37	0,106
8	2.XI 15 15	4 06 20	11 07 57 34	17 22 59 02	0,138
9	4 11 15	5 17 35	17 19 58 58	22 24 59 54	0,246
10	5 19 30	8 05 50	22 24 59 54	22 49 62 04	0,177
11	8 12 00	9 20 55	21 52 62 04	16 49 62 03	0,216
12	11 13 00	12 08 50	12 08 62 14	08 40 61 55	0,191
13	13 15 00	15 05 25	08 37 61 55	03 27 62 07	0,160
14	15 13 10	16 16 20	03 30 с. ш. 62 18	00 02 ю. ш. 62 17	0,137
15	16 19 40	18 22 20	00 02 ю. ш. 62 21	00 01 ю. ш. 66 02	0,048
16	19 03 10	20 12 20	00 03 с. ш. 66 10	04 49 с. ш. 66 04	0,201
19	25 07 40	26 05 10	15 10 65 57	19 15 65 56	0,147
20	27 10 55	28 13 05	19 30 65 56	23 01 63 21	0,157

состав проб взвеси Индийского океана

Гранулометрический состав											
%						г/м³					
фракции, *мм*											
>0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	>0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001
4,56	2,10	21,40	8,07	8,42	55,4	0,0066	0,0030	0,031	0,012	0,012	0,08
2,54	0,73	16,0	9,45	6,54	64,73	0,005	0,001	0,029	0,017	0,012	0,118
3,20	0,64	14,74	2,56	5,77	73,08	0,011	0,002	0,050	0,009	0,02	0,248
5,96	3,16	21,05	8,07	1,40	60,35	0,02	0,01	0,069	0,027	0,005	0,199
4,59	0,71	13,78	6,71	7,77	66,43	0,012	0,002	0,035	0,017	0,02	0,17
3,82	1,39	19,44	8,33	7,29	59,72	0,007	0,003	0,037	0,016	0,014	0,113
3,18	1,71	19,43	9,19	8,13	59,36	0,003	0,001	0,021	0,01	0,009	0,063
2,11	1,06	14,08	21,83	6,69	54,22	0,003	0,001	0,019	0,030	0,009	0,075
1,07	0,35	12,86	7,86	5,71	72,14	0,003	0,001	0,032	0,019	0,014	0,177
2,50	1,43	21,07	7,86	5,36	62,14	0,004	0,002	0,037	0,014	0,009	0,110
4,22	1,41	21,13	5,99	6,34	60,91	0,009	0,003	0,046	0,013	0,014	0,132
6,32	3,16	22,10	7,37	4,91	56,14	0,012	0,006	0,042	0,014	0,009	0,107
4,56	4,56	22,81	6,67	5,26	56,14	0,007	0,007	0,036	0,011	0,008	0,090
5,96	2,81	16,14	7,37	8,77	58,95	0,008	0,004	0,022	0,01	0,012	0,081
2,82	0,70	15,84	7,75	9,51	63,38	0,001	0,0	0,008	0,004	0,005	0,030
3,18	2,12	21,55	9,89	10,60	52,65	0,006	0,004	0,043	0,02	0,021	0,106
10,04	2,15	17,20	7,53	3,23	59,85	0,015	0,003	0,025	0,011	0,005	0,088
2,87	0,72	16,49	6,44	9,32	64,16	0,004	0,001	0,026	0,010	0,015	0,101

№ пробы	Часы и дата работы сепараторов		Координаты участков работы		Средняя концентрация взвеси, *г/м³*
	начало	конец	начало отбора	конец отбора	
21	28.XI 60 г. 15^h05^m	30 XI.60 г. 05^h35^m	23°01′ с. ш. 63 21	20°42′ с. ш. 69 08	
22	7.XII 07 25	8.XII 15 20	17 50 72 10	13 19 70 56	0,200
23	8 18 75	10 07 05	13 05 70 58	07 18 71 00	
25	11 19 00	14 07 45	01 34 с. ш. 70 51	03 00 ю. ш. 71 18	
26	14 11 40	16 04 55	02 59 ю. ш. 71 21	07 09 ю. ш. 72 30	0,290
27	17 20 00	18 06 10	07 55 71 50	08 56 70 49	
29	24 23 00	26 21 30	30 40 71 12	36 36 71 15	
30	28 16 25	29 22 10	34 20 77 09	29 57 83 01	0,103
31	30 03 40	31 08 00	29 57 83 01	24 44 83 05	
34	7.I 61 г. 17 15	9.I 61 г. 02 45	10 28 82 45	04 25 с. ш. 83 04	
35	9 10 30	11 19 30	03 55 ю. ш. 83 08	00 58 ю. ш. 82 53	0,106
36	12 00 25	13 16 25	00 59 ю. ш. 83 54	04 39 с. ш. 77 31	
37	20 21 40	22 06 55	03 56 80 38	00 02 ю. ш. 83 11	0,109
38	23 02 05	24 06 05	00 01 ю. ш. 83 07	04 22 с. ш. 83 06	
40	26 06 15	28 14 40	10 42 с. ш. 82 46	14 11 83 54	
41	29 19 35	31 04 10	14 05 83 00	18 10 85 04	0,098
42	31 12 50	1.II 21 05	18 29 85 37	15 20 87 00	
43	2.II 00 10	4 16 40	15 17 86 57	08 58 87 04	0,111

Таблица 1 (продолжение)

Гранулометрический состав											
%						г/м³					
фракции, мм											
> 0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001
4,25	3,19	23,40	10,64	7,80	50,71	0,008	0,006	0,047	0,021	0,016	0,101
1,05	5,99	27,82	8,80	6,34	50,00	0,003	0,017	0,081	0,025	0,018	0,145
2,82	1,06	11,27	7,39	8,45	69,01	0,003	0,001	0,012	0,008	0,009	0,071
0,74	5,18	24,07	10,37	18,52	41,11	0,001	0,005	0,025	0,011	0,02	0,044
1,08	9,71	22,66	9,35	16,55	40,65	0,001	0,011	0,025	0,01	0,018	0,044
0,73	4,38	24,45	8,03	19,37	43,06	0,001	0,004	0,024	0,008	0,019	0,042
0,73	6,93	31,39	9,12	31,75	20,08	0,001	0,007	0,035	0,01	0,035	0,022

№ пробы	Часы и дата работы сепараторов				Координаты участков работы		Средняя концентрация взвеси, $г/м^3$
	начало		конец		начало отбора	конец отбора	
46	14.II 61 г.	13^h50^m	15.II 61 г.	19^h30^m	09°36′ с. ш. 90 51	13°33′ с. ш. 90 54	
44	5	10 10	7	11 20	06 52 87 02	01 40 87 07	
45	10	20 00	12	08 30	01 20 с. ш. 90 58	06 31 с. ш. 90 40	0,138
51	9	15 35	11.III	11 30	03 44 с. ш. 94 04	01 23 с. ш. 95 31	
47	27	10 00	28.II	12 00	20 21 89 55	18 04 90 55	
48	28	22 00	2.III	15 15	18 02 90 56	12 19 95 58	0,115
50	7.III	21 20	9	11 35	07 50 95 14	03 48 94 07	0,230
52	11	16 45	14	18 20	01 23 с. ш. 95 24	01 49 ю. ш. 96 10	0,120
53	16	08 00	17	09 00	04 00 ю. ш. 99 20	05 18 ю. ш. 100 38	
54	21	13 00	22	15 00	11 24 104 36	08 10 104 39	
55	23	17 45	24	11 30	08 15 ю. ш. 104 11	06 16 ю. ш. 105 22	0,127
57	31	23 00	1.IV	17 00	01 25 с. ш. 104 39	02 49 с. ш. 107 43	0,370
58	3.IV	09 20	4	12 20	05 55 114 40	08 22 119 15	0,213
59	4	14 25	5	16 50	08 18 119 37	06 30 122 40	0,172
60	5	18 50	6	21 50	06 12 123 08	04 56 126 59	

Результаты гранулометрического анализа взвеси сведены в табл. 1. В ней также даны время и координаты начала и конца работы сепараторов, концентрация взвеси и режим работы установки. Большинство проб получено при последовательной работе камерного и тарельчатого сепараторов, но в двух случаях взвесь собиралась только на одном камерном. Так как концентрация взвеси определялась по сумме всех фракций, полученных на обоих сепараторах, то в случае работы одного камерного сепаратора для определения концентрации вводилась по-

Таблица 1 (окончание)

Гранулометрический состав											
%						г/м³					
фракции, *мм*											
>0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	>0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001
0,73	4,40	21,24	12,09	13,92	47,62	0,001	0,006	0,029	0,017	0,019	0,066
1,06	8,10	33,80	5,28	13,73	38,03	0,001	0,009	0,039	0,006	0,016	0,044
1,77	6,71	30,74	9,89	14,85	36,04	0,004	0,015	0,071	0,023	0,034	0,083
0,72	4,69	21,30	8,66	20,22	44,41	0,002	0,01	0,047	0,019	0,044	0,097
0,71	3,20	27,05	8.54	25,27	35,23	0,001	0,004	0,034	0,011	0,032	0,045
0,35	8,83	39,59	8,83	7,77	34,63	0,001	0,033	0,146	0,033	0,029	0,128
0,66	0,99	8,30	6,32	18,60	65,13	0,001	0,002	0,018	0,013	0,04	0,139
1,78	1,78	15,66	19,57	18,86	42,35	0,003	0,003	0,027	0,034	0,032	0,073

правка. Она определялась по среднему количеству взвеси, полученной тарельчатым сепаратором в двух соседних пробах.

В некоторых случаях количества взвеси из одной пробы для производства анализа было недостаточно. Поэтому приходилось объединять две, иногда три соседние пробы, и содержание фракций определять в пересчете на среднюю концентрацию суммарных проб.

Как видно из табл. 1, основную часть взвеси составляют частицы размерностью менее 0,01 *мм*, т. е. относящиеся к пелитовой фракции.

В подавляющем большинстве проб количество пелитовой фракции составляет около 70% и более, т. е. взвешенный материал по существующей классификации осадков [3] соответствует глинистым илам.

Рассмотрим особенности распределения различных фракций взвеси в поверхностном слое вод северной части Индийского океана по данным 33-го рейса э/с «Витязь» (рис. 2). Этот вопрос подробно освещен А. П. Лисицыным по материалам 2-го рейса д/э «Обь» в основном для южной части океана [7]. Для северной части океана приводятся данные только по отдельным участкам южной части Аравийского моря и Бенгальского залива, которые входят в рассматриваемый район; эти данные могут быть сравнимы с нашими данными. При сопоставлении данных «Оби» и «Витязя» различия обусловлены в основном двумя причинами: сбор взвеси производился различными типами сепараторов и в разное время года (материалы «Оби» относятся к весенне-летнему сезону, «Витязя» — к осенне-зимнему).

Частицы размером более 0,05 *мм* составляют незначительную часть взвеси, превышая в редких случаях 10%, основная же масса этих частиц составляет 5—7% (рис. 2, *А*). Довольно отчетливо исследованная акватория разделяется по содержанию частиц более 0,05 *мм* на две области: северную — с содержанием частиц более 5% и южную — с содержанием частиц менее 5%. Граница между ними проходит примерно в районе 10—20° ю. ш. Небольшая область, с содержанием частиц менее 5%, выделяется также в западной части Аравийского моря, прилегающей к Аравийскому полуострову, в Красном, Южно-Китайском и Целебесском морях. Лишь в двух местах количество таких частиц несколько превышает 10%: в северной части Аравийского моря — 12,9% и у острова Цейлон — 10,8%. Естественно было бы предположить, что по мере приближения к побережью Индии, где впадают такие мощные водные системы, как Инд и Ганг, будет наблюдаться увеличение содержания во взвеси частиц размерностью более 0,05 *мм*. По нашим данным, как и по данным, полученным на д/э «Обь», этого не происходит. Вероятно, разгрузка крупнозернистого речного материала происходит в непосредственной близости от берега.

По данным А. П. Лисицына, в районе 10—20° ю. ш. также фиксируется граница между северной областью, более обогащенной частицами крупнее 0,05 *мм*, и южной. Но количество их несколько меньше: для северной области — 1—2%, для южной — 0,5—1%.

Распределение мелкоалевритовой фракции (0,05—0,01 *мм*) в основных чертах сходно с распределением частиц крупнее 0,05 *мм* (рис. 2, *Б*). Здесь также можно выделить две большие области: северную и южную, характеризующиеся соответственно значениями концентраций мелкоалевритового материала более и менее 20%. В западной части рассматриваемой области район с содержанием фракции 0,05—0,01 *мм* (менее 20%) более обширный, чем показанный на рис. 2, *А* для фракции более 0,05 *мм*, и охватывает большую часть Красного моря и воды, омывающие восточное побережье Аравийского полуострова и Сомали. В северной части Аравийского моря выделяется район с содержанием во взвеси мелкого алеврита менее 20%, что говорит о незначительном влиянии на содержание этой фракции терригенного стока реки Инд. Повышенное содержание мелкоалевритовых частиц (более 30%) отмечается в северо-восточной части океана, охватывающей восточную часть Бенгальского залива, Андаманское море и район западнее острова Суматра. Это объясняется высоким содержанием в этих водах фитопланктона, в основном диатомовых [5], которые по размерам попадают во фракцию 0,05—0,01 *мм*.

По данным 2-го рейса д/э «Обь», северная часть Индийского океана также характеризуется содержанием мелкоалевритовой фракции порядка 20—30%, но область пониженной концентрации в западной части и в Красном море этими данными не фиксируется, что связано с сезонными особенностями.

Несколько иная картина наблюдается в распределении пелитового материала взвеси (размерность частиц менее 0,01 *мм*, рис. 2, *В*). В центральной части исследованной площади количество их составляет 60—70%, уменьшаясь к северо-востоку (Андаманское море) до значений, несколько превышающих 50%. К югу и западу происходит постепенное увеличение концентрации пелита, достигающее в западной части Аравийского и Красного морей и южнее 20° ю. ш. 80% и более. Увеличение количества пелитового материала в северных частях Аравийского моря и Бенгальского залива, по данным микроскопии, связано в основном со значительным поступлением терригенного материала с водами рек Инда и Ганга. Это увеличение происходит в основном за счет фракции мелкого пелита.

Такая же картина наблюдается в западной части Аравийского моря и в Красном море, но увеличение количества пелитовых частиц происходит здесь за счет поступления эолового материала с берегов Аравийского полуострова и Африки, причем основную массу частиц составляет крупный пелит.

По данным А. П. Лисицына, полученным во 2-м рейсе д/э «Обь», увеличение пелитового материала с востока на запад в водах северной части Индийского океана не отмечается и количество его составляет 70—80%, т. е. совпадает с нашими данными.

Своеобразная картина вырисовывается при рассмотрении распределения пелитового материала во взвеси по отдельным фракциям.

Крупный пелит (размерность частиц 0,01—0,005 *мм*, рис. 2, *Г*) распределен почти по всей акватории довольно равномерно около 10%. Лишь в восточной части Аравийского моря его количество увеличивается до величины, превышающей 20%, что, как уже отмечалось, связано с поступлением эолового материала с суши.

В распределении более тонкого пелитового материала (фракция 0,005—0,001 *мм*, рис. 2, *Д*) обнаруживается четкая субмеридиональная зональность. Западная часть Индийского океана характеризуется содержанием частиц 5—10%. В восточной части количество частиц превышает 10%, а в водах у побережья Суматры и в центральной части Бенгальского залива достигает соответственно 25 и 32%.

Обратная картина наблюдается в распределении наиболее тонкого пелитового материала (фракция меньше 0,001 *мм*, рис. 2, *Е*). Как видно из рис. 2, *Е* и табл. 1, пелитовая фракция, как правило, более чем на 80—90% состоит из мелкопелитового материала, т. е. составляет основную часть океанской взвеси вообще. Наибольшее количество таких частиц, достигающее 60—70%, отмечается в Красном море и в северо-западной части Аравийского моря, что связано с поступлением терригенного материала, как эолового с Аравийского полуострова, так и речного с водами реки Инд. По мере продвижения на восток количество мелкопелитовых частиц постепенно уменьшается в центральной части океана и составляет 40—50%, а в восточной части Бенгальского залива и Андаманском море — менее 40%. Минимальное значение — 20,1% отмечается в южной части Бенгальского залива. С другой стороны, количество этих частиц несколько увеличивается при движении с севера на юг и южнее 20° ю. ш. достигает 69%. При сравнении распределения тонкопелитового материала в Аравийском море и Бенгальском заливе обращает на себя внимание слабое влияние терригенного стока Ганга и Иравади по сравнению с Индом. Это связано с тем, что работы в Аравийском море производились осенью, когда происходит смена летнего муссона на зимний, сопровождающаяся обильным выпадением ссадков

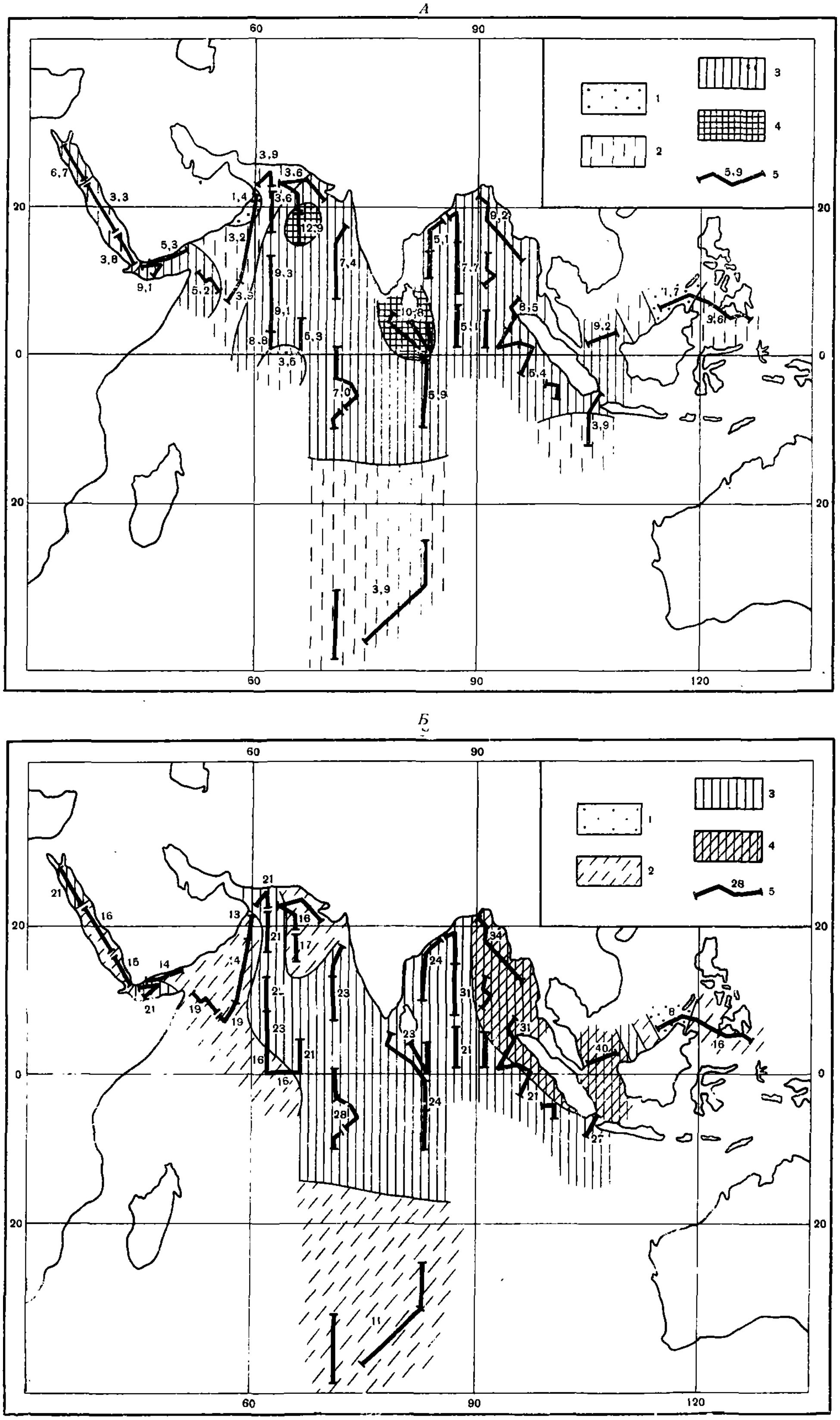
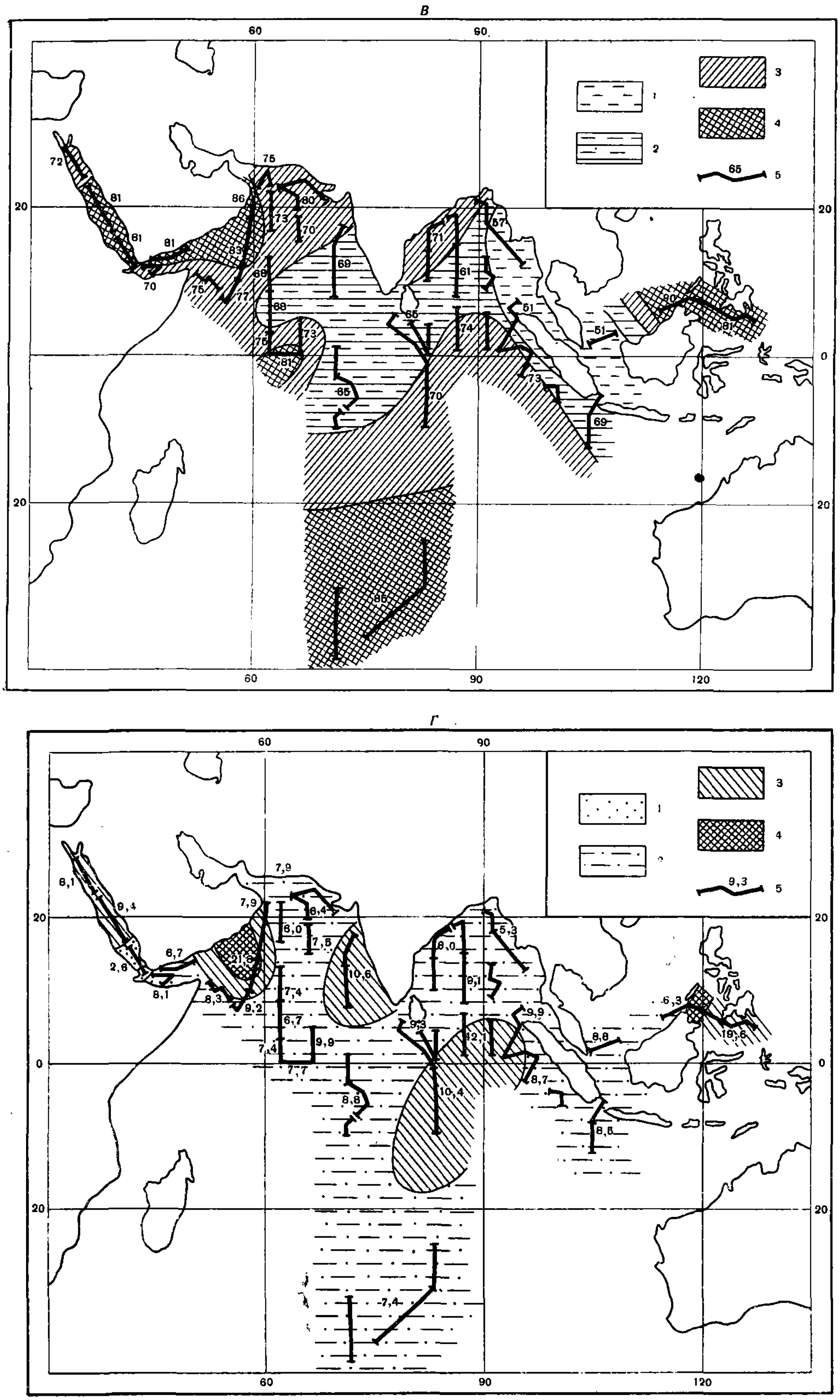


Рис. 2. Схемы грануломет

А — сумма фракций больше 0,05 *мм*: *1* — меньше 2,5; *2* — 2,5—5; *3* — 5—10, *4* — более 10; *5* — фактическое содержание в пробе: *Б* — мелкоалевритовая фракция (0,05—0,01 *мм*): *1* — меньше 10; *2* — 10—20; *3*—20—30; *4*— более 30; *5*— фактическое содержание в пробе;



рического состава взвеси (в %)

В — пелитовая фракция (меньше 0,01 *мм*): *1* — меньше 60; *2* — 60—70; *3* — 70—80; *4* — более 80; *5*—фактическое содержание в пробе; *Г* — фракция 0,01—0,005 *мм*: *1*— меньше 5; *2*—5—10; *3*—10—20; *4*—более 20; *5*— фактическое содержание в пробе

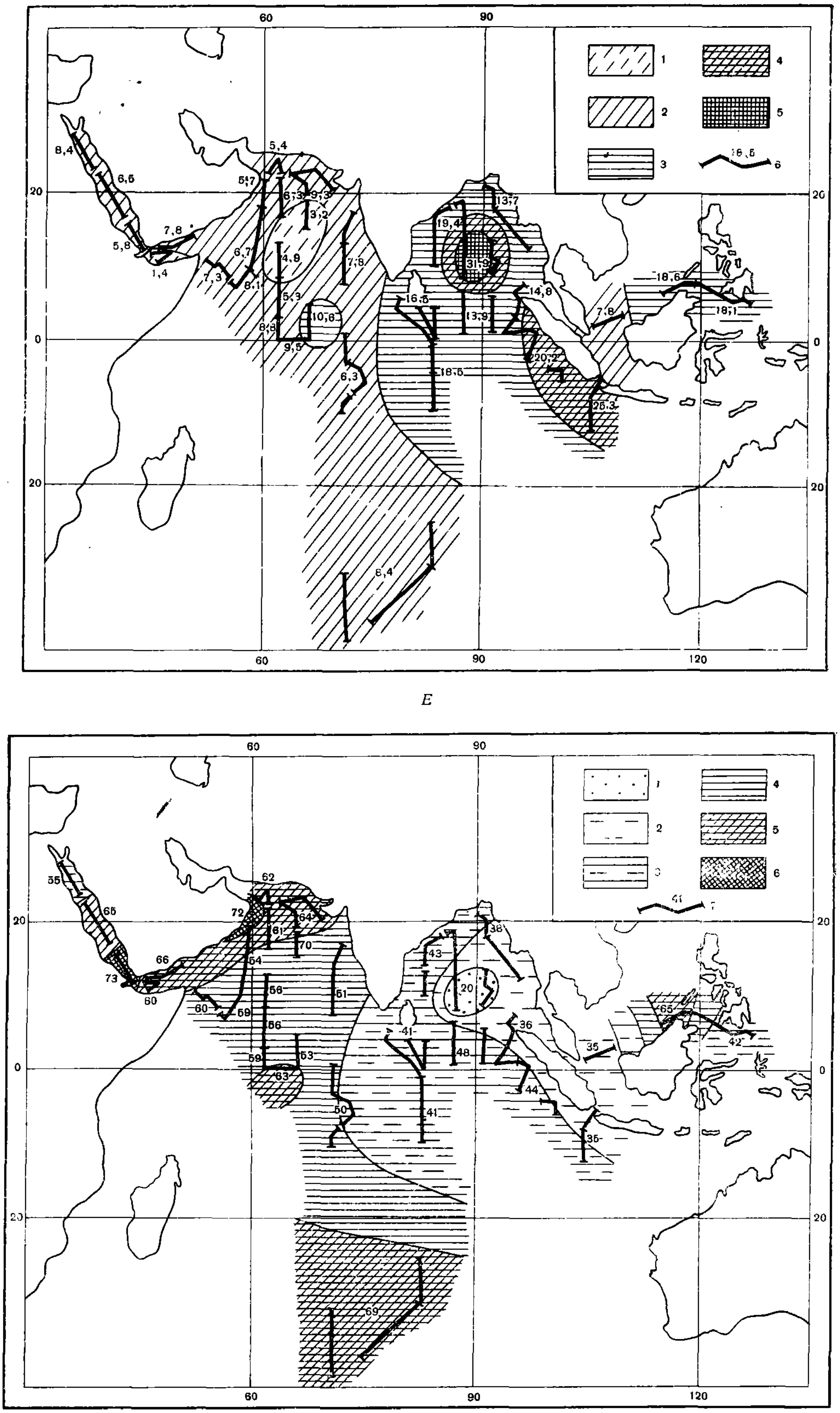


Рис. 2. Схемы гранулометрического состава взвеси (в %)

Д — фракция 0,005—0,001 *мм*: *1* — меньше 5; *2*—5—10; *3*—10—20; *4*—20—30; *5*— более 30; *6*— фактическое содержание в пробе; *Е* — фракция меньше 0,001 *мм*: *1*— меньше 30; *2*—30—40; *3*—40—50; *4*—50—60; *5* — 60—70; *6* — более 70; *7* — фактическое содержание в пробе в бассейне реки Инд. В Бенгальском же заливе работы производились зимой, когда твердый сток реки Ганг минимален.

Из рассмотрения рис. 2, *Е* отчетливо видно, что воды западной части Индийского океана больше обогащены тонким пелитовым материалом, чем восточной. Такая же картина выявляется и по данным А. П. Лисицына, полученным для южной части Индийского океана во 2-м рейсе д/э «Обь».

В распределении частиц взвеси в зависимости от их крупности намечается определенная тенденция. Так, если для фракции крупнее 0,05 *мм* ясно выражена широтная зональность, то с уменьшением размерности частиц происходит постепенная перестройка общего плана распределения взвеси и во фракциях 0,005—0,001 *мм* и менее она переходит в субмеридиональную.

Из рис. 2 видно, что основная часть взвешенного материала в поверхностных водах (в среднем около 70%) имеет пелитовую фракцию, причем наиболее мелкая ее подфракция (менее 0,001 *мм*) составляет около половины всего количества взвеси.

Микроскопические исследования указывают на то, что основная часть взвеси представлена частицами органического происхождения. Это подтверждается также картиной распределения органического углерода и фосфора, которая близко совпадает с распределением основной фракции — менее 0,001 *мм*.

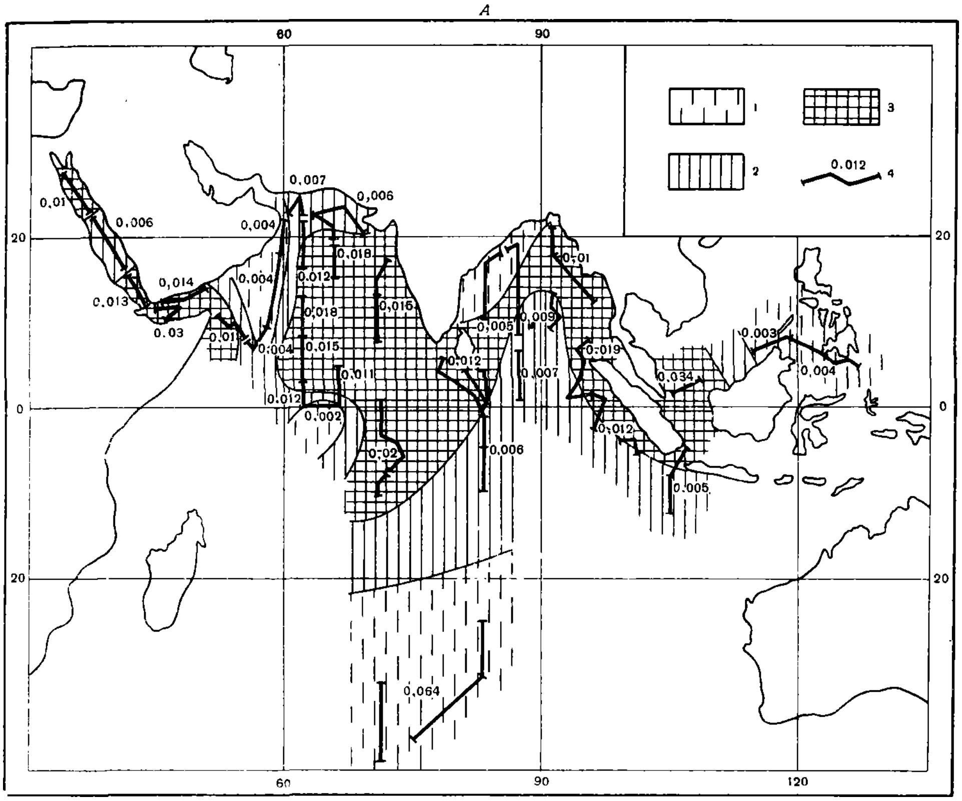
Определенную роль в распределении взвеси, особенно ее пелитовой фракции, в северных частях Аравийского моря и Бенгальского залива играет терригенный материал, поступающий в результате эолового переноса и с речными водами Инда и Ганга, причем влияние Ганга сказывается меньше, чем Инда. Увеличение содержания пелитовых частиц в субантарктических широтах связано в основном с более активными биогенными процессами.

Выше рассматривался гранулометрический состав взвеси в процентах каждой фракции от общего ее количества. Во многих случаях большой интерес представляет распределение частиц взвеси различных фракций в *мг/л*. Так как количество взвешенного материала в каждой пробе мало, то при таком пересчете величины оказываются низкими, особенно для некоторых фракций в районах с низкой концентрацией взвеси (правая часть табл. 1).

На рис. 3, *А—Е* показано распределение различных фракций в единице объема воды для поверхностного слоя Индийского океана.

Концентрация наиболее крупных частиц взвеси (фракция более 0,05 *мм* рис. 3, *А*) колеблется в пределах от менее 0,005 *г/м*^{3} (восточные части Аравийского моря и Бенгальского залива в район южнее 20° ю. ш.) до 0,03—0,034 *г/м*^{3} (Аденский залив и Южно-Китайское море). По содержанию этих частиц исследованную акваторию можно в первом приближении разделить на две части: северную и южную. Северная часть (севернее 0—10° ю. ш.) характеризуется значениями концентраций частиц более 0,05 *мм* — 0,01—0,02 *г/м*^{3}, южная — более низкими — менее 0,01 *г/м*^{3}. Такая же область пониженного содержания этих частиц выделяется в восточной части Аравийского моря. Концентрации частиц более 0,05 *мм*, по данным 2-го рейса д/э «Обь», значительно ниже и составляют для Бенгальского залива 0,001—0,005 *г/м*^{3}, а для Аденского залива — 0,002 *г/м*^{3}.

Количество мелкоалевритовых частиц (фракция 0,05—0,01 *мм*, рис. 3, *Б*) значительно больше, и картина их распределения близка к предыдущей. Области пониженного содержания (менее 0,025 *г/м*^{3}) выделяются южнее 10—20° ю. ш. (0,012 *г/м*^{3}) и к югу от Аравийского полуострова вдоль 60° в. д. (около 0,02 *г/м*^{3}). Область, расположенная к северу от 10—20° ю. ш., характеризуется в основном средней концентра-



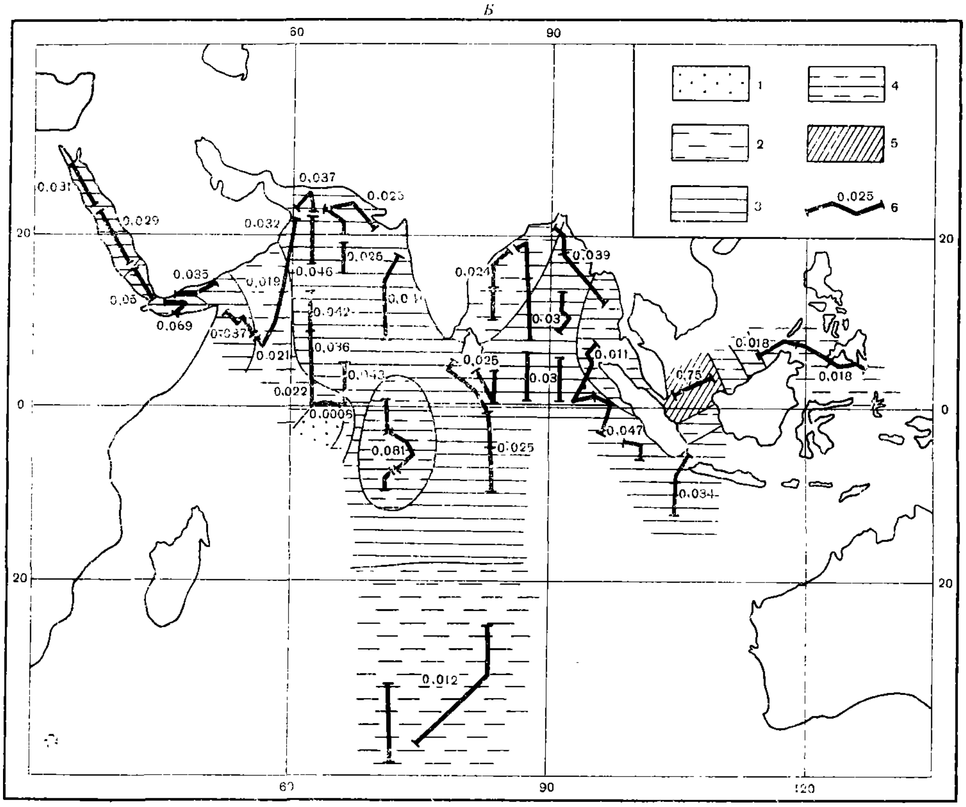
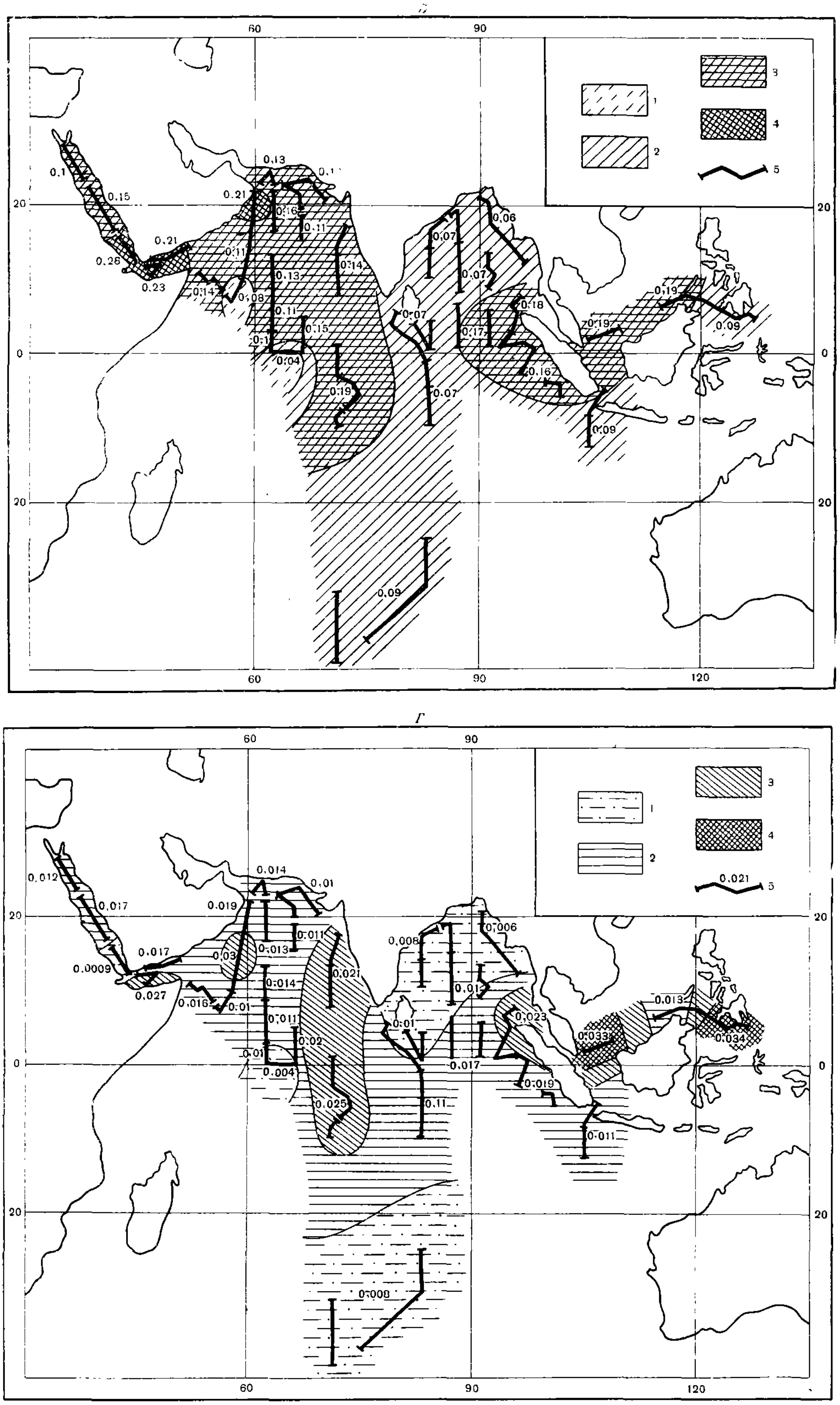


Рис. 3. Гранулометрический

А — сумма фракций больше 0,05 *мм*: *1* — меньше 0,005; *2* — 0,005–0,01; *3* — более 0,01; *4* — фактическое содержание в пробе. *Б* — мелкоалевритовая фракция (0,05—0,01 *мм*): *1* — меньше 0,01; *2* — 0,01—0,025; *3* — 0,025—0,05; *4* — 0,05—0,1; *5* — более 0,1; *6* — фактическое содержание в пробе;



состав взвеси (в *мг/л*)

В — пелитовая фракция (меньше 0,01 *мм*): *1* — меньше 0,05; *2* — 0,05—0,1; *3* — 0,1—0,2; *4* — более 0,2; *5* — фактическое содержание в пробе; *Г* — фракция 0,01—0,005 *мм*: *1* — меньше 0,1; *2*—0,001—0,02: *3*—0,02—0,03; *4*— более 0,03; *5*— фактическое содержание в пробе

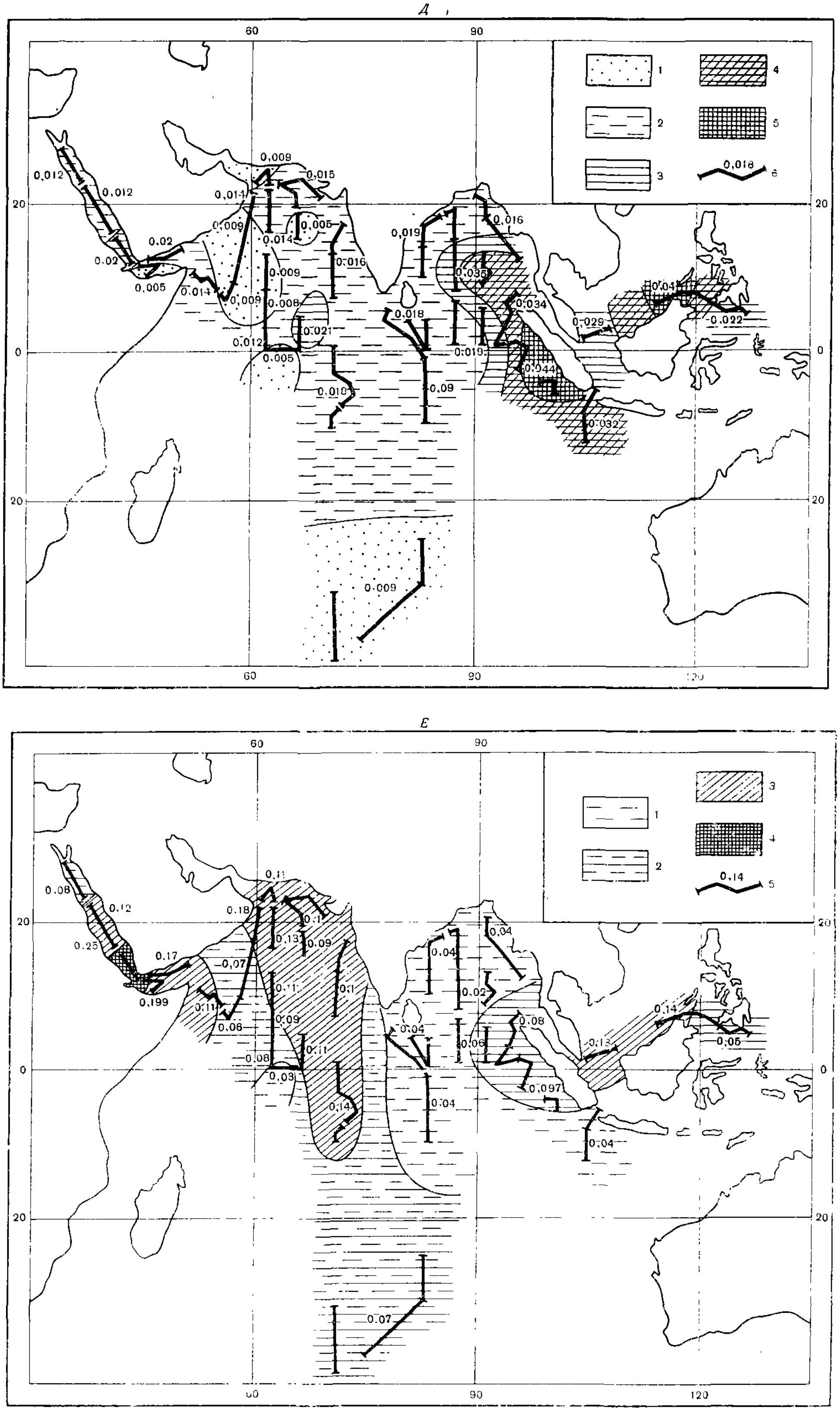


Рис. 3. Гранулометрический состав взвеси (в *мг/л*)

Д — фракция 0,005—0,001 *мм*: *1* — меньше 0,01; *2* — 0,01—0,02; *3* — 0,02—0,03; *4* — 0,03—0,04; *5* — более 0,04; *6* — фактическое содержание в пробе; *Е* — фракция меньше 0,001 *мм*: *1* — меньше 0,05; *2* — 0,05—0,1; *3* — 0,1—0,2; *4* — более 0,2; *5* — фактическое содержание в пробе цией мелкоалевритовых частиц — 0,025—0,05 *г/м*^{3}. Более высокое их содержание (0,07—0,08 *г/м*^{3}) отмечается в Аденском заливе, в районе архипелага Диего-Гарсия и в Андаманском море, что связано с более интенсивным развитием диатомовых [5], основная часть которых попадает по размерам в мелкоалевритовую фракцию. Самая большая концентрация обнаружена в южной части Южно-Китайского моря и составляет 0,146 *г/м*^{3}. По данным 2-го рейса д/э «Обь», количество мелкоалевритовых частиц в Бенгальском заливе составляет 0,11 *г/м*^{3}, в Аденском заливе — 0,03 *г/м*^{3}, а по нашим данным — соответственно 0,035 и 0,069 *г/м*^{3}.

Несколько иная картина наблюдается в распределении пелитовой фракции (частицы менее 0,01 *мм*, рис. 3, *В*). Повышенные концентрации этой фракции (больше 0,1 *г/м*^{3}) отмечаются в северо-западной части рассматриваемой области, особенно в Аденском заливе и Красном море, где она достигает 0,277 *г/м*^{3}. Такая же область выделяется в восточной части, примыкающей к острову Суматра, и в Южно-Китайском море. В южной же части и Бенгальском заливе концентрация колеблется в пределах 0,06—0,09 *г/м*^{3}.

Из рассмотрения рис. 3, *В*—*Е* видно, что распределение пелитового материала контролируется в основном фракцией тончайшего пелита (менее 0,001 *мм*), которая составляет основную часть взвеси. Остальные подфракции не оказывают существенного влияния на распределение всей фракции.

Количество частиц размерностью 0,01—0,005 *мм* (рис. 3, *Г*) в большинстве проб колеблется в пределах 0,01—0,02 *г/м*^{3}, несколько сокращаясь (до 0,006—0,008 *г/м*^{3}) в южной части и Бенгальском заливе, и увеличивается до 0,02—0,025 *г/м*^{3} в районе Мальдивских островов, архипелага Чагос и западнее острова Суматра. Максимума (0,033 *г/м*^{3}) они достигают в Южно-Китайском море.

Аналогичная картина, как по пространственному распространению, так и по концентрации, представляет собой распределение фракции 0,005—0,001 *мм* (рис. 3, *Д*). В основном количество этих частиц составляет 0,01—0,02 *г/м*^{3}, и лишь на северо-востоке выделяется область более высоких концентраций (до 0,03—0,04 *г/м*^{3}).

Распределение наиболее тонкого пелитового материала (фракция менее 0,001 *мм*, рис. 3, *Е*) существенно иное. Здесь выделяются в основном две области: западная и восточная. В западной — количество фракции составляет более 0,05 *г/м*^{3} (чаще всего более 0,1 *г/м*^{3}), достигая в южной части Красного моря 0,25 *г/м*^{3}. В восточной — концентрация, как правило, не превышает 0,05 *г/м*^{3}, за исключением района западнее острова Суматра, где она несколько выше 0,05 *г/м*^{3}.

Из рассмотрения карт концентраций отдельных фракций взвеси в единице объема воды (рис. 3) и карты количественного распределения взвеси (рис. 1) видно, что пространственное распределение отдельных фракций зависит в основном от концентрации взвешенного материала в поверхностном слое воды.

ABSTRACT

The paper analyses the chemical composition of suspension obtained by the separation method from the surface waters of the north and central parts of the Indian Ocean during the 33rd cruise of the e/s «Vityaz». The schemes of the area distribution of separate elements and chemical compounds are given in per cent of the total amount of suspension and in mm of dry matter per 1l of water.

The mean content of organic carbon in suspension is 13.6% (limits of variation 7.2—19.6%, in convertion to volume the surface waters have

0.01—0.03 mg/l). The maximal quantity of organic carbon is found in the waters of the Aden Gulf and the Red Sea: 0.47—0.67 mg/l (16—20% of suspension). The mean iron content is 10.4% (the variations limits are 3.8—19.0%) and 0.017 mg/l (0.009—0.044 mg/l). The eastern part of the studied area of the ocean is characterised by higher concentration of iron in suspension, i. e. more than 10% (0.02—0.03 mg/l). The calcium carbonate in suspension makes from 3.5 to 10% with the mean value 6.5% and in convertion to the volume of water it is 0.005—0.026 mg/l (average value is 0.012 mg/l). Two parts of the ocean are distinguished according to calcium carbonate content: eastern (less than 7.5% and less than 0.01 mg/l) and western (more than 7.5% and more than 0.01 mg/l). Amorphous silica was determined only for the Arabian Sea. Its southern part contains about 2% of suspension (0.0017 mg/l), while on the periphery it is not less than 0.5% (less than 0.001 mg/l). Phosphorus in suspension makes 0.21—0.46% (mean value 0.34%) and correspondingly 0.0004—0.0011 mg/l (mean 0.0006 mg/l). Maximal quantities of it are noted in the north-western part of the studied area and minimal in the eastern.

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Reprinted from *Okeanol. issled.*, no. 18, 1968, p. 175-192

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ХИМИЧЕСКИЙ СОСТАВ ВЗВЕСИ ИЗ ПОВЕРХНОСТНЫХ ВОД СЕВЕРНОЙ И ЦЕНТРАЛЬНОЙ ЧАСТЕЙ ИНДИЙСКОГО ОКЕАНА

(по данным 33-го рейса э/с «Витязь»)

Количественное распределение и гранулометрический состав взвеси в поверхностном слое вод Индийского океана рассматривался ранее как для южной его части [6—8], так и для северной [4]. В данной статье дается распределение некоторых химических элементов во взвеси из поверхностных вод центральной части Индийского океана по данным 33-го рейса э/с «Витязь» [1]. Широкий круг вопросов, связанный с распределением химических элементов во взвеси, детально исследовался А. П. Лисицыным [9] по материалам 2-го рейса д/э «Обь» для южной части океана и некоторых районов северной части.

Химический состав взвешенного вещества формируется в результате совместного действия многих факторов, часто связанных между собой сложными генетическими переходами. На количественное содержание, как и на химический состав взвеси океанических вод, огромное влияние оказывают процессы, связанные с биологической продуктивностью. Многие химические элементы концентрируются организмами фито- и зоопланктона в верхнем биологически активном слое вод. Так как распределение и состав этих организмов связан с климатическими условиями, то распределение химических элементов во взвеси и, в конечном счете, в донных осадках связано с климатической зональностью.

Другим важным фактором генезиса химических элементов во взвеси океанических вод является терригенный материал, который также зависит от климатической зональности. На распределение химических элементов во взвеси этот материал может оказывать влияние в связи с привносом с суши частиц, обогащенных теми или иными соединениями, или сорбированием некоторых химических элементов тонкими глинистыми частицами.

Некоторое влияние на химический состав взвеси оказывает вулканическая деятельность и поступление космогенного материала.

Изучение взвешенного вещества является составной частью исследования морских донных осадков, поэтому для исследования количественного и качественного состава взвеси применялась та же методика, что и для донных осадков.

Для химического анализа отбирались пробы сухой взвеси весом до 5 *г*. Так как каждая проба взвеси, полученная сепарационной установкой, состоит из 6 фракций [3], то для анализа взвесь отбиралась из каждой фракции пропорционально весу. Как правило, в открытых частях океана количество взвеси в одной пробе недостаточно

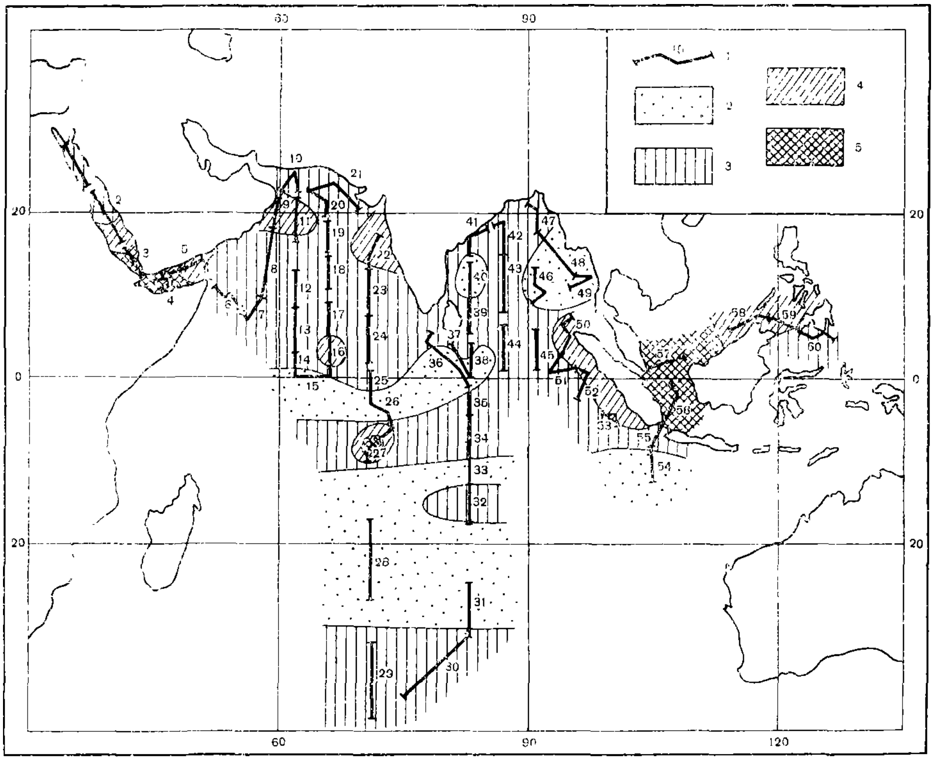

Рис. 1. Схема расположения сепарационных проб и концентрация взвеси в поверхностном слое воды

1 — места взятия пробы и ее номер; концентрация взвеси (в *мг/л*): *2* — менее 0,1, *3* — 0,1—0,2, *4* — 0,2—0,3; *5* — более 0,3

для производства гранулометрического и химического анализов. Поэтому приходилось объединять две-три, иногда четыре близлежащие пробы, что приводило к усреднению значений отдельных компонентов взвеси. Каждая проба взвеси характеризует участок протяженностью 250—300 миль; поэтому при объединении нескольких проб содержание компонентов определяется уже для довольно больших участков — до 500 миль и более. Это ведет к уменьшению степени дифференциации значений компонентов взвеси по площади и к скрадыванию локальных участков экстремальных значений.

Химические анализы были выполнены в Лаборатории морской геологии и геохимии Союзморниипроекта сотрудниками М. И. Гохват, А. Г. Самосудовой и М. И. Вознесенской под руководством О. И. Зеленской.

Было проанализировано 48 сепарационных проб (21 объединенных), полученных из поверхностных вод северной части Индийского океана на протяжении пути следования судна в 15 000 миль. Сбор проб выполнен в этом рейсе в осенне-зимне-весенний период (октябрь 1960 г.— апрель 1961 г.). Особенности сбора взвешенных частиц сепарационной установкой в 33-м рейсе э/с «Витязь», данные о количественном содержании взвеси и гранулометрическом составе были приведены ранее [4]. В работах по сбору взвеси в 33-м рейсе, кроме автора, принимал участие В. В. Шипорин.

Таблица 1

Химический состав взвеси из поверхностного слоя вод Индийского океана по данным 33-го рейса э/с «Витязь»

№ проб взвеси	Средняя концентрация, *мг/л*	$C_{орг}$		$CaCO_3$		Fe		$SiO_{2 аморфн.}$		P		Mn	
		%	*мг/л*	%	*мг/л*	%	*мг/л*	%	*мг/л*	%	*мг/л*	%	*мг/л*
3	0,340	19,60	0,0666	14,66	0,0158	3,77	0,0128	1,73	0,00590	0,32	0,0011	0,01	0,00003
4+ 5	0,292	16,10	0,0470	8,94	0,0261	6,00	0,0175	0,30	0,00088			0,01	0,00003
6+ 8	0,173	15,32	0,0265	*9,64*	*0,0167*	7,38	*0,0128*	*0,50*	*0,00086*	0,43	*0,0007*	*0,01*	*0,00002*
9+10	0,211	16,73	0,0353	7,68	0,0162	6,47	0,0136	0,15	0,00032	0,44	0,0009	Незначит. сл.	Незначит. сл.
14+15+16	0,129	12,45	0,0161	7,23	0,0093	9,48	0,0122	1,36	0,00170	0,39	0,0005	0,01	0,00001
18	0,142	18,64	0,0265	3,48	0,0049	7,14	0,0101	0,80	0,00114	0,36	0,0005	0,01	0,00001
20+21	0,157	17,71	0,0278	8,73	0,0137	5,62	0,0088	0,49	0,00077	0,46	0,0006	0,02	0,00003
22+23+24	0,190	13,41	0,0255	9,96	0,0189	9,68	0,0184	0,21	0,00039	0,35	0,0007	0,01	0,00002
25+26+27	0,290	10,72	0,0311	8,25	0,0239	14,95	0,0433	—	—	0,35	0,0010	0,02	0,00006
28+29+30+31	0,101	16,33	0,0165	8,23	0,0083	9,90	0,0100	—	—	0,36	0,0004	Сл.	Сл.
32+32+35	0,106	14,19	0,0150	6,37	0,0067	17,80	0,0189	—	—	0,34	0,0004	»	»
36+37+38+39	0,112	12,74	0,0143	7,95	0,0089	13,16	0,0147	—	—	0,35	0,0004	»	»
40+41+42	0,098	15,11	0,0148	5,04	0,0049	10,93	0,0107	—	—	0,39	0,0004	»	»
43+46	0,111	12,67	0,0141	5,02	0,0056	18,60	0,0206	—	—	0,34	0,0004	0,02	0,00002
39+44+45+51	0,134	11,24	0,0151	6,18	0,0083	14,50	0,0194	—	—	0,32	0,0004	0,03	0,00004
47+48	0,115	11,95	0,0137	4,95	0,0057	8,92	0,0103	—	—	0,31	0,0004	Сл.	Сл.
50	0,230	10,05	0,0231	4,91	0,0113	18,96	0,0436	—	—	0,27	0,0006	0,02	0,00005
52+53	0,220	7,22	0,0159	4,36	0,0096	12,17	0,0268	—	—	0,21	0,0005	Сл.	Сл.
54+55	0,127	10,24	0,0130	5,18	0,0066	10,88	0,0138	—	—	0,28	0,0004	0,03	0,0004
58	0,213	11,17	0,0238	4,14	0,0088	4,46	0,0095	—	—	0,29	0,0006	Сл.	Сл.
59+60	0,172	11,71	0,0201	6,39	0,0110	7,89	0,0136	—	—	0,29	0,0005	»	»

Результаты химических анализов взвеси сведены в табл. 1, где количественное содержание отдельных компонентов дано в процентах и миллиграммах сухого вещества на 1 *л* воды, из которой извлечена взвесь. Схема расположения участков, на которых производился отбор проб, и концентрация взвеси в поверхностном слое воды даны на рис. 1.

Рассмотрим содержание основных компонентов взвеси в порядке их распространения.

ОРГАНИЧЕСКИЙ УГЛЕРОД

Из рассмотрения табл. 1 видно, что наиболее существенную часть взвеси как в процентном отношении, так и в абсолютных величинах (в *мг/л*) составляет органический углерод ($C_{орг}$), в то время как содержание аморфного кремнезема ничтожно мало. Этим северная часть Индийского океана значительно отличается от южной, где наблюдается обратная картина [9]. Это объясняется тем, что сбор взвеси производился в тропических и субтропических водах Индийского океана, т. е. в областях преимущественного распространения бескремнистой взвеси. В этих водах состав взвеси в основном определяется развитием сине-зеленых и перидиниевых водорослей и фораминифер, кремнесодержащие же организмы (диатомовые, радиолярии и силикофлагелляты) в формировании взвеси играют подчиненную роль.

Таблица 2

Содержание основных элементов и соединений во взвеси из поверхностного слоя вод северной части Индийского океана

Элементы и соединения	Количество проб (объединенных)	% от сухого вещества			*мг/л*		
		максимальное	минимальное	среднее	максимальное	минимальное	среднее
$C_{орг}$	21	0,0666 (0,39) *	0,0130 (0,001)	0,0234 (0,07)	19,60 (18,84)	7,22 (0,00)	13,58 (8,67)
Fe	21	0,0436 (0,15)	0,0088 (0,002)	0,0172 (0,018)	18,96 (19,55)	3,77 (0,50)	10,39 (3,14)
$CaCO_3$	21	0,0261 (0,038)	0,0049 (0,00)	0,0115 (0,003)	9,96 (8,03)	3,48 (0,00)	6,49 (1,28)
$SiO_{2аморфн.}$	8	0,0059 (1,09)	0,0003 (0,0001)	0,0015 (0,13)	1,73 (38,95)	0,15 (0,39)	0,69 (11,45)
P	20	0,0011 (0,009)	0,0004 (0,00)	0,00057 (0,003)	0,46 0,82	0,21 0,08	0,34 (0,30)
Mn	21	0,00006 (0,002)	0,00 (0,00)	0,000017 (0,00003)	0,03 0,05	0,00 (0,00)	0,017 (0,004)

* В скобках для сравнения даны цифры, полученные во 2-м рейсе д/э «Обь» [9] в основном для вод южной части Индийского океана.

В северной части Индийского океана, в отличие от южной, количество органического углерода во всех пробах взвеси в пересчете на сухое вещество относительно постоянно (табл. 2). Минимальное содержание — 7,22%, максимальное — 19,6%, т. е. колеблется менее чем в три раза (для южной части эта цифра превышает 13).

Среднее содержание органического углерода 13,58%, т. е. примерно в полтора раза выше, чем в южной части океана по данным 2-го рейса д/э «Обь». Повышенное содержание $C_{орг}$ во взвеси объясняется тем, что все пробы, кроме пробы 3, получены в зоне развития перидиниево-фораминиферовой взвеси, которая, наряду со взвесью с сине-зелеными водорослями, содержит наибольший процент органического углерода. Проба 3 взята в Красном море, в водах которого развиты преимущественно сине-зеленые водоросли. Взвесь этой пробы содержит самое высокое количество органического углерода — 19,6%. В табл. 3 приведены данные по содержанию $C_{орг}$

Таблица 3

Содержание основных элементов и соединений во взвеси по основным типам биогенных остатков

Элементы и соединения	Число проб	Значение и пределы колебаний	Среднее	Число проб	Значение и пределы колебаний	Среднее
		%			мг/л	
Пиридиниево-фораминиферовая взвесь						
$C_{орг}$	20	18,64—7,22	13,48 (9,44) *	20	0,0470 —0,0130	0,0162 (0,03)
Fe	20	18,96—4,46	10,74 (6,48)	20	0,0436 —0,0088	0,0174 (0,0150)
$CaCO_3$	20	9,96—3,48	6,58 (2,97)	20	0,0261 —0,0049	0,0121 (0,008)
$SiO_{2 аморфн.}$	7	1,36—0,15	0,54 (2,19)	7	0,0017 —0,0003	0,00086 (0,016)
P	19	0,46—0,21	0,34 (0,23)	19	0,001 —0,0004	0,00054 (0,0004)
Mn	20	0,03—0,00	0,015 (0,0007)	20	0,00006—0,00	0,000015 (0,000001)
Диатомовая взвесь [9]						
$C_{орг}$	50	18,84 —1,41	8,03	50	0,389 —0,003	0,086
Fe	49	9,22 —0,94	2,32	49	0,15 —0,004	0,02
$CaCO_3$	50	8,03 —0,00	0,55	50	0,016 —0,00	0,002
$SiO_{2 аморфн}$	50	38,95 —1,39	14,89	50	1,0863—0,0042	0,1674
P	46	0,82 —0,08	0,31	46	0,007 —0,0087	0,003
Mn	49	0,031—0,00	0,004	49	0,0003—0,00	0,00003
Взвесь с сине-зелеными водорослями						
$C_{орг}$	1	19,60 (14,04)	—	1	0,0666 (0,014)	—
Fe	1	3,77	—	1	0,0128	—
$CaCO_3$	1	4,66 (5,65)	—	1	0,0158 (0,006)	—
$SiO_{2 аморфн}$	1	1,73 (1,54)	—	1	0,0059 (0,0015)	—
P	1	0,32	—	1	0,0011	—
Mn	1	0,01	—	1	0,00003	—

* В скобках для сравнения даны средние значения по данным 2-го рейса д/э «Обь» [9].

и других компонентов во взвеси из различных зон, в которых преобладают определенные типы биогенных остатков. Данные по процентному содержанию органического углерода в тех же районах океана во 2-м рейсе д/э «Обь» близки к вышеприведенным. Так, в зоне развития пиридиниево-фораминиферовой взвеси среднее содержание $C_{орг}$ составляет 9,44%, а во взвеси с сине-зелеными водорослями 14,04%.

В отличие от южной части Индийского океана, в северной части в большинстве проб встречаются довольно высокие в процентном отношении

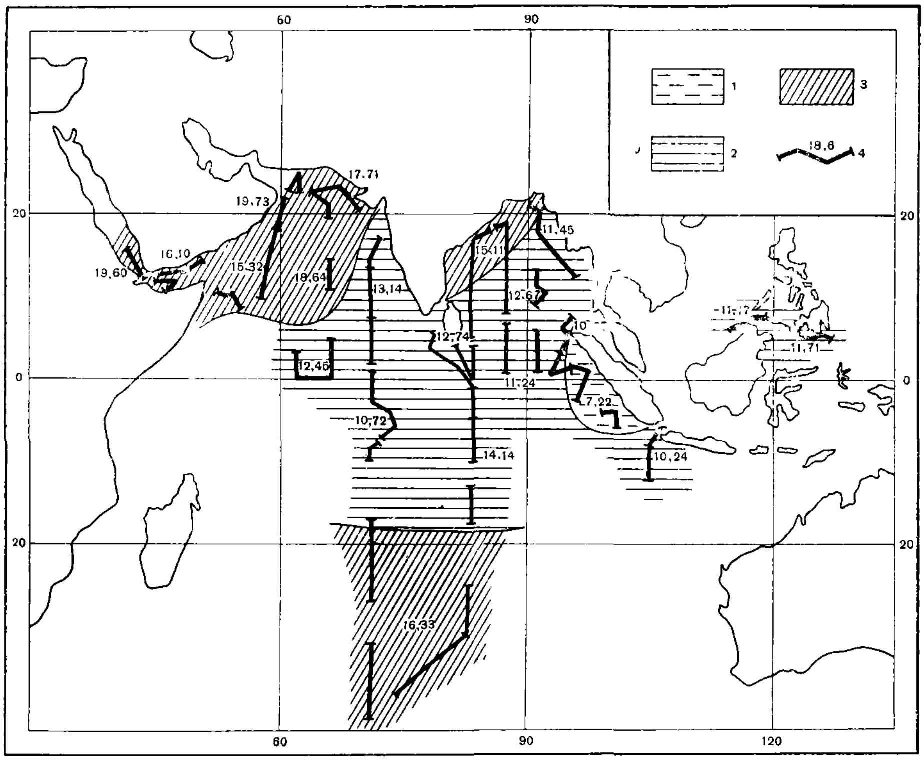

Рис. 2. Схема распределения $C_{орг}$ во взвеси (в % от сухого вещества)

1 — менее 10; *2* — 10—15; *3* — более 15; *4* — фактическое содержание в пробах

содержания $C_{орг}$ (табл. 4). Практически во всех пробах количество $C_{орг}$ превышает 10%, тогда как для южной части в 70% проб его содержание менее 10%.

Таблица 4

Частота встречаемости различных концентраций $C_{орг}$ во взвеси из вод северной части Индийского океана

Концентрация $C_{орг}$	% от сухого вещества						
	10	10—15	>15	0,01—0,02	0,02—0,03	0,03—0,04	>0,04
Частота встречаемости, % . .	4,8	57,1	38,1	47,6	33,3	9,5	9,6

На рис. 2 виден равномерный характер количественного распределения органического углерода на всей исследованной площади. Нельзя выделить отдельные области со значительными отклонениями в содержании $C_{орг}$ от среднего (10—15%). Условно выделены области с содержанием $C_{орг}$ более 15%, но менее 20%. К ним относятся западные части Аравийского моря и Бенгальского залива и район южнее 20° ю. ш. Лишь в южной части Красного моря количество $C_{орг}$ во взвеси приближается к 20%.

Несколько иная картина наблюдается в распределении $C_{орг}$ в пересчете на объем воды (рис. 3, табл. 1 и 4). Правда и здесь нет резких колебаний в содержании $C_{орг}$, но они все же более значительны. Основная масса поверхностной воды содержит во взвеси от 0,01 до 0,03 *мг/л* $C_{орг}$. При

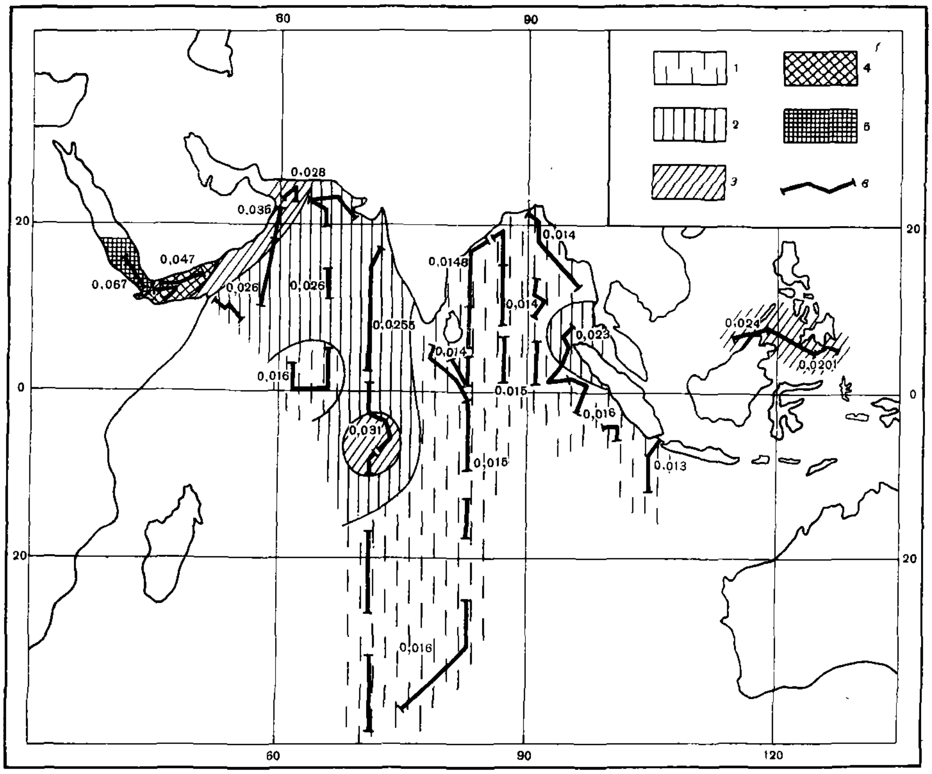

Рис. 3. Схема распределения $C_{орг}$ во взвеси (в *мг/л*)

1 — 0,01—0,02; *2* — 0,02—0,03; *3* — 0,03—0,04; *4* — 0,04—0,05; *5* — более 0,05; *6* — фактическое содержание в пробах

этом намечается определенная зональность: воды с концентрацией $C_{орг}$ во взвеси менее 0,02 *мг/л* находятся в восточной и южной частях океана, с концентрацией более 0,02 *мг/л* — в западной, причем в сторону Аравийского полуострова она постепенно увеличивается и в Красном море достигает максимального значения — 0,067 *мг/л*.

Среднее содержание $C_{орг}$ во взвеси из поверхностных вод северной части Индийского океана составляет 0,0234 *мг/л* (табл. 2), т. е. в три раза меньше, чем для южной части по данным А. П. Лисицына (0,07 *мг/л*). Если рассмотреть содержание $C_{орг}$ во взвеси по отдельным зонам (табл. 3), то наибольшее количество $C_{орг}$ содержится во взвеси из зоны развития диатомового планктона (0,086 *мг/л*), несколько меньше (0,0666 *мг/л*) — во взвеси с синезелеными водорослями (данные по одной пробе) и наименьшее (0,0162 *мг/л*) — в области развития перидиниево-фораминиферовой взвеси.

Основным поставщиком $C_{орг}$ являются организмы фитопланктона. Это было наглядно показано в 4-м рейсе Морской Антарктической экспедиции, когда одновременно проводились работы по сбору взвеси из поверхностного слоя воды и определение первичной продукции [2,5].

ЖЕЛЕЗО

Железо является необходимым элементом во всех жизненных процессах, происходящих в морях и океанах, в частности оно необходимо для развития планктонных организмов.

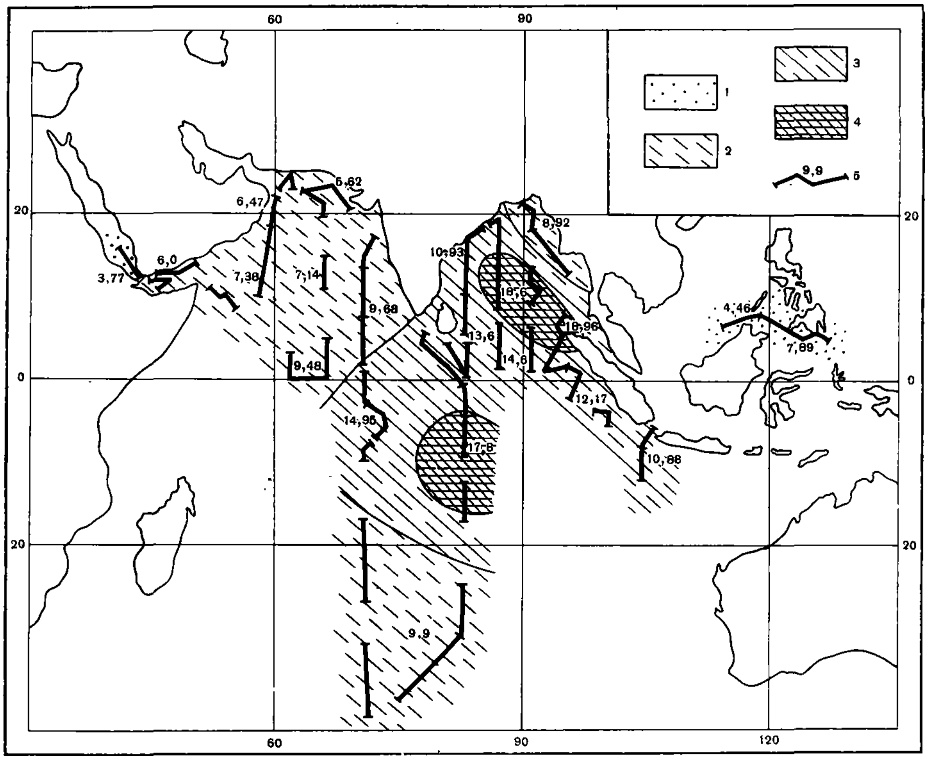

Рис. 4. Схема распределения железа во взвеси (в % от сухого вещества)

1 — менее 5; *2* — 5—10; *3* — 10—15; *4* — более 15; *5* — фактическое содержание в пробах

Основная масса железа поступает в океан из рек в виде тонкой взвеси. В растворенном состоянии железо выносится реками в гораздо меньших количествах. Например, М. А. Глаголева [12] дает для рек бассейна Черного и Азовского морей следующие цифры выноса железа: во взвешенном состоянии — 80—99%, в растворенном — 1—20%. Взвешенное железо в морской воде существует в основном в форме гидроокиси $Fe(OH)_3$ [11]. Основная часть гидроокиси железа, вынесенной реками, в океане, перерабатываясь организмами фитопланктона, включается в пищевые цепи и в итоге попадает на дно.

Рассмотрим количественное распределение валового железа во взвеси (в % от сухого вещества) в поверхностных водах Северной части Индийского океана (табл. 1, рис. 4).

Количество железа во взвеси колеблется в пределах от 3,77 до 18,96%, при среднем значении для всей исследованной площади — 10,39% (табл. 2), что намного выше, чем для южной части океана, где его среднее значение 3,14% [9].

Из табл. 5 видно, что более чем три четверти проб содержат от 5 до 15% железа, тогда как в южной части океана в подавляющем большинстве случаев содержание железа в пробах менее 5%.

Выявляется довольно четкая картина в расположении проб взвеси с различным содержанием железа (рис. 4, табл. 5). Западная и южная части описываемой площади океана характеризуются содержанием железа во взвеси 5—10%, за исключением пробы № 3 из Красного моря, где количество его минимально, — 3,77%. Во взвеси же из восточной ча-

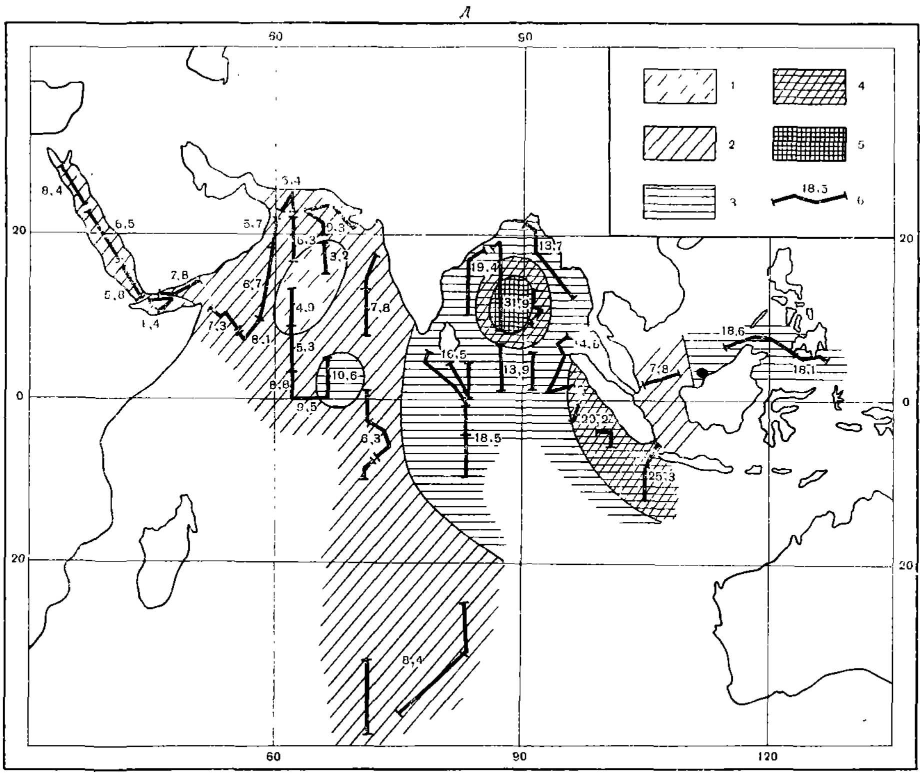

Рис. 5. Схема содержания во взвеси фракции 0,005—0,001 *мм* (в % от сухого вещества) *1* — менее 5; *2*—5—10; *3*—10—20; *4*—20—30; *5*— более 30; *6*— фактическое содержание в пробах

сти концентрация железа превышает 10%, достигая максимума у северо-западной оконечности острова Суматра — 18,96%, и лишь в северной части Бенгальского залива она уменьшается до 8,92%.

При сравнении рис. 4 с картами гранулометрического состава взвеси [4] бросается в глаза большое сходство в распределении содержания во взвеси железа и фракции 0,005—0,001 *мм* (рис. 5). Таким образом,

Таблица 5

Частота встречаемости различных концентраций Fe во взвеси из поверхностных вод северной части Индийского океана

Концентрация Fe, % от сухого вещества	% от сухого вещества				*мг/л*			
	5	5—10	10—15	> 15	0,01	0,01—0,02	0,02—0,03	> 0,03
Частота встречаемости, %	9,5	47,6	28,6	14,3	14,3	66,7	9,5	9,5

можно предположить, что основная часть взвешенного железа в поверхностных водах имеет размерность от 1 до 5 *мк*. По данным Е. Гольдберга, М. Беккера и Д. Фокса [13], большая часть взвешенного железа приходится на фракцию меньше 10 *мк*. По данным В. В. Мокиевской [10], для поверхности Черного моря количество железа в частицах, размерностью менее 0,5 *мк* составляет 50—70% от его общего содержания.

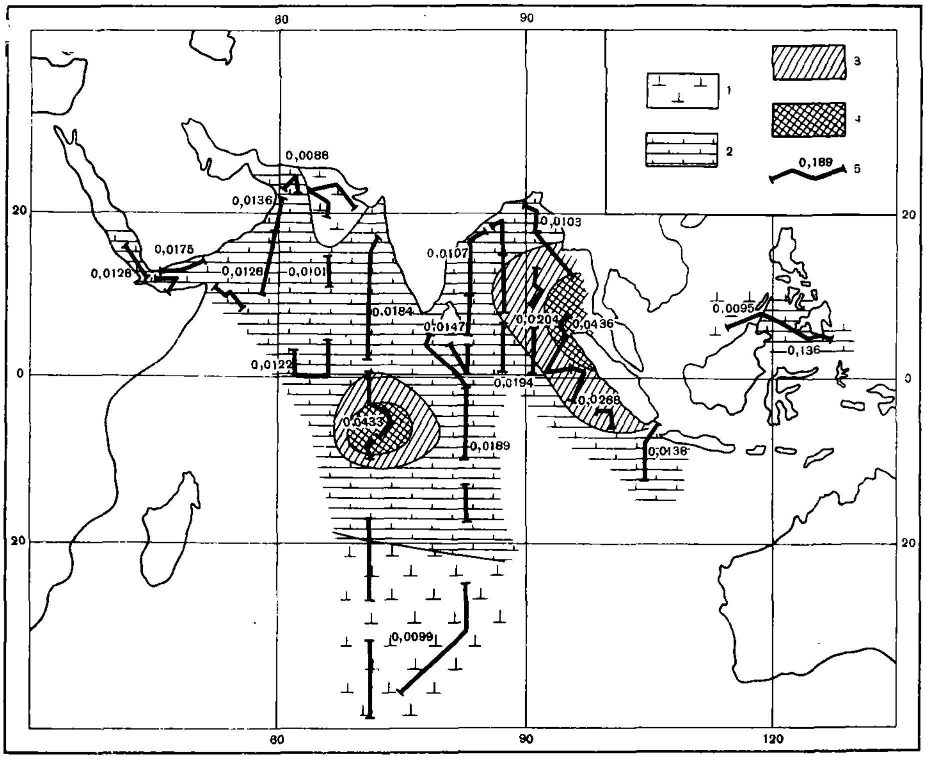

Рис. 6. Схема распределения железа во взвеси (в *мг/л*)

1 — менее 0,01; *2*—0,01—0,02; *3*—0,02—0,03; *4*— более 0,03; *5*— фактическое содержание в пробах

При сопоставлении распределения железа во взвеси с распределением субколлоидной фракции (менее 0,001 *мм*) наблюдается обратная зависимость по сравнению с распределением фракции 0,005—0,001 *мм*, т. е. бо́льшая часть железа в водах северной части Индийского океана существует во взвешенном состоянии, а не в субколлоидном.

Несколько неожиданная картина в распределении железа во взвеси обнаруживается в северных частях Аравийского моря и Бенгальского залива, куда впадают такие мощные реки, как Инд и Ганг, несущие громадное количество терригенного материала. Так как основная масса взвешенного железа поступает в океан с речными водами, было бы естественным ожидать резкое увеличение его во взвеси именно в северных частях Аравийского моря и Бенгальского залива. На самом деле наблюдается обратная картина: в пробе № 20+21 количество железа составляет 5,62% от взвеси, а в пробе № 47+48 равно 8,92%, т. е. меньше, чем в пробах, взятых на удалении от устьев Инда и Ганга. Уменьшение содержания железа во взвеси можно было бы объяснить разбавлением терригенным материалом, но заметного увеличения концентрации взвеси в этих местах также не отмечается (см. табл. 1).

Интересны данные о содержании взвешенного железа в пересчете на 1 *л* воды (рис. 6, табл. 2). В водах северной части Индийского океана количество его составляет 0,0088—0,0436 *мг/л*, при среднем значении 0,0172 *мг/л*. Последняя цифра близка к средним значениям содержания железа в водах южной части Индийского океана — 0,018 *мг/л* [9]. Из

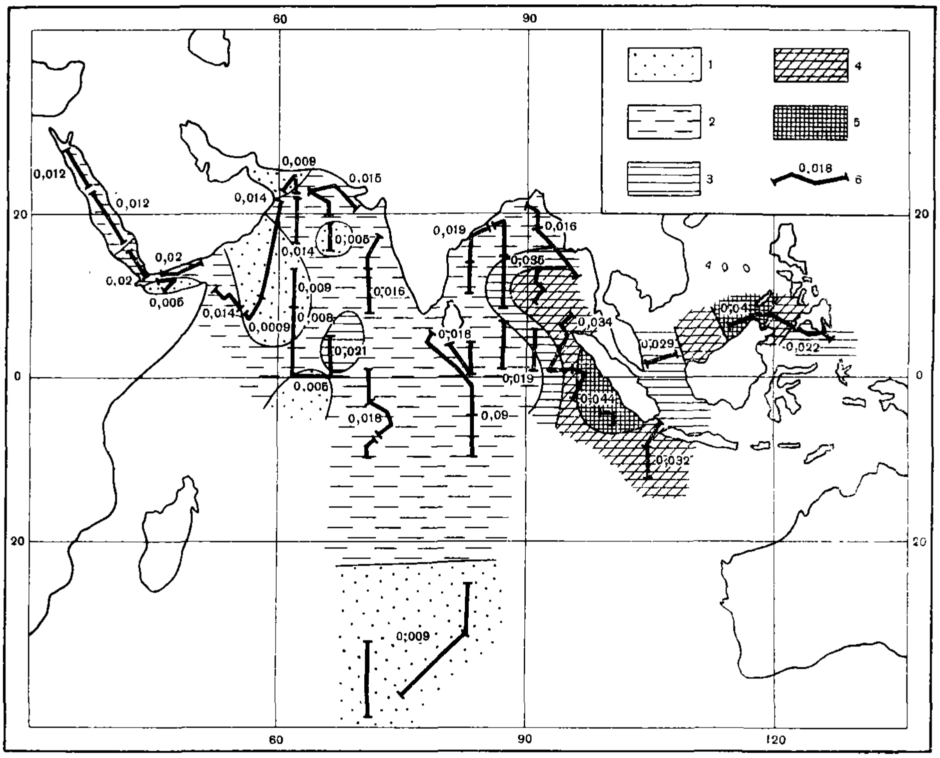

Рис. 7. Схема содержания во взвеси фракции 0,005—0,001 *мм* (в *мг/л*)
1 — менее 0,01; *2* — 0,01—0,02; *3* — 0,02—0,03; *4* — 0,03—0,04; *5* — более 0,04; *6* — фактическое содержание в пробах

табл. 5 видно, что в двух третях проб концентрация железа составляет 0,01—0,02 *мг/л*.

Схема распределения взвешенного железа в поверхностных водах значительно отличается от процентного содержания его во взвеси. На фоне средних значений (0,01—0,02 *мг/л*) выделяются две области повышенного содержания железа. Вблизи архипелага Чагос количество железа достигает 0,0433 *мг/л*, что связано со значительным увеличением концентрации взвеси в окружающих острова водах. Довольно обширная область повышенной концентрации железа расположена в восточной части Бенгальского залива и в водах у западного побережья острова Суматра. Содержание взвешенного железа здесь более 0,02 *мг/л*, а у северо-западного окончания острова достигает максимального значения — 0,0436 *мг/л*. Существование этой области повышенной концентрации взвешенного железа в воде можно объяснить деятельностью многочисленных действующих вулканов, расположенных, в частности, на острове Суматра.

На рис. 6, как и на рис. 4, не отмечается заметного влияния речного стока Инда и Ганга на концентрацию взвешенного железа в воде. Скорее, наоборот, в северной части Бенгальского залива концентрация его незначительно превышает 0,01 *мг/л*, а в северной части Аравийского моря составляет даже 0,0088 *мг/л*, т. е. является минимальной на всей исследованной акватории.

В схеме распределения железа намечается определенная связь с фракцией 0,005—0,001 *мм* (рис. 6, 7), т. е. область повышенного содержания взвешенного железа в восточной части Бенгальского залива и у западного побережья острова Суматра контролируется увеличением концентрации частиц размерностью 0,005—0,001 *мм*.

КАРБОНАТ КАЛЬЦИЯ

Карбонат кальция ($CaCO_3$) во взвеси определялся по методу Кнопа — Фрезениуса. Содержание его в пробах взвеси колеблется в пределах 3,48—9,96%, при среднем значении 6,49% (см. табл. 2 и 3). Так как все пробы были собраны в области развития перидиниево-фораминиферового планктона, то эти цифры характеризуют карбонатность перидиниево-фораминиферовой взвеси. А. П. Лисицын [9] дает для этой области (по 13 пробам) более низкое среднее значение — 2,97, что, вероятно, связано с сезонными изменениями в развитии планктона, который является основным поставщиком карбоната кальция во взвесь.

По содержанию $CaCO_3$ во взвеси рассматриваемую площадь можно грубо разделить на две части: западную и восточную (рис. 8). Западная часть характеризуется содержанием карбоната кальция во взвеси в 7,5—10%, за исключением центральной части Аравийского моря и более южной области, где оно уменьшается до 3,48%. Восточная часть (примерно восточнее 80° в. д.) характеризуется меньшим содержанием $CaCO_3$ во взвеси — 5—7,5%, а в районе Андаманского моря и западного побережья острова Суматра — менее 5%.

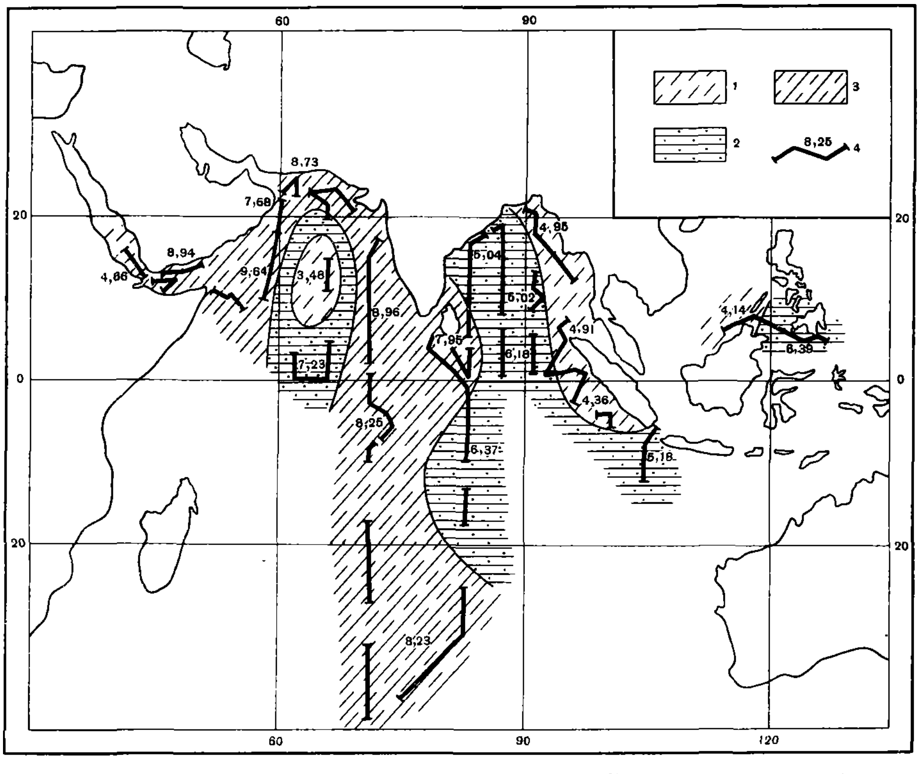

Рис. 8. Схема распределения $CaCO_3$ во взвеси (в % от сухого вещества)

1 — менее 5; *2* — от 5 до 7,5; *3* — более 7,5; *4* — фактическое содержание в пробах

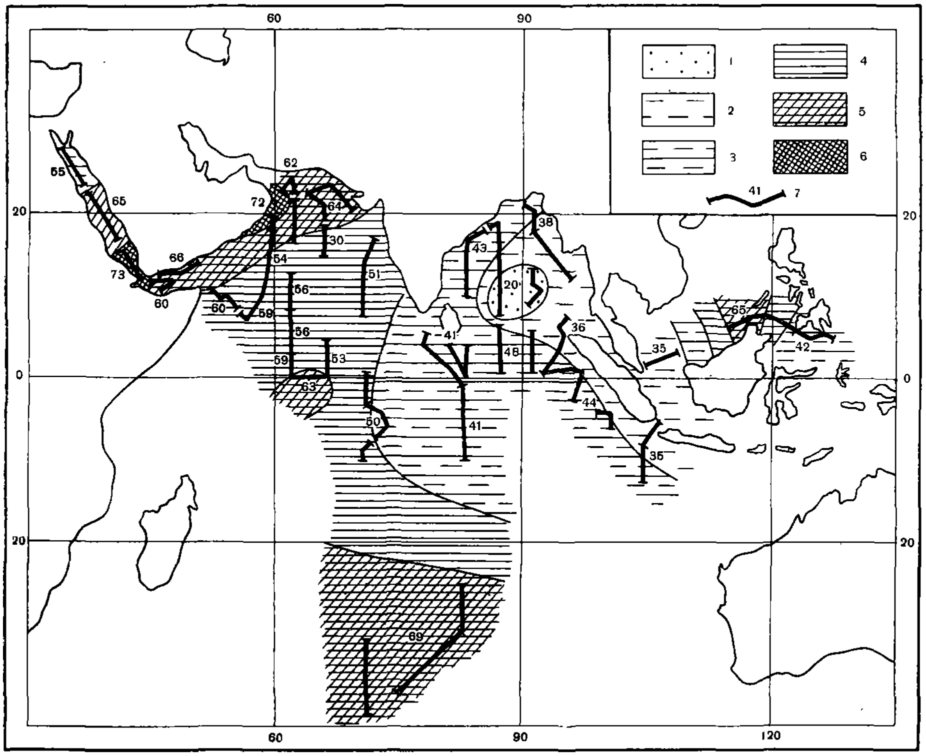

Рис. 9. Схема содержания во взвеси фракции менее 0,001 *мм* (в % от сухого вещества)

1 — менее 30; *2* — 30—40; *3* — 40—50; *4* — 50—60; *5* — 60—70; *6* — более 70; *7* — фактическое содержание в пробах

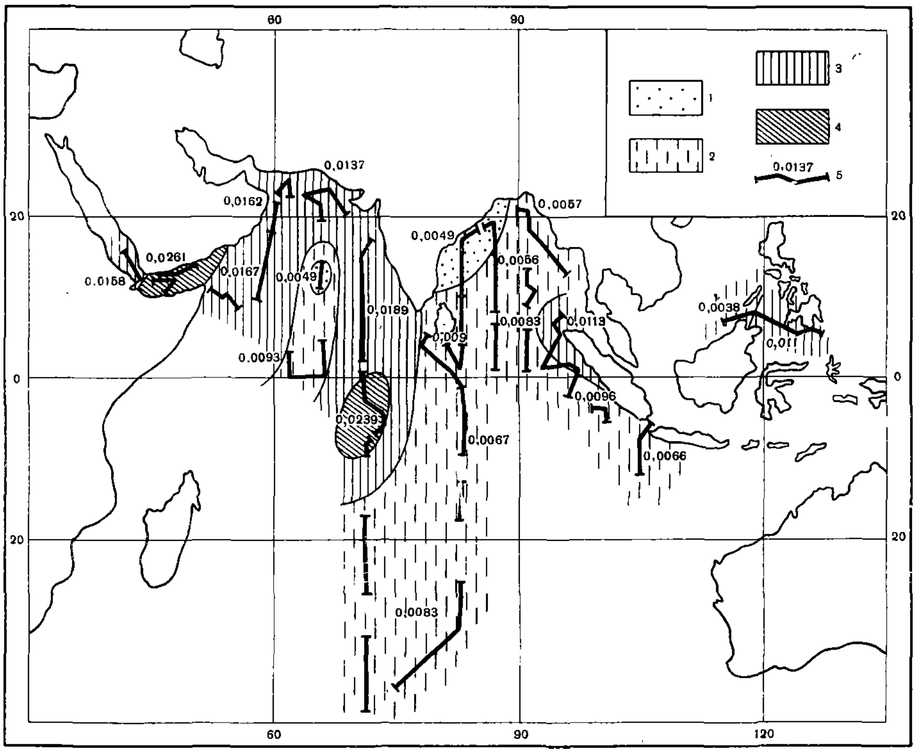

Рис. 10. Схема распределения $CaCO_3$ во взвеси (в *мг/л*)

1 — менее 0,005; *2* — 0,005—0,01; *3* — 0,01—0,02; *4* — более 0,02; *5* — фактическое содержание в пробах

Сравнивая рис. 8 с распределением фракции менее 0,001 *мм* во взвеси в процентах (рис. 9), можно отметить в общих чертах сходную картину, т. е. при движении с востока на запад количество карбоната кальция и частиц субколлоидной фракции возрастает. Следовательно, в состав карбоната кальция во взвеси входит значительная часть пелитоморфного карбонатного материала. Это подтверждается также при просмотре под микроскопом проб взвеси из поверхностного слоя воды, полученных методом мембранной ультрафильтрации. Как правило, карбонат кальция на фильтрах в основном состоит из мелкого пелитового материала размерностью 1 *мк* и менее. Другой существенной частью карбоната кальция во взвеси при просмотре под микроскопом являются кокколитофориды, размер которых также около 1 *мк*. Фораминиферы же во взвеси из поверхностного слоя воды встречаются относительно редко, хотя с глубиной количество их быстро возрастает и они составляют там существенную часть.

При пересчете карбоната кальция в *мг/л* также выявляются две различные по содержанию $CaCO_3$ части океана: западная и восточная (рис. 10). Западная часть характеризуется концентрациями $CaCO_3$ больше 0,01 *мг/л*, причем здесь выделяются две области с содержанием более 0,02 *мг/л*: Аденский залив (0,0261 *мг/л*) и район архипелага Чагос (0,0239 *мг/л*). В центральной части Аравийского моря и прилегающем к ней с юга районе концентрация $CaCO_3$ несколько меньше 0,01 *мг/л*.

В восточной части количество карбоната кальция не превышает 0,01 *мг/л*, кроме узкой полосы у северного побережья острова Суматра.

АМОРФНЫЙ КРЕМНЕЗЕМ

Аморфный кремнезем ($SiO_{2\,\text{аморфн}}$) определялся в сепарационных пробах только для северо-западной части океана (Красное море, Аденский залив и Аравийское море с прилегающей к нему частью Индийского океана). Количество аморфного кремнезема во взвеси здесь очень мало и составляет 0,15 — 1,73%, при среднем значении 0,69% (см. табл. 1 и 2).

Распределение аморфного кремнезема в процентах от взвеси (рис. 11) обратно распределению во взвеси $CaCO_3$. В центральной и южной частях Аравийского моря и в Красном море содержание $SiO_{2\,\text{аморфн}}$ несколько превышает 1,0%, а в восточной и северо-западной частях — достигает минимальных значений 0,21 — 0,15%, т. е. этот район характеризуется почти полным отсутствием во взвеси остатков кремневых организмов. Сравнивая эти данные с данными, полученными во 2-м рейсе д/э «Обь» [9], можно отметить близкую сходимость результатов в одних и тех же районах. Так, в Аденском заливе и Красном море количество $SiO_{2\,\text{аморфн}}$ во взвеси, по нашим данным, соответственно 0,30 и 1,73%, а по данным А. П. Лисицына — 0,44 и 1,54%.

Сходная картина наблюдается и в распределении аморфного кремнезема в *мг/л* (рис. 12). На северо-западе и востоке Аравийского моря концентрация $SiO_{2\,\text{аморфн}}$ всего лишь 0,003 — 0,004 *мг/л*, а в центральной части она несколько увеличивается (до 0,0017 *мг/л*). Самое высокое содержание аморфного кремнезема обнаружено в южной части Красного моря — 0,0059 *мг/л*.

ФОСФОР

Основная часть фосфора, попадающая во взвесь, связана с жизнедеятельностью планктонных организмов. Так, среднее количество фосфора в перидиниевых водорослях составляет 0,57% [9]. Содержание фосфора во взвеси колеблется в пределах 0,21—0,46%, при среднем значении 0,34% (см. табл. 1, 26). Это очень близко совпадает с данными по

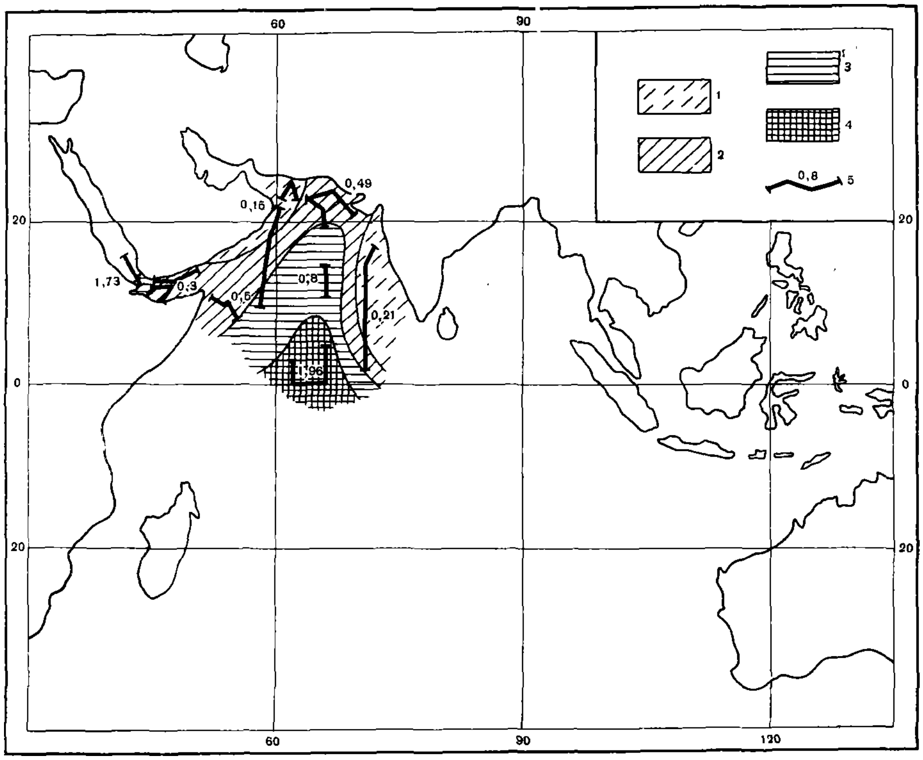

Рис. 11. Схема распределения $SiO_{2\,\text{аморфн}}$ во взвеси (в % от сухого вещества)

1 — менее 0,25; *2* — 0,25—0,5; *3* — 0,5—1,0; *4* — более 1,0; *5* — фактическое содержание в пробах

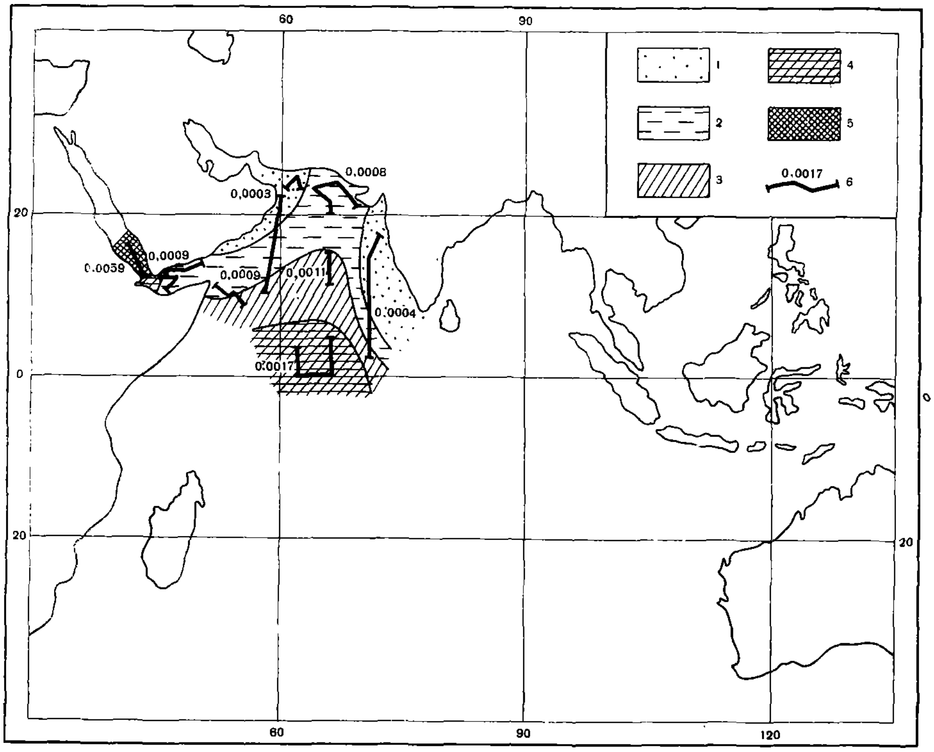

Рис. 12. Схема распределения $SiO_{2\,\text{аморфн}}$ во взвеси (в *мг/л*)

1 — менее 0,0005; *2* — 0,0005—0,001; *3* — 0,001—0,0015; *4* — 0,0015—0,002; *5* — более 0,002; *6* — фактическое содержание в пробах

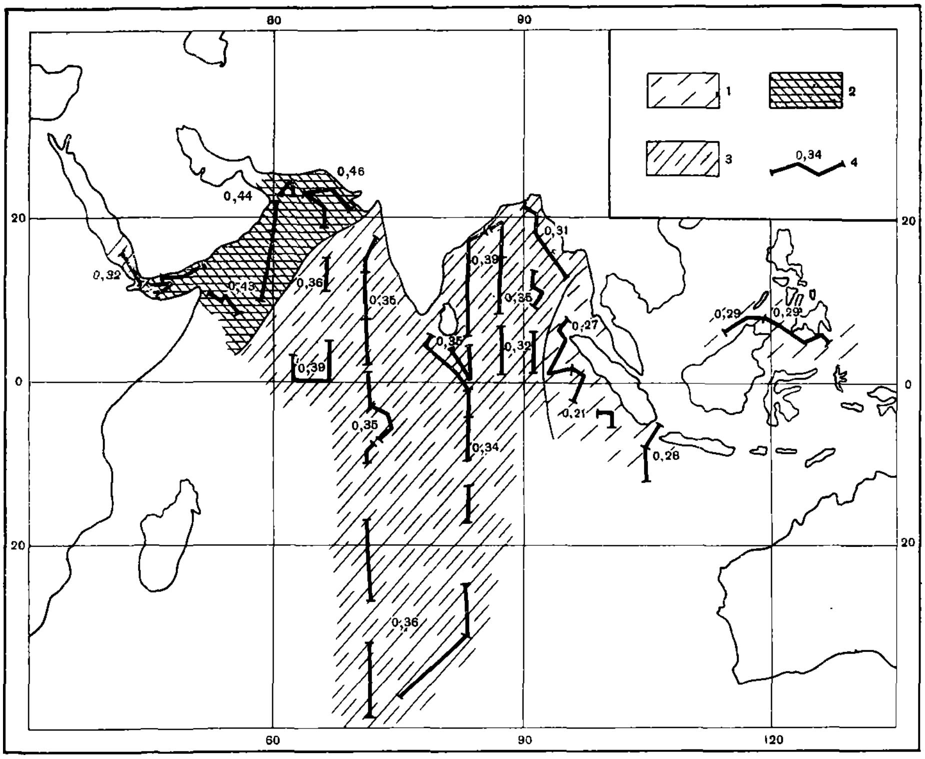

Рис. 13. Схема распределения фосфора во взвеси (в % от сухого вещества)
1 — менее 30; *2* — 30—40; *3* — более 40; *4* — фактическое содержание в пробах

южной части Индийского океана [9], где среднее значение равно 0,30%. Таким образом, количество фосфора во взвеси, полученной из области развития перидиниево-фораминиферового планктона, значительно меньше, чем в чистых перидиниевых водорослях, т. е. он разбавлен абиогенным материалом.

На рис. 13 показана схема распределения фосфора в процентах от сухой взвеси. Из рис. 11 и табл. 6 видно, что в основной части проб взвеси, расположенных в центральной части океана, фосфор составляет 0,3—0,4%. В восточной части количество его уменьшается до значений несколько бо́льших, чем 0,20%, а в западной половине Аравийского моря увеличивается до 0,43—0,46%.

Таблица 6

Частота встречаемости различных концентраций фосфора во взвеси из поверхностных вод северной части Индийского океана

Концентрация P, % сухого вещества	%			*мг/л*		
	0,30	0,3—0,4	0,4	0,0005	0,0005—0,001	0,001
Частота встречаемости, %	25	55	20	50	35	15

Сравнивая схему распределения фосфора в процентах со схемой распределения во взвеси $C_{орг}$ (см. рис. 2), видим довольно сходную картину. В западной части совпадают контуры максимальных значений, в во-

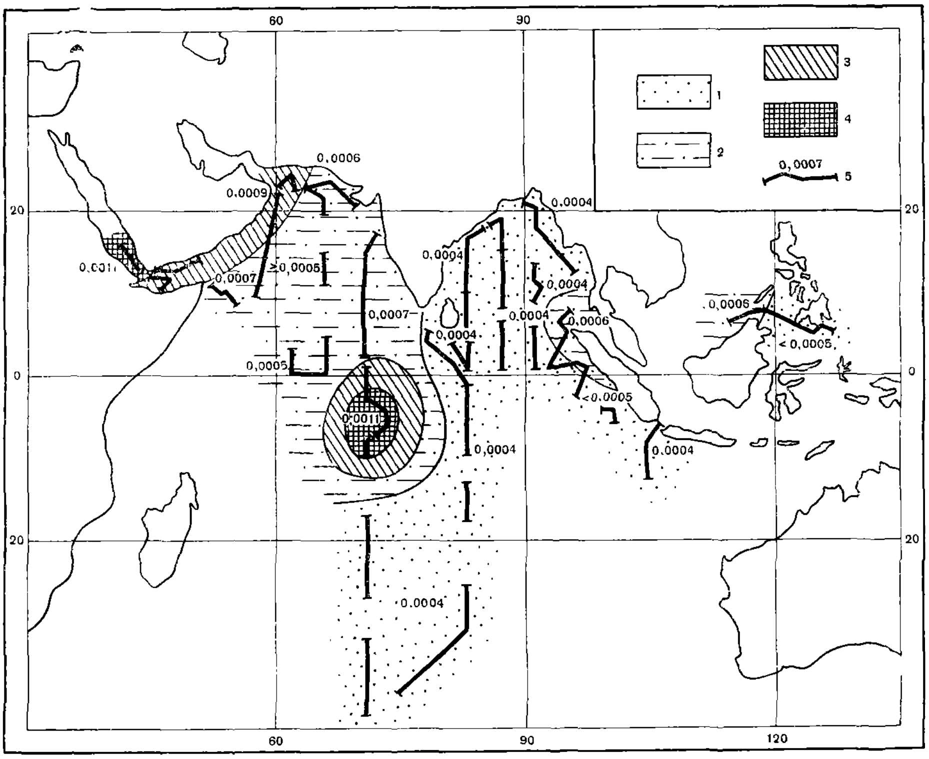

Рис. 14. Схема распределения фосфора во взвеси (в *мг/л*)

1 — менее 0,0005; *2* — 0,0005—0,00075; *3* — 0,00075—0,001; *4* — более 0,001; *5* — фактическое содержание в пробах

сточной — минимальных. Это говорит о том, что основная часть фосфора во взвеси связана с жизнедеятельностью морских организмов.

Количественное распределение взвешенного фосфора в поверхностном слое воды (в *мг/л*) показано на рис. 14. Наблюдается такая же картина, что и в схеме распределения $C_{орг}$ (см. рис. 3). На обоих рисунках совпадают области максимальных и минимальных значений $C_{орг}$ и P.

Содержание фосфора во взвеси колеблется от 0,0004 до 0,0011 *мг/л*, при среднем значении — 0,00057 *мг/л*. При этом в водах восточной части исследованной площади концентрация фосфора менее 0,0005 *мг/л*, а в западной — более 0,0005 *мг/л*, причем в районе архипелага Чагос и в Красном море она достигает 0,0011 *мг/л*.

ABSTRACT

The paper analyses the granulometric composition of the suspension obtained by the separation method from the surface waters of the northern and central parts of the Indian Ocean during the 33rd cruise of the e/s «Vityaz». The schemes of area distribution of suspended particles are given according to separate fractions (more than 0.05, 0.05—0.01; less than 0.01, 0.01—0.005, 0.005—0.001 and less than 0.001 mm) in per cent of the dry suspension matter and in mm per 1l of water. The major part of the suspension (averagely about 70%) is made by pelite particles less than

0.01 mm in size, while 50% of the suspension consists of particles of the subcolloidal fraction (less than 0.001 mm).

In the central part of the studied area (the region adjacent to the Hindustan Peninsula) the amount of the pelite particles in the suspension is 60—70%. On the north-east from it (eastern part of the Bay of Bengal, the Andaman Sea) their number is reduced to 50—60%, while to the north-west (western part of the Arabian Sea and the Red Sea) and to the south (to the south of 20° S) it increases to 80% and more.

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Reprinted from *Okeanol. issled.*, no. 19, 1968, p. 189-194

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ГЕОМОРФОЛОГИЯ И МОРФОМЕТРИЧЕСКИЕ ХАРАКТЕРИСТИКИ УЧАСТКА АРАВИЙСКО-ИНДИЙСКОГО ХРЕБТА

В последние годы большое внимание уделяется строению и генезису подводных срединно-океанических хребтов, представляющих собой единую систему, протягивающуюся в общей сложности более чем на 40 000 *км*.

Установлено [1, 2, 3], что эта система является непрерывным образованием, которое прослежено во всех океанах. Наиболее полно оно изображено на батиметрической и геоморфологической картах Мирового океана, помещенных в Физико-географическом атласе мира [4].

Большой интерес для выяснения природы срединно-океанических хребтов представляет детальное изучение их отдельных участков. Обобщение достаточно подробного материала по регионам позволит получить представление об устройстве всей системы, проследить морфологические и генетические особенности ее отдельных частей. Такое детальное изучение проведено для некоторых частей Срединно-Атлантического хребта [1].

Работы на небольших полигонах проводились английскими исследователями на «Оуэне» и советскими на «Витязе». Однако анализ геоморфологических данных по результатам этих экспедиций еще, по-видимому, не проводился.

Автором была предпринята попытка исследовать геоморфологию сравнительно хорошо обеспеченного промером участка Аравийско-Индийского хребта, входящего в систему срединно-океанских хребтов. Он ограничен координатами 58°30′—63° в. д. и 6°—10° с. ш. Имевшиеся в распоряжении автора материалы позволили построить 22 профиля (рис. 2), схема расположения которых с названиями выполнявших промер судов показана на рис. 1.

Эти профили, а также некоторое количество отдельных отметок глубин были использованы для построения батиметрической (рис. 3) и геоморфологической (рис. 4) карт, а также карт расчлененности и углов наклона.

Батиметрическая карта построена по методу геоморфологической интерполяции, разработанному советскими исследователями под руководством Удинцева [5—7].

Легенда геоморфологической карты составлена автором на основе легенд ряда геоморфологических карт [4, 8, 9] и районирования Аравийско-Индийского хребта, предложенного Белоусовым [10].

Для составления карт морфометрических характеристик оказалось необходимым провести ряд методических исследований, поскольку ранее имелся только опыт составления карты интенсивности расчленения (крутизны склонов) мезорельефа дна Охотского моря [8, 11]. Работы Г. Б. Удинцева

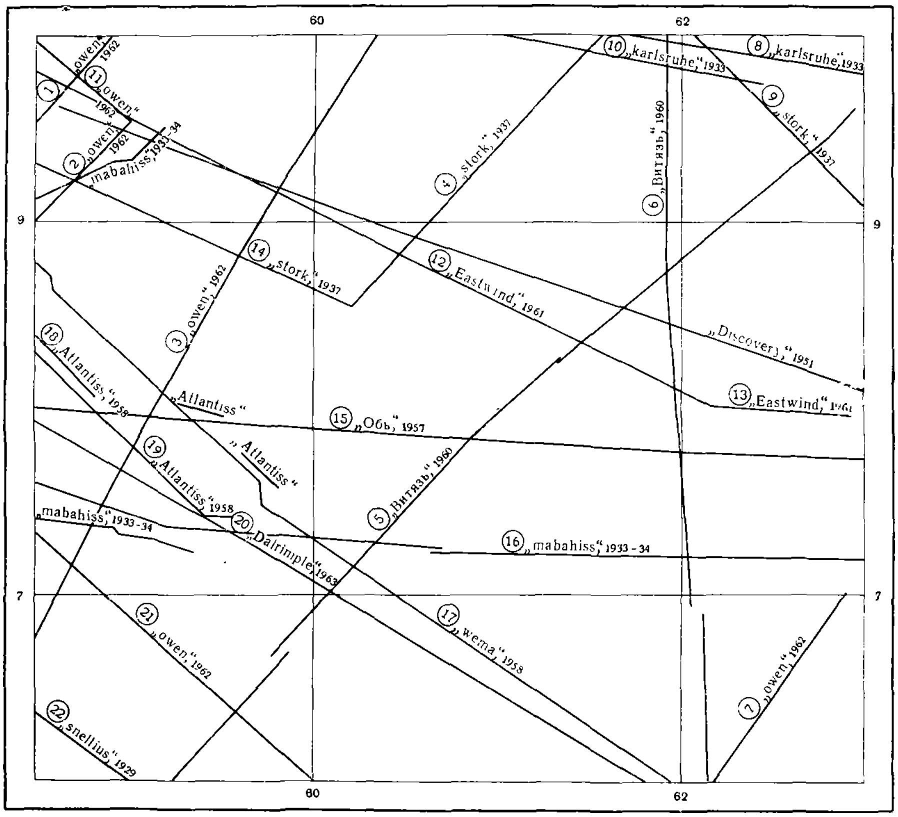

Рис. 1. Схема маршрутов экспедиций, проводивших промерные работы на рассматриваемом участке Аравийско-Индийского хребта.

Номера на галсах соответствуют номерам на профилях, приведенных на рис. 2

показали необходимость построения морфометрических карт морского дна. Однако работ по методике изучения морфометрии дна с тех пор не появлялось.

Нами, так же как и Г. Б. Удинцевым, за основу была взята методика определения морфометрических характеристик, разработанная Ченцовым [12] и Волковым [13]. Ими предложено для числовой характеристики рельефа суши применять следующие показатели: а) ритм рельефа — расстояние по горизонтали между соседними поднятиями и понижениями; б) глубину расчленения — величину перепада высот между соседними вершинами и депрессиями; в) крутизну склонов — величину, характеризующую угол наклона поверхности.

Основным отличием нашей методики от рекомендованной Волковым и Ченцовым было проведение расчетов по профилям рельефа дна, а не по сетке взаимно перпендикулярных профилей, снятых с крупномасштабных топографических карт. Это, естественно, объясняется отсутствием таких карт для дна открытого океана. Кроме того, были несколько модифицированы формулы Ченцова и Волкова, которые приобрели следующий вид.

Ритм рельефа $d = \frac{D}{m-1}$, где D — длина определенного участка профиля, принятого для расчета, m — число точек перегиба профиля, считая

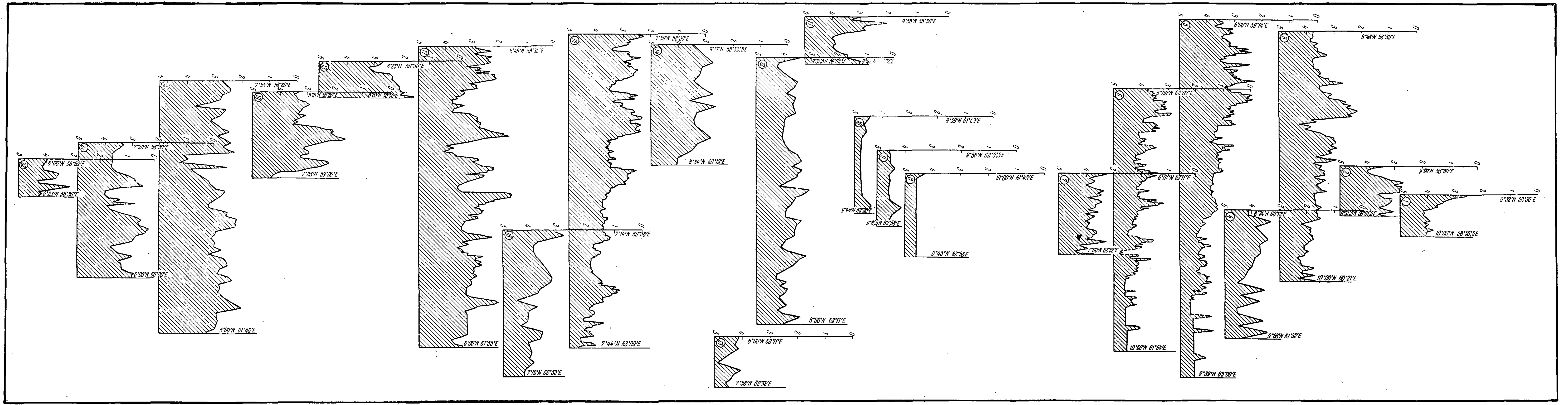

Рис. 2. Профили рельефа дна участка
Аравийско-Индийского хребта

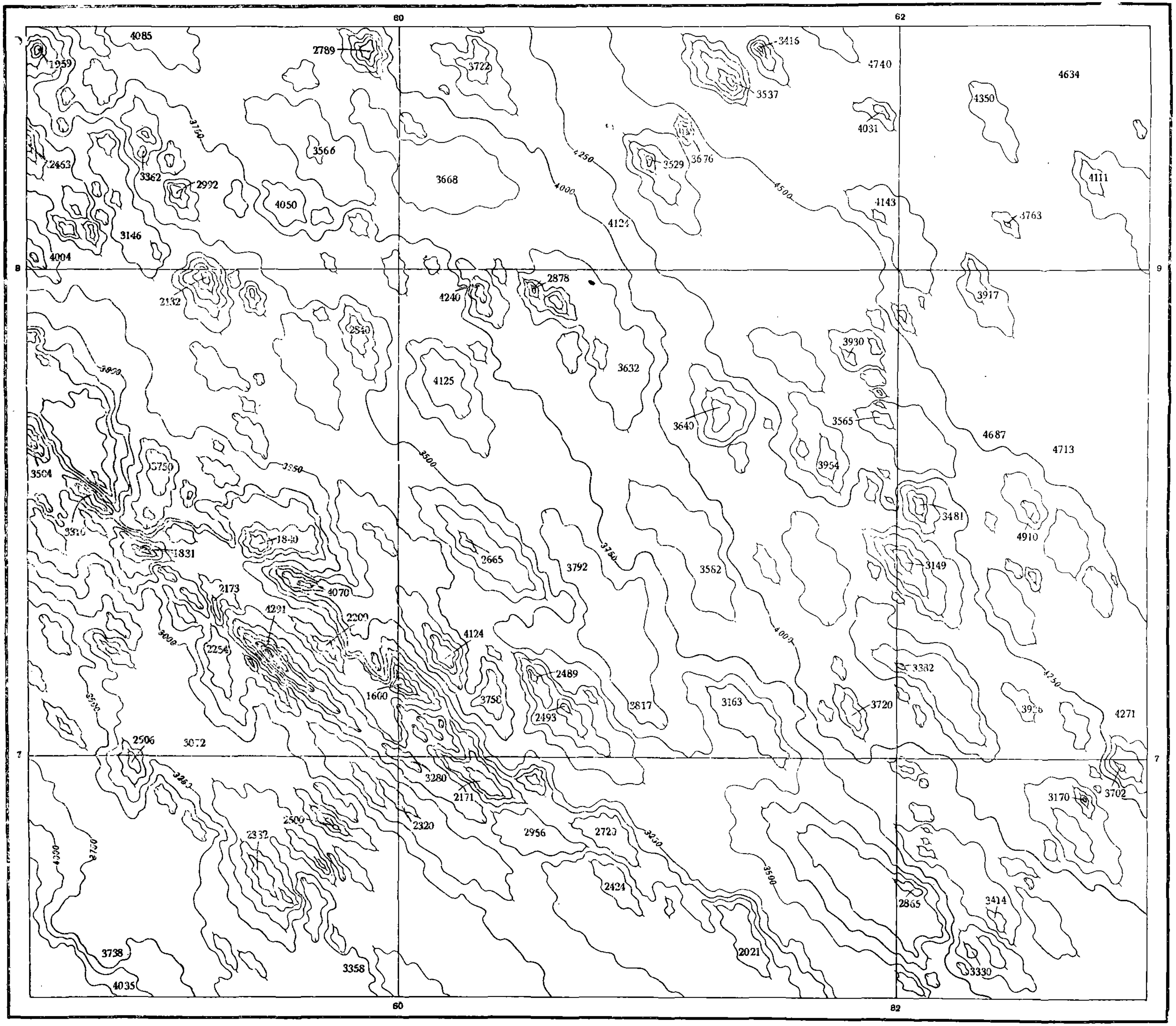

Рис. 3. Батиметрическая карта участка Аравийско-Индийского хребта. Сечение изобат — 250 *м*

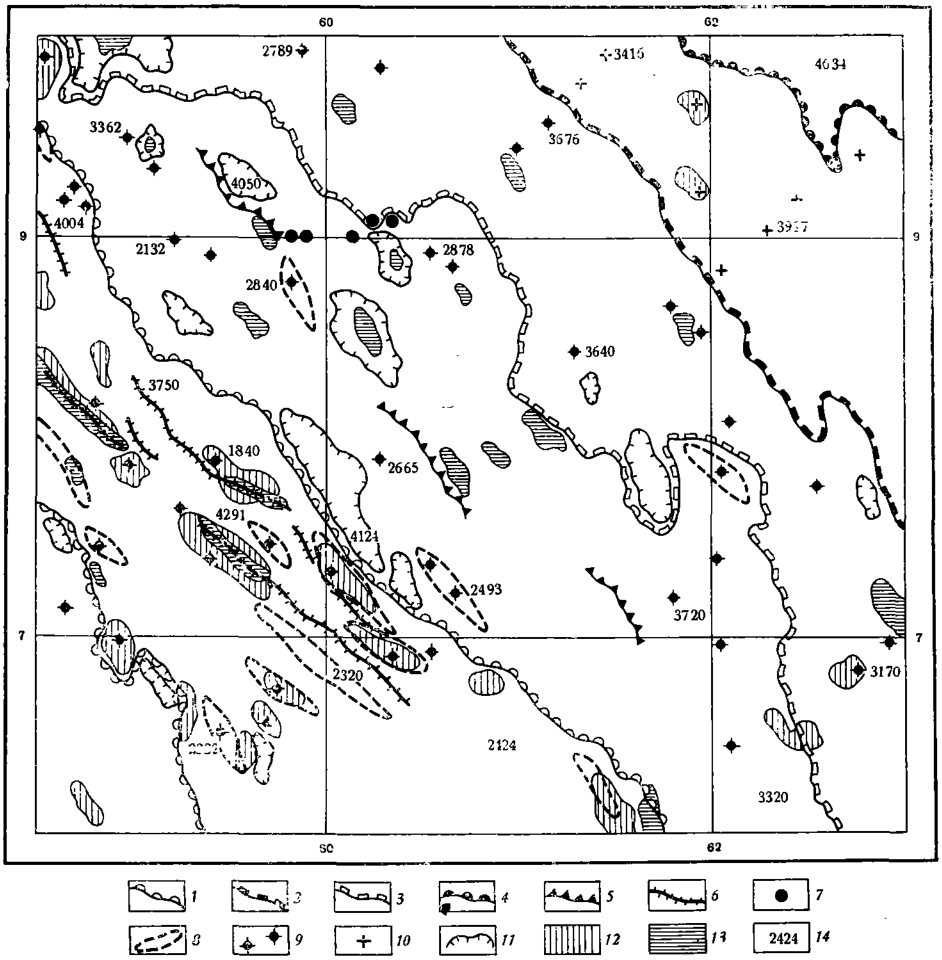

Рис. 4. Геоморфологическая карта участка Аравийско-Индийского хребта.

1 — границы центральной части; 2 — границы внутренней ступени; 3 — границы хребта (совпадают с краем внешней ступени); 4 — границы области субгоризонтальных аккумулятивных равнин с отдельными поднятиями, не погребенными под осадками; 5 — края вторичных ступеней; 6 — зона рифтовых долин; 7 — эпицентры землетрясений; 8 — гребни поднятий; 9 — отдельные вершины; 10 — отдельные подводные горы; 11 — отдельные замкнутые впадины; 12 — области интенсивного сноса осадочного материала; 13 — области аккумуляции осадочного материала в пределах хребта; 14 — отметки глубин

начало и конец профиля за точки перегиба.

Глубина расчленения $h_{ср} = \frac{\sum\limits_{1}^{m}[H_{ср} - H]}{m}$, где $H_{ср} = \frac{\sum\limits_{1}^{m} H}{m}$, $\sum\limits_{1}^{m} H$ — сумма глубин, включая глубины начальной и конечной точек профиля, H — глубина точек перегибов.

Средняя крутизна склонов — $\operatorname{tg}\gamma = \frac{h_{ср}}{d}$.

Данные для расчетов по этим формулам можно снимать с эхограмм или с профилей, построенных по снятым с эхограмм или с планшетов и карт отметкам. Очевидно, что лучше всего пользоваться эхограммами. Но они, как правило, не публикуются.

Чтобы выяснить, насколько отличаются показатели, вычисленные по профилям и эхограммам, был произведен расчет d, $h_{ср}$ и $\operatorname{tg} \gamma$ по данным 31-го рейса э/с «Витязь» на галсе от Сейшельских островов до Бомбея [14]. Как и следовало ожидать, весьма значительными оказались расхождения в величинах ритма рельефа. Величины, характеризующие расчлененность, различаются мало. Несмотря на значительные расхождения в крутизне наклона, характер ее изменения как по профилю, так и по эхограмме совпадает и в общем отражает изменения крутизны форм рельефа. Отсюда следует, что карты расчлененности и сравнительной крутизны склонов можно строить на основе расчетов, проведенных по снятым с профилей глубинам. Не следует забывать, конечно, что профили, построенные не по эхограммам, а по отметкам глубин с карт и планшетов, будут менее детальны и отразят только наиболее общие морфометрические закономерности рельефа.

По формулам [2], [3] нами были вычислены глубина расчленения и крутизна склонов для всех 22 профилей (см. рис. 2). Расчет проводился по участкам длиной 5—15 миль, в каждый из которых входили однородные по внешнему виду формы рельефа. За величину d была принята длина каждого участка. При построении карт предполагалось, что между соседними точками изменение значений морфометрических характеристик плавное.

После нанесения в центр каждого рассчитанного участка точки со значением глубины расчленения и крутизны склонов были составлены с применением метода геоморфологической интерполяции карта глубины расчленения (рис. 5) и карта относительной крутизны склонов (рис. 6).

Комплект из батиметрической и геоморфологической карт, карт глубины расчленения и крутизны склонов, а также профили, данные подводного фотографирования рассматриваемого участка и материалы по донным отложениям позволяют получить достаточно подробное представление о рассматриваемом участке. Он располагается в средней части Аравийско-Индийского хребта, захватывая его гребень и северо-восточные склоны. Юго-западные склоны входят в принятую нарезку карты частично. На северо-востоке участка хребет переходит в дно Аравийской котловины. Он имеет направление юго-восток — северо-запад.

Наиболее поднятая центральная часть хребта представляет собой сводовое поднятие, осложненное рядом подводных гор, часто имеющих форму конуса, что позволяет считать их вулканами. К центральной части приурочена область наибольших углов наклона и максимального расчленения. Однако местами, в основном в межгорных депрессиях, наблюдаются участки ровного или слабо наклоненного дна, что хорошо видно на профилях. На морфометрических картах эта особенность рельефа центральной части хребта выражена в своеобразном рисунке изолиний, образующих ряд мелких замкнутых ареалов. Рассмотрение профилей, расположенных вдоль центральной части, позволяет заметить, что она не непрерывна, а состоит из отдельных массивных поднятий, имеющих общее основание. Эти блоки весьма разнообразны по высоте и протяженности. Местами они разбиты глубокими трещинами. Разделяющие их депрессии также различаются по форме. Горизонтальные размеры большинства форм рельефа, по-видимому, не превышают 20—40 миль, так как на профилях, находящихся один от другого на незначительном расстоянии, не удается проследить одну и ту же форму.

Центральная часть хребта, ближе к ее северо-восточному краю, раздроблена глубоким разломом — рифтовой долиной, ширина которой между соседними вершинами около 18 миль, а относительная глубина достигает 2230 *м*. Склоны долины наклонены под углом 7,5°. Эти данные близки к средним, определенным для рифтовой долины всего Аравийско-Индийского хребта [10].

По имеющимся в нашем распоряжении данным трудно определить характер дна рифтовой долины, но материалы промера прецизионным эхолотом,

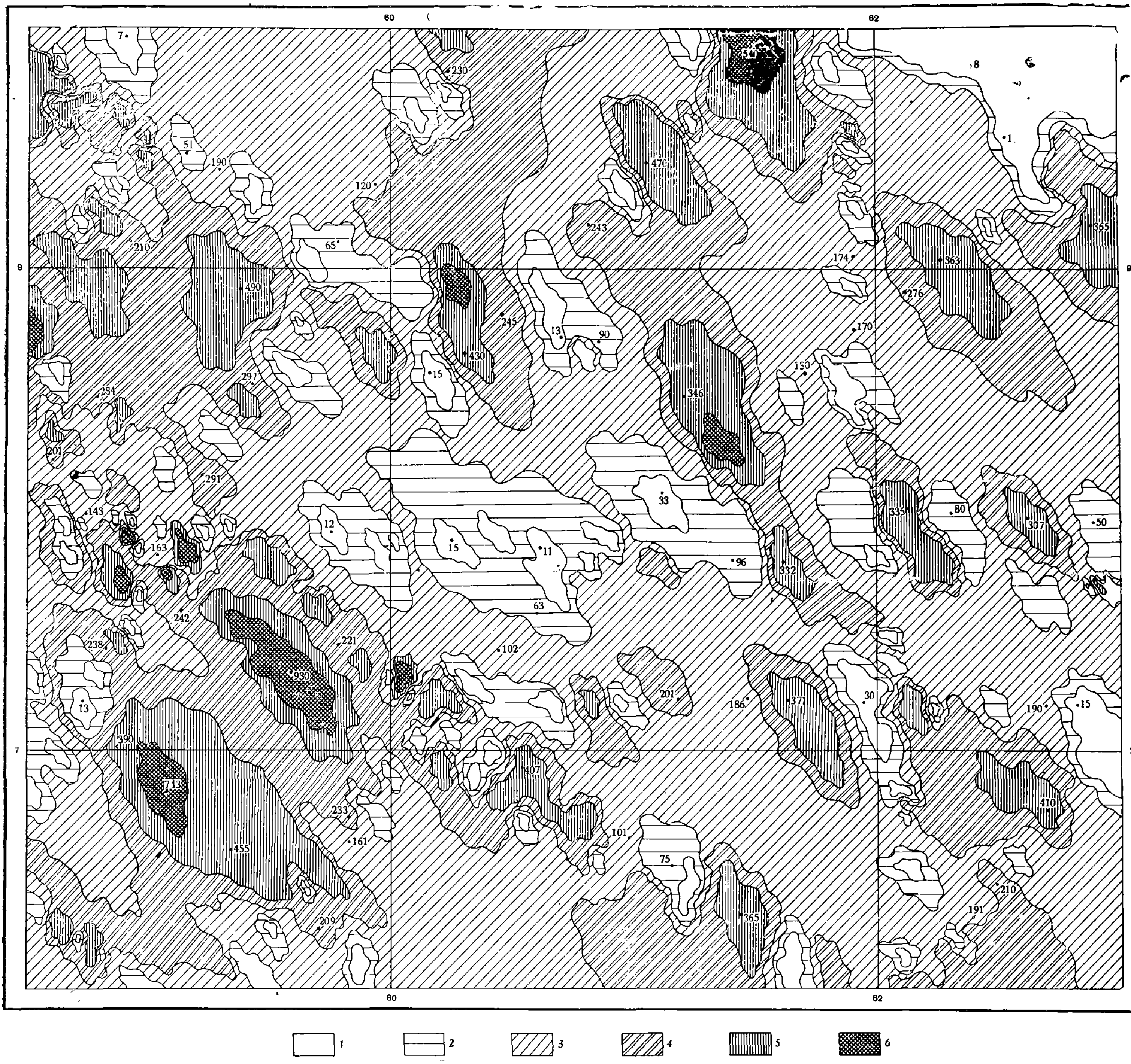

Рис. 5. Карта глубины расчленения участка Аравийско-Индийского хребта

1 — 0—50 *м*; *2* — 50—100 *м*; *3* — 100—200 *м*; *4* — 200—300 *м*; *5* — 300—500 *м*; *6* — > 500 *м*

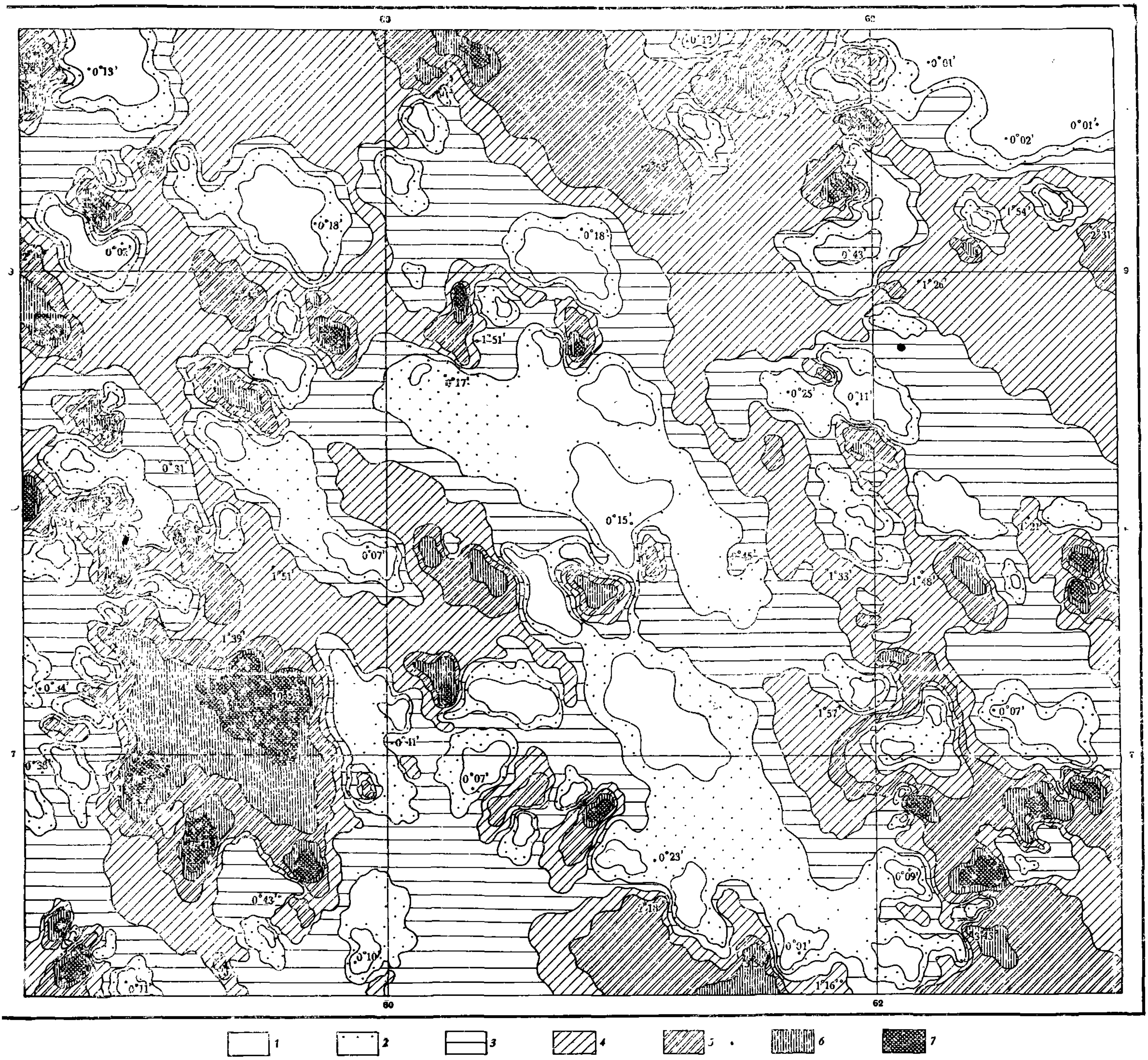

Рис. 6. Карта относительной крутизны склонов участка Аравийско-Индийского хребта

1 — 0—0°15'; *2* — 0°15' — 0°30'; *3* — 0°30' — 1°0'; *4* — 1 — 2°; *5* — 2—3°; *6* — 3—4°; *7* — > 4 полученные учеными США в 1958 г. в желобе «Вима» [15], свидетельствуют о том, что дно ее волнистое, местами на нем встречаются холмы. Возможно, это также говорит о молодости Аравийско-Индийского хребта и его рифтовой долины, так как в противном случае она была бы засыпана осадками, поступающими с крутых склонов соседних вершин, где должны быть развиты суспензионные потоки и оползневые явления.

Рифтовая долина на рассматриваемом участке не является единым непрерывным образованием. В ряде мест она исчезает и вместо нее наблюдается ряд депрессий различной глубины и простирания. Эта особенность хорошо видна на геоморфологической карте (см. рис. 4). То же заключение можно сделать и при внимательном рассмотрении батиметрической карты. Это противоречит утверждению Хизена [2] о единстве и непрерывности рифтовой долины на всем протяжении хребта.

В исследуемый нами участок входит небольшая часть юго-западной внутренней ступени, которая выделена на основании анализа профилей. Она расположена на глубинах примерно 3200—3800 *м* и представляет собой незначительно наклоненную в сторону Сомалийской котловины поверхность, на которой развиты отдельные поднятия, достигающие высоты более 1000 *м*. Глубина расчленения этой поверхности составляет в среднем 50—100 *м* при средних углах наклона до 1°. Ширина ее примерно 69 *миль*.

Северо-восточная внутренняя ступень хребта лежит в среднем на глубинах 3000—3900 *м*, но местами наблюдаются существенные отклонения за пределы этого диапазона. Ширина внутренней ступени весьма непостоянна и в деталях значительно отклоняется от общего линейного простирания хребта. Характер ее поверхности весьма разнообразен. Можно заметить небольшой общий наклон в сторону внешней ступени. На ней прослеживаются подводные поднятия — горы, массивы, небольшие гребни различных форм и очертаний. В ряде мест можно обнаружить замкнутые впадины.

Небольшие «вторичные» ступени прослеживаются на незначительном расстоянии. Такой характер рельефа накладывает отпечаток и на морфометрические карты. Среднее расчленение в 100—200 *м* сменяется гористым рельефом или ровными участками, являющимися, по-видимому, областями накопления осадочного материала. Как правило, они приурочены к значительным понижениям рельефа. Крутизна склонов также различна. Области горизонтальных равнинных поверхностей резко переходят в крутые склоны повсеместно разбросанных поднятий.

Переход к внешней северо-восточной ступени осуществлен в виде пологой, местами раздробленной поверхности. Ширина внешней ступени в среднем меньше внутренней и составляет соответственно 52 и 64 *мили*. Располагается она в среднем на глубинах 3600—4600 *м*, т. е. расчлененность ее больше, чем у внутренней ступени. Это отражает и карта глубины расчленения, где для внешней ступени обычной является глубина расчленения, превышающая 200 *м*. Встречается расчленение свыше 500 *м*, что не отмечалось на внутренней ступени. Больше и средняя крутизна склонов, реже встречаются горизонтальные участки. На внешней ступени почти нет ровных участков. Склон одного поднятия сменяется другим, причем сами склоны, как можно судить по эхограммам и составленным по ним профилям, также сильно расчленены. Возрастают горизонтальные размеры поднятий по сравнению с внутренней ступенью.

Граница внешней ступени находится в северо-восточном углу рассматриваемого района и прослеживается на небольшом расстоянии. Она несколько менее извилиста, чем граница внутренней ступени. Внешняя ступень довольно резко переходит в почти плоское дно Аравийской котловины, осложненное рядом изолированных поднятий, имеющих в ряде случаев конусообразную форму. Для этих поднятий характерно отсутствие плавного перехода от склонов ко дну котловины. Возникает предположение, что основание их засыпано осадками. Это может быть подтверждено и характером осадкообразования в Аравийской котловине, которая является как бы гигантской ловушкой для огромной массы материала, выносимого Индом и другими реками западной Иидии. Об этом свидетельствуют данные 33-го рейса «Витязя» о мощности рыхлых отложений Аравийского моря, которая уменьшается с севера на юг от 2,5 до 0,5 *км* у подножия Аравийско-Индийского хребта [16, 17].

Анализ ряда подводных фотографий, полученных в 33-м рейсе э/с «Витязь» (1960 г.), позволяет сделать ряд замечаний о микрорельефе дна исследуемого района: участки с выходами коренных пород на незначительном расстоянии сменяются участками, покрытыми крупным фораминиферовым песком. На ряде снимков видна крупная рябь, свидетельствующая о наличии значительных придонных течений, смывающих и уносящих легкие частицы к основанию поднятий и в межгорные долины.

Рассмотрение особенностей рельефа дна исследуемого района позволяет заметить некоторые закономерности. Так, юго-западные ступени хребта расположены на более низком гипсометрическом уровне, чем северо-восточные; ширина ступеней больше с юго-запада, чем с северо-востока; рифтовая долина смещена от средней оси хребта к северо-востоку; юго-западные гребни, расположенные рядом с рифтовой долиной, как правило, выше северо-восточных. Эти особенности подтверждают вывод об асимметричиом строении Аравийско-Индийского хребта [10].

ABSTRACT

The paper discusses the part of the Arabian-Indian Ridge, which is the most studied region by means of soundings. The author compiled maps of depth of dissection, tilt of slopes, and bathimetric and geomorphological maps.

The method is elaborated for the determination of morphometric characteristics of the ocean bottom for the compilation of morphometric maps. The analysis of the bottom relief profiles and the compiled maps allowed to provide the geomorphological description of the area and confirm the asymmetric structure of the Arabian-Indian Ridge.

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Reprinted from *Deep-sea Res.*, vol. 15, 1968, p. 521-534

Basalts dredged from the Amirante Ridge, western Indian Ocean*

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(*Received* 14 *November* 1967)

Abstract—Oceanic tholeiitic basalts were dredged from 2500 to 3000 m depth on each flank of the Amirante Ridge, 1200 km southeast of Somalia in the western Indian Ocean, by R.V. *Argo* in 1964. One sample, probably shed from a flow or dike in basement beneath the coralline cap, gave a whole-rock K–Ar age of $82 \pm 16 \times 10^6$ years. The age is similar to those reported by others for agglomerate from Providence Reef, nearer Madagascar, and for gabbro from Chain Ridge, the southwest member of Owen Fracture Zone, nearer the Somali coast. The Amirante Cretaceous–Early Tertiary occurrence lies between the "continental" 650×10^6 years granites of Seychelles Archipelago and the large Precambrian " continental " block of Madagascar.

Trends of major structures and distribution of the related topographic and magnetic-anomaly lineations in $7\text{–}8 \times 10^6$ km^2 of the surrounding Indian Ocean suggest that in addition to spreading of the seafloor from the seismically-active Mid-Indian Ocean Ridge–Carlsberg Ridge complex there has been, since mid-Mesozoic time, distributed left-lateral shear along 52°–54°E that has moved Madagascar at least 700 km south relative to Seychelles Bank. Measurements by others indicate the absolute movement of Madagascar has been southward as well. The emplacement of oceanic tholeiitic basalts at shallow depth, the development of volcanic topography between the sedimented Somali and Mascarene basins, and the existence of the faulted Amirante Trench and Ridge are consequences of the displacement.

INTRODUCTION

THE AMIRANTE Bank and the associated coralline atolls and sand cays lie in the western Indian Ocean about 1200 km southeast of Somalia, Africa. The area has been visited recently by research vessels participating in the International Indian Ocean Expedition 1960–1965. It lies within the sector studied by the United Kingdom ships *Owen* (1958, 1961-2, 1963–4) and *Discovery* (1963, 1964, 1967), and visited by *Vityaz* (U.S.S.R., 1959, 1967), *Akademik Kurchatov* (U.S.S.R., 1967), *Atlantis II* (U.S.A., 1963, 1965), *Vema* (U.S.A., 1963), *Horizon* (U.S.A., 1962), *Argo* (U.S.A., 1962–3, 1964), and *Meteor* (F.D.R., 1965).

The islands and their foundation are areally insignificant but of current geological and geophysical interest because they are adjacent to the anomalous granitic rocks of the Seychelles Archipelago and seemingly are linked to Madagascar, 600 km SSW, by as yet unsampled ridges and shoals (Fig. 1). Moreover, the region shown in Fig. 1 is currently of intense interest to proponents of continental drift.

No volcanic rocks are exposed on the islets in the Amirante group, but the magnetic anomaly profiles of the research vessel *Owen* (ANONYMOUS, 1963) suggest that a basaltic foundation is present at a depth of less than 1 km beneath the bank (MATTHEWS and

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DAVIES, 1966). The Amirante Trench, discovered by *Vityaz* in 1959 (BELOUSOV, 1961) lies along the western border of the Amirante Ridge (Fig. 1). Recent, precise bathymetric explorations have delineated the trench and traced its possible extension northward as a zone of irregular topography and short ridges which bounds the Somali Basin on the southeast. To the southeast a possible extension of the trench appears as a complex of ridges and deeps to the latitude of Agalega. The Amirante Ridge and trench apparently form a volcanic arc that intersects and terminates the more extensive Mascarene Plateau (Fig. 1).

The granitic rocks of the Seychelles Archipelago are about 650 × 10^6 years, or Late Precambrian, in age (MILLER and MUDIE, 1961; WASSERBURG, CRAIG, MENARD, ENGEL and ENGEL, 1963, p. 788) and geophysical studies summarized by MATTHEWS and DAVIES (1966) indicate that the Seychelles Bank is underlain by a continental crust. Gravity studies suggest that the deep continental crust-mantle contact under the Seychelles Bank rises sharply just north of the bank, and seismic refraction results indicate a sharp termination of the thickened crust to westward as well (FRANCIS, DAVIES and HILL, 1966). However, FRANCIS and SHOR (1966) reported seismic refraction results west of Saya de Malha and state :

> "... granitic material similar to that forming the Seychelles Bank appears to exist west of the Saya de Malha Bank, in all probability part of the same block. If the westward limit of this material occurs between (57° 10′E and 57° 55′E), as seems likely, its east–west extent is about 250 km—comparable in dimension to the Seychelles Bank." (p. 435).

Madagascar is composed largely of Precambrian igneous and metamorphic rocks, with late Cretaceous to Tertiary volcanics in the northern portion (FURON, 1963, pp. 354–366, for review). The only data in the region between Madagascar and the Seychelles are from large slabs of volcanic sandstone dredged near Providence Reef (at 9° 26′S, 50° 57′E, Fig. 1) at a depth of 1360 m (WISEMAN, 1936). The sandstone (samples are large slabs of volcanic agglomerate) consists of fragments of altered augite and olivine-bearing basalt and organic remains, cemented by calcite. WISEMAN suggests that these rocks may form the foundation of Providence Reef. On the basis

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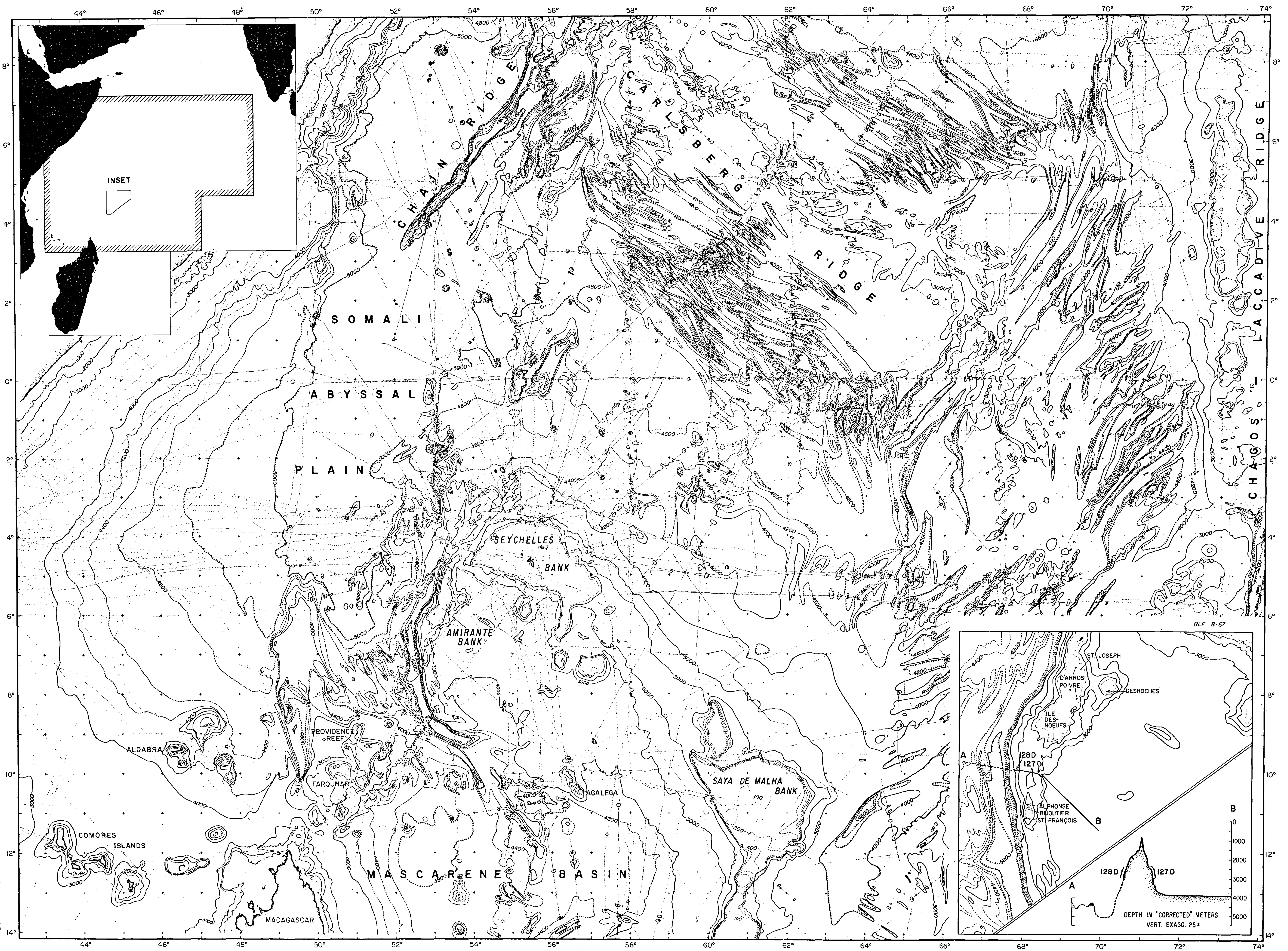
Fig. 1. (Opposite) Submarine topography of the Amirante Ridge, Somali Basin, Chain Ridge, northern part of the Mascarene Plateau, and part of the Carlsberg Ridge–Mid-Indian Ocean Ridge and Chagos–Laccadive Ridge. Contouring is in "corrected" metres, based on soundings adjusted according to MATTHEWS (1939) tables of sounding velocities. Individual soundings are represented by dots.

Note : In areas of greater than 4000 m depth a 200 m contour interval was employed. *Inset:* Location of samples dredged from the Amirante Ridge by R.V. *Argo* in July, 1964.

In addition to older, generally less precise sounding data from expedition, naval, commercial, cable, and survey vessels, the recent research and survey ship tracks include :

Federal Republic of Germany		United States of America	
Meteor II	1964–5	*Anton Bruun*	1963, 1964
France		*Argo*	1962–3, 1964
Robert Giraud	1963	*Atlantis II*	1963, 1965
		Chain	1964
United Kingdom		*Horizon*	1962
R.R.S. *Discovery*	1963, 1964, 1967	*Vema*	1958, 1963
H.M.S. *Dalrymple*	1963		
H.M.S. *Dampier*	1964	U.S.S.R.	
H.M.S. *Owen*	1961–2, 1963–4	*Vityaz*	1959, 1960, 1962, 1964


CHAIN RIDGE
CARLSBERG RIDGE
CHAGOS – LACCADIVE RIDGE
SOMALI ABYSSAL PLAIN
SEYCHELLES BANK
AMIRANTE BANK
PROVIDENCE REEF
ALDABRA
FARQUHAR
AGALEGA
SAYA DE MALHA BANK
COMORES ISLANDS
MADAGASCAR
MASCARENE BASIN
INSET
RLF 8-67
ST JOSEPH
D'ARROS
POIVRE
DESROCHES
ILE DES NOEUFS
ALPHONSE
BIJOUTIER
ST. FRANÇOIS
128D
127D
A
B
DEPTH IN "CORRECTED" METERS
VERT. EXAGG. 25×
0
1000
2000
3000
4000
5000
44°
46°
48°
50°
52°
54°
56°
58°
60°
62°
64°
66°
68°
70°
72°
74°
8°
6°
4°
2°
0°
2°
4°
6°
8°
10°
12°
14°

of the included orbitoid Foraminifera he concludes that they are probably Eocene or Oligocene in age. Actually such Foraminifera are also found in the Upper Cretaceous, although in smaller numbers (WISEMAN, 1936, p. 441).

DESCRIPTION AND COMPOSITION OF DREDGED ROCK SAMPLES

Two dredge hauls were made on the Amirante Ridge north of Alphonse Island during DODO Expedition (1964) of the Scripps Institution of Oceanography, University of California. One dredge haul, DODO 127, came from the east flank of the ridge, at a depth of 2430–3000 m, near 6° 40′S, 52° 53′E (Fig. 1, inset). The dredge hung up at the shallow end of this haul. The other dredge haul, DODO 128, was made on the west flank of the Amirante Ridge at depths of 2400–2700 m, near 6° 40′S, 52° 35′E.

Table 1. *Chemical compositions of basalts dredged from the Amirante Ridge, Indian Ocean.*

	DODO 128*C*	*DODO* 128*B*	*DODO* 127*Dd*	*Average* ‡ *Indian Ocean*, 8 *samples* (*calculated water-free*)
		Weight %*		
SiO_2	48·90	48·42	50·20	50·29
TiO_2	0·89	0·88	1·25	1·21
Al_2O_3	16·53	17·02	16·31	17·16
Fe_2O_3	4·15	3·13	4·56	2·26
FeO	5·90	6·22	6·58	6·51
MnO	0·17	0·16	0·20	0·16
MgO	7·68	8·26	6·72	7·75
CaO	12·22	11·12	9·16	11·55
Na_2O	2·21	2·49	2·78	2·83
K_2O	0·12	0·28	0·21	0·19
$H_2O +$	0·63	0·75	0·81	—
$H_2O -$	0·44	1·03	0·77	—
P_2O_5	0·07	0·05	0·22	0·09
Total	99·91	99·81	99·77	
		Parts per million†		§
Ba	8	9		14
Co	33	34		32
Cr	230	220		297
Cu	160	170		77
Ga	14	16		17
Ni	97	93		97
Sc	50	52		61
Sr	43	40		130
V	300	310		292
Y	20	30		43
Yb	4	4		5
Zr	40	40		95

*Analyst, C. G. ENGEL.

†Analyst, A. L. SUTTON, Jr., U.S. Geological Survey, Denver, Colorado.

‡6 samples from ENGEL, FISHER and ENGEL (1965, p. 606, Table 1), 1 from KORZHINSKY (1962), and 1 from CANN and VINE (1966, p. 200).

§10 Pacific and Atlantic ocean basalts in ENGEL, ENGEL and HAVENS (1965, p. 720–721, Tables 1 and 2).

Both hauls collected fragments of basalt, slabs of calcareous sandstone, some siltstone, and coralline fragments, all probably from talus slopes rather than from outcrops. The bulk of the rocks from the dredge sites consists of the slabby sandstone. The sandstones are composed of basaltic fragments, variously altered to palagonitic material, discrete grains of pyroxene, plagioclase, altered olivine, fragmental organic remains, collaphonite, and rare hornblende(?), cemented by calcite. They are very similar to the rocks described by WISEMAN, but are less altered and obviously are derived locally from the mechanical and/or chemical erosion of volcanic rocks, probably basalts.

The chemical compositions of three basalt specimens dredged from the Amirante Ridge are listed in Table 1, together with the composition of an "average" Indian Ocean tholeiitic basalt. Table 1 lists trace element analysis for two DODO samples and an average trace element composition derived from Pacific and Atlantic ocean tholeiitic basalts. Sample DODO 127 Dd is a dense, gray, angular fragment approximately 10 × 7 × 7 cm in size. The rock is very fine-grained and contains feathery intergrowths of pyroxene and plagioclase, opaque minerals, quartz(?), and rare olivine. Some of the plagioclase occurs as scattered phenocrysts or several grains of plagioclase intergrown with pyroxene. The phenocrysts of plagioclase are variously altered to chloritic and palagonitic material. Two samples of relatively fresh basalt were recovered on station DODO 128 (Fig. 1). Sample DODO 128B is a gray, dense, equigranular basalt approximately 6 × 10 × 11 cm in size. The surface of the rock is partially coated with hydrated iron and manganese oxides. The rock has a distinct doleritic texture with lathes of labradorite enclosing grains of clinopyroxene, as well as minor olivine and opaque minerals. Approximately 5% of the minerals (largely pyroxene) are altered to greenish palagonitic material. Another piece of basalt from the same dredge haul, sample DODO 128C, is light gray, porphyritic basalt about 6 × 7 × 9 cm in size. The rock contains clots as large as 3 mm in diameter of bytownite intergrown with pyroxene. The sample contains (in vol. %) : bytownite, 42%, 6% of which forms large phenocrysts; clinopyroxene, 48%, with about 1% as phenocrysts; opaque minerals 5%; and alteration minerals. The groundmass has a doleritic texture.

These Amirante basalts, dredged from talus slopes, were probably shed from flows or dikes in the basement of the Amirante Ridge. It is unlikely that the rocks were rafted by kelp from mainland areas, for throughout the year surface currents in this area are west to northwest (ANONYMOUS, 1960, pp. 50–51).

The basalts reported are chemically and mineralogically similar to many of the basalts dredged from varous locations in the Indian Ocean (ENGEL, FISHER and ENGEL, 1965, p. 606; CANN and VINE, 1966, p. 200) and from the Pacific and Atlantic oceans (ENGEL, ENGEL and HAVENS, 1965, p. 720). Characteristically, these oceanic tholeiitic basalts have a silica content near 50% by weight and low concentrations of K, Ti and P, and extremely low concentrations of Ba, Sr and Zr (Table 1). Mineralogically, most oceanic tholeiites are composed predominantly of plagioclase (usually labradorite or bytownite) with pyroxene, opaque minerals, and minor olivine.

The recovery of slabby sandstone composed of basaltic minerals along with pieces of oceanic tholeiitic basalt suggests that volcanic rocks of predominantly basaltic composition form the foundation of the Amirante group. This would support the magnetic interpretation cited earlier.

RADIOMETRIC AGE OF THE AMIRANTE RIDGE BASALT

The porphyritic plagioclase-rich basalt (DODO1 28C) was submitted to Geochron Laboratories, Cambridge, Massachusetts for whole rock K–Ar age analysis (Table 2).

Table 2. Analytical data and ages calculated for Amirante Ridge basalt and a similar low-potassium tholeiitic basalt from the Experimental Mohole, Guadalupe site.

Sample number	^{40}Ar* (ppm)	^{40}Ar*/*Total* Ar^{40}	*Average* ^{40}Ar* (ppm)	K (%)	*Average* K (%)	*Age* (× 10^6 years)
DODO 128-C	0·00057	0·061	0·00049	0·087	0·081	82 (± 16)
	0·00041	0·039		0·075		
Mohole† Basalt R-0107	0·00030	0·063	0·00030	0·122	0·13	32 (± 10)
				0·129		
	0·00029	0·040		0·136		

*Indicates radiogenic component.
†Data from KRUEGER (1964, p. 1155)

Constants used :
$\lambda_\beta\,{}^{40}\text{K} = 4{\cdot}72 \times 10^{-10}$/year
$\lambda_\epsilon\,{}^{40}\text{K} = 0{\cdot}585 \times 10^{-10}$/year
$^{40}\text{K/K} = 1{\cdot}22 \times 10^{-4}$ g/g.

The age obtained, 82 (± 16) $\times 10^6$ years, suggests a possible mid- to late Cretaceous emplacement of the rock. It is clear from the analytical data (Table 2) that, due to the small amounts of K and radiogenic Ar in these basalts, age determinations are liable to large errors. We have obtained an average K content of 0·102 (weight %) on sample DODO 128C (Table 1, K_2O : 0·12). The age of the rock is possibly as old as Cretaceous but it could be Eocene or younger. Such a range in age is consistent with that reported by WISEMAN (1936, p. 441) for the fossiliferous, volcanic agglomerates of the Providence Reef occurrence.

The nearest subaerial occurrences of basaltic rocks are the dolerites on the Seychelles Islands (BAKER, 1963). There, Tertiary doleritic and basaltic dikes cut and intrude xenoliths of the Late Precambrian Mahé granite and are the youngest rocks of the islands; BAKER and MILLER (1963, p. 347) report an average radiometric age of about 50 $\times 10^6$ years for these dikes. The dikes reported by BAKER (1963, p. 19–20) range in width from a few centimetres to about 10 m and are vertical in attitude. They are pyroxene dolerites, porphyritic plagioclase dolerites, olivine dolerites and olivine-bearing basalts. Locally, shearing has produced hornblende and epidote-rich lenses. Many of the dike rocks are altered to uralitic metadolerites containing chlorite and epidote. However, most of the chemical analyses of these Seychelles mafic rocks show they have more potassium and sodium than basalts from the DODO dredge sites. This is one characteristic difference between tholeiitic basalts emplaced in, respectively, continental and oceanic environments (ENGEL, ENGEL and HAVENS, 1965, p. 722).

DISCUSSION

The existing data indicate that much tholeiitic magma has been emplaced at shallow crustal depths, in the western Indian Ocean, during the Tertiary and possibly in Cretaceous times. This basaltic upwelling must have occurred both prior to and during the evolution of the Amirante Trench. Much if not all of the basalts also were emplaced after the fragments of Precambrian granitic crust represented by Madagascar and the Seychelles reached their present geographic positions.

The similarities of old, granitic continental-type rocks in the Seychelles and Madagascar and the occurrence of crust of continental thickness even in the isolated Seychelles Bank have led to the suggestion they were once connected to each other, and possibly to the eastern margin of Africa. If so, their fragmentation and migration to their present sites must have begun in pre-Cretaceous times, prior to the emplacement of basalt now found along the Amirante Bank. In addition the structural and morphological features of the Amirante Bank must have evolved in the wake, or well after any separation, of Madagascar and the Seychelles, and probably after most of the basaltic " basement " in the Amirante region was emplaced.

Submarine topography

Evidence for crustal displacements in the Madagascar–Amirante–Seychelles region, as well as in the deeper oceanic areas to the north and east, was sought by examination of seafloor relief. Figure 1 is one interpretation of the bathymetric data; other recent charts of this area are those of BELOUSOV (1965) and LAUGHTON (1963, unpublished).

By conservative count 65–70% of the sounding track shown on Fig. 1, and a far higher proportion of the soundings themselves, were logged recently by IIOE ships equipped with Precision Depth

Recorders, or equivalent. Such sounders have a recording precision of better than 2 m in 5000. Except on the 1965 *Atlantis II* cruise, ships were dependent on celestial navigation so their fixes have an accuracy of about ± 4 km. Within these limits, older or less-well-controlled tracks were adjusted in position until their soundings made good crossings with the accepted lines. Although there were such minor adjustments, and slope corrections were not made, raw discrepancies at crossings were not great; these were only 2–20 m for recent lines in the abyssal plains. The availability of precise soundings (and many published profiles) in the deeper areas encouraged an attempt at correlation of local, narrow, flattish-floored deeps—or minor rises in generally-sedimented areas—between adjacent sounding lines some tens of kilometers apart. Such correlations resulted in the striking lineation patterns of Fig. 1.

Supporting evidence for such interpretative contouring is found in two well-controlled, detailed surveys (conducted aboard H.M.S. *Owen* in 1962) on the crest and flank of the Carlsberg Ridge, near 5° 30′N, 62°E and 3°N, 60°E, respectively. Bathymetric charts of these areas, at 100 fm contour intervals, are available (Figs. 5B and 6B, ANONYMOUS, 1965). The corresponding portions of Fig. 1 were redrawn by interpolation directly from those published charts, using 2000, 3000, 4000, 4200, 4400, 4600 and 4800 m contours. In both areas northwest-trending lineations appear; they are more obvious in both flank versions than in those of the ridge crest, even that (Fig. 5B, ANONYMOUS, 1965) at 100 fm interval.

Submarine topography of about 7,700,000 km^2 of the west-central Indian Ocean is represented on Fig. 1. The western margin includes the continental slope off East Africa, with thick Karroo, late Mesozoic and Tertiary sediments underlying the shelf and slope, and possibly extending for several hundred kilometers beyond the slope (FRANCIS, DAVIES and HILL, 1966, p. 259). Tertiary and Quaternary sediments mantle the slope and rise, and blanket irregular basement topography in the Somali Abyssal Plain (BUNCE, LANGSETH, CHASE and EWING, 1967). Seychelles Bank, the northwest extremity of the aseismic Mascarene Plateau, and bordering sedimented rises extending west to Agalega comprise a second topographic-structural unit.

The Mid-Indian Ocean Ridge forms the largest province. The northwest-trending part of that ridge—extending from near 2°N, 67°E to the Gulf of Aden, with major offset at the Owen Fracture Zone (MATTHEWS, 1966, p. 183)—is termed the Carlsberg Ridge. South of 2°N the mid-ocean ridge, less well explored, extends with a north-south trend to the latitude of Rodriguez, about 20°S. Both segments of the ridge are active seismically; shallow shocks occur along the central rifted(?) crest and on cross-fractures. Epicenter plots (e.g. STOVER, 1966, p. 2576) show the north-trending segment to be the more active. On the Carlsberg Ridge topographic lineations on the flanks, expressed as low ridges and flattish-floored sedimented deeps, are chiefly parallel or sub-parallel to the ridge crest. The flanks, and locally the crest, of the south-striking portion of the mid-ocean ridge appear cut by numerous northeasterly-trending ridges and sedimented deeps. The latter lineations disappear, possibly by burial, at the edge of the apron west of the Chagos–Laccadive Ridge and at the southern border of the Indus sedimentary fan, near 8°N, 69°E. Topographic patterns at the intersection of the major northwest and north-northeast lineations are not clear; exploration is lacking within several square degrees centered on 1° 30′N, 64° 30′E and is sparse near 5°N, 68°E.

As here contoured, the northwest-trending ridge-and-trough topography of the southwest flank of the Carlsberg Ridge extends west to approximately 57°E. West of that longitude the north–northeast-trending Owen Fracture Zone, 250–300 km wide, disrupts and supplants the Carlsberg Ridge. Within the area pictured in Fig. 1 the fracture zone consists of sub-parallel ridges—of which Chain Ridge is longest and best explored—and sedimented re-entrants. Several narrow basins (e.g. near 5° 20′N, 55° 30′E and 5°N, 56° 45′E) are the deepest regions on the chart; their limited extent, paucity of fill and depth greater than the regional level imply rather recent formation, and current tectonic activity along the zone.

If the mid-ocean ridge system is developed by addition of crustal material at the crest and lateral movement of the flanks, in the manner suggested in 1963 by L. W. MORLEY (unpublished)* and VINE and MATTHEWS (1963), the two segments of the ridge pictured on Fig. 1 have behaved so that their topographic expression and degree of observed seismic activity differ. The Carlsberg Ridge, bounded or decoupled by the northeast-trending Owen Fracture Zone on the northwest and by a northeast-trending set of deeps on the southeast, may be the less constrained. Widening by spreading normal to the active crest may have allowed development, by faulting and intrusion, of lineations parallel to that crest. The north-trending portion of the ridge may be superimposed upon a group of northeast-trending fractures or faults which modify or control the topography. These possibly inherited fractures lie in general between the north-trending, aseismic Chagos–Laccadive Ridge and the north-trending but offset southern portion of the aseismic Mascarene Plateau (FISHER, JOHNSON and HEEZEN, 1967). Some of these fractures, if active as transcurrent faults subsequent to ridge initiation, could then function as transform faults (WILSON, 1965) oblique to the north-trending, spreading ridge. The obliquity may result in a slower rate of spreading and greater seismic activity than occurs in the Carlsberg Ridge segment. A region of strongly-lineated flank topography, similar to that of the Carlsberg Ridge as here contoured, lies just south of Rodriguez Fracture Zone on the southwest-trending branch of the mid-ocean ridge (FISHER, JOHNSON and HEEZEN, 1967). There, the western flank shows ridges and exceptional deeps, and seismic activity along the ridge is not so high as in the area of oblique cross-fractures. The Rodriguez Fracture Zone, a zone of major displacement, may provide decoupling that permits more facile and rapid widening of the southwest branch of the mid-ocean ridge.

North of 4°S a zone of hills or ridges extends northward near 53°E for at least 500 km along the southeastern edge of the Somali Abyssal Plain. The southern end of this zone joins the Amirante Ridge–Trench system. North of the Equator the zone consists of hills protruding from the sediments and apparently does not connect to the southwest end of the Owen Fracture Zone mapped by MATTHEWS (1966) and BUNCE, BOWIN and CHASE (1966), that is, the spectacular " Chain Ridge " of HEEZEN and THARP (1965). However, a *Vema* reflection profile (BUNCE, LANGSETH, CHASE and EWING, 1967, p. 2551) oblique to this trend indicates an abrupt west-to-east shoaling of basement topography at about 1° 05′N, 52° 45′E which may be the northern continuation of the boundary.

South of 5°S, between 49° and 50°E, a broader zone of rugged topography, shallow at the northern end and deep at the southern end, extends south to 11°S and may be related to the postulated fault scarp along the steep northeast slope of Madagascar. Between this zone and the Amirante Trench is a region of small north-to-northwest-trending basins and ridges, and the large platforms of Providence Reef and Farquhar Atoll (Fig. 1). The complex of peaks, ridges and deeps separates the

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*MORLEY's ideas, clearly outlined in a letter submitted to journals early in 1963, came to the present authors' attention by that letter being reproduced in part in " Canada's unappreciated role as scientific innovator " by JOHN LEAR, *Saturday Review*, 2 September, 1967, p. 45–50.

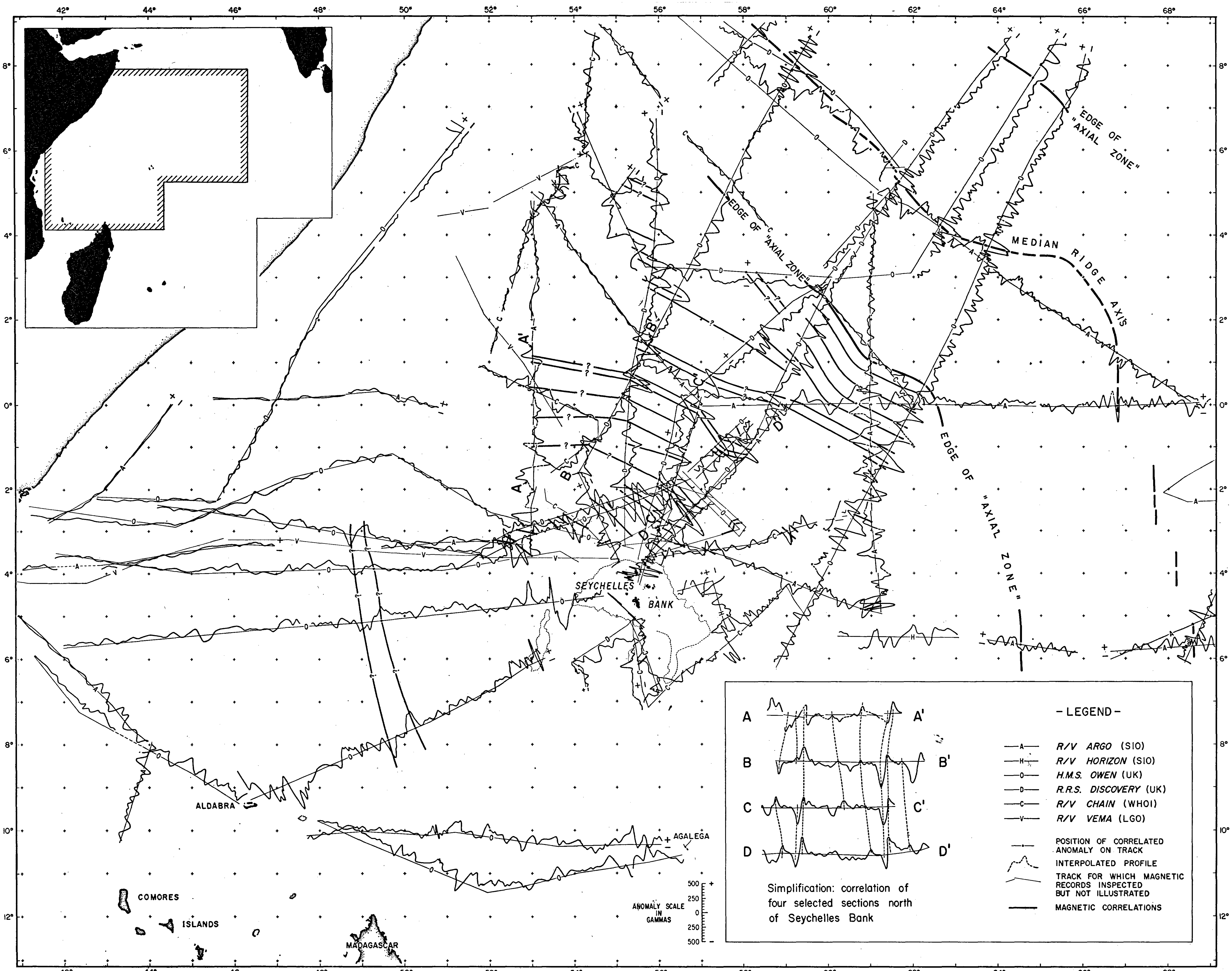

Fig. 2. Magnetic anomaly profiles recorded by IIOE vessels, and suggested correlations

sedimented continental rise and Somali Abyssal Plain from the flattish northern portion of the Mascarene Basin. WILSON (1963, p. 927) suggested that the Seychelles had been displaced northeast relative to Madagascar along a fault extending from the Seychelles along the east side of Farquhar and Providence to the faulted and linear east coast of Madagascar. If this is correct, the intervening transcurrent ridges, almost surely involving northwest-trending faults, must accompany or postdate much of the northern migration of the Seychelles. But whatever the exact displacements, we believe the northwest-trending features between the Seychelles and Madagascar in Fig. 1 indicate a major pattern of distributive movements, with offsets and volcanism, throughout the area. Any migration of the Seychelles northward from Madagascar reflected by the intervening oceanic features would seem to require either crustal extension along NE–SW lines, or aggregate shearing extension along NNW–SSE lines. For reasons given below it is suggested that the overall movement of Madagascar has been southward relative to the Seychelles and to East Africa.

Magnetic data

Magnetic lines recorded in the northwest Indian Ocean by R.V. *Argo*, R.V. *Horizon*, H.M.S. *Owen*, R.R.S. *Discovery* and R.V. *Chain* have been compiled in Fig. 2 to determine whether the magnetic lineations reported by MATTHEWS (1966) and BOWIN and VOGT (1966) can be extended and related to the tectonic movements of Madagascar and the Seychelles.*

Three distinct magnetic provinces are indicated by this compilation : (1) the zone of small-amplitude, " high-frequency " anomalies associated with the Carlsberg Ridge, (2) a field of predominantly northwest-striking, large-amplitude, " low-frequency " anomalies occurring north and northeast of the Seychelles to the vicinity of that ridge, and (3) a field of low magnetic relief west of 53°E (Fig. 2).

The small amplitude, high-frequency magnetic anomalies associated with and subparallel to the Carlsberg Ridge extend for approximately 450 km on either side of the ridge's magnetic axis. Analogous regions occur in the Atlantic within the Mid-Atlantic Ridge, and are called the " axial zone " by HEIRTZLER and LE PICHON (1965, p. 4015).†

The axis of the Carlsberg Ridge as determined by magnetics and topography is shown in Fig. 2. There is a large bend and a related sinuous arc in the ridge axis between 63°E and 67°E, and 2° and 4°N. If our interpretation is correct, the border of the

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*The R.V. *Argo* and R.V. *Horizon* data are derived from a stern-towed, total-intensity proton-precession magnetometer. For these records, and for those of R.V. *Chain*, the regional gradient was removed by inspection. No attempts were made to remove diurnal variations or any effects due to magnetic storm activity. Profiles (with the regional gradient already removed) by H.M.S. *Owen* were taken from Admiralty Marine Science Publications (ANONYMOUS, 1963, 1965); those of R.R.S. *Discovery* were provided by the Department of Geodesy and Geophysics of the University of Cambridge and by LAUGHTON. The method of removing the regional gradient and consideration of corrections is described in the texts of the Admiralty publications. Crossings between British and other lines display large apparent discrepancies. These seem due to the difference in methods of removing the regional magnetic values rather than to poor positioning.

†It is within this zone of the Carlsberg Ridge that VINE (1966, p. 1409) has matched the central portions of two *Owen* magnetic profiles to the reversal time scale of COX, DOELL and DALRYMPLE (1964) and DOELL and DALRYMPLE (1966). A present attempt to fit magnetic profiles across the full width of the axial zone to the extrapolated 10 × 10^6 years reversal model of PITMAN and HEIRTZLER (1966, p. 1166) gave an approximate match. However, profiles within the Carlsberg Ridge's axial zone neither show bilateral symmetry nor correlate among themselves so clearly as do the Pacific–Antarctic Ridge or Reykjanes Ridge profiles of the latter authors. Additional closely-spaced profiles over the complex and faulted Carlsberg Ridge would be necessary to make extensive correlations and define the reversal pattern. The present writers are concerned primarily with the anomalies outside the axial zone and have shown no correlation within the zone except the axial anomaly itself (Fig. 2).

magnetic axial zone to the southwest and the strike of the large anomalies immediately outside the zone also exhibit this bend, although in a smaller and less exaggerated pattern (Fig. 2). FISHER, JOHNSON and HEEZEN (1967) and MATTHEWS (1966) postulated that this change in trend of the zone is due to displacements along a series of northeast-trending faults that cross the ridge. There is, however, a well developed ridge-axis anomaly on the only magnetic profile within the bend, near 4°N, 64°E. In contrast, the characteristic ridge-axis anomaly does not appear over one well-surveyed ridge-cutting fracture near 5° 30′N, 62°E (MATTHEWS, VINE and CANN, 1965). In areas between such observed faults the more typical ridge magnetic characteristics are preserved. If a fracture zone exists at and in the vicinity of the large bend in the ridge near 3°N, 66°E, perhaps it is composed of individual *en echelon* NE–SW-striking fractures, as expressed by the NE–SW troughs cutting the ridge further south (Fig. 1). These NE–SW troughs may represent faults whose origin predates the Carlsberg Ridge growth and that probably have been active at times during ridge growth (FISHER, JOHNSON and HEEZEN, 1967). Despite the structural and morphological complexities in this region the central rift valley is more obvious and continuous here than in most other segments of the ridge that have been mapped in detail (Fig. 1).

The large-amplitude, low-frequency anomalies that characterize the region southwest of the axial zone, between the Carlsberg Ridge and the Seychelles, may be traced and correlated for distances as great as 600 km. Near the axial zone their trend commonly follows the edge of that zone, and the topographic lineations, for example, in the region northeast of the Seychelles where the border of the axial zone displays the bend. These anomaly patterns suggest that the large anomalies are relics of earlier ridge development and mark parallel structures which are " fossilized " parts of the ridge system. The high amplitude and low frequency of these anomalies could be attributed either to a more intense magnetic field and less frequent reversals of the earth's magnetic field in a former epoch (VINE, 1966, p. 1414) or to an earlier, greater rate of seafloor spreading and hence less adulteration of the upper crust by reversely-magnetized intrusions near the ridge crest.

The boundary between the magnetic axial zone and the field of large anomalies does not coincide with the southwest border of the topographic ridges and troughs but lies well into the ridge-and-trough zone (Figs. 1 and 2). The fact that the topographic features of the ocean floor do not change across the magnetic boundary seems to support the argument for a change in the intensity and/or frequency of reversals of the magnetic field.

Whereas the Mid-Indian Ocean Ridge is definitely inflected south near 2°N, 67°E, it is possible that the strike of the corresponding large anomalies (at 0°, 62°E) is not. A few additional magnetic survey lines in this region would resolve what happens to these large discrete anomalies at the bend. No obvious correlation can be made between the large anomalies here and the similar anomalies west of the axial zone on the profile that extends E–W along 5½°S (Fig. 2).

MATTHEWS (1966, p. 183, Fig. 8) shows nearly E–W correlations of similar large-amplitude, low-frequency anomalies north of the Carlsberg Ridge which do not parallel the ridge. Plotting of the published profiles (ANONYMOUS, 1963) suggest that the strike of these anomalies, extended, may be disconformable to the Carlsberg Ridge's magnetic axial zone. Assuming that ridge growth has produced the large anomalies outside the axial zone, this could mean the " median ridge " has a different orientation than it did some time in the past, or that new median ridges evolve at the expense of pre-existing ones. EWING and EWING (1967) have suggested, on the basis of relative sediment thickness on mid-ocean ridges and their flanks and in basins, that magnetic anomalies outside the axial zone belong to a prior phase of spreading, separated from the present period (i.e., about 10 × 10^6 years) by 60 ± × 10^6 years of quiescence in which little or no spreading occurred. Such a hiatus does provide a ready explanation for the possible discordance of the large-amplitude, low-frequency anomalies and those of the axial zone, since the present cycle of spreading need not proceed from the same axis as did a supposedly much-older cycle.

Magnetic anomalies just north of Seychelles Bank, where correlatable between closely-spaced lines, display parallelism in a manner similar to those near the axial zone border. Their strike, however, progresses from northwest to nearly east–west when followed west to the north–south profile along 53°E. Suggested correlations of four of these profiles are more easily seen in the simplified inset (Fig. 2). It is not clear whether this bend in anomaly-producing bodies is due to faulting, warping of the sea-floor, or to other complex characteristics of the anomaly-producing motions and bodies. Divergence in trend of this type clearly makes it difficult to attribute these anomalies to simple ridge-spreading from the present Carlsberg Ridge. The fact that bathymetric contours of the basin north of the Seychelles appear displaced successively south when traced from east to west suggests that offsets along northeast-trending faults are instrumental in the change of the magnetic anomalies' strike.

BOWIN and VOGT (1966) found no structures on seismic reflection records to correlate with the large-amplitude, low-frequency anomalies observed along the track of R.V. *Chain* northeast of the Seychelles. No obvious correlation between magnetic observations and the large topographic high near 0°, 56°E can be made; neither, seemingly, does this northeast-trending high disrupt the strike of magnetic lineations indicated on Fig. 2. Similarly large, non-magnetic seamounts lying northwest of the Owen Fracture Zone, of which Mount Error (10° 20′N, 56° 15′E) is best studied, have been described by MATTHEWS (1966, p. 180). These, however, are in the vicinity of Socotra, well off the seismically-active mid-ocean ridge, and also seem quite unlike the volcanic peaks of the Carlsberg Ridge. In this northwest region, and likewise showing little character magnetically, is Chain Ridge, from which gabbro has been dredged (BUNCE, LANGSETH, CHASE and EWING, 1967); the 150-γ anomalies observed were less than had been expected for that spectacular topographic feature (*ibid*, p. 2550). An east–west *Vema* profile (*ibid*, p. 2552) does, however, show correlation between sharp magnetic anomalies and topography just north of Amirante Ridge near 3° 30′S. Other lines crossing Amirante Ridge and the highs in the Providence–Farquhar–Aldabra sector show similar correlation.

A distinct change in magnetic character occurs just west of 52° 30′E and north of 5°S, near the northern segment of the Amirante Bank. East of that longitude the pattern of large-amplitude anomalies described above is present. West of 52° 30′E such anomalies were not observed, as though the extension of the westerly magnetic trends mapped north of the Seychelles had been sheared away. This abrupt change can be recognized on the several profiles between 2°S and 4°S and identified on three magnetic lines farther north : at 0° 35′N, 52° 27′E, at 2° 57′N, 52° 35′E (Fig. 2) and at 1° 20′N, 52° 30′E on a NW–SE *Vema* profile (*ibid*, p. 2551). To the west magnetic relief is low and no correlations can be made except for a suggestion of north–south continuity south of 3°S (Fig. 2).* North–south profiles are lacking in this region. The boundary between these two magnetic provinces is marked by topographic irregularity, small peaks and ridges which extend north of the Amirante Ridge to the Equator. Although these peaks and ridges do not have great relief, they do form a definite zone, in sharp contrast to the flat sedimented basin on the west and a gently sloping rise to the Seychelles on the east. It is suggested that this topography represents a partially buried fracture zone of major proportions.

West of 52° 30′E and south of 6°–7°S there is greater relief on the few magnetic profiles. This increased relief is probably due in part to latitude as well as to much greater topographic irregularity of supposed volcanic origin. It could be a displaced extension of the zone north of the Seychelles; however, the shapes of the anomalies are rather different than those in the latter area.

Summary of observations taken to indicate a southward movement of Madagascar

The evidence, from this and other studies, here taken to indicate that large-scale left-lateral movement along 52°–53°E longitude has moved Madagascar south relative to the Seychelles is as follows :

(1) There is a northward continuation, from the Amirante Ridge and Trench, of ridge-and-trough topography within a narrow N–S zone. This zone separates a flat, sedimented basin on the west from a continental-type rise to the Seychelles on the east. A N–NE projection of this band intersects the Owen Fracture Zone, an area of large displacement of the Carlsberg Ridge.

(2) Northwest to E–W magnetic lineations which exist north of the Seychelles are terminated at this zone.

(3) Both magnetic lineations and bathymetric contours between the Seychelles and the Carlsberg Ridge, and east of 53°E, are successively offset to the south when viewed from east to west, suggesting left-lateral shear for a large block of oceanic crust.

(4) The tholeiitic basalt dredged from the Amirante Ridge, dated radiometrically at 82 ($\pm$ 16) $\times$ 10^6 years, indicates volcanism, probably extensive, between the Seychelles and Madagascar during Cretaceous time.

(5) Paleomagnetic measurements in Madagascar cited by NAIRN (1964) can be interpreted to indicate that the crustal block was approximately 20°N of its present position relative to Africa in the Permian, but occupied its present approximate position relative to Africa in Cretaceous time.

(6) Anomalous oceanic crust, reported by FRANCIS, DAVIES and HILL (1966, p. 259), though in the southern part of the sedimented Somali Basin, 150–450 km west of the Amirante Ridge, lies just north of a region of shoal and irregular seafloor extending northward into that basin and south toward the linear, probably faulted northeast coast of Madagascar. This crust can be interpreted as wholly volcanic except for an uppermost layer of sediments (the 6·8 km/sec crustal layer is thin or absent and the Mohorovičić discontinuity is unusually shallow) and may be the crustal scar or volcanically-filled chasm left behind by the southward movement of Madagascar.

(7) The age of 90 $\times$ 10^6 years reported (BUNCE, LANGSETH, CHASE and EWING,

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*The N–S correlation shown west of the Seychelles on Fig. 2 is supported by a similar anomaly on a here-unfigured *Vema* profile that falls along the correlation between 3° and 4°S (*ibid*, p. 2552).

1967, p. 2550) for basement rocks from the Chain Ridge, along with the Amirante Ridge date (4, above), suggests similarity in time of origin for these two ridges. Certainly both ridges formed along fractures in the crust on a scale to indicate movement of large crustal blocks during this period.

(8) The occurrence of Late Precambrian granites both on northern Madagascar and the Seychelles Bank, with both units having continental crustal structure and being separated by oceanic crust whose topography indicates extensive past volcanism and faulting, strongly suggests these two units were once connected.

If the hypothesis of seafloor spreading from mid-ocean ridges is accepted and if the East African Rift is considered to have formed in a tensional zone, it is difficult to understand any contemporaneous northward movement of Madagascar or the Seychelles. It may be that spreading has moved both the Seychelles and Madagascar away from the Carlsberg Ridge axis. If so, the processes that cause seafloor spreading have also caused differential movements along transcurrent faults which have separated these two crustal blocks.

Acknowledgements—WILLIAM R. RIEDEL, scientific leader of DODO Expedition, provided the rock samples. The Hydrographic Department of the Admiralty, GÜNTHER DIETRICH of the Institut für Meereskunde der Universität Kiel, and VICTOR KANAEV of the Institute of Oceanology, Academy of Sciences, Moscow, furnished recent United Kingdom, *Meteor* and *Vityaz* sounding data, respectively. Miss E. T. BUNCE, A. S. LAUGHTON and ARTHUR RAFF provided part of the magnetic records. Discussions with VICTOR VACQUIER, C. G. A. HARRISON and ARTHUR RAFF are gratefully acknowledged. The writers are especially indebted to T. J. G. FRANCIS for use of his unpublished thesis, for several discussions of paleomagnetic results, and for calling to their attention the important paper of A. E. M. NAIRN. Illustrations were drafted by D. G. CROUCH.

Field and laboratory work were supported by the Office of Naval Research of the U.S. Navy 2216 (23) and by the National Science Foundation (G-22255, GP-5469 GA-800), and laboratory work by the U.S. Geological Survey.

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Part IV

Marine chemistry

Reprinted from *Inv. Pesq.*, vol. 33, no. 1, 1969, p. 163-177

Distribución del nitrógeno orgánico en el Océano Índico occidental. II*

por

F. FRAGA **

En la comunicación anterior, FRAGA (1966), se dio a conocer la distribución espacial del nitrógeno orgánico disuelto y del particulado en un corte vertical desde 25° lat. N a 20° lat. S, entre los meridianos 55° a 65° E. Las muestras fueron tomadas en octubre al final del monzón del SO a bordo del R/V «Anton Bruun», durante la Expedición Internacional al Océano Índico. Los datos de ese crucero se encuentran en el «report» de la Woods Hole Oceanographic Institucion, 1965.

En la presente comunicación se estudia la distribución del nitrógeno orgánico en un corte N-S desde el Mar Rojo hasta la convergencia subtropical. Las muestras fueron tomadas a bordo del «Magga Dan», equipado por el «Institut Royal des Sciences Naturelles» de Bélgica. La situación de las estaciones puede verse en la figura 1 y las muestras fueron tomadas en el mes de marzo durante el monzón del NE.

Métodos. — Las muestras de agua se tomaron siempre de día, excepto en la estación 241 que se tomaron de noche, utilizando botella metálica y se filtraron inmediatamente a través de filtros de celulosa «Cellafilter grob» de 25 mm de diámetro y 0,5 μ de poro. Las cantidades filtradas fueron ; 500 ml para las muestras de 0 a 30 m de profundidad ; 1 litro para las muestras de 50 a 300 m y 2 l para las profundidades mayores. Los filtros con la materia particulada se colocan en pequeños recipientes de vidrio y se desecan sobre gel de sílice.

El agua filtrada se recoge directamente en ampollas de vidrio de 300 ml, se le añade 0,3 ml de cloroformo y se sueldan las ampollas.

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* Recibido para su publicación el 8-III-68.

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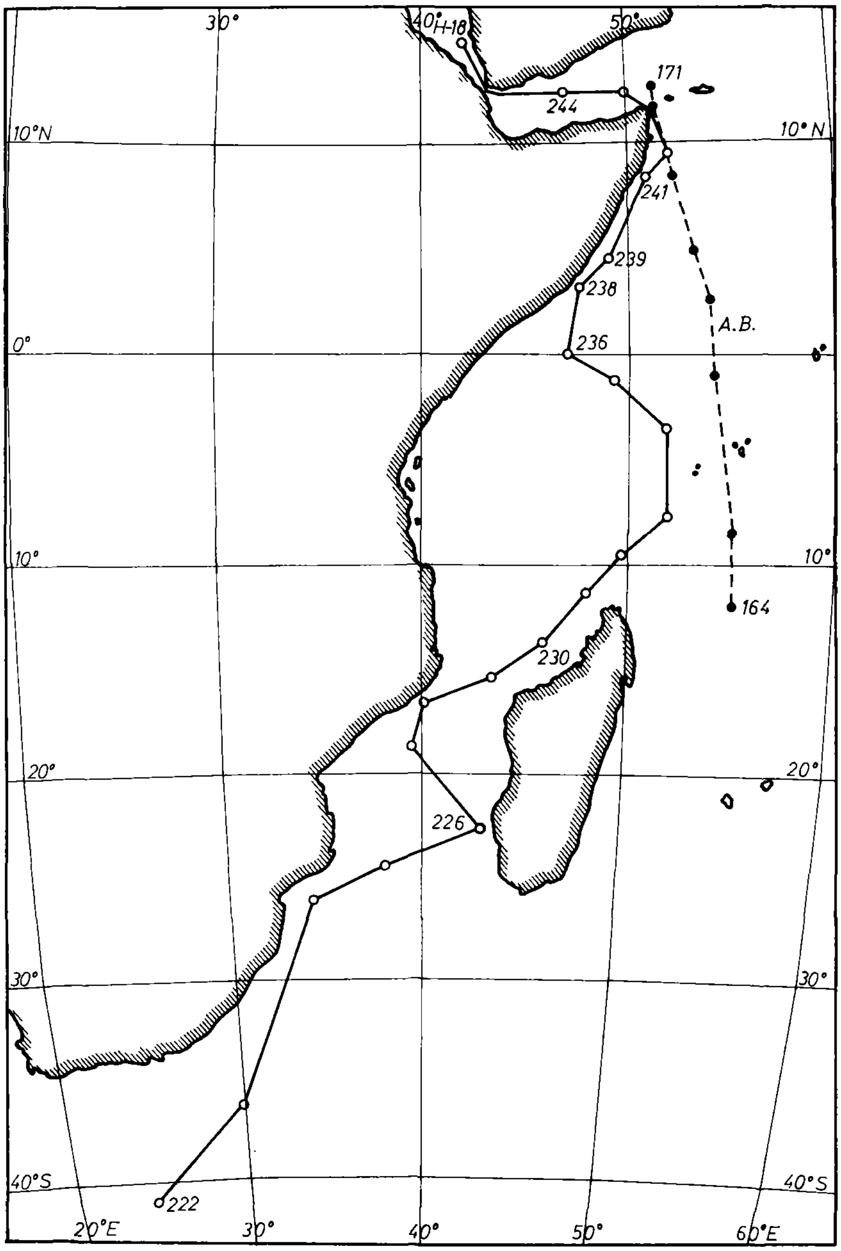


Fig. 1. — Círculos blancos; localización de las estaciones estudiadas en el crucero del «Magga Dan» desde febrero a marzo. Puntos negros; parte de las estaciones estudiadas por el R/V «Anton Bruun» de septiembre a octubre.

El nitrógeno particulado se determinó por el método de Kjeldahl directamente sobre el filtro. Para la corrección del ensayo en blanco se tomó un filtro de cada lote de 25, en total 10 filtros. El contenido en nitrógeno de los filtros da una media bastante baja pero su cantidad varía bastante de unos a otros, presentando una desviación de 0,19 at - μg de N, esto supone un error probable de $\pm$ 0,3 at - μg N/l para las muestras tomadas de 0 a 30 m ; $\pm$ 0,2 para las de 50 a 300 m y $\pm$ 0,1 para las de profundidades superiores a 300 m.

El nitrógeno orgánico disuelto se determinó por duplicado, también por el método de Kjeldahl en la forma descrita por FRAGA (1959). El error probable de la media fue $\pm$ 0,4 at - μg N/l.

La principal diferencia entre las técnicas utilizadas en esta expedición y en la anterior fue la de los filtros utilizados en la separación de la materia orgánica particulada. En el «Anton Bruun» utilizamos filtros de fibra de vidrio, aproximadamente de 13 μ de tamaño de poro, mientras que en esta expedición se utilizaron filtros de 0,5 μ de poro, por consiguiente la cantidad de materia particulada retenida deberá ser mayor. No podemos comparar los valores absolutos de la materia particulada de ambas expediciones porque las estaciones cubiertas por el «Magga Dan», ya sea por su posición geográfica, que no coincide con las anteriores, o bien por la estación del año, resultaron más pobres en general. Por esto comparamos las pendientes de las rectas de regresión encontrada entre el nitrógeno orgánico particulado (NOP) y el intrógeno orgánico disuelto (NOD), que para las muestras recogidas entre 600 y 2000 m de profundidad son las siguientes :

«Magga Dan» poro del filtro 0,5 μ, $N_d = 3{,}5\ N_p + 3{,}3$
«Anton Bruun» 13 μ, $N_d = 7{,}8\ N_p + 4{,}3$

donde N_d es el nitrógeno orgánico disuelto y N_p el nitrógeno orgánico particulado, expresados ambos en at - μg de N/l. El término independiente debiera ser igual en las dos ecuaciones, pero su diferencia se debe a la distinta proporción de las masas de agua como se verá más adelante. Volviendo al significado del diferente valor de las pendientes de las dos rectas ; si llamamos c a la proporción de NOP retenido por el filtro grueso de la total retenida por el filtro fino, tenemos que

$$c = \frac{1 + a_1}{1 + a_2}$$

donde a_1 y a_2 son las pendientes de las rectas obtenidas de las muestras filtradas por filtro de 0,5 μ y 13 μ respectivamente. Se obtiene así, para c, un valor de 0,51, o sea, que el filtro grueso retiene solamente el 51 % del NOP que retiene el filtro fino.

La importancia del tamaño de poro de los filtros también la hacen notar HUMPHREY y WOOTTON (1966) en las determinaciones de clorofila utilizando papeles Schleicher & Schüll 1575 y Millipore HA, cuyos tamaños de poro coinciden aproximadamente con los utilizados por nosotros y la relación de valores encontrados también es del 50 %.

Distribución espacial del nitrógeno orgánico disuelto. — El nitrógeno orgánico particulado sufre variaciones diurnas incluso hasta 300 m de profundidad y a mayores profundidades su cantidad es tan pequeña que sus diferencias están por debajo del límite de error de los análisis, por este motivo sólo se estudiará la distribución del nitrógeno orgánico disuelto, representado en la figura 2.

MENZEL (1964) ha encontrado que para el agua profunda el carbono orgánico disuelto se puede considerar como una propiedad de las masas de agua y su cantidad es característica de cada tipo de agua. Él calcula para una superficie isopícnica la proporción de mezcla de dos tipos de agua por la fórmula

$$D = \frac{X_2 - X_0}{X_2 - X_1} 100 \qquad (I)$$

donde X_1, X_2 y X_0 son la salinidad o el contenido en carbono orgánico disuelto de los tipos de agua 1 y 2, y el agua en que se quiere calcular la proporción de mezcla de ambas, encontrando que la proporción de mezcla calculada utilizando los datos de salinidad coincide con la misma calculada por los datos de carbono orgánico disuelto.

En nuestro trabajo anterior se encontró que entre el carbono orgánico disuelto y el nitrógeno orgánico disuelto hay una cierta correlación, al menos para los valores bajos de carbono, por lo cual hay que esperar que éste también esté relacionado con las masas de agua. Aquí hemos aplicado a varias superficies isopícnicas la ecuación I, pero en lugar de calcular D y comparar sus valores, hemos igualado ambas ecuaciones eliminado D, y despejando N_0 obtenemos la ecuación de una recta

$$\mathrm{N}_0 = S_0 \frac{\mathrm{N}_1 - \mathrm{N}_2}{S_1 - S_2} - S_1 \frac{\mathrm{N}_1 - \mathrm{N}_2}{S_1 - S_2} + \mathrm{N}_1$$

donde las variables N_0 y S_0 son el NOD y la salinidad del agua en un punto cualquiera de la superficie isopícnica de mezcla, S_1 y S_2 son las salinidades de las dos masas de agua antes de mezclarse y N_1 y N_2 es el NOD de las mismas. En la representación gráfica en un sistema de coordenadas S ‰, NOD se obtendrá una recta cuando se trata de dos masas de agua y dos rectas si hay una tercera masa de agua que se interpone entre las dos y se está mezclando con ambas. Al representar gráficamente los valores experimentales para σ_t = 26·3, 26·9, 27·3 y 27·7 hemos obtenido siempre dos rectas aun en aquellas superficies en las que se están mezclando sólo dos masas de agua. Esto se debe a que cuando un tipo de agua abandona la zona eufótica hundiéndose, su NOD no permanece constante sino que se descompone, incluso la fracción que hemos llamado «inerte», FRAGA (1961), si bien su velocidad de descomposición es muy lenta, del orden de años. Así un agua pobre a medida que se aparta del punto de origen, sigue descendiendo su contenido de NOD hasta que su pérdida es compensada por el mezclado con otra agua más rica y la pérdida es más rápida cuanto mayor es su temperatura. Según este razonamiento la representación gráfica es una curva pero dada la dispersión de los puntos experimentales, ésta se puede asimilar a dos rectas.

En el cuadro I damos los valores de NOD para cada masa de agua, calculados de las rectas de regresión y el valor mínimo de NOD que es la intersección de cada par de rectas.

CUADRO I

Cantidad de nitrógeno orgánico disuelto (NOD) expresado en at-μg N/l de las masas de agua a diferentes profundidades, expresadas en función de σ.

	σ_t							
	26·3		26·9		27·3		27·7	
Masa de agua	NOD	S ‰	NOD	S ‰	NOD	S ‰	NOD	S ‰
Profunda Superior ...							5.5	34,68
Intermedia Antártica .					6,0	34,40		
Central	4,5	35,61	4,4	34,82				
Ecuatorial	4,8	35,11	4,1	35,00	3,9	34,96		
Mínimo de NOD	4,1	35,17	3,4	35,33	3,1	35.18	2,9	34,83
Mar Rojo			3,7	35,86	3,3	35,56	3,0	35,05

El valor más alto corresponde a la masa de agua Intermedia Antártica que va descendiendo a medida que aumenta la salinidad hasta confundirse con el agua Ecuatorial. Los valores mínimos se encuentran en el frente de mezcla del agua procedente del Mar de Arabia y Mar Rojo con las masas de agua Ecuatorial y Profunda Superior. Esta masa de agua muy pobre se encuentra localizada según los datos de *S* ‰ y σ_t del cuadro I, entre las estaciones 238 y 241 según la profundidad, que coincide de un modo aproximado con la distribución real, figura 2.

Para otras masas de agua el orden decreciente de NOD es, Profunda Superior, Central, Ecuatorial y la procedente del Mar Rojo. Para estas últimas el orden es el encontrado por Menzel para el carbono orgánico disuelto, pero si tenemos en cuenta el factor de conversión 1 mg de COD = 9 at - μg de NOD, tenemos que la cantidad de NOD en el agua Central es muy inferior a la que le corresponde calculada a partir del COD. Esto en parte se debe a que en general los valores de NOD encontrados durante el crucero del «Magga Dan» fueron inferiores a los encontrados por el «Anton Bruun» como se indicó más arriba, pero la causa

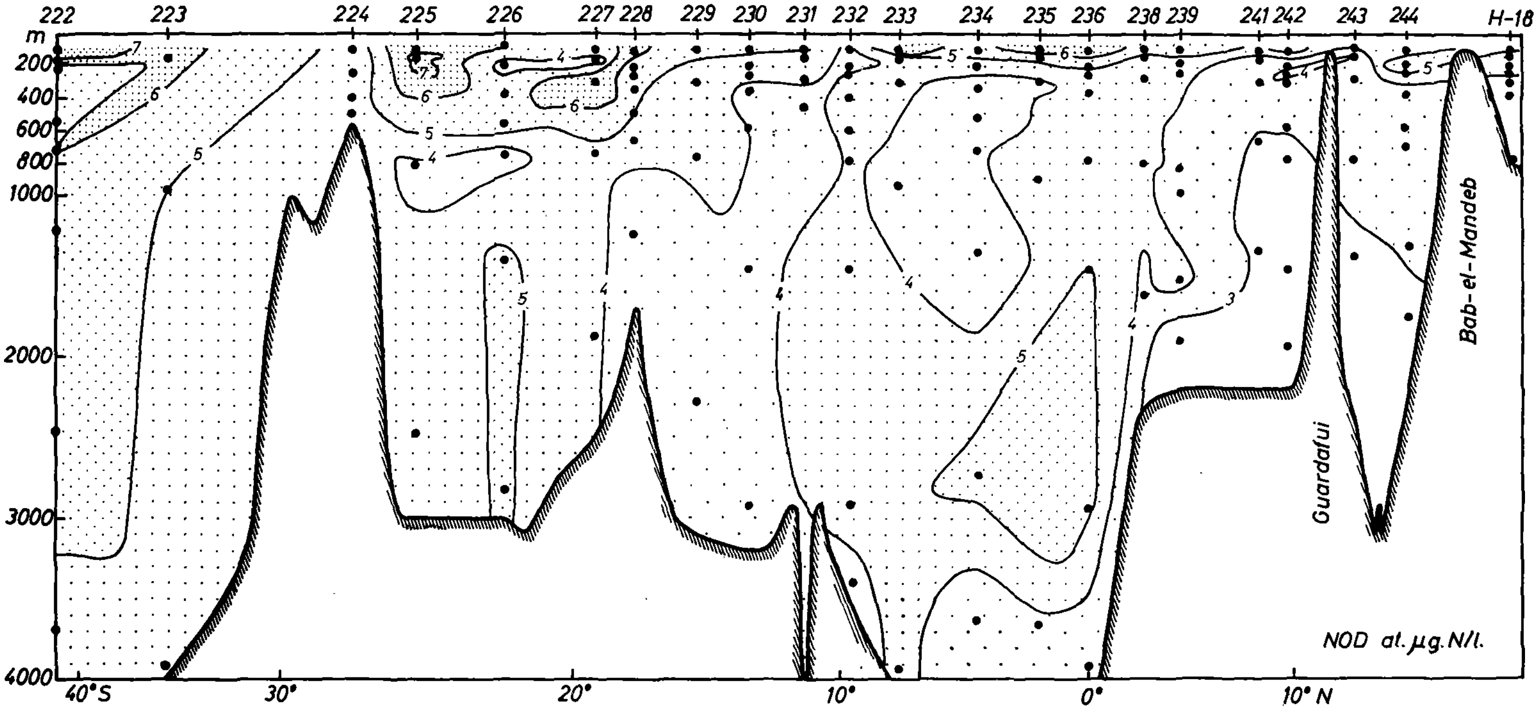


FIG. 2. — Corte vertical del crucero indicado en la figura 1, mostrando la distribución del nitrógeno orgánico disuelto, expresado at-μ N/l., durante el monzón del NE.

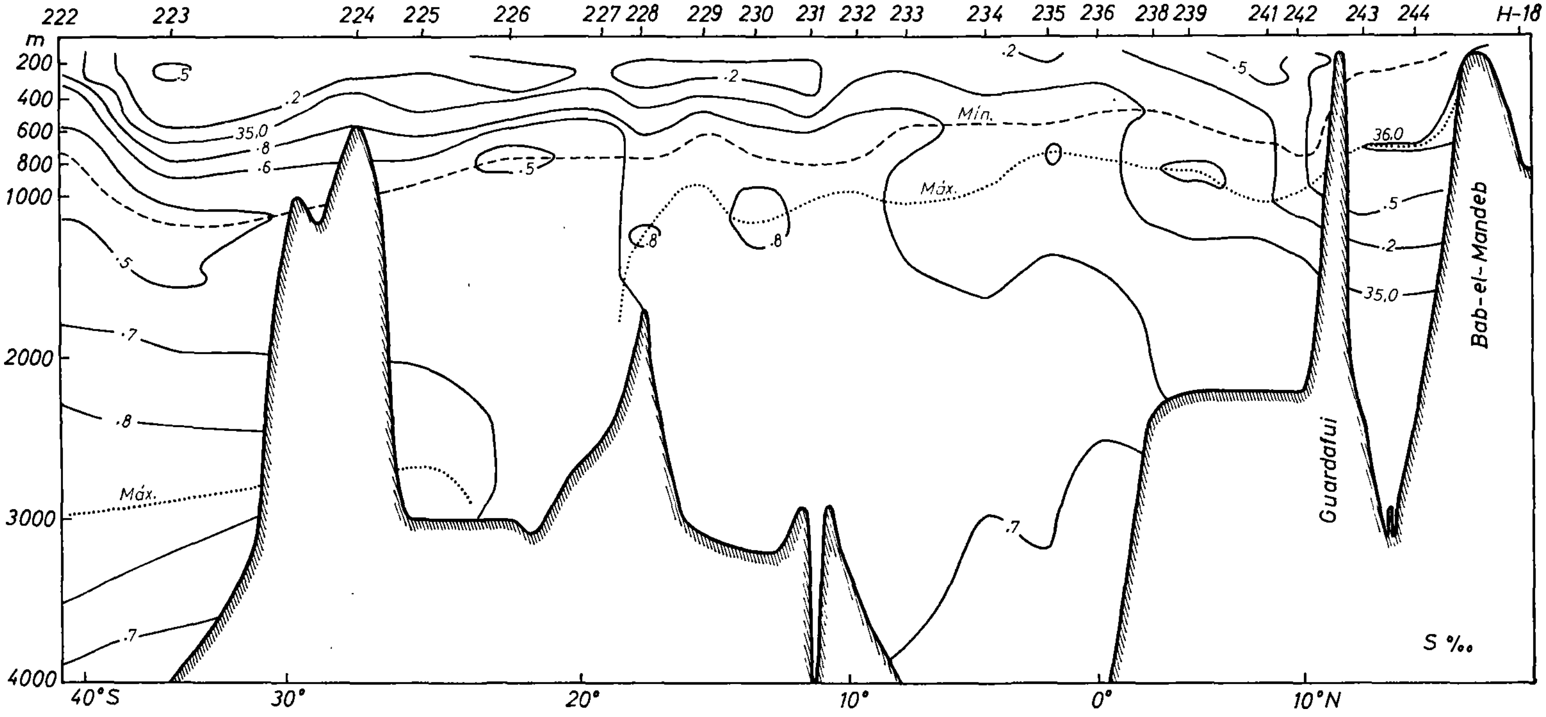


FIG. 3. — Distribución de la salinidad en el mismo corte de la figura 2. Línea de trazos, nivel principal de salinidad mínima. Línea de puntos, nivel de salinidad máxima.

principal es que los valores de COD en el agua Central son muy altos, 1,5 a 2,0 mg C/l (Menzel, 1964) y como ya se indicó claramente en nuestra publicación anterior, por encima de 1,5 mg C/l ya no hay correlación ninguna entre el nitrógeno y el carbono.

La cantidad y distribución del NOD en las distintas masas de agua se ve todavía mejor en la figura 4, donde se han representado los valores de NOD en at - μg N/l sobre un sistema de coordenadas *T-S*. En la misma figura se indica por curvas de nivel a puntos la profundidad media a que se encontró cada agua. En esta representación las curvas de NOD de las muestras superiores a 300 m tienen poco valor porque están sujetas a variaciones muy rápidas tanto locales como temporales y dependen de las sales nutrientes, temperatura y luz, por consiguiente el NOD sigue las curvas de profundidad porque en su mayor parte está formado por la fracción de nitrógeno lábil.

Para profundidades mayores el NOD depende de las masas de agua pero las curvas de los valores experimentales trazadas sobre las coordenadas *T-S*, no son muy regulares por lo que no es de extrañar que algunos de los valores calculados por regresiones lineales que figuran en el cuadro I, se aparten de los encontrados en la figura 4, por otra parte las curvas representadas en esta figura corresponden a valores medios por lo que los valores encontrados para algunas masas de agua en determinadas estaciones también se apartan bastante de este esquema general.

La relación entre el NOD y las masas de agua, también se deduce de la simple comparación con la figura 3 en la que está representada la distribución de salinidad para el mismo corte de la figura 2, en ella se ha indicado con línea de trazos la capa principal de salinidad mínima que corresponde claramente a la masa de agua Intermedia Antártica que avanza por debajo de un agua Central de características atlánticas, hasta el Canal de Mozambique. Más al norte se va perdiendo por mezclado con el agua Central Índica. Con línea de puntos se indica también la capa principal de máxima salinidad que corresponde a la masa de agua procedente del Mar Rojo hasta que ésta se va mezclando con la parte inferior de la masa Ecuatorial. Al sur del Canal de Mozambique aparece de nuevo otra capa de máxima salinidad que corresponde a una masa de agua Atlántica Profunda Superior.

En la comparación de las figuras 2 y 3 se ve que aun por debajo de los 300 m, la relación entre la distribución del NOD y la salinidad no está, a veces, de acuerdo con el esquema general como sucede en las estaciones 225-226 en las que a 800 m aparece una intensificación de la masa Intermedia Antártica que no se traduce en un aumento de NOD, sino al contrario.

Para aguas comprendidas entre 200 y 1500 m los diagramas *T-S* definen bien las diferentes masas de agua mientras que el NOD, sobre todo en las capas superiores, está sujeto como se indicó anteriormente a gran-

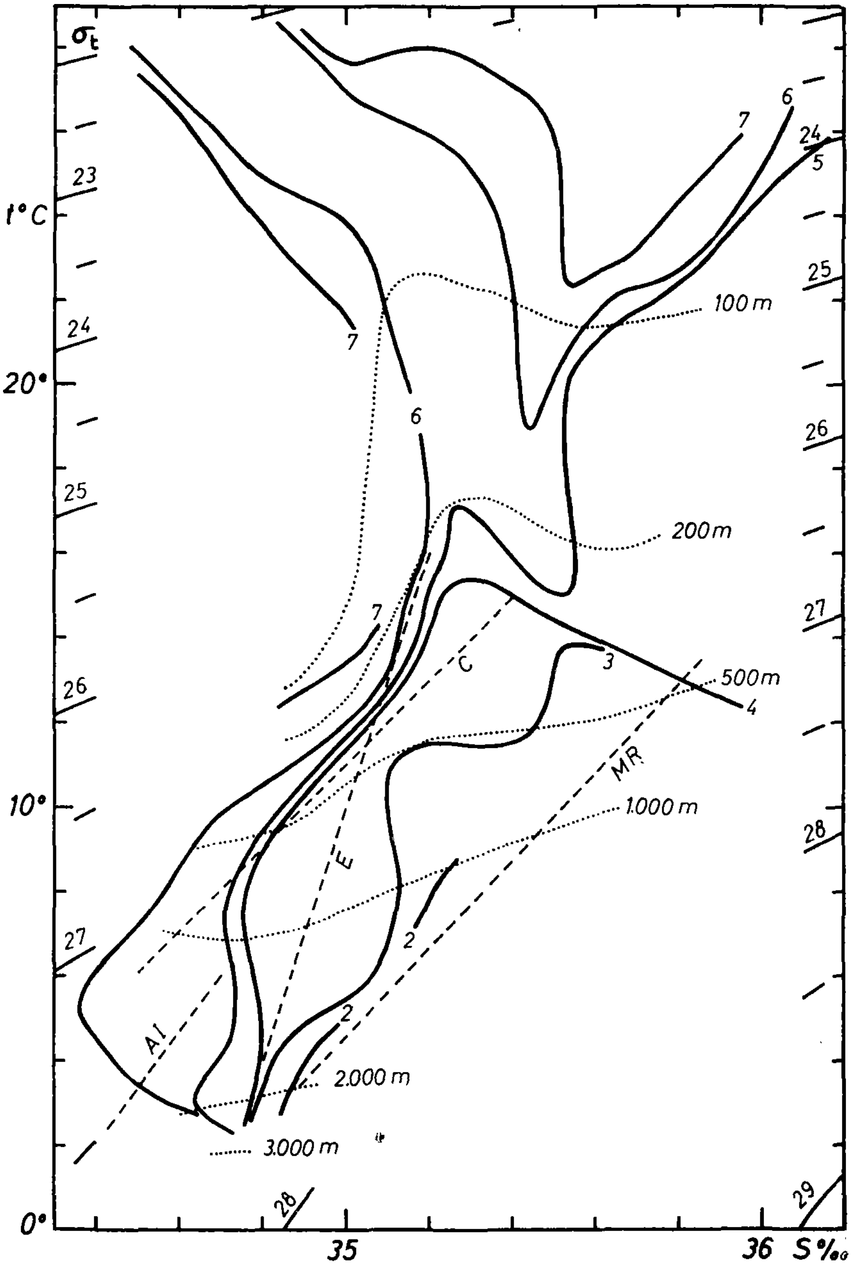


FIG. 4. — Distribución aproximada del nitrógeno orgánico disuelto expresado at-μg de N/l., representada sobre un sistema de coordenadas t°C, S ‰. Con líneas de trazos se representan las masas de agua típicas: C, central; E, ecuatorial; AI, antártica intermedia, y MR, agua procedente del mar Rojo. Línea de puntos; profundidad media a la que se encontró cada agua.

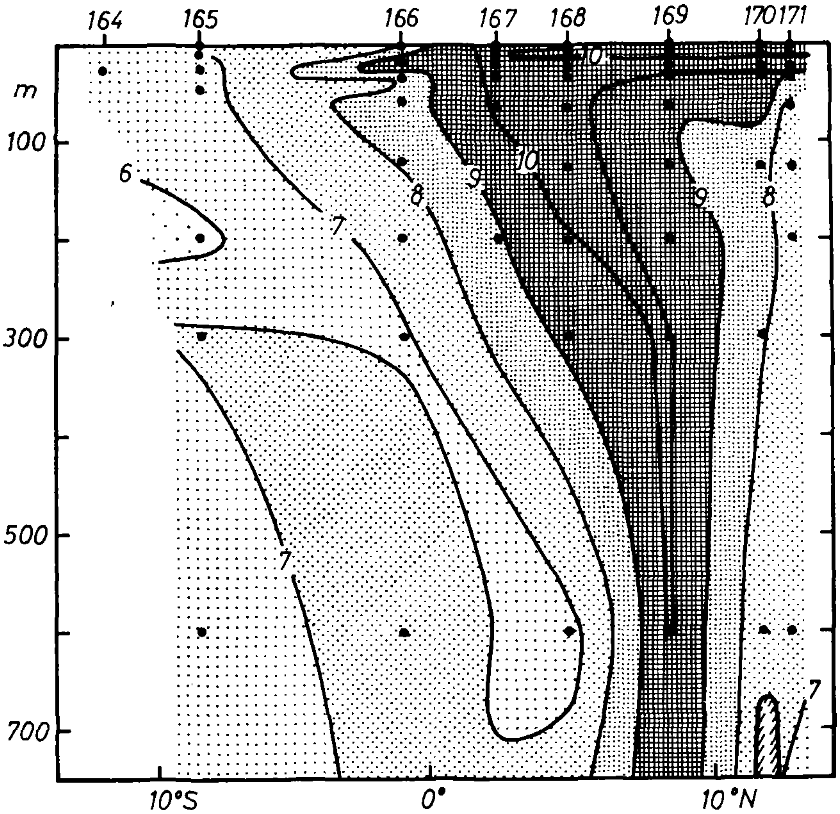
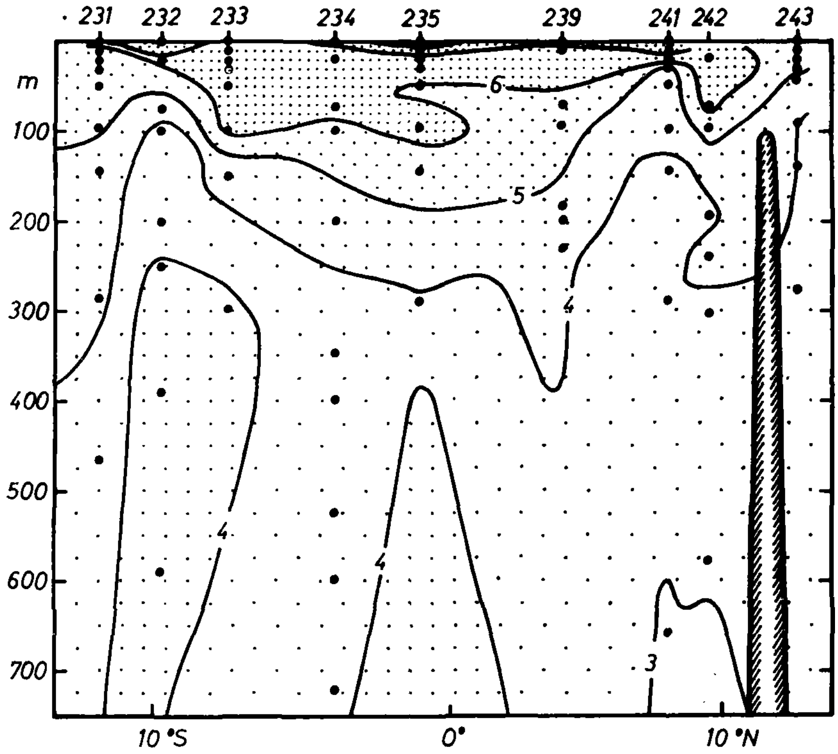


FIG. 5. — Distribución vertical del nitrógeno orgánico disuelto expresado en at-μg de N/l., al final del monzón del SO., siguiendo el corte AB de la figura 1.

des variaciones. Por el contrario, por debajo de 1500 m las diferencias de salinidad son muy pequeñas mientras que las diferencias de NOD son grandes y muy características de cada masa. En la capa de agua profunda se distinguen bien dos masas de agua. Una, con un contenido muy bajo de nitrógeno, típica del Mar de Arabia, situada entre 1000 a 3000 m próxima al cabo de Guardafui, que en la expedición anterior se encontró frente a la costa de Arabia. La otra, tiene un contenido alto de nitrógeno y se ha encontrado próxima a la costa de Madagascar haciendo un frente con el agua Profunda Superior Atlántica. Más al norte, en la cuenca de Somalia, se encuentra otra análoga a la anterior entre los 1500 a 3000 m.

Variación monzónica de la distribución del nitrógeno orgánico di-

FIG. 6 (*parte superior*). — Distribución del nitrógeno orgánico disuelto durante el monzón del NE., expresado en at-μg N/l. (*Parte inferior*): Distribución de la salinidad en el mismo corte de la figura de la parte superior. En línea de trazos, la isoterma de 11°C.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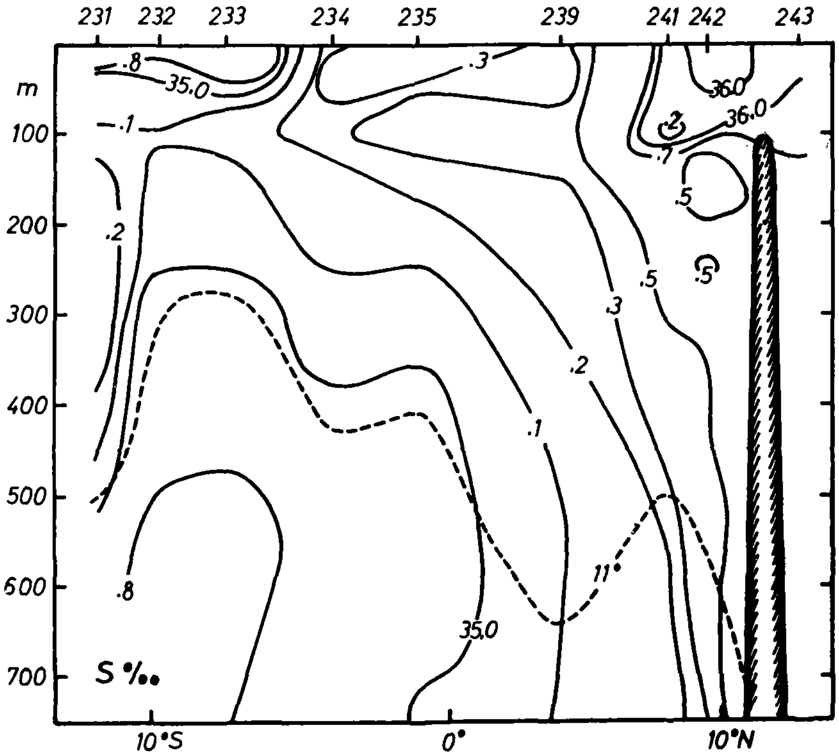
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suelto. — La parte ecuatorial del Océano Índico está sujeta a un régimen de vientos con una variación estacional bien definida, los monzones. Durante los meses de agosto a septiembre el viento sopla constantemente del SO y en el Mar Rojo del NO ; como consecuencia se produce un afloramiento de agua a lo largo de la costa de Arabia y Somalia y un hundimiento a lo largo de la línea ecuatorial. De febrero a marzo la dirección del viento es contraria, soplando del NE y en el interior del Mar Rojo, en la parte norte, el viento sigue soplando del NO pero en la parte sur tiene dirección contraria, o sea, del SE, este viento produce la entrada de agua superficial e intensifica la salida de agua profunda del interior del Mar Rojo, mientras que en el Océano el monzón del NE produce un hundimiento de agua en las costas de Arabia y Somalia y un afloramiento a lo largo de la línea ecuatorial.

Todo este sistema de circulación de la capa superior producido por los monzones, repercute claramente en la distribución del NOD e incluso se transmite a la capa subyacente. En las figuras 5 y 6 están representadas las distribuciones en los dos monzones ; la 5 al final del monzón del SO y en la 6 durante el monzón del NE. En la primera las líneas verticales de la distribución del nitrógeno corresponden a un hundimiento producido por la convergencia de agua superficial que se mueve en dirección N y se encuentra hacia el paralelo 3° N con un agua que se mueve en dirección E, rica en NOD por proceder de una zona de afloramiento costero y que ya ha permanecido durante algún tiempo en la zona eufótica. En la figura 6, monzón del NE, la distribución del NOD (parte superior), por el contrario, es horizontal. Por debajo de los 300 m se observa de nuevo una estructura vertical producida por un intento de afloramiento provocado por la divergencia que se produce al sur de la corriente nor-ecuatorial que se mueve hacia el oeste y se manifiesta durante este monzón. La intensificación del vertido de agua profunda del Mar Rojo junto con la elevación de las capas algo más profundas hacen aparecer una masa de agua muy pobre en NOD típica del Mar Rojo que se eleva en esta zona hasta menos de 600 m y es bien patente en la figura a 8° N, otras dos elevaciones de agua se observan en las latitudes 1° S y 10° S, pero éstas son de agua diferente, más rica en NOD y menos salada, éstas dos últimas también están reflejadas en el corte de salinidad, figura 6 (parte inferior) en general se ve la analogía entre ambas distribuciones por debajo de la zona eufótica. En la figura 6 también está representada a trazos la isoterma de 11°C que confirma la elevación local de estas tres pequeñas masas de agua.

Agradezco al doctor A. CAPART, director del Institut Royal des Sciences Naturelles de Bélgica, el haberme dado la oportunidad de participar en la expedición del «Magga Dan» y a los doctores M. STEYAERT, jefe de la expedición, Mme. STEYAERT, A. BALLESTER y J. SAN FELIU, su amable colaboración a bordo.

SUMMARY

The spatial distribution of the particulate organic nitrogen and the dissolved organic nitrogen (NOD) has been studied in the sea water in a North-South cut in the Western Indian Ocean from 24° to 52° East longitude, from the subtropical convergence, 42° S, to the Red Sea entry, 15° N.

It has been verified that under 400 m the DON is a characteristic of the water masses, the Intermediate Antartic Water having the highest value and the lowest values being found in the zones from the Red Sea, the Equatorial and the upper deep water one mix.

In deep water the DON can clearly distinguish the differences in water masses which are hardly different in their values of T.-S. The most typical of all of them is the deep water of the Arabian Sea having extremely low values of DON.

The distribution of DON in the upper layer of the equatorial zone found by the «Magga Dan» during the North East monsoon has been compared with that found formerly by the R/V «Anton Bruun» at the end of the South West monsoon and remarkable differences were found in agreement with the monsoon wind patterns.

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Nitrógeno orgánico particulado (P) y nitrógeno orgánico disuelto (D), ambos expresados en at-μg de N/litro.

222			223			224		
m	P	D	m	P	D	m	P	D
1	1,6	6,6	1	2,9	8,2	1	1,6	6,3
20	1,8	8,4	10	1,8	7,4	20	4,4	7,8
74	0,6	7,5	20	5,2	7,4	74	1,7	5,9
99	1,0	7,9	30	1,5	6,2	99	1,0	4,7
170	1,5	6,7	50	1,0	6,9	190	0,4	
220	0,5	4,9	100	0,2		250	0,9	4,0
360	2,1		150	0,3	6,3	400	0,0	4,2
540	0,8	5,6	270	0,0		500	1,3	4,2
650	0,4	6,0	970	0,6	5,0			
1200	0,6	5,5	3900	0,2	4,6			
2500	0,6	5,7						
3700	1,0	4,5						

225			226			227		
m	P	D	m	P	D	m	P	D
1	1,7	6,2	1	0,9	7,1	1	0,1	7,9
10	1,9	7,2	20	0,0	6,6	10	0,0	7,5
19	1,2	8,0	75	0,1	6,1	19	0,0	6,9
29	10,4	7,5	100	0,4		29	0,0	6,3
48	0,7	7,2	200	0,1	4,6	49	0,0	6,2
97	0,5	6,8	249	0,2		97	0,6	5,7
150	0,3	7,4	370	0,1	5,7	150	0,2	4,8
270	0,7		560	0,0	5,5	290	1,3	6,8
820	0,1	3,9	750	0,3	3,7	740	0,3	4,7
2500	0,3	4,5	1400	0,0	5,2	1900	0,0	4,2
			2800	0,2	5,1			

228			229			230		
m	P	D	m	P	D	m	P	D
1	0,5	7,2	1	0,5	7,3	1	1,3	6,5
20	1,3	7,0	10	1,1	8,0	20	0,3	7,4
75	0,1	6,3	20	0,2	9,3	75	0,5	5,6
99	0,3	6.2	30	0,2	7,6	100	0,7	5,1
200	0,5	5,6	50	0,3	7,3	200	0,8	4,6
250	0,0	5,3	100	1,7	5,3	250	0,8	4,2
340	0,2	5,3	150	1,1	4,2	360	0,0	3,8
490	0,0	5,1	300	0,0	4,2	580	0,4	4,0
660	0,2	4,4	760	0,3	4,3	770	0,2	
1200	0,1	3,1	2300	0,3	3,9	1500	0,0	3,8
						2900	0,0	3,4

231			232			233		
m	P	D	m	P	D	m	P	D
1	2,7	6,1	1	2,0	5,4	1	0,8	6,3
10	3,2	5,8	20	2,1	6,1	10	0,0	7,0
19	0,0	5,5	75	0,9	4,3	20	0,4	6,9
29	0,9	5,8	100	0,5	3,7	30	0,0	6,1
48	0,6	5,6	200	0,3	3,6	50	0,0	6,6
95	0,1	5,1	250	0,0	4,1	100	0,1	6,2
140	0,3	4,6	390	0,9	4,6	150	0,0	4,2
290	0,0	4,1	590	0,6	4,7	300	1,3	4,2
470	0,0	3,5	770	0,4	4,0	930	0,2	3,6
			1500	0,4	4,4	3900	0,6	4,2
			2900	0,6	4,5			
			3400	0,0	3,6			

Nitrógeno orgánico particulado (P) y nitrógeno orgánico disuelto (D), ambos expresados en at-μg de N/litro.

234			235			236		
m	P	D	m	P	D	m	P	D
1	0,5	5,9	1	0,0	6,2	1	0,0	6,7
20	0,0	6,9	10	0,1	5,8	20	0,1	6,6
74	1,2	6,2	19	0,0	7,0	74	0,1	6,7
99	0,0	5,8	29	3,7	6,9	99	0,0	6,8
200	0,0	4,3	48	0,4	5,9	200	0,1	5,2
240	0,0		97	0,1	6,3	250	0,4	4,3
350	0,0	3,5	150	0,3	5,4	360	0,0	4,2
530	0,0	3,2	290	1,3	3,9	580	0,1	
720	0,0	3,9	910	0,0	4,6	780	0,1	4,8
1400	0,2	3,2	3700	0,3	3,9	1500	0,1	5,0
2700	0,2	5,4				2900	0,0	5,1
3600	0,0	3,2				3900	0,0	3,2

238			239			241		
m	P	D	m	P	D	m	P	D
1	4,4	6,3	1	0,4	5,8	1	0,5	5,4
10	0,5	6,3	19	5,1	6,6	10	0,0	5,8
19	0,7	6,4	69	0,6	5,8	19	0,1	6,1
29	0,8	5,6	93	0,0	5,4	29	0,0	4,9
48	0,4	6,5	190	0,0	4,8	48	0,2	4,5
96	0,0	5,5	200	0,3	4,1	97	3,0	4,8
140	0,0	4,7	230	0,0	4,1	150	0,0	3,4
290	0,0	4,2	840	0,0	3,8	290	0,0	3,5
810	0,0	4,2	990	0,1	3,5	660	0,0	2,9
1600	1,0	3,9	1500	0,0	4,3	1300	0,0	2,8
			1900	0,0	2,3			

242			243		
m	P	D	m	P	D
1	0,5		1	0,0	5,0
19	0,2	6,8	9	0,0	5,7
72	0,0	6,2	19	0,0	5,4
97	0,0	5,3	28	0,9	5,5
190	0,0	3,7	46	0,8	4,5
240	0,3	4,8	93	0,2	4,0
310	0,0	3,2	140	0,3	4,0
580	0,2	3,2	280	0,0	3,4
770	0,0	2,3	810	0,1	3,8
1500	0,0	2,2	1400	0,0	2,5
1900	0,0	2,4			

244			H-18		
m	P	D	m	P	D
1	0,4	5,4	1	0,1	6,7
19	0,0	6,8	10	1,3	7,3
72	0,2	5,4	19	1,1	
95	0,0	4,6	29	0,3	7,3
190	0,0	5,8	48	0,5	7,1
240	0,2	5,0	73	0,3	6,3
380	0,0	3,3	97	0,0	5,5
570	0,0	3,9	150	2,7	4,2
700	0,0	3,9	190	0,3	4,8
1300	0,0	3,2	240	0,3	4,2
1800	0,0	2,6	290	0,0	3,6
			390	0,1	3,7
			540	0,4	
			780	0,0	3,6

Part V

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567. Aboussouan, A. Sur quelques larves pélagiques de téléostéens récoltés à Tuléar, p. 149-164.
568. Weiss, H. Aperçu préliminaire sur les rapports entre le milieu et la distribution des palétuviers le long d'une mangrove littorale proche de Tuléar, p. 165-173.
569. Weiss, H. Aperçu préliminaire sur une mangrove naturelle à l'intérieur des terres au sud de Tuléar, p. 175-178.

STRUCTURE
OF AN ARABIAN SEA
SUMMER MONSOON SYSTEM

by Forrest R. Miller
and R. N. Keshavamurthy

EAST-WEST CENTER PRESS HONOLULU 1968

Contents

PART 3: DISCUSSION

Abstract

A detailed study of an Arabian Sea summer monsoon system has become possible because of frequent and accurate upper air observations that were recorded between 26 June and 10 July 1963 by research aircraft of the U. S. Weather Bureau Research Flight Facility and the Woods Hole Oceanographic Institution. These unique data, particularly for the northeast Arabian Sea region, provide, with conventional observations, a three-dimensional data coverage from the surface to 14 km on several days of an active Arabian Sea monsoon.

Part 1 presents a discussion of the long-term-mean, three-dimensional structure of the summer monsoon circulation over the Arabian Sea and India. A general review of the early investigations and proposed hypotheses reveals the difficulties that are encountered in attempting to explain the vagaries and complexities of the summer monsoon regime. The procedures used to incorporate and analyze the great variety of observations obtained during the International Indian Ocean Expedition are also given, together with a summary of the types of observations recorded on research flights.

Part 2 presents specific details of the kinematic and thermo-dynamic structure of a particular mid-tropospheric cyclone — the principal activators of heavy rains over the northeast Arabian Sea and western India. This cyclone had its beginning in the mid-troposphere over the northeast Arabian Sea during the preactive monsoon period of June 1963; it matured quickly, and remained nearly stationary and apparently anchored to the subcontinent throughout the active monsoon period. After 12 days of heavy rains the cyclone system decayed, the weather improved, and an inactive or relatively dry monsoon period commenced. This monsoon system exhibited remarkably stable characteristics, which are exemplified by composite representations and a

model of observed and derived meteorological parameters. TIROS weather satellite photographs, which pictorially display the cloudiness associated with the Arabian Sea cyclone system, reveal the changing cloud structure as it progressed through its life cycle.

Although the entire atmosphere over the subcontinent responds to changes in the summer monsoon regime, the response of the mid-troposphere is quickest, and most direct, to the changes in the circulation and moisture content. Part 3 presents a discussion, in terms of case histories, of the direct role of the mid-troposphere circulation and its influence on the weather over the west coast of India and interaction with the low and high troposphere. Some examples are presented of TIROS photographs which visually portray the various stages in development and decay of mid-tropospheric cyclones over the Arabian Sea and subcontinent which occurred during 1962 and 1964.

AVERAGE CLOUDINESS IN THE TROPICS FROM SATELLITE OBSERVATIONS

by James C. Sadler

Honolulu *East-West Center Press* *1969*

Contents

Abstract

Two years of weather-satellite cloud observations, subsequent to the launching of TIROS IX in late January 1965, are summarized for the global strip between 30N and 30S. Daily data were extracted over a 3456-point grid of mesh size 2.5 degrees longitude-latitude, and monthly averages computed.

Tables and graphs are presented of the average monthly cloudiness summed around the globe between 30N and 30S, and between the equator and 30 degrees of latitude in each hemisphere.

The 2.5-degree "square" averages were analyzed and are presented as maps of monthly cloudiness for (1) the individual years of 1965 and 1966; (2) the two-year average; and (3) the difference between 1965 and 1966. The distribution of cloudiness is discussed in terms of persistent features, annual variation, and inter-annual variation, in particular. In total cloudiness and in location of the major areas of minimum and maximum cloudiness, there is little annual or inter-annual variability, however, *within* these areas the inter-annual variability is large. This circumstance produces a large inter-annual variability in cloudiness gradients.

Cloudiness averaged by latitude bands is presented in tabular and analyzed form; meridional profiles are shown for July and February.

Results are compared with previously published cloud climatology and with mean rainfall distribution over Africa.

„METEOR“ FORSCHUNGSERGEBNISSE

Herausgegeben von der Deutschen Forschungsgemeinschaft

Reihe A - No. 4

ALLGEMEINES
PHYSIK UND CHEMIE DES MEERES

Redaktion: G. Dietrich - Kiel
W. Hansen - Hamburg und J. Joseph - Hamburg

1968

GEBRÜDER BORNTRAEGER · BERLIN · STUTTGART

Schichtungs- und Bewegungsverhältnisse am Südausgang des Roten Meeres

von

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Conditions of layering and water movements in the entrance of the Red Sea

Summary

This publication deals mainly with the results of the physical investigations that were carried out in November and December 1964 during the expedition of R/V "Meteor" to the Indian Ocean.

In the beginning a short summary is given of earlier oceanographic work concerning water stratification and currents near Bab el Mandeb. In addition, some particulars are given about bottom topography and climate in this region. Representations of average temperature and salinity distribution in the Red Sea and the Gulf of Aden are shown that have been received from data collected by different ships on 12 expeditions from 1923 to 1963.

The main aim of the physical measurements on R/V "Meteor" in 1964 has been to answer the following questions:

1. What influence is exerted on the water layering and the currents near Bab el Mandeb and in the strait itself by bottom topography?
2. What kind of fine structure is to be found in the vertical distribution of temperature, salinity, density and currents?
3. What kind of short-time variations of this structure can be observed?
   a) What are the changes in water transport through the strait, especially those caused by tides and wind?
   b) Do there exist any internal seichès in the strait?
4. What is the average distribution of temperature, salinity, density, and currents in the Strait of Bab el Mandeb?

a) What net amount of water and salt transport can be calculated from that distribution?

b) What is the relation between the depth of current interface and density boundary layers?

A network of stations was included in the program of the expedition, covering the southern part of the Red Sea, the Strait of Bab el Mandeb and the inner part of the Gulf of Aden. Physical data were collected by the following instruments: Bathysonde, water samplers with reversing thermometers, two types of Savonius-rotor current meters used from aboard the ship, and anchored self-recording current meters. The positions of the measurements can be seen in figs. 15 and 16. The methods of measurements, the reduction of measuring data and their accuracy are discussed.

Summing up the data of temperature, salinity and density, and some current meter data for 4 selected sections, an insight can be given into the "average" layering in this region, provided almost quasi-stationary conditions can be assumed for the time of three weeks. It follows from these sections that warm high-salinity water runs out of the Red Sea through Bab el Mandeb near the bottom and is separated into two flows when spreading in the Gulf of Aden. Most of the water goes to the south, but a considerable amount also runs through a narrow channel in a southeast direction. The current interface in a cross section slopes from right to left. This slope is caused by the action of the Coriolis force.

Except in the deep water in the Red Sea below about 200 m depth and in a surface layer about 50 to 200 m depth, strong inhomogeneities appear nearly everywhere in the temperature and salinity distributions. They are extraordinarily great near the temperature minimum in the Gulf of Aden, where mixing processes create a lens-like or laminante structure.

The order of magnitude of variations in time is given by a section which has been repeated after one week and by the data of a one-half day anchor station in a region of Red Sea water outflow.

The record of a current meter that was anchored in the northern channel indicates an almost constant direction of the Red Sea water outflow with a strong maximum in speed at about 40 cm/sec. The time variations of the current speed are small, but maxima for tidal periods can be clearly seen in the computed power spectra.

A great part of the investigations concentrated on the strait about 300 m deep near the island of Perim. Selfrecording current meters were anchored during several weeks on different positions in the strait and over the sill about 10 nautical miles to the north. In addition, the R/V "Meteor" was anchored from December 2 to 5, 1964 in the strait itself, and repeated measurements of temperature, electrical conductivity, and currents were carried out. The vertical distribution of temperature, salinity, and density is characterized by three layers: A homogeneous surface layer, a complicated intermediate layer with great variations in time, and an almost homogeneous bottom layer. The recordings demonstrate that sections cannot be represented by a few isolated measurements. Repeated measurements and subsequent averaging of the data are necessary in this complex region.

It can be seen from the records that the boundary layers between the three layers move vertically with a diurnal period.

A two-layer current distribution has been found, the current interface moving vertically between 0 and 100 m depth. The vertical displacements of the current interface are greater than those of the density boundary layers. This can be explained by the addition of normal to internal tides.

The average profiles of vertical temperature, salinity, density, and current distribution have been drawn in figs. 43 and 44. The average current profile is parabolic in the upper layer, but has a maximum below the current interface. This maximum can be explained by a jet-like behaviour of the Red Sea water having passed the sill 10 nautical miles to the north.

The histogram plots of anchored current meter data and computed residual current values are discussed and compared with the average current profile of the anchor station. Some understanding can be gained from this discussion concerning the question whether the average current profile is representative for the whole time of the investigations. A summary of wind data, residual currents, and 25-hour overlapping means of the water level at Aden (fig. 63) leads to the following conclusion: An increase of wind speed to about 2 Bft above normal for November and December in the region caused a strong increase in the currents directed towards the Red Sea and a decrease of average water level at Aden. It is supposed that the inflow to the Red Sea was enlarged directly by wind stress and indirectly by a change in water level, thus being far larger than under normal wind conditions during the winter season.

The average current and salinity profiles can be used to compute the net transport of water and salt amount during the time the ship was anchored in the strait. It is assumed that the average profiles are valid for the whole width of the strait except for a region on the western side where a countercurrent has been found by anchored current meter data. The inflow to the Red Sea is computed to be $2.1 \cdot 10^9$ m^3 water per hour and $80 \cdot 10^9$ kg salt per hour; the outflow being $1.5 \cdot 10^9$ m^3 water per hour and $61 \cdot 10^9$ kg salt per hour. These values are compared with the average net transport of water and salt necessary to compensate the evaporation of 200 cm per year in the Red Sea. The result is as follows:

The net amount of water flowing to the Red Sea during the time of the anchor station was about six times larger than expected. This apparently was caused by the wind conditions and evaporation processes characteristic of the winter season and the special wind conditions during the time of the measurements.

The average profiles of vertical density and current distribution are used to compare the depths of the density boundary layers with the depth of the current interface. A theory has been developed to compute the relation between these depth values from the pressure field. A two-dimensional, three-layer density model has been used, assuming steady-state conditions, constant bottom depth and surface pressure, and neglecting vertical velocities, horizontal accelerations, compressibility of sea water, Coriolis and external forces. The results are given in fig. 67. The measured density and current profiles reveal that the current interface occurs in a depth only half as great as that predicted by the theory. This is probably caused by the bottom topography. As the bottom depth is not constant, the jet-like behaviour of the outflowing current will cause a higher depth of the current interface.

The data obtained by selfrecording current meters during several weeks were used to compute power and amplitude spectra of current velocity for selected positions. The following information is revealed about internal waves: The spectra prove the existence of diurnal and semidiurnal internal tides and internal shallow-water tides with a period of 8 and 6 hours. In addition, maxima at a period of 5 hours have been found in the spectra of the current meters that were anchored on the sill north of the strait. They probably indicate the existence of internal seiches in the channel, since the same period is found as the first-order solution in a three-layer model computation.

Struktur und Verteilung des Wassers aus dem Roten Meer im Nordwesten des Indischen Ozeans

von

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Structure and distribution of Red Sea Water in the western Arabian Sea.

Summary

During the Indian Ocean Expedition of R/V "Meteor" in 1964/65 the spreading of water of the Red Sea was investigated off the Somali coast. Temperature and salinity were measured continuously as a function of the depth by a Bathysonde at every station. There was found no spatial coherence between the fine-structure of two stations. The same result was shown by HAMON (1967) by measurements with an STD-recorder in the Indian Ocean. In order to present the results in sections, the original continuous data were smoothed using a running mean of 70 meters which eliminated the fine-structure. This method allows hydrographic sections to be drawn which show the main structure horizontally and vertically of temperature and salinity. There are large differences between the averaged sections and those obtained by hydrographic casts.

The results of the continuous measurements are:

1) The outflow of Red Sea water is concentrated within a distance of 350 km off the Somali coast. It is suggested that the spatial variations are due to meandering of the flow. Outside this range a mixing process takes place with a rather low diffusion rate.

2) The direct influence of the Red Sea overflow seems to end near the equator (see figures 14 and 15), but the last two sections of figure 15 indicate a return of this water which may be due to the seasonal fluctuations of the overflow.

3) The water which is influenced by the Red Sea outflow, is separated from underlying water masses by a sharp discontinuity layer. The vertical gradient of average temperature and salinity increases with distance from the source. It is suggested that due to the loss of energy of the flow, the mixing processes become weaker. This is thought to be the reason that the Red Sea mixed water, although small in quantity compared with the surrounding waters, is found at such a large distance from its source.

4) The continuous records very often show two well defined temperature and salinity maxima at depth. There are two possible explanations:

a) There is a distinct stratification of the overflow at the Strait of Bab el Mandeb with Arabian Sea water above flowing into the Red Sea and an underlying layer of Red Sea water flowing into the Gulf of Aden. The periodic mixing of the two water types due to the tides is proposed as a mechanism for the formation of the two maxima in temperature and salinity observed along the Somali coast.

b) The effect of bottom topography in the inner Gulf of Aden causes the outflow to be divided into two arms of nearly equal water transport. The southern part of the outflow takes place in a large area, the northern one in a very small channel with no lateral mixing. The two arms have a different history which will cause two layers of different densities further downstream.

„METEOR"
FORSCHUNGSERGEBNISSE

Herausgegeben von der Deutschen Forschungsgemeinschaft

Reihe C - No. 1

GEOLOGIE UND GEOPHYSIK

Redaktion: E. Seibold - Kiel
und H. Closs - Hannover

1968

GEBRÜDER BORNTRAEGER · BERLIN · STUTTGART

Die Echolotungen des Forschungsschiffes „Meteor“ im Arabischen Meer während der Internationalen Indischen Ozean Expedition

von

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Echo-sounding sections of the course of R. V. “Meteor” in the Arabian Sea during the International Indian Ocean Expedition

Summary

As a result of the participation of R. V. “Meteor” in the International Indian Ocean Expedition during the winter 1964/65 altogether 37 sounding profiles were obtained in the Arabian Sea (plate 2–18). They are showing the topographic peculiarities of the main features of the sea bottom in this northwestern part of the Indian Ocean: Shelves, continental slopes and rises, deep-sea plains and hills, the Mid-Oceanic Ridge, fracture zones and seamounts.

A control chart (plate 1) shows the geographical position of the sounding lines. The coordination of the soundings with the bathymetric sketch and the map of physiographic provinces (B. C. HEEZEN and M. THARP) is represented in fig. 1 and 2. All soundings were obtained by the modern ELAC-Narrow Beam sounder which also accurately records very steep slopes of the sea bottom (fig. 3 and 4).

Two series of sounding profiles (fig. 5 and 6) are showing the main topographic differences of shelf and slope between the eastern African and the western Indian continental margin.

The descriptive analysis of all the sounding sections carried out by “Meteor” show the following main results:

a) discovery of a very steep towering up seamount in the northern Somali basin at $\varphi = 8° 16' \mathrm{N}$, $\lambda = 53° 12' \mathrm{E}$, which is rising up from a depth of 5000 m to about –2000 m (plate 3),
b) registration of numerous steep canyons in the upper part of the eastern African continental slope near the coast of Kenya (plate 6),
c) complete representation of a characteristic section across the Carlsberg-Ridge inclusively rift mountains and the Rift-Valley (plate 9),
d) new characteristic results of sounding profiles across the Alula-Fartak trench showing very steep slopes on its flancs (plate 18).

Untersuchungen an der heißen Salzlauge und am Sediment des Atlantis II-Tiefs im Roten Meer

von

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und

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Investigation of the hot salt brine and sediment of the Atlantis II-Deep in the Red Sea

Summary

Two water samples and two sediment samples taken in 1965 by the R. V. "Meteor" in the area of the hot salt brine of the Atlantis II-Deep were chemically investigated, and in addition the sediment samples were subjected to X-ray and optical analysis.

The investigation of the sulfur-isotope-ratios showed the same values for all water samples. This information combined with the Ca-sulfate solubility data leads us to conclude that, for the most part, the sulfate content of the salt brine resulted from mixing along the boundary with the normal seawater. In this boundary area gypsum or anhydrite is formed which sinks down to the deeper layers of the salt brine where it is redisolved when the water becomes undersaturated. In the laboratory, formation of $CaSO_4$ precipitate resulted from both the reheating of the water sample from the uppermost zone of the salt brine to the in-situ-temperature as well as by the mixing of the water sample with normal Red Sea water.

The iron and manganese delivered by the hot spring is separated within the area of the salt brine by their different redox-potentials. Iron is sedimented to a high amount within the salt brine, while, as evidenced by its small amounts in all sediment samples, the more easily reducible manganese is apparently carried out of the area before sedimentation can take place.

The very good layering of the salt brine may be the result of the rough bottom topography with its several progressively higher levels allowing step-like enlargements of the surface areas of each successive layer. Each enlargement results in larger boundary areas along which more effective heat transfer and mixing with the next layer is possible.

In the sediment samples up to 37.18 % Fe is found, mostly bound as very poorly crystallized iron hydroxide. Pyrite is present in only very small amounts. We assume that the copper is bound mostly as sulfide, while the zinc is most likely present in an other form.

The sulfur-isotope-investigations indicate that the sulfur in the sediment, bound as pyrite and sulfides, is not a result of bacterical sulfate-reduction in the iron-rich mud of the Atlantis II-Deep, but must have been brought up with the hot brine.

Zusammensetzung, Gefüge und mechanische Eigenschaften rezenter Sedimente vom Nildelta, Roten Meer und Golf von Aden

von

GERHARD EINSELE
Geologisches Institut der Universität Tübingen

und

FRIEDRICH WERNER
Geologisches Institut der Universität Kiel

Composition, texture, and physical properties of recent sediments from the Nile Delta, Red Sea, and Gulf of Aden

Summary

The study of textural, structural, chemical, and physical properties of fine-grained recent marine sediments leads to the conclusion that only a few compositional factors are responsible for significant changes in mass physical characteristics in the upper meters below sea bottom. Fossil-induced porosity (text fig. 6) increases water content and liquid limit. It also seems to have partially influenced the plastic limit and plasticity index of calcareous sandy silts from the Red Sea and the western Gulf of Aden so that they become similar to the montmorillonite rich prodelta clays from the Nile Delta. Diagrams based on liquid limit and plasticity loose their original meaning in these cases (text fig. 7a). Activity of sediments rich in microorganisms can be higher than that of montmorillonitic clay (text fig. 7b).

The shear strength-depth relationship of normally consolidated sediments (text fig. 8a) is surprisingly little influenced by changes in sand or clay content and clay mineralogy. Only high lime content, submarine erosion and beginning cementation increase the strength considerably (part of curves in text fig. 8b). Erosional disconformities near the present surface can be deduced from the strength-depth curve when as little as 1 or 2 m sediment have been removed (text fig. 9).

Flat or irregular strength-depth curves (text fig. 8b, curves B and GO) indicate beginning cementation and probably discontinuous sedimentation, provided the composition of the material remains in some degree constant. In our samples diagenetic pyrite, but no recristallisation of carbonates could be detected under the microscope.

Underconsolidation and excess pore-water pressure, factors which tend to foster submarine slides, mud lumps, and diapiric folding, seem to be restricted

Die Verteilung höherer, geradkettiger Paraffine und Fettsäuren in einem Sedimentprofil aus dem Persischen Golf

von

DIETRICH H. WELTE und GÖTZ EBHARDT
Geologisches Institut der Universität Würzburg

The distribution of higher straight chained paraffins and fatty acids in a sedimentary profile from the Persian Gulf.

Summary

Sediments from a 3.40 m core out of the Persian Gulf were investigated for their content of straight chain paraffins and fatty acids. The samples range in age between 2000 and 9000 years (C-14-age of organic C). They contain 100—300 ppm of extractable fatcompounds and 20—70 ppm of hydrocarbons. There is no connection between the original distribution of the homologous series of n-fatty acids and n-paraffins. However, there is evidence that part of the n-fatty acids was reduced to n-paraffins, although the sediment itself does not look as if it were deposited under reducing conditions.

„METEOR“
FORSCHUNGSERGEBNISSE

Herausgegeben von der Deutschen Forschungsgemeinschaft

Reihe D - No. 1

BIOLOGIE

Redaktion: J. Krey - Kiel, A. Bückmann - Hamburg
O. Kinne - Hamburg und W. Schäfer - Frankfurt a. M.

1967

GEBRÜDER BORNTRAEGER · BERLIN-NIKOLASSEE

Fische des Indischen Ozeans
Ergebnisse der ichthyologischen Untersuchungen während der Expedition des Forschungsschiffes „Meteor“ in den Indischen Ozean, Oktober 1964 bis Mai 1965

von

Adolf Kotthaus,
Biologische Anstalt Helgoland, Zentrale, Hamburg

Fishes of the Indian Ocean

Results of the Ichthyological Investigations during the Indian Ocean Expedition of the Research Vessel "Meteor", October, 1964 to May, 1965

An English summary will be given at the end of the last issue of this publication series

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„Multinetz“, ein Mehrfachschließnetz für Phytoplankton

von

Reimer Simonsen,
Institut für Meeresforschung, Bremerhaven

"Multinet", a multiple closing net for phytoplankton

Summary

A phytoplankton net is described with which samples from six different depth zones can be obtained by a single vertical haul. The closing net is released by an electromagnet through single conductor wire (220 V D. C.). On a revolving disc which is driven by a spring, there are six buckets which are successively brought before the net opening. The parts made of bolting silk can be exchanged, the entrance opening can be reduced. The apparatus is independent from depth by means of pressure compensation.

„METEOR“ FORSCHUNGSERGEBNISSE

Herausgegeben von der Deutschen Forschungsgemeinschaft

Reihe D - No. 2

BIOLOGIE

Redaktion: J. Krey - Kiel, A. Bückmann - Hamburg
O. Kinne - Hamburg und W. Schäfer - Frankfurt a. M.

1967

GEBRÜDER BORNTRAEGER · BERLIN-NIKOLASSEE

Bericht über den Forschungsaufenthalt der Litoralgruppe auf der Insel Sarso (Rotes Meer)

1. Beitrag der Arbeitsgruppe Litoralforschung

von

SEBASTIAN A. GERLACH,
Institut für Meeresforschung, Bremerhaven

Report on the work of the litoral group in Sarso Island (Red Sea)

Summary

Within the frame of the German research vessel "Meteor" participation in the International Indian Ocean Expedition 8 members of the "litoral group" worked on a biological survey of the shores of the Sarso Islands (Farasan Archipelago) from 24. 11. to 8. 12. 1964. This report gives details about the expedition and deals with organisation and technical supplies.

Die Fauna des Küstengrundwassers am Strand der Insel Sarso (Rotes Meer)

2. Beitrag der Arbeitsgruppe Litoralforschung[1]

von

SEBASTIAN A. GERLACH,
Institut für Meeresforschung, Bremerhaven

The interstitial subsoil fauna on the beach of Sarso Island (Red Sea)

Summary

The scope of this research was to find out, how important is the presence of brackish water for the formation of the characteristical littoral subsoil fauna in the interstitial spaces of beaches.

There is little precipitation in the Red Sea area and therefore little influence of freshwater on the beach. Moreover, the sandy beach of Sarso Island (Farasan Archipelago) is bordered landwards and underneath by solid limestone, preventing subsoil fresh water, if there is any, from penetrating into the beach region. The salinity of the interstitial water from Sarso beach lies a little above the salinity of the adjacent sea.

The microfauna of Sarso beach is composed to a rather big proportion of such species that are known to be characteristical littoral subsoil water species, partially of world wide distribution. The ecological analysis of this fauna, i. e. the freeliving Nematodes, reveals the presence of two distinct associations:

1. the association of the low level subsoil region, close to the sea, with clear interstitial water, subject to regular exchange with the water of the adjacent sea.
2. the association of the high level subsoil region, 4—10 meter distant from the sea, with brownish water.

Contrary to earlier results there is no distinction in salinity between the two associations, so it is not longer justified to apply the term brackish water fauna on the animals living in the association of the high level subsoil region.

Freilebende Meeres-Nematoden von den Sarso-Inseln (Rotes Meer)

3. Beitrag der Arbeitsgruppe Litoralforschung

von

SEBASTIAN A. GERLACH,
Institut für Meeresforschung, Bremerhaven

Freeliving marine Nematodes from the Sarso Islands (Red Sea)

Summary

Report on a collection of freeliving marine Nematodes from the sandy beach and the littoral subsoil water of Sarso Island (Southern Red Sea). 58 different species have been identified, one is the type species of a new genus:

Sarsonia murphyi gen. n. sp. n.

13 more species are new to science:

Oxystomina circulosa sp. n.
Halalaimus relatus sp. n.
Halalaimus sarsi sp. n.
Halalaimus florescens sp. n.
Mesacanthion monhystera sp. n.
Oncholaimus flagellatus sp. n.
Oncholaimellus meteori sp. n.
Eurystomina mammillata sp. n.
Paracyatholaimus saradi sp. n.
Desmodora (Pseudochromadora) bipapillata sp. n.
Nygmatonchus minutus sp. n.
Haliplectus caudopapillatus sp. n.
Haliplectus minimus sp. n.

Beobachtungen über den Fischadler im Roten Meer Pandion haliaetus (L.)

7. Beitrag der Arbeitsgruppe Litoralforschung

von

Wolfgang Kost, Schwäbisch Hall

Ethological observations on the Osprey (*Pandion haliaetus* L.).

Summary

Ospreys were observed during November and December at various areas of the Red Sea and the Gulf of Aden, where the bird is fairly abundant at suitable localities. Territorial behaviour is little developed, and sometimes up to six birds join in

„METEOR“ FORSCHUNGSERGEBNISSE

Herausgegeben von der Deutschen Forschungsgemeinschaft

Reihe D - No. 3

BIOLOGIE

Redaktion: J. Krey - Kiel, A. Bückmann - Hamburg
O. Kinne - Hamburg und W. Schäfer - Frankfurt a. M.

1968

GEBRÜDER BORNTRAEGER · BERLIN · STUTTGART

COELOPLANA METEORIS nov. spec. (Ctenophora, Platyctenea)
Beschreibung und systematische Stellung mit einem Vergleich der Gastrovascularsysteme in dieser Ordnung

von

Hjalmar Thiel
Institut für Hydrobiologie und Fischereiwissenschaft der Universität Hamburg

Summary

1. *Coeloplana meteoris* is described as a new platyctene ctenophore (with 11 photographs and 1 coloured figure).
2. Its systematic position is discussed and understood as preliminary.
3. A comparison is made of the gastrovascularsystem of the Platyctenea. These can be used for systematic characterisation.

Fische des Indischen Ozeans
Ergebnisse der ichthyologischen Untersuchungen während der Expedition des Forschungsschiffes „Meteor" in den Indischen Ozean, Oktober 1964 bis Mai 1965
A. Systematischer Teil, III
Ostariophysi und Apodes

von

Adolf Kotthaus
Biologische Anstalt Helgoland, Zentrale, Hamburg

Fishes of the Indian Ocean

Results of the Ichthyological Investigations during the Indian Ocean Expedition of the Research Vessel "Meteor", October, 1964, to May, 1965

An English summary will be given at the end of the last issue of this publication series

Zur Küstenvegetation der Sarso-Inseln im Roten Meer

8. Beitrag der Arbeitsgruppe Litoralforschung

von

REIMER SIMONSEN
Institut für Meeresforschung, Bremerhaven

The coastal vegetation of the Sarso islands in the Red Sea

Summary

During the expedition of R. V. "Meteor" to the Indian Ocean 21 species of marine algae and 2 phanerograms were collected on the Sarso islands. A littoral zone (in the botanical sense) and three sublittoral zones could be diffentiated by means of the algae. Of these the most conspicuous is the *Sargassum-Turbinaria* belt. A small strip of *Avicennia* mangrove was observed. The collected marine plants belong to 5 types of geographical distribution which indicate the origin of the flora from the Indian Ocean.