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to the

INTERNATIONAL ZOOPLANKTON COLLECTIONS

Curated and processed at the

INDIAN OCEAN BIOLOGICAL CENTRE

VOLUME V

HANDBOOK

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INTERNATIONAL ZOOPLANKTON COLLECTIONS

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NATIONAL INSTITUTE OF OCEANOGRAPHY

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VOLUME V : PAPERS ON THE ZOOPLANKTON COLLECTIONS OF THE IIOE

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CONTENTS

PREFACE

The present volume is a continuation in the series of Handbooks to the International Zooplankton Collections issued by the Indian Ocean Biological Centre. Like Volume IV (1973), this contains a number of papers arising out of the studies on the zooplankton collections of IIOE as well as other plankton studies made at the IOBC.

The first paper by Dr. Marta Vannucci and Miss D. Navas is on the ecological distribution of the hydromedusae of the Indian Ocean. 131 different species have been listed and the autecology of 50% of these which had sufficiently large representation in the collections is given. The major patterns of distribution in relation to environmental factors like salinity, temperature, dissolved oxygen content and transport by water masses are described. Two papers deal with the distributional records and ecology of a few species of pelagic polychaetes of the Indian Ocean; another one records two deep-water species of hyperiid amphipods for the first time from the Indian waters. Developmental stages of *Penaeopsis rectacuta*, one of the deep-water species of penaeid prawns of potential commercial importance along Indian coasts, as well as some stages of few other prawns are described in two other papers. Bay of Bengal is found to be an important nursery area for cephalopods in another study. The breeding of chaetognaths in the Cochin waters is also studied. In addition to an article on the general distribution of decapod larvae in the Indian Ocean the larval history of one of the pasiphaeid shrimps *Leptochela robusta* which is an important forage species of pelagic fishes is traced in another paper. Three short communications on calanoid copepods deal with description of a new species *Macandrewella cochinensis*, redefinition of the genus *Gaussia* and description of *Haloptilus acutifrons* (male). Dr. N. K. Panikkar and Dr. T. S. S. Rao give a summary of the zooplankton studies carried out in Indian waters since 1930. Since the zooplankton forms the secondary level in the trophic chain of the sea, it is important to study on a more regular basis, the zooplankton population of the Indian coastal areas, particularly in the region of the Malabar upwelling system.

Cochin-18,
August, 1973

N. K. PANIKKAR
DIRECTOR

ON THE ECOLOGY OF INDIAN OCEAN HYDROMEDUSAE *

M. VANNUCCI[1] & D. NAVAS[2]

ABSTRACT

This study investigates the ecological distribution of about 45,000 specimens of hydromedusae taken in the Indian Ocean during the International Indian Ocean Expedition (IIOE); 480 stations were occupied and more than 900 plankton samples were sorted for medusae and all the specimens analysed. Several hauls, mostly stratified were taken at each station, not all contained medusae. The distribution of each species was studied in relation to salinity, temperature, dissolved oxygen content and water masses. The limits of tolerence found are given for each and the following groups of species may be recognized, 1) Deep water species, cold loving often eurytopic; 2) Antarctic species, cold loving, usually stenothermal and rather low salinity species; 3) Indian Ocean Central Water species, prefer temperature lower than 19°C and salinity not much higher than 35°/oo, usually found at subsurface or intermediate depths and spread into the Arabian Sea and Bay of Bengal in surface layers; 4) Indian Ocean Equatorial System species, warm loving, usually perfer comparatively low salinity, high temperature and high oxygen content; 5) Bay of Bengal Surface Water group of species in the surface layer of the Bay, prefer very low salinity, high emperature and high oxygen content; 6) Arabian Sea Surface Water group of species prefer very high salinity and high temperature; 7) Rare species. Also immigrants from the Mediterranean Sea are described and many species were found to tolerate very low dissolved oxygen content, down to 0.2ml/1. Many specimens and many species show aggregation at the boundary layers.

INTRODUCTION

Volumetrically or gravimetrically speaking the hydromedusae are not one of the major constituents of the zooplankton and only a small fraction of the living matter and energy that constitute the trophic web are bound as jelly-fishes. Nevertheless they represent an important ecological category because of their specialized position as exclusive carnivores, because of their frequent presence and wide distribution and, at times and places, their great abundance in terms of number per unit volume of water. Taxonomically the hydromedusae are in good order, mainly due to the work done by the late Dr. W. J. Rees (British Museum), by Sir Frederick S. Russell (Marine Biological Association of United Kingdom) and by Dr. P. L. Kramp (Zoological Museum of the University of Copenhagen, Denmark). The wealth of plankton material collected during the International Indian Ocean Expedition (IIOE) affords a good opportunity to study the patterns of distribution of the medusae of the Indian Ocean (IO). The sampling design at sea and the cruise tracks were dictated mainly by what was known or suspected at the time of the phenomena of particular oceanographic interest, such as monsoonal cycles, areas of upwelling, equatorial surface and subsurface current systems and the like, rather than following a random exhaustive sampling in time and space, both vertically and horizontally. While the procedure chosen allows for excellent study of particular phenomena and current systems, it is not the best for studies for distribution of plankton organisms.

Nevertheless, the great number of specimens taken (about 45,000) and the presence of environmental data for almost all stations occupied, made it worthwhile to attempt an ecological interpretation of the distribution.

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An earlier paper by Navas (1971) reports on the distribution of the species taken during the IIOE that were previously unknown from the IO; Vannucci & Navas (1971) discuss some of the results of this work and show that water masses, boundary layer and major geographical areas sustain different associations and have a characteristic medusan fauna of their own. Immigrants were also described.

In the present report all the species encountered are listed and their distribution is discussed individually in detail. The study has revealed the major patterns of distribution as determined by environmental factors, mainly salinity, temperature, dissolved oxygen content, transport by water masses and major currents and food availability.

MATERIAL AND METHODS

Details on the material studied are given in Navas (1971) and Vannucci & Navas (1971). The collection studied was given on loan by the Smithsonian Institution (Washington, D. C.-U. S. A.) and comprises about 45,000 specimens that were sorted from more than 900 samples taken by R. V. "Anton Bruun" during the IIOE; the plankton samples were taken at 480 stations, more than one haul was made at each station, at different depth levels with closing nets or from different depths to the surface. Each haul received a different sample number. Hydromedusae were present at 321 stations or about 67% of the total. Different types of nets and different mesh sizes were used at sea, details are given in the papers mentioned.

The following procedure was used in the study of each species: The list of stations was prepared—the autoecology was assessed first, then the vertical and horizontal distribution and the distribution in relation to water masses and circulation. Finally an attempt to analyse causes of numerical abundance was made. Figs. 2-16 are examples of the graphs made to implement this study.

Hydrographical data are given in the Station Lists of the Cruise Reports published by Woods Hole Oceanographic Institute (Anonymous, 1963-1965).

The abbreviations used throughout the paper are taken from Gallagher (1966):

ABW—Antarctic Bottom Water
AIW—Antarctic Intermediate Water
ASDW—Arabian Sea Deep Water
ASIW—Arabian Sea Intermediate Water
ASSW—Arabian Sea Surface Water
ASSSW—Arabian Sea Subsurface Water
BBSW—Bay of Bengal Surface Water
BBSSW—Bay of Bengal Subsurface Water
BBDW—Bay of Bengal Deep Water
EIW—Equatorial Intermediate Water
IOCW—Indian Ocean Central Water
IOEW—Indian Ocean Equatorial Water
SCSW—Indian Ocean South Central Surface Water
IOSTempSW—Indian Ocean South Temperate Surface Water
IOSTropSW—Indian Ocean South Tropical Surface Water
NIODW—North Indian Ocean Deep Water

LIST OF SPECIES

Species are arranged by family in taxonomic order, numbers in brackets indicate number of specimens taken, abbreviations indicate water masses through which the net was hauled or those in which the species is known to occur for sure.

Order ANTHOMEDUSAE

Family Tubulariidae

Ectopleura sacculifera Kramp, 1957 (5)
ASSSW

Euphysilla pyramidata Kramp, 1955 (9)
BBSSW, ASSW (?), ASSSW, IOCW, IOSTropSW, IOEW (?).

Euphysora annulata Kramp, 1928 (6)
BBSW.

Euphysora bigelowi Maas, 1905 (25)
BBSW, ASSW (?), ASSSW.

Euphysora furcata Kramp, 1948 (20)
AIW, BBSSW, ASIW, ASSSW, ASDW(?), NIODW, (?) ABW (?)

Vannuccia forbesi (Mayer, 1894) (7) BBSW, BBSSW, ASSSW, SCSW, IOSTropSW, IOCW (?)

Family Zancleidae

Zanclea costata Gegenbaur, 1856 (8) ASSW, BBSSW, IOEW, IOSTropSW.

Zanclea dubia Kramp, 1959 (5) BBSW or BBSSW, ASSW or ASSSW, IOSTropSW or IOCW.

Zanclea orientalis Browne, 1916 (25)
BBSW, BBSSW, IOSTropSW, ASSSW, IOCW.

Zancleopsis tentaculata Kramp, 1928 (5)
BBSW, IOCW or IOEW.

Zancleopsis gotoi (Uchida 1927) (10)
BBSW, BBSSW ?, SCSW.

Family Cytaeidae

Cytaeis tetrastvla Eschscholtz, 1829 (1823)
ASSW, ASSSW, BBSW, BBSSW, IOEW, IOCW, IOSTropSW, SCSW, ASIW, AIW(?).

Family Clavidae

Oceania armata Kölliker, 1853 (4)
ASSW.

Turritopsis nutricula Mc Crady, 1856 (2)
BBSSW, IOCW.

Family Hydractiniidae

Podocoryne apicata Kramp, 1959 (4)
IOCW, ASSSW, ASSW (?).

? *Podocoryne carnea* M. Sars, 1846 (1)
BBSW, BBSSW (?).

? *Podocoryne meteoris* Thiel, 1938 (2)
ASSW.

Podocoryne minima (Trinci, 1903) (1)
IOSTropSW.

Family Bougainvilliidae

Bougainvillia fulva Agassiz & Mayer, 1899 (36)
BBSW, SCSW.

Bougainvillia maniculata Haeckel, 1879 (1)
IOCW.

Bougainvillia niobe Mayer, 1894 (2)
AIW, IOCW, IOSTropSW (?).

Bougainvillia platygaster (Haeckel, 1879) (404)
BBSW, ASSSW, SCSW, IOCW.

Bougainvillia remosa (van Beneden, 1844) (17)
BBSW.

Koellikerina constricta (Menon, 1932) (4)
BBSW, BBSSW (?).

Koellikerina elegans (Mayer, 1900) (1)
BBSW.

Koellikerina fasciculata (Péron & Lesueur, 1809)(1)
ASSW or ASSSW.

Koellikerina multicirrata (Kramp, 1928) (3)
BBSW or BBSSW.

Koellikerina octonemalis (Maas, 1905) (21)
BBSW, BBSSW.

Family Pandaeidae

Amphinema dinema (Péron & Lesueur, 1809) (3)
BBSW, BBSSW.

Amphinema rugosum (Mayer, 1900) (25)
BBSW, BBSSW.

? *Cirrhitiara superba* (Mayer, 1900) (1)
BBSW.

? *Halitiara formosa* Fewkes, 1882 (1)
BBSW or BBSSW.

Leuckartiara gardineri Browne, 1916 (1)
BBSW or BBSSW.

? *Leuckartiara zacae* Bigelow, 1940 (2)
BBSW or BBSSW, ASSSW.

Leuckartiara octona (Fleming, 1823) (69)
BBSW, BBSSW, ASSW, ASSSW, IOCW, or IOEW.

Merga reesi Russell, 1956 (1)
BBSSW.

Merga tergestina (Neppi & Stiasny, 1912) (155)
BBSW, IOCW, SCSW.

Merga violacea (Agassiz & Mayer, 1899) (9)
BBSW, BBSSW, ASSSW, SCSW.

Neoturris pileata (Forskål, 1775) (1)
ASSSW.

Octotiara russellii Kramp, 1953 (1)
BBSW.

Pandea conica (Quoy & Gaimard, 1827) (5)
IOEW, SCSW, IOSTropSW.

Pandeopsis scutigera Kramp, 1959 (24)
BBSW.

Protiara haeckeli Hargitt, 1902 (1)
BBSW.

Protiara tropica Bigelow, 1912 (14)
BBSW, ASSW, ASSSW, SCSW.

Stomotoca atra L. Agassiz, 1862 (2)
BBSW or BBSSW.

Stomotoca pterophylla Haeckel, 1879 (2)
BBSW or BBSSW.

Family Calycopsidae

Calycopsis papillata Bigelow, 1918 (1)
ASSW or ASSSW.

Calycopsis simulans (Bigelow, 1909) (1)
IOEW or IOCW.

Heterotiara anonyma Maas, 1905 (7)
ASSW, BBSW (?), BBSSW.

Heterotiara minor Vanhöffen, 1911 (27)
ASSW or ASSSW, BBSW, or BBSSW, IOEW or IOCW.

Sibogita geometrica Maas, 1905 (2)
IOCW, AIW (?)

Order LEPTOMEDUSAE

Family Laodiceidae

Laodicea fijiana Agassiz & Mayer, 1899 (96)
IOEW, BBSW or BBSSW, ASSW or ASSSW.

Laodicea indica Browne, 1905 (51)
BBSW.

Melicertissa mayeri Kramp, 1959 (1)
ASSW or ASSSW.

? *Melicertissa orientalis* Kramp, 1961 (2)
BBSW.

Ptychogena hyperborea Kramp, 1942 (1)
IOCW or EIW.

Staurodiscus tetrastaurus Haeckel, 1879 (2)
BBSW, SCSW.

Toxorchis polynema Kramp, 1959 (3)
BBSW or BBSSW.

Toxorchis sp. nov. (2)
BBSW, BBSSW.

Toxorchis thalassinus (Péron & Lesueur, 1809) (2)
BBSW.

Family Mitrocomidae

Halistaura bruuni Navas, 1959 (13)
BBSW, BBSSW.

Family Campanulariidae

Obelia spp. (17)
BBSW, BBSSW, ASSW, ASSSW.

Phialidium hemisphaericum (L.) (18)
BBSW, BBSSW, IOEW or IOCW.

Phialidium mccradyi (Brooks, 1888) (1)
BBSW or BBSSW.

Phialidium simplex Browne, 1902 (1)
BBSW.

Family Lovenellidae

Cirrholovenia tetranema Kramp, 1959 (2)
BBSW.

Eucheilota duodecimalis A. Agassiz, 1862 (1)
BBSW or BBSSW.

Eucheilota menoni Kramp 1959 (16)
BBSW or BBSSW, ASSW or ASSSW, SCSW, IOSTropSW (?)

Eucheilota tropica Kramp, 1959 (3)
BBSW.

Lovenella assimilis (Browne, 1905) (1)
BBSW.

Lovenella cirrata (Haeckel, 1879) (5)
BBSW.

Family Phialellidae

Phialella falklandica Browne, 1902 (1)
IOEW or IOCW.

Phialella quadrata (Forbes, 1848) (1)
BBSW.

Family Phialuciidae

Octophialucium bigelowi Kramp, 1955 (1)
BBSW.

Octophialucium indicum Kramp, 1958 (69)
BBSW.

Octophialucium medium Kramp, 1955 (2)
BBSW, ASSSW.

Phialucium carolinae (Mayer, 1900) (38)
BBSW or BBSSW.

Phialucium condensum Kramp, 1953 (1)
BBSW.

Phialucium multitentaculatum Menon, 1932 (9)
BBSW.

Family Eirenidae

Eirene brevigona Kramp, 1959 (2)
ASSW or ASSSW.

Eirene elliceana (Agassiz & Mayer, 1902) (5)
BBSW, BBSSW.

Eirene hexanemalis (Goette, 1886) (12)
BBSW, BBSSW.

Eirene viridula (Péron & Lesueur, 1809) (76)
BBSW, ASSW, or ASSSW, STempSW, SCSW.

Helgicirrha malayensis (Stiasny, 1928) (2)
BBSW or BBSSW.

Helgicirrha medusifera (Bigelow, 1909) (2)
BBSW or BBSSW.

Family Eutimidae

Eutima curva Browne, 1905 (1)
ASSW or ASSSW.

Eutima gentiana (Haeckel, 1879) (9)
IOSTropSW.

Eutima mira Mc Crady, 1857 (5)
IOEW.

Eutima orientalis (Browne, 1905) (2)
BBSW, BBSSW ?.

Family Aequoreidae

Aequorea aequorea (Forskål, 1775) (24)
BBSW, IOEW or IOCW, ASSW.

Aequorea coerulescens (Brandt, 1838) (34)
BBSW.

Aequorea conica Browne, 1905 (50)
BBSW, IOSTempSW, AIW (?).

Aequorea globosa Eschscholtz 1829 (2)
BBSW, BBSSW (?).

Aequorea macrodactyla Brandt, 1835 (13)
BBSW or BBSSW, ASSSW, IOCW, IOSTropSW, SCSW or AIW.

Aequorea parva Browne, 1905 (2)
STempSW or AIW.

Aequorea pensilis (Eschscholtz, 1829) (87)
BBSW or BBSSW, IOCW, ASSW or ASSSW.

Order LIMNOMEDUSAE

Family Olindiadidae

Olindias singularis Browne, 1905 (7)
BBSW.

Family Proboscidactylidae

Proboscidactyla ornata (McCrady, 1857) (35)
BBSW or BBSSW, IOSTropSW, ASSW or ASSSW, IOEW or IOCW, SCSW.

Order TRACHYMEDUSAE

Family Geryoniidae

Geryonia proboscidalis (Forskål, 1775) (13)
IOCW, IOSTropSW, BBSW or BBSSW, ASSW or ASSSW.

Liriope tetraphylla (Chamisso & Eysenhardt, 1821) (7217)

Family Halicreatidae

Botrynema brucei Browne, 1908 (37)
AIW or ASSSW, BBSSW.

Halicreas minimum Fewkes, 1882 (191)
IOCW, AIW, ASIW, ASSSW, IOSTropSW.

Haliscera racovitzae (Maas, 1906) (2)
BBSSW.

Halitrephes maasi Bigelow, 1909 (22)
IOCW, BBSSW, AIW.

Family Rhopalonematidae

Aglantha elata (Haeckel, 1879) (5)
AIW, IOCW.

Aglaura hemistoma (Pêron & Lesuer, 1809) (13047)

Amphogona apicata (Kramp, 1957) (181)
IOCW, ASSSW, BBSSW.

Amphogona apsteini Vanhöffen, 1902 (1)
ASSW.

Colobonema sericeum (Vanhöffen, 1902) (638)
IOCW, BBSSW, ASSSW.

Crossota alba Bigelow, 1913 (3)
AIW, IOCW, BBSSW.

Crossota brunnea Vanhöffen, 1902 (45)
AIW, IOCW, NIODW.

Pantachogon haeckeli Maas, 1893 (230)
ASSW, ASSSW, ASIW, EIW, IOCW, AIW, NIODW.

Pantachogon scotti Browne, 1910 (2)
ASSW, ASSSW, ASIW.

Persa incolorata McCrady, 1857 (119)
BBSW, BBSSW, ASSW, ASSSW, IOCW, AIW.

Rhopalonema velatum Gegenbaur, 1856 (5301)
BBSW, BBSSW, ASSW, ASSSW. IOCW, IOEW, IOSTropSW, SCSW, AIW.

Sminthea eurygaster Gegenbaur, 1856 (143)
IOCW, BBSW, BBSSW, ASSSW, IOCW, EIW, SCSW, IOSTropSW.

Tetrorchis erythrogaster Bigelow, 1909 (8)
ASSSW.

Order NARCOMEDUSAE

Family Aeginidae

Aegina citrea Eschscholtz, 1829 (42)
BBSSW, IOCW, ASIW, SCSW, EIW, AIW, IOSTropSW.

Aeginura grimaldii Maas, 1904 (46)
BBSSW, AIW, IOCW, ASIW, EIW.

Solmundella bitentaculata (Quoy & Gaimard, 1833) (3113)
ASSW, ASSSW, BBSW, BBSSW, IOCW, IOSTropSW, SCSW.

Family Solmariidae

Pegantha clara R. P. Bigelow, 1909 (21)
ASSW, ASSSW, BBSW, SCSW.

Pegantha laevis H. B. Bigelow, 1909 (28)
BBSW, IOEW, SCSW.

Pegantha martagon Haeckel, 1879 (932)
ASSW, ASSSW, BBSW, IOCW, IOEW.

Pegantha triloba Haeckl, 1879 (57)
ASSW, ASSSW, BBSW, BBSSW, IOCW, IOEW, IOSTropSW, AIW.

Solmaris rhodoloma (Brandt, 1838) (1)
BBSW or BBSSW.

Family Cuninidae

Cunina duplicata Maas, 1893 (5)
ASSSW, BBDW, AIW

Cunina frugifera Kramp, 1948 (60)
BBSW, BBSSW, ASSW, ASSSW, IOSTrop-SW, IOCW.

Cunina octonaria Mc Crady, 1857 (496)
BBSW, ASSW, ASSSW, IOEW, IOCW, IOSTropSW, SCSW, EIW.

Cunina peregrina Bigelow, 1909 (132)
BBSW, BBSSW, ASSW, ASSSW, SCSW, IOSTropSW, IOCW.

Cunina tenella (Bigelow, 1909) (427)
ASSW, ASSSW, BBSW, BBSSW IOEW, SCSW, IOSTropSW.

Solmissus marshalli Agassiz & Mayer, 1902 (40)
BBSW, BBSSW, ASIW, SCSW, ASSW, ASSSW, IOCW, AIW, IOSTropSW.

RESULT BY SPECIES

1. *Ectopleura sacculifera* Kramp, 1967. Five specimens; a new record for the Indian Ocean (Navas, 1971); taken in ASSSW; found in the discontinuity layer off the Arabian coast and in the Gulf of Aden; stenohaline. It was found in 35.5-35.9 °/oo salinity, 15.1 to 17.2° C (or higher) temperature and 0.2 to 0.6 ml/1 (or slightly higher) dissolved oxygen content.

Earlier record is from the Pacific Ocean, coast of Ecuador (Kramp, 1957) under a slightly lower salinity interval. It may be a species restricted to upwelling areas. The different environmental requirements may indicate divergent adaptation, as has been shown to occur in rare species with populations widely separated (Vannucci, 1966).

2. *Euphysilla pyramidata* Kramp, 1955. Nine specimens; a stenohaline species, found in salinity ranging from 34.8 to 36.0 °/oo, usually living at about 35 °/oo. It is eurythermal, living between 13 °C (or lower) to 23 ° C (or higher); it is also widely tolerant of oxygen content, having been taken in waters with 4.4 ml/ 1 or more and as low as 0.5-0.6 ml/1 dissolved oxygen content. It was found living in BBSSW, ASSSW, IOCW, IOSTropSW and it may perhaps be living also in ASSW and IOEW. It very clearly keeps away from BBSW that has low salinity. It was found also in upwelling water off Saudi Arabia; its distribution is mainly governed by salinity and it may be a boundary layer species.

Earlier records are from the Gulf of Guinea (Kramp, 1955), west of Madagascar (Kramp, 1965) and in the Arabian Sea off the southern coast of India (Vannucci & Santhakumari, 1971) in ASSW or ASSSW, or at the boundary between the two.

3. *Euphysora annulata* Kramp, 1928. Six specimens were taken in a single shallow haul (60-0 m deep) near to the western coast of Thailand in BBSW 33.1 to 33.8 °/oo salinity, 26.2 to 28.4 °C temperature and 2.3 to 4.4 ml/1 dissolved oxygen content. A shallow water coastal species.

Earlier records include N. E. Australia, one specimen under 24.1 ° C temperature (Kramp, 1953); Sunda Strait (Kramp, 1928) and Madras in the Bay of Bengal (Menon, 1932).

4. *Euphysora bigelowi* Maas, 1905. Twenty five specimens taken over shallow depths except when carried by swift currents, as appears to be the case off the Somali coast. A euryhaline, high temperature species. It was found to be most abundant at 33.1 to 33.2 °/oo salinity, but it endures a range from 31.9 to 35.8 °/oo or 36.0 °/oo salinity; the optimum temperature is at about 28.0 ° C, but it was found in a range from at least 24.0 to 28.0 ° C; the oxygen requirements seem to be high, not lower than about 3.5 ml/1 dissolved oxygen. It was taken in the Bay of Bengal in BBSW and off the Somali coast in upwelled ASSSW mixed with ASSW.

Earlier records show it to be widely distributed in the equatorial and tropical area of the Pacific and Indo-Malayan region, also in coastal areas of Japan and China (Kramp, 1961 a).

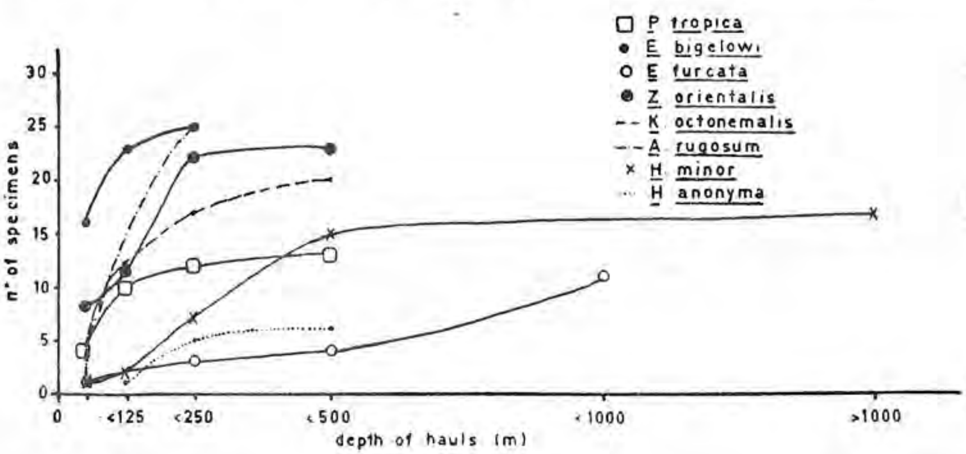

Fig. 2—Cumulative frequency distribution with depth. Shows different patterns of distribution and aggregation at specific depths for most species, thus *Protiara tropica* at less than 125 m, *Zanclea orientalis* at less than 250 m, *Heterotiara minor* at less than 500 m and *Euphysora furcata* with numbers increasing with depth.

5. *Euphysora furcata* Kramp, 1948. Twenty specimens were taken; it was present in several deep hauls, stratified samples that show it to be a deep cold water species. It was repeatedly taken in AIW that is formed by sinking at the Antarctic Convergence and flows north. From this water mass it spreads to BBSSW and to ASIW and ASSSW. It is not sure whether it can live also in deeper layers such as ASDW, NIODW and ABW. When found near to or at the surface, it is a sure sign of upwelled waters. Its optima are around 34.8 °/oo salinity, 5-9 °C temperature and 3 ml/1 dissolved oxygen. Its limits of tolerance are 34.7 to 35.3 °/oo salinity; 4 °C or lower to 12 °C temperature or perhaps higher and 18. or lower to 4.2 ml/1 dissolved oxygen content. It thus appears to be stenohaline, rather eurythermal and tolerant of low oxygen content. One single specimen was found at the surface in 36.0 °/oo salinity, 24.9°C temperature and 4.6ml/1 dissolved oxygen content; this was in upwelled waters at the mouth of the Gulf of Aden and the specimen was dead when taken, probably due to mixing with high salinity and high temperature waters.

Earlier records show it to be widely distributed, mainly in upwelling areas, as the west coast of Africa (Kramp, 1955a, 1957a, 1959a), and Navas (in preparation)has found it in subantarctic waters.

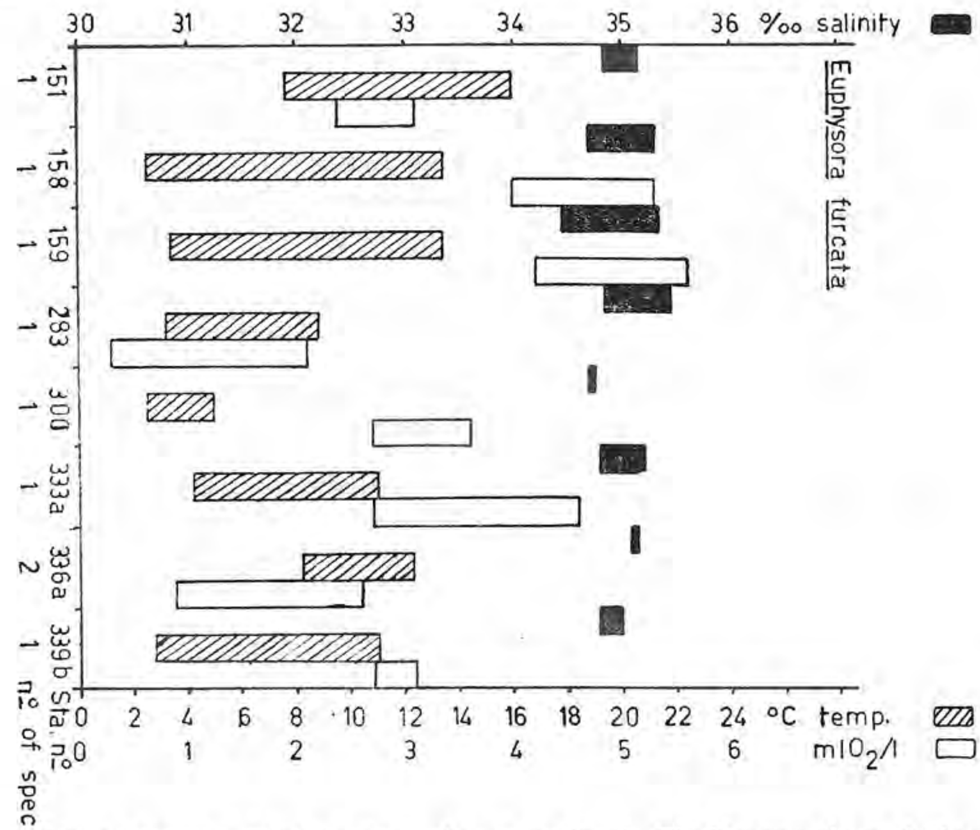

Fig. 3—Selected stations at which *Euphysora furcata* was found. The histogram shows the intervals of salinity, temperature and dissolved oxygen content at which the species was found to occur. The columns indicate the values for each of the three parameters at the depths sampled with closing nets. It shows it to be eurythermal and widely tolerant of dissolved oxygen content, while it is stenohaline. Fig. 2 shows it to be an eurybathic species and Map 1 to be widely distributed geographically.

6. *Vannuccia forbesi* (Mayer, 1894). Seven specimens were taken; it is euryhaline, eurythermal and has a wide range of tolerance for dissolved oxygen content. Its salinity range goes from 33.0 to 35.9 °/oo, its temperature tolerance goes from 16.0 °C or lower to 27.4 °C and its oxygen tolerance goes from 0.8 to 5.1 ml/1. Accordingly it is found in many different water masses, BBSW, BBSSW, ASSSW, SCSW, IOSTropSW; perhaps also in IOCW. It seems to require waters rich in zooplankton standing stock.

Earlier records show it to be a coastal water species (Kramp, 1961a), that agrees with its eurytopic peculiarities.

7. *Zanclea costata* Gegenbaur, 1856. Eight specimens, one of them doubtful. The salinity tolerance was 34.8 to 36.0 °/oo, and it prefers warm waters of about 24.5 to 25.2 °C and perhaps higher. It has high oxygen requirements and about 4 ml/1 seems to be the lowest end of its range. It was found in ASSW and BBSSW, in IOEW and IOSTropSW. It seems to avoid salinity higher than 36 0 °/oo and lower than 34.0 °/oo as well as temperature lower than 20.0 or 22.0°C. Its main limiting factor however seems to be the amount of dissolved oxygen content in the water. A boundary layer species.

Earlier records show it to be a coastal water species, widely distributed in warm and temperate waters (Vannucci, 1957; Kramp, 1968a).

8. *Zanclea dubia* Kramp, 1959. Five specimens were taken in BBSW or BBSSW, ASSW or ASSSW and IOSTropSW or IOCW. One of the specimens comes from the coast of Saudi Arabia in upwelled ASSSW waters. The presence of this species appears to be linked to the discontinuity layer between Subsurface and Surface waters or to plankton rich waters in upwelling areas. It probably requires abundant food supply. It was found to live in 34.5 to 35.6 °/oo salinity and perhaps as low as 32.9 °/oo and as high as 36.0 °/oo. Its temperature range is from 15.0 to 20.0 °C and it can tolerate waters with as low as 0.4 to 0.5 ml/1 dissolved oxygen content. It was first recorded in the Indian Ocean by Navas (1971), who also

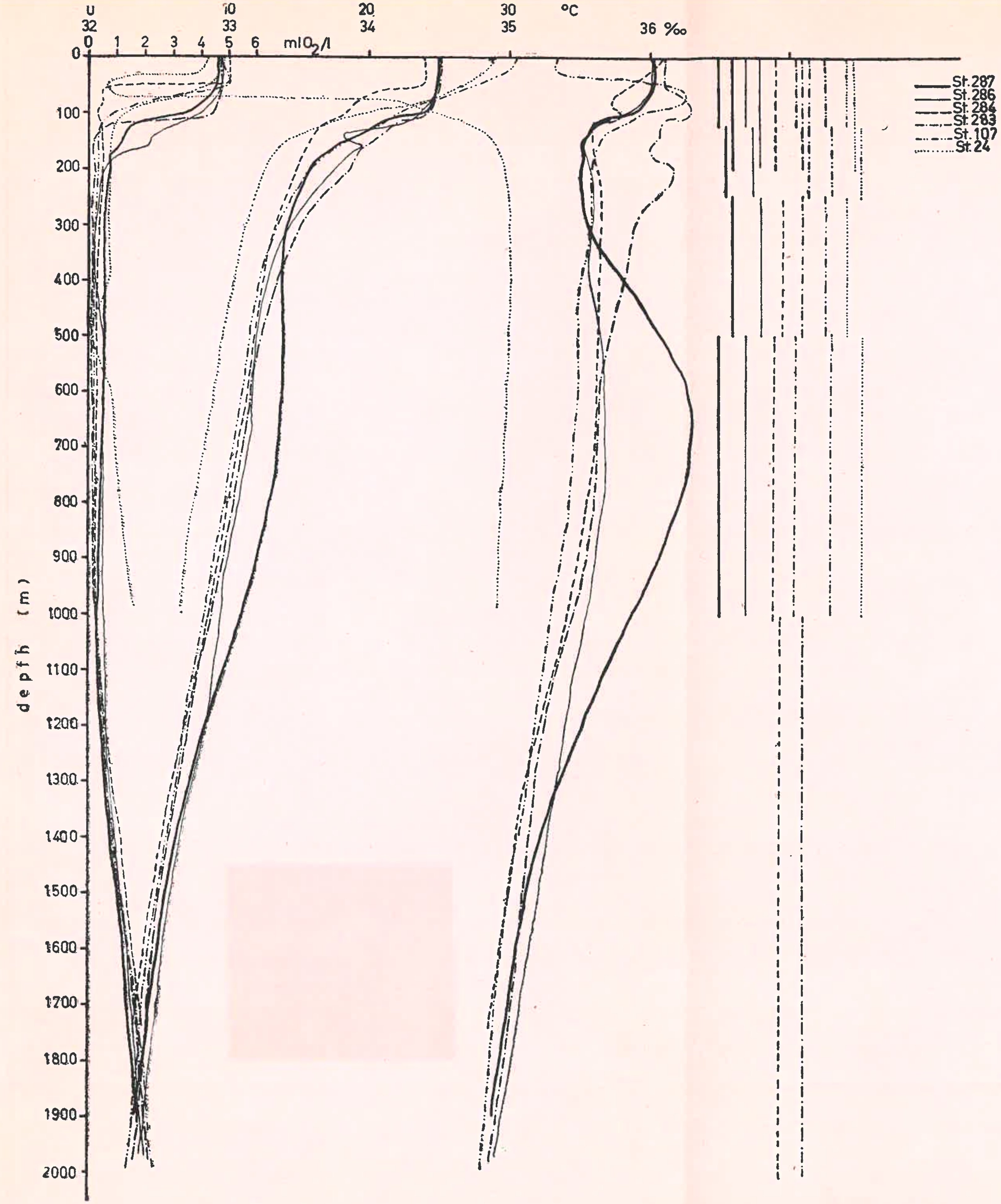

FIG. 1

Fig. 1 — Oxygen, temperature and salinity profiles of stations that were positive for each species studied. On the right hand side, station number indicating depth of haul and presence or absence of the species. Thus, St. 24 had the following catch:

125-Om: *Zancleopsis tentaculata* (1), *Cytaeis tetrastyla* (3), *Aglaura hemistoma* (18), *Cunina frugifera* (1), *Cunina octonaria* (1), *C. peregrina* (1), *Solmundella bitentaculata* (3).

200-Om: *A hemistoma* (4), *Liriope tetraphylla* (1), *Rhopalonema velatum* (3), *C. peregrina* (1).

250-125 m: *Euphysilla pyramidata* (1), *Vannuccia forbesi* (1), *Koellikerina octonemalis* (1), *A. hemistoma* (1), *L. tetraphylla* (12), *R. velatum* (7), *Sminthea eurygaster* (2). *C. octonaria* (2), *C. peregrina* (1), *C. tenella* (1), *Pegantha triloba* (1), *S. bitentaculata* (2).

500-250 m: *Heterotiara anonyma* (1), *Obelia spp.* (1), *L. tetraphylla* (1), *Persa incolorata* (1), *R. velatum* (1), *C. peregrina* (2), *S. bitentaculata* (4).

St. 107:

125-0 m : *Liriope tetraphylla* (1).

250-125 m: *L. tetraphylla* (28), *R. velatum* (3), *C. tenella* (1), *S. bitentaculata* (8).

unknown depth: *L. tetraphylla* (4), *R. velatum* (3).

St. 283:

surface : *L. tetraphylla* (139), *R. velatum* (10), *C. tenella* (2), *S. bitentaculata* (45).

125-0 m : *A. hemistoma* (45), *L. tetraphylla* (19), *R. velatum* (19), *C. octonaria* (10), *C. tenella* (2), *S. bitentaculata* (1).

200-0 m : *A. hemistoma* (10), *L. tetraphylla* (1), *R. velatum* (4), *C. tenella* (2), *S. bitentaculata* (3).

250-125 m : *A. hemistoma* (10), *L. tetraphylla* (9), *R. velatum* (5), *C. octonaria* (1), *C. tenella* (1), *S. bitentaculata* (5).

500-250 m : *A. hemistoma* (1), *S. bitentaculata* (12).

1000-500 m : *Pantachogon haeckeli* (6).

2000-1000 m : *Euphysora furcata* (1), *Halicreas minimum* (1).

St. 284 :

200-0 m : *A. hemistoma* (24), *L. tetraphylla* (1), *R. velatum* (2).

500–250 m : *Cytaeis tetrastyla* (4), *A. hemistoma* (71), *Amphogona apicata* (4), *L. tetraphylla* (31), *R. velatum* (13), *Cunina octonaria* (1), *C, tenella* (10), *S. bitentaculata* (14).

2000–1000 m : *Pantachogon haeckeli* (5).

St. 286 :

125-0 m : *C. tetrastyla* (1), *A. hemistoma* (23), *A. apicata* (1), *L. tetraphylla* (15), *R. velatum* (8), *C. tenella* (1), *S. bitentaculata* (1).

200-0 m : *C. tetrastyla* (2), *A. hemistoma* (26), *L. tetraphylla* (21), *R. velatum* (10), *C. tenella* (6), *S. bitentaculata* (1).

250-125 m : *C. tetrastyla* (3), *A. hemistoma* (41), *A. apicata* (4), *L. tetraphylla* (25), *R. velatum* (9), *C. octonaria* (2) *C. tenella* (16), *S. bitentaculata* (1).

500-250 m : *A. hemistoma* (2), *A. apicata* (1), *L. tetraphylla* (1), *R. velatum* (1), *S. bitentaculata* (4).

1000-500 m : *Aegina citrea* (1),

St. 287 :

125-0 m : *C. tetrastyla* (1), *A. hemistoma* (10), *L. tetraphylla* (6), *Persa incolorata* (1), *R. velatum* (5), *C. octonaria* (1).

200-0 m : *Euphysilla pyramidata* (1), *A hemistoma* (14), *A. apicata* (4), *L. tetraphylla* (15), *R. velatum* (21), *C. peregrina* (3), *C. tenella* (14), *S. bitentaculata* (2).

250-125 m : *Bougainvillia* sp. (1), *C. tetrastyla* (4), *Ectopleura sacculifera* (1), *Zanclea orientalis* (1), *A. hemistoma* (96), *A. apicata* (1), *L. tetraphylla* (35), *R. velatum* (72), *Sminthea eurygaster* (1), *C. octonaria* (14), *C. peregrina* (7), *C. tenella* (31), *Pegantha martagon* (1), *P. triloba* (3).

500-250 m : *S. bitentaculata* (11).

1000-500 m : no medusae were taken at this haul.

compares its present distribution with the only earlier record, from the Java Sea (Kramp, 1959c).

9. *Zanclea orientalis* Browne, 1916. Twenty-five specimens. They were taken from BBSW, IOSTropSW and ASSSW or the boundary with underlying BBSSW and IOCW or at the boundary with overlying ASSW. It avoids high salinity or relatively cold waters. Its salinity interval is 32.2 to 35.6 °/oo and its temperature range is 19.0 to 29.4 °C or perhaps as low as 15 °C but is usually found in temperature higher than 20 °C; likewise it may tolerete 0.6 ml/1 dissolved oxygen content but prefers high values such as 4.0 ml/1 or higher. A warm water species that tolerates the higher salinity and colder temperature of the boundary layer between hot low salinity tropical water and the adjacent water masses.

Earlier record is also from the Indian Ocean (Browne, 1916a).

10. *Zancleopsis tentaculata* Kramp, 1928. Five specimens, one of them doubtful. Two specimens taken in BBSW show that this species lives in low salinity: 33.8 to 34.7 °/oo and high temperature; 23.4 to 30.0 °C. Two specimens, found in IOEW or IOCW or at the boundary between the two show that it may tolerate lower temperature and higher salinity than indicated. In either case the dissolved oxygen content was higher than 1.7 ml/1. It was first recorded in the Indian Ocean by Navas (1971), who mentions earlier records of the species, in the West Pacific (Kramp, 1965).

11. *Zancleopsis gotoi* (Uchida, 1927). Ten specimens were taken, all except one in the Bay of Bengal. The isolated specimen was taken at 24° 42′ S–35° 23′E on the African side of the Mozambique Channel. The specimens from the Bay of Bengal come from the BBSW or down near the boundary with the BBSSW; salinity not higher than 35.0 °/oo and as low as 33.0 °/oo; temperature as high as 29.2 °C down to 20.0 °C and oxygen content higher than 4.0 ml/1. The southern, isolated specimen was found in 35.3 °/oo salinity, 15.6–22.5 °C temperature and 4–5 ml/1 dissolved oxygen content. The Bay of Bengal population seems to be adapted to lower salinity.

Earlier records are from the western Pacific, Mozambique Channel and near Nicobar Islands (Kramp, 1968a).

12. *Cytaeis tetrastyla* Eschscholtz, 1829. A widely distributed and abundant species. It was present in 45% of the stations. Its ambundance decreases quickly with depth but a few specimens were taken as deep as 1000–500 m deep hauls, seven between 500–250 m and 27 between 250–125 m. Out of 1823 specimens taken in all, 66% were found living in the upper 50 m and 83% in the upper 125 m. It was recorded in 31.9 to 36.0 °/oo salinity, with a single animal recorded in 25.4 °/oo, in the north of the Bay of Bengal (contaminated sample?); the temperature interval was found to be from 8.6 to 29.2°C and the range of dissolved oxygen content tolerated was from 2 to 5.4 ml/1. The greatest densities however were always found at the surface in oxygen rich water of about 5.3 to :.5 ml/1 or more, about 35.4 to 35.6 °/oo salinity and 17 21 °C temperature in both coastal and oceanic waters.

This is a species that has a metagenetic cycle with a bottom living hydroid but has also a remarkable potential for vegetative reproduction in the medusa stage that explains the formation of dense swarms in the high seas; one such was found at 29°38′S–49°23′E with 470 specimens in a single sample, at 35.6 °/oo salinity, 18.8°C temperature and 5.3ml/1 dissolved oxygen content. The eurytopic properties of this species explain its wide horizontal and vertical distribution. Different congeneric species had been described under the name *Cytaeis*, at present reduced to two species, although there is pronounced intraspecific morphological variation. This agrees with the earlier finding of Vannucci (1966) who showed that eurytopic widely distributed species tend to break up in a number of ecological races and to form patches of morphologically similar individuals, as is the case of *Liriope tetraphylla* that has no vegetative reproduction but has a direct development without a hydroid in its life cycle.

Cytaeis tetrastyla does not seem to be linked to the DSL or other boundary areas and was found in the following water masses: ASSW, ASSSW, BBSW, BBSSW, IOEW, IOCW, IOSTropSW, SCSW, ASIW and perhaps also AIW. It is found as far south as the subtropical convergence.

Earlier records agree with these findings (Kramp, 1959a, 1961a, 1968a).

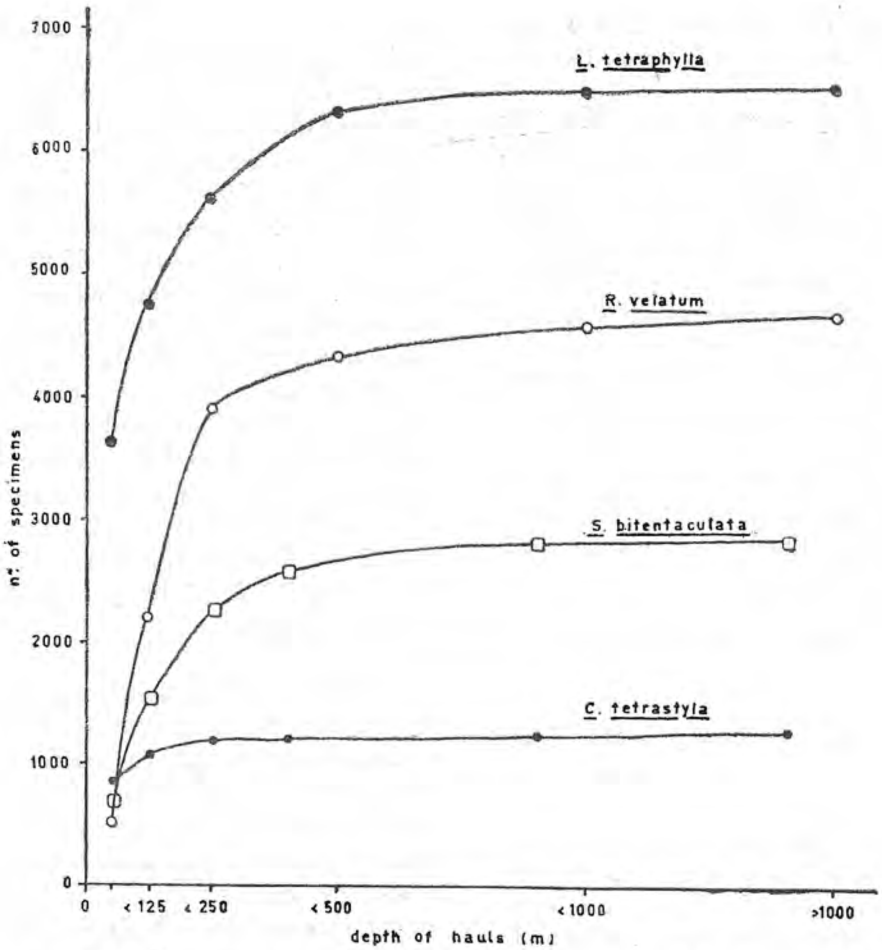

Fig. 4—Cumulative frequency distribution with depth. *Cytaeis tetrastyla* is a surface layer species, while the three others show aggregation at different depths

13. *Oceania armata* Kölliker, 1853. Four specimens found in ASSW, 36.0 to 36.4 o/oo salinity, 25.3 (or lower) to 28.0 °C temparature and 4.6 (or lower) ml/1 dissolved oxygen content. Found only in the Arabian Sea.

Earlier records show it to be widely distributed in tropical and subtropical waters (Kramp, 1968a).

14. *Turritopsis nutricula* McCrady, 1856. Two specimens taken between 34.4 to 35.0 o/oo salinity; 11.1 (or lower) to 19.2 °C (or higher) temperature and 4.5 ml/1 or lower dissolved oxygen content. They were probably living in BBSSW and IOCW (one haul from 1000 to 500 m depth at 23°47'S-69°05'E).

Earlier records show it to be widely distributed (Kramp, 1968a).

15. *Podocoryne apicata* Kramp, 1959. Four specimens were taken between 250-125 m and 200-0m at two stations, both of them in the high seas over 3000 m depth; salinity about 35.1 o/oo, temperature from 14.2 to 18.2°C and dissolved oxygen content from 0.4 to 2.8 ml/1. Three specimens come from IOCW and one from ASSSW or ASSW.

Specimens of the genus *Podocoryne* are usually short-lived and the hydroid, known as *Hydractinia* is a commensal living on gastropods; the present finding would indicate that the gastropod lives at great depths. One station (three specimens) was at 06°28'S-55°12'E, while the second was at 06°51'N-75°02'E. This species was first recorded in the Indian Ocean by Navas (1971), who also discusses earlier records (Gulf of Siam and Java Sea; Kramp, 1959c).

16. *Podocoryne carnea* M. Spars, 1846. A single doubtful specimen taken in the Bay of Bengal, in a haul that traversed BBSW and BBSSW. Salinity was from 33.4 to 35.0 o/oo, temperature from 13.3 to 29 °C and dissolved oxygen content 0.1 to

4.0 ml/1. A new record for the Indian Ocean, if determination shows to be correct.

Earlier records show it to be rather widely distributed in relatively cold waters also in upwelling areas, as the coast of Chile and South Africa (Kramp, 1961a, 1968a).

17. *Podocoryne meteoris* Thiel, 1938. Two doubtful specimens were taken in ASSW at 35.9 to 36.0 °/oo salinity, 24.5 to 25.2 °C temperature and 3.6 to 4.5 ml/1 dissolved oxygen content, in the Gulf of Aden. Eckart-Schmidt (in litt.) found this species in the Red Sea and the eastern Mediterranean ("Meteor" material taken during the IIOE) and ponders whether this species is an immigrant from the Mediterranean Sea, a hypothesis that appears to be very likely.

It is the first record for the Indian Ocean, a single specimen being hitherto known, described by Thiel from the Cape Verde Islands.

18. *Podocoryne minima* (Trinci, 1903). A single specimen was taken at the surface, in November, at 10 °57′S-42 °46′E in IOSTropSW that has salinity from 34.5 to 35.2 °/oo, temperature between 25 and 28°C in summer and 3.6 to 4.8 ml/1 dissolved oxygen content. It was first recorded in the Indian Oecan by Navas (1971).

Earlier records show it to be a euryhaline and eurythermal species preferring high temperature and low salinity (Vannucci, 1957, 1963; Navas, 1971).

19. *Bougainvillia fulva* Agassiz & Mayer, 1899. Thirty-six specimens were taken in BBSW and SCSW. A surface water species tolerant of salinity range going from 33.1 to 35.5 or 35.6 °/oo; it is eurythermal and was found in a range of 20.8 °C (or lower) to 26.8 °C (or higher) but appears to prefer temperature from 22 to 26 °C; it was usually taken in water with oxygen content of 4.0 ml/l or higher but may perhaps tolerate lower oxygen content. Oxygen requirements may be the limiting factor for this relatively large species usually found in swarms.

Earlier records indicate tropical parts of the Indian and Pacific Oceans (Kramp, 1968a).

20. *Bougainvillia maniculata* Haeckel, 1879. One specimen, described as a new record for the Indian Ocean by Navas (1971). Taken in IOCW at 09 ° 28′ N-54 ° 52′ E. Navas suggests that it may have migrated from the Mediterranean that is the only other known area of occurrence, to the Indian Ocean through the Suez Canal.

21. *Bougainvillia niobe* Mayer, 1894. Only two specimens were recorded in the Southern Indian Ocean, 19 ° 24′ S–65 ° 30′ E in a 2600–250 m haul that filtered AIW, IOCW and IOS TropSW. Salinity range was small, 34.7 to 35.6° / oo and oxygen content was high throughout, from 3.9 to 4.8 ml/l but temperature varied widely.

Earlier records are all from the western subtropical and temperate Atlantic Ocean.

22. *Bougainvillia platygaster* (Haeckel, 1879). About 400 specimens were taken. It is a surface layer species that aggregates at the boundary with subsurface waters. It is euryhaline, having been found in a salinity range from 33.1 to 36.0 ° / oo, eurythermal, found from 17.2 (or lower) to 28.0° C (or higher), but does not seem to tolerate dissolved oxygen content lower than 2.7 ml/l. It was taken in BBSW, ASSSW, SCSW and IOCW. It was most abundant in BBSW, thus indicating preference for high temperature and rather low salinity. This species has a remarkable capacity for vegetative reproduction of the medusoid that explains its presence in swarms and high seas as for *Cytaeis tetrastyla*, although it usually has a bottom dependent hydroid stage in its life cycle. It was recorded in most stations in the Bay of Bengal; the reason why it is not as widespread as *cytaeis tetrastyla* to which it can be compared ecologically may well be that, although eurythermal and euryhaline it does not seem to be competitive in as low temperature and as high salinity as *C. tetrastyla*. It probably also has comparatively higher oxygen requirements. Also *B. platygaster* aggregates at the boundary layer while *C. tetrastyla* prefers the surface layer.

Earlier records show it to be widely distributed in tropical seas (Kramp, 1959a, 1968a). Kramp (1957 a) also discusses asexual propagation.

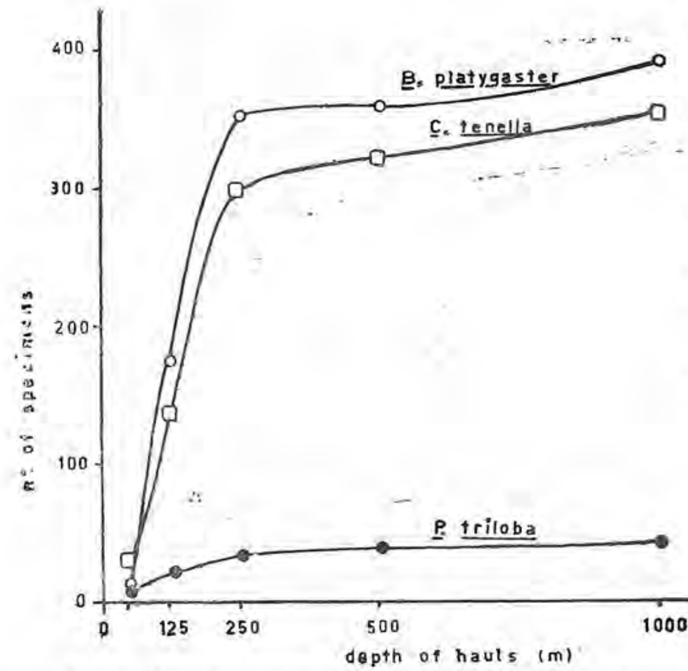

Fig. 5—Cumulative frequency distribution with depth

23. *Bougainvillia ramosa* (van Beneden, 1844). Seventeen specimens taken in BBSW with low salinity and high temperature and high oxygen content may be young stages of *B. ramosa.* They were all found in the Andaman Sea in the Bay of Bengal. None of these were mature and since juveniles of this species are extremely similar to young *B. platygaster*, the present specimens of this short-lived species are only tentatively assigned to *B. ramosa.*

Earlier known distribution shows this to be a cosmopolitan species in coastal waters (Kramp, 1968 a).

24. *Koellikerina constricta* (Menon, 1932). Four specimens were taken all in the Bay of Bengal, two in BBSW and two either in the Surface layer or at the boundary between Surface and Subsurface waters. The salinity interval was found to be 33 to 35 °/oo, the temperature interval 25.8 to 27.4° C, perhaps higher and lower as well, and dissolved oxygen content 3.8 to 4.5 ml/l.

Previously recorded only once, also from the Indian Ocean (Menon, 1932).

25. *Koellikerina elegans* (Mayer, 1900). A single specimen was taken in BBSW, in 32.7 to 33.5 °/oo salinity, 26.3 to 29.2° C and 3.6 to 4.6 ml/l dissolved oxygen content.

Earlier records are from Florida (Mayer, 1900b) and the Indian Ocean (Nair, 1951; Ganapati & Nagabhushanam, 1958).

26. *Koellikerina fasciculata* (Pèron & Lesueur, 1809). A single specimen was recorded by Navas (1971) for the first time in the Indian Ocean in the Gulf of Oman in 36.0 to 36.44 °/oo salinity in ASSW or ASSSW. Navas suggests that the species may have migrated from the Mediterranean into the Indian Ocean through the Suez Canal. It is otherwise known as an endemic Mediterranean speeies (Petersen & Vannucci, 1960).

Earlier records are discussed by Navas (loc. cit.)

27. *Koellikerina multicirrata* (Kramp, 1928) Three specimens were taken all in the Bay of Bengal, all of them were probably living at the boundary between Surface and Subsurface Water Masses. It was not found in salinity higher than 35.0 °/oo.

Earlier records are from tropical waters, in the Indo-Pacific region (Kramp, 1968a).

28. *Koellikerina octonemalis* (Maas, 1905). Twenty specimens. It was recorded for the first time in the Indian Ocean by Navas (1971). It was found only in the eastern part of the Bay of Bengal, in BBSW, BBSSW or at the boundary between the two. The salinity interval was from 33.1 (or perhaps lower) to 34.7 °/oo, never higher than 35.0 °/oo. It was taken in 16 (perhaps lower) to 26.8 °C(or higher). It probably prefers temperature higher than 20°C or more and oxygen content around 4 ml/l or more. It seems capable of tolerating values as low as 0.8 ml/l dissolved oxygen content. Eurybathic.

It was earlier known only from the Malay Archipelago (Maas, 1905; Kramp, 1968 a).

29. *Amphinema dinema* (Peron & Lesueur, 1809). Three specimens were taken in BBSW or at the boundary between BBSW and BBSSW. Salinity limits were 33 to 34.8 °/oo, temperature not higher than 29, certainly higher than 25.8 °C and perhaps tolerates lower temperature. It can certainly live in dissolved oxygen from 3.8 to 4.4 ml/l. Widely distributed in temperate and subtropical waters (Kramp, 1959 a, 1968 a.).

30. *Amphinema rugosum* (Mayer, 1900). Twenty-five specimens were taken all in the Bay of Bengal in the Surface Water Mass, or at the boundary between the Surface and Subsurface Waters. Its upper salinity limit is at about 35.0 °/oo and it can tolerate as low as 33.4 °/oo and perhaps lower. It tolerates up to 29.2° C (or higher) temperature, down to 27°C, or lower.

Earlier records show it to be widely distributed in subtropical and temperate waters (Kramp, 1959 a, 1968 a). Both species of the genus were exclusively found in the Bay of Bengal.

31. ? *Cirrhitiara superba* (Mayer, 1900). A single doubtful specimen from the Bay of Bengal, taken from 125-0 m in a haul that went mainly through BBSW. Salinitywas 34.8 down to 32.45 °/oo. It could be the first record for tne Indian Ocean.

Earlier records are from the western Atlantic and North-Eastern Australia (Kramp, 1959a, 1968a)

32. ? *Halitiara formosa* Fewkes, 1882. One doubtful specimen from the Bay of Bengal in a 125-0m haul taken through BBSW and BBSSW, in which salinity varied from 32.6 °/oo-34.7 °/oo, temperature 19.2 to 29.1 °C and dissolved oxygen content varied from 0.7 to 4.5 ml/1.

Earlier records show it to be a tropical water species (Kramp, 1959 a, 1968 a).

33. *Leuckartiara gardineri* Browne, 1916. A single specimen from the Bay of Bengal in a 125-0m deep haul that filtered BBSW and BBSSW. Salinity from 32.7 to 34.9 °/oo, temperature 13.3 to 29.3 °C dissolved oxygen content 0.6 to 4.3 ml/l.

Earlier records are also from the Indian Ocean (Browne, 1916; Kramp, 1968 a) and western Pacific Ocean (Kramp, 1953).

34. *Leuckartiara zacea* Bigelow, 1940. Two doubtful specimens, one from the Bay of Bengal in a 125-0 m deep haul that filtered BBSW and BBSSW, and the other from Arabian Sea, in ASSSW. Salinity not higher than 35.1 °/oo.

Earlier records are from scattered localities of the Indo-Pacific region (Bigelow, 1940; Kramp, 1968a).

35. *Leuckartiara octona* (Fleming, 1823). Sixty-nine specimens were recorded, all except three in the Bay of Bengal. Twenty percent of the specimens come from BBSW and only 2.8% from ASSSW. The remaining 77% comes from the boundary layer btween BBSW and BBSSW, one comes from the boundary between ASSW and ASSSW or from one of the two layers. Most specimens come from salinity lower than 35 °/oo down to 32.8 °/oo and perhaps lower. One specimen comes from IOCW or IOEW. The three specimens taken in the Arabian Sea come from 35.2 to 35.8 °/oo salinity. The temperature interval is from 26.8 to 28.7 °C (or higher) and down to 12.5 to 13.1 °C. It seems to tolerate very low dissolved oxygen content, since a specimen taken in ASSSW was living in 0.2 ml/l oxygen: most specimens however were taken in dissolved oxygen content higher than 2.8 ml/l. Apparently the population living in the Arabian Sea has become adapted to higher salinity, lower temperature and lower oxygen content. It was shown by Vannucci (1966) that for hydromedusae, widely distributed species tend to break up into populations and perhaps sub-species, as in *Liriope tetraphylla* and *Cytaeis tetrastyla* adapted to different environmental conditions; thus the species at large may be described as eurytopic while each population or single individual may have restricted limits of tolerance.

Earlier records show *Leuckartiara octona* to be widely distributed (Kramp, 1968a) who suggests that young animals live near to the surface while they sink to greater depths as they become older.

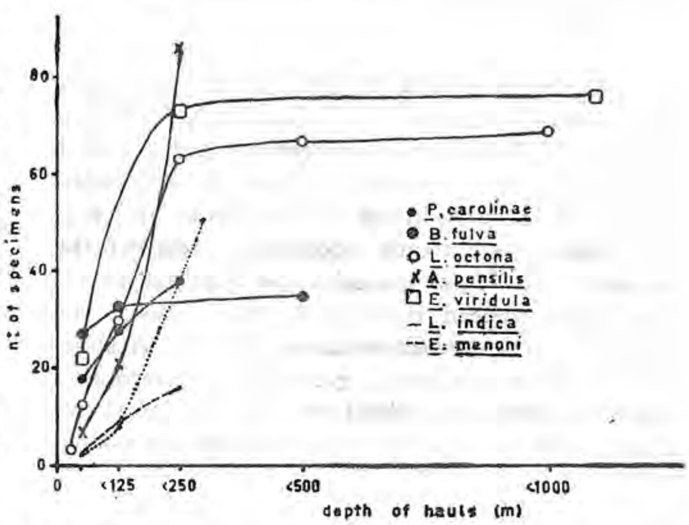

Fig.6—Cumulative frequency distribution with depth.

36. *Merga reesi* Russell, 1956. A single specimen taken in BBSSW, in 34.9 to 35 °/oo salinity, 5.8 to 9.8° C temperature and 0.5 to 0.8 ml/1 dissolved oxygen content. First recorded in the Indian Ocean by Navas (1971). A deep water species earlier found in the English Channel in the same salinity and temperature interval, at great depth.

37. *Merga tergestina* (Neppi & Stiasny, 1912). First recorded in the Indian Ocean by Navas(1971). Only two of the 155 specimens taken come from the southern Indian Ocean, all the others are from the Bay of Bengal in BBSW, salinity 32.7 (or lower) to 33 °/oo, temperature 27.4 to 28.3 ° C (or higher) and 4.5 to 4.7 ml/1 dissolved oxygen The southern specimens come from IOCW and SCSW at about 35.3 °/oo salinity, temperature as low as 18 °C or lower and oxygen as low as 2.8 to 2.9 ml/1. As pointed out by Navas (loc. cit.) this agrees with earlier records and laboratory rearing experiments (Vannucci, 1960). It is an eurytopic species preferring high temperature, low salinity and rather high dissolved oxygen content. Vannucci & Santhakumari(1971) found it also in ASSW.

38. *Merga violacea* (Agassiz & Mayer, 1899), Nine specimens were taken in BBSW, BBSSW, ASSSW, SCSW. It was found in 33.4 (or lower) to 35.8 °/oo salinity, in 17 to 29.2 °C temperature and 0.2 to 5.3 ml/1 dissolved oxygen content. It seems to be well adapted to surface and subsurface waters alike and its scarcity is rather puzzling.

Earlier records show it to have a wide, though scattered distribution, in all tropical and subtropical seas (Kramp, 1968 a).

39. *Neoturris pileata* (Forskål, 1775). A single specimen was taken in ASSSW, in 35.5 to 35.8 °/oo salinity, 12.7 to 14.4 °C temperature and 0.5 ml/1 dissolved oxygen content. Navas (1971) recorded it for the first time in the Indian Ocean and suggests that this Atlantic species has reached the Indian Ocean either around Cape Agulhas or via the Mediterranean through the Suez Canal; the North Atlantic, Mediterranean and the Arabian Sea populations, although geographically separated appear to have maintained similar ecological requirements in relation to the factors considered here.

40. *Octotiara russelli* Kramp, 1953. A single specimen taken in BBSW, in 34.0 to 34.2 °/oo salinity, 4.4 to 4.6 ml/1 dissolved oxygen content and 28.6 to 28.9 °C temperature.

Earlier records are from coastal waters, in the Indo-West Pacific region (Kramp, 1968a).

41. *Pandea conica* (Quoy & Gaimard, 1827). Five specimens come from IOEW, SCSW and IOSTropSW, they were found living in 34.5 to 35.5 °/oo salinity, 20°C (or lower) to 29°C tempertaure and oxygen content not lower than 2.7 ml/1.

Earlier records are from all tropical and subtropical waters, most common in the Mediterranean (Kramp, 1968 a).

42. *Pandeopsis scutigera* Kramp, 1959. It was first recorded in the Indian Ocean by Navas (1971). Twenty-four specimens all from BBSW, in salinity from 32.7 or lower to 34.5 °/oo, temperature from 26 to 29 °C and oxygen content higher than 3.5 ml/1.

Earlier records confirm this to be a shallow water, low salinity, high temperature species (Navas, loc. cit)

43. *Protiara haeckeli* Hargitt, 1902. A single specimen earlier referred to as a new record for the Indian Ocean (Navas, 1971); it comes from BBSW: 33.1 to 33.2 °/oo salinity, 26.2 to 28.9 °C temperature and 2.0 to 4.4ml/1 dissolved oxygen content. Previously recorded from the West Altantic (Hargitt, 1902).

44. *Protiara tropica* Bigelow, 1912. Fourteen specimens were taken, first recorded for the Indian Ocean by Navas (1971). It was found in BBSW, ASSW, ASSSW, SCSW and at the surface in upwelled ASSSW. It was found in 33.2 (or lower) to 35.6 °/oo (or higher) salinity; in 20.2 to 26.2 °C(or higher)temperature and 3.2 to 5.5ml/1 dissolved oxygen content. A coastal shallow water euryhaline and eurythermal species with high oxygen requirements.

Earlier findings from the Philippines, Kei Islands and Sunda Strait are from a similar environment (Navas, 1971).

45. *Stomotoca atra* L. Agassiz, 1862. First recorded by Navas (1971), two specimens taken in hauls that filtered both BBSW and BBSSW; it may have been living at the discontinuity layer between the two.

46. *Stomotoca pterophylla* Haeckel, 1879. Two specimens first recorded for the Indian Ocean by Navas (1971). Both specimens come from hauls that traversed BBSW as well as BBSSW.

Earlier records from the Atlantic and East Pacific are given in Navas (1971).

47. *Calycopsis papillata* Bigelow, 1918. A single specimen taken in the Gulf of Aden, in salinity higher than 36.0 °/oo, a haul from 1000 m depth to the surface

Previously recorded from tropical waters of the Atlantic and West Indian Ocean (Kramp, 1968a)

48. *Calycopsis simulans* (Bigelow, 1909). A single doubtful specimen in a 275-0 m haul that filtered IOEW and IOCW.

Earlier records are from coastal waters of the tropical Pacific and Indian Oceans (Kramp, 1968a).

49. *Heterotiara anonyma* Maas, 1905. Seven specimens, one of them doubtful. Two specimens from ASSW, one from BBSSW and the other probably near the boundary between and Subsurface waters of the Bay of Bengal and the Arabian Sea. Salinity always higher than 35.0 °/oo, found to be from 35.0–35.6 °/oo or higher (up to 36 °/oo) temperature from 11.8°C (or lower) to 22.0 °C and dissolved oxygen content from lower than 0.7 to 3.3ml/1 or higher. A stenohaline, eurythermal species that may tolerate low oxygen content.

Earlier records show it occuring in the tropical region most probably in subsurface waters (Kramp, 1968a).

50. *Heterotiara minor* Vanhöffen, 1911. Twenty-seven specimens were taken mainly at the boundary between surface and subsurface layers in the Arabian Sea, in the Bay of Bengal and under the IOEW. It was taken also in BBSW, IOEW and IOCW. The salinity interval was from 34.3 to 35.1 °/oo, with one specimen from the ASSSW/ASSW boundary with salinity as high as 35.6 °/oo; it is tolerant of temperature down to 12 °C or lower and as high as 20°C and perhaps higher; it is tolerant of low oxygen values, down to 1.2 ml/1 or less. The greatest density was in IOCW. Vannucci & Santhakumari (1971) also found it in ASSW.

Recorded previously in the Indo-West Pacific, the specimens of Kramp (1965) also were caught, most probably, at boundary layers.

51. *Sibogita geometrica* Maas, 1905. Two specimens were taken in the Southern Indian Ocean, one in the Mozambique Channel and the other in the central Southern Indian Ocean at 13°57′ S-65°05′ E. They were found living in IOCW and perhaps AIW in 34.7 to 35.4 °/oo salinity: 14.6 (or lower) to 16.4°C (or higher) in not less than 2.1 ml/1 dissolved oxygen content.

Earlier records are from the Indo-West Pacific and Eastern Atlantic (Kramp 1968), also taken in intermediate layers.

52. *Laodicea fijiana* Agassiz & Mayer, 1899. Ninety-six specimens, over 92% of them at a single station in IOEW, salinity between 34 and 35 °/oo, temperature presumably higher than 25°C and high oxygen content.

Although no data are available for the station, these are the values to be expected at that position, 07° 57′ S-42° 16′E, on December 8th, 1964.

Otherwise this species was always taken at the boundrry layer between Surface and Subsurface waters, mainly in the Bay of Bengal but also in the Arabian Sea; all specimens come from salinity lower than 35 °/oo, one of them from higher salinity; temperature presumably not lower than 19 to 20 °C and up to 25°C or more and high dissolved oxygen content. Navas (1971) recorded this species for the first time in the Indian Ocean.

53. *Laodicea indica* Browne, 1905. Fifty-one specimens all from the Bay of Bengal, plus eight undetermined *Laodicea* specimens that may belong to the same species. They come from BBSW and near its deeper level at the boundary with subsurface waters. Salinity always lower than 35 °/oo as low as 33°/oo; temperature as high as 29.2°C and high oxygen content can be tolerated or is preferred. It forms swarms.

Earlier records show it to be distributed in the Indo-West Pacific region (Kramp, 1965), older specimens being caught at deeper levels.

54. *Melicertissa mayeri* Kramp, 1959. A single specimen recorded for the first time in the Indian Ocean by Navas (1971) was taken in a 500-0m haul that traversed ASSW and ASSSW, with salinity

between 35.4 to 35.5°/oo, temperature 11.2 to 26.8°C and dissolved oxygen content 0 8 to 5.0 ml/1.

Recorded previously only by Mayer (1910) in the West Atlantic.

55. *Melicertissa orientalis* Kramp, 1961. Two doubtful specimens were taken in BBSW at 32.9°/oo salinity, 27.8°C temperature and 4.7 ml/1 dissolved oxygen content at the surface.

Earlier records are from N. E. Australia (Kramp, 1961 b); if confirmed this would be a new record for the Indian Ocean.

56. *Ptychogena hyperborea* Kramp, 1942. A single specimen probably belonging to this species was taken between 746 and 275 m depth, at 06 °00' S-65 °10' E, in 34.8 to 35.0°/oo salinity, 7.3 to 10.8°C temperature and 1.7 to 2.7 ml/l dissolved oxygen content. The water masses present were IOCW and EIW. A new record for the Indian Ocean, hitherto known only from Greenland (Kramp, 1942) and in Antarctic waters (Navas, in preparation).

57. *Staurodiscus tetrastaurus* Haeckel, 1879. Two specimens were found both in shallow waters, one in BBSW and the other in SCSW. The intervals at the two stations were different; salinity was 34.2 to 34.3 °/oo, temperature was 27.2 to 28.2°C and 21.6 to 22.5°C; dissolved oxygen content was high in both cases: 3.8 to 4.5 ml/1 in one and 5.2 to 5.3 ml/l in the other.

Earlier records are given in Kramp, (1965), from coastal waters in the Atlantic and Indian Ocean, in scattered localities.

58. *Toxorchis polynema* Kramp, 1959. Three specimens from the Bay of Bengal taken in hauls that filtered through BBSW and upper layer of BBSSW. Always the salinity was lower than 35.0°/oo.

Earlier records are from the tropical Atlantic (Kramp, 1959a) and the Bay of Bengal, Nicobar Islands (Kramp, 1959c).

59. *Toxorchis thalassinus* (Pèron & Lesueur, 1902). Two specimens were found in BBSW, with salinity 33.0-33.4 °/oo, temperature 25.2 to 28.8°C, and dissolved oxygen content 3.8 to 4.6 ml/1. This would be a new record for the Indian Ocean, the species being recorded only from West Pacific (New Guinea and North Australia), from where it was described. A redescription of this rare species will be published soon.

60. A new species of *Toxorchis* was found in the Bay of Bengal also living exclusively in BBSW and boundary layer with BBSSW. The new species will be described in a separate paper.

61. *Halistaura bruuni* Navas, 1969. It was first described from the Bay of Bengal, thirteen specimens taken from the discontinuity layer between BBSW and BBSSW (Navas, 1969).

62. *Obelia* spp., an assemblage of species. The genus as a whole is eurytopic. It is a cosmopolitan genus, accordingly 17 specimens were taken in BBSW, BBSSW, ASSW and ASSSW and at the boundary between surface and subsurface waters in a wide range of salinity, temperature and dissolved oxygen content.

Earlier records are given in Kramp, (1959 a, 1961 a, 1968 a).

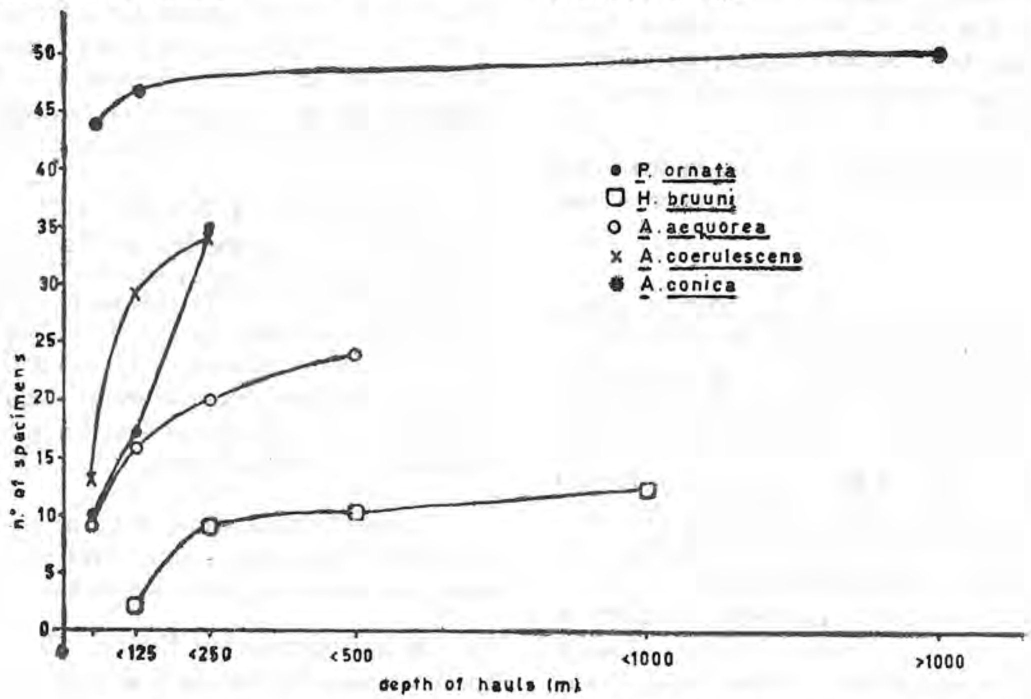

Fig. 7—Cumulative frequency distribution with depth. *Halistaura bruuni* was nevre taken in the surface layers.

63. *Phialidium hemisphaericum* (L.). Eighteen specimens, all but one from the Bay of Bengal. They were found in BBSW or at the boundary with subsurface waters. One specimen was found very far from land over deep bottom in IOEW perhaps at the boundary with IOCW. All the specimens were taken in salinity from 33.9 (or lower) to 35.0 °/oo, temperature not lower than about 20 °C and up to 28 °C or higher; dissolved oxygen content higher than 2.1 ml/1.

Earlier work (Kramp, 1968 a) shows it as a widely distributed species in tropical and subtropical waters; intraspecific morphological variation is very great in this species as also in *Phialucium carolinae*, *Blackfordia virginica*, and other related Leptomedusae.

64. *Phialidium mccradyi* (Brooks, 1888). A single specimen taken in 32.8 to 34.7 °/oo salinity; 21 to 28.7 °C temperature and 0.3 to 4.7 ml/1 dissolved oxygen content in BBSW mixed with BBSSW in the lower layer, a haul from 250-0 m. First recorded in the Indian Ocean by Navas (1971).

Earlier records, exclusively from Florida, are discussed in Navas (loc. cit).

65. *Phialidium simplex* Browne, 1902. A single specimen taken in BBSW, salinity 34.2 to 34.8°/oo, 22 to 28.6 °C temperature and 1.0 to 4.8 ml/1 dissolved oxygen content.

Earlier records are mainly from cold water (Kramp, 1959a), being found also in N.E. Australia (Kramp, 1953) and Indo-West Pacific region (Kramp, 1965).

66. *Cirrholovenia tetranema* Kramp, 1959. Two specimens in BBSW. It was first recorded in the Indian Ocean by Navas (1971). Earlier records suggest that it is a surface layer species.

67. *Eucheilota duodecimalis* A. Agassiz, 1862. A single specimen taken in a haul from 250-0 m that traversed BBSW and BBSSW. The Species was first recorded by Navas (1971) for the Indian Ocean; it was then pointed out that salinity and temperature ranges for the species agree with those of earlier records from Brazil (Vannucci, 1960b, 1963).

68. *Eucheilota menoni* Kramp, 1959. Sixteen specimens from different water masses show it to be euryhaline and eurythermic. It was taken in 32.8 (or lower) to 36 °/00 salinity; 22 °C (or lower) to 28 °C (or higher) temperature, and oxygen content higher than 2 ml/1. The largest numbers come from the Gulf of Aden. It was taken in BBSW, ASSW, SCSW and in hauls that filtered both surface and subsurface layers. A doubtful specimen comes from IOSTropSW at 13 °22'S–47 °54'E. It was often taken over great depths far from land but it seems to be always found in the surface layer and to require high oxygen content.

Earlier records include the Indian Ocean and the West Pacific (Menon, 1932; Kramp, 1959c).

69. *Eucheilota tropica* Kramp, 1959. Three specimens from BBSW, taken in 34.3 (or lower) to 34.4 °/00 (or higher) salinity and 27.2 (or lower) to 28.2°C (or higher) temperature and high dissolved oxygen content, around 4.0 ml/1.

Earlier records are from Indian Ocean and West Pacific (Menon, 1932, Kramp 1959c, 1962, 1965).

70. *Lovenella assimilis* (Browne, 1905). A single specimen taken in BBSW in 34.4 to 34.5 /oo salinity, 26.7 to 28.7 °C temperature and 4.0 to 4.4 ml/1 dissolved oxygen content.

Earlier records show it as an Indo-West Pacific species (Kramp, 1968a).

71. *Lovenella cirrata* (Haeckel, 1879). It was first recorded in the Indian Ocean by Navas (1971). Five specimens were taken in BBSW in 32.9 to 33.4 °/oo salinity, 29.2 to 29.8 °C temperature and 4.5 to 4.6 ml/1 dissolved oxygen content. Navas (loc. cit.) pointed out the different environmental requirements of the population of this species from the Bay of Bengal with that of those living in the Mediterranean and off southern Brazil (Vannucci, 1957).

72. *Phialella falklandica* Browne, 1902. A single doubtful specimen in IOEW or IOCW at 03 °07' S - 40 ° 39'E.

Previous records are only from cold waters (Kramp, 1959a). It would be a new record for the Indian Ocean.

73. *Phialella quadrata* (Forbes, 1848). A single doubtful specimen in BBSW with 32.3 to 33.8 °/oo salinity, 26 to 29°C temperature and 3.2 to 4.5ml/1 dissolved oxygen content.

Earlier records are mainly from temperate waters (Russell, 1953), a few from warmer regions (Kramp, 1955a).

74. *Octophialucium bigelowi* Kramp, 1955. A single doubtful specimen from BBSW with 33.4 to 34.4 °/oo salinity; 27.7 to 28.9 °C temperature and 2.0 to 4.8 ml/l dissolved oxygen content. It would be a new record for the Indian Ocean; previously found on both sides of the American Continent, in warm waters (Vannucci & Soares Moreira, 1966).

75. *Octophialucium indicum* Kramp, 1958. Sixty-nine specimens all from BBSW, Sixty-six of them at a single station. A surface layer species found in 31.9 to 33.2 °/oo salinity, 26 to 29 °C temperature and high oxygen content, higher than 3.3 ml/1.

Earlier records are from the Indo-West Pacific region (Kramp, 1968a).

76. *Octophialucium medium* Kramp, 1955. Two specimens, found one in BBSW, in 33 °/oo salinity, 27.4 °C temperature and 4.5 ml/1 dissolved oxygen content and the other in ASSSW in 35.2 to 35.3 °/oo salinity, 12.3 to 18 °C temperature and 2.0 to 2.4 ml/1 dissolved oxygen. Thus it appears to be a euryhaline and eurythermal species requiring rather high oxygen content.

Earlier records, according to Kramp (1968a), show it to have a scattered distribution near the Equator, from the eastern Atlantic through the Indian Ocean, to the western Pacific.

77. *Phialucium carolinae* (Mayer, 1900). Thirty-eight specimens were taken in the Bay of Bengal, either from Surface Water or at the boundary between Surface and Subsurface waters. Salinity range is 32.8 (or lower) to 35.0 °/oo; it prefers temperatures from 20.3 to 29.3 °C (or higher) and high oxygen content. Need of high oxygen content and high temperature keeps this species in the surface layers.

Earlier records show it to be widely distributed in tropical waters (Kramp, 1959a, 1968a), sometimes with variation in number of radial canals (Kramp, 1953, and the present collection), mainly in the Indo-Pacific region.

78. *Phialucium condensum* Kramp, 1953. A single specimen taken in BBSW in 32.7 to 34.0°/oo salinity, 24.2 to 28.7°C temperature and 2.1 to 4.7ml/1 dissolved oxygen content, in a haul from 50 m depth to the surface.

It was first recorded in the Indian Ocean by Navas (1971), who showed it to be a warm, shallow water species, throughout its geographic range.

79. *Phialucium multitentaculatum* Menon, 1932. Nine specimens all from BBSW; salinity range from 33.0 (or lower) to 34.3 °/oo; temperature 25.8 to 29 °C and oxygen content higher than 3.0 ml/1. A surface layer species.

Earlier records are only from the Indian Ocean and Gulf of Tonkin (Menon, 1932).

80. *Eirene brevigona* Kramp, 1959. Two specimens taken in a single haul from 200-0 m in the Arabian Sea that went through ASSW and ASSSW. The salinity range was 35.2 to 35.5 °/oo. Navas (1971) recorded it for the first time in the Indian Ocean.

Earlier records from the Malayan coast (Navas, loc. cit.) were from warm waters but low salinity.

81. *Eirene elliceana* (Agassiz & Mayer, 1902). Five specimens, first recorded for the Indian Ocean by Navas (1971). All the specimens come from the Bay of Bengal from hauls that reached the boundary layer between Surface and Subsurface Waters or where there was presence of mixed subsurface water. Salinity range lower than 35.0 °/oo down to about 33.0 °/oo or lower; temperature from 18 to about 26 °C or lower.

As shown by Navas (loc. cit.), earlier records confirm this to be a subsurface species.

82. *Eirene hexanemalis* (Goette, 1886). Twelve specimens, all from the Bay of Bengal, two of them from BBSW the others from the discontinuity layer between BBSW and BBSSW. It was always taken in salinity lower than 35 °/oo down to 34.1 °/oo or lower; temperature up to 23.7 °C (or higher). The range of dissolved oxygen tolerance may be wide. It probably aggregates at the lower boundary of the Surface Water layer. A specimen taken in 32.2 to 32.7 °/oo salinity and 28 3 to 28 9 °C was a doubtful specimen, perhaps dead when taken.

Earlier records are from the Indo-West Pacific region, in coastal waters (Kramp, 1968a).

83. *Eirene viridula* (Péron & Lesueur, 1809). Seventy-six specimens were taken in only five hauls, where it was present in swarm abundance. A surface layer species,eurythermal and euryhaline, taken in BBSW, ASSW(or ASSSW), IOSTempSW and SCSW, from 13°06'N to 40°S at the subtropical convergence. The salinity range was from 34.4 to 36 °/oo or higher; temperature from 12.9 to 26.7 °C (or higher) and oxygen content always higher than 4.0 ml/1.

Previously recorded from the Atlantic (including Mediterranean) and Indian Ocean(Kramp,1961); could be an Atlantic species that penetrated the Indian Ocean through the Mediterranean and Suez Canal, as in the case of *Necturris pileata*, discussed by Navas (1971), or more probably around South Africa.

84. *Helgicirrha malayensis* (Stiasny, 1928). Two specimens from the Bay of Bengal, in surface or subsurface water, salinity between 33 and 35 °/oo, temperature as high as 27.4 °C and perhaps higher, oxygen content around 4.5 ml/1.

Earlier records are from the Indo-West Pacific region (Kramp, 1968a)

85. *Helgicirrha medusifera* (Bigelow, 1909). First recorded in the Indian Ocean by Navas (1971). Two specimens from the Bay of Bengal in salinity lower than 34.9 °/oo and perhaps as low as 32.9 °/oo. In either case the net filtered through BBSW and BBSSW. Earlier records are from surface waters on the Pacific coast of Mexico and Panama. Vannucci & Santhakumari (1971) recorded it in the eastern Arabian Sea off the southern Indian coast.

86- *Eutima curva* Browne, 1905. A single specimen from the Arabian Sea taken in a haul from 250-0m that filtered ASSW and ASSSW. The ranges for the water colum were 35.4 to 35.7 °/oo salinity, 15.2 to 27.2 C temperature and 1.4 to 5.0 ml/1 dissolved oxygen content.

Earlier records are from the Indo-West Pacific region (Kramp, 1968a) in coastal waters.

87. *Eutima gentiana* (Haeckel, 1879). First recorded in the Indian Ocean by Navas (1971). Nine specimens from a single haul at 07 °57' S-42°16' E, from 50 to 0 m. The water mass must have been IOSTropSW, environmental data absent.

Earlier record: the Canary Islands (Haeckel, 1879), and a doubtful record from China (Vanhöffen, 1913b).

88. *Eutima mira* McCrady, 1857. First recorded in the Indian Ocean by Navas (1971). Five specimens in the same haul as *E. gentiana* and two more at 05 °19' S-53 °32'E, also at the surface, probably in IOEW. Known to be a high temperature, high salinity, surface species (Vannucci, 1957).

89. *Eutima orientalis* (Browne, 1905). Two specimens taken in the Bay of Bengal. one in BBSW, 33.1 to 33.2 °/oo salinity, 26.0 to 27.6 °C temperature and 4.0 to 4.5 ml/1 dissolved oxygen content. The second specimen comes from a 500-0 m deep haul that filtered both BBSW and BBSSW.

Earlier records indicate it as a coastal water species, in the Indo-West Pacific region (Kramp, 1968a).

90. *Aequorea aequorea* (Forskål, 1775). Twenty-four specimens were taken, all except four in the Bay of Bengal. A low salinity species, most specimens come from BBSW. It was found in the following ranges: salinity 31.9 to 34.6 °/oo, never higher than 35 °/oo; temperature 22.0 to 27.7 °C, perhaps higher and lower; dissolved oxygen content usually high. Two specimens were taken at 4 °40' S-65° E in a haul that sampled through IOEW and IOCW and two specimens were taken in the northern Arabian Sea where salinity was 35 6 to 35.9 °/oo, the temperature 11.8 to 28.4° C. This species appears to be eurythermal, preferring low salinity since it was seldom taken beyond 35 °/oo. It prefers or requires high oxygen content. A long lived species, may be found far from land.

Earlier records show it as a widely distributed species, being more frequently found in temperate waters (Kramp, 1959 a, 1968a).

91. *Aequorea coerulescens* (Brandt, 1838). Thirty-four specimens all from the Bay of Bengal. A surface water species, usually taken in shallow waters. The salinity range was found to be 32.7 (or lower) to 33.9 /oo (or higher): the temperature 25.8 to 28.3°C (or higher) and dissolved oxygen content higher than 3.8 ml/1. A BBSW species.

Earlier records include coastal waters in the tropical Pacific, Indian Ocean, and southern Atlantic (Kramp, 1968a), and from the Antarctic (Navas, in preparation).

92. *Aequorea conica* Browne, 1905. Fifty specimens, all except three from the BBSW, in shallow waters with 32 to 34.5 °/oo salinity, 23.8 to 27.7 °C temperature and oxygen content higher than 4ml/1. Three specimens were taken at 40° 48' S-65° 03'E in a 1650-0 m haul over great depth, the haul filtered IOSTempSW and AIW; salinity 34.6 to 35.1 °/oo; 2.8 to 12.9 °C temperature and 4.2 to 4.9 ml/1 dissolved oxygen content. It thus appears that this species may endure lowering of temperature but does not endure salinity higher than 35.0 °/oo nor low oxygen content.

Earlier records are only from the Indo-West Pacific region, mainly in coastal waters (Kramp, 1968a).

93. *Aequorea globosa* Eschscholtz, 1829. Two specimens from the Bay of Bengal, one in BBSW and one in a haul that filtered both BBSW and BBSSW. Salinity lower than 35.0 °/oo, temperature up to 27.7 °C or higher.

Earlier records are from scattered localities in the Indo-Pacific (Kramp, 1968a).

94. *Aequorea macrodactyla* Brandt, 1835. Thirteen specimens taken where the net filtered through the boundary of two water masses. A discontinuity layer or DSL species. It may be found from the extreme north of the Arabian Sea, southwards to 30°S far from land and over great depths as well as near shore. A long lived species. It was taken in 34.8 (or lower) to 35.4 °/oo salinity; 10.8 (or lower) to 21.2°C (or higher) temperature and appears to require high oxygen content. It was taken in BBSW/BBSSW boundary, upwelling ASSW, IOCW at the boundary with IOSTropSW, with SCSW and with AIW.

Earlier records show it to be widely distributed in the Indo-Pacific region, but scattered in the Atlantic (Kramp, 1968a).

95. *Aequorea parva* Browne, 1905. Two specimens were taken, one from IOSTempSW at 40° 48' S-65° 03' E perhaps at the boundary with AIW, 34.6 to 35.1 °/oo salinity, 2.8 to 12.9°C temperature and 4.2 to 4.9 ml/1 dissolved oxygen content. One specimen taken at 07 °57 ' S-42° 16' E bears no hydrographical data. May have been upwelled waters.

Earlier records show a scattered distribution in the Indo-West Pacific (Kramp, 1968a).

96. *Aequorea pensilis* (Eschscholtz, 1829). Eighty seven specimens, mostly from the Bay of Bengal. It was taken in BBSW, IOCW and at the boundary between BBSW, ASSW and the respective subsurface water masses. Eurythermal and euryhaline; taken in 33 to 36 °/oo (or higher) salinity, 13.9 (or lower) to 27.4 °C but may have high oxygen requirements; it was taken as far south and far from land as 30 °34' S-69 ° 55' E.

Earlier records are from the Indo-West Pacific region (Kramp, 1968a).

97. *Olindias singularis* Browne, 1905. Seven specimens from the Bay of Bengal, from BBSW. The ranges were 33.1 to 33.5 °/oo salinity, 27.0 (or lower) to 28.0°C temperture and dissolved oxygen content higher than 3.5 ml/1.

Earlier records are from the Indo-West Pacific region (Kramp, 1968a).

98. *Proboscidactyla ornata* (McCradv, 1857). Thirtyfive specimens from BBSW, ISSTropSW, ASSW and BBSW at the boundary with Subsurface water, IOEW and IOCW, and SCSW and IOSTropSW. The salinity interval found was from 32.9 to 35.6 °/oo or higher but it appears to prefer salinity around 35.0 °/oo; it tolerates up to 29.2 °C but prefers temperature lower than 20 °C to 21 °C and it tolerates down to 13 to 14 °C and also tolerates low oxygen content.

Earlier records are from all tropical and subtropical regions (Kramp, 1959a, 1968a), over the continental shelf and slope.

99. *Geryonia proboscidalis* (Forskäl, 1775), Thirteen specimens were taken in IOCW, IOSTropSW and the boundary between surface and subsurface waters in the Bay of Bengal, Arabian Sea, Equatorial system and as far south as the subtropical convergence. The salinity range within which it was found was 34.8 to 35.5 °/oo; the temperature 12.9 °C or lower (at the convergence) to 21.2 °C or higher. It appears to require rather high oxygen content, not lower than 2.9 or 3 ml/1, usually higher. A boundary layer species.

Earlier records are from all the tropical and subtropical regions (Kramp, 1959a, 1968a), widely distributed

100. *Liriope tetraphylla* (Chamisso & Eisenhardt, 1821). The second species in order of abundance by 7217 specimens. A detailed study of the distribution of this species and of *Aglaura hemistoma* will be done separately.

101. *Botrynema brucei* Browne, 1908. Thirty-seven specimens. An Antarctic species that spreads in the Indian Ocean through AIW. It was taken either in AIW or at the boundary with the water masses above AIW or at the lower level between ASSSW and BBSSW and the surface water. The salinity range was 34.4 to 35.6 °/oo; the temperature range was from 5.8 °C (or lower) to 16 °C; Oxygen content not lower than 2.8 ml/1. The single specimen taken in the Bay of Bengal, in BBSSW, was probably dead when taken, oxygen content was about 1 ml/1; 70% of the specimens come from 40 °S lat. in the area of the subtropical convrgence, taken in two hauls, one from 2750-275 m and the other from 885-0 m.

Earlier records are from deep waters of the Pacifiic, Indian and Atlantic Oceans (Kramp, 1059a, 1968a) and from the Antarctic (Navas, in preparation.

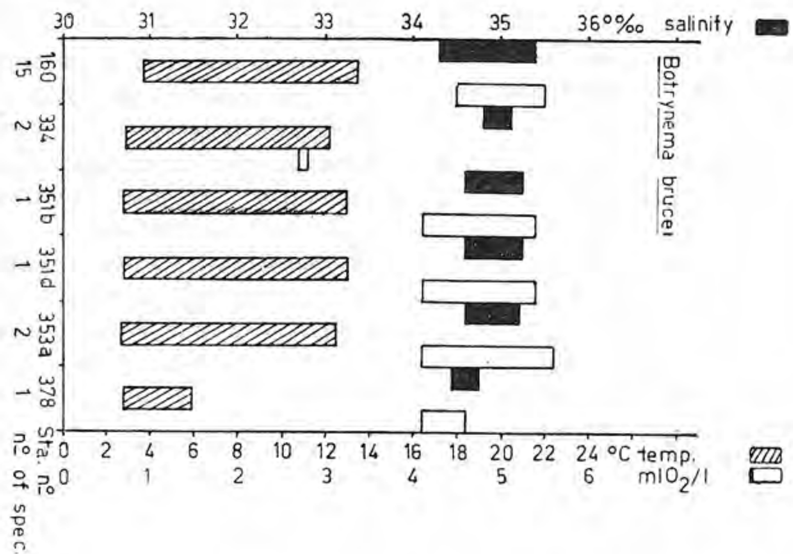

Fig. 8—Selected stations at which *Botrynema brucei* was found; show it to be a cold water species, stenotopic for salinity, temperature and dissolved oxygen content. Fig. 10 and Map 8 show it to be widely distributed geographically, in intermediate layers.

102. *Halicreas minimum* Fewkes, 1882. On the whole 191 specimens were taken of this Antarctic species found to sink at the subtropical convergence and probably sinks also at the subantarctic convergence, since it is found to spread north in the IOCW and AIW. It was found as far north as 07° 27' in the Bay of Bengal and 07° 55' in the Arabian Sea. Single specimen in the Bay of Bengal and two in the Arabian Sea at 07 °N although 19 were taken between 7° N and the Equator in ASIW and ASSSW. Like in other Antarctic species that sink at the convergence it rises to shallower depths at the Equator and in the northern hemisphere as waters of Antarctic origin mix and come up as they loose their identity. Increase of temperature, lowering or increase of salinity and decrease in dissolved oxygen content are the limiting factors in the distribution of this species that is clearly associated with low temperature of Antarctic or deep waters. The limits within which it was taken were; 34.6 to 35.5 °/oo salinity, 5 °C (probably tolerates down to 2.8 °C) to 13.4 °C temperature. Two specimens were taken in higher temperature, one in IOCW at 29° 22'S at 18.4 °C and one in IOSTropSW at up to 23 °C. These three specimens were probably dead when taken since only the jelly, that is recognizable in this species long after death was left. Dissolved oxygen content was never below 1.4 ml/1. The data show very clearly the following interval of preferences:

salinity from 34.6 to 35.0 °/oo, temperature from 5.0 to 9.0°/C and about 4 ml/1 dissolved oxygen content.

Earlier records show it as an Antarctic species, widely distributed in deep waters of the Atlantic, Indian and Pacific Oceans (Kramp, 1959a, 1968a).

103. *Haliscera racovitzae* (Maas, 1906). First recorded in the Indian Ocean by Navas (1971). An Antarctic species, two specimens taken in a deep haul (1000-500m) in BBSSW, 34.9 to 35 °/oo salinity, 5.8 to 9.8 °C temperature and 0.5 to 0.8 ml/1 dissolved oxygen content. Probably dead when taken. It was taken at 07°27' N, both specimen had surely spread into the Bay of Bengal from AIW.

Previously known from Antarctic and subantarctic waters, and in deep waters north and east of New Zealand (Kramp, 1959 a, 1965).

104. *Halitrephes maasi* Bigelow, 1909. Twenty-two specimens. An Antarctic species that sinks at the convergence and spreads as far north as 20°N lat. in the Bay of Bengal through BBSSW and deep water, but was not taken in the Arabian Sea. The specimens were found in AIW from the subtropical convergence northwards in IOCW and in BBSSW. It was most abundant at the boundary layer between AIW and overlying IOCW. The salinity interval was 34.9 to 35.5 °/oo, temperature 9.7 to 15.4 °C and perhaps higher; it is tolerant of as low as 0.8 ml/l oxygen tension. A single specimen was taken in as high salinity as 35.5 to 35.6 °/oo and 15.4 to 18.8°C temperature and high oxygen content in mixed IOCW and SCSW at 29°S.

Earlier records show it as a circumglobal cold water species, in deep waters, or in upwelling areas (Kramp, 1968 a).

105. *Ag lantha elata* (Haeckel, 1879). Five specimens. A deep water,'rare low salinity species that was taken in AIW and spreads through IOCW also into the deep layers of the Bay of Bengal. Its salinity optimum appears to be around 34.8 °/oo, the temperature interval is from 6 to 9 °C and appears to require high oxygen content, not lower than about 1.8 ml/l.

Earlier records include a single specimen taken in ASSW (Vannucci & Santhakumari, 1971) just off the shelf of the southern coast of India, a finding that does not agree with the present ones, since it comes from high salinity and high temperature waters. Kramp (1959 a) mentions that it is found in upwelling areas, but none of our specimens come from such a one.

106. *Aglaura hemistoma* (Pèron & Lesueur, 1809). The most abundant species in this- Ollection with 13047 specimens. Its distribution is being studied separately, together with that of *Liriope tetraphylla.*

107. *Amphogona apicata* Kramp, 1957. A common species, 181 specimens were counted, spread over the Indian Ocean in IOCW and the water masses with which it mixes, ASSSW, BBSSW. It was taken also in ASSW. A boundary layer species taken usually at the upper boundary of the IOCW or at the lower boundary with AIW. A few specimens come from AIW and very rarely also in ASSW. The salinity interval tolerated appears to be from 34.6 to 36.0 °/oo with the optimum at about 35.5 °/oo; the temperatre interval is very great, from 8 °C or perhaps lower up to 24.9 °C, the optimum however is between 10 and 14 °C. It was found in 0.3 up to 4 ml/1 or higher dissolved oxygen content. It is most abundant in the Arabian Sea in ASSSW at its upper and also lower boundaries with other water masses.

Earlier records are from the Atlantic and Indian Ocean (Kramp, 1959a) an isolated occurrence in the Pacific (Kramp, 1965); always in deep waters.

108. *Amphogon a apsteini* (Vanhöffen, 1902). A single specimen was taken in 36.6 to 37.2 °/oo salinity, 19.6 to 28.9°C temperature and 0.6 to 4.9 ml/1 dissolved oxygen content in a haul from 250-0 m at 22° N-59° E.

Earlier records show it as an epipelagic species with a scattered distribution, from the east Atlantic to the eastern Pacific, including the Indian Ocean; probably a circumglobal distribution (Kramp, 1965).

109. *Colobonema sericeum* Vanhöffen, 1902. An Antarctic water species abundantly represented throughout the Indian Ocean, 638 specimens were taken. Most abundant in IOCW where the greatest densities were found; it aggregates at the upper boundaries of the IOCW. A boundary layer species. Not taken in surface waters. It was ound in IOCW, BBSSW and the boundaries.

Its salinity interval is rather narrow from 34.7 to 35.7 °/oo; temperature from 6 to 18 °C and perhaps lower; oxygen content not lower than 2 ml/l. Its preferences are around 9 to 12 °C and high oxygen content. Its density decreases from south northwards very sharply and its limiting factor is high temperature, higher salinity and lower oxygen content. Typically an Antarctic species.

Earlier records show it as a widely distributed bathypelagic species, circumglobal, except in the Mediterranean and Arctic seas (Kramp, 1965), but widely distributed in the Antarctic, as found by Navas (in preparation).

110. *Crossota alba* Bigelow, 1913. Three specimens, first recorded for the Indian Ocean by Navas (1971). A cold deep water species found in AIW, IOCW and BBSSW. A widely distributed rare bathypelagic species(loc. cit.). Itwas found in about 35 °/oo salinity (or slightly less), in about 6 °C temperature and as low as 0.8 ml/l dissolved oxygen. Navas has summarized its known distribution, also in the Antarctic (Navas, in preparation).

111. *Crossota brunnea* Vanhöffen, 1902. Altogether 45 specimens were taken. An Antarctic species found in the intermediate layer in the Indian Oceean It was taken in 34.4 to 35.5 °/oo salinity, in 6 °C or lower to 15.5 °C or higher temperature and dissolved oxygen content not lower than 3.4 ml/l. It was found only in the southern Indian Ocean, the northernmost station was St, 298 at 12°33′ S-54°33′ E, its abundance decreases from the subtropical convergence northwards and thus appears to be clearly linked to the flow of AIW. From this water mass it spreads also to IOCW and NIODW.

Earlier records show it widely distributed in deep cold waters from the Antarctic to slightly north of the Equator in the three great oceans (Kramp, 1965).

112. *Pantachogon haeckeli* Maas, 1893. Two hundred and thirty specimens were taken. A frequent Antarctic species found throughout the Indian Ocean in deep layers, except in the Bay of Bengal, but sampling of deep layers was rare in that part of the Indian Ocean. It is an eurytopic species that endures a wide range of environmental conditions and this may explain its wide distribution and frequency. It was taken in 34.7 °/oo

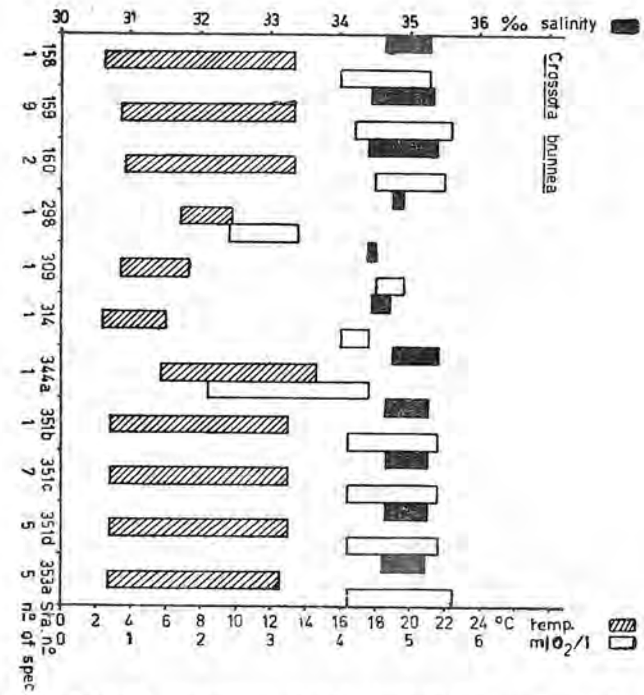

Fig. 9—Selected stations at which *Crossota brunnea* was taken. It shows it to be stenohaline with high oxygen requirements. An intermediate water species widely distributed geographically and eurybathic, see Fig. 10 and Map 8.

or less to 35.6 °/oo or higher salinity and in 3.4 to 17.1 °C temperature. Two specimens were taken in ASSW at 10° 21′ N-54 °17′ E on February 2nd, 1964, off Cape Guardafui. It tolerates very low oxygen values and several specimens come from waters with 0.1 to 0.3 ml/l dissolved oxygen and it is common in waters with less than 2.7 ml/l dissolved oxygen content. It was found living in the following water masses: ASSW, ASSSW, ASIW, EIW, IOCW, AIW, NIODW. It seems to be most frequent in AIW and IOCW, in salinity around 35 °/oo or lower, 3 to 12 °C temperature and 3 ml/l or higher dissolved oxygen content.

Earlier records show it widely distributed in deep cold waters, from the Antarctic almost to the Arctic, except in the Mediterranean (Kramp, 196a).

113. *Pantachogon scotti* Browne, 1910. Only two specimens were taken in the Arabian Sea at 17 °41′ N-68 °03′ E, at depth not greater than 1000 m, on March 3rd, 1963. Salinity was about 35.5 °/oo, 11.9 to 14.5 °C temperature and 0.1 to 0.2 ml/l dissolved oxygen content. They could have come from any of the following water masses: ASSW, ASSSW, ASIW.

Earlier records are only from the Antarctic (Kramp, 1959 a).

114. *Persa incolorata* McCrady, 1857. First recorded by Navas (1971) in the Indian Ocean; she gives also a detailed ecological distribution. One hundred and nineteen specimens were taken; although six specimens were taken at depths greater than 1000 m most animals were found to live in the boundary layer between surface and subsurface layers. It is a species that prefers living in 34.6 to 35.2 °/oo salinity but a few specimens were taken in salinity as low as 33 °/oo and as high as 36 °/oo, although dead when taken. It is quite tolerant of temperature, since it was taken in a range from 12.6 to 26.8 °C temperature. Six specimens were taken in 6 °C or lower and low salinity, 34.5 to 34.7 °/oo, only very few were found in the higher range, and most appear to be limited by 19 to 20 °C. This species tolerates low amounts of oxygen, 2 ml/l or less and two specimens come from 0.3 ml/l dissolved oxygen content. It was taken in BBSW, BBSSW, ASSSW, IOCW, AIW and at the boundaries between surface and subsurface layers. Its limiting factor seems to be high salinity, it is accordingly rare in the Arabian Sea, and more abundant in the Bay of Bengal, even more abundant in intermediate depths of the southern Indian Ocean, where low temperature and low salinity are found together.

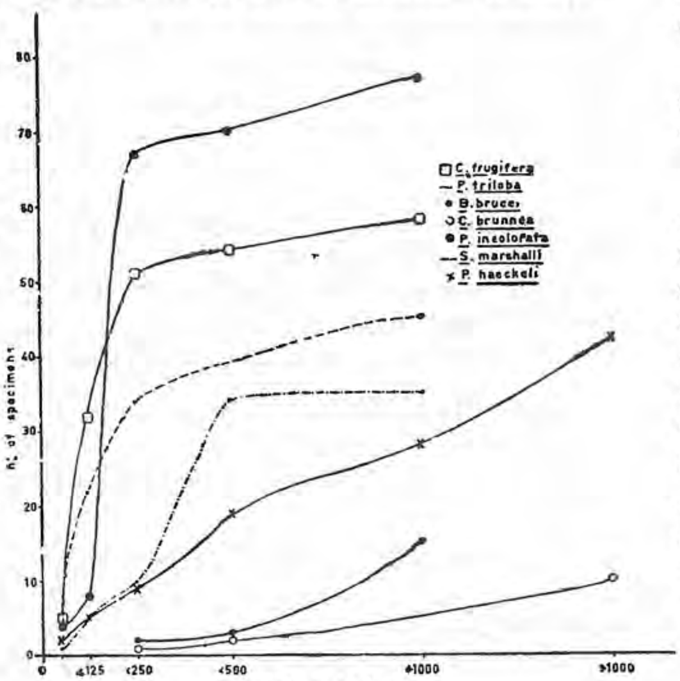

Fig. 10—Cumulative frequency distribution with depth; shows well marked aggregation of the many species at certain depths, thus *Persa incolorata* between 125 and 250 m and *Solmissus marshalli* at 500 m (or less).

115. *Rhopalonema velatum* Gegenbaur, 1856 This is the third most abundant species after *Aglaura hemistoma* and *Liriope tetraphylla*, with 5301 specimens. It is perhaps the most frequent species found in almost all the samples where hydromedusae were at all present. It is euryhaline and was taken from 30.4 to 36.0 °/oo salinity, very rarely up to 36.6 °/oo. The largest numbers come from around 35 °/oo salinity or lower. It is also strongly eurythermic and was taken in temperature ranging from 5.1 to 29.2 °C although they were rare in such extreme temperatures. It also tolerates a wide range of dissolved oxygen values and was found in as low as 0.2 ml/1 dissolved oxygen content. Due to its preference for lower salinity and temperature between 15 and 20 °C it is common in the Bay of Bengal and in the southern Indian Ocean, while it is relatively rare in the Arabian Sea and in the Equatorial belt. It is mainly to be found at the boundary layer between surface and subsurface water; its greatest density is between 250 and 125 m depth at the boundary layer. It definitely avoids salinity higher than 35.5 °/oo although it can tolerate it, and it avoids temperature lower than 12 or 13 °C although it can tolerate much lower temperature. It was found in the following water masses: BBSW, BBSSW, ASSW, ASSSW, IOCW, IOSTropSW, SCSW, AIW (rarely).

Earlier records agree with this wide distribution; it occurs in all warm and temperate waters (Kramp, 1959 a, 1968 a).

116. *Sminthea eurygaster* Gegenbaur, 1856. A total of 143 specimens was taken, in salinity ranging from 34.7 (or lower) to 35.7 °/oo. It is usually found in a temperature range from about 11 to almost 20 °C, but as low as 6.4 and as high as 21.8 °C or higher. It is tolerant of very low oxygen content, as low as 0.2 ml/l. It is most abundant in IOCW but may be found also in BBSW, BBSSW, ASSSW, IOCW, EIW, SCSW, IOSTropSW. It is most abundant at the boundary between surface and subsurface waters. It was not taken further south than 33 °S.

Earlier records show it as occuring in deep and intermediate layers, in warm and temperate regions, which agrees with the present data (Kramp, 1959 a, 1965).

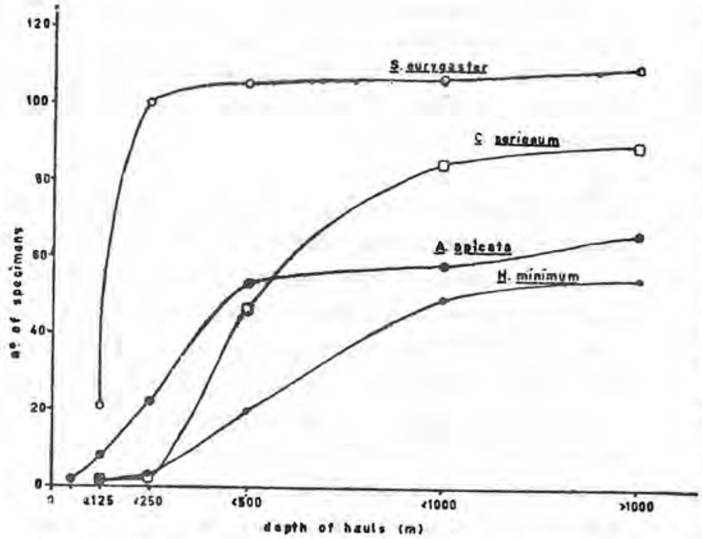

Fig. 11—Cumulative frequency distribution with depth. Surface (*Sminthea eurygaster)* and deep water species.

117. *Tetrorchis erythrogaster* Bigelow, 1909. This species was first recorded in the Indian Ocean by Navas (1971) who gave the salinity and temperature limits for this species. Eight specimens were found, seven of them from the mouth of the Gulf of Aden, in a 250-0 m haul and one from 1000-500 m in the southern Indian Ocean. Probably widespread in deeper layers. It tolerates temperature as high as 15 °C and salinity as high as 35.6 °/oo. It is tolerant of low dissolved oxygen content. May be an indicator of upwelling. Navas (1971) discusses the earlier records that indicate that this is a deep water species.

118. *Aegina citrea* Eschscholtz, 1829. Fortytwo specimens were taken. It is fairly eurybathic but most abundant from 300 to 200 m depth. The salinity range tolerated was from 33.5 to 35.6 °/oo. The temperature range found was from 7 to 26 °C. Only very rare specimens however were found in the extremes of low salinity and high temperature. It was taken in waters with 0.8 or less ml/l dissolved oxygen content. It was found to live in BBSW (only one specimen), BBSSW, IOCW, ASIW, SCSW, EIW AIW, IOSTropSW. It is mainly found in colder waters at intermediate depths.

Earlier records include the Antarctic Ocean, the species being widely distributed, mainly in deep and intermediate waters, almost to the Arctic, not yet found in the Mediterranean (Kramp, 1965).

119. *Aeginura grimaldii* Maas, 1904. Fortysix specimens were taken. A deep, relatively cold water species, not found in surface layers in the area of the IIOE, north of the subtropical convergence. It is found in deep and intermediate waters, and BBSSW. It was taken in 34.9 to 35.4 °/oo salinity, in about 6 to 12 °C and it tolerates oxygen content as low as 0.4 ml/1. It was taken in BBSSW, AIW, IOCW, ASIW, EIW and deep layers of Arabian Sea and southern Indian Ocean.

Earlier records show it to be widely distributed in deep and intermediate layers, except in the Mediterranean and Arctic (Kramp, 1965), but Navas (in preparation) has found it also in the Antarctic.

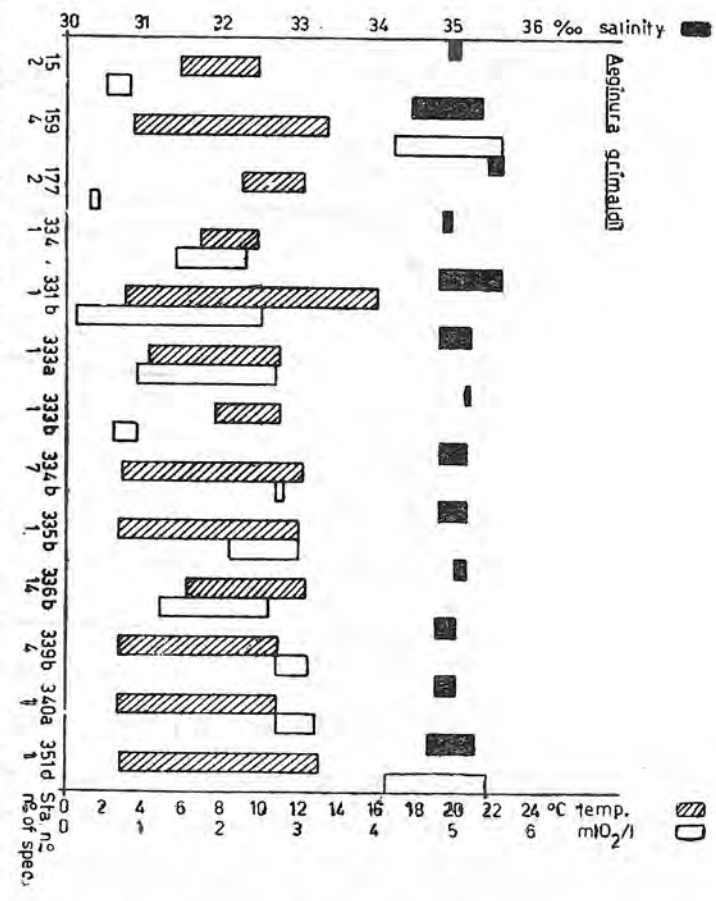

Fig. 12—Distribution of *Aeginura grimaldii* in relation to environ mental parameters; it is stenohaline, rather eurythermal and tolerant of varied dissolved oxygen content. Map 10 shows it to have a wide geographic distribution.

120. *Solmundella bitentaculata* (Quoy & Gaimard, 1833). This was found to be the fourth species in order of abundance, with 3113 specimens counted. It was found to be widely distributed in almost all the water masses sampled, ASSW, ASSSW, BBSW, BBSSW, IOEW, IOCW, IOSTropSW, but not in intermediate or deep waters. It is mainly found in the lower strata of the surface waters, in the boundary layer. It is euryhaline, having been found in 31.9 to 36.0 °/oo salinity; it is also eurythermal although it prefers warm waters, it was taken in temperature ranging from 11.4 to 29 °C. A single specimen may have been taken in 9.4 °C, at a depth of 1000-500 m in IOCW. It tolerates low oxygen content down to 0.2 ml/1. It does not appear to be affected by salinity since dense swarms were found in high and low salinity, but it becomes rare in temperature lower than 15-18 °C; it also becomes rare in low oxygen content waters. Stratified samples show it to be most abundant in surface and subsurface layers.

Earlier records show it as a very common species, in tropical, subtropical or cold waters, from the Antarctic continent as far as 40 °N, also common in the Mediterranean (Kramp, 1959a, 1968a).

121. *Pegantha clara* R. P. Bigelow, 1909. Only twentyone specimens were taken of this surface water species. It was taken in ASSW, BBSW, SCSW and ASSW, in salinity from 34.7 (or lower) to 35.9 °/oo; the temperature was from 15.8 (or lower) to 24.5 °C (or higher), but it does not seem to tolerate dissolved oxygen content lower than 1.7ml/1. It was found in the Bay of Bengal, Arabian Sea and at 29 °S. It is known to occur also in Antarctic waters (Navas, in preparation).

Earlier records are from all the three great oceans, between 40 °S and 40-50 °N, mainly in upper waters (Kramp, 1965).

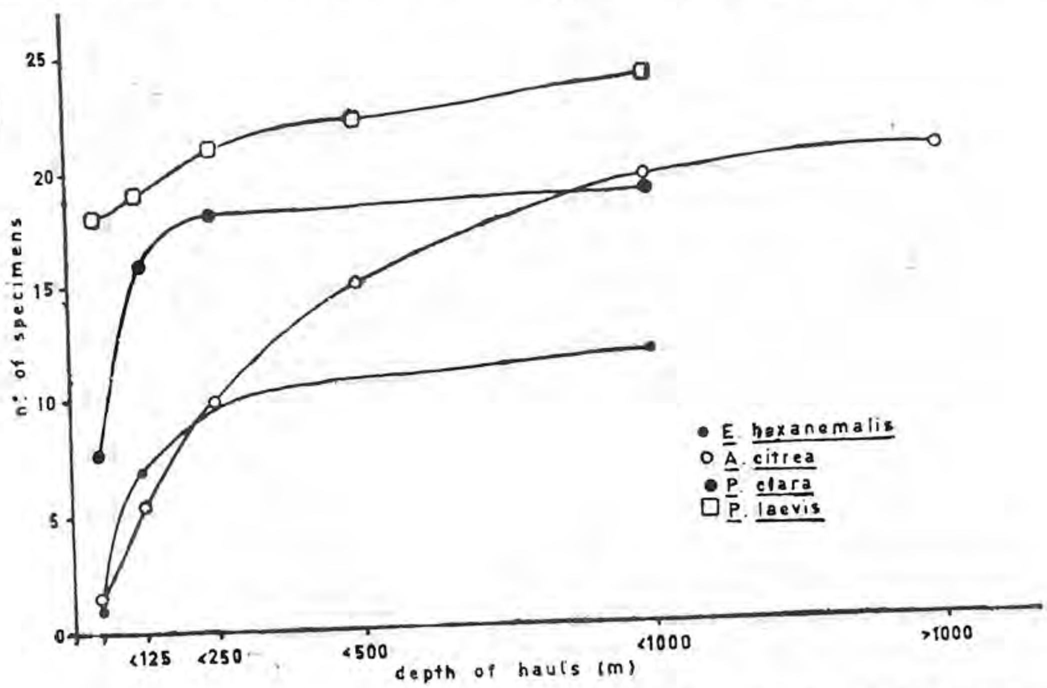

Fig. 13—Cumulative frequency distribution with depth. *Aegina citrea* and eurybathic species.

122. *Pegantha laevis* H. B. Bigelow, 1909. Twentyeight specimens of this surface layer species were taken. They come from BBSW, IOEW, SCSW, but were not found in the Arabian Sea. It was found as far south as 29 ° 29′S in SCSW. The salinity tolerance was found to be from 33.8 to 35.6 °/oo, the optimum seems to be 35 °/oo or higher; the temperature interval seems to be from 18.8 to 24.4 °C and it is found in oxygen rich waters.

Earlier records show it as a widely distributed but not very common species, in warm and temperate waters, mainly in upper levels (Kramp, 1965).

123. *Pegantha martagon* Haeckel, 1879. This was found to be a common species with 932 spe-

cimens; it was taken in ASSW, ASSSW, BBSW, IOCW, IOEW. Ninety percent of the specimens come from a surface haul in the Gulf of Aden where swarms of other species of hydromedusae were also found. This swarm was taken in 36°/oo salinity, 24 °C temperature and 4.6 ml/l dissolved oxygen content. It is however euryhaline and eurythermal, having been taken from 31.9 to 36 °/oo salinity and 14.4 to 28.4 °C temperature. It seems to require high dissolved oxygen content. Only seldom it is found in subsurface layers. It is known also from Antarctic waters (Navas, in preparation).

Earlier records are from upper waters of the three great oceans, as far north as 40°, southwards to the Antarctic continent (Kramp, 1965, Navas in preparation).

124. *Pegantha triloba* Haeckel, 1879. Fiftyseven specimens of this species were taken mainly in surface layers. It was taken in ASSW, ASSSW, BBSW, BBSSW, IOEW, IOSTropSW and one specimen perhaps come from AIW. It is probably most abundant at the boundary layer between surface and subsurface waters. It was found to be euryhaline and eurythermal and was taken between 32.8 and 36 °/oo salinity, and 17.2 to 29 °C. One specimen may have been taken in AIW at about 6 °C temperature. It was found in as low oxygen content as 0.2 ml/1. It was also found as far south as 33 °S.

Earlier records show it with an extensive vertical distribution in the three great oceans between about 30 °N and 30 °S, exceptionally at 50 °S in the Atlantic (Kramp, 1965).

125. *Solmaris rhodoloma* (Brandt, 1838). Only one specimen was taken. It was first recorded in the Indian Ocean by Navas (1971), who also comments on earlier records. It was taken in a haul that filtered both BBSW and BBSSW, in the Bay of Bengal in 1.7 to 35 °/oo salinity, 11. to 28.2° C temperature and 0.1 to 4.9 ml/1 dissolved oxygen content.

126. *Cunina duplicata* Maas, 1893. Five specimens were taken in deep and intermediate waters in the Bay of Bengal, Arabian Sea and at the subtropical convergence at 40°54'S-60°01'E. In the Arabian Sea it was taken in ASSSW. The salinity tolerance of the present specimens is from 34.9 to

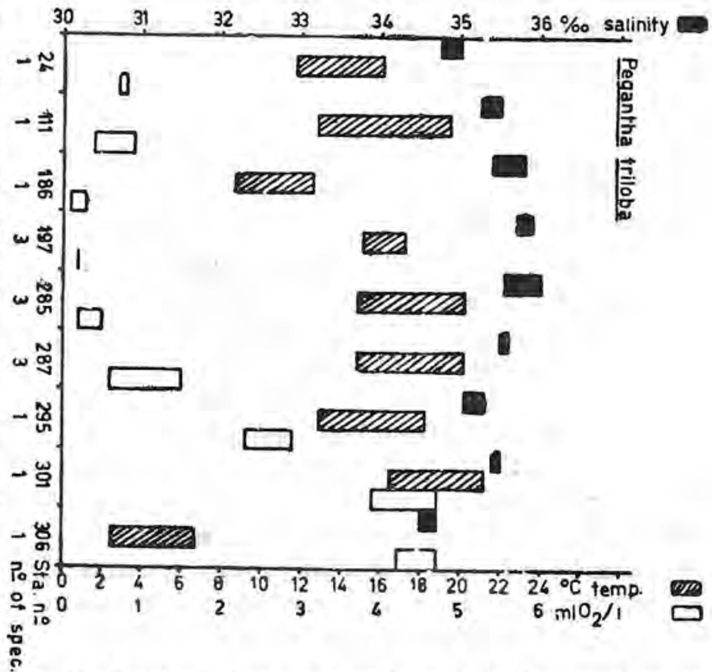

Fig. 14—Selected stations at which *Pegantha triloba* was found to occur. It shows well marked eurytopic capacity of this species for the three parameters considered, with preference for warm waters; this accounts for its extensive vertical and geographical distribution; see Map 10 and Fig. 10. It also shows increased abundance at the boundary layer.

35.2 °/oo; the temperature interval from 6.7 to 11 °C and may tolerate as low as 0.9 ml/1 dissolved oxygen content. It is found in the Antarctic and probably spreads north via AIW and from there to deep, intermediate and subsurface waters, in areas of upwelling.

Earlier records also show a wide and scattered distribution, probably worldwide in intermediate and subsurface layers, in Antarctic waters and may occasionally be taken in areas of upwelling (Kramp, 1959a, 1965).

127. *Cunina frugifera* Kramp, 1948. Sixty specimens were taken in the Bay of Bengal, in the Arabian Sea and in the tropical Indian Ocean, as far south as 22 °S. It is a surface layer species to be found mainly at the discontinuity layer between surface and subsurface waters. It was taken in BBSW, ASSW, IOSTropSW and mainly at the boundary between these waters and underlying water masses, the BBSSW, ASSW and IOCW respectively. The limits of tolerance found were 33.4 to 36 °/oo salinity; 21.1 (or lower) to 25.2 °C and appears to require high oxygen content.

Earlier records show it to be a widely distributed species in surface layers and warm waters (Kramp, 1965).

128. *Cunina octonaria* McCrady, 1857. Altogether 496 specimens were taken. A widely distributed surface water species, it was taken as far south as 29°18'S. It was taken in BBSW, ASSW, ASSSW, IOEW, IOCW, IOSTropSW, SCWS, and EIW and at the boundary between surface and subsurface waters. The salintty tolerance ranges from 25.4 to 36.2°/oo but it is most abundant in 33 to 35°/00 salinity, the temperature interval ranges from 14.1 (perhaps as low as 9.3) to 28.8°C or higher, however it is most abundant in temperature higher than 19 to 20°C. This species tolerates dissolved oxygen content as low as 0.8 ml/1 but it is usually found in waters with about 3 ml/1 or higher dissolved oxygen content. It also appears to have high food requirements.

Earlier records confirm this to be a widely distributed frequent species in warm waters [Kramp, 1965].

129. *Cunina peregrina* Bigelow, 1909. Altogether 132 specimens were taken in the Bay of Bengal, Arabian Sea and Equatorial Indian Ocean. It was found in BBSW, BBS>W, ASSW, ASSSW, SCSW and in IOSTropSW at the boundary with IOCW. It is most abundant in the upper layers of subsurface waters while *C. octonaria* is most abundant in the lower level of the surface water mass. Its salinity optimum is also higher than that of *C. octonaria*. The salinity tolerance in this sample was from 31.9 to 36°/00 while the optimum appears to be around 35.5°/00; it appears to avoid high salinity above 36°/00; it is also strongly eurythermic, 12.6 to 29.2°C temperature interval with an optimum probably around or below 20°C. It endures low oxygen tension and was found in as low as 0.2 ml/1 dissolved oxygen content.

Earlier records show it to be a widely distributed species in equatorial, tropical and subtropical latitudes (Kramp, 1965).

130. *Cunina tenella* (Bigelow, 1909). This species was first recorded in the Indian Ocean by Navas (1971) who discusses this species' distribution in detail, on the basis of the 427 specimens present in this collection. It was found living in 31.9 to 36.6°/00 salinity, in 14.1 to 29 2 C temperature interval and is tolerant of oxygen content as low as 0.2 ml/1. It appears to be most abundant at the boundary between surface and subsurface waters, in around 35 °/oo salinity and 20 °C temperature. It was taken in ASSW, ASSSW, ASSSW, BBSW, BBSSW, IOEW, IOSTropSW and SCSW and especially at the boundary between these waters and the subsurface layers. It was recorded as far south as 29°38'S.

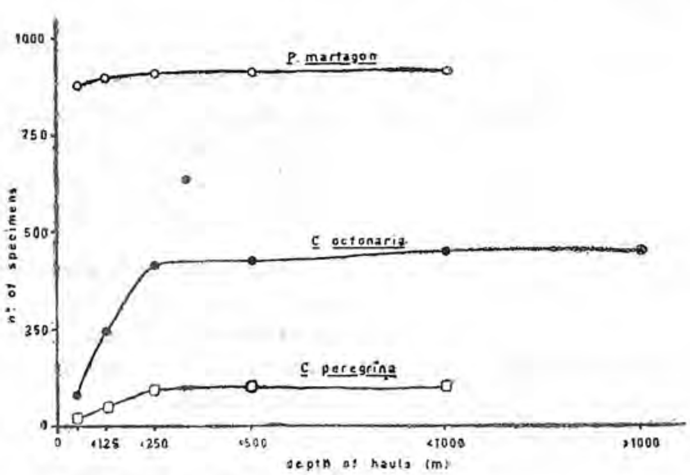

Fig. 15—Cumulative frequency distribution with depth. *Pegantha martagon* a surface layer species, as well as*Cunina peregrina* the latter however shows some aggregation at 250 m depth or less.

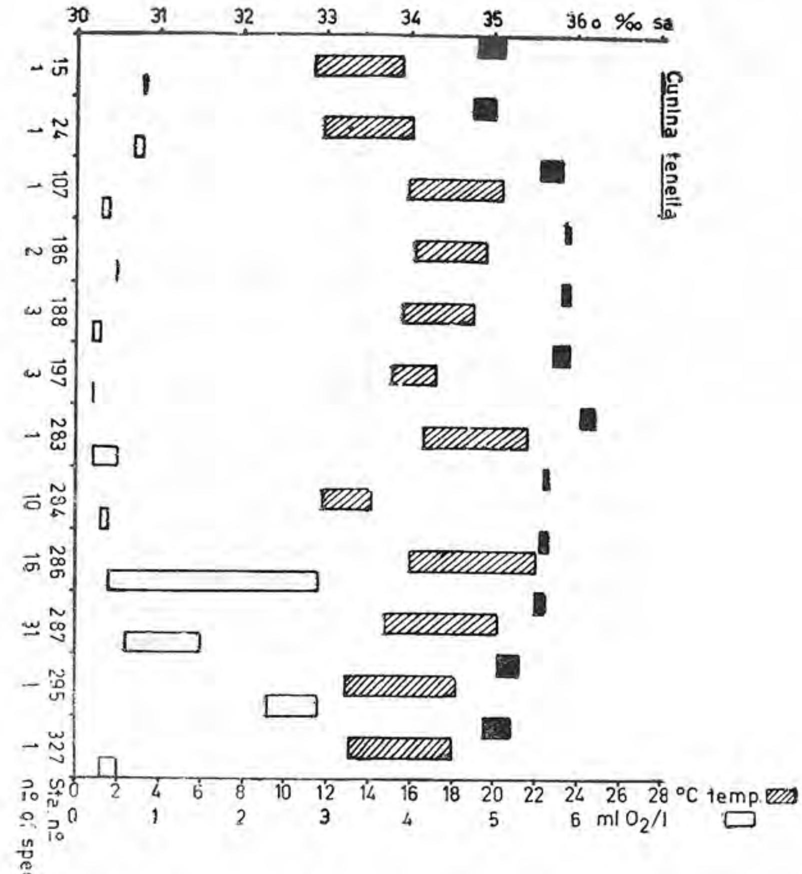

Fig.16– Selected stations at which *Cunina tenella* was taken. The figure shows that this is an eurythermal, euryhaline species, widely tolerant of dissolved oxygen content. Fig.5 shows that this species has a boundary layer aggregation. It also shows a wide geographical distribution in warm waters.

131. *Solmissus marsha* Agassiz & Mayer, 1902. Forty specimens were taken of this deep water species that may be found also in surface layers in all the Indian Ocean as far south as 43°59'S. It was found living in BBSW, BBSSW, ASIW, SCSW and at the boundary between ASSW and ASSSW; IOCW and AIW, and IOstropSW with IOCW. It is often found in upwelling areas. It was found living in 32.9 to 36.7°/00 salinity; the temperature interval was 10 °C (or lower) to 27.9 °C and it was not taken in less than 0.8 ml/1- dissolved oxygen content.

Earlier records indicate an extensive vertical distribution as well as horizontal in warm and temperate waters (Kramp, 1965)·

Ecological Distribution of the Hydromedusae taken during the I. I. O. E.

Table 2

Roughly 45,000 specimens were studied, they belong to 131 different species; 59 of them are represented by less than five specimens and are not shown on Table 2. Some of these are rare in the collection because they are rare species anywhere, such are *Podocoryne meteoris*, *Bougainvillia maniculata*, *Leuckartiara zacae*, *Toxorchis thalassinus*, and others. However, most of the species that are rare in this collection are so because of sampling bias due to that most stations were occupied in the open ocean over great depths and only a very small percentage was occupied over the shelf or nearer to the coast. Three of the rare species are cosnidered to be Medeterranean immigrants into the Indian Ocean, that may have travelled through the Suez Canal and Red Sea, and they are *Podocoryne meteoris*, *Bougainevillia maniculata*, *Koellikerina fasciculata:* other two rare species also appear to be immigrants, but in either case it seems more likely that they have reached the Indian Ocean by the way of Cape of Good Hope; they are *Neoturris pileata* and *Bougainilia niobe*.

It is significant that the great majority of the species that are rare in this collection were taken in the surface layer of the Bay of Bengal. These waters have a high temperature and low salinity and is in this sense comparable to coastal waters at low latitude, although it is oceanic in the sense that it is far from land and has great depths.

Conversely, the very great majority of specimens taken belong to oceanic species again due to the same sampling bias mentioned above that was introduced by the geographical distribution of the stations. Over 61% of the specimens taken belong to four species that, significantly, are holoplanktonic and have no fixed hydroid in their life cycle; the four species are; *Aglaura hemistoma*, with almost 29% of the specimens taken; *Liriope tetraphylla*, with almost 14%; *Rhopalonema velatum* with almost 12% and *Solmundella bitentaculata* with almost 7%.

Another sampling bias introduced during sampling at sea refers to depth since the number of stratified samples that were taken decreases with depth and bottom water samples were not taken. Nonetheless, the number of specimens belonging to Antarctic and sub-antarctic species whose dispersal is temperature controlled was relatively great and shows that cold water dependent species spread north even beyond the northern limit of the AIW mass that has its northern limit at roughly 10 °S lat. Intermediate and deep water species are by and large the same in the Arabian Sea as in the Bay of Bengal, but a few were found so far only in one of the two seas. The main discriminating ecological factors are probably the higher salinity and the very low or nil oxygen content in the oxygen minimum layer in the Arabian Sea.

About one quarter of the species taken have a distribution that shows clearly aggregation at the boundary layer, whether this is between surface or subsurface layers, at deeper levels or at the surface, along fronts

One amazing finding refers to the great number of species and specimens that were found to be living in water with very low oxgyen content and were healthy and normal, so far as can be judged from the preserved specimens. Hydromedusae have a low metabolism in relation to total body weight (Buddenbrock 1952; Prosser & Brown, 1951) and this may be a factor that favours these species against others that have higher oxygen requirments. Many species and many specimens were found to tolerate and live in waters with as low or lower oxygen content than 0.2 ml/1 dissolved 0^2, even when they were not restricted to the oxygen minimum layer. Fraser (1969) quotes a high conversion factor of 37 % for medusae and this may be related to their capacity to endure unfavourable surroundings. More precise and finer methods of analysis of ecological distribution and more detailed sampling at sea may provide more precise information. Vinogradov and Voronine (1962) discussed this matter.

Finally the study of the distribution of closely related species such as congeneric species, shows that (Table 2) in no case their distribution is controlled by the same factors. Thus in the genus *Zanclea*, for instance, one species, *Z. costata* is stenohaline, stenothermal and has strict oxygen requirements, while the distribution of another, *Z. dubia*. is regulated by high food requirement and third one, *Z. orientalis*, that also had high food requirements, is found in different water masses. Similar observations can be made for all the other genera that were represented by more thanone species. The genus *Eirene* appears, from the table, to bean exception, since both *E. eiliceana* and *E. hexanemalis* are stenohaline found only in the Bay of Bengal and at the boundary layer. However, *E. elliceana* seems to prefer lower salinity and is tolerant of lower temperature, while *E. brevigona* from the Arabian Sea prefers higher salinity and *E. viridula* is found in the Bay of Bengal, in the Arabian Sea and in the Tropical Equatorial System and is widely tolerant of different salinities and temperatures.

Also in the genus *Cunina*, *C. perearina* and *C. octonaria* appear to have the same distribution, but the latter seems to have its optimum at lower salinity(33-35 °/oo) and 19 °C to 20 °C temperature, while *C. peregrina* replaces it at 35.5 to 36 °/oo salinity and 20 °C or lower temperature, the great difference between the two, however, is that

C. peregrina is found in as low as 0.2 ml/1 0^2 while *C. octonaria* was not taken below 0.8 ml/1 0^2 and it is usually found to have higher oxygen requirements.

These examples could be multiplied but they may easily be deduced from the text for each species and from the tables. They show clearly how plankton species are maintained separate by ecological mechanisms, especially so closely related species, even if they are geographically and temporally sympatric at times. Hutchinson (1959) discussed how the larger the number of species the greater becomes the stabliity of the ecosystem and also how a group containing many diversified species will be able to seize new evolutionary opportunities more easily than an unidentified group. Margalef has repeatedly demonstrated the same point.

According to the principle first enunciated by Volterra (1926) and later developed by Gause (1934), different species cannot share indefinitely the same ecological niche since one of them will eventually and inevitably be displaced by the other. The results of the present work show again that even at a gross level the optima for different ecological factors do not coincide in separate species, consequently at every time interval, however small, one species will be favoured against the others. Considering that developmental stages may have different requirements and that conditions in the surface and subsurface layers of the oceans are continuously changing, no species in a given water mass will be favoured for a very long time and it will not have time to displace others. Successively and at alternate times, most or all of the species will find their optima and are in turn favoured; by this mechanism many different species may coexist for a long time in a single body of water. The rate of variability of environmental conditions, whether quick or slow becomes an ecological factor of importance since the adaptive capacity both physiological and selective of the species must be tuned to it; in this sense the time factor acquires the value of an ecological niche.

The study of Antarctic Ocean Hydromedusae underway (Navas, in preparation) shows clearly how different species spred northwards with Antarctic Intermediate Water. The species however reach different distances from the convergence according to their ecological valence, since AIW gradually changes by mixing and is finally replaced by other water masses. In an earlier paper, one of us (Vannucci, 1966) compared the ecological valence of the conspecific populations from the Gulf of Naples and from the southern Brazilian coast and showed that widely distributed species were in both places at about the same intervals for the ecological factors considered (temperature and salinity) while the sparsely distributed species appear to have broken up into distinct populations that are more closely adapted to local conditions, which can have been brought about by isolation. The comparison of the ecological valence in the Indian Ocean, South Atlantic Ocean(south Brazil) and Mediterranean shows that, for the species that occur in all three areas, *Cytaeis tetrastyla*, *Proboscidactyla ornata*, *Rhopalonema velatum* and *Solmundella bitentaculata* show the same salinity preferences but different temperature intervals in the three regions; the four of them are widely distributed in warm waters and either are holoplanktonic or have vegetative reproduction. *Phialidium hemisphaericum* is coastal and metagenetic, it shows the same temperature intervals in the three regions but appears to be adapted to somewhat higher salinity in the Mediterranean. *Liriope tetraphylla* and *Aglaura hemistoma* are the most widely distributed species, they are euryhaline and eurythermal and the former shows salinity and temperature optima different in the three regions, while for *A. hemistoma* there are differences in salinity preferences (not yet clear for temperrature):

Discussion

Geographic distribution of Hydromedusae has been the subject of several studies, mainly by Kramp (1959a, 1961, 1968a) who summarized all the information available in his Monographs on the Atlantic and Indo-Pacific Hydromedusae and in his Synopsis of the Medusae of the World. Studies on the distribution of Hydromedusae in relation to environmental factors, mainly salinity, temperature and dissolved oxygen content were carried out by Vannucci (1957, 1963, 1966), Vannucci, Santhakumari & Santos (970) and Vannucci & Navas (in press). Studies of the geographic distribution of plankton organisms in our opinion have a restricted value when only the geographic cordinates of the stations are considered and not the depth of haul and ecological factors. This because environmental conditions in the oceans vary drastically with depth while the same salinity, temperature, oxygen content and other characteristics are approximately the same over very extensive horizontal geographic areas, specially in intermediate and deep waters. It thus appears more reasonable to study the patterns of distribution in relation to water masses and other oceanographic phenomena rather than in relation to geographic coordinates alone.

Earlier studies on geographic distribution of hydromedusae revealed some geographical patterns and arctic, antarctic, temperate, tropical, Atlantic, Mediterranean or Indo-Pacific faunae of medusae were described. However, as more data were gathered and as more and more hitherto unsampled areas were studied, the gaps gradually were filled and the boundaries between so called geographic regions became more and more blurred, while the ecological distribution of most species has become more and more evident. Similar ideas guided Bary (1963a, b) in his studies of plankton distribution in relation to environmental factors, and led him to construct the T-S-P diagram.

The geographic distribution of species is originated by geological and evolutionary phenomena that act on plankton organisms as much as on other organisms, but differently from land animals, the plankton is distributed along a world wide continuum, the World Ocean in which barriers are usually ill defined and are variable in time and space. Thus there has been ample time for the mixing of faunas of different geographic origin. Furthermore, in the hydromedusae spreading and mixing of species is favoured by the presence in the life cycle of a bottom living stage that propagates asexually; the long lived hydroid that often grows on ship hulls, turtle shells, natural and man-made rafts of all sorts and forms large colonies by vegetative growth and may bud off medusae during a long time, seeding them over a wide area of the ocean. Some such species widely distributed by passive means and by interference of vegetative reproduction in the hydroid or medusoid stage are *Clytia cylindrica* (or *C. attenuata; Clytia* is the hydroid of *Phialidium) Obelia* spp., *Cytaeis tetrastyla*, *Bougainvillia platygaster*.

It seems reasonable to disregard geographic distribution as such in hydromeduase and try to find out whether ecological distribution shows any sensible patterns and whether the causes that determine the geographic distribution may be related to environmental parametres. As mentioned earlier (Vannucci & Navas, 1971) the water mass is considered as the environmental unit while the species is taken to be the biological unit. The sampling design during the IIOE was far from satisfactory from our point of view, since it was not random in space, depth or time, it did not cover the whole Indian Ocean and many samples were taken with open nets rather than with closing nets manipulated according to the hydrographic structure of the water colum at the point of sampling. Nevertheless, the wealth of data and the large number of stratified samples allow for a tentative interpretation.

1. Deep and intermediate water hydromedusae. This is a group of species that tolerate water colder than 2 °C and salinity lower than 35 /oo: deep waters are usually poorer in oxygen content and in the Arabian Sea they may be very poor. Only a few samples were taken in deep waters but a large number comes from intermediate water masses. Most deep and intermediate water species have a temperature controlled distribution, but some have not been found so far in the Antarctic. This indicates that there is a group of Antarctic species that are tolerant of great depths and sink at the Antarctic and sub-Antarctic convergences then spread north with AIW and ABW and latter diffuse to other cold water masses, while there are other species that are depth dependant and more often found in deep layers, suggesting that some factor other than temperature limits their distribution or that they are unable to compete with other species at higher levels. Thus many deep water species are euryhaline. eurybathic, eurythermal and oxygen tolerant, such are; *Solmissus marshalli, Tetrorchis erythrogaster*, *Aequorea pensilis*, *Protiara tropica*, *Merga violacea*, *Zanclea orientalis, Vannucci forbesi.* These species are only rarely found in shallow depth. They are, as it were, pushed down to great depth by the more successful surface or sub-surface species. The latter, however, are unable to live at great depth because of one or another of their stenotopic properties.

The following are deep water species not yet recorded in the Antarctic Ocean; *Merga reesi*, *Aglantha elata, Tetrorchis erythrogaster.*

Deep water species usually have a wide but scattered distribution and are not abundant numerically nor frequently found. It is not yet clear whether the deep water fauna of medusae is separate from the Antarctic fauna or whether it has not yet been recorded in the Antarctic because of scarce sampling and infrequent use of small nets. Some eurythermic and eurybathic deep water species are not restricted to cold deep water such as *Pantachogon haeckeli and Euphysora furcata.*

The Antarctic fauna, similarly to the deep water has preference for low temperature. It spreads north with the water sinking at the convergences and although AIW cannot be traced as such north of 10° S latitude in the Indian Ocean, many of the species it carries are often found throughout the Indian Ocean far north in the Arabian Sea and in the Bay of Bengal intermediate and subsurface water. Those that tolerate relatively higher temperature occur in upwelling areas. Also in this case, it is not yet clear whether the population found north of 10 °S latitude are separate populations or whether mixing goes on with the southern populations. The Antarctic species found to sink at the Antarctic and sub-Antarctic convergences are usually found also in the upper layers of the Antarctic Ocean.

The following species were found in Antarctic water (Navas, in preparation) and also north of the subtropical convergence: *Botrynema brucei, Halicreas minimum, Colobonema sericeum, Crossotā brunnea, C. alba, Pantachogon haeckeli, Cunina duplicata, Solmissus marshalli, Halitrephes maasi, Aegina citrea, Aeginura grimaldii, Pegantha clara P. martagon, P. laevis* and *Haliscera racovitzae*. All of them were found to be cold loving or cold tolerant species, but some are not restricted to very cold nor to deep waters. Thus *Solmissus marshalli* and *Cunina duplicata* were found in upwelling waters in the eastern Bay of Bengal, the western Arabian Sea and in the central Indian Ocean near to the Equator. *Pegantha martagon* was found also in surface waters all over the Indian Ocean. Each of the Antarctic species has a different pattern of distribution northwards. A detailed study of the behaviour and pattern of distribution of these species is in preparation (Navas). However, the exclusively Antarctic and sub-Antarctic species were not taken in temperature higher than about 12 °C and most of them are tolerant of low dissolved oxygen content, but not lower than about 1.5 ml/1. Of those encountered during the IIOE, only *Pantachogon haeckeli, Crossota brunnea* and *Botrynema brucei* appear to have high oxygen requirements.

Sinking of Antarctic species at the subtropical convergence is very clear and some species are not found north of the northern boundary of the AIW, as for instance *Crossota brunnea*.

The presence of deep water or Antarctic species in relatively shallow depths in the Arabian Sea and in the Bay of Bengal is noteworthy.

2. We have earlier (Vannucci & Navas, 1971) indicated that from the point of view of distributional patterns a group of Indian Ocean Central Water species may be recognized and is represented by an assemblage of species from subsurface to intermediate depths usually concentrated at the boundary between water masses. They spread horizontally from the sub-tropical convergence to the Arabian Sea and to the Bay of Bengal excluding coastal areas. This group includes those species that prefer or tolerate temperature as high as about 19° C and salinity between 34.5 to 36.0 °/oo. In the Arabian Sea many species of this group are selected against by low oxygen content, while in the Bay of Bengal they are selected against by low salinity, not higher than 34.1 to35.0 °/oo (Table 1). The species of this group (Table 2) tend to have a wide geographic distribution, *Sibogita geometrica, Amphogona apicata* are examples of this group.

3. The Bay of Bengal has a peculiar association of species that prefer or tolerate a combination of high temperature and low salinity over a very wide area in the surface layer. Furthermore, salinity decreases from south to north and there is a complicated circulation. The surface layer does not extend below 150 m depth, thus relatively cold waters (temperature lower than 19 °C) with salinity lower than 35.0 °/oo are found near surface. Neritic species are found widely distributed in the surface in BBSW, even very far from land and the continental shelf and many are hitherto unrecorded from the other parts of the Indian Ocean. These specimens may be found as far as current velocity and their longevity will take them. The species mentioned below are very commonly found in BBSW, while those that so far were found nowhere else in the Indian Ocean are indicated in table 2. The most common species in BBSW are Anthomedusae and Leptomedusae that all have a hydroid in their life cycle, the cosmopolitan *Liriope tetraphylla* and *Cunina tenella* are those most commonly encountered. Among the species that have vegetative reproduction of the medusa, *Bougainvillia platygaster* is the most frequent. This list refers to BBSW in the oceanic part of the Bay of Bengal since coastal areas were not at all or only very poorly sampled during the IIOE. It is our belief that when coastal waters will be studied throughout the Indian Ocean and especially in the low salinity regions and waters near estuaries, coastal lagoons, river deltas and similar

areas, many of the species that were taken during the IIOE only in the Bay of Bengal will be found also in other parts of the Indian Ocean, even in the Arabian Sea (Vannucci & Santhakumari, 1971).

4. In the Arabian Sea also there is a peculiar association of species, given the combination of high temperature and salinity higher than 35.5 °/oo in the surface 150 m thick layer (ASSW) and temperature lower than 19 °C and salinity always higher than 35.0 °/oo in subsurface and intermediate depths. The Arabian Sea has also a very peculiar pattern of oxygen distribution with extremely low or even oxygen free layer at shallow depths. The oxygen minimum layer actually rises to the surface at times, off the Indian coast. Nevertheless, many species of medusae that might have been thought of as having high oxygen requirements due to their habits of active predators, were found to be living in this oxygen depleted environment. Some of the Bay of Bengal species are found in coastal and estuarine areas of the Arabian Sea, such as *Pandeopsis scutigera*, *Phialucium condensum*, *Helgicirrha medusifera*, (Vannucci & Santhakumari, 1971); it is noteworthy that these species have a restricted distribution in the Arabian Sea, while they are spread over a wide area in the Bay of Bengal, by BBSW. The following are the species more frequently found in ASSW and ASSSW: *Solmundella bitentaculata*, *Cunina octonaria* and furthermore, *Aglaura hemistoma* is characteristically relatively more abundant than *Liriope tetraphylla*.

Summing up, among the dominant species, *Liriope tetraphylla*, *Rhopalonema velatum* and *Cunina tenella* characterize the Bay of Bengal waters, while a preponderance of *Aglaura hemistoma* and *Solmundella bitentaculata* characterize the Arabian Sea.

5. Finally another group of species may be recognized; it pertains to the Equatorial Indian Ocean System. The distribution of these species is centred in the surface and thin layer of the IOEW mass that has comparatively low salinity, from 34.0 to 35.0 °/oo; high temperature throughout the year, from 26.0 to 27.0 °C and high dissolved oxygen content ranging from 3.40 to 7.46 ml/1. From the Equatorial Water mass, species spread to adjoining waters where conditions are favourable. The system of equatorial currents and counter currents maintains the species in the belt of warm surface waters near the Equator. Such are, for instance: *Euphysora furcata*, *Bougainvillia fulva*, *B. platygaster*, *Laodicea fijiana*, *Eirene viridula*, *Rhopalonema velatum*, *Pegantha clara*, *P. laevis*, *Cunina octonaria* and *Cunina peregrina*.

Summary

1. The material was collected in the Indian Ocean by different gear; most samples are stratified, collected with the Bé sampler.

2. 131 different species of hydromedusae were collected during the International Indian Ocean Expedition, in the Indian Ocean, from the subtropical convergence northward. No samples are available from the Persian Gulf, Gulf of Oman and Red Sea.

3. A total of about 45,000 specimens were studied. They come from about 900 samples taken at 480 stations, 67% of which were positive for hydromedusae. Most samples are stratified but they were taken mainly in the high sea, beyond the continental shelf and in the upper 500 m; 61% of the total number of specimens is represented by four species; *Aglaura hemistoma*, (29%), *Liriope tetraphylla* (14%); *Rhopalonema velatum* (12%) and *Solmundella bitentaculata* (7%). The collection represents mainly oceanic species while neritic and coastal areas were seldom sampled.

4. The autoecology of about 50% of the species is given, the others were represented by too few specimens. The water masses in which they were found are given for each species (see list at p. 2 to 6 and Tables 1 and 2).

5. On the basis of the results, 5 groups of species are recognized: a) rare species that appear to be rare anywhere and usually have a scattered geographic distribution; b) deep and intermediate water species that may or may not be Antarctic and sub-antarctic species; they are usually cold-loving but not stenothermal; c) Antarctic and sub-antarctic species that sink at the sub-antarctic or sub-tropical convergences and thence spread northward in intermediate layers, they are cold loving, usually stenothermal species that prefer or need relatively high dissolved oxygen content; d) a group of species that belongs to the Indian Ocean Central Water System, that spread from IOCW to ASSSW and BBSW and avoid temperature lower than 8-9 °C and higher than 19-20 °C; they endure

very low dissolved oxygen content, geographically speaking, they occupy a very extensive vertical and horizontal area; e) the species of Indian Ocean Equatorial Water System; belong to the surface layer and have high oxygen requirements; they are not usually taken in temperature lower than 20 °C. They are to be found in the system of equatorial currents and countercurrents. Those that tolerate high salinity are taken by the monsoonal circulation into the Arabian Sea while those that tolerate low salinity are taken also by the monsoonal circulation into the Bay of Bengal. To the south they may extend into the Mozambique Channel and perhaps even survive in the warm Agulhas Current; f) Bay of Bengal Surface Water species, all of them have high temperature and low salinity requirements and are quite tolerant of dissolved oxygen content variations; g) Arabian Sea Surface Water species are all high salinity and high temperature species that in some cases may tolerate a very low dissolved oxygen content.

6. About one third of the species was found to aggregate at the boundary layer between water masses or along fronts.

7. A great number of hydromedusae is found to tolerate very low oxygen tensions, as low as 0.2 ml/1.

8. Congeneric species are found to have different requirements for the ecological factors considered in this paper and this is interpreted as the mechanism by which closely related species are maintained isolated.

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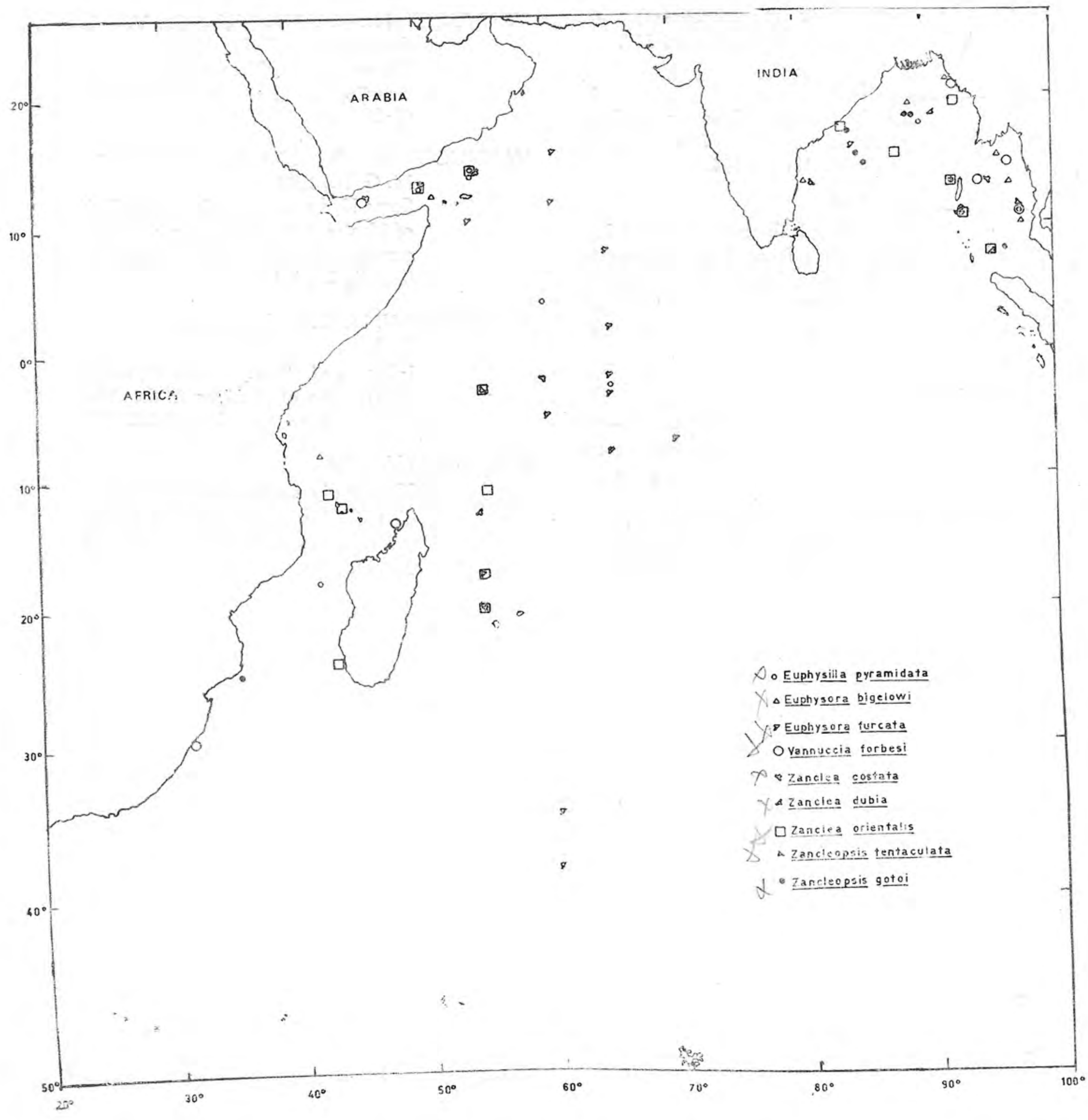
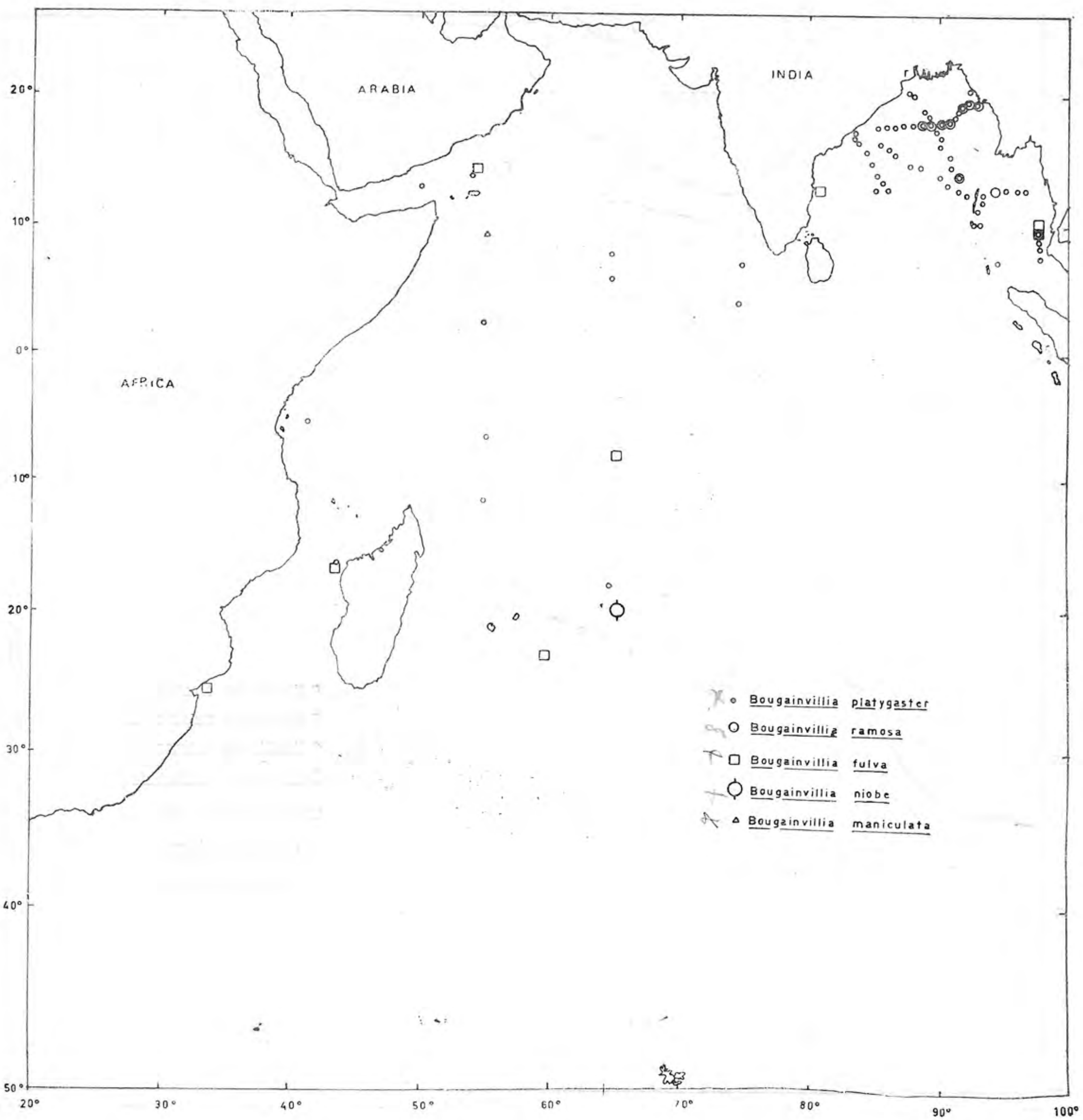
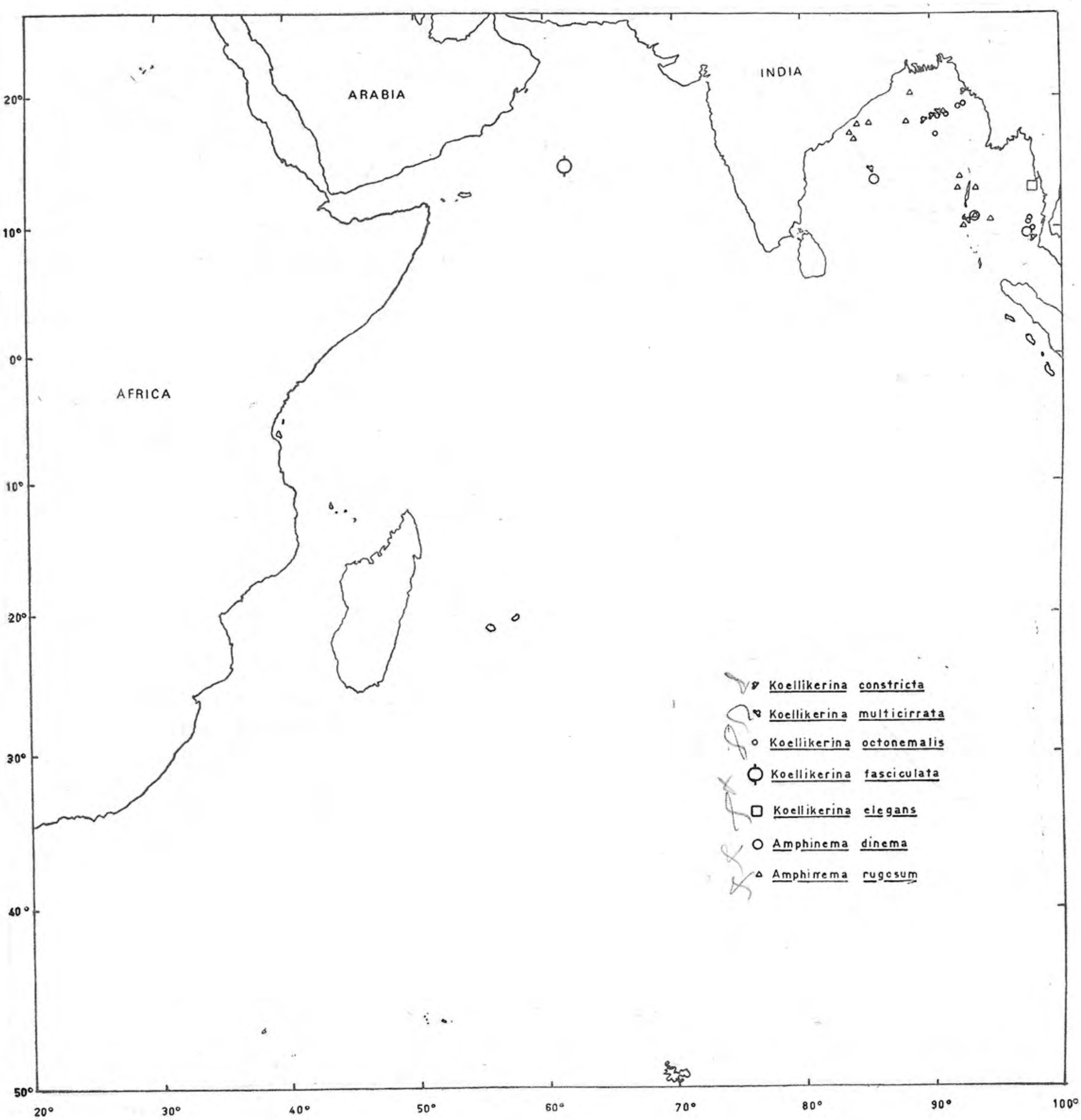


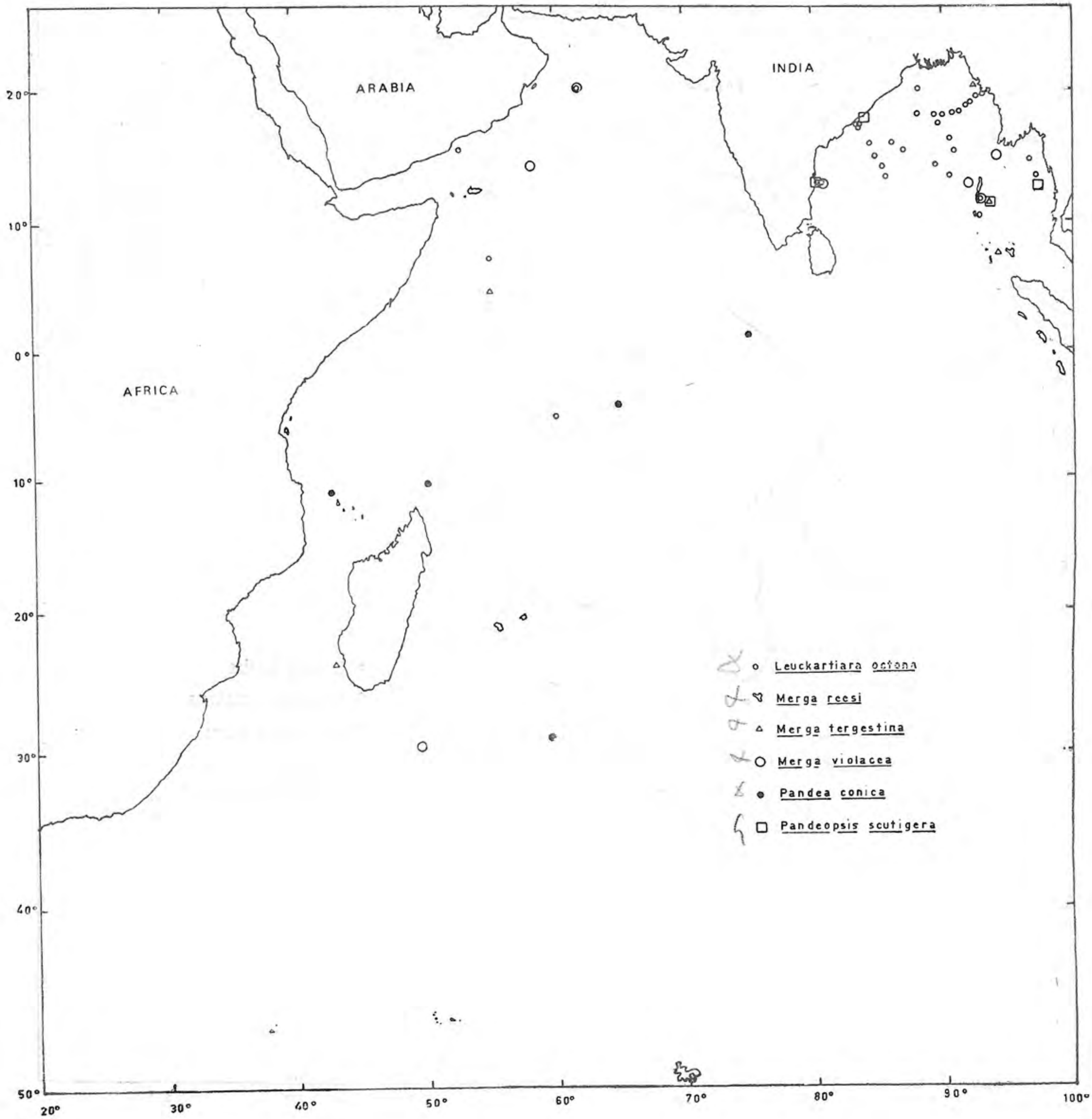
Map 1—Geographic distribution of some of the species that avoid waters with high salinity; when present in the Arabian Sea they sink to greater depth, thus avoiding the high salinity of the surface layer.



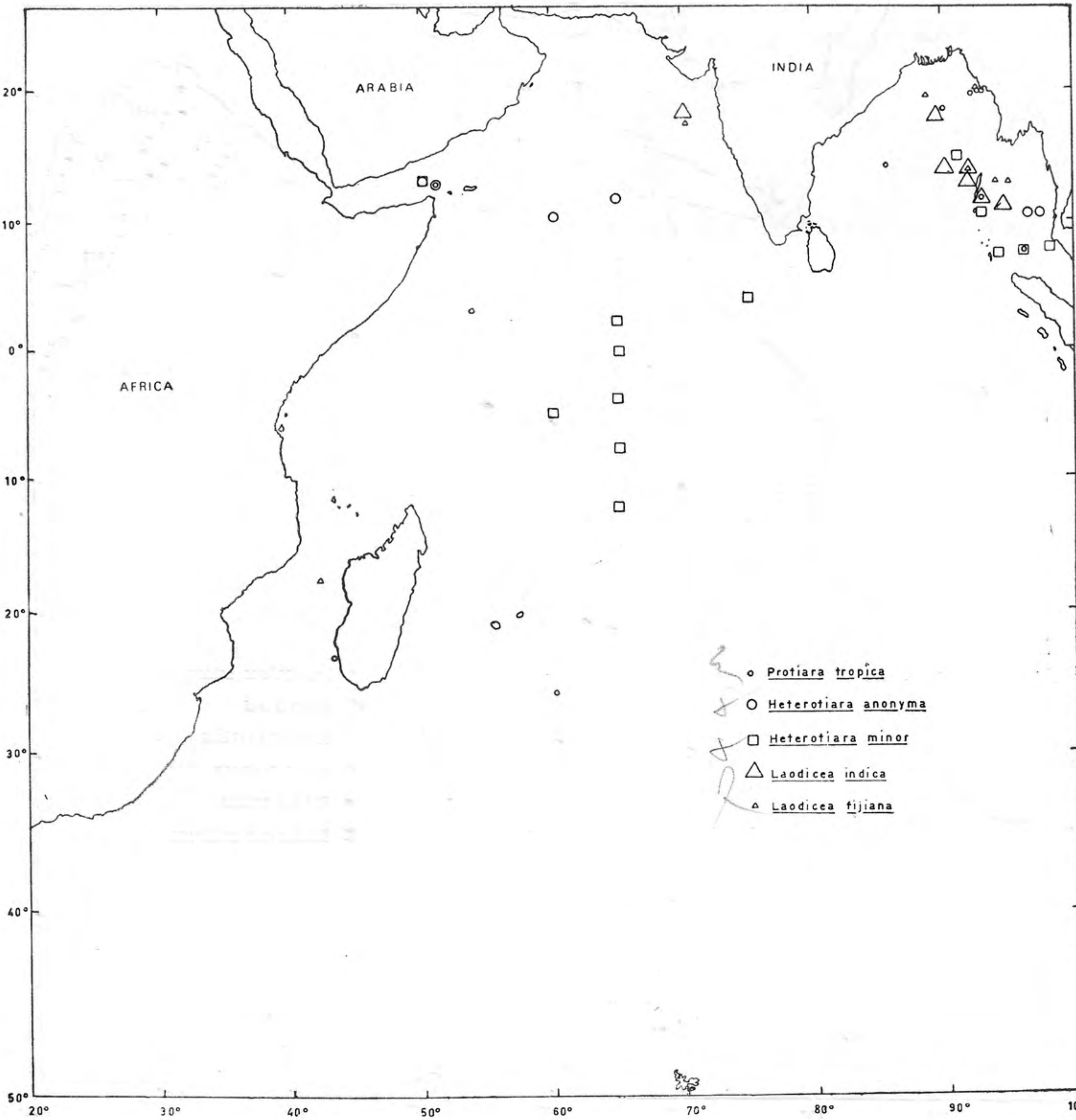
Map 2 – Geographic distribution of the species of the genus *Bougainvillia*. These species avoid very high salinity and cold waters; they are to be found in surface or intermediate layers.



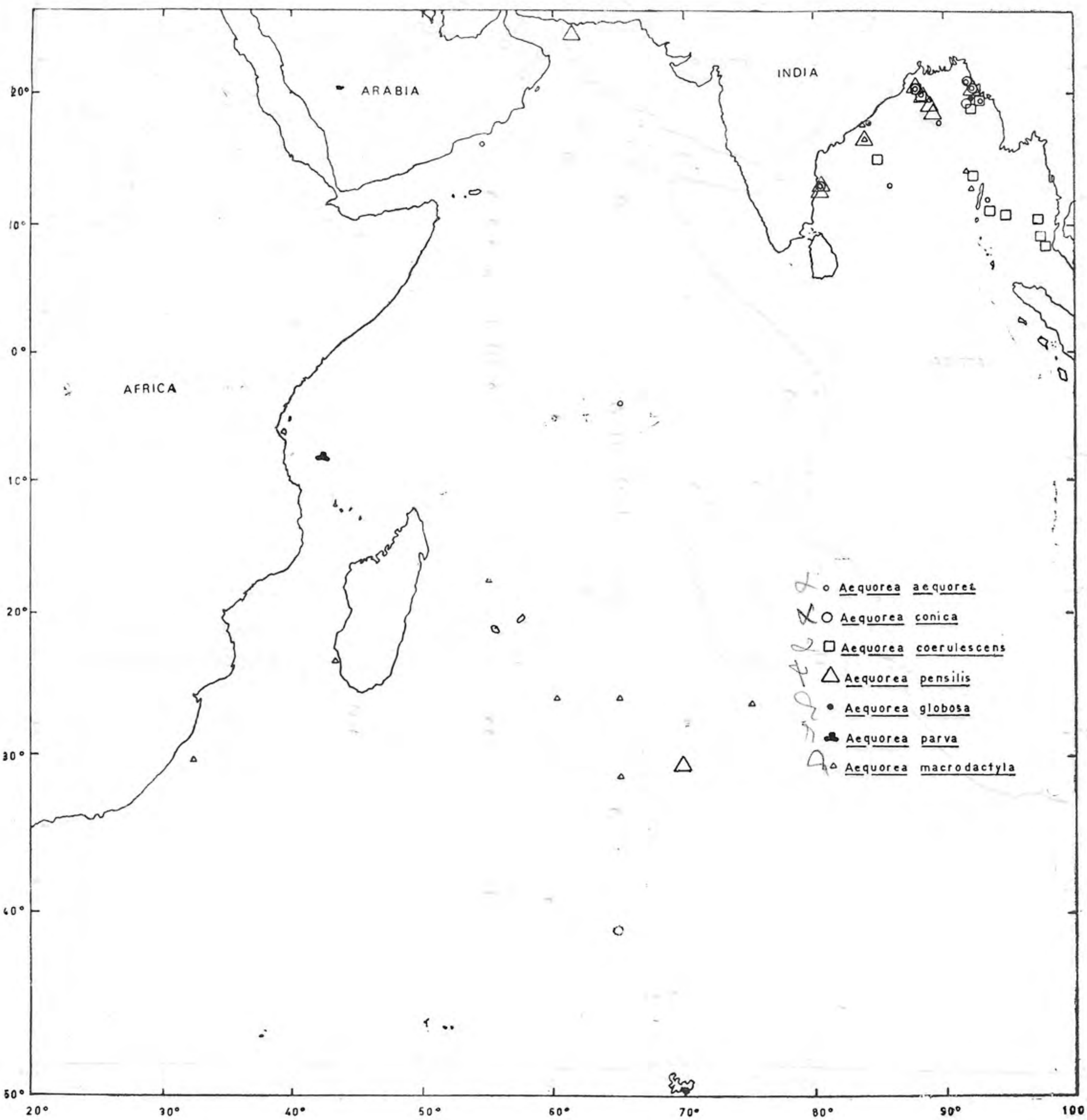
Map 3—Geographic distribution of species restricted to the surface and subsurface waters of the Bay of Bengal. *Koellikerina fasciculata* taken in the Arabian Sea, that may have migrated through the Suez Canal; it is a high salinity species.



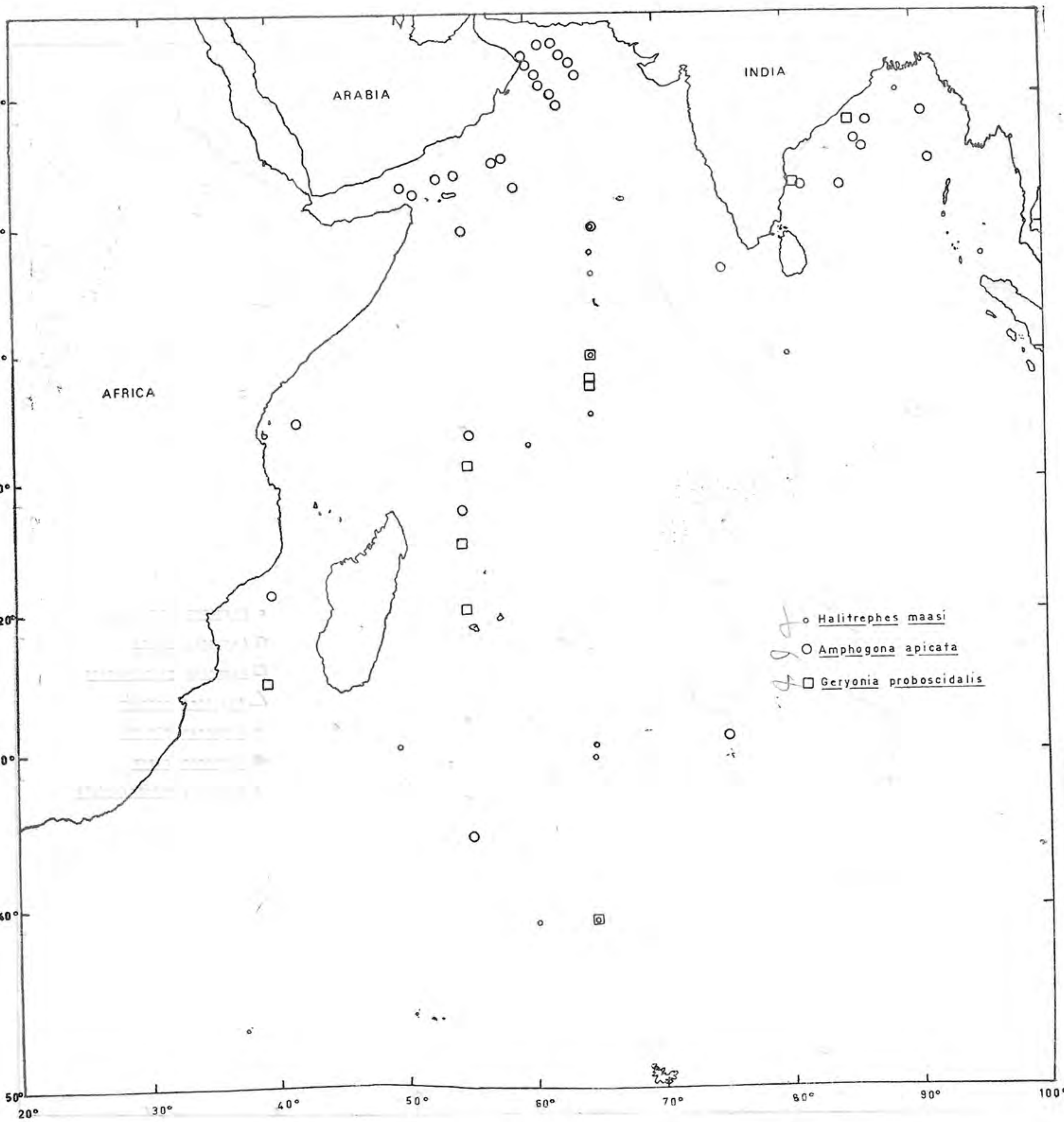
Map 4—Geographic distribution of some low salinity warm water species, taken in surface and intermediate waters.



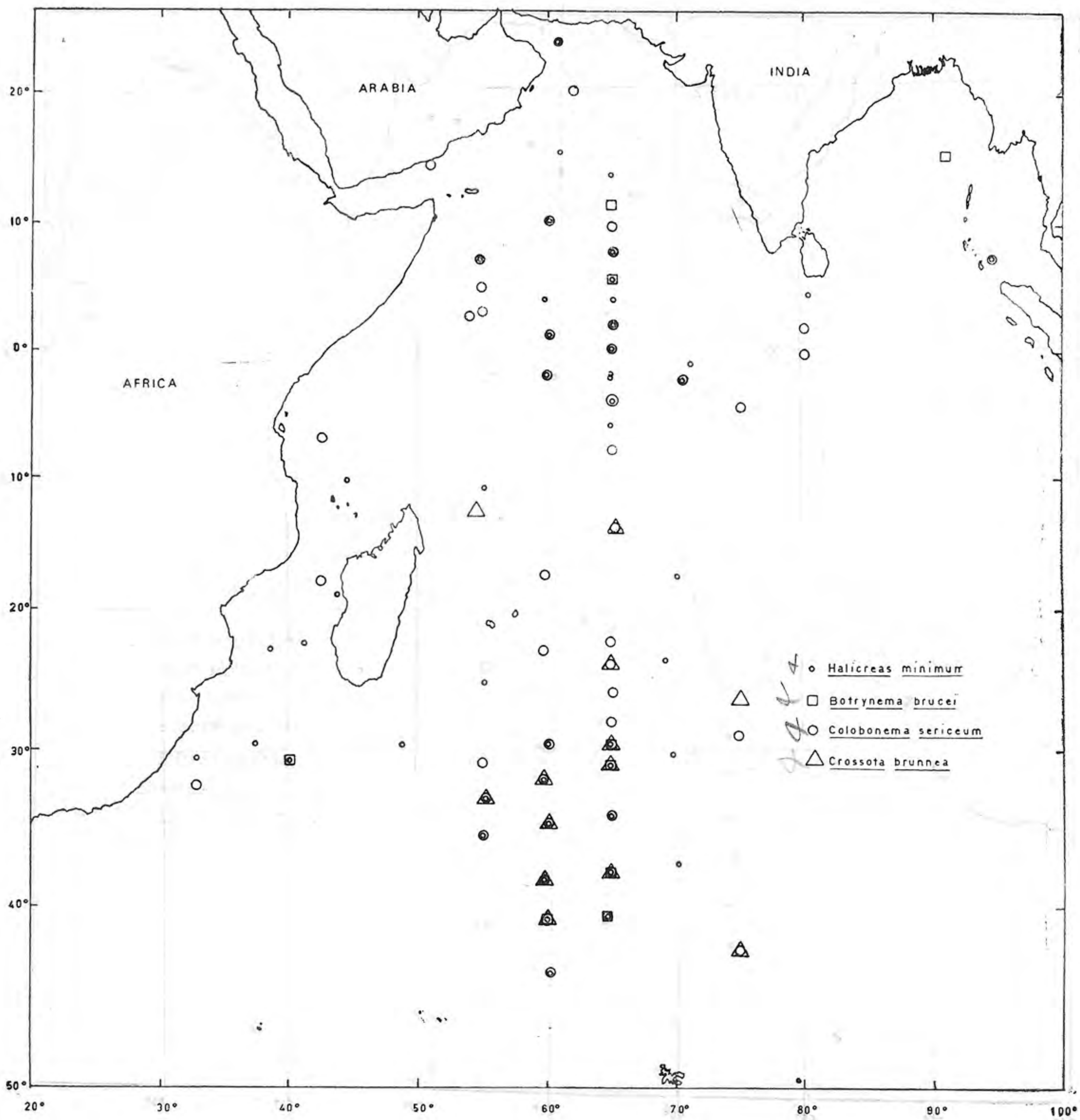
Map 5—Geographic distribution of warm water species from surface and subsurface waters.



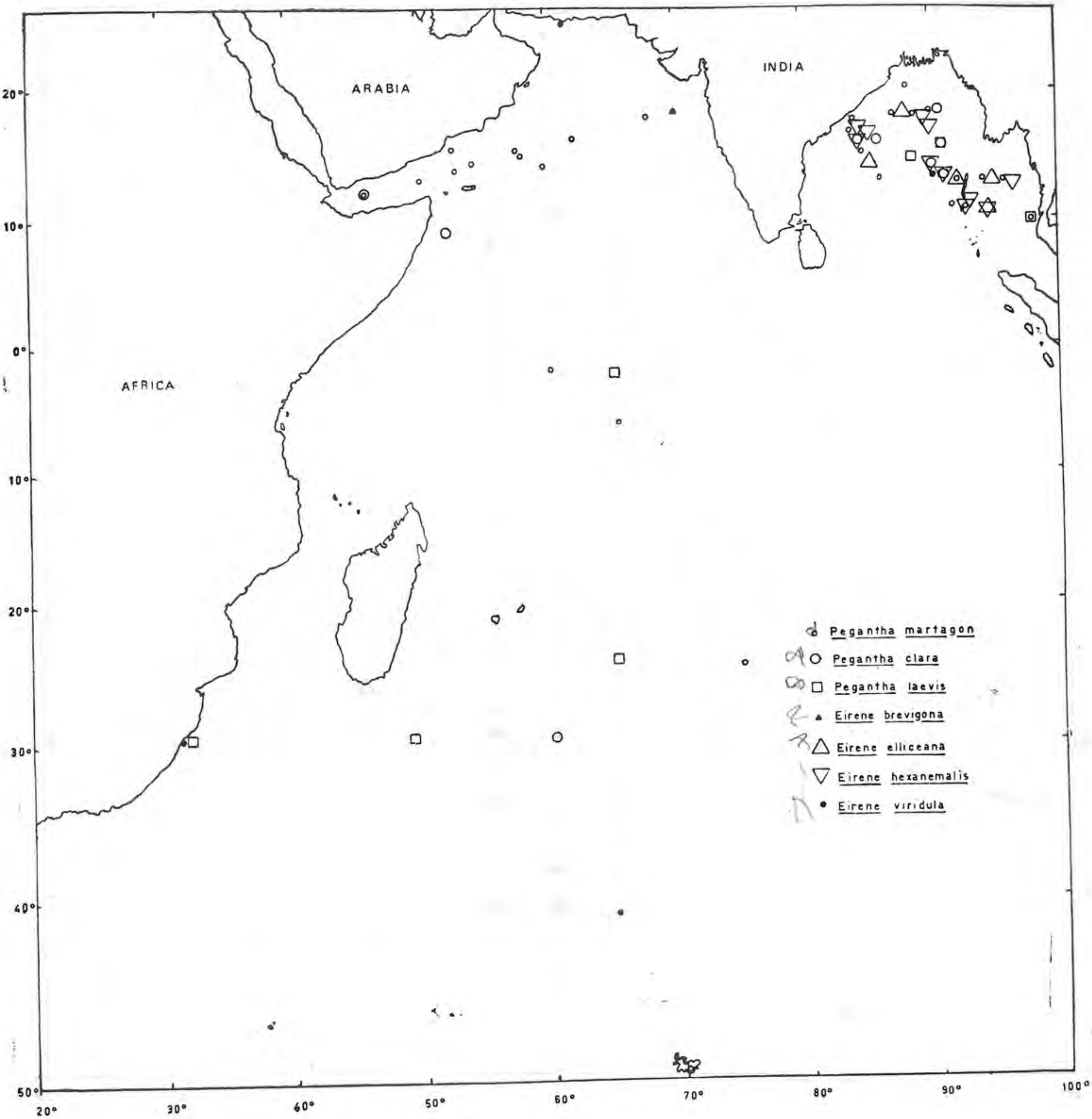
Map 6—Geographic distribution of the species of the genus *Aequorea* with varied patterns, including well pronounced stenohalinity in those restricted to the Bay of Bengal Surface Waters.



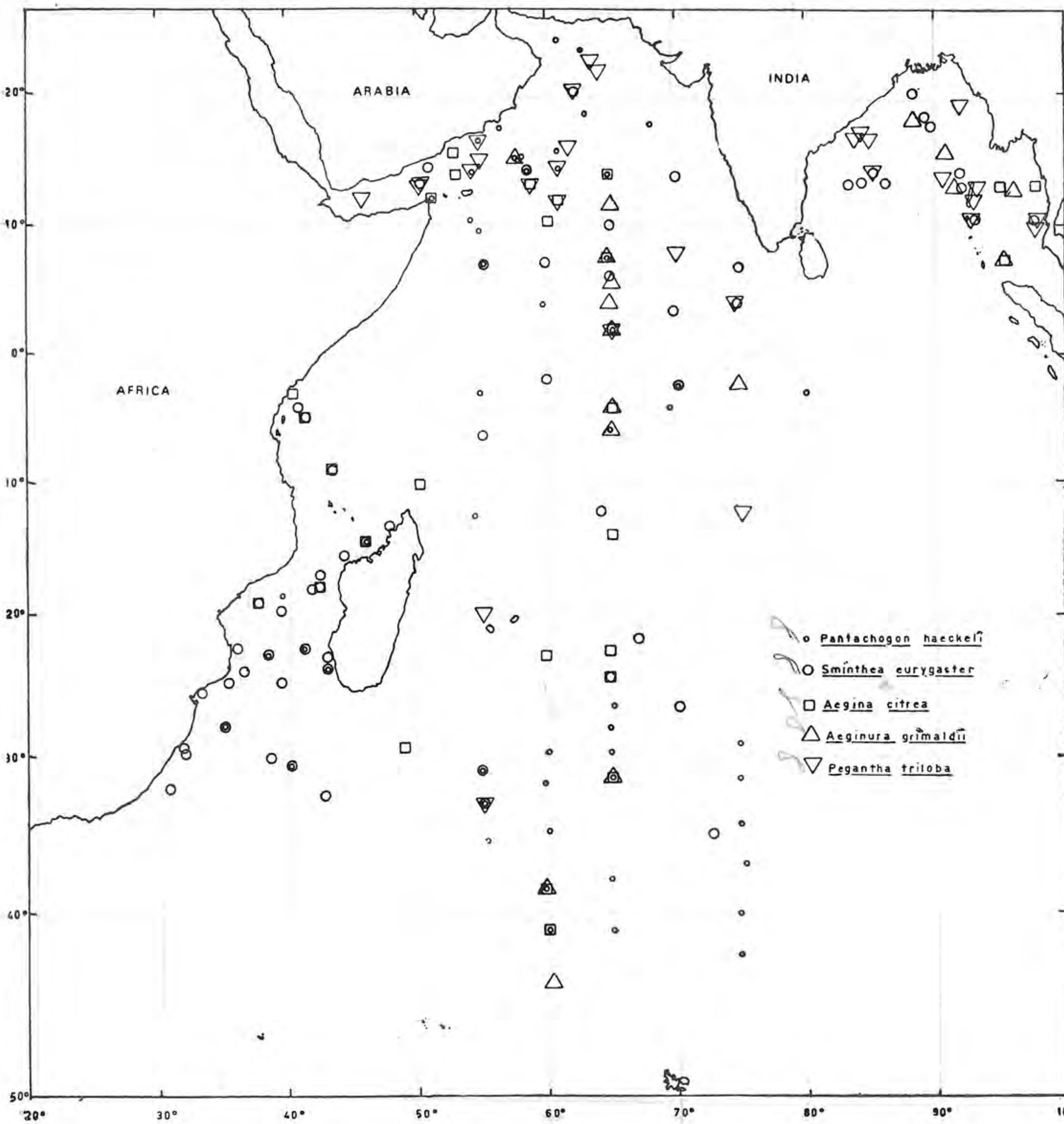
Map 7—Species with a wide geographic distribution due to eurytopic capacities as with *Geryonia proboscidalis* or because they belong to intermediate waters, the Indian Ocean Central Water System, as *Halitrephes maasi* and *Amphogona apicata*.



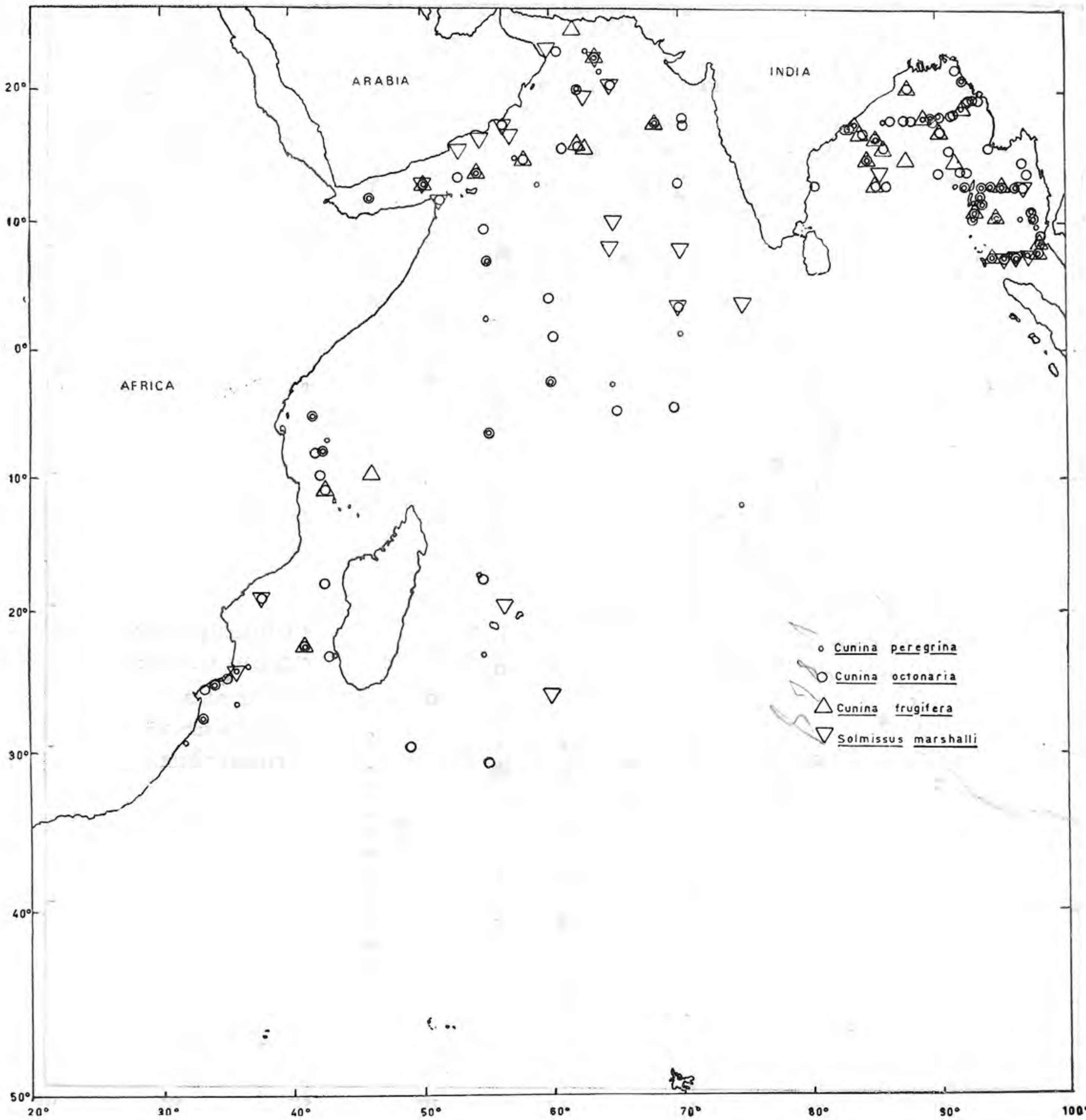
Map 8—Geographic distribution of species of the Antarctic Intermediate Water System. Each extends northwards to a different extent; *Crossota brunnea* was never found beyond the northernmost limit of the AIW.



Map 9—Wide geographic distribution of eurytopic species as compared to the restricted distribution of two stenotopic species *Eirene hexanemalis* and *Eirene elliceana.*



Map 10—Wide geographic distribution of eurytopic species to be found in many different water masses. One of them, however, *Pantachogon haeckeli*, was not taken in the Bay of Bengal.



Map 11—Geographic distribution of the species of the genus *Cunina* and of *Solmissus marshalli*; they are warm water, surface or intermediate water eurytopic species with a wide distribution but were not taken in the colder waters sampled during the IIOE.

TABLE 1.

Bay of Bengal

Depth M	Water Mass Name	Salinity °/oo	Temperature °C	Dissolved Oxygen ml/1	Origin
o ↓ 100-150	Bay of Bengal Surface Water	North dilute 20 or more Transition Southern <34	23–29		Large rivers + South Bay of Bengal Surface Water
100–150 ↓ 1000	Bay of Bengal Sub-Surface Water	34.1-35.0	5-15		Arabian Sea Intermediate Water + North Indian Ocean Deep Water
>1500	Bay of Bengal Deep Water	34.68–34.78	1.6–2.8	3.18-4.17	North ndian Ocean Deep Water + some Antarctic Ocean Bottom Water + some Arabian Sea Bottom Water

Central and Southern Indian Ocean

Depth M	Water Mass Name	Salinity °/oo	Temperature °C	Dissolved Oxygen ml/1	Origin
0-60	Indian Ocean Equatorial Water 1-2 to 6-8°S	34. 0–35.0	26-27	3.40-7.46	Precipitation greater than evaporation
0-150	Indian Ocean South Surface Water 6-8 to 18–25°S	34. 5–35.2	20-26 winter 25-28 summer	3.64-4.83	Precipitation greater than evaporation
0-150	South Australian Surface Water 23–25°S Eastern side	35. 0-35.8	15-20 winter 19-24 summer	3.64–4.83	Precipitation small
0–150	South Central Surface Water 23-40°S Western side	35. 0-36.5	20-26 February 15-21 August	4.27–4.93	Evaporation greater than Precipitation
0-200	South Temperate Surface Water 40-50°S (W) 35–55°S (E)	35. 0–33.8 N to S	N to S 15-5, August N to S 20-27 February	6.22–8.30 N to S	Inflows from Atlantic Ocean by West Wind Drift

TABLE 1 (Contd.)

100-150 ↓ 600-700	Sub-surface Water or Indian Ocean Central Water	34.6→36.0	8-19	0.21-2.09	Sinking surface water at subtropical convergence, flows north
600-700 ↓ 1000-1600	Intermediate Water— AIW and EIW	AIW 34.2-34.8 E W 34.8-35.1	AIW 3-9 EIW 4-10	1.41-4.40 0. 8-2. 0	Sinking at Antarctic Convergence
1000-1600 ↓ 3500	North Indian Deep Water	34.68-34.78	1.6-2.8	3.18-4.17	Arabian Sea Intermediate Water and Antarctic Intermediate Water + Bottom Water
	Antarctic Bottom Water	34.67-34.69	0.24-0.07	4.70-5.27	Sinking along Antarctic + mixing Deep Water
	Indian Ocean Bottom Water	34.69-34.77	0.2-1.47	4.03-4.68	Antarctic Bottom Water+ North Indian Deep Water

Arabian Sea

o ↓ 100-150	Arabian Sea Surface Water	W- >36.5 35. 8-36.5	20-29 North; August 30 January 22-23, Somali Coast SW monsoon 21, Arabian coast SW monsoon	0-50 m 3.94-4.75 50 m down 1.13-2.39	
100-150 ↓ 400	Arabian Sea Sub-Surface Water	Red Sea W- 39.7 Persian Gulf 35.0-36.0	10-19	0.21-2.09	
400 ↓ 1500	Arabian Sea Intermediate Water	36. 5 to 35. 0-35.5	4-13	0.40-1.43	
>1500	Arabian Sea Deep Water	34.68-34.78	<2 below 3000 m <2	3	

TABLE 2

Ecological Distribution of the Hydromedusae Taken During the I. I. O. E.

Species	Salinity controlled	Temperature controlled	Oxygen controlled	Boundary layer	Only in Bay of Bengal	Only in Arabian Sea	Indian Ocean Central Water System	Equatorial System	Upwelling	Antarctic & Sub Antarctic
	1	2	3	4	5	6	7	8	9	10
Ectopleura sacculifera	+	+				+			+	
Euphysilla pyramidata	+			+			+		+	
Euphysora annulata	+	+	+		+					
E. bigelowi		+	+					+		
E. furcata	+	+							+	+
Vannuccia forbesi				high food +			+			
Zanclea costata	+	+	+	+						
Z. dubia				high food +			+		+	
Z. orientalis				+				+		
Zancleopsis tentaculata	+	+		+				+		
Z. gotoi	+	+	+							
Cytaeis tetrastyla	widely distributed, tropical, subtropical, temperate, surface	+						+		
Bougainvillia fulva		+	+					+		
B. platygaster	widely distributed, tropical, subtropical, surface		+	+				+		
Koellikerina octonemalis	+	+		+	+					
Amphinema rugosum	+	+		+	+					
Leuckartiara octona	+	+		+			+			

TABLE 2 (Contd.)

Ecological Distribution of the Hydromedusae Taken During the I. I. O. E.

Species	Salinity controlled	Temperature controlled	Oxygen controlled	Boundary layer	Only in Bay of Bengal	Only in Arabian Sea	Indian Ocean Central Water System	Equatorial System	Upwelling	Antarctic & Sub Antarctic
	1	2	3	4	5	6	7	8	9	10
Merga tergestina	+	+	+							
Merga violacea							+			
Pandea conica			+					+		
Pandeopsis scutigera	+	+	+		+					
Protiara tropica		+	+	+			+			
Heterotiara anonyma	+			+						
Heterotiara minor				+			+			
Laodicea fijiana	+	+	+	+				+		
L. indica	+	+	+	+	+					
Halistaura bruuni	+	+		+	+					
Phialidium hemisphericum	+	+	+							
Eucheilota menoni		+	+	+				+		
I ovenella cirrata	+	+	+		+					
Octophialucium indicum	+	+	+		+					
Phialucium carolinae	+	+	+	+	+					
Phialucium militentaculatum	+	+	+		+					

TABLE 2 (Contd.)

	1	2	3	4	5	6	7	8	9	10
Eirene elliceana	+			+	+					
E. hexanemalis	+	+		+	+					
E. viridula			+	+				+		
Aequorea aequorea	+	+	+					+		
A. coerulescens	+	+	+	+	+					
A. conica	+		+							
A. macrodactyla			+	+			+	+	+	
A. pensilis			+ ?	+			+	+		
Olindias singularis	+	+	+		+					
Proboscidactyla ornata	+			+			+	+	+	
Liriope tetraphylla		widely	distributed,							
Geryonia proboscidalis	+	+	+	+			+	+		
Botrynema brucei	+	+	+	+						+
Halicreas minimum	+	+	+				+			+
Haliscera racovitzae	+	+	+				+			+
Halitrephes maasi	+	+		+			+		+	+
Aglaura hemistoma		widely	distributed,							
Aglantha elata	+						+			?
Amphogona apicata	+			+			+			

TABLE 2 (Cond.)

	1	2	3	4	5	6	7	8	9	10
Colobonema sericeum	+	+	+	+			+			+
Crossota alba	+	+					+			+
Crossota brunnea	+		+							+
Pantachogon haeckeli							+			+
Persa incolorata	+			+			+			
Rhopalonema velatum				+			+	+		
Sminthea eurygaster				+			+			
Tetrorchis erithrogaster							+		+	
Aegina citrea							+			+
Aeginura grimaldi	+	+					+			+
Solmundella bitentaculata		+		+			+			
Pegantha clara		+	+	+				+		
Pegantha laevis			+					+		
Pegantha martagon			+				+		+	
Pegantha triloba				+			+			
Cunina duplicata	+	+							+	+
Cunina frugifera		+	+	+			+			
Cunina octonaria				+			+	+		
Cunina peregrina				+			+	+		
Cunina tenella				+			+			
Solmissus marshalli				+			+		+	

ON THE OCCURRENCE OF DAIRELLA LATISSIMA AND DAIRELLA CALIFORNICA (AMPHIPODA) IN THE INDIAN OCEAN

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ABSTRACT

Studies on the taxonomy and distribution of the family Dairellidae (Hyperiidea, Amphipoda) of the IIOE collections are presented. Dairellidae comprises only one genus, *Dairella* (Bovallius, 1887) with two species, *Dairella latissima* and *Dairella californica*. Both the species were originally recor ded from the tropical and temperate regions of Atlantic and are deep water forms mostly collected at depths varying between 1000 m — 3000 m. *D. latissima* was known to occur in the Atlantic and Mediterranean and also in the Gulf of Aden, where as, *D. californica* was recorded from the Pacific. The present record of the species form the first of its kind from the Indian Ocean.

INTRODUCTION

The report presented here arise from the study on the taxonomy and distribution of hyperiid amphipods of the IIOE collections carried out at the Indian Ocean Biological Centre. Out of 1927 samples collected from 200-0 m with IOS net only two had representatives of the family Dairellidae.

This family was treated as a sub family, Dairellinae by Bovallius (1887) under the family Phronimidae. Later it was raised to a separate family and the recent classification of Hyperiidea by Bowman & Gruner, 1968 (unpublished) has treated it as an independent family under the super family Phronimoidea.

Only one genus *Dairella* with two species, *D. latissima* and *D. californica* is hitherto known in the family Dairellidae. From the two samples of the present collections (Table 1), one juvenile male belonging to each of these species was obtained. Previous records of the species being from the Atlantic and Pacific oceans, opportunity is taken here to record them for the first time from the Indian Ocean. Detailed description of *D. californica* (male) is given since the original description of this species is based on a female.

ORDER AMPHIPODA
Sub-order Hyperiidea
Super family Phronimoidea
Family Dairellidae (Bov.) Vosseler 1901
Genus *Dairella* Bovallius, 1887

Dairella latissima Bovallius, 1887.

Dairella latissima. Bovallius, 1887, p. 24; 1889, p.336; Stebbing, 1888, p.342; Vosseler, 1901, p.51; Tattersall, 1906, p.18; Stewart, 1913, p.254; Stephensen, 1924, p.112; Spandal, 1927, p.169; Pirlot, 1929, p.108; Barnard, 1932, p.282; 1937, p.184; Chevreux, 1935, p.184; Reid, 1955, p.19; Grice and Hart, 1962, p.300; Dick, 1970, p.36.

Material examined: One juvenile male; Length 8.5 mm

Diagnostic features:

Head shorter than the first three peraeonal segments: first two peraeonal segments coalesced leaving a little trace of segmentation on the dorsal side. The fifth pair of peraeopods larger than the fourth, femur longer than the carpus. Femur of the last three pairs moderately dilated; first pair of uropods do not reach the apex of the last pair; rami of the last pair broadly ovate.

Remarks

The original description by Bovallius (1887) agrees fairly well with the present specimen (Fig.1) except in the following. The second and third joints of the first and second pairs of peraeopods (Fig. 1 D, E.) with small spines at their distal mar-

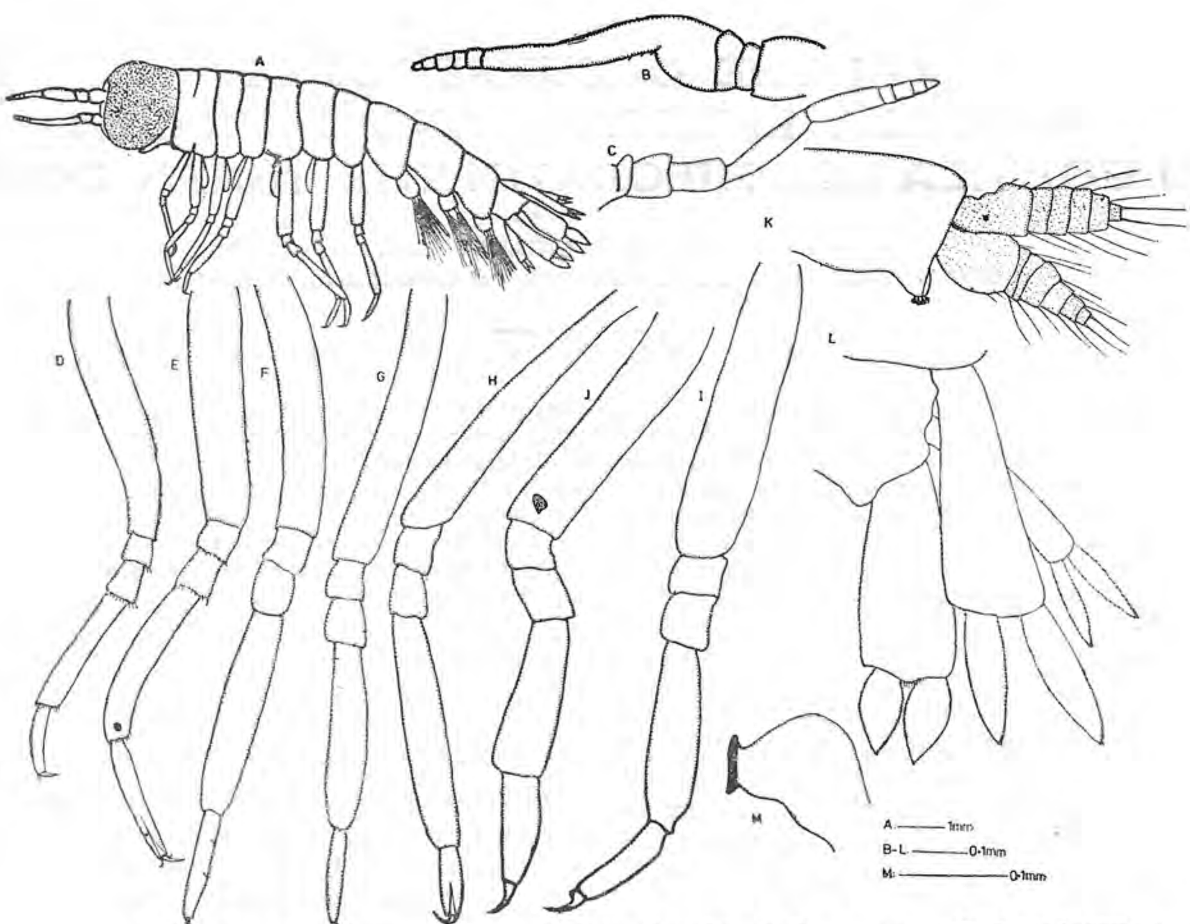

Fig. 1- A. *Dairella latissima* (young male from the side); B. First antenna; C, Second antenna; D- J. Peraeopods (one to seven); K. Pleopod; L. Urus; M. Mandible

gin. At the base of the dactylus of the second pair there are two spines, a smaller inner and a sharply curved outer. Dactylus of the sixth pair (Fig. 1. I)is quite thick and sharply curved.

Distribution

Atlantic:

A deep water species (Stephensen, 1924) previously recorded from the tropical and temperate regions of north Atlantic (Bovallius and Vosseler), off Cape Verde Islands (Stebbing), west coast of Ireland (Tattersall), west of British Islands (Stephensen), centre of Gulf of Biscay between Azores and Lisbon and between Tristan da Cunha and Cape of Good Hope (South equatorial current) (Spandal), between New York and Bermuda (Grice and Hart).

Mediterranean:

Between Cape Crosso and Monaco (Vosseler), Gulf of Genova and south of Formentera (Chevreux) and from the western basin of Mediterranean (Stephensen).

Indian Ocean:

One female specimen was recorded by Barnard (1937) from the Gulf of Aden which forms an adjacent body of water to the Indian Ocean. The present record forms the first record of a male from the Indian Ocean and it also indicates a considerable extension of its geographical range to southeast.

Dairella californica Bovallius, 1887.

Paraphronima californica (Bovallius, 1885) No.14, p. 11.

Dairella californica Bovallius, 1887, No. 16, p.24;

Bovallius, 1889, part 1 & 2, p.333.

Material examined: One juvenile male; Length 11.5 mm.

***Diagnostic features*:**

Head as long as the first three peraeonal segments together. First two peraeonal segments coalesced leaving only a little trace of segmentation. The fifth pair of peraeopods longer than the fourth unlike in the female in which it is shorter, femur longer than the carpus. First pair of uropods reach the apex of the last pair, rami of the last pair narrowly ovate.

Body broad, not compressed, the head and peraeon together longer than pleon.

Head globular, inflated, rising above the dorsal side of the peraeon, deeper than long; antennae fixed on the front side of the head inside antennal groove.

Eyes divided into four portions and occupy the whole surface of the head.

First pair of antennae (Fig.2 B) not fully devetoped, first joint of the peduncle longer than the following together, the third joint is longer than second. Flagellar joint finger-like and twice as long as the whole peduncle with a small notch at the inner side, olfactory hairs not developed.

Second antennae (Fig. 2 C) not fully formed, the third segment of the peduncle is longer than the last peduncular joint and the following are short. Flagellum with sixteen joints and under margin without hairs.

The mouth parts are closely like that of the female (Bovallius, 1889).

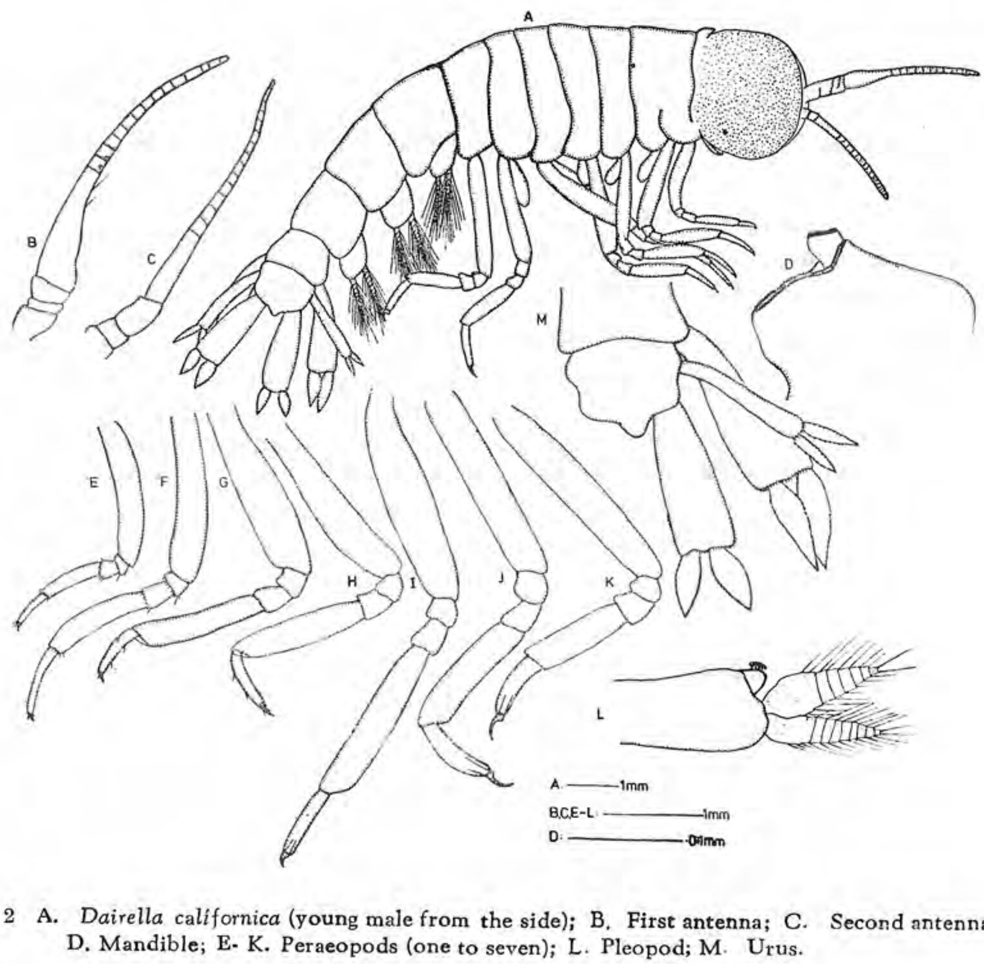

Fig. 2 A. *Dairella californica* (young male from the side); B. First antenna; C. Second antenna; D. Mandible; E- K. Peraeopods (one to seven); L. Pleopod; M. Urus.

The peraeon (Fig. 2 A), body broad, depressed as in isopods. First and second segments coalesced, the epimerals being free; along the front margin of the first segment there is a duplicature of the integument probably serving the articulation of the head, third segment short, equal to fourth, the sixth and seventh longer. Epimerals coalesced with the corresponding segments but their upper limit marked by a ridge as in *Dairella latissima*. Branchial vesicles are five pairs, bottle shaped, attached to the second and the four following peraeopods, fourth and fifth are comparatively longer.

First peraeopod (Fig. 2 E) shorter than the second, femur longer than the following segments together, second, third and fourth segments with small spines towards the distal margin, the fourth slightly curved. Metacarpus short with spines at the distal margin, dactylus simple and not so long.

Second peraeopod (Fig. 2 F) closely resembles the first except being longer.

Third and fourth peraeopods (Fig.2 G&H) have both carpus almost as long as the femur, metacarpus with three to four spines, dactylus more developed and slightly curved than the preceeding pair.

Fifth peraeopod (Fig. 2 I) longer than the following two, carpus shorter than femur; metacarpus narrow, dactylus curved.

Sixth and seventh pairs (Fig. 2 J & K) are almost equal in length, femur thick especially the sixth, dactylus well developed, sharply curved.

Pleon (Fig. 2 A) deeper than peraeon, hind corner of the pleonal segments slightly rounded.

Rami of pleopods (Fig. 2 L) shorter than peduncle, coupling spines planted in a straight row.

Urus (Fig. 2 M) longer than the last pleonal segment, first ural segment slightly broader than the last coalesced segment.

Uropod (Fig. 2 M): First pair reach beyond the apex of the 3rd pair, peduncle laminar, twice as broad at the apex as at the base. Inner margin fingered with spine-like teeth; rami lanceolate, equal in length, serrated on both margins and widely placed. In the second pair, peduncle much narrower with small spines towards the inner margin, raim lanceolate, sub-equal, outer being longer and serrate on both margins. Peduncle of the third pair broad, laminar and constricted at the base, the outer margin fringed with minute spines, rami equal in length, distant from one another, inner ramus serrated on both margins, outer serrated only on the inner margin.

Remarks:

The original description of this species was based on a female by Bovallius (1887) and the present record of the male specimen agrees fairly well with the original except mainly in the characters like the fifth leg longer than the fourth, presence of a second pair of antennae, and antennal groove. The specimen on hand being a juvenile male, first and second antennae are not fully formed.

Distribution:

Originally female of this species was recorded from the temperate and tropical regions of the Pacific off the west coast of California (Bovallius, 1887). This is the first record of this species from Indian Ocean.

DISCUSSION

It is not easy to distinguish males of *Dairella latissima* and *D. californica* as it is possible in the case of the females of the two species. The characters given by Bovallius (1889), apply mainly to the females. For males the most reliable character seems to be the form of the third uropods (Fig 1 L & 2 M).

The members of the family Dairellidae are deep water forms (Stephensen 1924). *Dairella latissima* has been mostly collected at depths varying between 1000 m — 3000 m except in one or two instances where it has been recorded from the subsurface waters (Chevreux, 1913). In the present collections *D. latissima* has been recorded from a haul made from 200 — 0 m and *D. californica* from 100 — 0 m (Table 1). The thermocline at these stations was observed at 50 m and 100 m (Table 1)respectively. From the vast collections

Table 1. Station position and hydrographic data

Vessel	Cruise No.	Station No.	Date	Latitude & Longitude	Time (local) hrs	Wire	Depth (m)(sounding)	Temperature °C at		Salinity °/oo at		Thermocline at m.
								0 m	100 m	0 m	100 m	
Anton Bruun	A	12-B	3-3-63	17°36'N-68°30'E	1630	100-0	3400	27.97	25.12	35.58	36.23	100
								0 m	200 m	0 m	200 m	
,,	5	327	30-4-63	06°51'N-75°02'E	0849	200·0	2699	30.11	14.17	33.53	35.09	50

made mostly from 200 — 0 m their presence in only two stations points to the fact that either they are mostly confined to deep waters as suggested by Stephensen (1924) or their distribution is quite restricted in the Indian Ocean.

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ON A COLLECTION OF PLANKTONIC DECAPODA (PENAEIDEA) FROM THE SOUTH WEST COAST OF INDIA

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ABSTRACT

Planktonic decapoda belonging to the tribe Penaeidea sorted out from collections made during two cruises on the vessel 'Blue Fin' off Cochin, Alleppey and Quilon are described. The species *Lucifer typus* is reported for the first time from the Arabian Sea. Acanthosoma stage of *Sergestes crassus*, mastigopus stage of *Sergestes orientalis*, mysis stages of *Trachypenaeus curvirostris*, *Parapenaeopsis stylifera* and *Parapenaeus investigatoris* and protozoea stage 3 of *Solenocera crassicornis* are described for the first time.

INTRODUCTION

The present contribution deals with the Decapod larvae (Penaeidea) sorted out from the plankton collections made during two cruises conducted in the fishing-cum-training vessel "Blue Fin" under a joint project of National Institute of Oceanography and Central Institute of Fisheries Operatives off Cochin, Alleppey and Quilon coasts in depths ranging upto 1000 metres. The samples were collected in vertical hauls from 200 metres or less to surface. In the context of the various decapod species constituting the local inshore fishery as well as some of the caridean prawns increasingly coming into the commercial fishery from the deeper waters of the continental slope off the south west coast of India, the study of the decapod larvae is highly pertinent. Although the importance of these studies has been fully demonstrated by the extensive works of Gurney (1924, 1927, 1937, 1942) followed by Williamson (1967, 1970), Heegaard (1966, 1969) and others, this has attracted comparatively lesser attention in India. Menon (1933, 1937, 1940) did some pioneering works on the decapod larvae of the east coast of India from the Madras plankton. Later (1952) he studied the development of a penaeid species from the south west coast of India also. Pillai (1955) described some decapod larvae occurring in the plankton of the Trivandrum coast. Sankoli (1967), Shenoy (1967), Mohamed *et al.* (1968) among others dealt with developmental stages of some of the decapod crustaceans occurring along the west coast of India. So a series of plankton samples collected in the Indian Ocean Biological Centre was utilised to make a study of the various larval forms occurring in these waters and the Penaeidean decapoda are dealt with in the present report.

TRIBE PENAEIDEA

Family *Sergestidae*

Subfamily *Sergestinae*

Sergestes crassus Hansen

Gurney & Lebour, 1940: 24-27, Figs. 15-19 (Larval stages)

Material : St. No. 5A. 25-2-1970.
1 specimen, acanthosoma -1, 2.8 mm (Fig.1).

The single specimen of acanthosoma stage I to hand resembles so well with the figures and descriptions given by Gurney & Lebour (1940) from Bermuda waters of the same stage of *S. crassus* that there is no hesitation to identify the specimen as belonging to that species. Rostrum which is spiny extends a little beyond the antennular peduncle; the antero-inferior margin of the carapace with 9 spinules posterior to the lateral spine.

This is the first record of this larval stage from outside Bermuda waters.

Sergestes orientalis Hansen

Hansen, 1919: 22-26, Plate II, Fig.2 (larval stages)
Menon, 1940: 11-13, Fig.33 (acanthosoma)

Material: St. No. 5B. 25-2-1970.
1 specimen, mastigopus stage, 4.8 mm (Fig. 2).

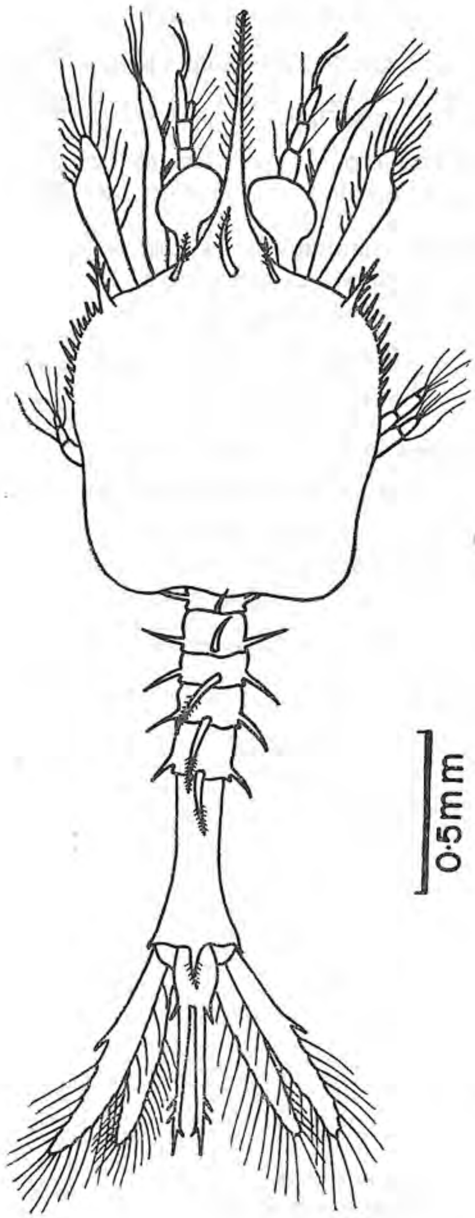

Fig. 1. *Sergestes crassus*—acanthosoma I.

Gurney and Lebour (1940) described *S. edwardsi* as the only species with the acanthosoma with median ventral abdominal spines on somites 1 to 5. According to Hansen (1919) *S. orientalis* and *S. edwardsi* are very closely allied species, although he does not mention the median ventral abdominal spines in *S. orientalis*. Menon (1940) described acanthosoma stage II of *S. orientalis* from the Madras coast and he noticed the presence of the median ventral spines on abdominal somites. The present specimen, an early mastigopus stage also possesses the median ventral abdominal spines on segments 1 to 5 and is identified as belonging to *S. orientalis*. The number of spines and other characters of the carapace agree with the description given by Hansen (1919). This is the first record of the mastigopus stage from the Arabian Sea. The species is known to have a wide distribution in the Indo-Pacific.

Acetes erythraeus Nobili

Menon, 1933: 3-17, pt. I-III, Figs. 1-40 (larval stages)

Material: St. No. 1 24-2-1970.
1 specimen, Protozoea III.

The specimen of protozoea stage III is quite in agreement with the description and figures of Menon (1933) and differs from the same stage larva of *A. cochinensis* described by Rao (1970) from more or less the same locality of the present collection, in the presence of 6 pairs of spines on the telson. As Menon's description of the larval stage of the species is from Madras coast this is the first time this larva is reported from the west coast of India. The adults have been recorded from Trivandrum coast by Kurien (1954).

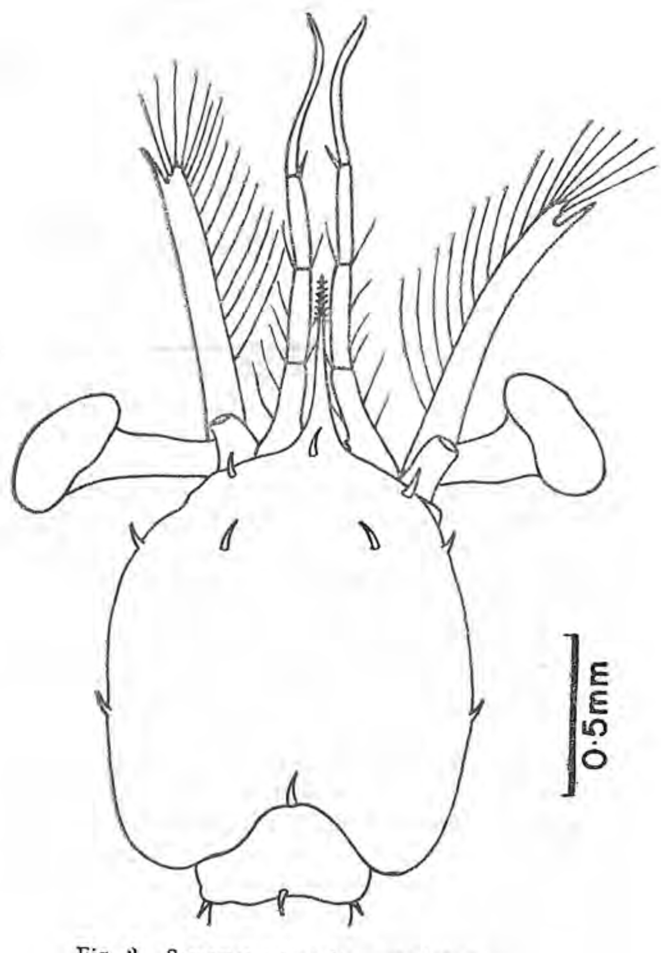

Fig. 2. *Sergestes orientalis*—mastigopus

Acetes cochinensis Rao

Rao 1970: 298-320, Figs. 1-10 (adult and larval stages)

Material: St. No. 9. 25-2-1970.
3 juvenile specimens, 5.6-6.0 mm.

This species has been recently described from Cochin waters by Rao (1970) and the specimens to hand are in agreement with his descriptions.

Subfamily *Luciferinae*

Lucifer typus H. Milne Edwards

Hansen, 1919: 53-55, Pl. 4, Figs. 6 a-k (adult)
Williamson 1966: 33; 1970:4 (1 young male).

Material: St. No. 11. 25-2-1970.
1 male and 1 female (Figs. 3 a-c)

Lucifer hanseni Nobili

Hansen 1919: 63-65, Pl. V, Fig. 4 a-o.

Menon 1940: 7-8; Figs. 13-22 (larval stages)

Material: Numerous specimens of larval stages, juveniles and adults from most of the stations.

This is a common species met with in these waters and the larvae as described by Menon (1940) commonly occur in these waters.

Family *Penaeidae*
Subfamily *Penaeinae*

Penaeus indicus Milne Edwards

Menon 1937: 2-5, Figs, 1-14 (Protozoea stages)

Material: St. No. 1. 24-2-1970.
1 specimen, Protozoea II.

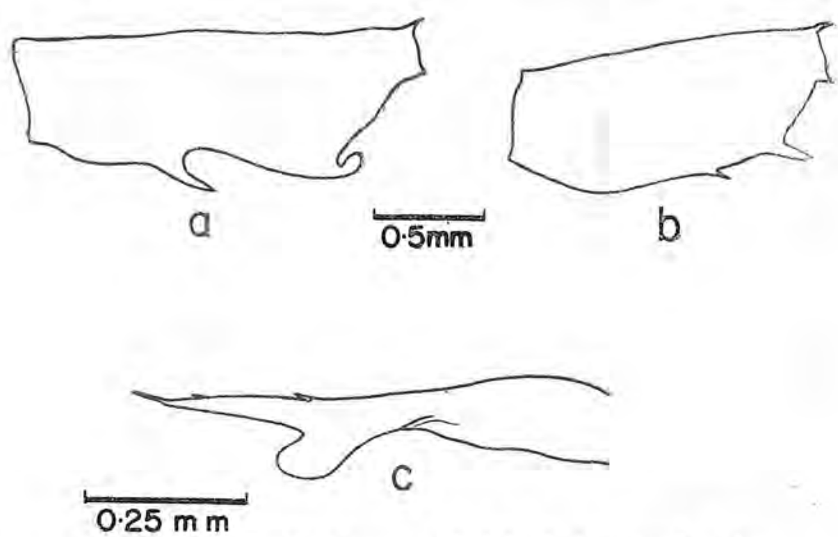

Fig. 3. *Lucifer typus*—a. 6th abdominal segment in male.
b. 6th abdoiminal segment in female. c. telson of male

According to Hansen (1919), the Copenhagen Museum possesses specimens of this species from the Bay of Bengal (Galathea), Manila and from other places. Williamson (1969 and 1970) recorded the species from Israel waters and Red Sea respectively. This is the first record of the species from the Arabian Sea, thus establishing a continuity of distribution through these waters.

As shown in Fig. 3 the curved swollen posterior spine on the 6th abdominal segment in the male is prominently seen. As figured by Hansen (1919) the posterior margin of the ventral protuberance on the telson is quite remote from the tip. Posterolateral spine on the exopod of uropod is almost at the tip.

The presence of a supraorbital spine with a small spinule on its lateral margin (Menon 1937) is the most important character by which protozoea, stage II of this species could be identified. This character is quite clear in the specimen to hand. The spines on the telson number 7+7. Menon has reported this stage larva from the east coast of India. Hence this is the first report from the west coast .

Mohamed *et al.* 1968: 489-91, Fig. 1 (postlarva-1)

Material: St. No.11 and 19 B. 25-2-1970 and 9-4-1970.

2 specimens, postlarva 3, 8 mm length.

Rostrum with 4 teeth, anterior-most being very small, exceeding the eye slightly; hepatic spine well developed. Telson spines same as on postlarva I described by Mohamed *et al.* (1968). Pereopods without exopodites. Pleopods uniramous and decreasing in length from 1st to 5th pair.

Metapenaeus dobsoni (Miers)

Menon 1952: 80-93, Figs. 1-60 (larval stages)
Mohamed *et al* 1968: 496-97 (postlarva-1)

Material: St. No. 24. 10-4-1970.
1 specimen, Postlarva-1, 3.1 mm.

The specimen to hand agrees well with the descriptions given by Menon (1952) and Mohamed *et al.* (1968).

Trachypenaeus curvirostris? (Stimpson)

Pearson 1939: 39-53 (larval stages of *Trachypenaeus constrictus)*

Cook 1965: 437-47 (key to larvae).

Kirkegaard 1969: 15-25 (larval stages of *Trachypenaeus fulvus*)

In assigning few mysis stages in the present collection to the genus *Trachypenaeus*, the key for identification of mysis stages given by Cook (1965) and other publications on larvae of various genera and species have been used. The absence of hepatic spine on the carapace, presence of rostral spine, ventral antero-lateral spine and antennal spine on carapace from the first stage mysis onwards, the prominent median posterodorsal spine on the 5th abdominal somite, the spine formula of 8+8 on the telson, slight hump posterodorsally on the third abdominal somite, the absence of lateral spine on the 5th abdominal somite as well as posterodorsal median spine on 4th abdominal somite and the size of the early mysis stage in comparison with other species are important characters by which, by a process of elimination these mysis stages have been ascribed to the genus *Trachypenaeus*. The only species of the genus fairly common in the waters of the south west coast of India (George, 1971) is *T. curvirostris* (Stimpson). Hence these mysis stages may be tentatively assigned to this species. Pearson (1939) described the larval stages including two mysis stages of *T. constrictus* from the South Atlantic. Kirkegaard (1969) reported the larvae of *T. fulvus* from Australian waters. The larval stages of this genus is recorded for the first time from Indian waters.

Material:

Mysis stage I - 1 specimen 3.2 mm - St. No. 8. 25.2.1970.

,, ,, II - 3 specimens 3.7-4.2 mm-St. No. 10. 25-2-1970 and St. No.22 & 25. 10.4.1970.

,, ,, III - 1 specimen 4.8 mm. - St. No. 20 A. 10.4.1970 Figs. (4, 5).

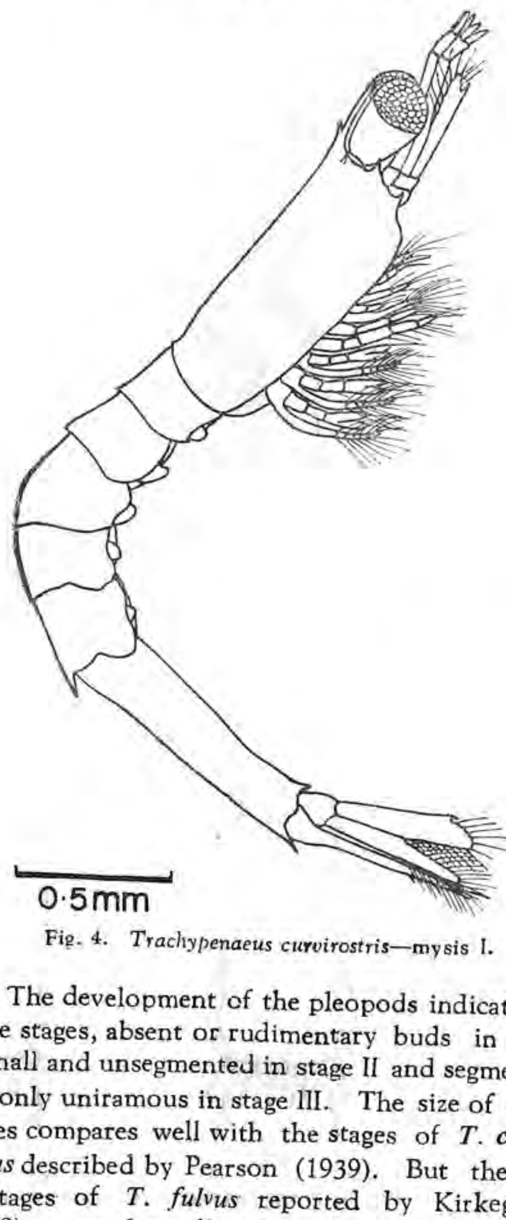

Fig. 4. *Trachypenaeus curvirostris*—mysis I.

The development of the pleopods indicate the three stages, absent or rudimentary buds in stage I, small and unsegmented in stage II and segmented but only uniramous in stage III. The size of these stages compares well with the stages of *T. constrictus* described by Pearson (1939). But the mysis stages of *T. fulvus* reported by Kirkegaard (1969) are much smaller than the present specimens, probably due to the comparatively smaller size of the adults in the case of *T. fulvus*. The rostrum has 1 tooth in stage I, 2 in stage II and 3 in stage III (Fig. 5a, b, c). On the carapace hepatic spine absent; minute supraorbital spine and pterygostomian spine present in all the 3 stages; Kirke-

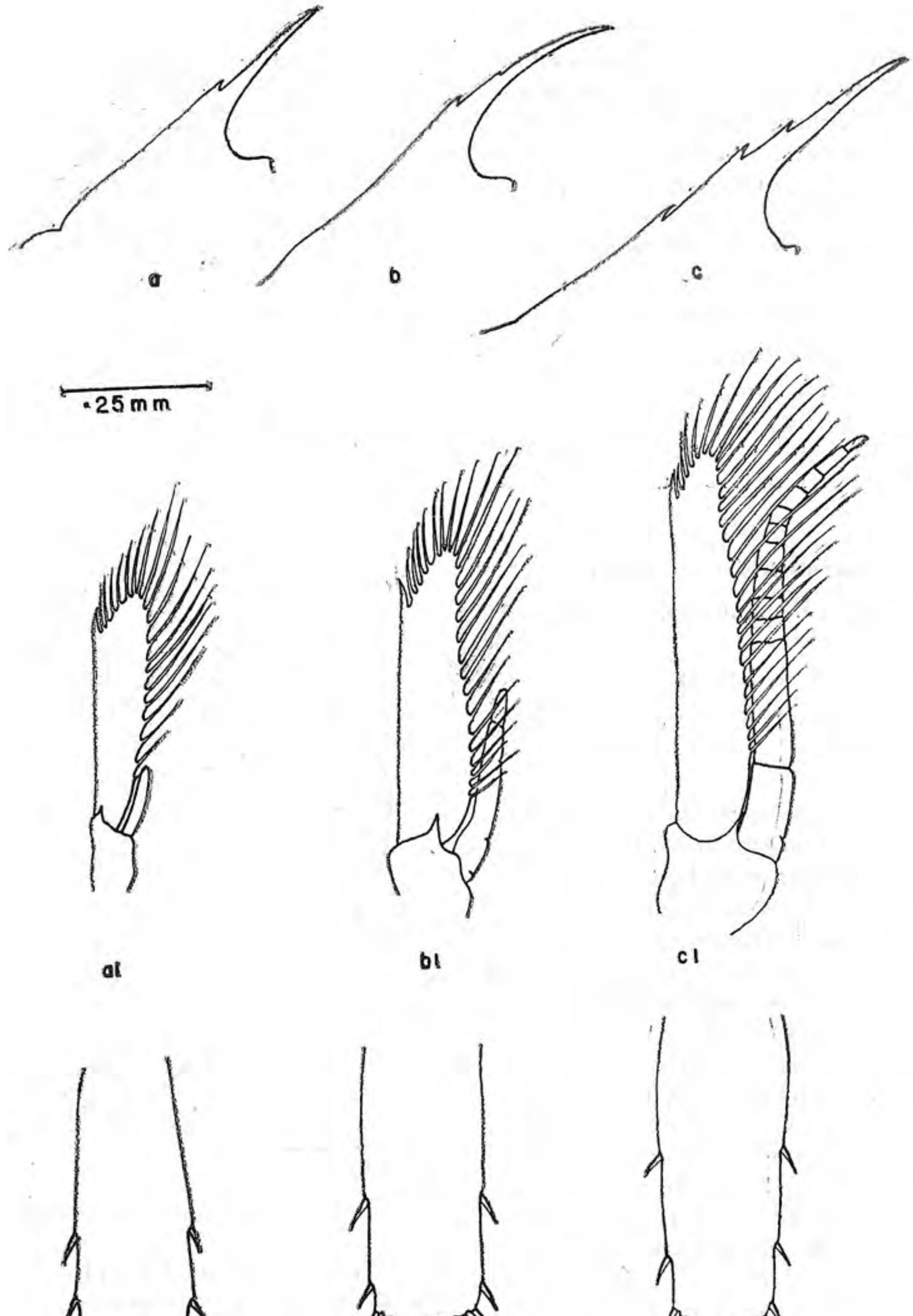

Fig. 5. *Trachypenaeus curvirostris*—a - c^2. rostrum, antenna and telson of mysis I - III resctively

gaard (1969) mentioned an acute antennal angle in all the stages of *T. fulvus*. However, in this species the antennal spine is seen distinctly in all the three mysis stages. The development of the antenna through the stages is figured. (Fig. 5a[1], b[1], c[1]). As in *T. fulvus* there are neither lateral spines on any of the abdominal somites nor dorsomedian spine on 4th abdominal somite. The third abdominal somite has a slight dorsal hump-like carination giving characteristic bend shape to the abdomen. Telson spine formula 8+8 in all stages (Fig. $5a_2$, b_2, c_2). The appendages are quite similar to that of *T. fulvus* with slight differences in the number of setae on some.

The mysis stages of the Australian species *T. fulvus* described by Kirkegaard (1969) differs from the same stage of the American species *T. constrictus* reported by Pearson (1939) in the absence of supraorbital spines on the carapace and dorsomedian spine on the fourth and posterolateral spines on the fifth abdominal somites. The present series agrees with *T. constrictus* in the presence of supraorbital spines but differs from it in the other two characters in which it is similar to *T. fulvus*. The pterygostomian spine on the carapace is found in all the three species.

Parapenaeus investigatoris? Alcock & Anderson

Heldt 1938: 165-175 (larval stages of *Parapenaeus longirostris*).

Pearson 1939: 54-60 (larval stages of *Parapenaeus longirostris*).

Subrahmanyam 1971: 250-51 (mysis stages of *Parapenaeus* sp.)

Material: St. No. 18A. 9-4-1970.

1 specimen, Mysis stage III, 7.2 mm (Fig.6).

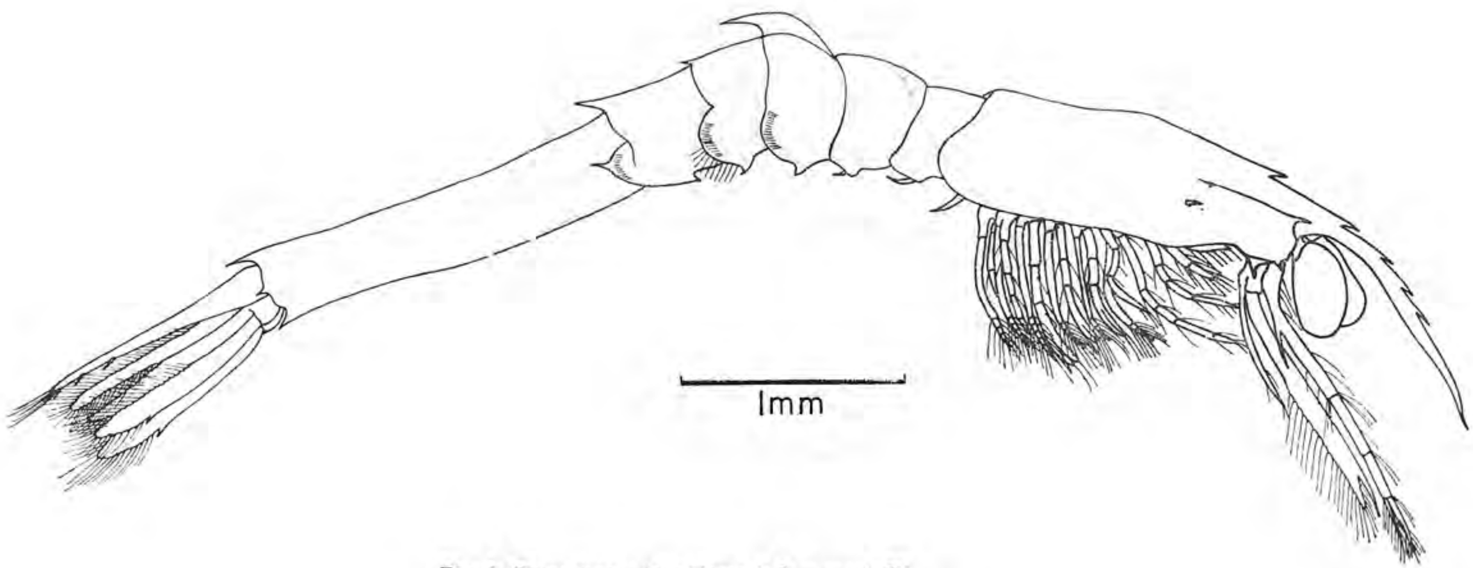

Fig. 6. *Parapenaeus investigatoris ?* — mysis III

Rostrum very long and decurved extending much further than the eye, beyond the second segment of the antennular peduncle; with 4+1 dorsal teeth. Hepatic, supra orbital and branchiostegal spines present on carapace. Dorsal spine on 3rd abdominal segment prominent, triangular, being broad at the base, followed by shorter dorsal spines on 4th and 5th somites. Ventral spines present on anterior 3 abdominal somites. Pleura of the abdominal somites with pointed spines. Lateral spines present on 5th and 6th abdominal somites. Pleopods are present as buds. The distinguishing characters by which the mysis of this genus could be easily identified are the long rostrum and the elongated median dorsal spine on the third abdominal somite.

The present specimen resembles the mysis of the Atlantic species *P. longirostris* described by Heldt (1938) and Pearson (1939). But it differs from it in size, in the number of rostral teeth and the nature of median dorsal spine on the third abdominal segment The two species which are so far recorded from the west coast of India are *P. longipes* and *P. investigatoris* (George, 1969). Out of these the former is recorded from shallower waters while the latter from deeper waters. Also in the adult, *P. longipes* is characterised by absence of branchiostegal spine. The collection of the mysis stage from a deeper station at a sonic depth of 1005 m as well as presence of branchiostegal spine in the mysis point to the fact that the mysis may be that of *P. investigatoris*. Hence it is tentatively identified as belonging to that species. This is the first record of the mysis of the species from these waters.

Parapenaeopsis stylifera (H. Miline Edwards)

Mohamed *et al.* 1968: 496-98, Fig. 5 (postlarva 1)

Material: St. No. 14. 8-4-1970.

2 specimens, Mysis 1, 1.6, 1.8 mm; 3 specimens, Mysis II, 2.5- 2.6 mm (Fig. 7 a-c).

In size these mysis stages are comparable to the zoea stages 1 and 2 of *Metapenaeus dobsoni* described by Menon (1952), although slightly smaller. But there are some distinctive characters which show that these belong to another species. In mysis stage I the rostrum is quite long extending to tip of the eye. On the carapace antennal spine and pterygostomian spine present; a distinct supraorbital spine also present; hepatic spine absent. The median dorsal spines on 5th and 6th abdominal somites very prominent; posterior margin of telson with a deep cleft and 8+8 spines. Exopod of the uropod possesses a distinct spine on the posterolateral margin. Pleopods absent.

Mysis stage 2 has a rostrum extending slightly beyond tip of eye upto the 1st segment of the antennular peduncle and without teeth, unlike 1 tooth in *M. dobsoni* at this stage. Antennal spine, pterygostomian spine and supraorbital spine present. Hepatic spine also present in this stage but very minute. Median dorsal spine on 5th abdominal somite quite prominent as in previous stage. Slight notch persists in the posterior margin of the telson which has spine formula of 8+8 (Fig. 7c, b). Exopod of uropod with posterolateral spine. Pleopods just beginning to appear as small buds.

In the matter of size and various other features like prominent median dorsal spine on 5th abdominal somite, the presence of supraorbital spine and externodistal spine on the exopod of the uropod, telson spine formula of 8 + 8 etc. by

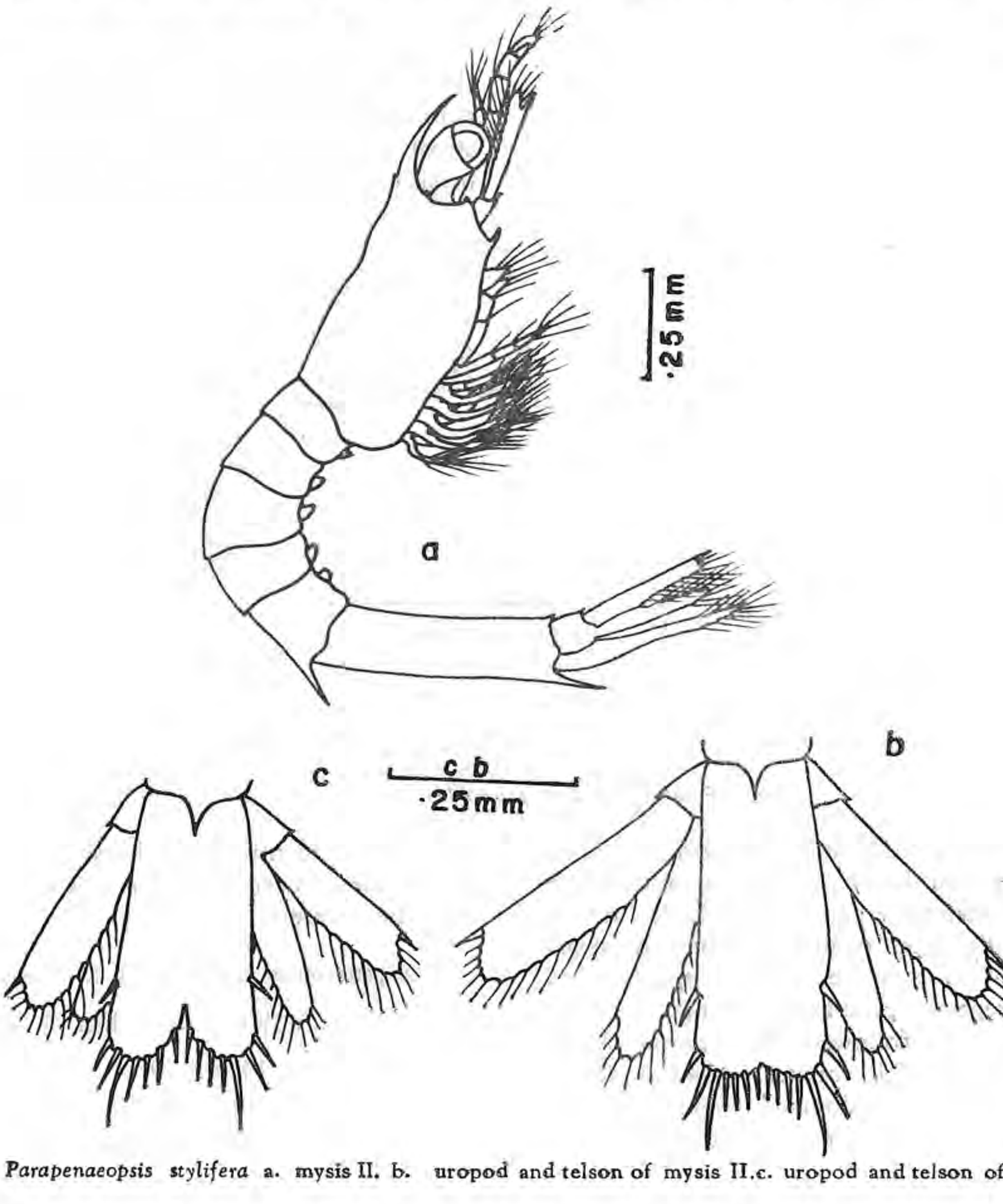

Fig. 7. *Parapenaeopsis stylifera* a. mysis II. b. uropod and telson of mysis II. c. uropod and telson of mysis I.

a process of elimination it is clear that these stages do not belong to any of the genera described so far from these waters. While they agree with the same stages of *M. dobsoni* in size they do not conform to some of the generic characters of the genus *Metapenaeus*, like, for instance, the telson spine formula of 8+8 in present specimens while it is 7+7 in *Metapenaeus*. Incidentally Menon (1952) has recorded 8+8 spines in the telson of his mysis 1 of *M. dobsoni*. Evidently he has confused with the same stage of another species, because in his own descriptions he recorded 7+7 spines both in the previous stage protozoea III as well as the next stage mysis 2 and it is quite improbable that the spines suddenly disappear in one particular stage and reappear in the next stage. The commonest species in the inshore waters of this coast is *Parapenaeopsis stylifera* and it grows to a similar size as *M. dobsoni* in the adult stage. Therefore these stages may be tentatively assigned to this species. This is the first report about these stages of the genus *Parapenaeopsis*.

Subfamily Solenocerinae

Solenocera crassicornis H. Milne Edwards

Menon 1940: 3-6, Figs. 1-11 (Mysis stage)

Material: St. No. 21. 9-4-1970.
1 specimen, Mysis stage I.

The available specimen is an early mysis stage of *Solenocera*, with the characteristic spiny nature of the carapace and abdomen. In most respects the specimen is similar to the mysis stage I of *S. crassicornis* described by Menon (1940). However, some of the characters like outer antennular flagellum with only 4 aesthetes instead of 8 in Menon's specimen, antennal flagellum without any seta and nature of spines on the carapace indicate that the present specimen is an earlier stage to that of Menon's specimen. So it is probable that the present specimen is mysis stage I and the stage recorded by Menon only mysis stage II of *S. crassicornis*. Since the previous record is from Madras waters, this is the first record of the larva from the west coast. This is the commonest species of *Solenocera* on the Indian coast since *S. indica* has been synonymised with this species by Muthu and George (1971).

Cheung 1963: 422-24, Figs. 8,9 (Protozoea of *Solenocera subnuda*)

Heegaard 1966: 89-93, Figs. 181-192 (Protozoea of *Solenocera* sp. larva *barbata*)

Material: St. No. 11. 8-4-1970 and St. No. 22. 9-4-1970.
2 specimens, Protozoea III, 3.3 mm and 3.5 mm (Fig. 8).

The surface of the carapace is covered with very minute spinules and the margin fringed with

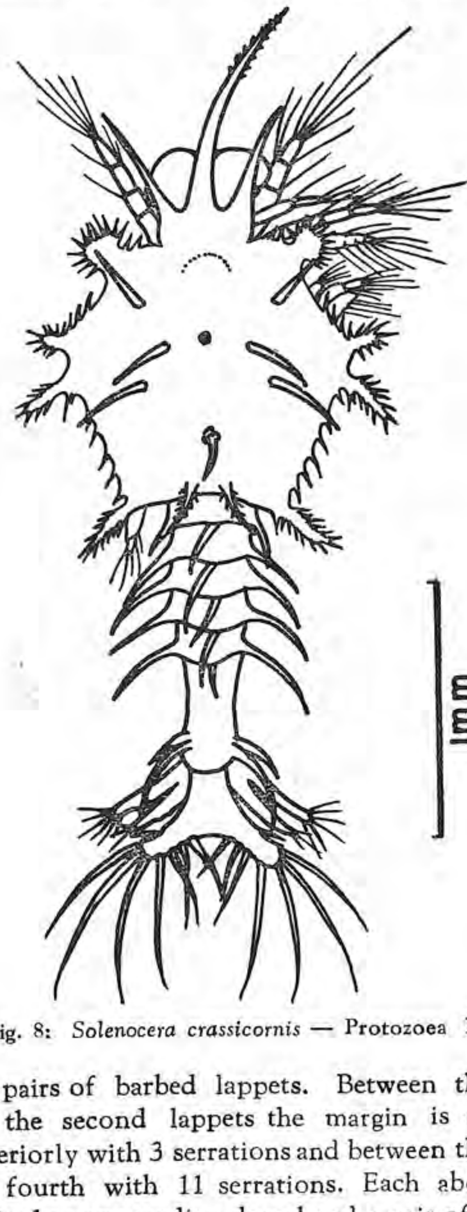

Fig. 8: *Solenocera crassicornis* — Protozoea III.

five pairs of barbed lappets. Between the first and the second lappets the margin is serrated posteriorly with 3 serrations and between the third and fourth with 11 serrations. Each abdominal somite has one median dorsal and a pair of lateral spines which are quite prominent. The bifurcate telson has a spine formula of 8+8. The exopods and endopods of the uropods are finger-shaped and tipped with 6 and 3 small setae respectively. In most of the characters the specimens agree with the descriptions of the older substage third protozoea of *S. subnuda* described by Cheung (1963) and the third protozoea of *Solenocera* sp. larva *barbata* described by Heegaard (1966). But in the number of serrations on the margin of the carapace in between the 3rd and 4th lappets the present protozoea differs from both and in the spine formula of the telson it differs from *S subnuda*, which has only 7 + 7 spines. As the specimens have been obtained from more or less the same locality from which the mysis stage I of *S. crassicornis* was obtained in the present collections, this may be assigned to the same species. If so, as the larval characters also do not agree, this gives additional strength to the view that *S. subnuda* and *S. crassicornis* (as *S. indica*) are distinct species and not synonyms, unlike the suggestion made by Cheung (1963) and the synonymy established by Kunju (1970).

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THE LOCATION OF CEPHALOPOD NURSERIES IN THE INDIAN OCEAN

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ABSTRACT

The cephalopod juveniles sorted out from the International Indian Ocean Expedition Zooplankton collections reveal that they are present in 65% of the total of 1927 collections from all over the Indian Ocean. They are abundant in the Bay of Bengal, south-west of Ceylon, off Kutch, South Arabian coast and the Somali coast. Of all these areas the Bay of Bengal accommodates the largest nursery in the Indian Ocean. The maximum percentage of frequency is found in the Bay of Bengal (80%) followed by the Equatorial zone (71 %), the Somali Sea (71 %), the North Arabian Sea (69 %), the West Australian Sea (54 %) and the South African Sea (25 %). The highest abundance is noticed in the North Arabian Sea (8.7/haul) followed by the Bay of Bengal (7.0/haul), the Somali Sea (5.6/haul), the Equatorial zone (5.1/haul), the South African Sea (3.9/haul) and the West Australian Sea (3.0/haul). The cycles of annual abundance show that the cephalopod juveniles reach their peak abundance (5-10/haul) during the south-west monsoon period (April—September) in the Bay of Bengal and the Equatorial zone including the Somali Sea. In the North Arabian Sea the major peak (17.7—19.6/haul) is observed during November and December followed by a minor peak (6.6—10.2/haul) in June and July.

INTRODUCTION

The cephalopods are active predators preying upon crustaceans, gastropods, clams, mussels and shoal fishes like anchovies, sardines and herrings; in turn they form the food of higher carnivores like sperm whales, tunas and eels (Clarke, 1966; Muus, 1966; Okutani and McGowan, 1969). The Cephalopoda forms one of the commercially important groups next to fishes and crustaceans. However, our knowledge on the biology, population size, distribution patterns, breeding, spawning etc. are very inadequate mostly owing to the difficulties in catching the adults which inhabit meso and bathypelagic zones.

The juveniles of cephalopods are pelagic, inhabiting the upper layers (Muus, 1962; Pearcy, 1965) and feeding planktonic animals. Neis (1965) who studied the food of the juveniles of *Gonatus* sp. found that the copepods, euphausids, amphipods, pteropods and chaetognaths form the major bulk of the food. Once the hooks are developed, fishes form an important part of the diet. The juvenile life lasts from one to three months. Allen (1945), Bouxin and Legendre (1936), Chun (1910), Clarke (1966), Degner (1926), Issel (1908, 1925), Naef (1923), Okutani (1965), Okutani and McGowan (1969), Silas (1968) are some of the authors who worked on juveniles of cephalopods. However, very little is known on the distribution of juveniles and other aspects from the Indian Ocean.

MATERIAL AND METHODS

The zooplankton collections of the International Indian Ocean Expedition (IIOE) during 1960-1965 (IOBC, 1969) subsorted at the Indian Ocean Biological Centre (IOBC) have been made use of for the present study. The detailed work on taxonomy and distribution of cephalopods at species level is being done by I. Taki and T. Okutani in Japan. The present report is based on the numerical data of cephalopod juveniles as a whole sorted from 1927 collections. An atlas on Planktonic Mollusca including Cephalopoda has already been published (Sakthivel and Aravindakshan, 1971). On the basis of density of observations, a few zones were taken into consideration for the comparison of frequency and abundance of juvenile cephalopods. The data from the Bay of Bengal, the Somali Sea, the North Arabian Sea and the East Arabian Sea were collected and the frequency (%) and abundance (mean number/haul) for each zone were calculated. These data on frequency and abundance from several cruises were combined on monthwise basis to estimate the cycles of annual variation in different parts of the Indian Ocean. In finding out the mean abundance and mean frequency a minimum of not less than 10 stations were taken into consideration.

THE DISTRIBUTION AND RELATIVE ABUNDANCE

The juveniles of Cephalopoda are found to be more common in the monsoon gyre especially the Equatorial zone, off the Somali coast, the South Arabian coast, off Kutch, off Cochin, around Ceylon and the Bay of Bengal including the Andaman Sea (Fig. 1). In the southern Indian Ocean the West Australian Sea, the areas around north-east of Madagascar and off Durban show more common occurrence. Of all these areas the Bay of Bengal stands first with maximum percentage of frequency (80%) followed by the Equatorial zone including the Somali Sea (71%), the North Arabian Sea (69%), the West Australian Sea (54%) the East Arabian Sea (31%) and the South African Sea (25%).

The areas of abundance fall mainly in the Bay of Bengal, the Andaman Sea, the south-west off Ceylon, off Kutch, the South Arabian coast, the south-eastern part of the Somali coast, isolated patches in the Equatorial zone and the southern tip off the South African coast. The mean abundance of cephalopod juveniles is found to be maximum in the North Arabian Sea especially along the South Arabian coast (8.7/haul) followed by the Bay of Bengal (7.3/haul), the Somali Sea (5.7/haul), the Equatorial zone (4.8/haul), the South African Sea (3.9/haul), the East Arabian Sea (3.5/haul) and the West Australian Sea (3.0/haul).

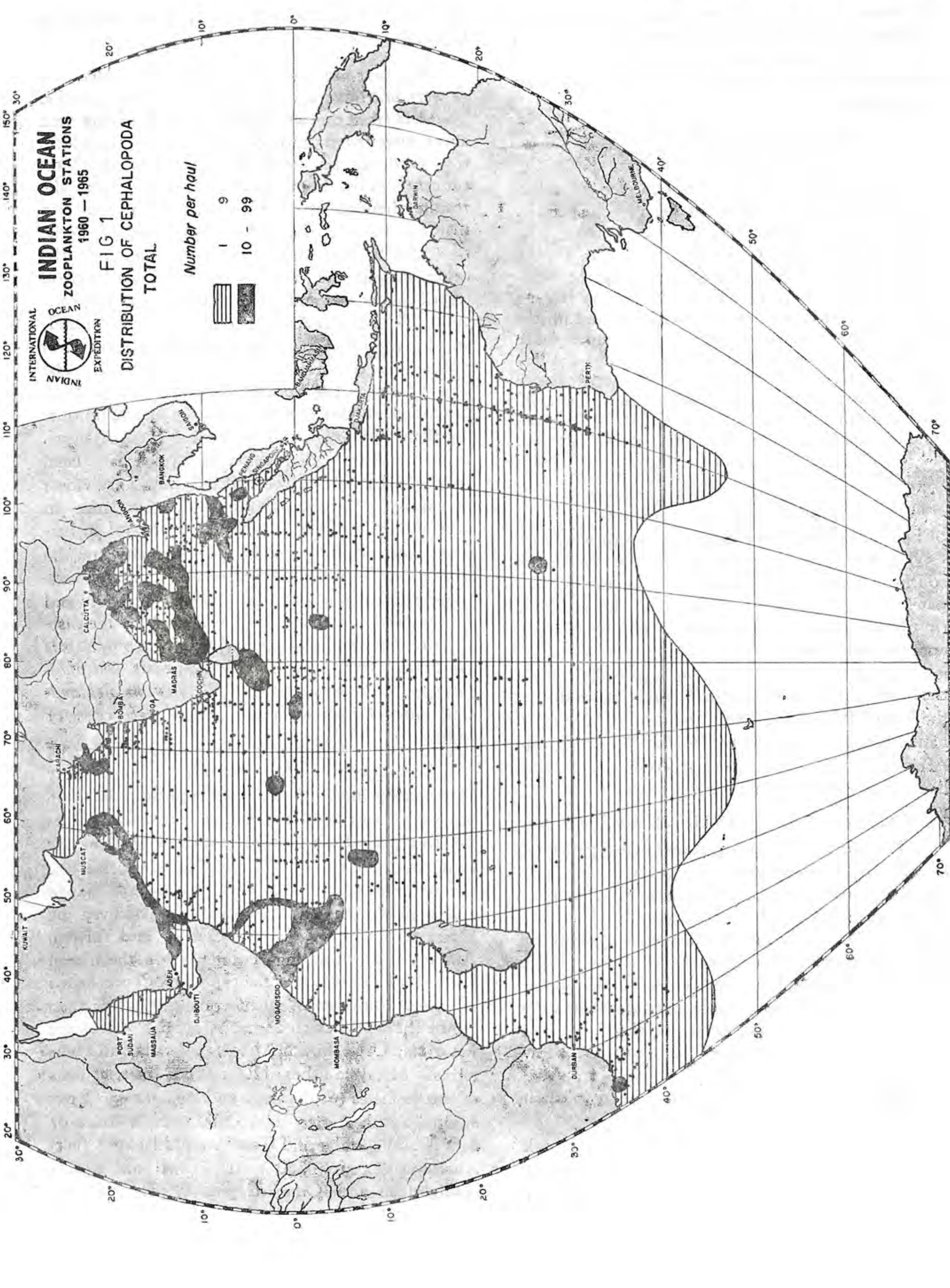
CYCLES OF SEASONAL ABUNDANCE

The Equatorial zone shows two peaks of abundance, a major peak (6.7/haul) during July and August and a minor peak (5.6/haul) in January. The frequency during these months varies from 66-70%. The high frequencies are found in the months of April (89%), May (79%), June (84%), and October (92%), but the density of the population is very low. As a whole the seasonal variation is not very pronounced in the Equatorial zone. The West Australian Sea does not show any appreciable seasonal cycles. However, August and December show moderate increase in catch (3.4-3.8/haul)

The North Arabian Sea shows a major peak (17.7-19.6/haul) during November and a minor peak (6.6-10.2/haul) in June and July. The Bay of Bengal is rich (6.0-9.8/haul) from April to September.

The seasonal coverage of these selected areas were not quite satisfactory for all the months. The data from the well-covered parts of the year alone were taken into consideration. Therefore, the results do not cover the months in which no observation has been held. However, from the results obtained it is clear that there are two major seasons in the spawning of cephalopods, one during the south-west monsoon and the other during the north-east monsoon period (April-September and December-February respectively). The South Arabian coast is more abundant during the north-east monsoon period than during the south west monsoon period. The Bay of Bengal, the Somali Sea and other parts of the monsoon gyre are found to be maximum during the south-west monsoon period (June-August). More or less similar seasonal cycles have been observed by Silas (1968) along the West Coast of India. He reports greater abundance in the Wadge Bank off Cape Comorin and in between Cochin and Quilon. The density of the population varies from year to year and the maximum number was obtained during April-July and November-December. He has also given the distribution charts of *Abralia andamanica*, *Abraliopsis gilchristi*, *Symplectoteuthis oualaniensis*, *Chiroteuthis* spp., *Liocranchia* spp., *Thelidioteuthis alessandrini*, *Japatella diaphana* along the west coast of India.

According to FAO Year Book of Fishery Statistics during 1964-1969 the cephalopods form less than 2% of the total world fish catch. During this period the highest catch (1170000 metric tons) was in 1968. Of this, the squids form 78%, the octopuses 16% and cuttle-fishes 6 . Japan fishes maximum of this quantity followed by Korea, Spain, Italy, USA, Canada and Taiwan. Among the bordering countries of the Indian Ocean and adjacent seas the cephalopods are fished by a few countries in small quantities (less than 5% of the world catch of cephalopods). They are Malaysia, UAR, South Africa, Australia and Mauritius. Malaysia fishes 1200 to 2600 metric tons of cuttle-fishes (*Sepia* spp. and *Sepiola* spp.) per annum, South Africa 100 to 400 metric tons of squids (Loliginidae and Ommastrephidae) per year, Australia 100 to 200 metric tons of squids (Loliginidae and Ommastrephidae) per year and


INTERNATIONAL INDIAN OCEAN EXPEDITION
INDIAN OCEAN
ZOOPLANKTON STATIONS
1960 — 1965
FIG 1
DISTRIBUTION OF CEPHALOPODA
TOTAL
Number per haul
1 - 9
10 - 99

Mauritius 200 metric tons of octopuses (*Octopus* spp. and *Eledone* spp.) per year. This clearly shows that the countries bordering the Indian Ocean, especially India have not yet realised the vast hidden resources of Cephalopoda in the Indian Ocean. It is strange to note that India has not yet been placed by FAO in the list of nations which fish cephalopods. According to the Indian Fisheries Year Book (Cheryan 1970) the cephalopods landing in India has gone to a maximum of 1604 metric tons in 1968.

Of all the areas explored in the Indian Ocean it is very interesting to observe the unique abundance of juvenile cephalopods in the Bay of Bengal, in the area off the Somalia and South Arabian Coast. This fact closely coincides with the dense concentration of fish eggs and larvae (Peter, 1969). Of the above three areas mentioned, the Bay of Bengal accommodates the largest nursery in the Indian Ocean. The probable reason for the high concentration of cephalopod juveniles appears to be correlated with the high concentraion of primary and secondary producers. The northern and western Bay of Bengal show moderate to high production of phyto and zooplankton.

The South Arabian coast and the Somali coast are well known for upwelling and high primary and secondary production (Kabanova, 1968; Prasad, 1968; Cushing, 1971). The areas of divergence especially in the Equatorial zone also show moderate abundance. The distribution of offshore divergence (Hidaka and Ogawa, 1958) shows a shift from the south-west coast of Ceylon in the northern spring and summer to the south-east coasts in the northern winter and this is the region of the main tuna fishery (Cushing, 1971). As squids and cuttlefishes form the food of tunas the abundance of cephalopod juveniles in the south-west of Ceylon directly correlates with this phenomenon.

Okutani and McGowan(1969) have made a few interesting observations on breeding and spawning of *Loligo opalescens* in the California Current region .This is a demersal spawner during the late winter and early spring. The area of spawning was estimated 1,600,00 m^2 of which 50% of the bottom area was covered with squid eggs cases. The total number of eggs spawned was 1.76×10^{12}. A large number of larvae was released into the water about one month after the spawning. They also found that there were no post-hatching mortality. As the spawning takes place at the bottom, it is believed that the larvae released from there may have wide range in distribution with wide tolerance to salinity and temperature.

The following seven species of squids are recorded in the Bay of Bengal alone excluding Indo-Malayan seas: *Liocranchia reinhardti*, *Henseinoteuthis joubini*, *Ommastrephes batrami*, *Onchia carribeea*, *Abralia andamanica*, *Abraliopsis morrisi* and *Chiroteuthis macrosoma* (Clarke, 1966). If these species spawned at a similar rate as *Loligo opalescens* one could expect a heavy population of squids in the Bay of Bengal. As the large area of concentration of juvenile cephalopods in the Indian Ocean is found in the Bay of Bengal it supports this assumption.

The catching efficiency of juvenile cephalopods by tow nets has been tested by Okutani and McGowan (1969). Of the six different sizes of gears (20, 40, 60, 80, 100 and 140 cm diameter nets) and sampling less than 400 m^3 of water all of them underestimated the numbers as well as species of juvenile squids as compared with a larger net sampling nearly the same volume of water. Of the nine species recorded from the California Current area the "best" 1 metre net tow caught only three. As the zooplankton sampling of IIOE collections have been made mainly by the IOSN with a mouth diameter of 113 cm by vertical haul from the depth of 200 m to the surface, the present estimate of abundance of juvenile cephalopods is subjected to similar sampling drawbacks.

In conclusion we would like to emphasize that a study of the distribution of cephalopod juveniles in the Indian Ocean has revealed the possible existence of rich cephalopod fishery particularly in the Bay of Bengal and North Arabian Sea and further work on breeding and spawning of these would be highly essential to assess the population of squids in the above areas.

ACKNOWLEDGEMENTS

We wish to acknowledge the staff of IOBC for sorting and counting of juvenile cephalopods from the IIOE collections. We are thankful to Dr. N. K. Panikkar, Director, National Institute of Oceanography for allowing us to make use of this data. Our thanks are also due to Dr. T. S. S. Rao, Officer-in-Charge and Dr. M. J. George, Scientist for their valuable suggestions.

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LATITUDINAL DISTRIBUTION OF A FEW SPECIES OF PELAGIC POLYCHAETES IN THE UPPER 200 METERS WATER OF THE INDIAN OCEAN

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ABSTRACT

The latitudinal distribution of the three most abundant species of pelagic polychaetes in the Indian Ocean has been studied. For the purpose of this study hydrological features along the longitudinal lines of 50°E, 60°E, 70°E, 80°E, 90°E, 100°E and 110°E in relation to its pelagic polychaete population were examined. Variations in the number of specimens with latitudes in the different longitudes are represented in figures 1-3.

The changes in the hydrological conditions and the plankton population seem to be more pronounced in the north-south direction than in the east-west direction. It is particularly noticed that the northern tropical zone is conspicuous not only for its abundance of the number of specimens of each species but for the number of species also. The penetration of some of the cold water species into warm equatorial waters is another interesting feature.

INTRODUCTION

It is an accepted fact that the Indian Ocean is the least known among oceans in the world and this is particularly true with regard to its pelagic polychaete fauna. There may not be much change in the hydrological conditions and the plankton population in the east-west direction but in the north-south direction the change in these factors is more pronounced. This is particularly so in the Southern Indian Ocean. So it is worthwhile to have a study of the latitudinal distribution of atleast the more abundant species during an investigation of the zoogeography of a particular group. For the purpose of this study the hydrographical features of a number of stations distributed along the longitudinal lines of 50°E, 60°E, 70°E, 80 °E, 90°E, 100°E, and 110°E in relation to their pelagic polychaete population were examined so as to study the variation in abundance in the different latitudes. Amongst a number of species of pelagic polychaetes occurring in large numbers in the collections only one species each belonging to the families Typhloscolecidae, Alciopidae, and Lopadorhynchidae have been taken for study in this connection.

Our knowledge on the distribution of pelagic polychaetes have greatly increased with the contributions of Stop-Bowitz (1948), Dales (1957), Tebble (1960,1962) and Day (1967). But an approach to a large scale distributional study of them in the Indian Ocean has not been attempted so far. In the present contribution the results of an analysis of distributional variation in a north south direction represented by the different latitudes are reported.

MATERIAL

The present study is based on the pelagic ploychaetes sorted out from the standard samples of plankton collected in vertical hauls using Indian Ocean Standard Net from a stratum of 200-0 m during the International Indian Ocean Expedition (1960-1965). The samples have been collected from various parts of the Indian Ocean during the different seasons of the year and different hours of day and night. As the samples from a number of north-south lines of stations have been used the data gives an overall picture about the latitudinal variation in abundance in the Indian Ocean. All the stations, where the concerned species has been collected, that occur along the particular longitudes have been taken into account. In the east-west direction the stations have been selected at approximately 10° intervels, giving a margin of 2 degrees to either side. The samples being collected during all the four years of the expedition at irregular intervels the conclusions drawn here are of course subject to inadequacies and although it does not give a concrete picture of the actual range of distribution, the overall pattern should be a fair representation of the latitudinal variation.

The samples are preserved in 5% formalin. The data are based on the computed values of 100% of samples as only a small fraction of each sample has been analysed. The complete list of station numbers with all the necessary details have been published in the IOBC Hand Book Volumes I and II (1969, 1972).

RESULTS

Figures 1, 2, and 3 show the variations in the number of specimens with latitudes in the different longitudes. The averages of the total number of specimens collected from all stations occurring at every 5 degrees of latitude in the various longitudinal lines mentioned above are represented in the figures.

Pelagobia longicirrata

This species belong to the family Lopadorhynchidae and this is the most abundant species under this family. Figure 1 shows the latitudinal distribution of *Pelagobia longicirrata* along the different longitudes.

In the region of 50°E longitude *Pelagobia longicirrata* is found to be very rare and all of the recorded specimens from this region belong to the Equatorial area with its southern limit set at the

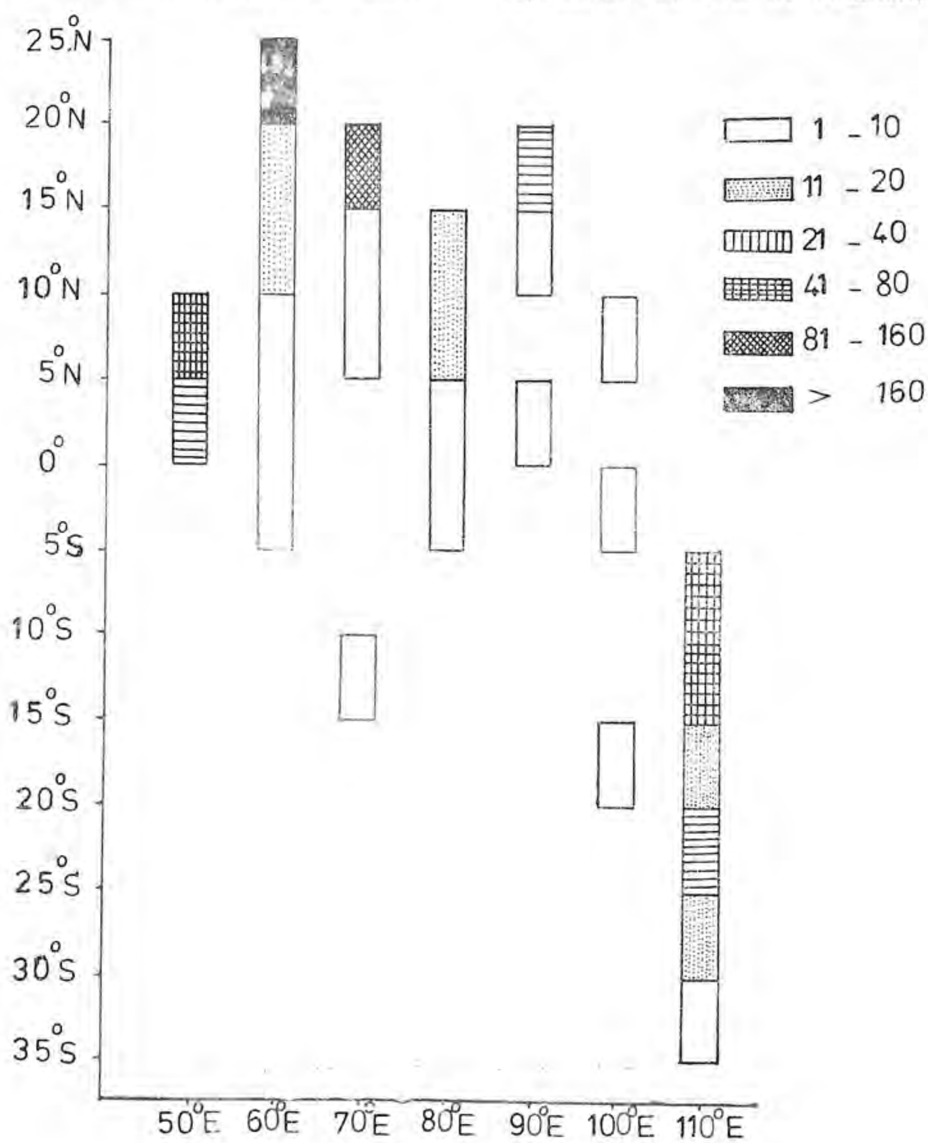

Fig. 1—Latitudinal distribution of *Pelagobia longicirrata*

Equator and northern boundary at 10°N. In the 60°E longitude it shows a further extension towards north and the maximum abundance of the species in the Indian Ocean is noticed in this region between 20°N and 25°N. This part of the Indian Ocean in general is very rich in zooplankton populations and this is reflected in the case of *P. longicirrata* too. They gradually decrease in their abundance along the line towards the south and become completely absent beyond 5°S. More or less the same pattern is noted in the next line of observation also (70°E), but the maximum abundance here is seen in 15°-20°N region. Towards the south they become rare and absent from 5°S downwards except for two specimens in 10°-15°S. From the figure it is clear that *Pelagobia longicirrata* is rare in the Bay of Bengal and the recorded ones occur to the east of India and off the south coast of Indian continent, west of Ceylon. In general the southern parts of Indian Ocean is completely devoid of this species with the exception of the vicinity of Australian coast where it has been found in large numbers. The maximum number of this species in the southeast part of the ocean is found in 5°S-10°S at 110°E. From here they gradually diminish towards south disappearing below 35°S.

Two species belonging to the same family occurring in large numbers in the Indian Ocean, namely *Lopadorhynchus nationalis* and *Lopadorhynchus henseni* show almost similar type of latitudinal distribution. But they have a far more extension to the colder waters, being found upto 35° S

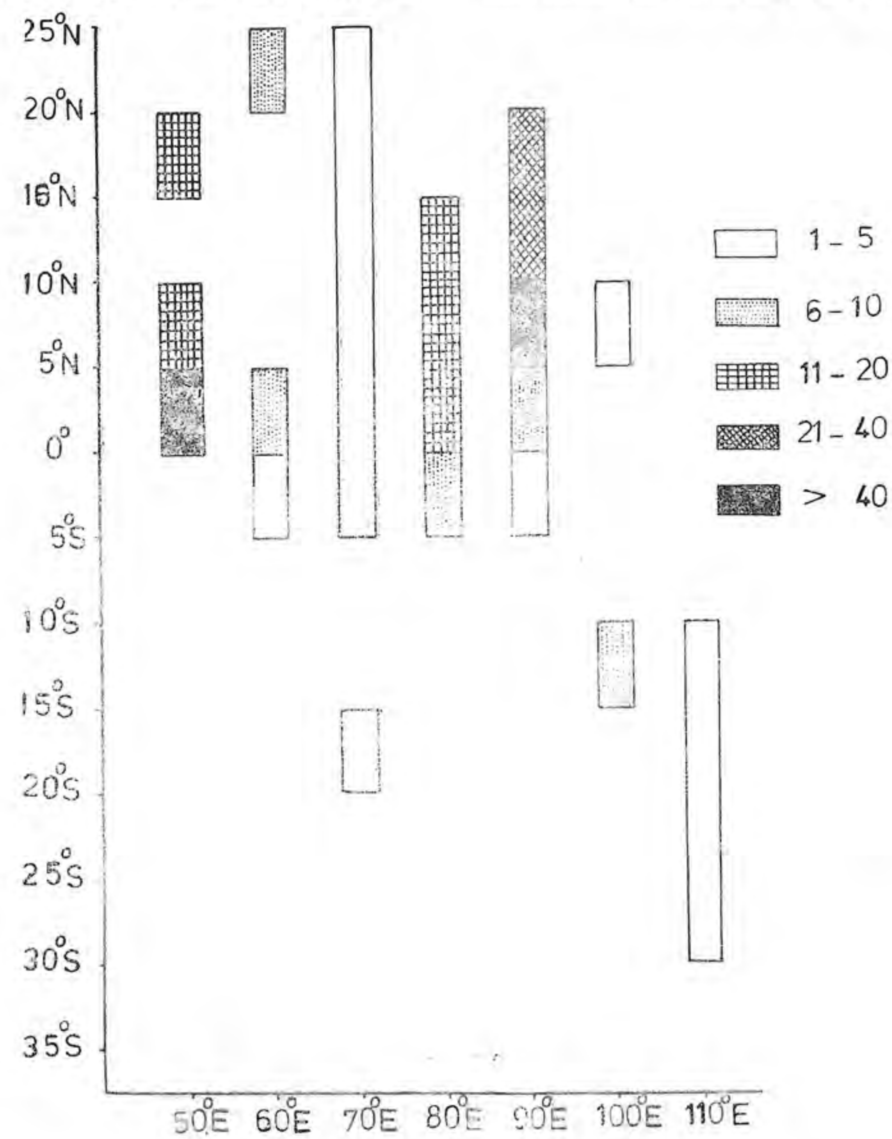

Fig. 2.—Latitudinal distribution of *Plotohelmis capitata*

in 70° E and 80° E longitude; though absent in the south west region of the ocean. *Phalacrophorus uniformis* is comparatively rarer than *Lopadorhynchus* spp. and the general pattern of latitudinal distribution is almost the same.

Plotohelmis capitata

This species represents the most abundant group under the family Alciopidae. Though there is no well marked difference from the general pattern that is exhibited by the previous species, the rarity of the species in the southeast parts of the ocean is noteworthy (fig. 2). *Plotohelmis capitata*, though collected from many stations in the Australian coast along 110° E, are found only in small numbers unlike *Pelagobia longicirrata*. In the 50° E region this species occurs upto 20° N and in the 60° E its distribution is further extended upto 25°N, but they are absent between 5° and 20° N. A few have been collected from 5°N-5°S region, beyond which it is nil. The maximum abundance of this species in the Indian Ocean is found in the Equatorial region, but found to be very rare south of 5° S where it has been recorded only from one place in the 17° S. In the Bay of Bengal it is not rare though practically absent in 100° E longitude.

Another species under Alciopidae that occur in fairly large numbers in the Indian Ocean is

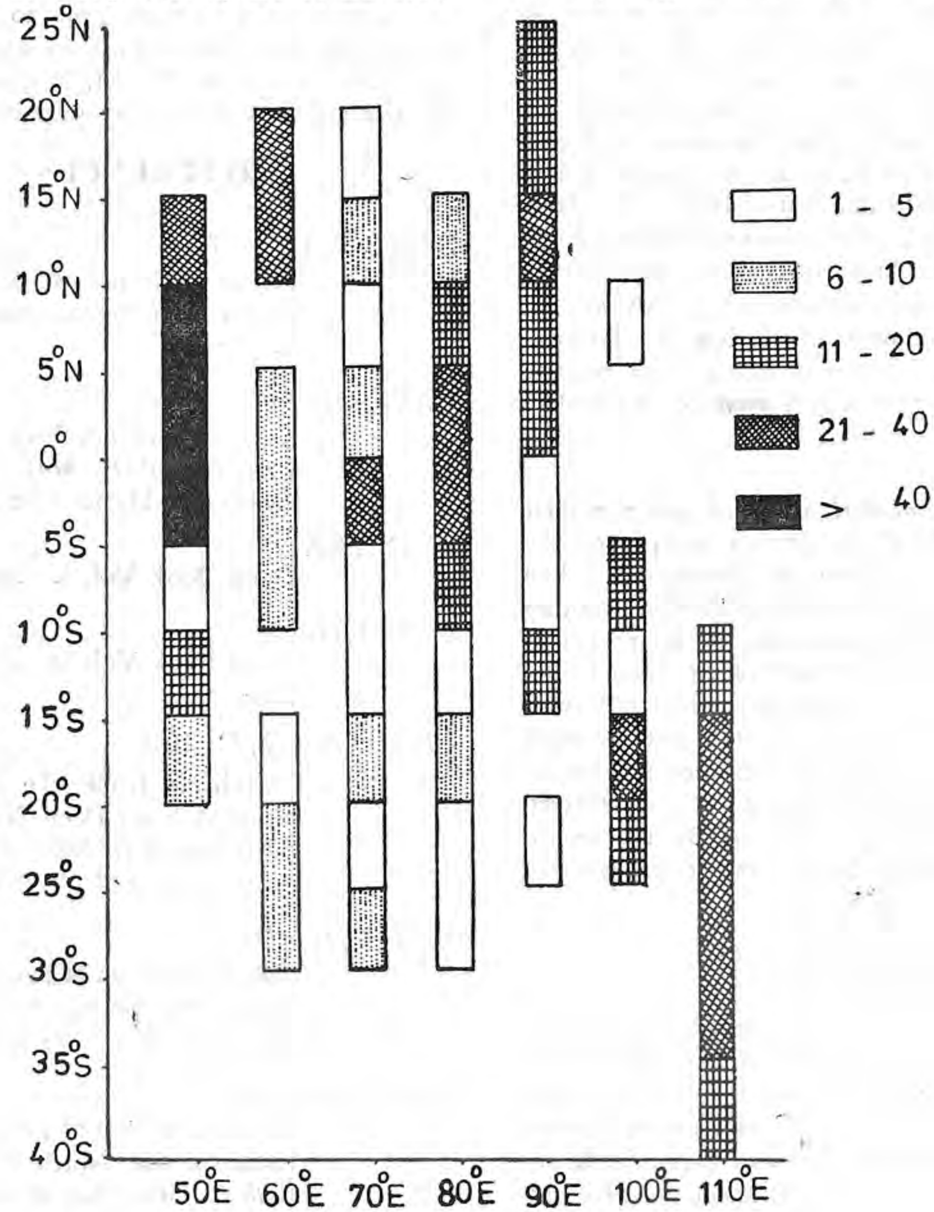

Fig. 3—Latitudinal distribution of *Sagitella kowalewskii*

Alciopina parasitica and this is found to have a wide distribution in the southern parts. Thus in the region of 60° E longitude they are found abundant in 10°-15° S region and also found to occur upto 30° S.

Sagitella kowalewskii

By far the most abundant group of pelagic polychaetes in the Indian Ocean belong to the family Typhloscolecidae, represented by all its three known genera of which *Sagitella* and *Typhloscolex* are more abundant. Latitudinal distribution of two species representing these genera have been studied and it is found that *Sagitella kowalewskii* represents the most widely distributed species in the Indian Ocean. From 50° E to 90°E it is found through out the ocean extending from 25° to 30°S. Its rarity is noticed only in the region south of Madagascar west of 50° E and the coasts of Sumatra and Jawa upto 10° S. In the Southeast Indian Ocean south of 10°S and east of 100°E it has been found to occur in large numbers and collected upto the region of Antarctic Convergence in the 110° E longitude. Like the foregoing, this species also has its maximum abundance in Tropical Indian Ocean and towards south they become fewer except in the region west of Australian coast.

Typhloscolex mulleri also has got a similar pattern in latitudinal distribution except for the fact that they are absent in Southwest Indian Ocean west of 60°E. *Travisiopsis levinseni*, another species under Typhloscolecidae, is of particular interest. This cold water species has been found in the warm equatorial water of the Indian Ocean. During the Northeast monsoon it is not recorded from the southern latitudes. Another species of the same genus, *T. lobifera* has a different pattern in having its maximum abundance in the region north of 15°N, thence become rare towards south excepting the Australian coast.

DISCUSSION

In spite of the shortcommings imposed by the nature of sampling the total catch of the pelagic polychaetes shows interesting variations in different latitudes. The abundance of various species at the northern tropical zone is of particular interest. This region is not only conspicuous for the abundance of the number of individuals of each species but also for the number of species. The penetration of some of the cold water species into warm equatorial waters is another interesting aspect. *Travisiopsis levinseni* is a typical example for this. Previously it was known to have been recorded only from great depths of North and South Atlantic waters as well as from Antarctic water. But in the Indian Ocean it has been found to occur in the southern latitudes and Tropical waters as well.

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ON THE ECOLOGY OF PELAGIC POLYCHAETES NEWLY RECORDED FROM INDIAN OCEAN

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ABSTRACT

The ecological distribution of pelagic polychaetes of IIOE collections is discussed. Seven species which are recorded for the first time from the various regions of the Indian Ocean are dealt with. Of these *Lopadorhynchus henseni* is abundant in both Arabian Sea and Bay of Bengal. *Pedinosoma curtum* and *Vanadis minuta* also are recorded from both seas but found to be rare. *Maupasia gracilis* and *Alciopina tenuis* are seen only in Bay of Bengal, while *Travisiopsis lanceolata* only in Arabian Sea and *Alciopina paumotanus* is found in the Southwest and Southeast Indian Ocean.

The general distribution pattern of these forms in the Indian Ocean is represented in maps. The environmental factors to which these worms are adapted are analysed to learn the ecology of each species and thus by comparing the catches and the environmental data the limits of tolerance for some ecological parameters in which the animals exist are detected.

INTRODUCTION

The systematics of pelagic polychaetes have been well studied and recently all the informations are put together in a paper by Dales and Peter (1971). The geographic distribution of each species also is included in this paper. Studies on the ecological distribution and relationship of the species to the environment have been attempted only by Tebble (1960, 1962). With the information gathered during the IIOE an attempt is made to correlate the presence and abundance of each species to the environmental factors, mainly salinity, temperature, oxygen and the water masses, hoping to obtain more knowledge on their ecology.

Investigations on the pelagic polychaetes of the Indian Ocean are very few. Fauvel's (1953) report gives us some idea about the polychaetous annelids of the Indian region and that too deals only very little with the pelagic species.

This report forms a part of the results obtained during an elaborate study on the systematics, abundance and distribution of polychaetes in the Indian Ocean. The polychaetes in general form a major group of invertebrates adapted for tubiculous, burrowing or other bottom dwelling life with planktonic larval stages. But a few of them have been found in the plankton even during the adult stage. The families Tomopteridae Typhloscolecidae and Alciopidae include exclusively pelagic forms and a few under Phyllodocidae also.

About 30 species belonging to pelagic families have been recognised during this study. Out of this, 7 species are found to be new records either for the whole Indian Ocean or for any of its four regions. The principal object of this paper is to report the occurrence of these species in the Indian Ocean and to evaluate the pattern of distribution in space and time, their relation to the physical and chemical characteristics of their habitats, the watermasses in which they live, their variation in abundance during the two different seasons and also during day and night.

MATERIAL AND METHODS

The present study is based on the processing of 1553 Standard Samples of plankton collected during the International Indian Ocean Expedition and deposited in the Indian Ocean Biological Centre. The Standard Sample is defined as the sample collected using the Indian Ocean Standard net in vertical hauls made through a standard stratum of 200 to 0 meters depth or to lesser depths in shallow waters. The sampling has the coverage of the whole Indian Ocean and for convenience the whole ocean is divided into four regions namely, Arabian Sea, Bay of Bengal, Southwest Indian Ocean and Southeast Indian Ocean. To study the seasonal variation the year is arbitrarily divided into two seasons: April 16 to October 15 represents the Southwest monsoon and October 16 to April 15 represents the Northeast monsoon. 0600 hours to 1800 hours is considered as day and 1800 hours to 0600 hours as night to study the variation in abundance in the upper layer between day and night.

In order to understand the ecology of the species each specimen was studied against the background of the water column through which the net filtered. The hydrographical data indicate whether a single water mass was present, what was the water mass, whether a thermocline was formed, whether there was upwelling in any form of vertical mixing and so on. Thus by comparing catches and environmental data the limits of tolerence for some ecological parameters in which the animals were found to exist were studied for each species. Likewise the watermasses in which the species were found also were detected in each case where they were known for sure.

LIST OF SPECIES

Family Phyllodocidae
- Genus - *Lopadorhynchus*
  - Species – 1. *Lopadorhynchus henseni* Reibisch 1893
- Genus – *Pedinosoma*
  - Species – 2. *Pedinosoma curtum* Reibisch 1895
- Genus – *Maupasia*
  - Species – 3. *Maupasia gracilis* (Reibisch) 1893

Family Alciopidae
- Genus – *Vanadis*
  - Species – 4. *Vanadis minuta* Treadwell 1906
- Genus – *Alciopina*
  - Species – 5. *Alciopina tenuis* (Apstein) 1900
  - Species – 6. *Alciopina paumotanus* (Chamberlin) 1919

Family Typhloscolecidae
- Genus – *Travisiopsis*
  - Species – 7. *Travisiopsis lanceolata* Southern 1910

Lopadorhynchus henseni Reibisch 1893

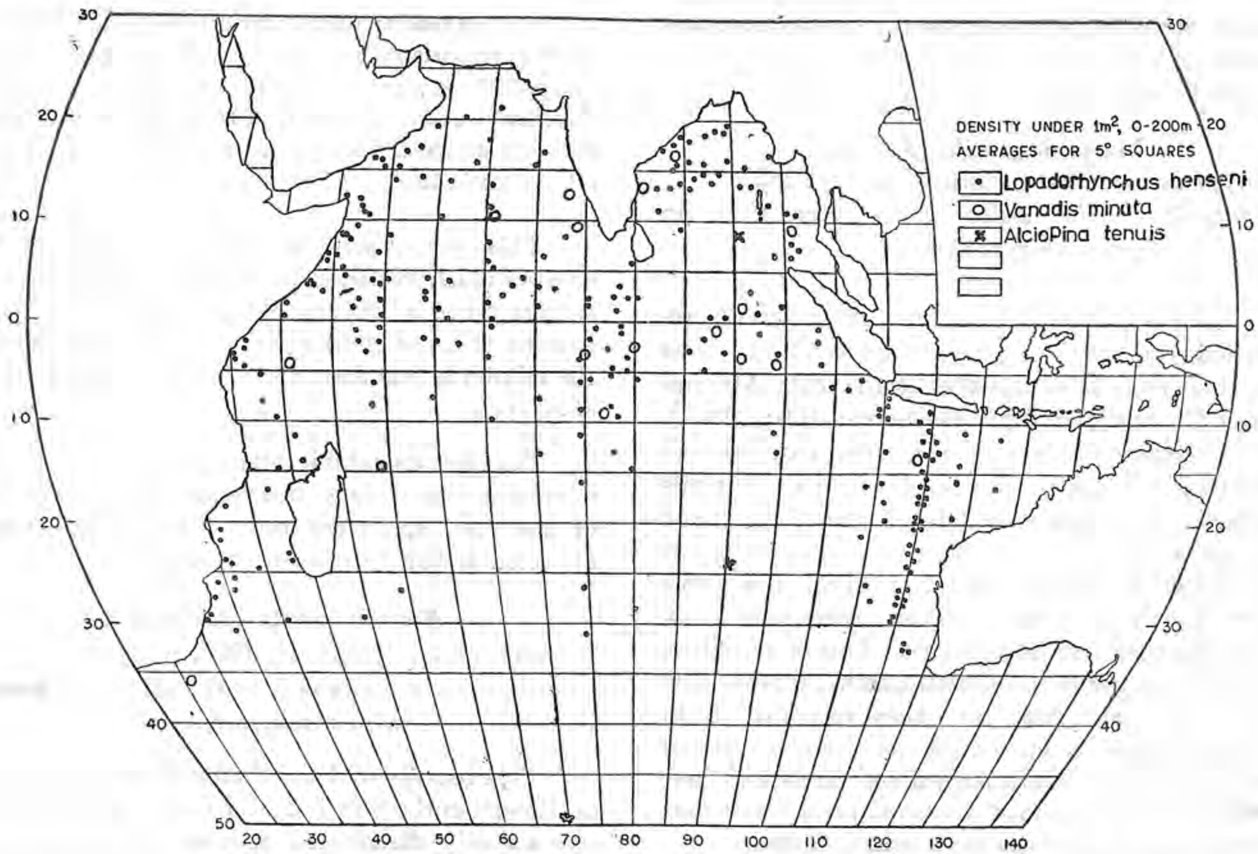
Lopadorhynchus henseni Reibisch 1893, p. 253
Lopadorhynchus henseni Dales and Peter 1971 (in press, with synonymy)

Lopadorhynchus henseni Reibisch was considered as a rare species found only in Atlantic Ocean, the original record by Reibisch (1893) being from South Atlantic Ocean north of Ascension Island. Subsequently it was found in the Central part of Atlantic between Brazil and North Africa and in the North Atlantic between New-Foundland and Ireland. Later, in 1967 Day recorded it in the Southeast Atlantic Ocean and in the Agulhas Current near the South African Coast.

The present investigation shows that it is abundant and widely distributed throughout the Indian Ocean, though rare in the South central region, and it is reported here for the first time from Arabian Sea and Bay of Bengal. It is particularly abundant in the Bay of Bengal and eastern parts of the Indian Ocean. A study of the distribution of this species in relation to the watermasses in the Indian Ocean reveals that it inhabits Arabian Sea Surface Water, Bay of Bengal Surface Water, Indian Ocean Equatorial Water, South Central Surface Water and South Temperate Surface Water and found to be more abundant in the Indian Ocean Equatorial Water.

The hydrological characteristics of their habitats indicate that it is a rather tolerent species for salinity and eurythermic. It defintely tolerates salinity as low as 33.86 °/oo as in station AB 43 (Bay of Bengal) but surely was not taken in less than 32.00 %o. It was taken in salinity as high as 36.00 %o as in station AB 285 in Arabian Sea but was not found in higher than 36.5 %o. With regard to its tolerance to temperature it seems to live in the waters with a temperature range of 18 °C and 22 °C. However, it is probable that it may tolerate up to 25.6 °C but not below 18 °C. This typical tropical and sub-tropical species has now been found to penetrate to colder regions up to 40 °S in the Indian Ocean. It is probable that they live in surface layers above the thermocline toward the south while in the tropical and sub-tropical parts of the Indian Ocean it lives below the thermocline.

The species shows a marked variation in its abundance during the two seasons, they are more abundant during the Southwest monsoon than the Northeast monsoon (ratio 57:43). In the Arabian Sea they are found to be very rare during Northeast monsoon, practically none in the Agulhas Current during this season. There is not such a



conspicuous difference in their abundance in the other parts of the ocean between the two seasons.

A comparison of the occurrence of this species during day and night shows no variation and there is no evidence of vertical movement.

Pedinosoma curtum Reibisch
Pedinosoma curtum Reibisch 1895, p. 27
Pedinosoma curtum Dales and Peter 1971 (in press, with synonymy).

Pedinosoma curtum was originally recorded by Reibisch (1895) from Azores in the North Atlantic. This is now described as a new record for the Arabian Sea and Southeast Indian Ocean. Day (1967) has described them from Agulhas Current and Mozambique Channel. Now a total number of 97 specimens have been collected from Arabian Sea, Southwest and Southeast Indian Ocean.

A scrutiny of the hydrological features of their habitats show that it is a eurythermic species. It can tolerate a temperature as low as 17.91° C as in South Central Surface Water of the West Coast of Australia and as high as 25.36 °C of the Indian Ocean South Tropical Surface Water of the Java Coast. It may perhaps occur in still colder waters but not below 12.24° C. It is evidently a surface dwelling form, probably living above 50m depth. This species has also been recorded from Sub Surface Water and Indian Ocean Equatorial Water. It appears to be a stenohaline worm which probably does not tolerate the salinity lower than 34.56 °/oo and higher than 35.7 or 36 °/oo. This may be the reason why it is not found in the Bay of Bengal where the surface water is less saline.

The present survey shows that this species though more widely distributed in the Southeast Indian Ocean, is less abundant there as compared to the Arabian Sea. It has been recorded from 17 stations in the Southeast Indian Ocean. It is abundant in Arabian Sea but recorded only from a few scattered stations off the Arabian and Bombay Coasts.

Southwest monsoon season seems to be more favourable to these animals in the Arabian Sea, only 5 specimens having been collected from this area during the Northeast monsoon. In the Southeast Indian Ocean they are more common during southern summer. It is found in station where upwelling is taking place. The data are not sufficient to draw any conclusion regarding their vertical migration.

Maupasia gracilis (Reibisch)
Halyplanes gracilis Reibisch 1893, p. 252
Maupasia gracilis Dales and Peter 1971 (in press, with synonymy)

This is a Central Atlantic worm, originally recorded from the Gulf Stream (Reibisch 1893). The previous records of this species are from Mozambique Channel and Agulhas Current (Day, 1967). The present records also are from tropical and sub-tropical waters as the previous ones. But this material forms new record for Bay af Bengal and Southeast Indian Ocean. In the Bay of Bengal it was found only in one place. 5 specimens came from Equatorial region and the others were from the Australian and Java Coasts. This is relatively abundant in the Indian Ocean South Tropical Surface Water and has also been recorded from Indian Ocean Equatorial Water, Bay of Bengal Surface Water, South Australian Surface Water and perhaps from Indian Ocean Central Water too. A total of 26 specimens have been collected.

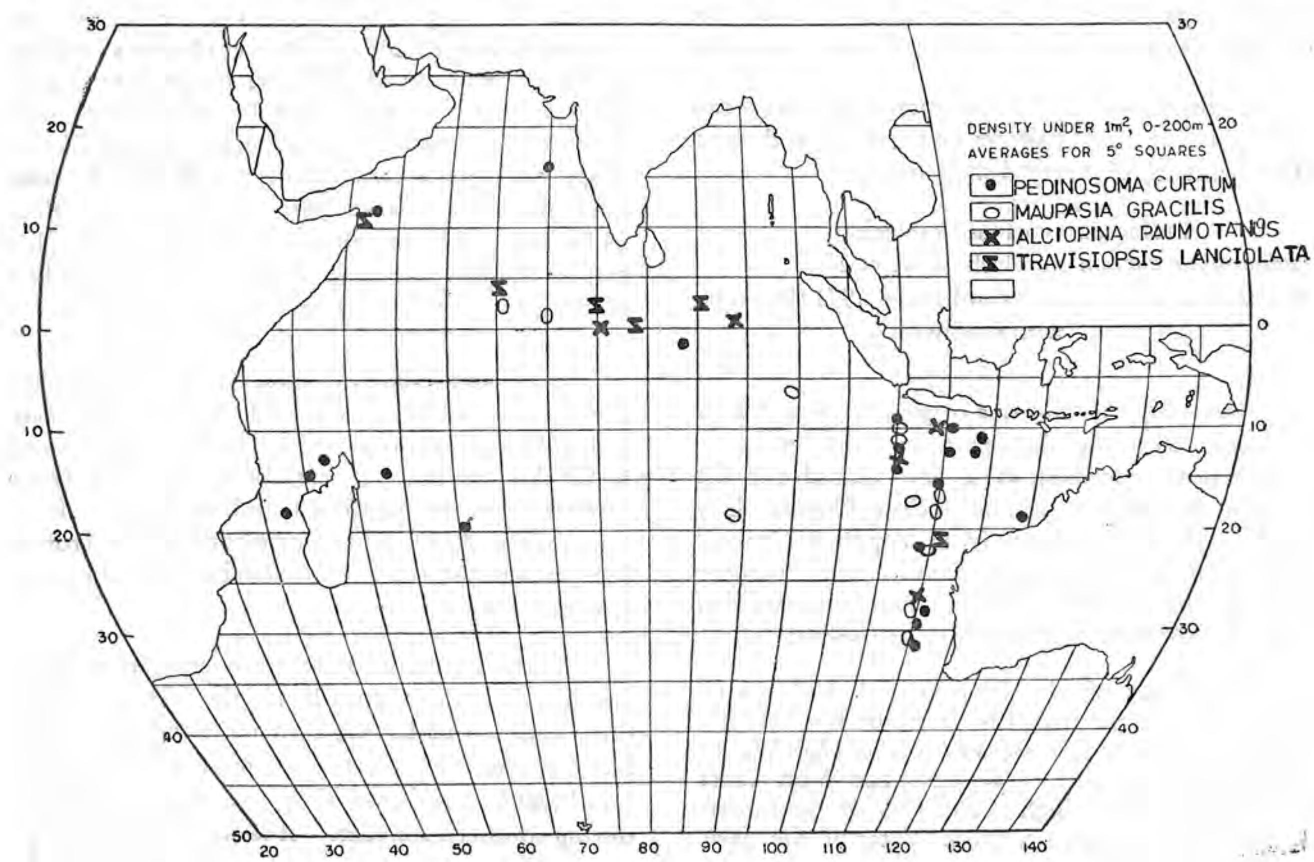
It tolerates temperature as low as 20.56 °C in the South Australian Surface Water and as high as 25.18°C in the Indian Ocean South Tropical Surface Water. Probably it lives above the thermocline where the temperature is above 20 °C at all the stations.

This stenohaline worm does not appear to tolerate much variation in salinity. Its optimum salinity range is between 34.6 °/oo and 35.43 °/oo. In none of the stations where they have been found the salinity is less than 33.4 °/oo and higher than 35.8 °/oo.

The species exhibit seasonal variation being more common during Southeast monsoon. Out of the 26 specimens only 6 specimens were collected during Northeast monsoon.

Vanadis minuta Treadwell
Vanadis min uta Treadwell 1906, p. 1158
Vanadis minuta Dales and Peter 1971 (in press, with synonymy).

Type locality of *Vandis minuta* is off the coast of Hawaii in the Sub Tropical Pacific Ocean and it is a widely distributed species in the Pacific.



Dales (1963) has recorded them from the western region of Indian Ocean off Kenya and Tanzania. But it is for the first time that it is obtained from Arabian Sea, Bay of Bengal and Southeast Indian Ocean. In the Bay of Bengal this is known to inhabit the Bay of Bengal Surface Water, in the Southwest Indian Ocean it probaly lives in South Central Surface Water and in the Southeast Indian Ocean it is found in the South Australian Surface Water. In the Arabian Sea it is an inhabitant of either of Arabian Sea Surface Water or Arabian Sea SubSurface Water. They are also likely to inhabit the Indian Ocean Equatorial Water, Indian Ocean South Tropical Surface Water and Indian Ocean Central Water. All the collections are from tropical and sub tropical regions. Most of the specimens are from central equatorial part. In the Bay of Bengal and Arabian Sea it is represented only in the coastal regions of India except for one specimen from Andaman Coast. Two specimens come from off the coast of Java, another from off Tanzania and one from Madagascar region.

Vanadis minuta does not show any difference in its abundance between the two seasons. The data clearly show that this species performs vertical migration.

A study of the hydrographic features of their habitat shows that it tolerates the temperature range between 21.36 °C and 25.77 °C and lives in the surface, above the thermocline. The optimum salinity range of this stenohaline species seems to be between 34.47°/oo and 35.14°/oo. It is probable that in the Bay of Bengal it occurs in more dilute waters. It is evident that it does not tolerate the high salinity water from the Arabian Sea. Whereever it was taken in the Araban Sea there was a layer of diluted water in the column sampled.

Alciopina tenuis (Apstein)

Corynocephalus tenuis Apstein 1900, p. 14

Plothelmis tenuis Dales and Peter 1971 (in press, with synonymy)

Only very few records have so far been made of this species. It was erected by Apstein (1900) from specimens from Tropical Atlantic and Naples in the Mediterranean. During the present investigation it has been collected from only two stations, 5 specimens from Bay of Bengal and one from Southeast Indian Ocean and these are the first records of this species for these regions. In the Southeast Indian Ocean it was taken in a haul that showed temperature between 17.44 °C and 22.13 °C and salinity between 35.2°/oo and 35.8°/oo of the South Australian Surface Water. But in the Bay of Bengal it was taken in less saline water (33.03 °/oo to 34.91 °/oo).

All the specimens were collected during the Southwest monsoon.

Alciopina paumotanus (Chamberlin)

Corynocephalus paumotanus Chamberlin 1919, p. 141

Alciopina paumotanus Dales and Peter 1971 (in press, with synonymy)

This also is a rare species first recorded from Pacific Ocean (Chamberlin, 1919). It is now recorded from Indian Ocean for the first time, from Southern part of the ocean. It seems to be more common towards the south eastern part, where it was found at 4 stations, than in southwestern region where it was collected only in one place. It is found that it can definitely withstand salinity as low as 34.4 ‰ and as high as 35.84 ‰. The data are not sufficient to show any relation to the temperature of the medium. However, it is clear that they occur somewhere in the temperature range of 13.3 °C and 28.5 °C.

It is probable that they live in Indian Ocean Equatorial Water, Indian Ocean South Tropical Surface Water, Indian Ocean Central Water and South Central Surface Water.

Out of the total 8 specimens from Indian Ocean 5 are collected during the southern winter (southwest monsoon) and 3 during southern summer (northeast monsoon). The data show that this species comes to the surface during night and goes down to deeper waters during day.

Travisiopsis lanceolata Southern

Travisiopsis lanceolata Southern 1910, p. 429

Travisiopsis lanceolata Dales and Peter 1971 (in press, with synonymy).

Travisiopsis lanceolata is a cold water species mainly recorded from South and North Atlantic waters where it occurs in deep layers (350-2000m). From the present collections it is found in eight stations. From the results of Tebble (1960) who studied stratified samples of 'Discovery' collections it was evident that this species occurred in the Sub Tropical Zone of the Atlantic Ocean in the Antarctic Intermediate Water as well as in South Atlantic Central Water with the temperature range from 2.7°C to 12°C. In the Tropical Zone it was caught in Tropical Surface Water. But in the Indian Ocean the present specimens were mostly taken in cold upwelled water with a temperature range of 13°C to 17°C. Other samples from non-upwelled waters show that the temperature was 14°C-19°C in deepest layer of the water column sampled where these worms might have been living. In the Arabian Sea Sub Surface Water and Indian Ocean Central Water it survives at a temperature of 13° to 18°C. So it seems to be a eurythermic species capable of tolerating a temperature range of 3°C or even less of South Atlantic Deep Water to 18°C of Arabian Sea Sub Surface Water and Indian Ocean Central Water. Whether they are also found in the upper layers is not clear but quite unlikely. Assuming that they are found in the lower layer the present findings show that the species can tolerate as high a temperature as 19.5°C as in station Ki 13 304. Thus the temperature range of its distribution has been considerably widened. In all the stations from where this species has been collected in the present study the temperature at the surface was high up to 29.6°C but as the collections were from 200-0 m depth probably these worms live in subsurface layers where the temperature is 12.13°C which may be tolerable to them. In the Somalia Coast the thermocline appears at 10 meters level where the temperature is 20°C and so there this species may survive very much near to the surface also.

The salinity range of this species is definitely above 35‰ as it lives in the sub surface level. It appears to be a stenohaline form.

Out of the total 13 specimens recorded 2 are from Arabian Sea and the rest from Southern Indian Ocean. This rare species was absent in the 300 samples taken in the upper 200 m of the Bay of Bengal. Of the total 13, 9 specimens were collected during the Southwest monsoon and the rest during Northeast monsoon. All the specimens except one came from night collections indicating that there is diurnal movement in this species.

ACKNOWLEDGEMENTS

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BREEDING AND GROWTH OF CHAETOGNATHS IN THE COCHIN BACKWATERS

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ABSTRACT

Studies on the breeding and growth of the common chaetognath species inhabiting the Cochin backwaters were made. Regular fortnightly collections were taken from two fixed stations during the year 1968. *Sagitta bedoti* Béraneck and *S. enflata* Grassi were the common species found in the estuary. Breeding is continuous in this tropical estuary and periods of heavy spawning are superimposed on continual spawning. The coincidence of the peak periods of chaetognaths and high density population of copepods are evidence of the acceleration of breeding with abundant food supply. The scarcity of adults in the samples is attributed to their preference for deeper layers. The annual length variations of different maturity stages of *S. bedoti* and *S. enflata* indicate great overlapping. However, in the same sample there is definite relationship between size of the individual and maturity upto stage II.

INTRODUCTION

Published information relating to the breeding cycles of *Sagitta* indicates that these cycles appear to vary with geographical location. The number of generations produced each year generally increases with distance from poles (Dunbar, 1941; Owre, 1960 and Ghirardelli 1968). In the Arctic, *S. elegans arctica* (Dunbar, 1941) and in the subantarctic *S. gazellae* (David, 1955) produce one brood per year. There are two spawning periods during spring and summer with a possible third in October in the North Sea (Wimpenny, 1937). In the Irish Sea *S. elegans* breeds in one long period (Pierce, 1941). Russell (1932 a, b) records 4 – 5 broods in the Plymouth area. Clark *et al.* (1943) found a major spawning in spring and another in late summer in Georges Bank. Off the west coast of Florida (Pierce, 1951) and off Miami, (Owre, 1960) many of the tropical oceanic species breed throughout the year.

However, little is known about the breeding of chaetognaths from the Indian Waters. Rao and Kelly (1962) have given an account of the breeding of *S. enflata* in Lawson's Bay. They found the species to breed almost throughout the year with several periods of intense breeding. Recent studies of Srinivasan (1971) on the chaetognaths of the Cochin Harbour area also indicate continuous breeding of. *S. enflata*.

In the present investigation attempt was made to study the breeding and growth of the common chaetognath species occuring in the Cochin backwaters, an estuary connected to the Arabian Sea. An assessment of the chaetognath fauna inhabiting this estuary and their seasonal fluctuations have already been studied (Vijayalakshmi, 1971). The incidence of juveniles or mature individuals of a particular species in regular plankton collections is taken as a measure to evaluate the reproductive conditions of the population.

ENVIRONMENT

The Cochin backwaters is part of a long chain of lakes and canals extending into the north and south of Cochin parallel to the coast in central Kerala. This is a tidal estuary and the conditions in the area are influenced both by the sea and by the freshwater influx which is considerable during the monsoon period. The hydrographical pattern characteristic of this area has been investigated by previous workers (Ramamirtham and Jayaraman, 1960, 1963; Qasim and Gopinathan, 1969 and others).

MATERIAL AND METHODS

The material is from the fortnightly collections from two fixed stations, one at Fairway Buoy (lat. 09°57' N and long. 76°10'E) and the other at Aroor (lat. 09°54'N and long. 76°17'E) during the year 1968. The stations are shown in fig. 1. The samples were taken from surface hauls of five minutes duration with a HT net (Tranter *et al.*, 1972). The details of the collections are given by Menon *et al.* (1971).

Chaetognaths from these collections were examined for stages of maturity and each species was separated into five stages based mainly on the works of Colman (1959) and Alvariño (1967).

Juveniles ... Testes and ovaries have not started developing.

Stage I ... Testes visible, but no sperm ball or spermatozoa free in the tail coelom. Ovaries small.

Stage II ... Tail filled with spermatozoa. Ovaries developing. Ova small.

Stage III .... Tail empty. Ovaries reaching a further step in their development, and filled with large and small ova, some of which are full size.

Stage IV ... Tail empty. All ova fully developed.

For indicating the frequency of different stages during the course of the year, the five stages were reduced to four categories i. e. juveniles, stage I, Stage II and Stage III + IV. The stages III and IV were combined into one category since they include individuals whose ovaries contained at least some mature eggs plus individuals which are fully mature and will be referred as Stage III + in the text. These two stages formed a very small percentage of the total chaetognath population and when combined, they had a better representation, more clarity and little accuracy lost.

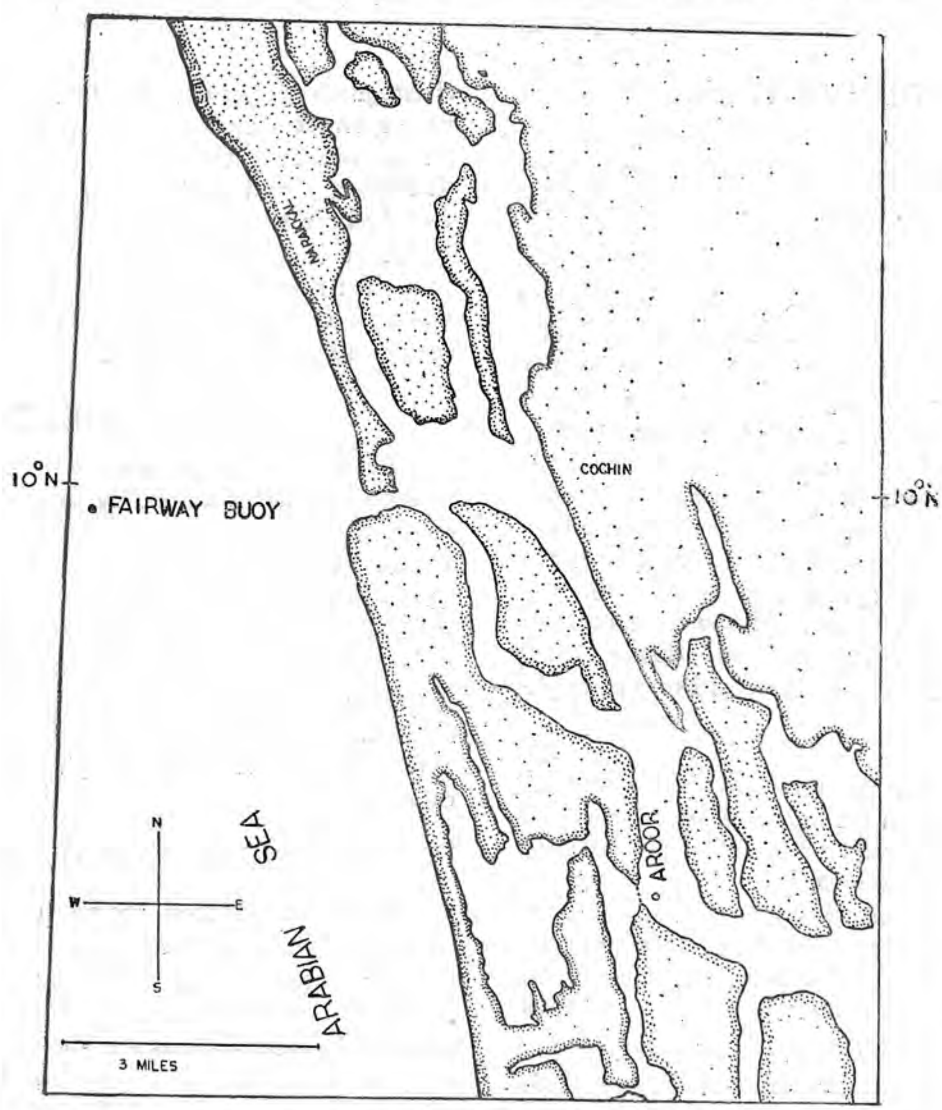

Fig. 1. Map of the Cochin backwaters showing the location of stations.

For the study of length distribution of different maturity stages, the total length, i. e. the distance from the anterior extremity of the head to the tip of the caudal segment excluding the caudal fin was measured. The values recorded are average measurements of 5-10 largest individuals of a particular stage in each sample.

OBSERVATIONS

The two stations, namely Aroor and Fairway Buoy were found to be under different hydrographical conditions. The salinity of the Aroor region varies from that of fresh water to practically that of sea water during the course of the year. In general the later part of June to November is the period of low salinity (0.4 to22.2°/oo) and December to May of high salinity (27.2 to 32.8°/oo). Fairway Buoy area is also influenced by monsoon cycle having low salinity water during the southwest monsoon period (11.6 to 21.5°/oo). These salinity variations had consequently affected the abundance and seasonal fluctuations of chaetognath population at the two locations (Vijayalakshmi, 1971).

Temperature of the water was almost constant at both the stations throughout the year except for a slight decline during the southwest monsoon period.

Four species were encountered in the collections, the species being *Krohnitta pacifica* Aida, *Sagitta bedoti* Béraneck, *Sagitta enflata* Grassi and Sagitta robusta Doncaster. Of these *S. bedoti* was found to occur more or less constantly in the Cochin backwaters, while *S. enflata* was a frequently occuring species (Vijayalakshmi, 1971). The other two species were rare in the collections and hence no attempt was made to study their breeding periods.

In these collections, mature individuals of *S. bedoti* and *S. enflata* were found to be rare and hence juveniles had been considered as an index to the breeding.

Breeding of chaetognaths at Aroor

Aroor is typically estuarine with a complete turnover of saltwater into fresh water and chaetognaths were found only during the period (December to early June) of relatively high salinity.

S. bedoti

Variation in the abundance of different maturity stages for *S. bedoti* is represented in Fig. 2A. The peak occurrenec of the different maturity stages coincided with the later part of February, the number of specimens for each category being 347/100m^3 for juveniles, 2798/100m^3 for Stage I, 121/100m^3 for Stage II and 5/100m^3 for Stage III+. This was followed by a small peak of juveniles during April to early May and this seems to be the young ones of mature individuals encountered in the later part of March. The second peak period for stage I was in the latter part of May.

Although breeding is continuous fluctuations in the relative abundance of juveniles should indicate periods of high and low spawning. The percentage variation of juveniles of *S. bedoti* is shown in Fig. 2B. The mean percentage of juveniles considered as the level at, and above which abundance indicates a period of heavy spawning. This assumption indicates the occurrence of three such periods of heavy spawning in the middle of January, middle of February and April to early May.

S. enflata

Fig. 2 C. shows two peak periods of juveniles, one in the latter part of December and the other in February. The other categories were only very sparcely represented. No attempt was made to find the periods of heavy spawning as they were poorly represented in the samples.

Breeding of chaetognaths at Fairway Buoy

A perusal of the hydrographical data at the time of collection reveals the existence of three different water masses at Fairway Buoy. From late October to May, diluted Arabian Sea Surface water prevailed, having a salinity range of 29.5 33.0°/oo and temperature 28.8-32.6° C. In July surface water was of low salinity (18.0 °/oo) and of relatively low temperature (25.4 °C). During early September, upwelled cold (25.7 °C) water was present, but the salinity was still lower (13.4°/oo) due to run off from land. These upwelled waters in July and September may or may not be the result of the same upwelling movement. So, unlike the single population existing at Aroor, different populations are bound to occur at different times at Fairway Buoy. The life cycle of the species was found to be correlated with the presence of different water masses.

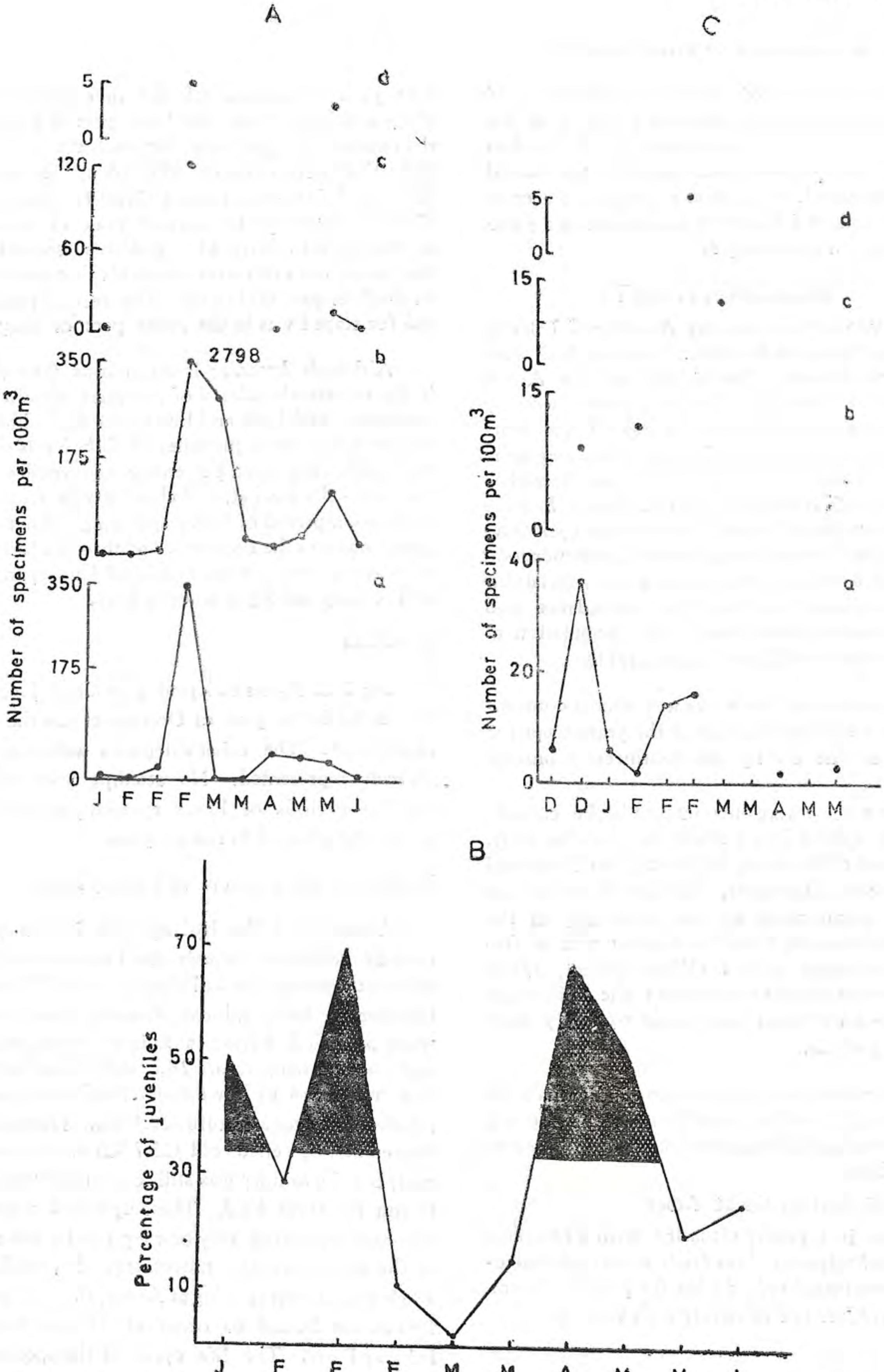

Fig 2. A Variation in the abundance of *S. bedoti* at Aroor.
a - juveniles c - stage II
b - stage I d - stage III+

B. Variation in the percentage distribution of juveniles of *S. bedoti* at Aroor. Darkened areas indicate values above the mean percentage.

C. Variation in the abundance of *S. enflata* at Aroor.
a - juveniles c - stage II
b - stage I d - stage III +

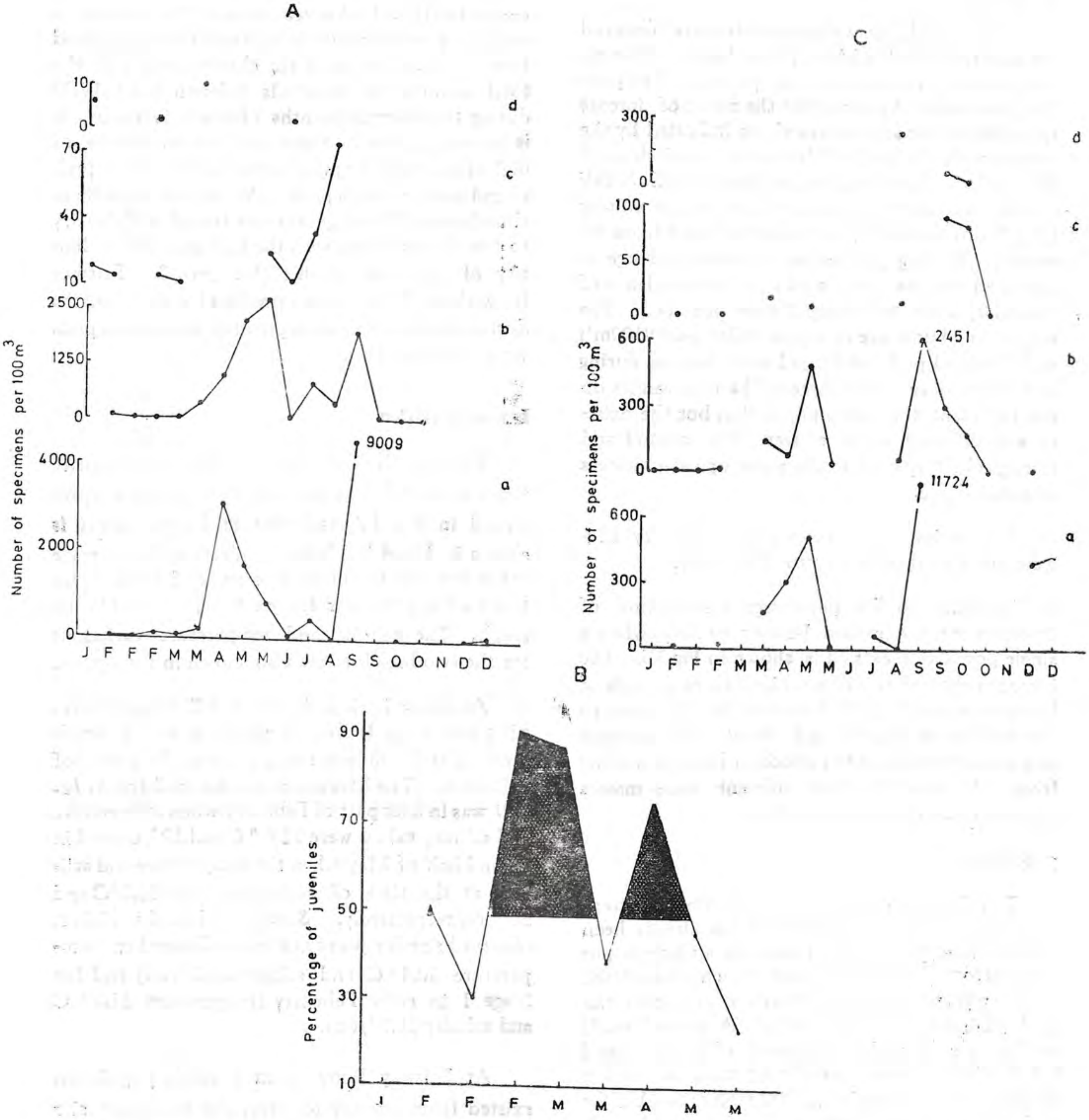

Fig. 3. A. Variation in the abundance of *S. bedoti* at Fairway Buoy.
a - juveniles c - stage II
b - stage I d - stage III +

B. Variation in the percentage distribution of *S. bedoti* at Fairway Buoy. Darkened areas indicate values above the mean percentage.

C. Variation in the abundance of *S. enflata* at Fairway Buoy
a - juveniles c - stage II
b - stage I d - stage III +

S. bedoti

Three peak spawning periods were observed for this species (Fig.3A.) From January through May a single population was present. The peak for juveniles in April may be the result of intense spawning in January to March as indicated by the presence ofindividuals with mature ova all through this period. Low population density of *S. bedoti* during June was correlated with lowering of salinity (21.5 °/oo) caused by the influx of water from the estuary. During July along with the presence of upwelled waters small peaks in the abundance of juveniles, Stage I and Stage II were observed. The maximum abundance of the juveniles (9009/100m^3) and the third peak for Stage I were noticed during early September. The three peaks of juveniles do not represent the same population but the existence of different water masses. The second and third peaks may refer to the same upwelled waters as stated above.

Mature individuals belonging to category III+ were not found from July to December.

Variation in the percentage distribution of juveniles for the period January to May when a single population existed is shown in Fig.3B. The juveniles showed two or probably three periods of heavy spawning in early February, late February to the middle of March and April. No attempt was made to study the periods of heavy spawning from July onwards since different water masses seem to exist during this period.

S. enflata

Fig. 3 C reveals a more or less similar pattern of abundance for *S. enflata* as has already been discussed for *S. bedoti*. There was a single population from January to May which had intense breeding from January to March resulting in the peak during April to early May. A second small peak was seen in July followed by the third and the maximum abundance during early September (number of juveniles being 11724/100m^3). Unlike *S. bedoti* a conspicuous peak abundance of juveniles was observed in December. Stage III + specimens were occasionally collected from August onwards. Even though the peak occurrence of juveniles is clearly evident from April to early May, the discontinuity of juveniles in the collection prevents an attempt to find the periods of heavy spawning.

An analysis of the stomach content of chaetognath in this backwater shows that copepods (mainly *Acartia* and *Oithona*) form the major food item. A comparison of the chaetognaths with the total number of copepods (Menon *et al.* 1971) during the different months (Table I) is made. It is interesting to note the coincident occurrence of high chaetognath population with that of the peak abundance of copepods At Aroor maximum abundance of chaetognaths was found in February to March coinciding with the high population density of copepods during this period. Fairway Buoy showed the maximum values for chaetognaths during April, May and September when copepods were also abundant.

Length variation

The length variation of different maturity stages of *S. bedoti* and *S. enflata* at Aroor is represented in Fig. 4 A and that at Fairway Buoy is shown in Fig. 4 B. In each collection the average value for the maximum size attained by different stages of a particular species is represented in the graph. The salinity and temperature variations for the two localities are also shown in the figures.

At Aroor both *S. bedoti* and *S. enflata* (juveniles and Stage I) showed variation in the length attained at the different stages during the period of collection. The Maximum size attained for *S. bedoti* was in later part of February when temperature and salinity values were 32.6 ° C and 29 °/oo and in second half of May when the temperature and salinity at the time of collection were 32.2 °C and 30 °/oo respectively. *S. enflata* had the highest observed size for juveniles in late December (temperature 30.4° C and salinity 28.2 °/oo) and for Stage I in early February (temperature 31.0° C and salinity 28.9 °/oo).

At Fairway Buoy when a single population existed from January to May, the maximum size attained for *S. bedoti* was in early February (temperature 29.8 °C and salinity 31.5 °/oo) and for *S. enflata* in early May (temperature 29.8 °C and salinity 33.0 °/oo). However, the maximum size attained for the two species was in August when temperature was 29 °C and salinity value was relatively low (16.8 °/oo).

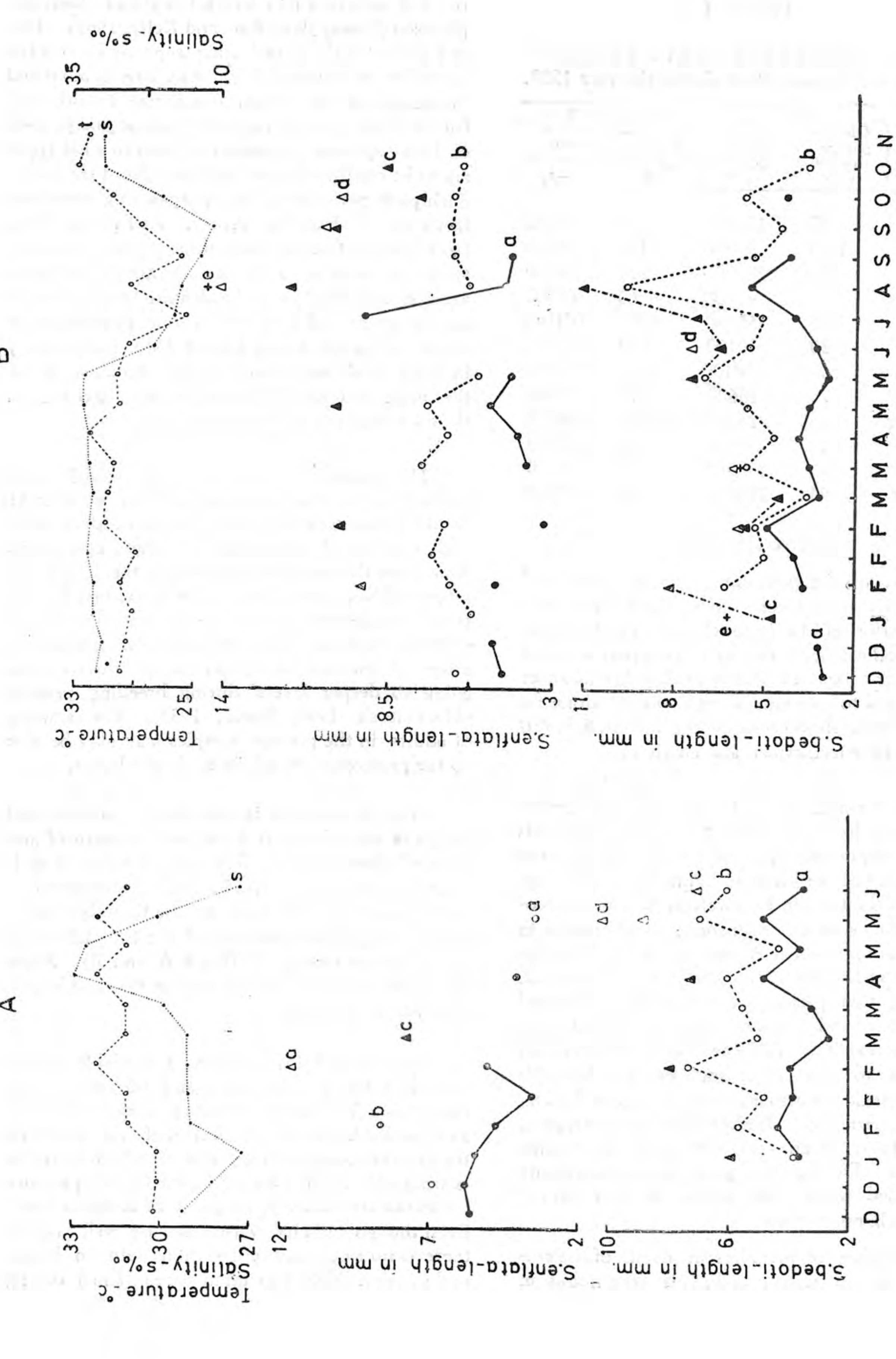

Fig. 4. A. Length variation of chaetognaths at Aroor.
a - juveniles
b - stage I
c - stage II
d - stage III
s - salinity
t - temperature

B. Length variation of chaetognaths at Fairway Buoy.
a - juveniles
b - stage I
c - stage II
d - stage III
e - stage IV
s - salinity
t - temperature

Table I

Average number of Chaetognatha and Copepoda at Aroor and Fairway Buoy during the year 1968.

Month	Aroor		Fairway Buoy	
	Chaetognatha (no/100 m^3)	Copepoda (no/100 m^3)	Chaetognatha (no/100 m^3)	Copepoda (no/100 m^3)
January	17	171100	24	90200
February	1121	97800	122	46200
March	175	303600	501	21700
April	80	41400	4765	469500
May	129	55800	4311	101100
June	20	20100	129	45900
July	..	30100	1378	87600
August	..	16600	777	351400
September	..	28500	12843	399300
October	..	8600	141	25800
November	..	297200	...	31900
December	44	116900	474	101900

DISCUSSION

In general, the estuarine fauna is constitued of relatively few species but their numerical representation will be large (Emery *et al.*, 1975). The tropical estuary is believed to support a much wider range of species (Emery *et al*, 1957); however *S. bedoti* and to a certain extent *S. enflata* alone are able to tolerate these estuarine conditions. *S. bedoti* seems to be eurythermal and euryhaline.

In an esturine habitat, with an environment of changing hydrographical conditions salinity is the most important physical factor that governs the existence of organisms. This is especially significant in the Cochin backwaters, where on account of the seasonal monsoon, rapid changes in salinity were noticed at Aroor and salinity continued to be at low level from late June to November. So during this period chaetognaths disappeared from Aroor and the area was repopulated when salinity increased during December to a level which is tolerant to the organism. Fairway Buoy is located outside the estuarine system, about 4.8 km. north of barmouth. Unlike the Aroor region, Fairway Buoy is an area dominated by marine conditions. During the periods of low salinity the upwelled water mass seems to maintain the chaetognath population.

Occurrence of juveniles in most of the collections suggest that breeding is continuous in tropical waters, a fact which has already been emphasised (Owre, 1960; Rao and Kelly, 1962). Rao and Kelly (1962) found nine separate broods for *S. enflata* in Lawsons' Bay. As Owre (1960) stated "it is difficult to recognize separate broods and follow them through maturity because the periods of heavy spawning are superimposed in what appears to be continual spawning throughout the year". Such peak periods of heavy spawning were seen thrice for *S. bedoti* at Aroor. At Fairway Buoy from January to early June, three periods of heavy spawning were noticed. Even though the data are not sufficient to make definite conclusions it can be presumed that the young population of chaetognaths are steady having distinct periodicity in their peak occurrence. The examination of the male and female gonads of the two species shows a tendency to be protandrous.

The frequency of adults was noticeably small in relation to the juveniles and the number of adults found was never sufficient to produce such high density of juveniles. All these collections were from the upper strata, leaving the deeper 5–6 metres without sampling. The adults may be aggregating in deeper layers while the juveniles ascend to surface waters. There is indication in the literature of the mature specimens of chaetognaths going to deeper layers during breeding periods (Mackintosh, 1937; David, 1955). The scarcity of adults in the present samples may also be due to the preference of adults to deeper layers.

Size at maturity is exceedingly variable and length is considered to be a poor indicator of any stage of development. The annual range of each stage for a particular species will greatly overlap. Nevertheless, in the same sample there is definite relationship between the size of the individual and maturity upto Stage II (Fig.4 A and B). After Stage II the maturity stages may or may not have a correlation with size.

Only limited information is available on the growth rates of chaetognath and the factors affecting this. The investigations of Russell (1932a,b) and Clark *et. al.* (1943) deal with the effect of temperature on growth and size at which maturity is attained. Being a tropical estuary, temperature variations are relatively insignificant in this habitat. Even though salinity variations are well marked there is no significant correlation between length and salinity. The maximum size attained during the period of low salinity in July and August at Fairway Buoy is an exception and this may be due to the presence of another population.

The high population density of chaetognaths at particular months indicates the presence of a high standing stock of plankton, since it can sustain an abundant population of highly predaceous carnivorous animals like chaetognaths. Chaetognaths mainly feed on any small animal of suitable size with which they come in contact in the plankton. Copepods being the commonest element of the zooplankton naturally they form the most frequent prey (Vijayalakshmi and Rao, in press). Investigations of Reeve (1966) on the feeding habits and food availability of *S. hispida* from Miami show definite indications of the relationship of *Sagitta* to its food supply. He found that increase in the *Sagitta* population was associated with the incidence of copepods and barnacle nauplii in the water. In the present samples also there is a relationship between the maximum abundance of chaetognaths and dense populations of copepods This coincidence of the peak periods of chaetognaths and copepods indicates the probability of chaetognaths coming in pursuit of the prey. The availability of abundant food along with other factors favoured intense breeding during February to March at Aroor and April to May and September at Fairway Buoy.

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DEVELOPMENTAL STAGES OF PENAEOPSIS RECTACUTA BATE (DECAPODA:PENAEIDAE) FROM THE INDIAN OCEAN

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ABSTRACT

This paper is one of a series of larval descriptions of penaeid prawns belonging to the sub-family Penaeinae resulting from materials collected during the International Indian Ocean Expedition programme, 1960-65. In addition, some collections made during the cruises of the fishing-cum-training vessel 'Blue Fin' in 1970, from the southwest coast of India were useful in obtaining some of the missing larval stages. The larval stages from 1st protozoea to the juvenile of *Penaeopsis rectacuta* Bate are described for the first time based on a collection of 165 larval specimens obtained from 109 samples.

The larvae are abundant off the Nicobar Islands in the Bay of Bengal and off Muscat and Oman in the north western part of the Arabian Sea. Appreciable quantities are also obtained from off Bombay and Mangalore in the west coast of India; off Colombo in the Gulf of Mannar; off the Gangetic delta in the northern part of the Bay of Bengal, and the Gulf of Aden, off Somali and the north-west Arabian Sea. It is observed that the larvae are mostly found in coastal waters. Although this species has not been recorded from Australian and South African regions, few larvae were obtained from 30-280 m depth regions on the north-western side of Australia and south of Africa in the Indian Ocean.

INTRODUCTION

The developmental stages of a number of penaeid prawns are known from the works of Monticelli & Lo Bianco (1901), Gurney (1924, 1926, 1927, 1943), Hundinaga (1942), Pearson (1939), Heldt (1938), Menon (1937, 1952), Dobkin (1961), Cook (1966), Cook & Murphy (1971), and Kirkegaard (1969). Apart from the descriptions of some stages of a few species (Menon 1937, 1952); Subrahmanyam 1965; Mohamed et al. 1968; Paulinose (in press); George & Paulinose (in press), no detailed work of the early life-history of Indian species of prawns is available.

The materials were obtained from samples collected during the International Indian Ocean Expedition in the Indian Ocean. About 165 larval specimens were obtained from 109 samples. The 1st protozoea and the juvenile are collected from the cruises of the vessel 'Blue Fin' in 1970 from the S. W. coast of India, in the Arabian Sea. All stages are obtained from plankton from depths varying from 30-300m. The larvae are widely distributed in the Indian Ocean, most abundant areas are off the Nicobar islands, in the Bay of Bengal and off Muscat and Oman in the Arabian Sea. The present records from the north-west Australian waters and the South African Coasts are new extensions in distribution of this species in the Indian Ocean.

The existing species of the genus *Penaeopsis* are *P. rectacuta, P. serratus* and *P. megalops*. The last mentioned being an Atlantic species, there are only two existing species in the Indian Ocean. Burkenroad (1934) states that no clear diagnostic distinction between *P. rectacuta* (as *P. rectacutus)* and *P. serratus* has ever been established. The two species are now separated through characters like the shape of the rostrum, ventral setae on the rostrum, the position of the pterygostomian spine, position of the hepatic spine in relation to the antennal spine etc. Besides, Ramadan's is the only record of *P. serratus* in the Indian Ocean while *P. rectacuta* is the common species from these waters (Bate, 1888; Alcock & Anderson, 1894; Alcock 1901, 1906; de Man, 1911; Burkenroad, 1934; Kubo, 1949; Ramadan, 1938; Hall, 1962; George; 1966, 1969). So it is felt that the present larvae may be reasonably assigned to *P. rectacuta.*

Scattered information of a few larval stages of this genus is available from the works of Gurney (1924, 1943) and Kurien (1954). Gurney described the protozoea (3 stages), mysis (3 stages) and post-larva (stage I). All the materials being from plankton he did not assign to any particular species. Although the stages obtained here also are collected from plankton, the protozoeae, myses and post-larvae are identified to be belonging to *Penaeopsis rectacuta* since that is the only species of the genus common in these waters.

LARVAL STAGES

Protozoea I - Length 0.84 mm (Fig. I a-f)
Material : 1 specimen
Locality : Stn. No. BF7 (NIO, 1971) - off Alleppey coast in Arabian Sea, Kerala Coast.

Carapace slightly concave at the anterior extremity. Eyes jointed; antennule uniramous with 3 apical setae of which one is very long (Fig. 1 b) and others short and slender; antenna (Fig. 1 c) biramous,, endopod with 2+2+4 setae, scale 9-segmented bearing 10 setae. Labral spine present.

Mandible (Fig. 1 d) with a well-developed masticatory surface, molar and incisor processes distinguished, suited for active feeding. 1st maxilla (Fig. 1 e) with the basal portion produced into two endites, 5 setae on the proximal endite and 4 on the distal. A papilla-like exopod with 5 plumose setae and a three - segmented endopod with 2 setae on each segment present. 2nd maxilla (Fig. 1 f) with protopodite possessing 5 endites

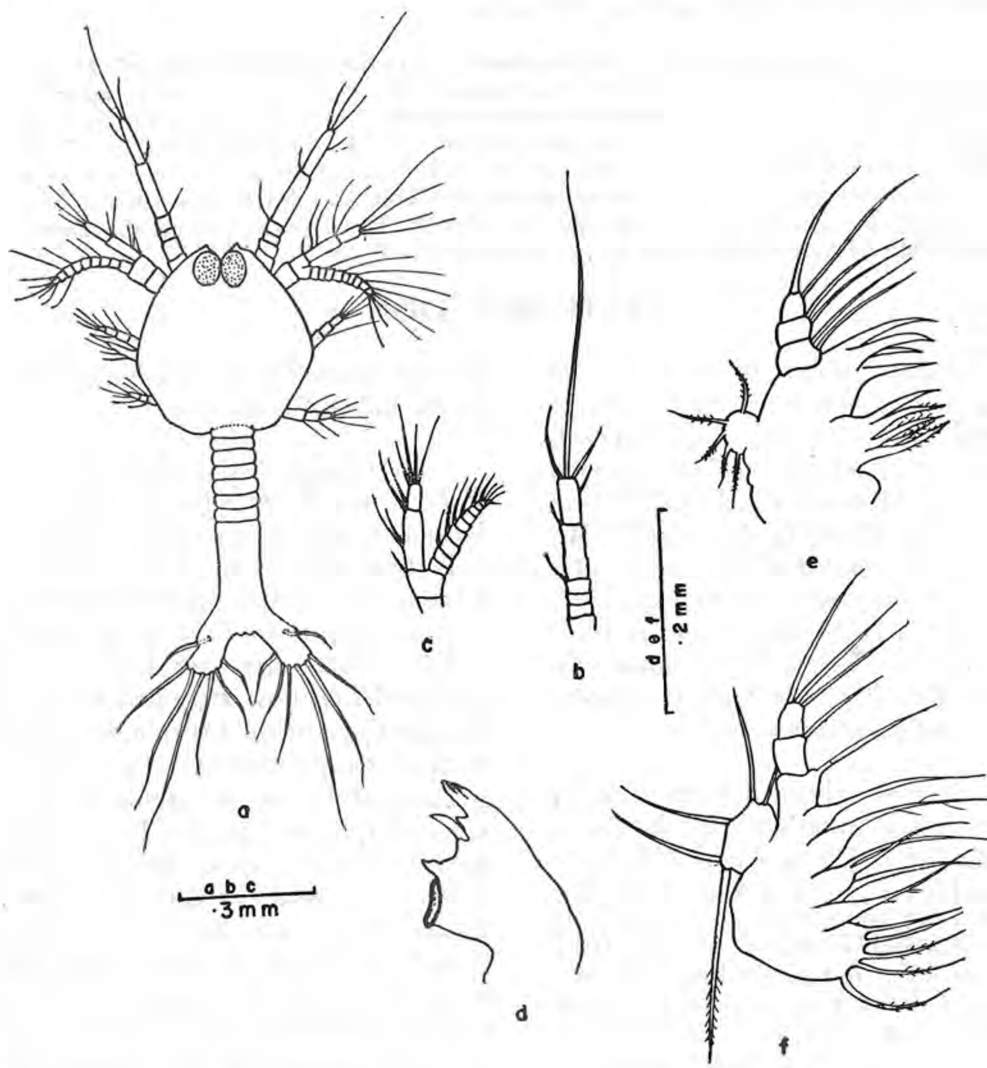

Fig. 1. *Penaeopsis rectacuta*
Protozoea I. a. dorsal view; b. antennule; c. antenna; d. mandible; e. 1st maxilla; f. 2nd maxilla.

each armed with setae, short exopod bearing 5 plumose seta e, endopod three-segmented, the dista segment with 3 terminal setae and 1 seta each on other segments. Maxillipeds are developing. Telsonl with rami very divergent, bears 7+7 setae, one ventro-lateral and visible only from below.

Protozoea II - Length 1.4 mm - 1.8 mm (Fig. 2a-f)
Material : 3 specimens
Locality : Stn. No. Me 73-(IOBC 1969) Gulf of Aden. Stn. Nos. AB 367 & 379 Madagascar region.

Carapace with rostrum nearly as long as the eyes. Supraorbital spines absent. Labral spine prominent. Eyes separate and stalked. Antennule (Fig.2 b) shorter compared to body length; peduncle 3-segmented, the basal segment subdivided into 4 and with 3 setae present on the distal segment. The antenna (Fig. 2 c) has a multi-segmented scale with marginal setae and three-segmented endopod with 4 apical setae.

Mandible (Fig. 2 d) with distinct molar and incisor processes. Ist maxilla (Fig. 2 e) has an additional segment in the endopod and only 4 setae on the exopod. 2nd maxilla (Fig. 2f) has the endopod four-segmented. Maxillipeds more developed and biramous. Telson (Fig. 2 a) carries the same number of setae, 7+7. The gap between the 2 rami is much reduced, and rami become long and narrow.

Protozoea III : Length 2.2 mm (Fig. 3a-f)
Material : 2 specimens
Locality : Stn. No. Ki 662 & Me 196 - off Mangalore in the Laccadive region.

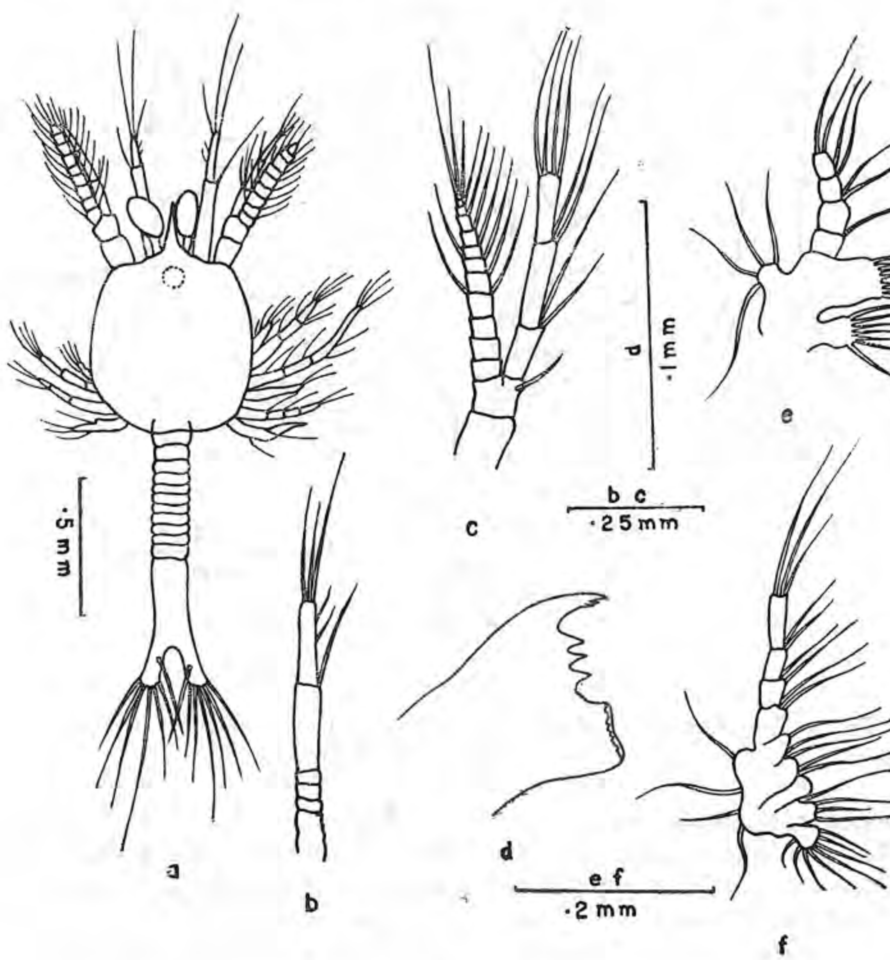

Fig. 2. Protozoea II. a. dorsal view; b. antennule; c. antenna; d. mandible; e. 1st maxilla; f. 2nd maxilla.

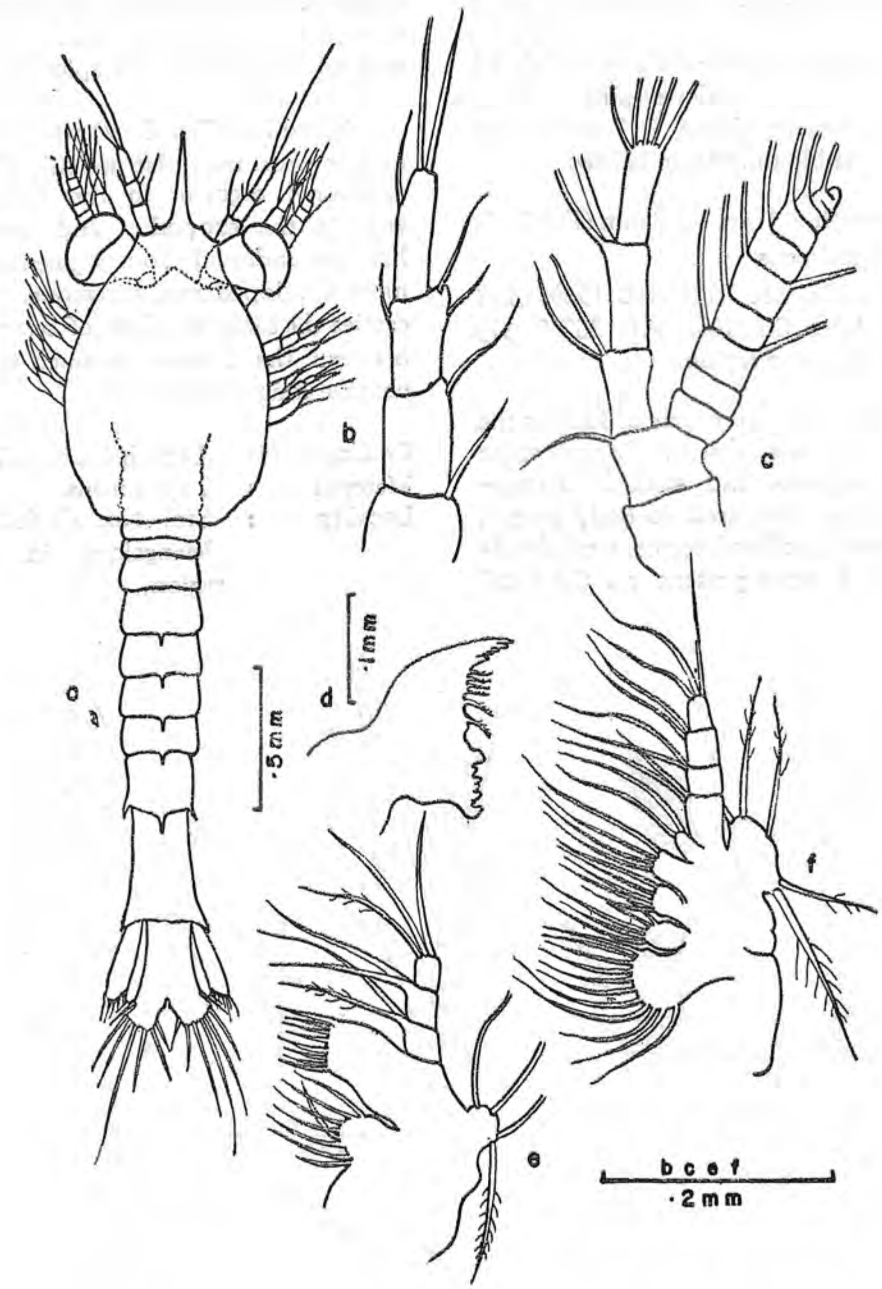

Fig. 3. Protozoea III. a. dorsal view; b. antennule; c. antenna; d. mandible; e. 1st maxilla; f. 2nd maxilla.

Carapace with minute supra-orbital and pterygostomian spines. Rostrum long extending to the tip of the antennular peduncle. Other important advances in this stage are the presence of dorso-median spines on the anterior 5 abdominal segments and appearance of the uropods. A pair of dorso-lateral spines present on the 5th abdominal segment and a pair of ventro-lateral spines on the 6th abdominal segment.

Antennule (Fig. 3b) shows the origin of the inner flagellum, with a 3-segmented peduncle. Mandible (Fig. 3d) has 6 denticular setae in between the incisor and molar processes. Maxillae (Fig. 3e, f) not much changed. Maxillipeds 1-3 biramous; legs 1-5 present in the form of biramous buds. The exopod of the uropod bears 6 setae and the endopod 3 setae. Telson rami about twice as long as wide and bears only 7+7 setae.

Mysis I - Length 2.8 mm- 3.5 mm (Fig. 4 a-h)
Material : 12 specimens.
Locality : Stn. Nos. AB 43,49; INSK 167, 662; Me 104, 195; Di 5528; Dm 31; BF 10-Bay of Bengal, Andaman Sea, Arabian Sea and N.W. Coast of Australia.

Rostrum with one or two small dorsal teeth and extends well beyond the eyes. Carapace with a small supra-orbital spire and a pterygostomian spine. Labral spine present. The region of the antennal spine angular. The antero-inferior margin of the carapace denticulate with nearly 10 minute teeth (Fig. 4a).

Antennule (Fig. 4b) with a 3-segmented peduncle, bearing 2 unjointed flagella; inner flagellum small, knob-like, with a single seta terminally, basal segment of the peduncle with a prominent

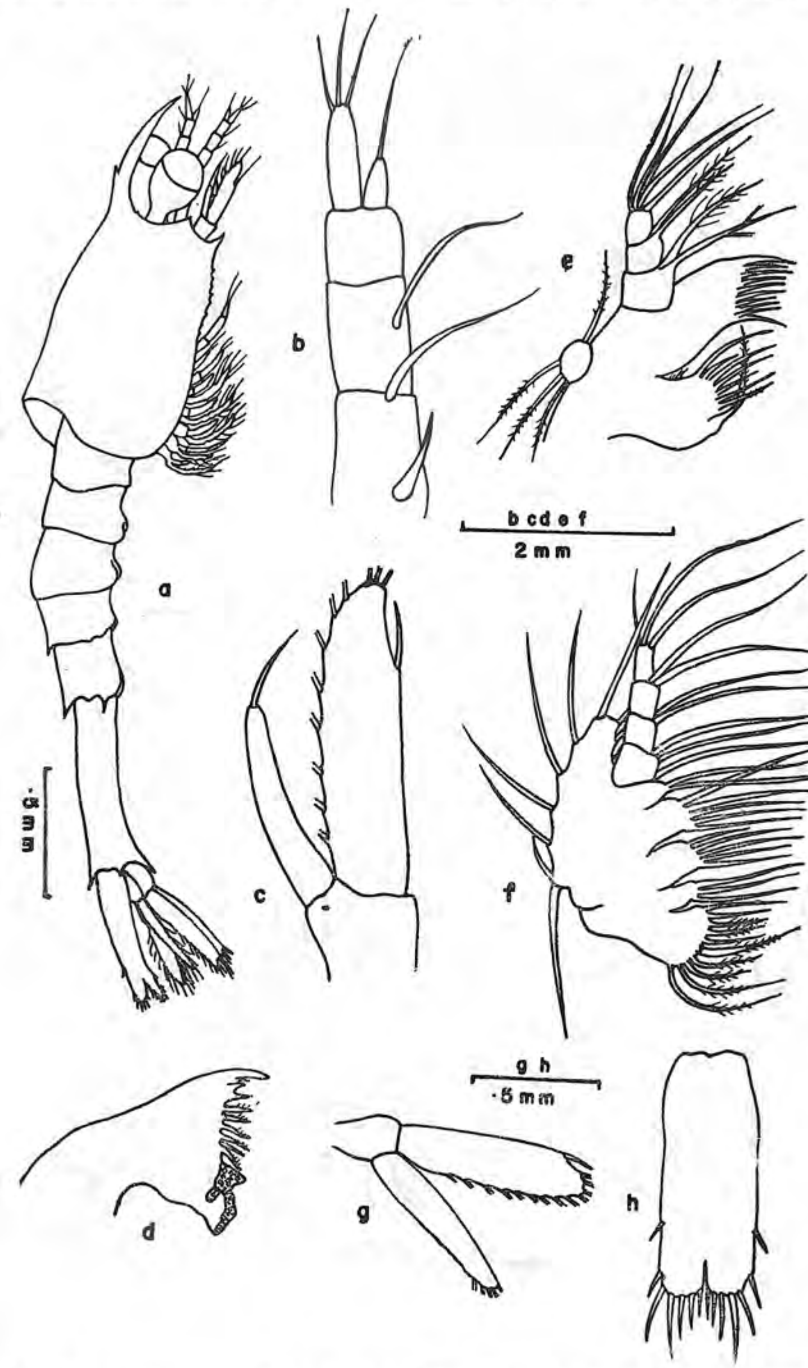

Fig. 4. Mysis I. a. side view; b. antennule; c. antenna; d. mandible; e. 1st maxilla; f. 2nd maxilla; g.uropod h. telson.

spine. Antenna (Fig.4c) with an unsegmented endopod with a terminal seta and unjointed scale, the latter bearing one outer seta and a few setae at its inner margin. Mandible (Fig.4 d) with incisor and molar processes; 6 denticular setae are found in between them. No palp present. 1st maxilla (Fig. 4e) with 5 setae on the terminal segment of the endopod and 4 setae on the exopod. 2nd maxilla (Fig. 4f) with a well-developed exopod having 10 setae. Maxillipeds 1-3 with developed exopod.s

Abdomen with dorso-median spines on 4-6 segments. Somites 5 and 6 with a pair of dorsolateral spines and 6 with a pair of postero-ventrai spines. Legs with long exopods; endopods of legs 1-3 bifid at the tips, forming chelae. Pleopods absent.

Telson (Fig.4h) quadrangular with a deep narrow posterior cleft and a pair of lateral spines. The spin formula is 7 + 7. The exopod (Fig. 4g) of the uropod with a spine.

Mysis II - Length 4 mm - 4.2 mm (Fig.5 a-k)
Material : 33 specimens
Locality : Stn. Nos. AB 26, 29, 37, 49, 65, 194, 195; Va 1803, 1815; INSK 163, 167, 397, 514, 515, 662; Ka 19; Me 104, 195; Di 5037, 5051, 5054; Dm 86- Different regions of the Indian Ocean.

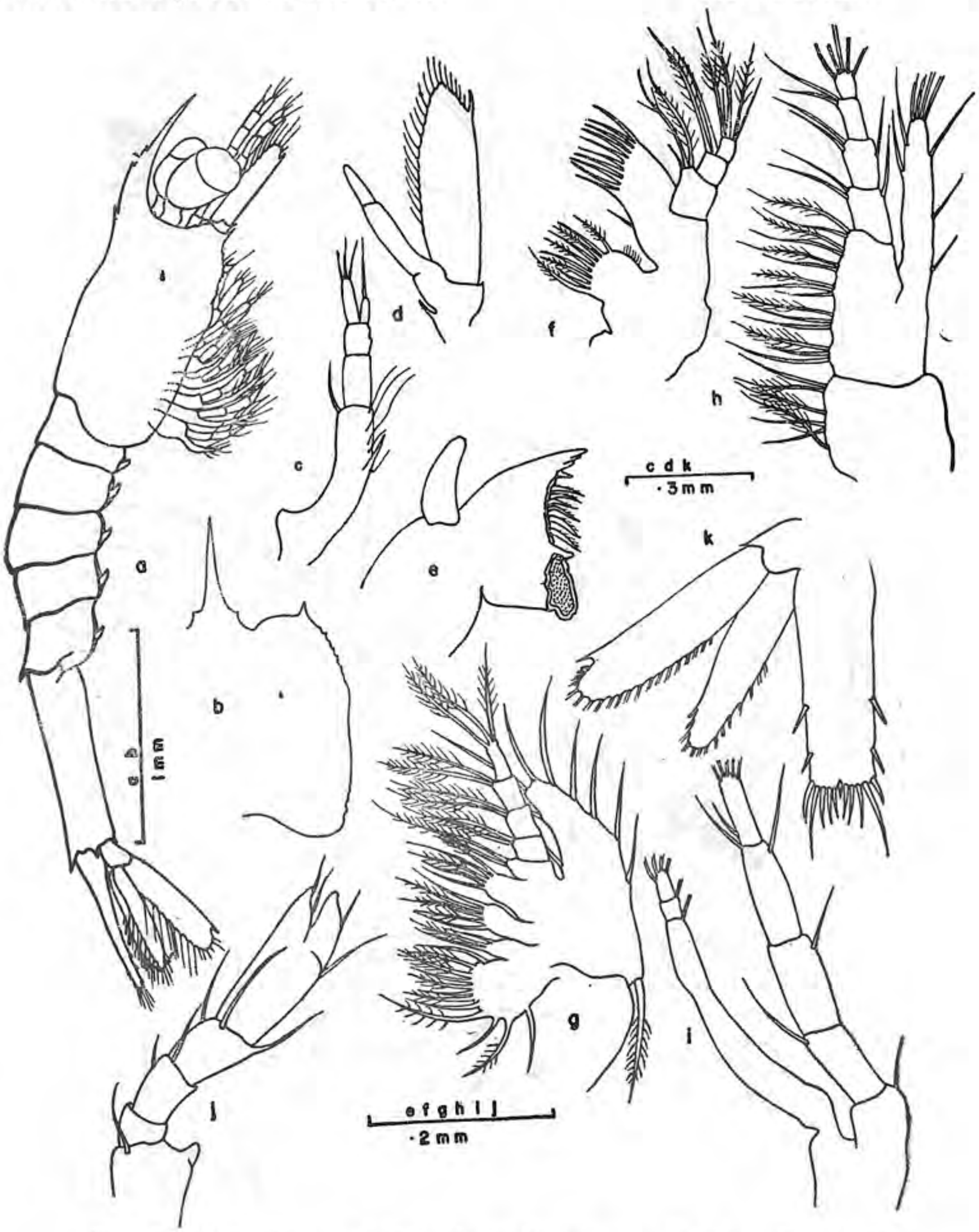

Fig. 5. Mysis II. a. side view; b. carapace; c. antennule. d. antenna; e. mandible; f. 1st maxilla; g. 2nd maxilla; h. 1st maxilliped; i. 3rd maxilliped; j pereopod; k. uropods.

Rostrum with 2 dorsal teeth and the epigastric; very minute hepatic spine present (Fig. 5a). The denticulation of the antero-inferior margin of the carapace is reduced. The supraorbital spine hardly visible in profile view (Fig.5b).

The antennule (Fig. 5c) not changed much except the size of the flagella. The antennal scale (Fig. 5d) with a spine and endopod 2-jointed. Mandible (Fig. 5e) with an unsegmented palp without setae; 6 stout spines in between the incisor and molar processes. 1st maxilla (Fig. 5f) without exopod; endopod short, 3-segmented; number of terminal setae on the distal segment remains the same. 2nd maxilla (Fig. 5g) with a large exopod, the narrow proximal part with only one large seta; endopod has 4 segments and the protopodite produced into 5 endites bearing strong setae. Maxillipeds (Fig. 5h, i) 1-3 well developed, bearing 5 setae terminally on the endopod. Legs 1 3 (Fig. 5j) chelate with exopods. No trace of gills.

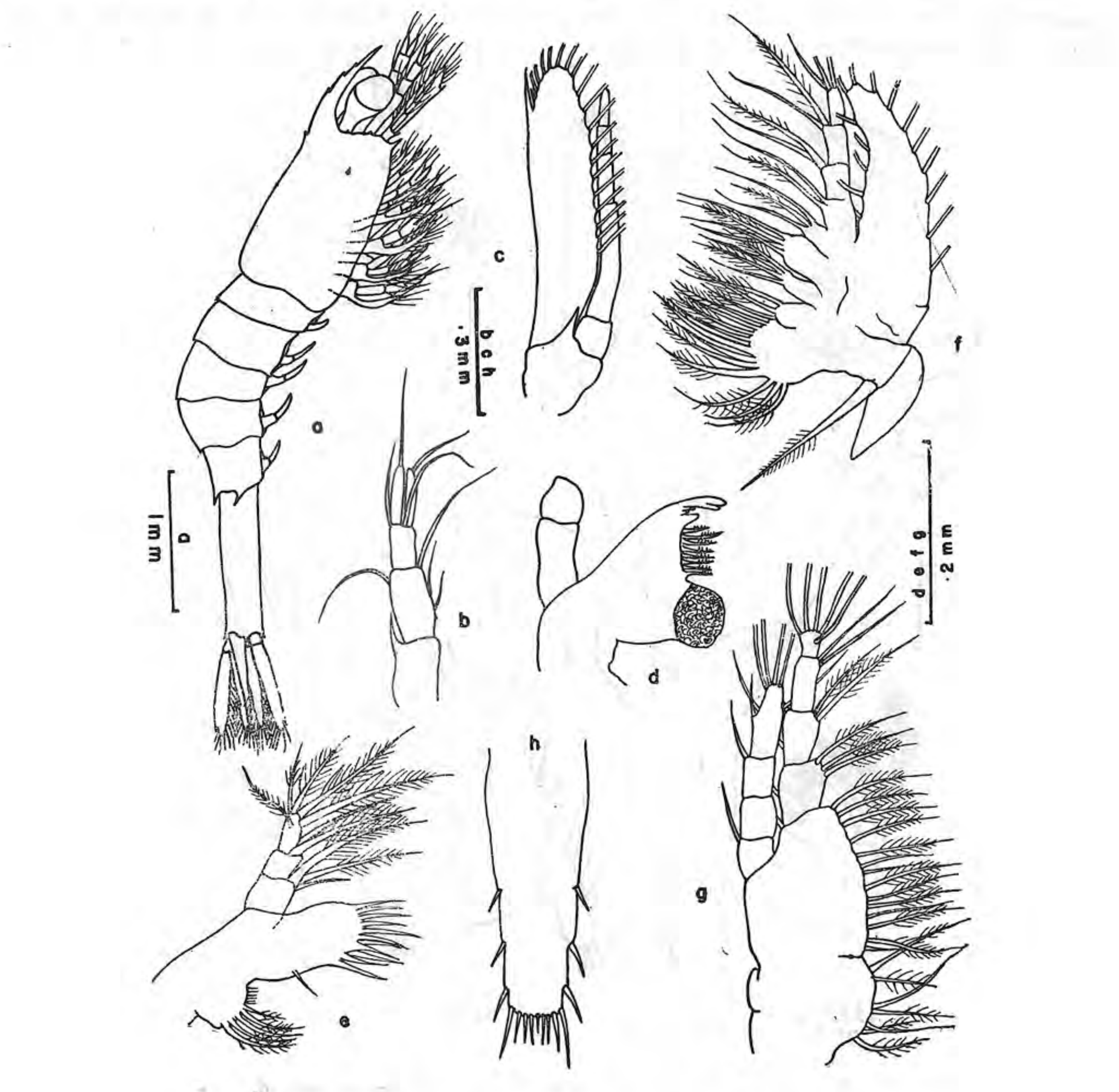

Fig. 6. Mysis III. a. side view; b. antennule; c. antenna; d. mandible; e. 1st maxilla; f. 2nd maxilla; g. 1st maxilliped; h. telson.

The exopod of the uropod (Fig. 5 k) bears a spine and 20 marginal setae. Telson (Fig 5 k) with 2 pairs of lateral spines, a small median and 5+5 apical spines; spine 4 the longest. Pleopod buds present.

Mysis III – Length 4.4 mm - 5.0 mm (Fig. 6 a-h)

Material : 92 specimens from 68 stations-All parts of the Indian Ocean except the central and southern regions.

Rostrum with 3 dorsal teeth + epigastric. Supra-orbital, antennal and hepatic spines persist (Fig. 6 a). The specimens agree well with Gurney's "Terra Nova" specimen in many characters, except for the presence of a pair of dorso-lateral spines on the 5th abdominal segment.

Antennule (Fig. 6 b) with flagella of equal length; peduncle 3-segmented, middle segment bearing 4 setae-3 on the inner margin and one on the outer margin; basal segment with a spine distally. Antenna (Fig. 6 c) has a 5-segmented endopod and scale with a large spine. Mandible (Fig. 6 d) with a 2-segmented palp. Number of setae between the incisor and molar processes is increased to 8. The terminal segment of the endopod of the 1st maxilla (Fig. 6 e) carries 5

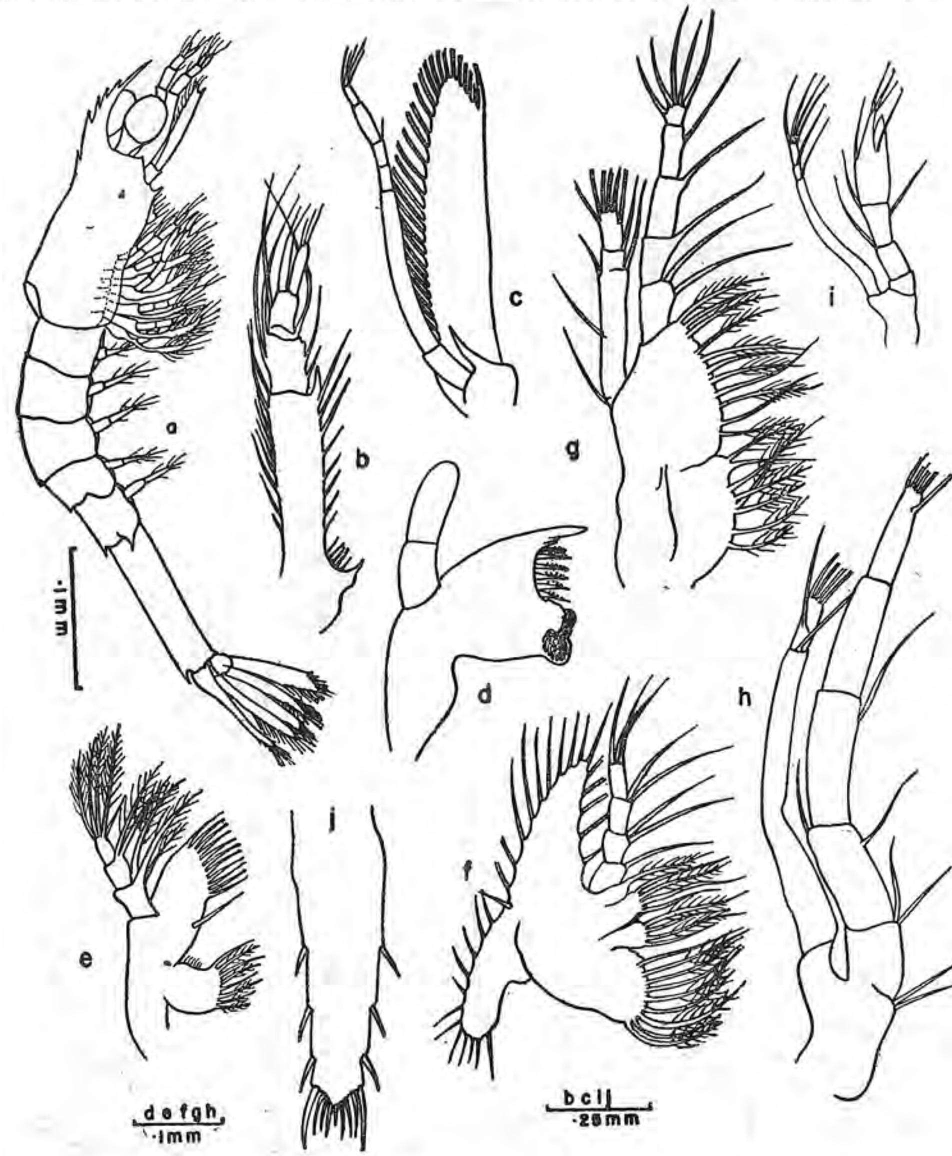

Fig. 7. Post-larva I. a. side view; b. antennule; c. antenna; d. mandible; e. 1st maxilla; f. 2nd maxilla; g. 1st maxilliped; h. 3rd maxilliped; i. pereopod; j. telson.

setae 2nd maxilla (Fig. 6 f) with a large exopod bearing one large seta at the proximal part and about 15 setae marginally; an epipod present without setae; endopod 4 - segmented, distal segment with 3 setae. Maxillipeds with longer exopods and large apical setae (Fig. 6 g). The thoracic legs with exopodites. The dorso-median spine on the 4th abdominal segment is slightly reduced. Anal spine present. Pleopods more developed, uniramous and without setae.

Telson (Fig. 6 h) truncate with a well-developed median spine, 3 pairs of marginal spines and 4+4 apical spines; with no addition of spines, but a pair of spines moving upward laterally. The exopod of the uropod bears a spine and no change in the number of the marginal setae.

Post larva I – Length 5.1 mm - 6.5 mm (Fig. 7 a-j)

Material : 19 specimens
Locality : Stn. Nos. AB 1, 4, 25, 67, 68, 286; Va 1809, 2004; INSK 104A, 161, 167, 339, 439, 664; Na 2, 97, 112; Me 116; Di 5010- Indian Ocean.

Rostrum with 4 dorsal teeth + epigastric; the latter placed behind the eye, medially on the carapace, leaving a wide gap between it and the 1st rostral tooth. Rostrum extends up to the tip of the 2nd segment of the antennular peduncle. Hepatic spine well developed (Fig. 7 a). Tip of the telson is tapering with 7+1+7 spines. Dorso-median spines present on the 5th and 6th abdominal segments and that of the 4th is reduced. Pleopods well developed with setae, but uniramous.

The antennule (Fig. 7 b) with stylocerite, strongly setose. The basal segment of the antennular peduncle is very long with a spine distally at its inner margin. Antenna (Fig. 7 c) with a many-segmented flagellum. Mandible (Fig. 7 d) with a 2-segmented palp, without setae; segments of equal length. 1st maxilla (Fig. 7 e) unchanged. 2nd maxilla (Fig 7 f) with setose exopod. Maxillipeds 1-3 with 5-segmented endopods and segmented exopods both bearing setae (Fig 7 g, h). All thoracic legs with exopodites (Fig 7 i). No gill rudiments seen on any of the pereopods. Spines of the telson remain the same 7+1+7 (Fig. 7 j).

Postlarva II :

The most important differences are the addition of a dorsal tooth on the rostrum, reduction of the pterygostomian spine, and telson very much narrowed.

Penaeopsis rectacuta Bata (1888)

Penaeopsis rectacuta George 1969:27 (with synonymy).

Material : 1 male juvenile : length 21 mm (Fig 8 a-i)

Locality : Stn. No. 3, cruise I of R/V 'Blue Fin' Lat. 09°51'N-Long. 75°47' E, 24-2-1970-off Quilon in the Arabian Sea.

Remarks: Though this species has a wide distribution in Indian Ocean it is not commercially very important; yet recent exploratory trawling operations in deeper waters off Kerala Coast (150-450 m) in the Arabian Sea indicate possibility of commercial exploitation.

Tip of the rostrum is slightly broken. Rostrum bears 9 or 10 dorsal teeth + the epigastric and ventral setae. Strong antennal spine present, hepatic spine behind the antennal, almost at the same level on the carapace (Fig. 8 a); the pterygostomian edge is angulated with a crowd of setae and placed at a higher level. In its position and in the absence of sutures on the carapace it agrees with the descriptions of Alcock (1906). The characters of the antennule and mandible (Fig. 8 b, d) are similar to that described by Kubo (1949) The thoracic legs with exopodites and the nature of the telson, having three movable lateral spines on each side of the telson in addition to the posterior fixed spine (Fig. 8 h) agree with the description of Hall (1962). The ischium of the 2nd pereopod has no spine, only a basial spine present. Other characters almost agree with the descriptions of Ramadan (1938).

Distribution of larvae:

The larvae are widely distributed (Fig. 9) in the Indian Ocean, extending to the north-west Australian and South African waters. The most abundant areas are off the Nicobar Islands in the Bay of Bengal and off Muscat and Oman in the north-west Arabian Sea. Also a good number of these larvae are obtained from off Bombay and Mangalore in the west coast of India; off Colombo in the Gulf of Mannar; off the Gangetic delta in the northern part of the Bay of Bengal; the Gulf of Aden and off Somali and the north-western part of the Arabian Sea. But, apparently no larvae are obtained from the

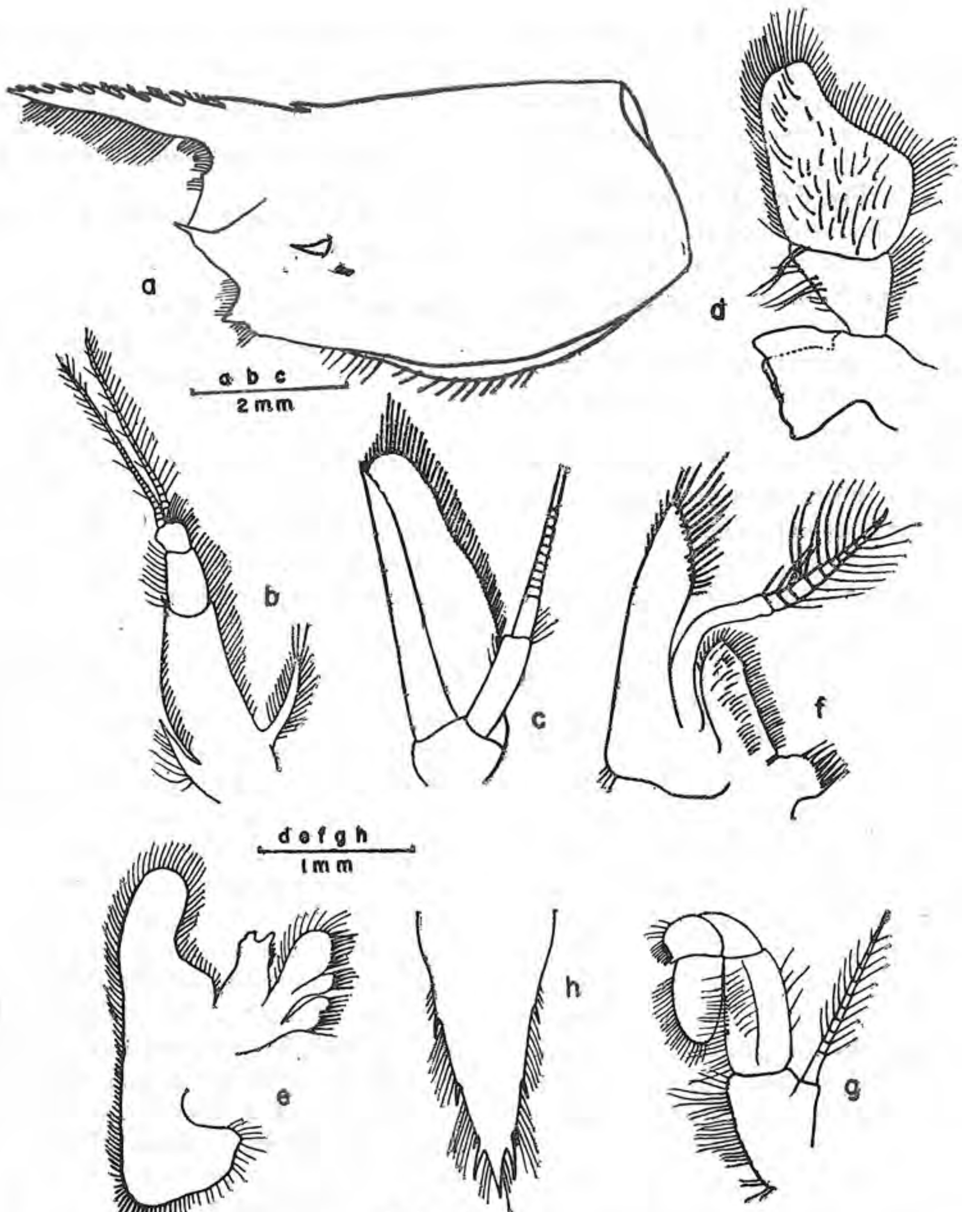

Fig. 8

Fig. 8. Juvenile. a. carapace; b. antennule; c. antenna; d. mandible; e. 2nd maxilla; f. 1st maxilliped; g. 2nd maxilliped; h. telson.

south central part of the Indian Ocean. From the pattern of distribution it is felt that the larvae are found mostly in the coastal waters.

It is interesting to note that few larvae are collected from the north-west coast of Australia and south-east coast of Africa, especially in view of the fact that no species belonging to *Penaeopsis* has been so far recorded from the Australian waters (Dall, 1957; Racek & Dall, 1965); and only *Penaeopsis serratus* is recorded (Ramadan, 1938) from the Zanzibar area. This might indicate two possibilities, that either the species *P. rectacuta* is already available in both these regions or that the larvae have been brought down there by the prevailing water currents. If this be the case, opportunity is taken to record the larval stages of this species for the 1st time from these localities.

It might be possible that the larvae collected from the north-west coast of Australia are carried down from the Indonesian waters by the Java Current. Similarly, the larvae obtained from the south-east coast of Africa are probably brought

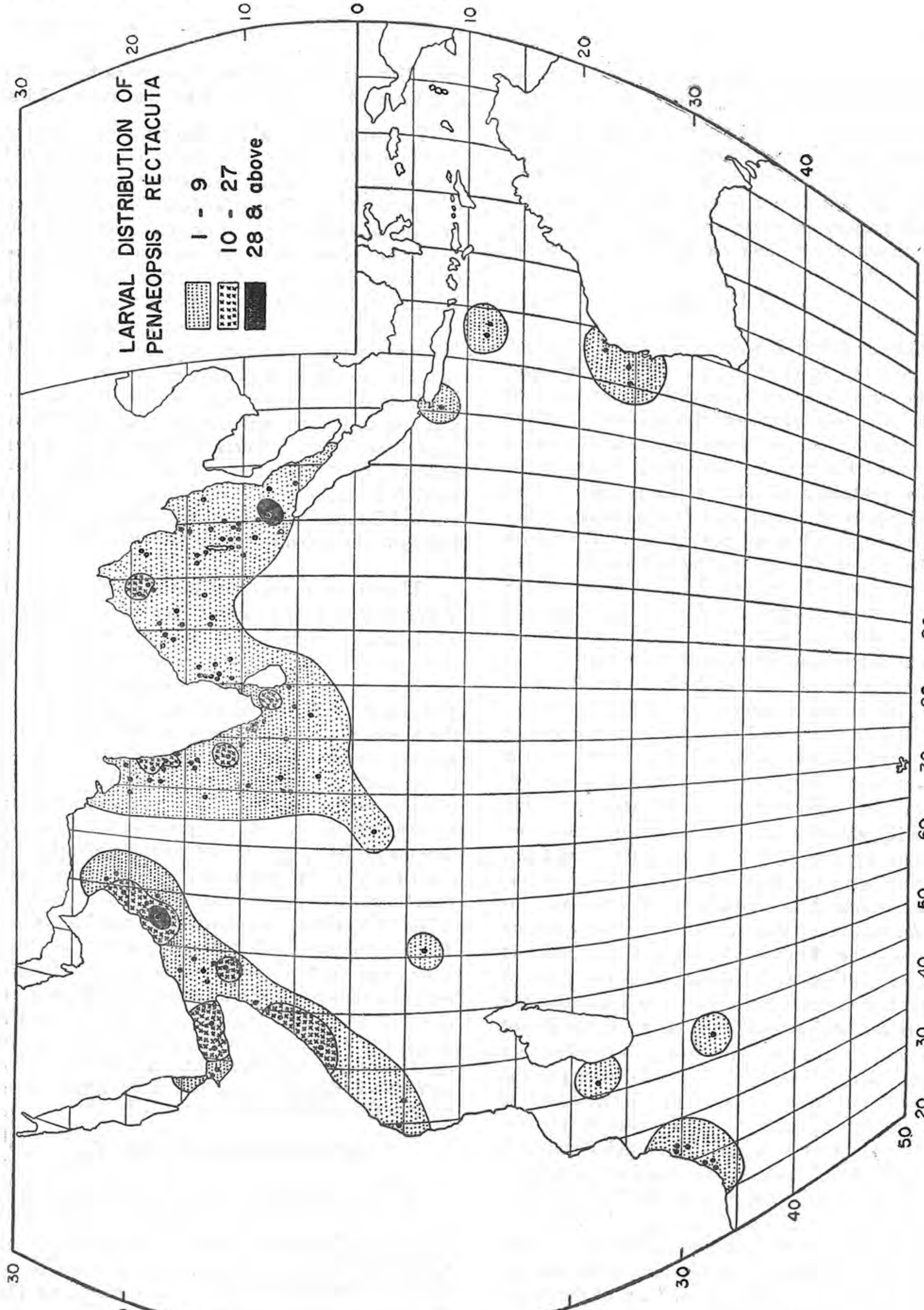

Fig. 9. The distribution of the larvae of *Penaeopsis rectacuta* in the Indian Ocean.

there by the existing current system. There is an effect of the monsoon drift (SW & NE) along the coast of Somalia; the Equatorial Counter Current flows southward along the east African coast and finally joins the Agulhas Current in the south-east coast of Africa. However, future collections of penaeid prawns in these two regions will probably throw more light on the distribution of these larvae.

DISCUSSION

Gurney (1943) has described larval stages of *Penaeopsis* sp. from Bermuda. The earlier stages of the present series agree with Gurney's description. But in later stages, though there are many characters in common, some important differences are noted. He recorded 8+8 setae on the telson in his protozoea III and mysis stages and also found 2 pairs of lateral and 7+7 terminal spines (9+9) in the telson of post-larva I. The spines on the telson of the specimens here are 7+7 in the protozoeae andmysis I and 7+1+7 in the following stages. In addition to this, all his mysis and post-larval stages are very small compared to the present specimens. The number of rostral teeth in these stages is comparatively less. Again in mysis III Gurney described an unsegmented mandibular palp which is 2-segmented in the present specimens. However, in all these characters the present material agrees more with Gurney's (1924) 'Terra Nova' specimen of mysis stage, probably mysis III, which he described doubtfully as *Penaeopsis* or *Artemesia*? But, Gurney (1943) did not mention anything about his 'Terra Nova' specimens, leaving it as *Penaeopsis* or *Artemesia*. In the description of postlarva of *Penaeopsis* sp. from Bermuda he himself mentioned that there is nothing in this stage distinctive of the genus to which it belongs. Therefore it is likely that the later stages he described in 1943 probably do not belong to *Penaeopsis*. According to Burkenroad (1934) *Parapenaeus* and *Penaeopsis* belong to the same section of the Penaeinae. *Parapenaeus* is characterised by the presence of a median spine on the telson. Hence in all likelihood *Penaeopsis* also might have median spine on the telson in the late mysis stages. If that is so the 'Terra Nova', specimen possesses that character and it is really *Penaeopsis* sp. The present material agree well with the 'Terra Nova' specimen. In the present collection the circumstantial evidence of the juvenile of *Penaeopsis rectacuta* occurring in the same collection as these larvae also point to the fact that these larve might belong to the same species.

Following the work of Gurney (1943) on the development of *Penaeopsis* sp. Subrahmanyam and Gunter (1970) described few larvae from off Mississippi similar to Gurney's 'Terra Nova' specimen as those of *Artemesia*! They reported "there is no record of *Artemesia* in the northern Atlantic Ocean and the occurrence of larvae in the Gulf of Mexico is puzzling. It may be that Gurney's *Artemesia*? larvae are incorrectly assigned and belong to some other penaeid genus". This also indicates to the possibility of Gurney's 1924 specimen belonging to only *Penaeopsis*. Subrahmanyam & Gunter agreed that this larvae resembled those from the 'Terra Nova' Expedition described by Gurney (1924). In that case the larvae doubtfully assigned to *Artemesia*? by Subrahmanyam and Gunter (1970) may reasonably be taken to belong to the Atlantic species of *Penaeopsis*.

There is some similarity in the development of *Penaeopsis* and *Metapenaeus* in having 7+7 telsonic spines in the protozoea and early mysis stages, But these larvae differ from larvae of *Metapenaeus* by their bigger size, longer rostrum, absence of prominent supra-orbital spine, divergent rami of the telson, presence of a very long seta on the antennule, ventral position of one of the setae on the telson and the exopod of 1st maxilla bearing 5 plumose setae. In the later mysis stages a median spine on the telson, and the presence of an exopodite on the last pereopod are clear differences. A similar median spine is present in *Parapenaeus* and *Funchalia*, in the late mysis stages. But *Penaeopsis* mysis stages are differentiated from those of *Parapenaeus* in having exopodites on all legs, absence of ventral spines on the abdominal somites and absence of the long dorso-median spine on the 3rd abdominal somite. *Funchalia* has the peculiarity of presence of ventral rows of spines on the 6th abdominal segment. In the possession of 7+1+7 spines on the telson *Penaeopsis* is separated from *Parapenaeopsis* too.

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ZOOPLANKTON INVESTIGATION IN INDIAN WATERS AND THE ROLE OF THE INDIAN OCEAN BIOLOGICAL CENTRE

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ABSTRACT

A brief review of the investigations made in the Indian coastal waters since 1930 is given, with special emphasis to the work done at the Indian Ocean Biological Centre. The salient features in the distribution of different zooplankton taxa in the Indian Ocean are presented on the basis of the study so far made on the International Indian Ocean Expedition Collections. In the distribution of zooplankton the occurrence of high density patches of the different groups at considerable distances from the coast has been noticed. The coastal waters off Somalia, Arabia, the southwest coast of India, the Orissa coast and some areas in the equator and in the Java Sea are confirmed to have rich zooplankton population. Bay of Bengal has emerged as an important area for fish eggs and larvae and also for juvenile cephalopods. The Somali-Saudi Arabian offshore upwelling areas, the Malabar upwelling system and the upwelling areas off the Orissa coast are likely to be the main centres for spawning and growth of pelagic fisheries in the north Indian Ocean.

INTRODUCTION

The study of zooplankton forms an important aspect of biological oceanography. This is because of the role played by zooplankton in the food web of the sea, where it constitutes an intermediate level between the primary producers such as phytoplankton and the larger fish and whales. Besides, the myriads of organisms constituting zooplankton, by themselves form a complicated ecological system worthy of special attention.

Contributions from Indian waters on the zooplankton are considerable and a bibliography of plankton of the Indian Ocean prepared by Prasad (1964) cites 881 publications. These include studies on phytoplankton also. Subsequent to this, a large number of papers have appeared, and some of these are referred to elsewhere in this paper. In the following account a brief review of work done (since 1930) at the different Indian coastal areas is given together with a discussion on the zooplankton ecology of the Indian Ocean and the part played by the Indian Ocean Biological Centre since its establishment in 1962 at Cochin.

Madras area

The credit for pioneering researches in the field of marine biology in general and zooplankton in particular goes to the Madras University and the Madras State Department of Fisheries with its substations at Ennore, Krusadai, Tuticorin and West Hill (Calicut). Menon (1931) gave a preliminary account of the Madras plankton followed by Aiyar *et al* (1936) who described the plankton records for the year 1929 and 1930 off Madras. The Scyphomedusae and Hydromedusae of the Madras and neighbouring coast were described by Menon (1930 , 1932). Panikkar (1936) gave a general account of the Anthozoan larvae and some of their developmental stages. John (1933, 1937) described the *Sagitta* of the Madras coast and seasonal variation in the distribution. Menon (1933, 1937, 1940) gave accounts of decapod larvae from the Madras plankton. Alikunhi (1949, 1951, 1967) gave accounts of the metamorphosis of phyllosoma and stomatopod larvae from the Madras plankton. Krishnaswamy (1953, 1957) described the copepods. The Amphipods of the Madras coast were described by Nayar (1959). Nair (1946-52) studied the fish eggs and larvae of the Madras plankton. Nair and Aiyar (1943) also studied the Thaliacea of the Madras plankton. It would appear from this that we have a fairly good account of the important components of zooplankton from the Madras area.

Andhra area

To the north of Madras, the Andhra University at Waltair started its oceanographic activities in 1952. Ganapati and his colleagues made significant contribution to our knowledge of the zooplankton from this area in a series of contributions. Ganapati and Rao (1958) made a quantitative study of plankton off Lawson's Bay. La Fond summarised oceanographic work done at the Andhra University in 1957. Ganapati and Nagabhushanam (1958) described the seasonal distribution of the Hydromedusae of the Visakhapatnam coast. The distribution of physalia in Indian waters was given by Ganapati and Rao (1962). Ganapati and Rao (1954) started studies on the various aspects of the distribution of Chaetognaths from the Indian waters (see also Rao, 1958 a & b, 1962). Ganapati and Radhakrishna (1958) gave an account of the Polychaeta larvae in the plankton off the Waltair coast. Ganapati and Rao (1959) noted the feeding habits of *Ianthina janthina* and Ganapati and Bhavanarayana (1958) studied pelagic tunicates as indicators of water movements off Waltair coast. Ganapati and Santakumari (1962) studied the distribution of Copepods at Lawson's Bay. Attention was also given to the studies on fish eggs and larvae by Ganapati and Raju (1961, 1963) and Raju and Ganapati (1969). Chandramohan and Rao (1969) studied the Copepoda of the Godavari estuary.

The contributions from the Andhra University are important in the sense that the studies made here include data collected from regular oceanographic cruises on board Indian Naval Minesweepers. Prof. La Fond of the Naval Electronics Laboratory, San Diego started these cruises when he was visiting the university as a Fulbright Scholar in 1952 and again in 1955. The Memoirs in Oceanography Vol. I and II published by the Andhra University form an important land mark in the development of oceanography in Indian waters.

Krusadai and Mandapam

Krusadai is a small Island off the east coast of India. The Madras State Fisheries Department has been maintaining a substation for research and the nearby inshore areas are extremely rich in marine life which includes the fascinating coral reefs. Chacko (1950, 1956, 1959) in a series of reports has given an account of the plankton in and around Krusadai Islands. The Central Marine Fisheries Research Institute commenced functioning at Mandapam from 1947 and since then this Centre and its field stations at various places along the Indian coast have substantially contributed to the knowledge of plankton. Prasad *et al.* (1952) and Prasad (1954, 1956, 1958) have given accounts of the plankton in the nearby Gulf of Mannar. Prasad (1954) has also described the Hydromedusae from the same gulf. Varadarajan and Chacko (1943) described the arrow worms of Krusadai. Ummerkutty (1960, 1961) has added to our knowledge of copepods from this area. Devanesan and Varadarajan (1940) have reported on the occurrence of Tornaria larvae at Krusadai. Sudarsan (1961) made observation on the Chaetognatha of the waters around Mandapam.

The annual reports of the Madras Fisheries Department and its substations contain information on the plankton in the waters off Tuticorin, Ennore and West Hill (Calicut) (Chacko, 1956, 1959).

Porto Novo

The Annamalai University at Chidambaram has a marine biological station at Porto Novo which is situated further south on the Madras coast. This laboratory has been doing some plankton work, though not in a sustained manner. Krishnamurthy (1961) published a paper on the daily variations in marine plankton from Porto Novo.

Kerala Coast

The important centres of plankton research on the Kerala coast are the University laboratories at Trivandrum and Cochin and the substation of the Central Marine Fisheries Research Institute at West Hill (Calicut). Menon (1945) studied the seasonal distribution of the plankton of the Travancore coast. George (1952, 1953) described the marine plankton of the coastal waters of Calicut with observations on the hydrographical conditions and gave an account of the Chaetognaths from the area. George (1958) made observations on the plankton of the Cochin backwaters. Nair (1946, 1951, 1954) described the medusae of the Travancore coast and their correlation with inshore fishing. Pillai (1944) gave an account of the Chaetognatha of the Travancore coast. He also in a series of papers (1955, 1957, 1961, 1964, 1966 a & b) dealt with pelagic crustacea of Travancore namely decapod larvae, Schizopoda, Amphipoda and Mysidacea. Balakrishnan (1959, 1961) gave an account of the fish eggs and larvae of the Kerala coast. Subramanyan (1959) made a detailed study of the relationship between phytoplankton and zooplankton of the west coast of India. Sudarsan

(1968) studied the Brachiopod larvae from the west coast of India. Mukundan (1967) reported on the plankton of the Calicut area.

At the Indian Ocean Biological Centre investigations on the Cochin backwater zooplankton were made to study the total zooplankton biomass and faunal composition (Nair and Tranter, 1971 and Menon *et al.* 1971). Detailed studies on the ecology of hydromedusae, (Santhakumari, 1970, Vannucci *et al.*, 1970 and Santhakumari and Vannucci, 1971), seasonal fluctuations of Chaetognaths (Vijayalakshmi, 1971 a& b) and coexistence of species of the copepod family Acartiidae (Tranter and Abraham, 1971) were also made. From a series of collections taken along the south west coast of India Vannucci and Santhakumari (1969) pointed out new records of hydromedusae and Nair (1972) recorded an amphipod swarm.

Bombay

Off the Bombay coast, the biology department of the Institute of Sciences and the research department of the Maharashtra State Fisheries Department have been active in plankton research. Lele and Gae (1936) gave an account of the common *Sagitta* of the Bombay harbour. Bal and Pradhan (1945) published a preliminary note on the plankton of Bombay harbour and followed it up (1952) with records of zooplankton during 1944-47 and progress report of fish eggs and larvae in Bombay waters. Chopra (1960) made notes on a sudden outburst of ctenophores and medusae in the waters of Bombay. Chhapgar (1956) described the breeding habits and larval stages of some crabs of Bombay. Desai (1961) gave a preliminary account of the eggs and larvae of some marine mollusca of Bombay. Sudarsan (1964) made observations on the plankton and trawler catches off Bombay. To the north of Bombay and for the Gujarat coasts we have hardly any publication dealing with the plankton, the exception being that of Ramamurthy and Dhawan (1963) who described the characteristics of the plankton at Kandla in the Gulf of Kutch during 1958-60.

We have hardly any information from the Orissa and Bengal coasts except for a few publications by Devasundaram and Roy (1954) and Dutta *et al* (1954) from Hooghly estuary. While the foregoing account of the work for the different areas does not claim to include every published paper, it is clear that centres of activity are in the south and as years go by more and more papers are appearing on the zooplankton in the Indian coastal waters.

International Indian Ocean Expedition and the Establishment of the Indian Ocean Biological Centre at Cochin

The International Indian Ocean Expedition took place during the period 1960 65 and the role played by the Special Committee on Oceanic Research and the Unesco, with the active support of many nations including India in organizing the expedition, is now part of the history of Oceanography in the Indian Ocean. The scientific activities generated by this expedition greatly benefitted India and the most important of this is the establishment firstly of the Indian Ocean Biological Centre at Cochin in 1962 and subsequently the establishment of the National Institute of Oceanography in India in 1966.

Since 1960 oceanographic activities in the Indian waters have greatly increased and in this paper the role played by the Indian Ocean Biological Centre is considered in detail.

The Indian Ocean Biological Centre came into existence in 1962 as a result of the desire of many of the participating nations who wanted a sorting centre to process the large number of zooplankton samples to be collected during the Expedition (see Hansen, 1966). The proposal was first discussed informally at the first Oceanographic Congress in NewYork between Mr. Robert Snider, Prof. Roger Revelle and Dr. N. K. Panikkar. Definite proposals for its establishment were introduced by the Indian Ocean Working Group in Copenhagen (1960) and again at a meeting of SCOR in Helsinki (IOC 1962-INCOR 1962) and supported by India's representative (Dr. N. K. Panikkar). Tranter (1969) has given a full account of the IOBC – its establishment, activities etc - in the guide to the IOBC issued by the Unesco. The Proceedings of the Unesco Consultative Committee which was responsible for handling of the zooplankton samples collected during the expedition have appeared in the IIOE news letters issued by Unesco and also in the reports published by INCOR and NIO (India.)

The principal functions envisaged for the IOBC are:-

1. Maintenance of named reference collections of Indian Ocean material.

2. Sorting of zoooplankton samples taken by standard methods.
3. Examination of the sorted material and sending it to specialists throughout the world.
4. Sorting of zooplankton samples at the request and expense of participating laboratories and
5. Training.

The Unesco Curator with the concurrence of the Advisory Committee defined the systematic groups to be used in subdividing the plankton samples. After measuring the total displacement volume and removing all larger organisms including fish eggs, fishes, cephalopods and larger medusae, a subsample of 3-5 ml was separated out of the total sample for sorting. If the sample was smaller than 3-5 ml, a standard fraction of 10% was stored as 'archive' and the rest sorted. The number of plankton groups sorted was 63 and each one of these was counted separately and preserved. The subsamples were stored in coded groups and data entered in scheme 'C' sheets (Appendix 1).

The sorting and subsorting of total number of 1927 samples took nearly 7 years to complete and in 1968 it became clear that the staff at IOBC had developed sufficient expertise to carry out research on most of the zooplankton groups and also prepare handbooks and atlases using the coded data available at the IOBC, as recommended by the Intergovernmental Oceanographic Commission at its sixth meeting in 1968. Subsequently the IOBC has published 5 volumes of atlases dealing with the distribution of zooplankton biomass, copepods and decapod larvae, fish eggs and larvae, mollusca and other groups in the Indian Ocean and 3 volumes of handbooks dealing with the station list, environmental data and proceedings of workshop on plankton methods. The next volumes (IV and V) of handbooks will deal with comprehensive papers on the International Collections both by the IOBC staff and specialists.

Now that the Indian Ocean Biological Centre is well established and made a permanent division of the National Institute of Oceanography (CSIR) its future is assured and the staff are continuing their studies on the International Collections without any break. Besides, a new programme of research has been initiated to study the variability and ecology of the tropical zooplankton, population dynamics of some selected species and their life cycles and ecological succession of zooplankton in the backwaters.

The IOBC is also participating in the Pelagic Fishery Survey of the Arabian Sea under the United Nations Development Project. It has been agreed that the plankton samples taken by the Survey will be turned over to IOBC where total biomass will be measured and studies will be made on the zooplankton.

In the introduction to this paper, an account on the work done in recent years (1930 onwards) on zooplankton in the coastal areas is summarised. Most of these papers (Bibliography of the Indian Ocean, 1971) deal with the systematics of the different groups of zooplankton with frequent reference to hydrography.

The significance of studies on the zooplankton in the open Indian Ocean is altogether different. Contributions mainly come from occasional

Table 1

Indian Ocean Stations (Prior to IIOE)

	Ship	Date	No. of Stations*
1.	Novara	1857-59	52
2.	Challenger	Dec. 1873-Mar. 1874	6
3.	Gazelle	1874-76	37
4.	Valdivia	1898-99	67
5.	Gauss	1902-03	26
6.	Sea lark	1905	23
7.	Siboga	1906	272
8.	Planet	1906-7	57
9.	Mowe	1912-13	7
10.	Dana	1928-30	171
11.	W. Snellius	1929	25
12.	Discovery II	1930, 32, 35, 38	124
13.	Mabahiss	1933-34	80
14.	William Scoreshy	1935,36,50	60
15.	Albatross	1947-48	22
16.	Charcot	1948-49	10
17.	Galathea	1950-52	48
18.	Umitaka Maru	1956	32
19.	Guilard	1961	77
		Total:-	1196

* The information under this column is not complete and does not include stations south of 45 °S Latitude.

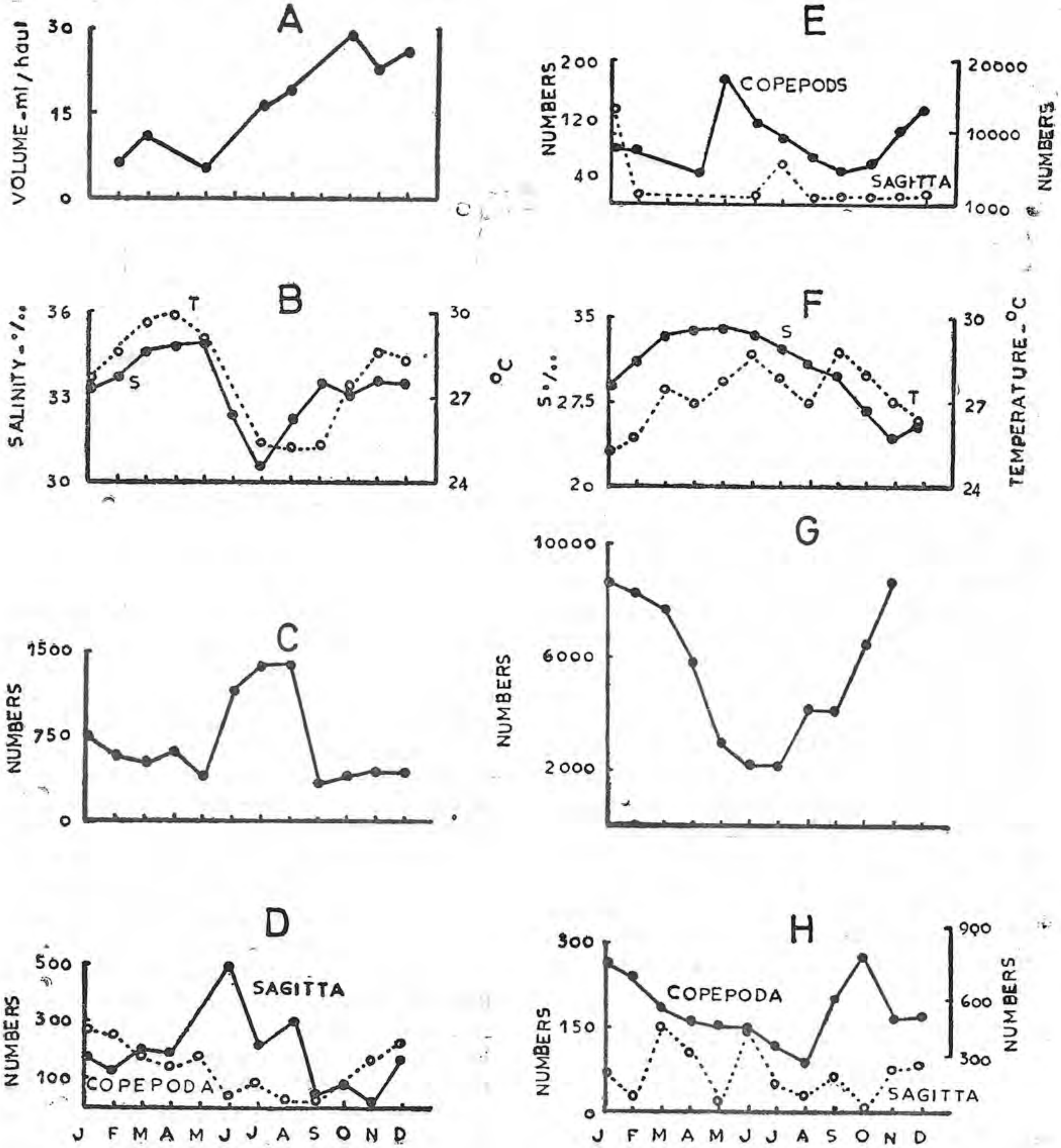

Fig. 1. A. Annual variation of zooplankton volume ml/haul off Bombay, 1963. Sudarsan, 1964.

B. Salinity & temperature variation during the period 1950 - '54 (5 year - average), off Calicut. Subramanyan, 1959.

C. Zooplankton variation. 5 year average (1950 - '54). Off Calicut. Subramanyan, 1959.

D. Annual variation of *Sagitta* and Copepods off Trivandrum 1939. Menon, 1945.

E. Annual variation of *Sagitta* and Copepods off Waltair 1951 - '52. Rao, 1951.

F. Salinity snd temperature variation off Waltair 1952. Rao, 1958.

G. Annual variation. Total Copepods off Madras during 1929 - '30 (2 year average). Menon, 1931.

H. Annual variation of *Sagitta* and Copepods off Mandapam, 1950. Prasad, 1954.

expedition reports and during the past 100 years about nineteen important expeditions have worked in the Indian Ocean (Table 1). The reports from these expeditions include some of the most comprehensive papers on the different components of zooplankton. Mention may be made of Kramp's work (1957, 1961) on Hydromedusae, on Copepods by Steuer (1904) and Sewell (1929, 1932, 1947), Tattersall's report on Mysidacea (1939), Pteropods and Heteropods by Tesch (1948, 1949, 1950), Apstein (1906), Sewell (1953) on Tunicates, Lohmann (1931) on Appendicularians, Fowler (1906) and Burfield and Harvey (1926) on Chaetognaths, and Delsman (1921–1938) on fish eggs and larvae of the Java Sea. Besides we have also some papers on zooplankton from the straits of Singapore and Kenya waters (Wickstead, 1961, 1962). From South Africa, we have a series of contributions from de Decker (1964)and de Decker & Mombeck (1965).

Since 1960 contributions on the distribution of various planktonic groups in the Indian Ocean has increased, mainly as a result of the activities of the IIOE. Mention may be made of the work on Chaetognaths by Alvarino (1964)and Vijayalakshmi (1969),Pteropods by Sakthivel (1969), Heteropods by Aravindakshan (1969), Foraminifera by Beljaeva (1962), plankton biomass by Bogorov and Vinogradov (1961) and Prasad (1966, 1968, 1969a, 1969b), Fenaux (1964) on Appendicularians, Jacob George (1969) on Ostracods, Gopalakrishnan and Brinton (1969) on Euphausiids, Grice and Hulsemann (1967) on copepods, Menon *e al* (1969), Menon & Williamson (1971) and Menon (1972) on decapod larvae, George Peter (1969) on Polychaetes, Peter (1969a & b) on fish eggs and larvae and Pillai (1973) on Mysidacea of the Indian Ocean.

DISTRIBUTION OF ZOOPLANKTON IN THE COASTAL AREAS OF THE INDIAN PENINSULA

The neritic and inshore waters of the peninsular India are extremely interesting in that they not only support a rich and abundant planktonic life, but also show special features of seasonal variation.

Throughout the Indian coast the general distribution of zooplankton is bimodal, with two peak periods, one in February-April period and other in September-October (Fig. 1). On the Waltair coast, Rao (1958a) found for the chaetognaths, particularly for *Sagitta enflata*, January February and June-July to be the peak periods. Menon (1931) found in the Madras plankton, abundance of copepods in November to March and again an increase in August. Prasad (1958) found that in the Gulf of Mannar and Palk Bay the standing crop of zooplankton showed two peaks, a higher peak in March (in Gulf of Mannar) and April (in the Palk Bay) and a lower peak in September–October at both these places. (Figs. 1-3 loc. cit). His data was based on averages for 5 years (1954-58). On the Trivandrum coast Menon (1945) observed a regular succession of planktonic groups and the zooplankton (Copepod) maximum during January to February. He reported swarms of *Sagitta enflata* in July to September and very rare during October to November.

Subramanyan (1959) while discussing the phyto - zooplankton relationship, gave average values for a 5 year period and noted the abundance of zooplankton during June to August and again smaller peaks in January, March and April off Calicut. (See Table XIII loc cit. p. 166). The distribution of chaetognaths along the Malabar coast shows (George, 1952) that their highest numbers are encountered in November and again in May-June. They were lowest in August. Bal and Pradhan (1945) working on the Bombay harbour reported January to March to be the most favourable months of the year for the occurrence of plankton as swarms. At Bombay *S. enflata* was found to be abundant in November-December months (Lele and Gae, 1936), whereas off Calicut it would be October- November and further south at Trivandrum it is much earlier ie. July-September. On the east coast the peak periods for the species occurs off Waltair and Madras during May–August and in the Gulf of Mannar it is November and December. It would therefore appear that there is some kind of a north to south movement in the peak periods of plankton on the east coast and just the opposite ie. from south to north on the west coast. Such a regular succession in the peak periods of phytoplankton was also noticed by Ganapati and Rao (1953).

The zooplankton distribution therefore shows abundance during different months both on the east and west coasts of India. Panikkar & Jayaraman (1966) have discussed oceanographic differences between the Arabian Sea and the Bay of Bengal. They point out the differences both in temperature and salinity range as also the periods of upwelling and surface currents. All these appear to be related to the influence of the prevailing monsoon. On the west coast the peak movement of plankton is from south to north. Upwelling is prevalent along this coast between 7°-16° N latitudes during the period August to early October (Panikkar & Jayaraman, 1966), but we do not know whether it occurs all at once over the entire stretch or progressively in any one direction. It would appear from the succession of plankton peaks that on the west coast the upwelling is initiated first in the south and then progressively moves up north. Sharma(1968) is of the opinion that upwelling sets in earlier in the south and gradually extends to the north. Further detailed work is necessary to substantiate this view.

On the east coast upwelling is reported only near the Vishakhapatnam coast (La Fond, 1954) during March. Sure enough high plankton values are reported from the area during April to July. Further to the south on the east coast of India no data is available on upwelling and if one could infer physical events in the sea based on biological processes, it could be stated that replenishment of nutrients resulting in peak periods of plankton takes place in April-May near Madras and August-September in the Gulf of Mannar.

On the west coast the southwest monsoon is strongest and under its influence heavy rainfall occurs during May-September. Therefore the lowest values of salinity on this coast are found in June to August months. Large scale upwelling also brings about lowering of temperature in the near-shore areas. However, on the east coast lower salinities are encountered during September to November months which is more due to river run off than rains. Low temperatures are found here during the period December to February, which is a winter phenomenon.

The average values for salinity for the Bay is much lower than in the Arabian Sea. However, the temperature shows much h gher range in the Arabian Sea than in the Bay. Besides these differences, as already stated the periods of low salinities and temperature are later in the year in the Bay as compared to the Arabian Sea. Such fundamental changes are bound to have marked influence on the development and fluctuation of plankton populations all along the two coasts.

Ganapati and Rao (1958) found clear differences in the hydrobiological conditions off the Waltair coast during the two periods namely August-December and January-August. The nature of the differences are summarised below:

In the Bay of Bengal
(East coast of India-Lawson's Bay)

Period	– August - December
Water mass	– Northern dilute water of the southern current
Salinity %o	– 20.79 - 32.97
Temperature °C	– 27.90 - 25.00
Plankton	– Minor plankton blooms, the chaetognaths are few in number and variety. Among the pelagic tunicates *Fritillaria foramina*, *Cyclosalpa pinnata* and *Pegia confoederata* are common.
Period	– January - August
Water mass	– Southern Bay of Bengal water of the northerly current.
Salinity %o	– 30.06 - 34.57
Temperature °C	– 24.33 - 29.80
Plankton	– Major planktonic blooms. very rich chaetognath populations are represented by *Sagitta serratodentata* and others. Among the Pelagic tunicates, *Fritillaria borealis*, *F. sargassi* and *F. pellucida* occur in large numbers.

In the Arabian Sea (West Coast of India)

Period	– May to October
Water mass	– Surface water of the northern Arabian Sea. Near the coast this water flows below less saline waters formed as a result of heavy precipitation during the period. The surface current is southerly.

Salinity ‰	– 36.5 - 33.0
Temperature °C	– 29.5 - 26.0 (lowest values in July near the coast due to upwelling).
Plankton	– Phytoplankton abundance. Copepods are scarce; peak period for *Sagitta enflata* and *S. neglecta* commences in October.
Period	– November - April
Water mass	– Surface water of the Indian equatorial region. The currents are northerly upto the end of January and thereafter they become southerly.
Salinity ‰	– 35.75 - 33.0
Temperature °C	– 29.5 - 25.0 (northward reduction)
Plankton	– Phytoplankton is scarce. Copepods are most abundant. Species of chaetognatha like *S. enflata*, *S. bedoti*, *S. robusta* continue to be dominant throughout this period.

As already stated the general picture of zooplankton distribution all along the Indian coast presents a bimodal oscillation with two peak periods, one early in spring and the other late in autumn. The usage of words spring and autumn are not very appropriate for the Indian waters since the magnitude of seasonal variations of hydrographical as well as biological factors are not marked except for salinity in coastal areas from one season to the other. Sometimes even the daily range in air temperature, water temperature, wind force and dissolved oxygen is almost equal in magnitude to the annual range of these factors on these tropical coasts (Rao and Rao 1962). Against such a background of environmental conditions fluctuations in plankton populations during a day, month or year in these waters could be sometimes of the same magnitude and therefore the picture cannot be generalised.

Zooplankton Biomass

Zooplankton biomass distribution in the Indian Ocean formed the subject matter for the Vol. I – Fascicles 1 and 2 of the Plankton Atlas prepared by Prasad and issued by the IOBC (Gen. Ed. Panikkar, 1968a&b). Prasad (1968, 1969a &b) has given a detailed account of the distribution of the biomass (wet zooplankton displacement volumes expressed as ml per haul taken by the IOS net) in the Indian Ocean based on the data from 1622 samples included in the above atlas.

Prasad observes that the volumes are highest in the Arabian Sea between the latitudes 10° to 25° N and longitudes 50° to 65° E, more particularly in the area off the Somali coast and coast of Saudi Arabia. Average values as high as 54.7 ml. (under 1 sq. meter for 200 meter column) were noted off Arabia, with Somali showing 15-35 ml and $\pm$ 15 ml all over the South eastern region of the Indian Ocean and again in the northern Bay of Bengal and South of Java. The rest of the Indian Ocean shows values less than 15 ml/haul.

The data for the atlases mentioned above were based on average values calculated from all the stations for every 5° square.

In order to obtain a more realistic picture of the distribution of the biomass, data from 1548 standard IOSN samples were replotted on 5 different charts (Figs. 2-6) to show the biomass distribution for five different monsoonal periods recognized by Duing (1970), for the northern Indian Ocean.

During the height of the north east monsoon (WM) (December to February) data from 431 samples indicate the occurrence of 20–39.9 ml biomass in the region of Gulf of Aden and north of Mombasa. A few spots indicating highest range ie. 80 and above were located off Madras in the Bay of Bengal and off Goa along the west coast of India (Fig. 2). Rest of the area shows low values from 0.1–9.9 ml.

March-April is a transitional period with 238 samples but the Somali and Arabian coasts are not covered (Fig. 3). Both the areas show patches of middle range values (10–32.9 ml) against a background of low biomass (0.1-9.9). Large patches in the central Arabian Sea and eastern Indian Ocean show values from 10-19.9 ml.

May-June period witnesses the commencement of the S. W. monsoon. Here also we have no data from the Somali and Arabia coasts nor from eastern Bay of Bengal (Fig. 4). Patches of high values are scattered with a rich patch of biomass

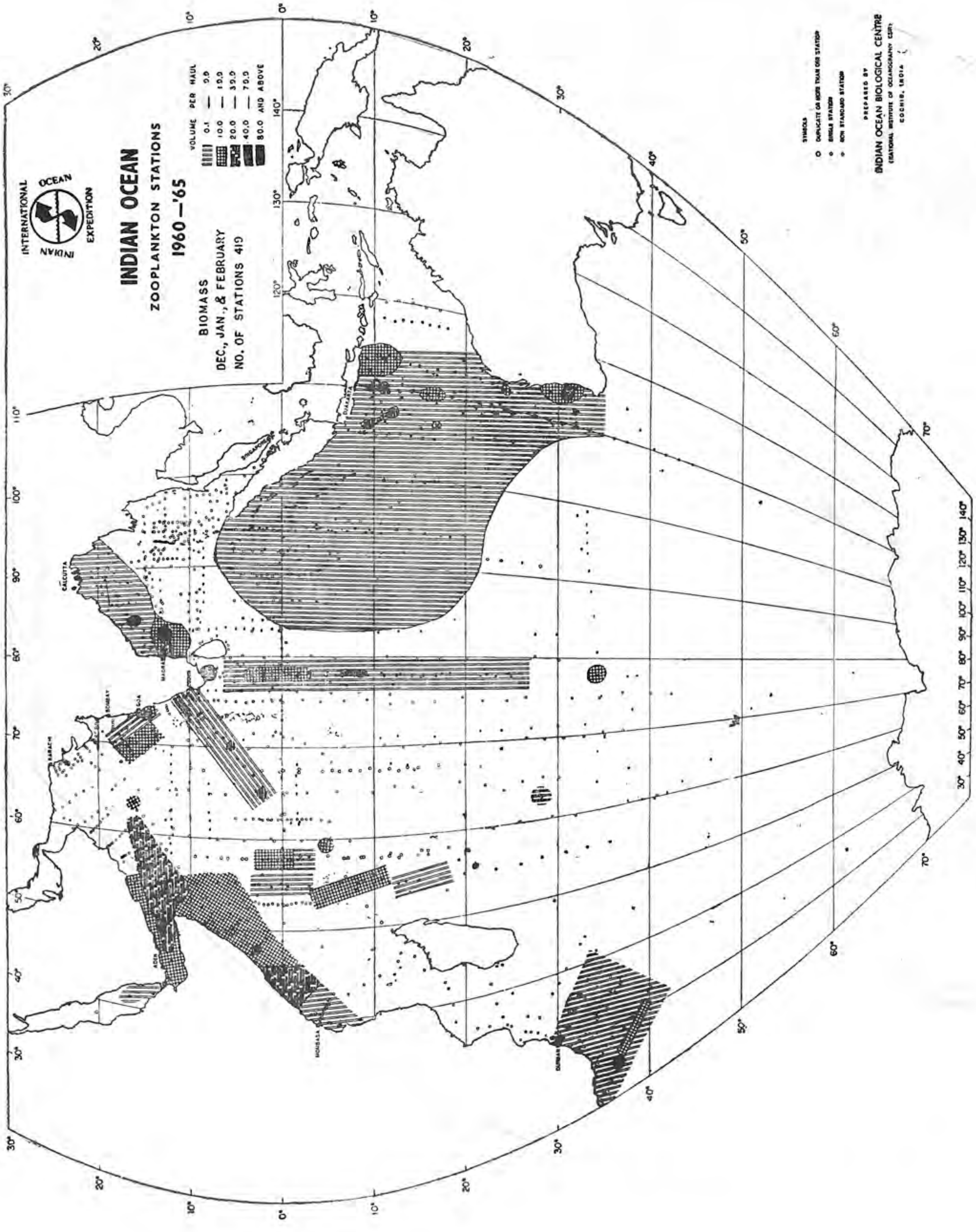

Fig. 2. Biomass distribution December - February

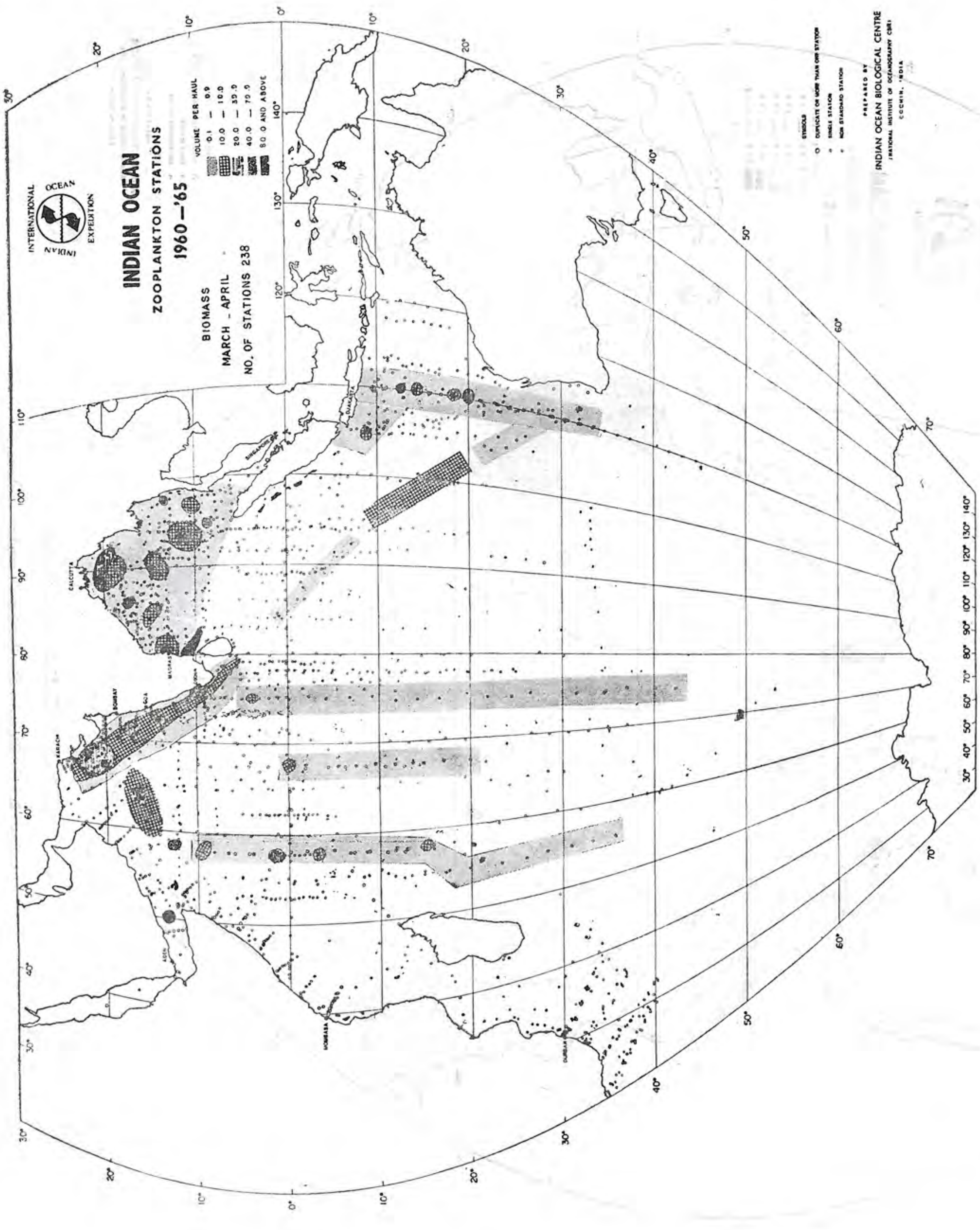

Fig. 3. Biomass distribution March - April.

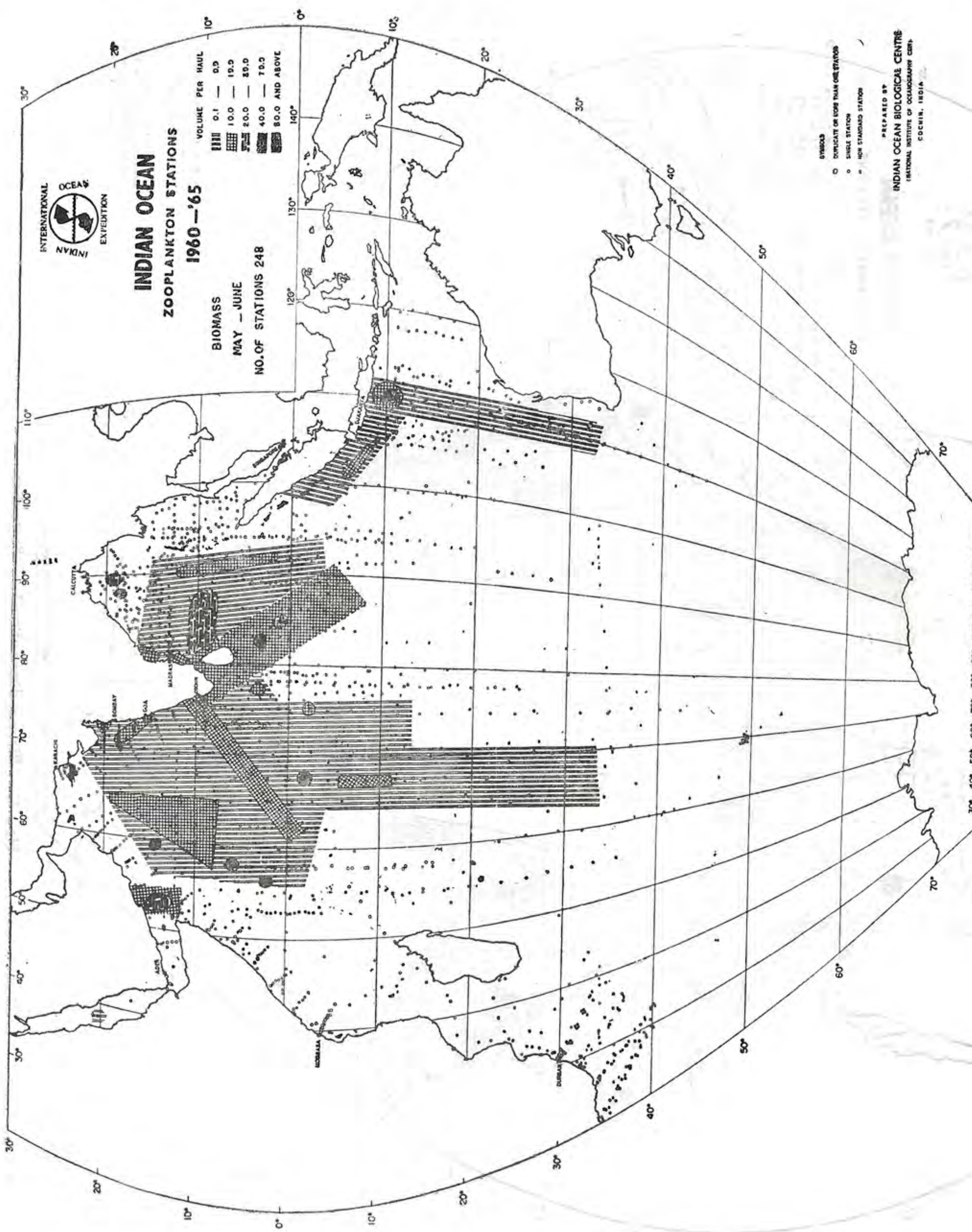

Fig. 4. Biomass distribution May - June.

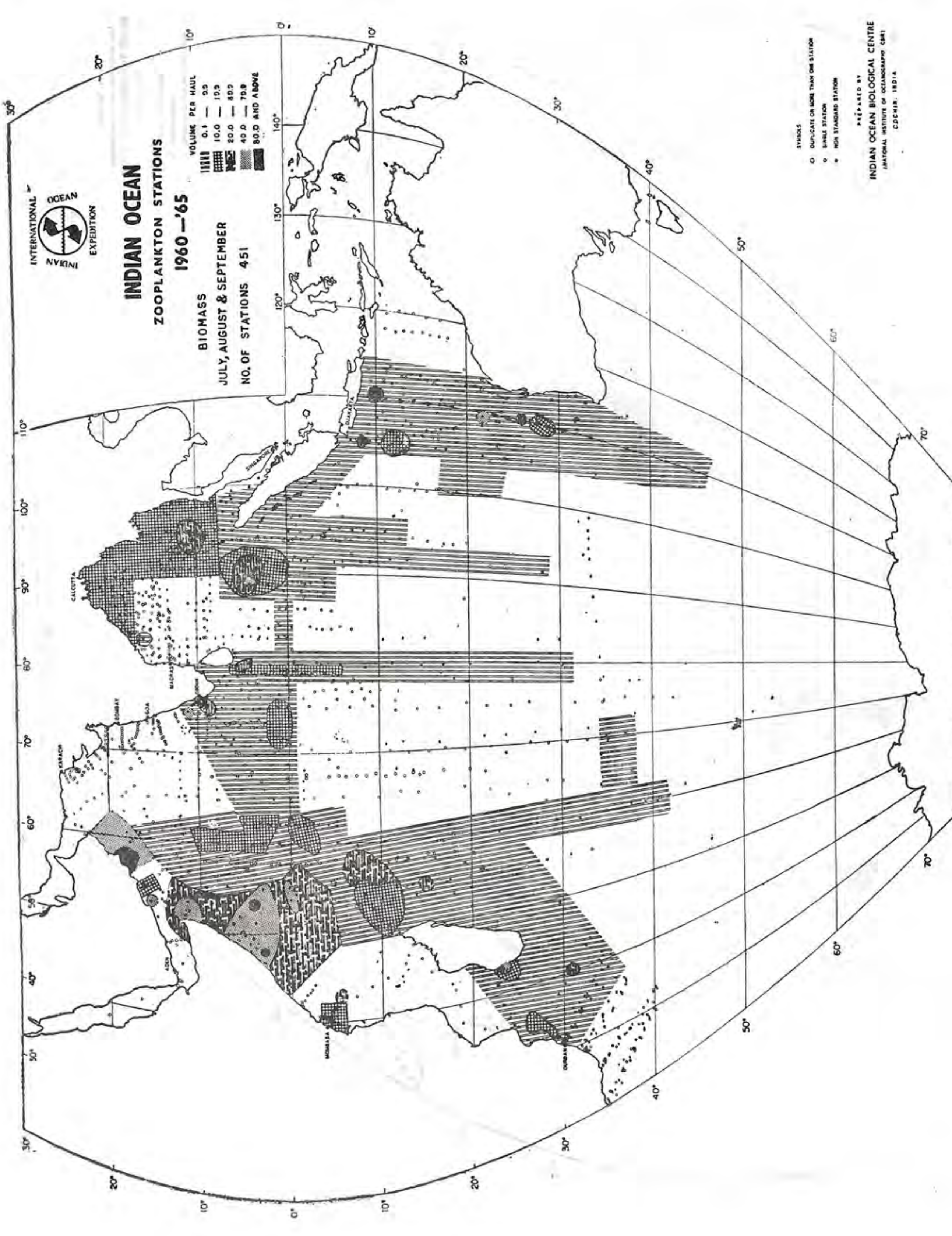

Fig. 5. Biomass distribution July - September.

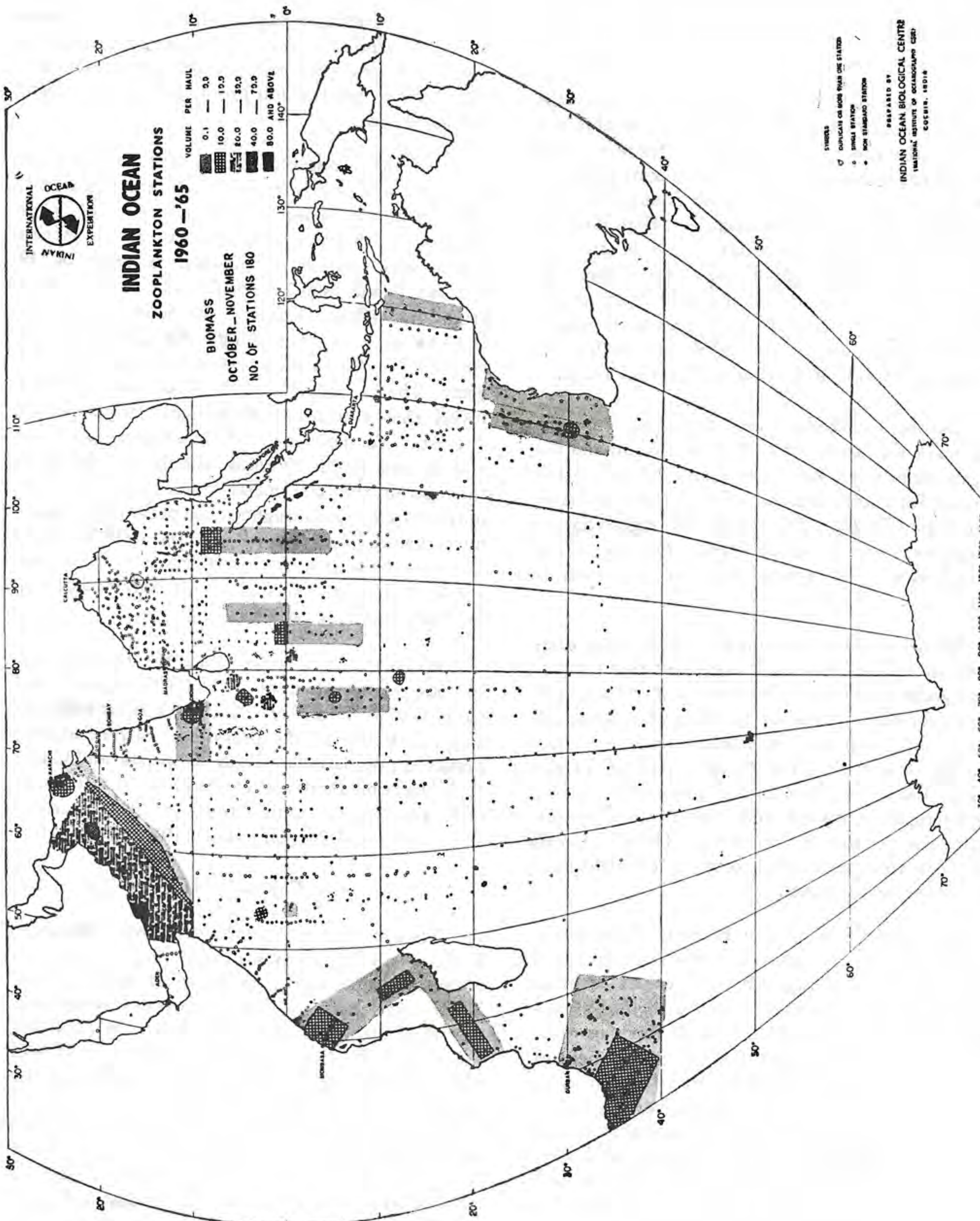

Fig. 6. Biomass distribution October - November.

(20-39.9 ml) to the east of Ceylon and a similar patch in the Gulf of Aden. Most of the samples out of the 248 for this season exhibit low values (10 ml).

July-August and September are the months where the south west monsoon is fully established all over the north Indian Ocean. There are 451 samples for this season and unfortunately most of the west coast of India north of Mangalore and Madras coast have no data (Fig. 5). High biomass values, 40 ml and above are found at stations off Somalia (between Garad and Ras Mabber) adjacent to Cabo Guardafui and off Oman coast. Values ranging from 20-39.8 are present south of the Andaman Sea, around 5°N and 90°E, off Cochin and south of Ceylon and also on 110°E.

October-November are transition months and mark the close of the S.W. monsoon and the beginning of north east monsoon. There are 180 samples for this period mostly off the Saudi Arabian coast (Fig. 6). This is the only region having a biomass value of 20-39.9 ml. The rest of the areas have all low values. No data are available for the Bay of Bengal.

From the above account of the seasonal distribution of the biomass, it is evident that the areas adjacent to the Saudi Arabian coast consistently show very high ranges of productivity during the prolonged south-west monsoon period. It may also be stated that the eastern portion of the Indian Ocean becomes highly productive during the northeast monsoon and the western portion during the southwest monsoon. There is also an overall increase in the area of productivity during the southwest monsoon.

A comparison of the biomass distribution with the surface thickness layer distribution (Fig.7) makes it clear that high biomass values overlap areas of shallow surface layer or regions of upwelling. In this respect the Saudi Arabian coast is unique. The persistent easterly component of the currents in the Arabian Sea from May to August (Wooster *et al.*, 1967) creates divergent conditions off the Saudi Arabian coast and thus favour large scale upwelling. In July, August and September this coast has lowest temperatures around 23°-25°C. Salinity is high and constant throughout the year. Distribution of nutrients (phosphates and nitrates) indicate high values for this area. Even at the surface, phosphates and nitrates show very high values of 1.61 and 12.1 ug/at/1 respectively which is no where else to be seen in the Indian Ocean. All these circumstances combine to make the Saudi Arabian coast the richest area for zooplankton production in the north Indian Ocean.

In the southern Ocean the number of samples available are few. This is however, made up by a series of cruises occupying same stations by Australia and again by South Africa whose ship 'Africana' worked a grid of 19 stations in the Agulhas bank area for 18 months from June 1965. Study of the biomass at these stations is very interesting. At 32°S 100-112°E we have 14 observations covering 8 months of the year. The hydrographical data from these stations reveal that conditions were highly stable during August. Temperature (19°C), salinity (35.7‰) and oxygen (5.0ml/1) show almost no variation throughout the 200 meter water column. The nutrients are low throughout the period, the maximum values being Po_4 - P 0.70 ug at/1, in July. The biomass at this station is very low and shows a bimodal fluctuation, high values observed during February and August.

In the 'Africana' collections the biomass values are higher than at 32°S-100°E station and variable (0.9-21.7ml for 100m^3). A clear relationship exists between the prevailing current and the plankton populations. Both Copelata and Chaetognaths come from the east and drift westwards and southwards with the Agulhas current (Chandrika and Pannampunayil 1973)

Copepoda (Fig. 8)

These are the main herbivores among the zooplankton and constitutes nearly 70-80% of total zooplankton collected at most of the stations. Their distribution during the two monsoons and day and night are represented in the plankton Atlas Vol. II, Fasc. 1 published by the IOBC (1970). Areas of highest density are located all along the east African coast north of Mombasa and continue along the Arabian coast and occupy a large area of the northern Arabian Sea. Then again the Wadge bank and gulf of Mannar, an area off Madras, head of the Bay of Bengal including the Orissa coast and some patches along the equatorial region show high densities. Low value

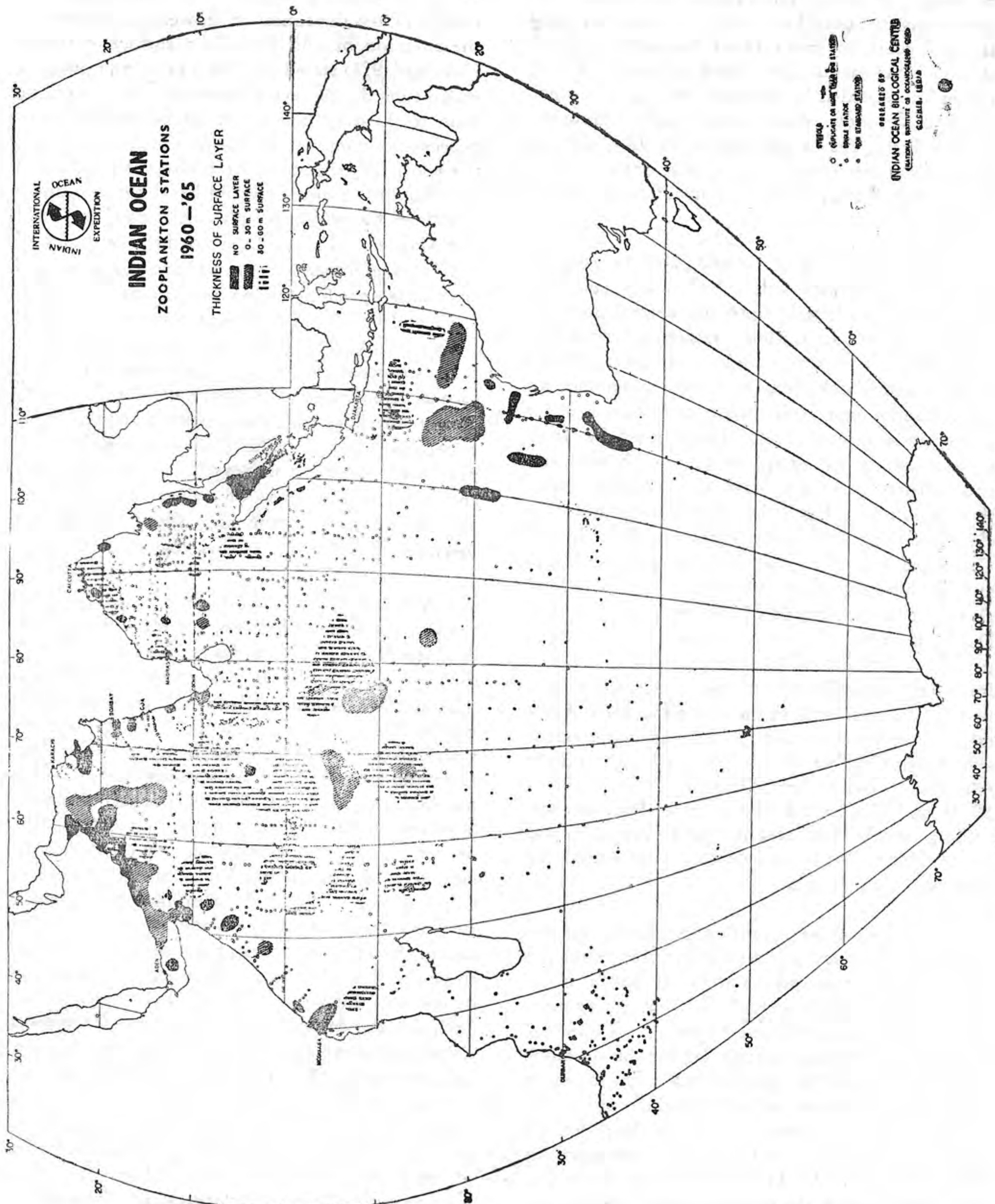

Fig. 7. Thickness of surface layer - distribution.

areas cover the central Arabian Sea and the Bay of Bengal. During the summer monsoon it is interesting to note low copepod densities along the west coast of India to as far north as Baluchistan, whereas in the winter monsoon higher values are recorded in the same region. In other words production of copepods is much more extensive during the winter monsoon than in the summer monsoon and covers large offshore areas including and away from regions of well known upwelling.

In the Bay of Bengal a rich patch is seen off the northern Andhra and Orissa coasts and this dense area extends right upto the central portions of the northern Bay during the summer monsoon. La Fond (1954) has reported upwelling off Visakhapatnam in March, but this local phenomon an alone cannot explain the occurrence of such dense populations far offshore. There must be large scale upwelling taking place off the Orissa coast and unfortunately no data is available from this region. In Fig. 7 the distribution and thickness of the surface layer is shown in the Indian Ocean and it is clear that shallow surface layers exist all along the north eastern coast of India and also cover a greater part of the head of the Bay. During the winter monsoon dense patches of copepods are present off Madras and southern tip of India and upwelling may take place there too. In the Java sea and in the seas off western Australia denser patches of copepods are more extensive during October--April (corresponds to northern winter) than in April-October. Wyrtki (1961, 1962) and Rocheford (1962) have described upwelling areas off Java and northwest Australia and in the Flores, Banda and Arafura Seas during the months of July-August.

In all these areas extensive production of copepods takes place during the winter monsoon (corresponding months in areas of south of the equator) and it is suggested that although primary production values are highest during the summer monsoon, there is some time lag for the development of zooplankton populations For example on the Malabar coast primary production is highest during July-August which is also the period of upwelling, but zooplankton peaks commence in October-November. In this way the biological activities between the two monsoons are complementary and the effects of the summer monsoon is perhaps, fully realized during the winter monsoon.

Another important point is that the areas of zooplankton productivity extends hundreds of miles from the zones of upwelling, mostly in the direction of the prevailing surface currents. Cushing (1971) stated that "at ½ knot, an upwelling which took 30-60 days to rise through the photic zone might drift 300-600 miles before the decay process was complete". Cushing also expects that the width of the zone of biological production (zooplankton quantity) would be about two and a half times the width of physical upwelling. Off Ras Mabber and around the northern latitudes of 8-10°N, the Somali current deflects eastward and an intense upwelling region develops at this divergence and here highest density contour for copepods extends upto a distance of nearly 600 miles from the coast. Po_4-P (ug at/1) values at the surface as summarized in Wooster *et al* (1967) very clearly correlates with the density distribution of copepods (Fig. 18). The highest values of phosphorous is along the shores of Somalia and Arabia and the contour lines of values above 0.75 ug at/1 Po_4-P neatly coincide with the highest densities of copepods, in this region.

At the IOBC special attention is also paid to the study of species for geographical distribution. Analysis of the 1927 samples received at the IOBC during the IIOE, yielded specimens of *Gaussia* (Copepoda-Metridiidae) from 19 stations (Saraswathy, 1973). At all these positive stations the sampling was from the upper 200m of water and excepting one, all the other stations were either in the Arabian Sea or the Bay of Bengal. Examinations of specimens of *Gaussia* collected from deeper levels in the Indian Ocean revealed that the species inhabiting the northern areas of the Indian Ocean can be separated from the type species. Recognition of a species endemic to the northern Indian Ocean is important, because it is beginning to be felt that there is a certain degree of isolation of fauna in this area. Gibbs and Hurwitz (1967) have also shown that in the case of *Chauliodus sloani* there appears to be at least two populations, a denser one north of the frontal zone (about 10°S) and less denser one further south of about 23°S, the two separated by a sterile region. The concept of a frontal zone separating the northern part of the Indian Ocean from its southern part, has been recognized by many workers and Ovcinnikov (1961) observes that north of frontal zone the Arabian Sea water characterized by a minimum

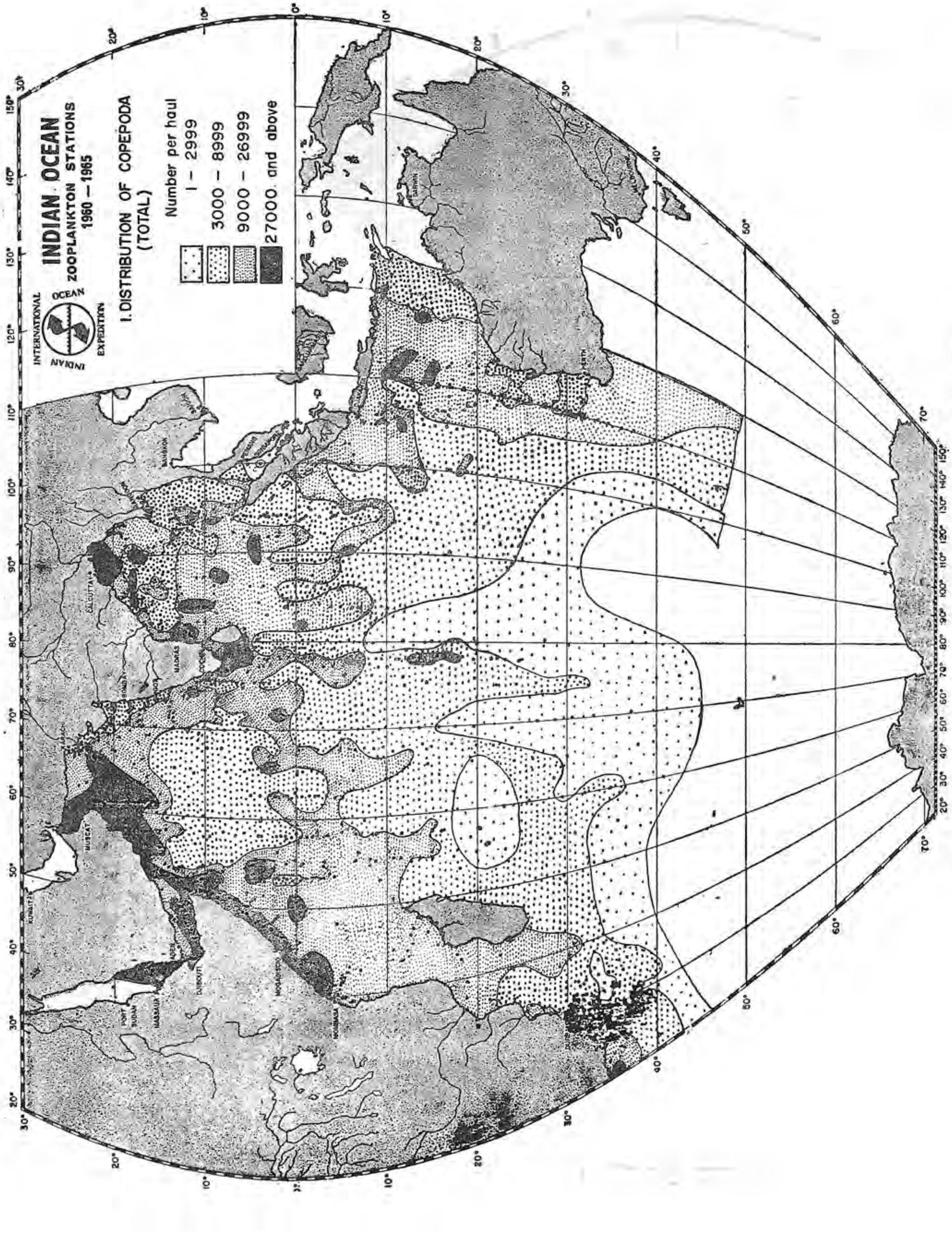

Fig. 8. Distribution of Copepoda (total) in the Indian Ocean.

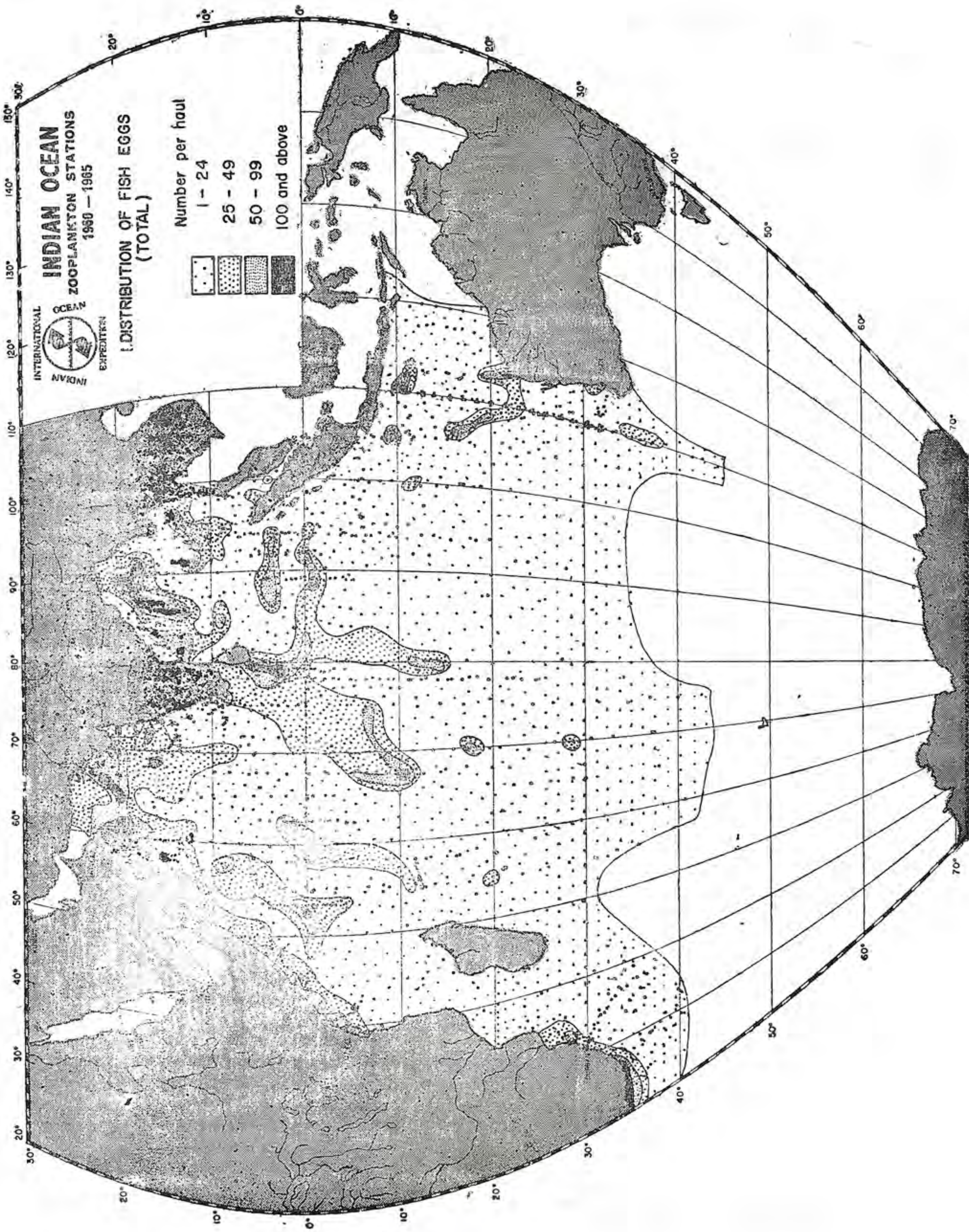

Fig. 9. Distribution of Fish eggs (total) in the Indian Ocean.

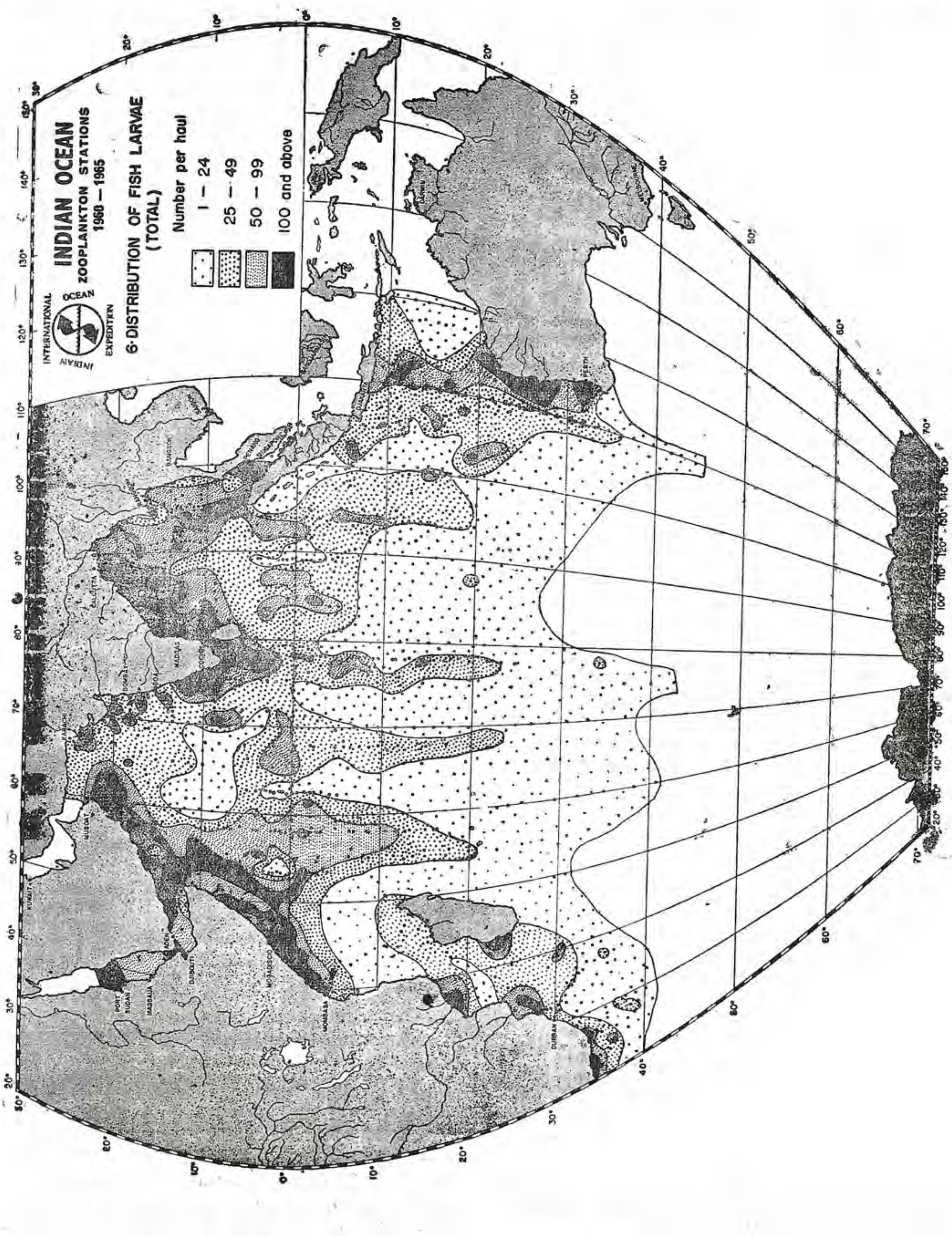

Fig. 10. Distribution of Fish larvae (total) in the Indian Ocean.

oxygen layer is present and the central water mass further to the south of 10°S has high oxygen content. Ivanov - Franskevic (1961) also stresses the importance of the frontal zone (at 10 - 12°S) which marks a clear boundary spreading down to 2000 m and is more sharply expressed in the eastern part of the Indian Ocean.

Fish eggs and larvae (Figs. 9-10)

Of the 1927 zooplankton samples collected and sent to the IOBC during International Indian Ocean Expedition, the eggs and larvae were present in about 87% of the samples. An estimate of abundance of fish eggs and larvae has been made on the basis of actual number present at each station. 10 charts were prepared and published by the IOBC in Plankton Atlas Vol. II -Fasc. 2 in 1970. These charts show total distribution and distribution during the two monsoon periods, day and night. The highest was about 2300 eggs per haul from the vicinity of the central Arabian coast (14°21 'N - 58°18'E) and larvae about 1600/haul from the Malabar coast (11°00'N - 74°35'E).

The pattern of distribution of fish eggs is extremely interesting. Higher numbers (100 and above) are found over an extensive area along the Saudi Arabian coast, southern coast of South Africa, some patches along the equator, an elongated patch radiating from Ceylon downwards along the 80° longitude, and in an extensive area in the western Bay of Bengal away from the Indian coast. Such a type of distribution persists both during the two monsoons as well as during the day and night.

The larval distribution overlaps the eggs; however, higher values cover an extensive area particularly in the east African - Arabian coasts and the Bay of Bengal. In contrast low larval numbers are found over most of the central Arabian Sea.

It is clear from these charts that the western Arabian Sea adjacent to African and Arabian coasts and the Bay of Bengal emerge as important spawning areas for fish in the Indian Ocean. During the southwest monsoon most of the coast of India shows low values for eggs. However, for larvae the Malabar and the Ceylonese coasts are rich and this rich zone continues into the Bay of Bengal during both the monsoons.

The total fish larvae collected were subsorted into 55 groups (upto the family level) and the distribution charts for the various families are being prepared. The results show that the oceanic zone is dominated by larvae of deep sea and bathypelagic fishes such as Goniostomids, Stomiatids, Paralepids, Scopelarctids, and Myctophids. The coastal zone includes larvae of strictly coastal fishes such as anchovies, sardines, lizard fishes, flat fishes, gobies and scorpionid fishes. The intermediate zone consists of a mixture of bathypelagic and coastal species and, as is to be expected, this zone is the richest for the variety of fish larvae. Most of the larvae of economically important fishes of families Thunnidae, Scomberomoridae, Carangidae and Gobiidae are collected from the zone. Even larvae of certain fishes such as Engraulids and Synodontids are represented here.

Investigations on the quantitative distribution of the flat fish larvae (Lalithambika Devi, unpublished) indicate that compared to other plankton taxa, the larvae of Heterosomata are represented only in very small numbers and that too only in about 11 per cent of the IIOE samples. In general, the flat fish larve are more abundant in the collections from the Bay of Bengal than from the Arabian Sea or from any other part of the Indian Ocean. The larvae are concentrated in the neritic region. The flat fish larvae were not found in the central and southern Indian Ocean (about 52°E to 100°E and 10°S to 45°S). They were seen more in the northern half of the Bay of Bengal. As the salinity in this region is comparatively low, it appears that the larvae prefer low salinity. The presence of 65 per cent of the larvae in the collections taken during night may indicate their preference to low light intensity and vertical migration from deeper layers. Flat fish larvae belonging to the families Bothidae, Pleuronectidae and Cynoglossidae are found in the Indian Ocean.

The credit for recording the early larval stages of mackerel larvae(probably *Rastrelliger kanagurta)* in the Indian Ocean goes to the IOBC (Peter, 1969). The 3 stations at which these stages were obtained, however, are widely separated both in space and time; namely Red Sea, Gulf of Oman (November-December) and Orissa coast in the Bay of Bengal (May). It may not be prudent to make comments on the spawning areas of the mackerel based on these collections, but the presence of these larvae

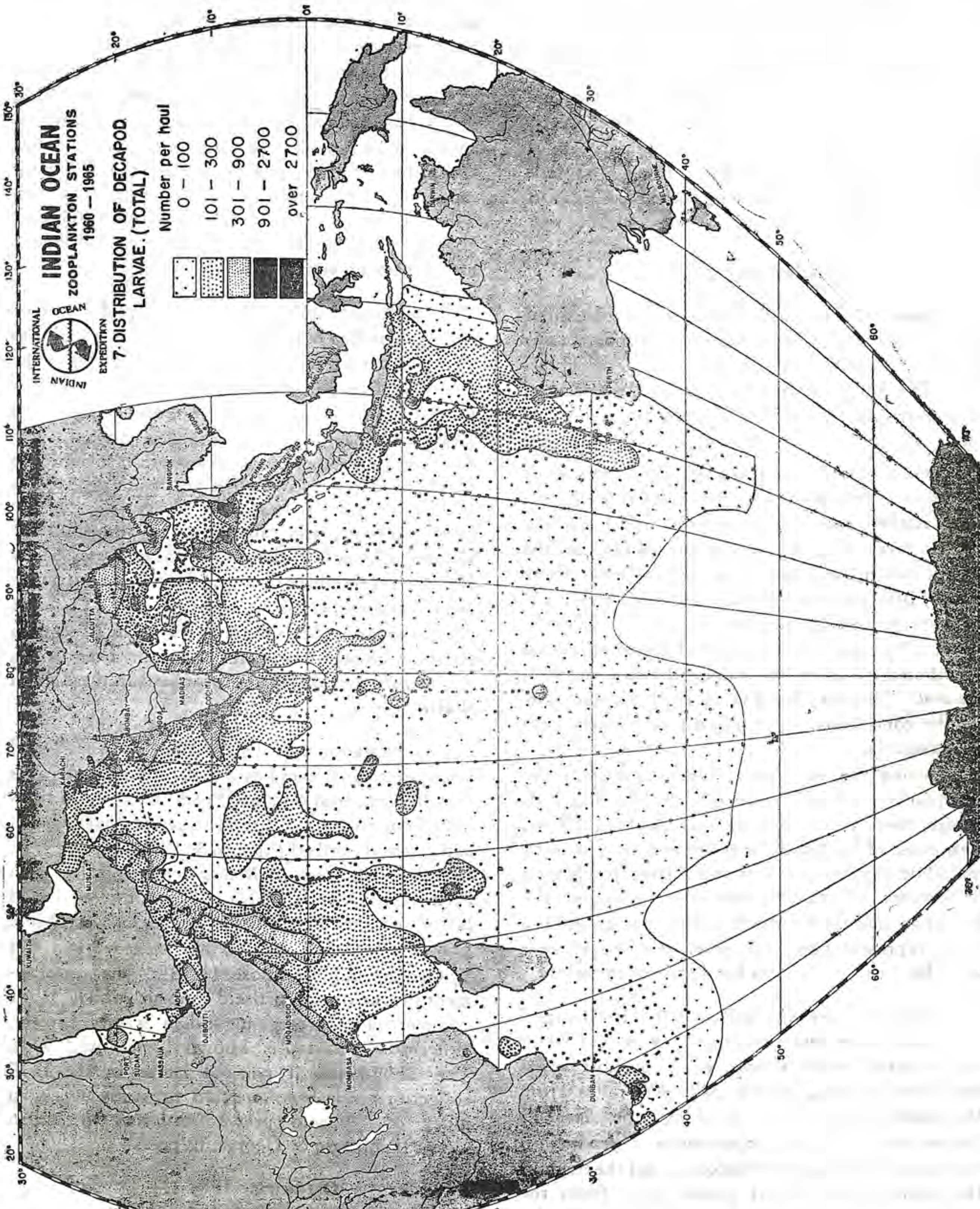

Fig. 11. Distribution of decapod larvae (total) in the Indian Ocean.

in only 3 collections out of the large number of IOBC samples perhaps indicates that early stages of the larvae of such fishes are not present in the upper two hundred metres, since most of the samples come from this layer. In the case of the flying fish (Balasubramanyan *et al*, 1969) the indications are that they spawn around the coasts of Ceylon. More detailed work on the fish larvae is in progress and charts showing the distribution of these families in the Indian Ocean are under preparation.

Decapod larvae (Fig. 11)

These larvae form an important constituent of the zooplankton. Out of the 1548 standard samples studied, 1518 samples contained decapod larvae. The distribution of these larvae are presented in 6 maps in the IIOE Plankton Atlas Vol.II Fasc. 1 (1970).

Very high concentrations of the larvae (over 2700/haul) are met with at one station each, off Port Elizabeth and south of Java and 3 stations off the west coast of Indian peninsula. In the central Indian Ocean south of 10°S latitude there is very little representation of decapod larvae. Except for the head of the Bay of Bengal, the brachyuran component of the decapod larvae is found distributed all over the Indian Ocean along with the rest. This may be due to the prevailing low salinity conditions off the mouths of Ganges and Brahmaputra.

During the southwest monsoon season the decapod larvae have a wider distribution and high density areas include Somali and Arabian coasts, west coast of India and the entire east coat of India including Ceylonese waters and a large patch west of Sumatra. During the northeast monsoon, the waters around the southern Indian peninsula has good representation and most of the east coast of India north of Madras has low concentration.

Another interesting feature is that the decapod larvae has lower concentrations close to the Saudi Arabian and Somali shores, while offshore areas has dense patches, nearly 300 - 400 miles from the coast. Ecologically speaking, the decapod larvae come late in the sequence of production commencing from phytoplankton, and they would therefore be located at places away from the actual upwelling areas (see discussion under copepods).

The concentration of the high density areas around the Indian coasts during the northeast monsoon into the southern region of the peninsula as compared to their occurrence all along both the coasts during the southwest monsoon, perhaps, indicate that spawning of some of the economically important families of decapods takes place all along the Indian coasts during the southwest monsoon and with the onset of more stable conditions of hydrography during the northeast monsoon, they all migrate and develop into rich fisheries along the Malabar, Madras and Ceylonese coasts. The distribution of fish eggs and larvae also suggests a similar pattern.

Preliminary notes on the decapod larvae of the Arabian Sea based on expedition material has already been published (Menon *et al.*, 1969). The trends in distribution of the larvae of the major groups of decapods are also under study. The larvae of penaeid prawns, Paguridae and Callianassidae, show a maximum concentration around the southern extremity of Indian peninsula, off Madras and off the Somali coast. However, the latter two families are equally abundant in the Gulf of Cambay region. In the case of Brachyuran larvae the greatest numbers occur in the region surrounding the Indian peninsula, northern part of Somali coast, Andaman Sea snd off the western Australian coast. Caridean larvae are abundant near South African coast and also south of Java in the eastern Indian Ocean.

The data on the distribution of the larval stages of several families of decapod crustaceans from the material obtained from IIOE collections have been analysed. Larval stages of *Thalassocaris* spp. were described (Menon & Williamson, 1971). Larval development of *Heterocarpus* spp. has also been traced (Menon, 1972). The complete larval history of one of the forage species of pasiphaeid prawns *Leptochela robusta* has been worked out by George and Paulinose (1973). The development of one of the penaeid prawns which is of commercial importance in Indian waters namely, *Penaeopsis rectacuta* is known (Paulinose, 1973). The abundance of penaeid larvae in the IIOE collections have been analysed to study it as an index of penaeid prawn resources in Indian Ocean (Paulinose & George, in press).

Ostracoda (Fig. 12)

A preliminary report on the distribution and abundance of planktonic Ostracoda has already been pubished (George, 1969). The ostracods are an important group next among import-

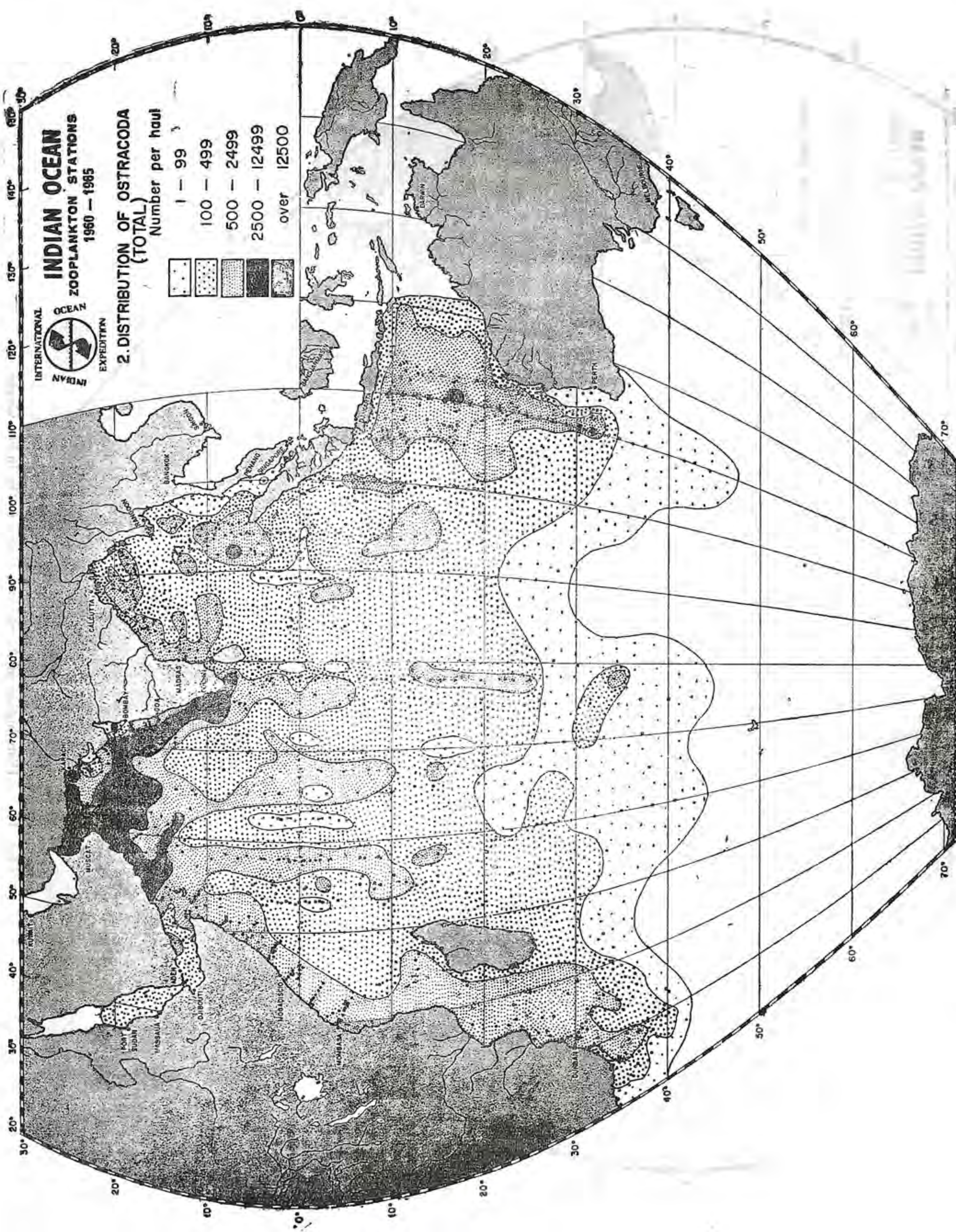

Fig. 12. Distribution of Ostracoda (total) in the Indian Ocean.

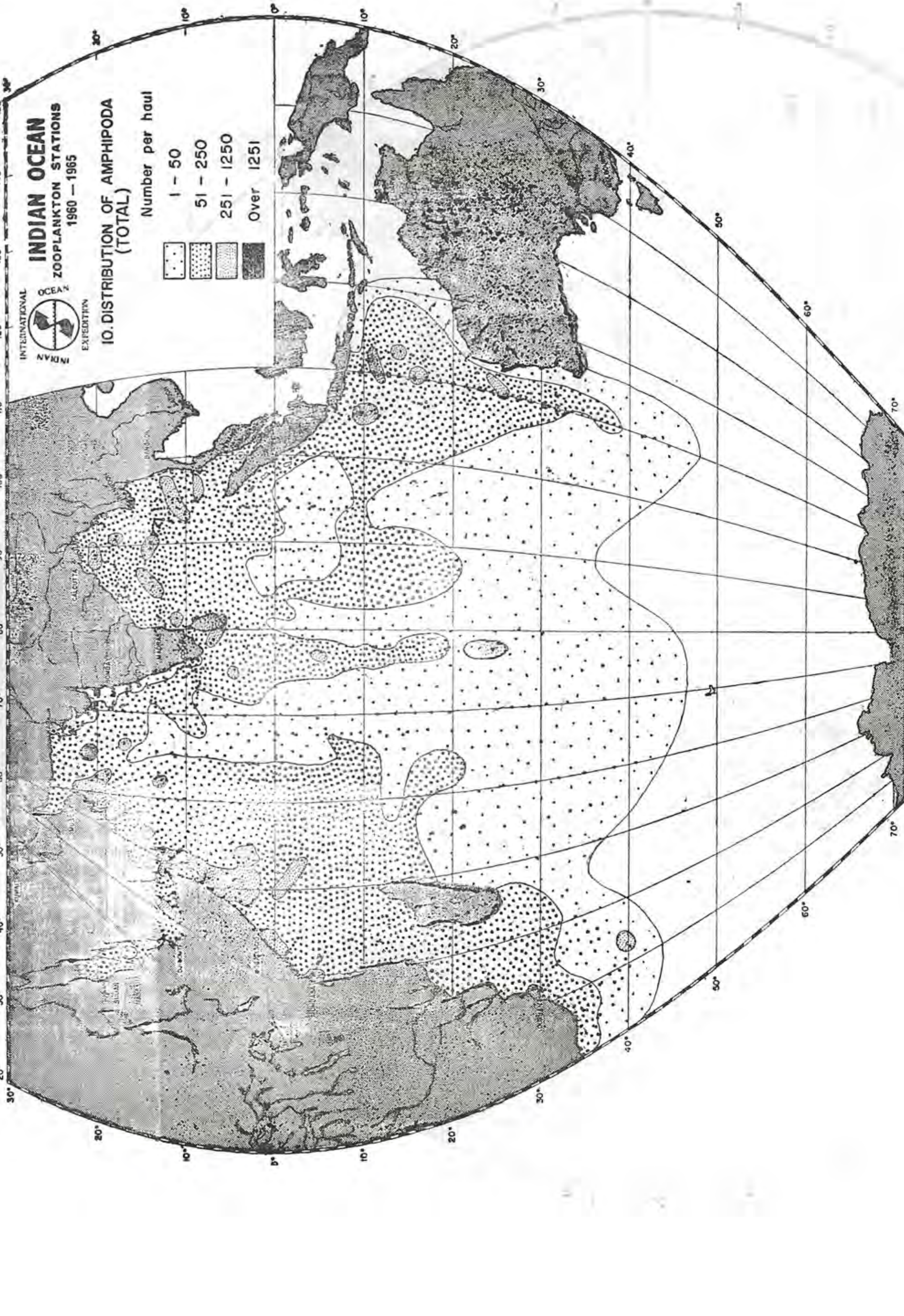

Fig. 13. Distribution of Amphipoda (total) in the Indian Ocean.

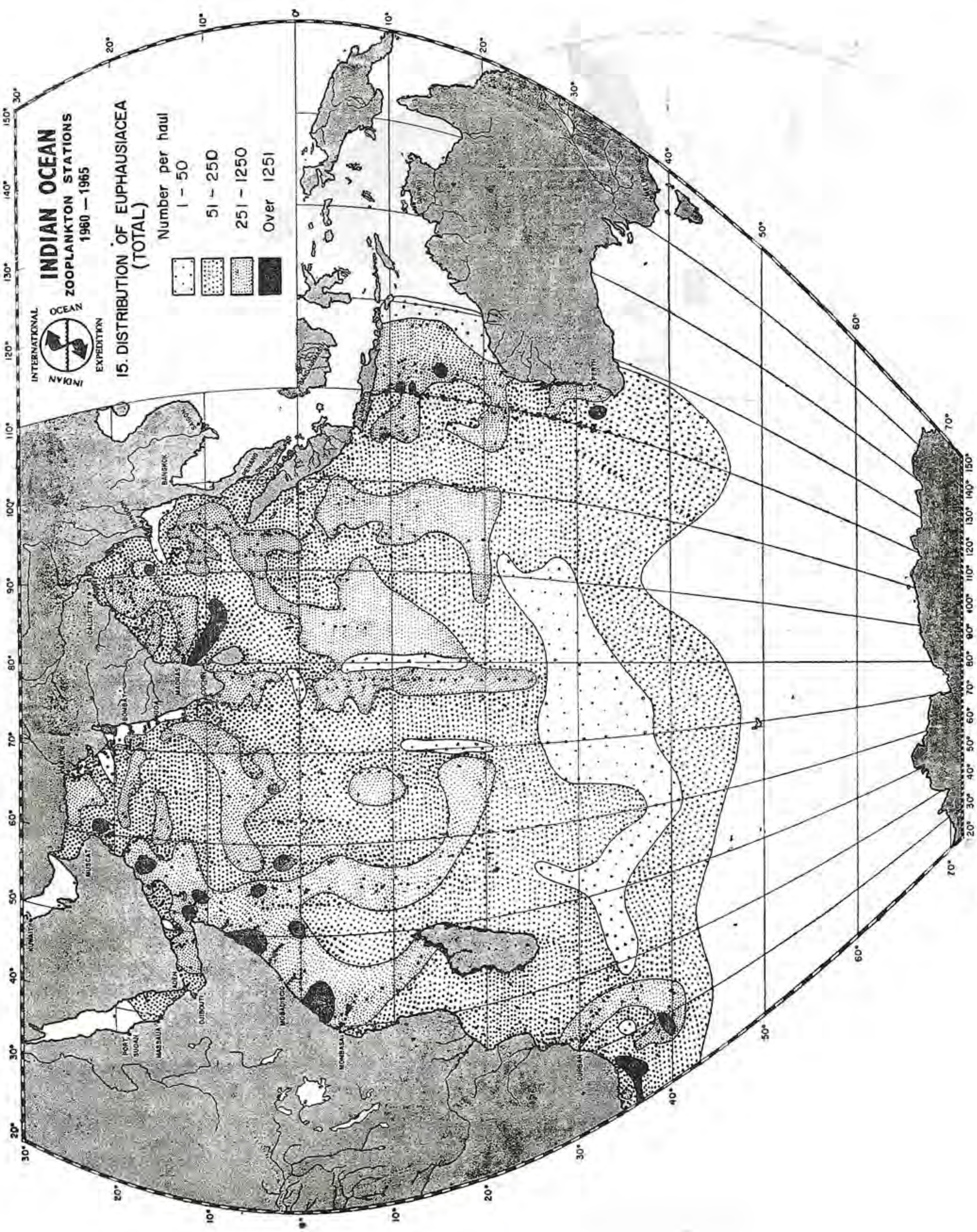

Fig. 14. Distribution of Euphausiacea (total) in the Indian Ocean.

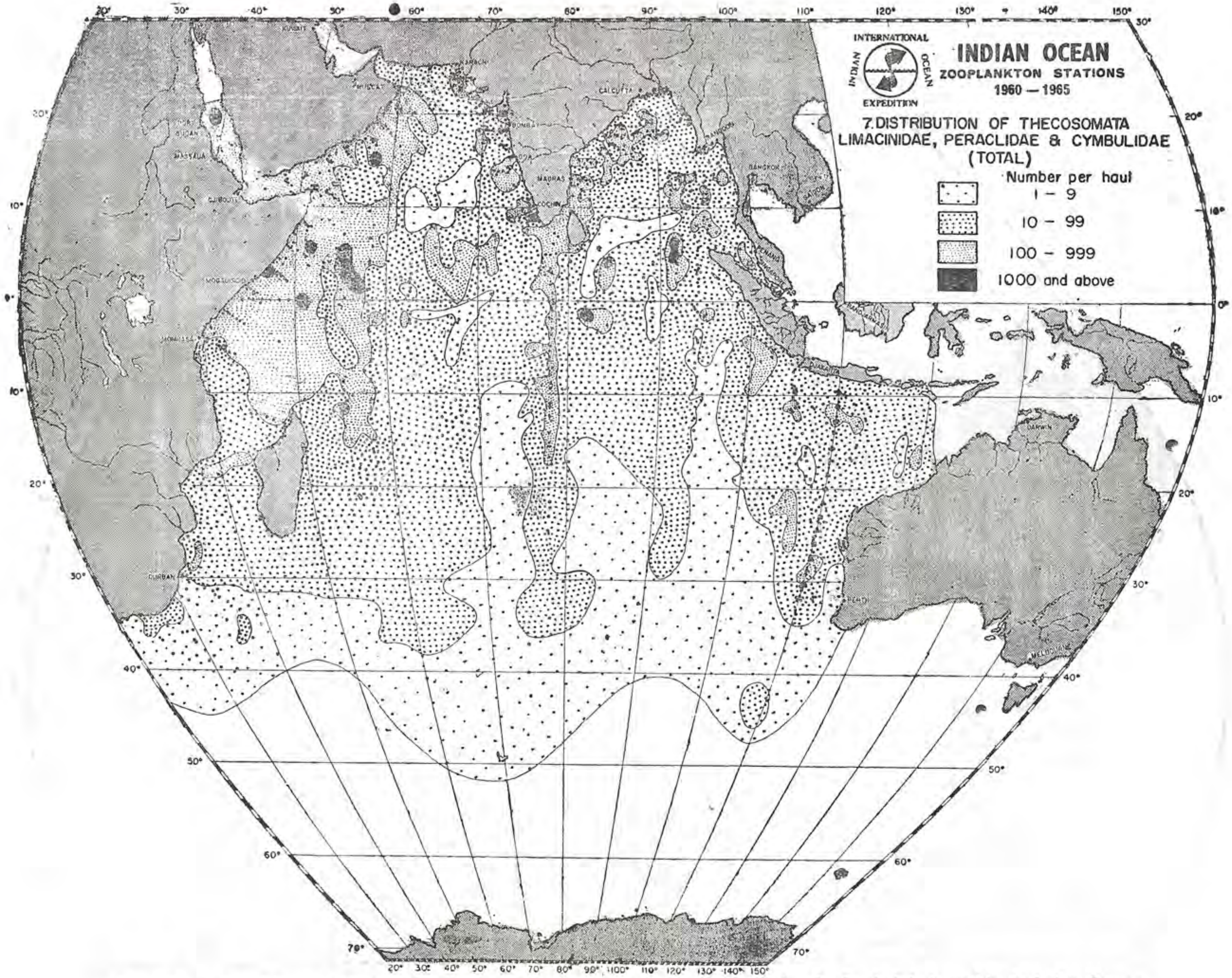

Fig. 15. Distribution of planktonic Mollusca. (Thecosomata - Limacinidae, Peraclidae & Cymbulidae) total in the Indian Ocean.

ance to copepods in numerical abundance. The majority of the species belong to the family Halocyprididae.

The distribution charts for the Ostracoda is given in the IIOE Plankton Atlas Vol. III – Fascicle 1 (1972). The total distribution of the ostracods is very interesting. There is a high density patch (2500/haul) originating on the Saudi Arabian coast and this spreads right across the Arabian Sea and extends upto southern extremity of the Indian peninsula; the coastal areas south of Karachi and off Bombay, however, support low density population. Swarms of ostracods (12500/haul) are present off Karachi, Gujarat and Kerala coasts.

During the southwest monsoon northern Arabian Sea north of 13 – 14°N latitude and excluding the Gulf of Cambay area, has high density ostracods, similarly the Kerala coast. During the northeast monsoon a similar distribution exists, with an extension of the high density patch into the Gulf of Aden. The Burmese and Thai coasts of the Bay of Bengal have low density ostracods during both the monsoons.

The 5° square falling in between 75°-80°E and 10° - 15°N has very high densities and contained on an average of more than 10,000 ostracods per haul and this happened during the northeast monsoon period. This area is adjacent to upwelling areas off Saudi Arabia and is also the home of other zooplankton groups, including fish eggs and larvae.

30 species of Ostracods were observed in the IIOE collections from the Arabian Sea. *Bathyconchoecia deeviae* is a new record for the Indian Ocean (George, 1971).

Amphipoda (Fig. 13)

Amphipods are also an important group of zooplankton, but their numbers are not as great as those of ostracods or copepods. They were found in almost all the samples at the IOBC. Their distribution is presented in 5 maps as part of Vol. III – Fascicle 1 of IIOE Plankton Atlas published by the IOBC (1972).

As in other groups, the amphipods also show high density areas along the African and Arabian coasts, isolated patches both in the Arabian Sea and Bay of Bengal and also in the West Australian area. Somehow the entire West Coast of India has very low densities of amphipods. Another interesting feature is that the dense patches of amphipods are not as extensive as in other groups such as ostracods, copepods, or euphausiids.

During the south west monsoon, high density patches (250/haul) are present adjacent to Somali and Arabian coasts, south of Ceylon and four patches in the Bay of Bengal and one south of Java. While the Somali and Arabian coasts are known for upwelling, nothing is known about the other areas mentioned above, except for Java Sea where upwelling is reported to take place. A reference to Fig. 17 showing the distribution of surface layer, indicates that some of the dense patches of amphipods in the Bay of Bengal are close to areas where the surface layer is thin. During the northeast monsoon, the dense patches off Somalia disappears, while the Saudi Arabian patch is located further east and extends to the Gulf of Oman. A new patch appears at the tip of the Indian peninsula and some patches in the west Australian seas. It is possible that upwelling takes place in the Gulf of Oman (Weigmann, 1970) and also off Ceylon and Australian areas to account for these dense populations during the northeast monsoon.

Most of the species belong to the family Hyperiidae. Two species from the family *Dairellidae* are new records for the Indian Ocean.

Euphausiids (Fig. 14)

These are omnivorous feeders and consume diatoms, other zooplankton and detritus. In turn they form an important food base for fish and whales and the importance of this group as 'krill'—the principāl food of the baleen whales of the Antarctic waters is well known. A recent estimate places the annual consumption of the krill by the whales in the Antarctic Ocean alone at 150 million tons/year and Russians are reported to be harvesting these organisms in place of baleen whales which are becoming scarce.

Preliminary observations on the distribution of Euphausiacea from the International Indian Ocean Expedition were made by Gopalakrishnan and Brinton (1969). Weigmann (1970) has given an account of the ecology and feeding habits of the euphausiids in the Arabian Sea based on Meteor collections (1964-65) during the IIOE, at the time of the northeast monsoon. Ponomareva (1964) has also dealt with the Euphausiacea of the Arabian Sea and Bay of Bengal.

As in the case of copepods and decapod larvae, highest densities of euphausiids (1250/haul) are confined to patches along the African and Arabian coasts, two patches in the Central Indian Ocean due south of Ceylon, a large patch off Madras, one north of Andaman Islands, three patches in the Java Sea and one off Perth. The next range of density (250/haul) is very widely distributed all along the East African coast mostly north of Mombasa and a tongue of this extends into the Central Indian Ocean. There are similar bands right across the Central Indian Ocean separated by low density patches. (Atlas Vol. 3. Fasc. 1)

During the southwest monsoon high density patches appear off Somalia, Saudi Arabia and also off the Madras coast. These patches extend for hundreds of miles off shore. Except for a band of low density, the whole of Bay of Bengal has similar populations as those of the African coast. It is interesting to note very low densities of euphausiids off the Bombay and Gujarat coasts and this persists even during the north east monsoon. However, during this monsoon the Bay of Bengal has lower densities and off Madras and Ceylon the highest density patches disappear. Besides, a much wider area extending from the African to the Australian coast is occupied by the euphausiids in densities of over 250/haul, during the north east monsoon than in the southwest monsoon. Here again we have an instance where biologically speaking northeast monsoon season is more productive than southwest monsoon.

In the geographical distribution of the euphausiids Gopalakrishnan and Brinton (1969) found interesting results. *Nematoscelis microps* and *Euphausia brevis* were present at most stations south of the equator, but not north of it. *Stylocheiron microphthalma* was, on the average 4 times more abundant in the south than in the north and the opposite was the case with *Nematoscelis gracilis*. *Euphausia tenera*, *Thysanopoda tricuspida* and *Nematoscelis gracilis* were dominant forms in the north.

As already referred to, south of the equator a frontal zone is present which effectively separates the northern Indian Ocean waters from the south. During the 'Lusiad' expedition the characteristics of the southwest monsoon current differed between the western and eastern sides of the ocean. The western side (west of 55°E) had cooler waters (26°C) in the upper 100 metres, with higher salinity, oxygen and inorganic phosphate content, perhaps due to upwelling in these areas. While the frontal zone separates north and the south Indian Oceans across the 10 - 12°S latitude, upwelling appears to give a special character to the western side as opposed to the eastern side of the Indian Ocean. Gopalakrishnan and Brinton (1969) found *Thyasanopoda tricuspidata*, *Euphausia diomediae* and *E. tenera* occur in large numbers on the western side and *E. brevis* on the eastern side of the Indian Ocean.

Planktonic mollusca (Fig. 15)

Under this, Thecosomata, Gymnosomata Heteropoda, meroplanktonic gastropoda, Nudibranchia, bivalve larvae and Cephalopoda are included and the distribution of these groups in the Indian Ocean is given in IIOE Plankton Atlas Vol. III - Fascicle 2 (1971).

Sakthivel (1969) has given a preliminary report on the distribution of Euthecosomata in the Indian Ocean based on 395 zooplankton samples collected by research vessels Argo and Anton Bruun. Aravindakshan (1969) has similarly reported on the geographical distribution of two families of Heteropoda, namely Carinariidae and Pterotracheidae. Saraswathy (1972) has given an account of the distribution of bivalve larvae.

All these studies emphasize the fact that southern Indian Ocean is very poor in most of these groups, while in the northern Indian Ocean different groups - particularly their constituent species - have a varied pattern of distribution. In most cases, the east African and Saudi Arabian coasts are rich, while the rest of the Arabian Sea, Bay of Bengal and the eastern Indian Ocean has isolated regions showing higher densities.

In the Family Cavoliniidae (the genera included here are *Clio*, *Creseis*, *Styliola*, *Hyalocylix* and *Cuvierina)* the total group distribution shows high density (> 100/haul) areas near East African coast, Red Sea, Arabian coast, large patches in the central Arabian Sea, off Canara and Kerala coasts,

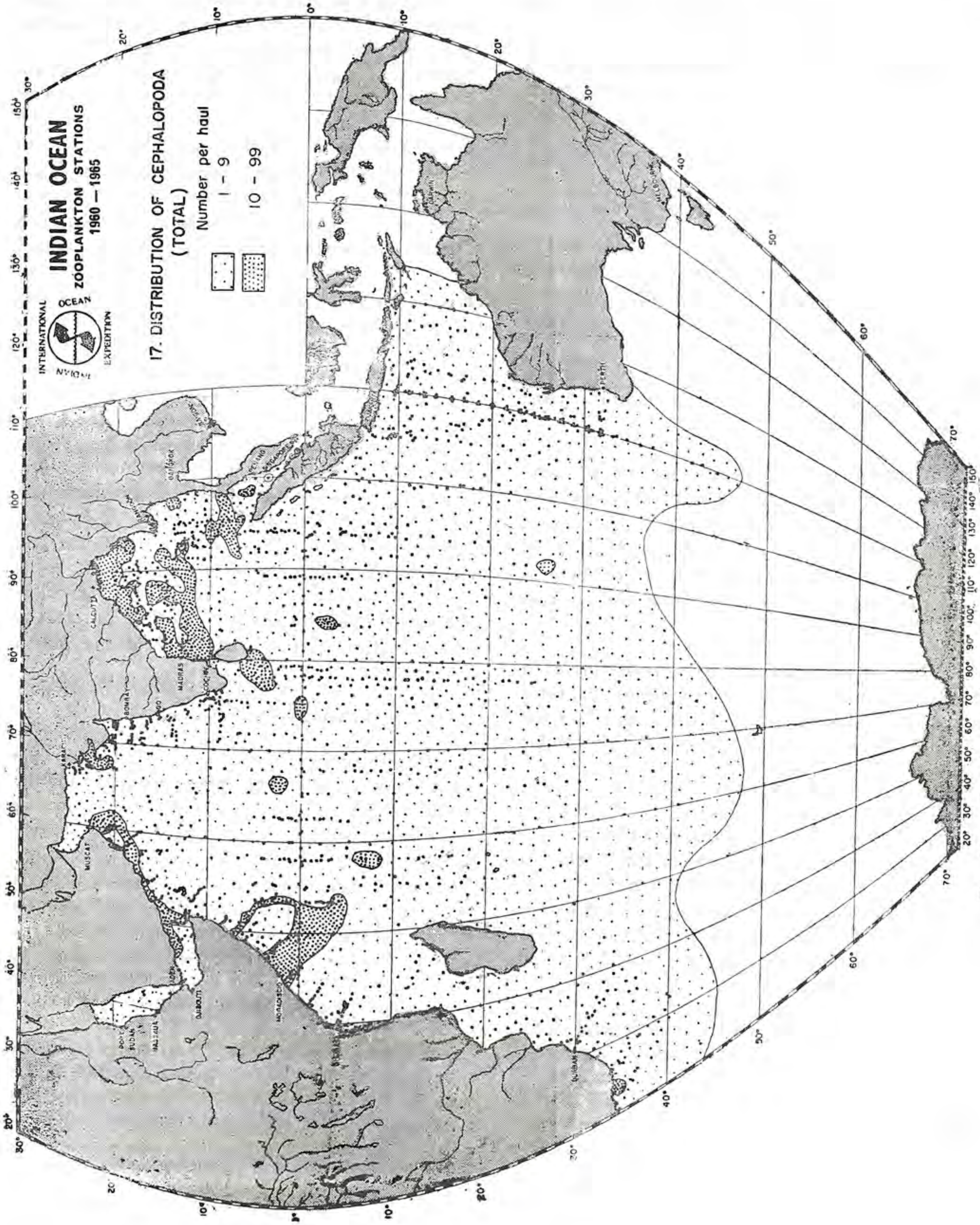

Fig. 16. Distribution of Cephalopods in the Indian Ocean.

off Madras, northern Bay of Bengal, south of Java and two patches south of Ceylon.

Swarms (>1000/haul) were present at 3 spots one in the Red Sea, one off Karachi and the other in the northern Bay of Bengal.

The genera *Diacria* and *Cavolinia* of the family Cavoliniidae have also a wide distribution, but their density is low over most of the Indian Ocean.

The families Limacinidae, Peraclididae and Cymbulidae have denser distribution than Cavoliniidae. High density areas (>100/haul) are extensive over a wide area off the East African coast, along 76—78°E longitude extending from southern tip of India, in the Bay of Bengal and also in the eastern Indian Ocean.

Swarms (>1000/haul) are present at many locations far from the coastal areas. Another interesting feature is that during the southwest monsoon the high density patch in the western Indian Ocean is broken, it forms a continuous band right across Arabian Sea from the African to the Indian coast.

The meroplanktonic gastropods have a similar distribution as the rest of the groups, their abundance hugs the east African and western Arabian coasts and also the coasts of peninsular India.

The distribution of bivalve larvae is interesting. Most of the stations in the southern Indian Ocean are poor in bivalve larvae or totally absent. As to be expected the western Arabian Sea including the Somalia region show the highest densities of bivalve larvae. Swarms (>300/haul) were present at two locations, one in the Red Sea and the other near Sumatra.

The distribution of Cephalopoda and their larvae (Fig. 16) is of great significance. While all over the Indian Ocean they are sparsely distributed, an extensive area off Mogadiscio, Saudi Arabian coast, Gulf of Kutch, off southern Ceylon and vast stretches of the Bay of Bengal show densities between 10—99/haul. There are some patches of the same density in the central Indian Ocean. The emergence of the Bay of Bengal as a rich area for Cephalopods is very interesting and should have economic implications.

Detailed studies on the geographical distribution of some selected species of euthecosomes and heteropods is in progress at the IOBC. Preliminary results indicate that species like *Carinaria cristata*, *Pterosoma planum*, *Cardiapoda placenta*, *Pterotrachea coronata*, *P. hippocampus* among the heteropods are confined mostly to the North Indian Ocean including the Arabian Sea and the Bay of Bengal. *Pterotrachea minuta* and *P. Scutata* appear to be confined to the southern Indian Ocean. Among the pteropods *Cuvierina columnella*, *Cavolinia globulosa* and *C. inflexa* appear to be central equatorial forms. Sakthivel (1968) has reported the abundant occurrence of *Desmopterus gardineri* in the Indian Ocean. A detailed account on the geographical distribution of thecosomes, their seasonal variation along 110°E, the annual variation along 78°E and the distribution in relation to the thermocline in the western Indian Ocean has also been given by him (Sakthivel, 1972). The pattern of change in the biogeography of Thecosomata of the unipolar Indian Ocean has been elucidated in comparison with Pacific and Atlantic. *Styliola subula* which has bi-subtropical distribution in the Pacific and Atlantic has continuous distribution from 10°N to 40°S and totally absent in the area north of 10°N in the Indian Ocean (Sakthivel, 1971).

Chaetognaths (Fig. 17)

Chaetognatha are extremely abundant in the sea and constitute an important part of the marine plankton. All of them except the species coming under the benthic genus *Spadella* are strictly planktonic, the majority being wholly oceanic. They are highly predaceous, carnivorous animals eating mainly copepods and other small animals of suitable size. They can be considered to represent part of the tertiary production in the sea, and also as indicators of water masses and other hydrographical conditions.

Vijayalakshmi and Rao (1971) have given an account of the distribution of chaetognaths in the Arabian Sea based on the IIOE collections. The collection includes nineteen species belonging to four genera. *Sagitta enflata* is the dominant chaetognath species in this area. *S. pacifica*, *S. bedoti*, *Pterosagitta draco*, *S. bipunctata* and *S. regularis* are the other common species in the order of their numerical abundance. The maximum observed density for most of the species is near Somalia and

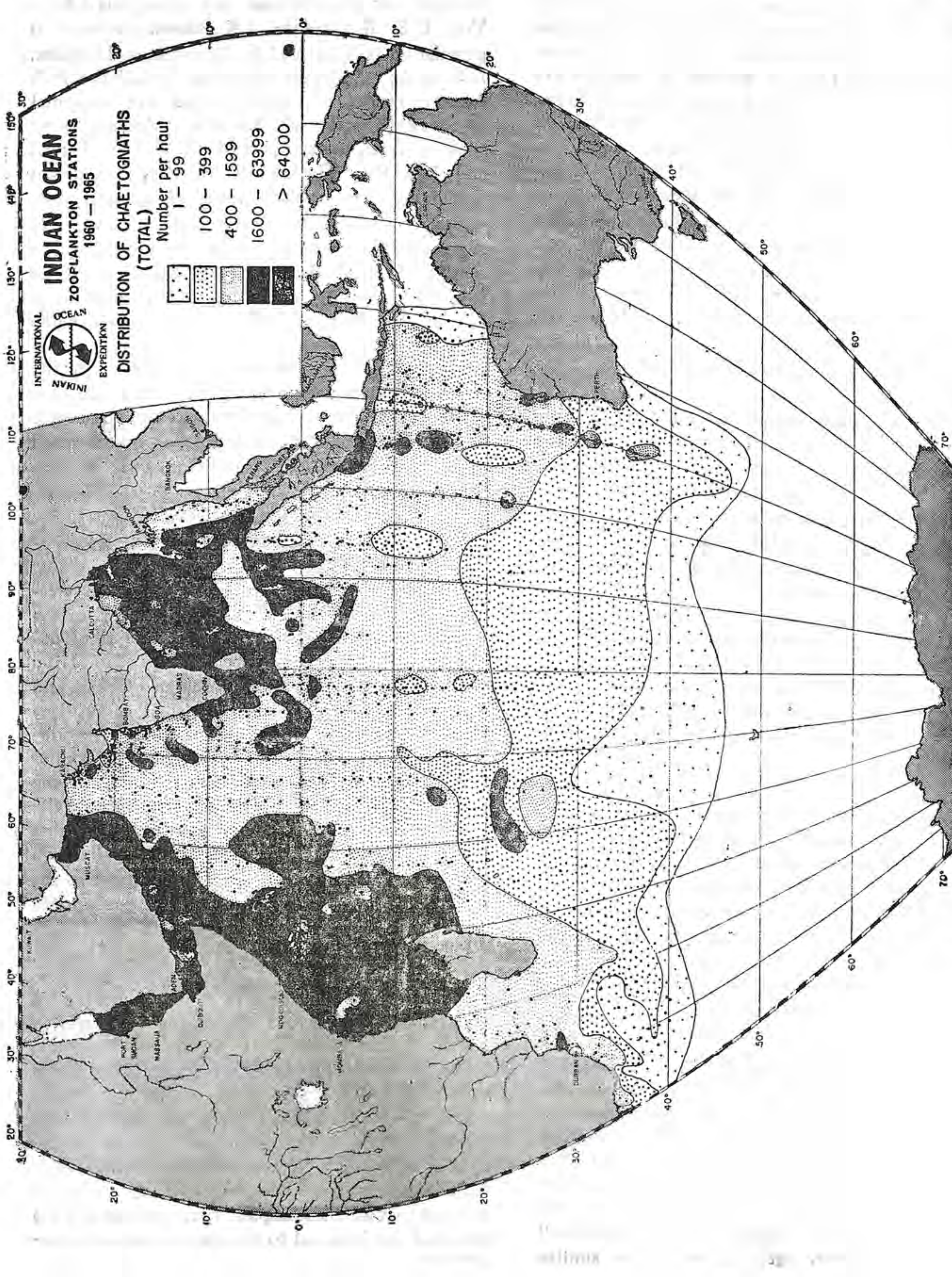

Fig. 17. Distribution of Chaetognaths (total) in the Indian Ocean.

Arabia and this can be attributed to the high productivity of the region. It is interesting to note that the abundance and scarcity of chaetognaths correspond to the pattern of distribution of copepods. The Arabian Sea chaetognath fauna are typical of the Indo-Pacific. *S. bombayensis* is restricted to the coasts of India. *Eukrohnia fowleri*, *S. decipiens*, *S. lyra* and *S. zetesios* are four deep and subsurface water species found in the collections. Variability in the distribution of chaetognaths in the Arabian Sea and adjacent rea is studied in selected localities and along the latitudes (Vijayalakshmi, (1972). There are two categories of species one having preference to northern latitudes and the other having higher abundance towards the southern latitudes.

Recently Silas and Srinivasan (1969) have reported on the chaetognaths from the Laccadive Seas and off the west coast of India. Their collections include fourteen species of which one—*Eukrohnia minuta* is new to science. Vijayalakshmi and Rao (1971) made a comparative account of the chaetognaths of the Kavaratti and Kalpeni, two atolls in the Laccadive Archipelagoes. *Spadella angulata* recorded from the Kalpeni lagoon is a new record for the Indian waters. Their studies indicate a general impoverishment of the chaetognath population inside the lagoon and the probability of these being utilised by the coral community is pointed out.

Vijayalakshmi (1969) has given a preliminary account on the distribution of the seasonal changes in the abundance of chaetognaths in the Indian Ocean based on the IIOE collections. The period mid April to mid October shows a comparatively higher density of chaetognaths for all areas except the eastern half of the Arabian Sea. In both the periods the areas of highest density are in the western part of the Arabian Sea.

Volume IV—Fascicle 2 of the IIOE Plankton Atlas (1973) includes the charts showing the distribution of Chaetognaths. These charts show the following features. The chaetognath fauna is rich in the western Arabian Sea bordering the northeast Africa and southern Arabia, Bay of Bengal and south of Sumatra and Java. Population maxima are found off the Somali and Arabian coast, agreeing with the similar findings for the biomass and copepods (Atlas Vol. I & II) values. A general decrease in population is observed in the southern latitudes. During the southwest monsoon period the high density ranges of chaetognaths are confined to coastal areas off Somalia, Arabia, west coast of India, eastern part of the Bay of Bengal and Java Sea. During the northeast monsoon there is an apparent shift in the abundance westwards, presumably due to the prevailing westerly currents. Another important feature is that centres of high denisity chaetognaths are removed from the areas of upwelling and this is as it should be, because ecologically chaetognaths appear at a later stage in the chain of biological events that commences with the upwelling in the sea. The time lag involved displaces the late secondary and tertiary production from the centre of upwelling by a distance dependent on the speed of the current and the generation time of the species concerned.

PRODUCTIVITY AND FISHERIES

Prasad (1966) and Kabanova (1968) have reported and discussed on the productivity of the Indian Ocean (see Table 2). Ryther *et al.* (1966) summarized the primary productivity data from 231 stations in the western Indian Ocean and found low levels of productivity (0.10 gc/m^2/ day) in the eastern part, intermediate levels of productivity (0.26-1.00) in the equatorial and Mozambique area, and high productivity (1.00) in the northern and western portions, particularly in the western Arabian Sea. They attribute this high productivity to the presence of unusually high concentrations of plant nutrients brought to the surface by large scale upwelling processes. No wonder, therefore, the same regions would naturally support high zooplankton production.

One of the main objects of making standard zooplankton collections during the IIOE was to obtain precise information on secondary production. Though the expedition extended over a 6 year period, unhappily most of the areas could not be covered seasonally and the data at best gives a picture at the particular stations on the days of sampling. No synoptic picture can emerge from such a coverage (see Rao, 1971), but the fact remains that all the samples were collected by a standard method and to that extent they are comparable.

TABLE 2.

INDIAN OCEAN

Productivity data (Kabanova 1968)

Northeast monsoon (December–April)	Southwest monsoon (July–September)
Values above 1.45 gC/m²/day.	
Off Tanzania, northwestern Madagascar, Visakhapatnam, head of the Bay of Bengal, Rangoon and northwestern Australia.	Off Saudi Arabia, Somalia, east coast of South Africa and central Java Sea.
Values between 0.38 – 1.45 gC/m²/day.	
Coasts of Tanzania and Kenya, east coast of India including Ceylon, whole of the Andaman and Java Seas and a patch along western equatorial region.	Central Arabian Sea with extension into the southwestern Indian Ocean, parts of eastern Indian Ocean extending from Sumatra to western Australia.
Low values - 0.38 gC/m²/day.	
Central parts of the Arabian Sea, Bay of Bengal and most of the southern Indian Ocean.	Central portion of the southern Indian Ocean.
No data	
From west coast of India, coasts of Sumatra, Somalia and Arabian coasts.	West coast of India north of Mangalore, most of Bay of Bengal.
Equatorial region and southern Indian Ocean poorly covered.	Equatorial region and southern Indian Ocean poorly covered.

Cushing (1971) has compiled all the productivity data in his excellent account prepared for the FAO Indian Ocean Fishery Commission on the survey of resources in the Indian Ocean and Indonesian area. He used a factor of 0.065 to convert the zooplankton biomass from the IOSN collections into gC/m² and with some corrections and assumptions estimated the third trophic level based on 10% of the secondary production or 1% of the primary production. His figures 12 a and 12 b *(loc cit)* are very revealing. The contours indicate 5, 10, 20 and 40 tons x 10^5 per 5° square. During the northeast monsoon the centre of the south equatorial anticyclone, centres of Arabian Sea and Bay of Bengal had low production values of about 0.5 m. tons/5° square. The west Australian region, an area of southward extension from Cape Comorin and along the equatorial belt extending from the East African coast and between equator and 5° south latitude, the whole of Bay of Bengal have values around 1-2 m. tons/5° square. Highest values indicating more than 2-4 m tons/5° square are found right across the northern Arabian coast, off Tanzania and in the Mozambique channel, around Andaman Islands and in the Java Sea.

During the southwest monsoon, the highest values 2-6 m tons/5° square are found over the entire western Arabian Sea, off Tanzania and Mozambique channel, off the southwest coast of India and Ceylon, northern Bay of Bengal, Central Bay and Java Sea. It would appear that the southwest monsoon period makes the whole of the Indian Ocean highly productive except for the central portions of south equatorial gyre. If Cushing's estimate for the tertiary production is nearer the truth, then we have more than 50 million tons available from the Arabian Sea alone. On the west coast of India the two 5° squares adjacent to Kerala and Ceylon are estimated to support more than 8 million tons. How much of this consists of exploitable fish biomass cannot be stated at present. Prasad *et al.* (1970) while discussing the potential yield in the Indian Ocean based on zoop-

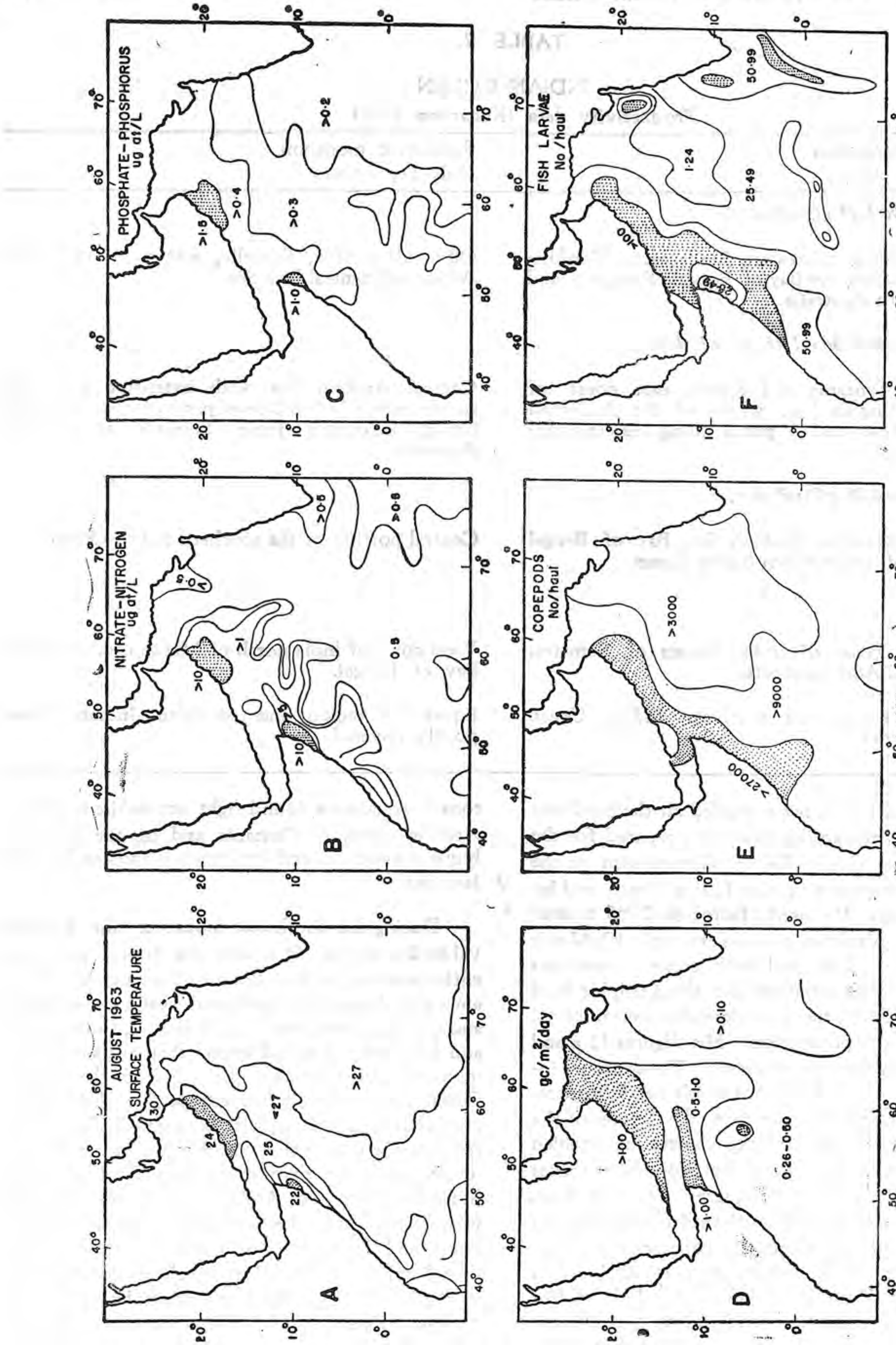

Fig. 18. Hydrobiological conditions during the Summer monsoon in the Arabian Sea.

lankton biomass, estimate that at 10 per cent efficiency of conversion the fish biomass may be in the order of 29 million tons and at 15 per cent efficiency it would be 45 million tons. They further state that such an estimate may be an underestimate since the zooplankton data on which it is based mostly comes from the oceanic areas of the Indian Ocean. However, the above reveals a pleasant picture of estimated production, particularly when it is realised that the total fish landings from the sea for the entire Indian coast was about 1 million tons in 1970.

We have very little data on the actual zooplankton production in the sea. Mullin (1969) has dealt with this problem and suggests that it is desirable to discontinue the practice of treating the whole zooplankton collection as a single entity. This is because a plankton catch represents the sum total of complicated histories of several hundred species, each, perhaps, at a different ecological or trophic level.

DISCUSSION

The picture of zooplankton distribution emerging from the study so far made on the international collection at IOBC and local collections all along the Indian coast, is of great significance for future investigations and also for planning exploratory survey for fishery resources.

The coastal waters upto a distance of a few hundred miles off Somalia, Arabia, the southwest coast of India, the Orissa coast, some areas on the equator and in the Java Sea are confirmed to support very rich zooplankton populations. We had occasion in the previous chapter to discuss broadly the reasons for such a type of distribution, while dealing with the different groups of zooplankton. For more meaningful results further studies based on species of zooplankton are in progress.

The hydrographical condition of the Indian Ocean is now fairly well known, thanks to a large number of papers published recently based on IIOE results. It is now well realized that the northern Indian Ocean north of the 'frontal zone' (10–12°S lat.) is greatly influenced by the alternating monsoons and all variations in hydrography and biology of these waters are monsoon dependent. South of the frontal zone, particularly in the central part of the southern Indian Ocean, the number of stations are few and therefore the results cannot be generalized. However, on either side of the vast stretch of the ocean, the Australians made an excellent seasonal study all along the 110°E longitude and similarly South Africa has a number of stations with seasonal information. We are particularly interested in the Arabian Sea and Bay of Bengal.

Arabian Sea (Fig. 18)

Oceanographically the southern limit of the Arabian Sea could be fixed at 10° south latitude. Intensive upwelling is reported on the African, Arabian and the Indian coasts and the hydrography is well summarised by Wooster *et al* (1967), Gallagher (1966), Banse (1968), Darbyshire (1967), Rama Sastry and Myrland (1959), Swallow and Bruce (1966), Warren *et al* (1966) and many others.

Both the western and eastern parts of the Arabian Sea adjacent to the land masses have become well known for upwelling and Cushing (1971) has discussed the role of upwelling in the production of biomass of zooplankton and fisheries in those upwelling areas.

Upwelling off Saudi Arabia and south of Cape Gaurdafin takes place during May to October, the intensity and the actual area may shift with seasons. Again off the west coast of India, July to October is considered as the period of upwelling. No precise knowledge of this shallow water upwelling is available. During the northeast monsoon upwelling is indicated off Bombay (Carruthers *et al* 1959), off Ceylon (Kabanova, (1968), off Karachi, Gulf of Persia and Aden. It would appear that these are the centres from which biological activity springs and the abundance and location of zooplankton distribution is chiefly governed by the current patterns prevailing at the time of upwelling. This is proved by the spatial and seasonal distribution of the various zooplankton groups discussed earlier in the paper. In Fig 18 are shown the excellent correlation between temperature, phosphates, primary production, copepods and fish larvae both during the northeast and southwest monsoon periods in the Arabian Sea. There is no denying the fact that positive relationship exists between the various factors in upwelling areas of the Arabian Sea. The dynamics of upwelling, the enrichment of

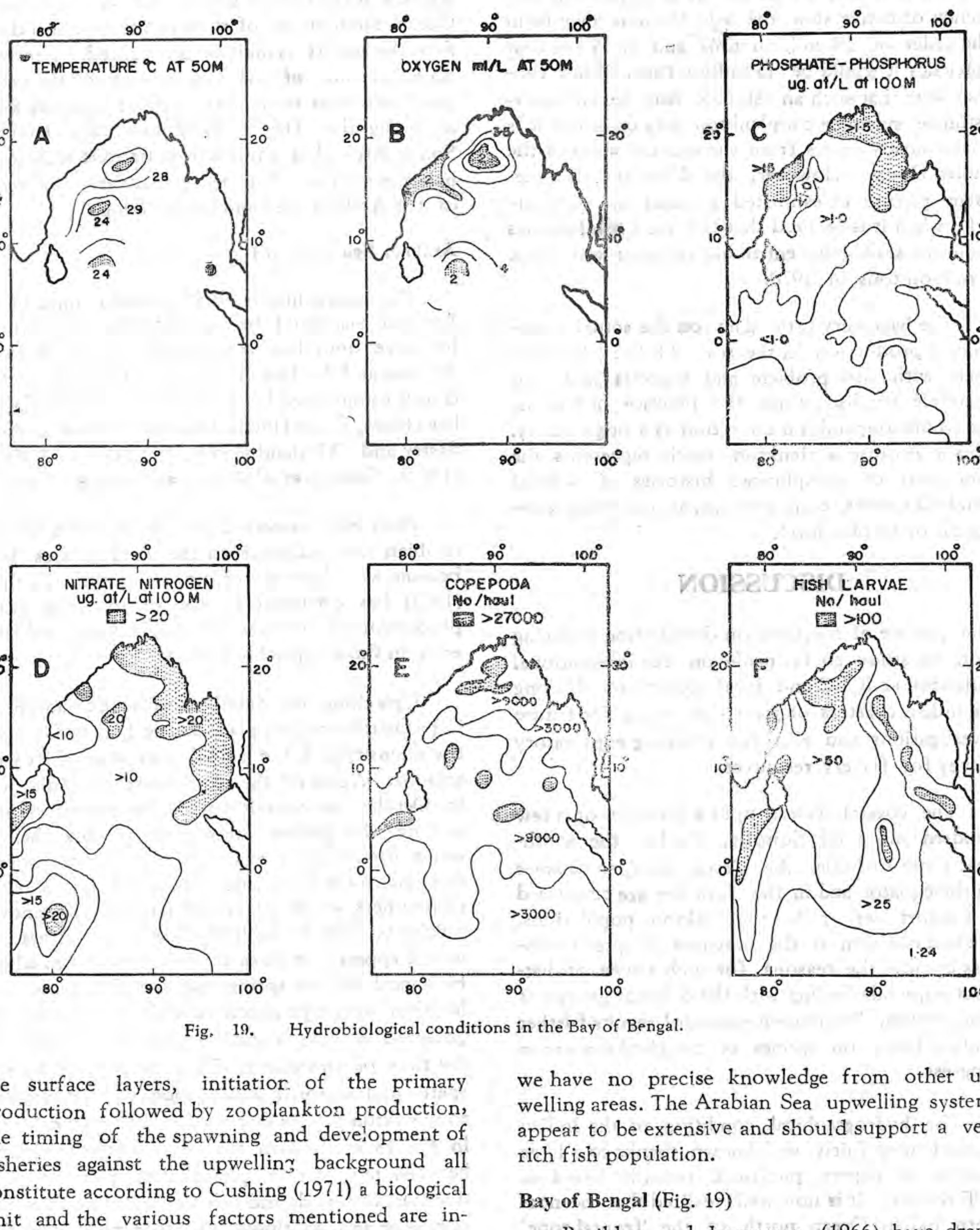

Fig. 19. Hydrobiological conditions in the Bay of Bengal.

the surface layers, initiation of the primary production followed by zooplankton production, the timing of the spawning and development of fisheries against the upwelling background all constitute according to Cushing (1971) a biological unit and the various factors mentioned are interlinked to form a single ecosystem.

The upwelling systems are highly productive. Wooster and Reid (1963) estimate that at least 4 million tons of anchovy are removed by man and birds from the Peruvian upwelling system alone. we have no precise knowledge from other upwelling areas. The Arabian Sea upwelling systems appear to be extensive and should support a very rich fish population.

Bay of Bengal (Fig. 19)

Panikkar and Jayaraman (1966) have drawn attention to the biological and oceanographic differences between the Arabian Sea and the Bay of Bengal as observed from the Indian region. In spite of the good coverage of the Bay of Bengal during the International Indian Ocean Expedition,

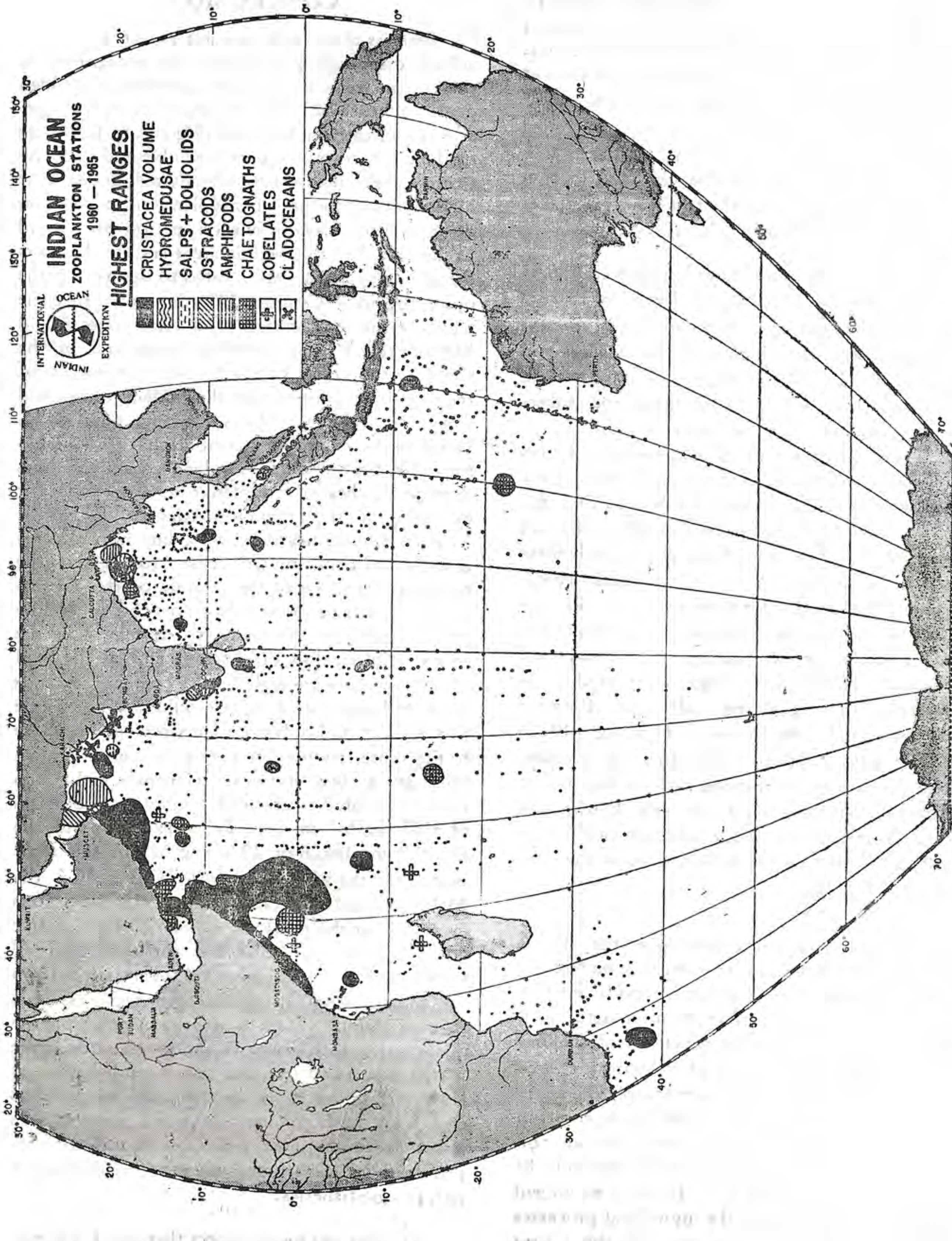

Fig. 20. Distribution of highest range of zooplanktonic groups in the Indian Ocean.

no comparable summary of the data similar to Wooster *et al.* (1967) for the Arabian Sea, is available for Bay of Bengal. No particular oceanographic phenomenon similar to the Somali current or the upwelling systems of the Arabian Sea have been reported from the Bay to attract detailed studies by any ship or country. Coupled with this is the discouraging fact that the contribution from the Bay of Bengal to the total annual fisheries of India is less than 30% (CMFRI, 1970).

However, plankton studies based on IIOE data have revealed that the Bay of Bengal is equally rich in zooplankton production and high biomass areas are present particularly off the Madras and Orissa coasts. La Fond (1954) was the first to report upwelling off Visakhapatnam and subsequently Anand *et al.* (1968) have confirmed upwelling off Madras and Visakhapatnam (June, 1964) and also intense subsurface upwelling off the mouths of Godavari and Kistna. In Figs. 6-7 (*loc cit.*) two low temperature/oxygen cells are present off Madras and Orissa coasts and these may well be centres of upwelling. Sankaranarayanan and Reddy (1969) show evidence for upwelling in the coastal areas of the northwestern Bay as early as in January. La Fond and La Fond (1968) has also reported the occurrence of upwelling off the Burmese coast and off Andamans. Cushing (1971) cites Kabanova (1968) for upwelling off Ceylon. While the intensities, duraion and the location of all these upwellings are not precisely known, all these areas mentioned above coincide with high density patches of zooplankton groups in the Bay of Bengal (Fig. 20).

As already mentioned elsewhere, the Bay of Bengal has emerged as an important area for fish eggs and larvae and also for Cephalopods. Further work is necessary to arrive at meaningful estimates as to the biological productivity of the Bay of Bengal and its importance as a spawning area for fish. The reported occurrence of the early larval stages of *Rastrelliger* off the Orissa coast in May supports the view that the upwelling areas off the Orissa coast may be the spawning grounds of this important fish in the Bay. There is an urgent necessity to understand the upwelling processes taking place in the Bay, particularly off the Orissa coast.

CONCLUSION

Perhaps the most important aspect of zooplankton distribution that must be recognized in the Indian Ocean areas is the occurrence of high density patches of the different groups at considerable distances from the coast (Fig 20). In fact most of the IOSN collections are taken beyond the continental shelf and we have already mentioned that higher concentration of zooplankton population during the southwest monsoon period are found to the east of the upwelling areas and in the northeast monsoon they are located to the west of the upwelling areas. Cushing (1971) has noted that the width of the zooplankton production zone would be twice that of the upwelling zone and in the absence of a precise knowledge of the extent of the upwelling zone along the Indian coasts and elsewhere, we can perhaps estimate their width based on the extent of distribution of zooplankton. On the Somali and Arabian coasts the high density patches of zooplankton (Copepoda for example, see IIOE Plankton Atlas Vol. II, Fasc-1, Map 1) extends nearly 200-300 km into the sea as a parallel band to the coast from about the north of Mombasa to the mouth of the Persian Gulf, and this band extends almost to the middle of the northern Arabian Sea. Similarly in the area west of Ceylon, off Madras and at the head of the Bay there are high density patches extending over hundreds of square kilometers. While this description holds good for open ocean, close to the shore, zooplankton production is known only at a few stations. Ganapati and Rao (1958) estimated a very high production biomass of 3107 mg/M^3 on 16th February 1956 and the monthly maximum of 1230 mg/M^3 in the same month for the whole year off Waltair. On the Malabar coast Subramanyan (1959) mentions 20 cc/M^3 for the plankton volume off Calicut *(loc cit.* Table XI, p. 147). But for these isolated values we have no quantitative information from the Indian coasts. It is therefore very essential that we should obtain a precise picture of the quantitative distribution of the zooplankton in the Indian coastal waters over an extended period. However, on the basis of the IIOE work, it is clear that offshore areas in many parts of the Indian Ocean support rich populations of zooplankton and these may therefore also harbour rich pelagic fisheries.

Another important aspect that could be surmised on the basis of zooplankton distribution in the Indian Ocean is the possible areas of fish spawning. On the Peruvian and Californian coasts, where upwelling systems are studied in detail, fish are known to spawn just about the beginning of upwelling season so that their larvae can make use of the primary and secondary production that follow the upwelling. Cushing (1971) while speaking of the California current system writes that "the extraordinary point is that they (Pacific hake) spawn in the south when the larvae can take advantage of the upwelling and they migrate north to feed in the upwelling off Oregon and Washington much later in the year; so the adults live in the upwelling regions for 6 months or more during the year". A similar situation may be anticipated for the pelagic fisheries of the African and Indian Coasts. It is highly likely that sardines and mackerels spawn in the upwelling areas and follow the dispersal pattern of the zooplankton populations on which they feed. It follows therefore that the Somali-Saudi Arabian offshore upwelling areas, the Malabar upwelling system and the upwelling areas off the Orissa coast are likely to be main centres for spawning and growth of pelagic fisheries of the northern Indian Ocean.

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APPENDIX 1

Log sheet used at the IOBC for maintaining the zooplankton data from the International Indian Ocean Expedition

INDIAN OCEAN BIOLOGICAL CENTRE, ERNAKULAM-6, KERALA, INDIA

Sample Serial No. Ship Cruise No./Name Station No. **Lat:** **Long:** Date & Year Collected Time (GMT) Time (Zonal) Day/Night Depth to Bottom	IOSN Gear Other M. Wire paid out Wire Angle Depth of Haul Vol. Water Filtered (V. W. F.) Method used to determine V. W. F. Measurements at time collected:- Biomass (Live weight) mg. Displ. Vol. ml.	Displ. Vol. IOBC ml. Size of subsample sorted % Dates of Sorting: From To Duration of Sorting (Hours) Sorter, Standard Sorting Sorter, Subsorting Supervision: Name Date

* In the case of Code numbers 23, 30, 47, 62 and 79, place the numbers in 3b or 4b; in all others, in 3a or 4a;
+ § in column indicates that specimens are left in the residue.

Code No.	Group	Number of specimens sorted				No. of specimens left in residue	Total No. in sample	No. per 1000 m3 water filtered	Percentage of total catch	Condition of specimens & other remarks
		From total		From subsample						
1	2	3a	3b	4a	4b	5	6	7	8	9
1	Residue (ml)									
§2	Ellobiopsidae.									
	Preserved with host organism, Yes/No									
	Host organism:									
§3	Porifera (also spicules)									
§4	Pilidium									
§5	Rotifera									
§6	Nematoda.									
	Preserved with host organism, Yes/No									
	Host organism:									
7	Actinotrocha (Phoronid)									
§8	Cyphonautes									

1	2	3a	3b	4a	4b	5	6	7	8	9
9	Cirripedia, larvae									
§10	Rhizocephala.									
	Preserved with host organism, Yes/No									
	Host organism:									
§11	Echinodermata, larvae									
§11a	Echinodermata, metamorphosing stages									
12	Echinodermata, postlarvae									
13	Tornaria									
14	Foraminifera & Radiolaria									
§15	Protozoa, excl. 14.									
16	Hydrozoa (Medusae and Hydroids)									
17	*Velella*									
18	*Porpita*									
19	*Physalia*									
20	Siphonophora excl. 17—19 (vol. ml.)									
21	Scyphozoa									
22	Anthozoa									
*23	Coelenterata, total 16—22									
24	Cestoidea									
25	Ctenophora, excl. 24									
26	Platyhelminthes									
27	Nemertinea, postlarvae									
28	Tomopteridae									
29	Polychaeta, excl. 28									
*30	Polychaeta, total									
30a	Trochophore larvae									
31	Sipunculida, larvae & postlarvae									
32	Lamellibranchiate postlarvae									
33	Nudibranchiata									

1	2	3a	3b	4a	4b	5	6	7	8	9
34	*Ianthina*									
35	Pteropoda gymnosomata									
36	Pteropoda, thecosomata : *Creseis* + *Euclio* + *Styliola* + *Cuvierina*									
37	Ditto: *Diacria* + *Cavolinia*									
38a	Thecosomatous Pteropods excl. 36 & 37 + meroplanktonic Gastropoda									
38b	Subsorting: meroplanktonic Gastropoda									
39	Atlantidae									
40	Heteropoda excl. 39									
41	Cephalopoda									
42	Cladocera									
43	Ostracoda									
44	*Megacalanus* + *Bathycalanus* + *Gaussia*									
45	Sapphirinidae									
46	Copepoda, excl. 44 + 45, size 1 mm & above									
*47	Copepoda, total (44—46)									
48	Parasitic & Semiparasitic Copepods. Note infections. Preserved with host organism, Yes/No Host organism :									
49	Leptostraca									
50	Mysidacea									
51	Cumacea									
52	Tanaidacea									
53	Isopoda									
54	Amphipoda (keep Phronima within case)									
55	Euphausiacea, all stages									
56	Sergestidae									

1	2	3a	3b	4a	4b	5	6	7	8	9
57	Eryonidae									
58	Phyllosoma larvae									
59	Anomura postlarvae									
60	Brachyura postlarvae									
61	Other Decapoda (excl. 56—60)									
*62	Decapoda, total									
63	Stomatopoda, larvae									
64	Halobates									
65	Brachiopoda									
66	Chaetognatha, length 3 mm and above									
67	Copelata, length 3 mm and above									
§67a	Copelata below 3 mm and Ascidian larvae									
68	Pyrosomidae. (colonies and individuals preserved together)									
69	Salps + Doliolids									
70	Branchiostoma									
71	Fish eggs									
	Fish larvae and postlarvae									
72	Clupeiformes									
73	Scopeliformes									
74	Anguiliformes									
75	Beloniformes									
76	Perciformes									
77	Pleuronectiformes									
78	Other orders (larvae and postlarvae)									
*79	Fishes, total (72—78)									
80	Unidentified									
81	Total No.									

DISTRIBUTION OF THE DECAPOD LARVAE IN THE INDIAN OCEAN

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ABSTRACT

General distribution of the decapod larvae in the Indian Ocean is described, based on 1548 standard samples from IIOE collections during 1960-65. Out of these, 1518 samples contained decapod larvae. Seasonwise and diurnal analysis of the samples have been made and it indicates a higher abundance of these larvae in the night collections.

Very high concentrations of the larvae are met with at one station each in western and eastern Indian Ocean, off Port Elizabeth and south of Java respectively and 3 stations off west coast of Indian peninsula, the latter constituted mostly by brachyuran larvae. In the central Indian Ocean below 10°S latitude there is very little representation of these larvae in the plankton. A stretch of this area of low abundance of decapod larvae extends along the middle of the Arabian Sea right up to the Makran coast. In Bay of Bengal also, in the central region there are areas with very little representation of decapod larvae.

The percentage occurrence of the major groups of larvae with reference to the total collections is brought out. As a single family sergestids dominated both in terms of representation in the various collections (95% of the standard collections) and in the total number of the larvae collected (5 times all other decapod larvae from the collections put together). But, samples from South African coast are particularly noticed as devoid of these larvae. In terms of abundance this group is followed by the Brachyura (55%), the pandalids (42.9%) and larvae of the penaeid subfamily Aristaeinae (33.4%). However, on the whole all the groups have a scanty distribution in the open ocean.

INTRODUCTION

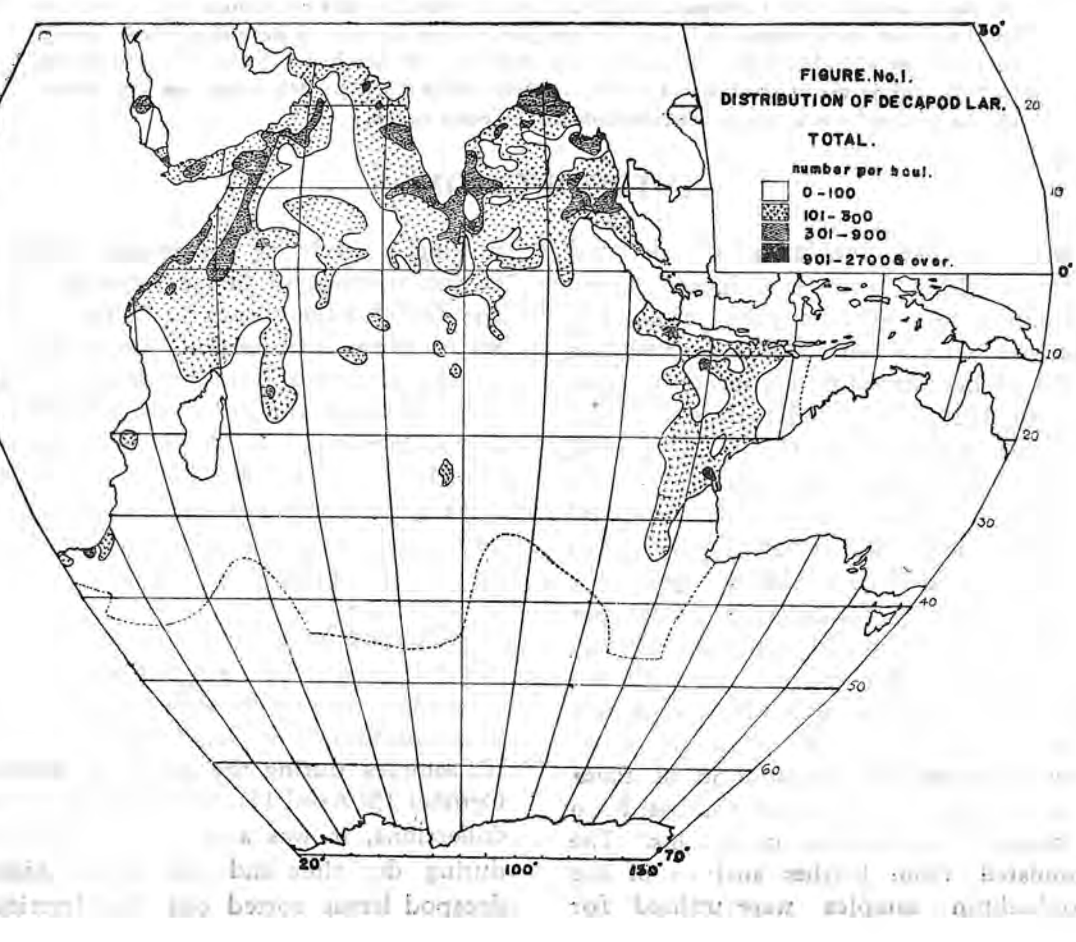
Investigations on the larvae of decapod crustaceans especially from the Indian Ocean region are limited to a few descriptive accounts of representative species of certain families based on some of the pioneer expedition collections (Bate 1888; Gurney 1924, 1927, 1942; Heegaard 1966, 1969). Studies by Menon (1933, 1937, 1940, 1951), Pillai (1955), Prasad and Thampi (1958), Sankolli (1967), Shenoy (1967), Shenoy and Sankolli (1967) and Williamson (1967, 1970) have considerably added to our knowledge of the larval stages of some of the decapod species belonging to different genera and families. However, a study of the distribution and abundance of the decapod larvae as a whole in this region has not been made so far. Menon *et al* (1967) made preliminary survey of the distribution of these larvae with reference to Arabian Sea based on a part of the IIOE zooplankton collections. The data accumulated from further analysis of the IIOE zooplankton samples were utilized for making a study of the general trends in distribution of decapod larvae, especially in view of the fact that the group includes, the life history stages of the commercially important crustaceans of the countries bordering Indian Ocean. A few maps showing the total distribution of these larvae in the Indian Ocean have been published already (Panikkar, Ed., 1970). The following account is mostly based on these maps and to a certain extent on the subsorting of the material into different families.

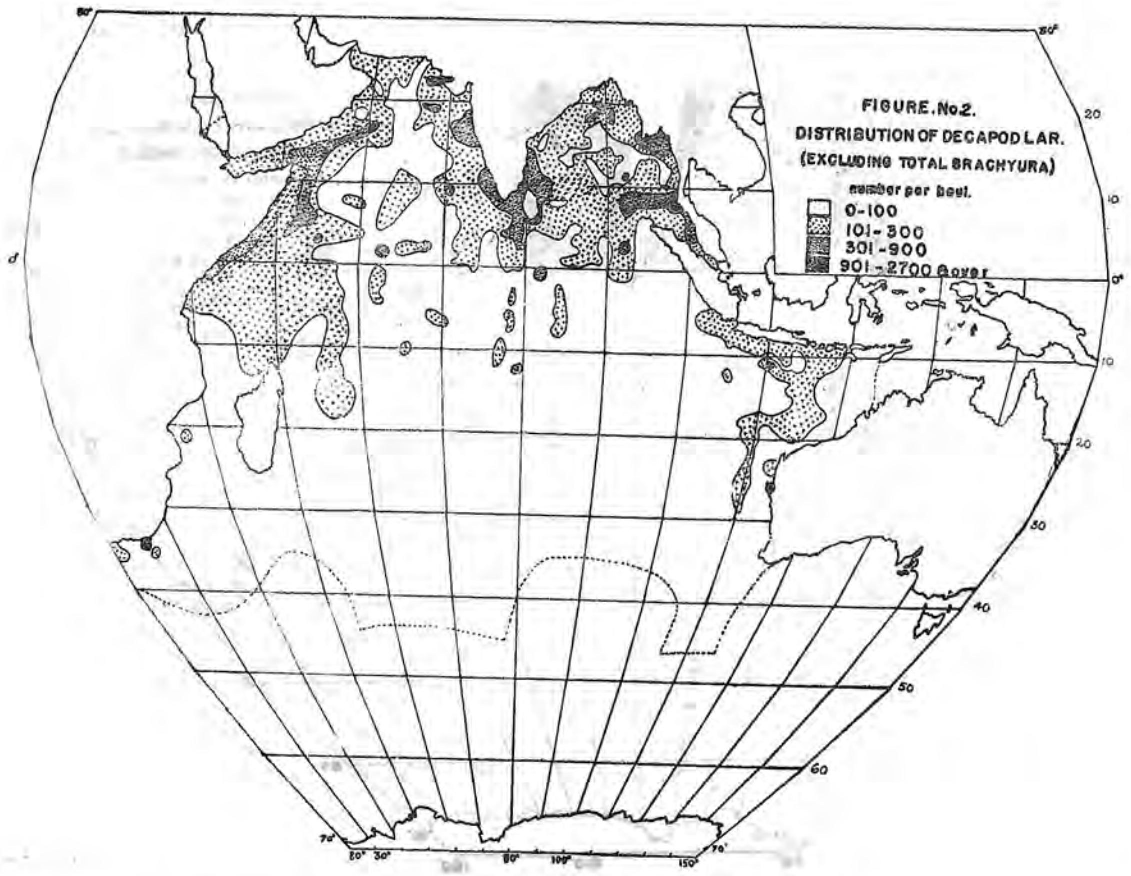
Decapod larvae were represented only in 1518 of the 1548 standard samples collected. Out of them 816 samples were collected during the southwest monsoon period(ie., April 16-October 15) and 702 samples during the northeast monsoon (ie., October 16- April 15). Splitting into day and night collections, it was seen that 823 were made during day time and 692 during night. The decapod larvae sorted out from fractions of the whole zooplankton sample from each station, was calculated for the total. These figures were then plotted with the station position and the areas of similar density within slab limits were contoured. Distribution maps were prepared for total decapod larvae, total decapod larvae excluding Brachyura, decapod larvae during southwest monsoon and northeast monsoon, during day and night time.

OBSERVATIONS

Areas of high density of decapod larvae (301-2700 per standard haul) (Fig. 1) are invariably near or along the coast, though all the coasts are not having such high values. High concentrations are noticed near the mouth of river Gascoyne in northwestern Australian coast; around Java head, off and around Phuket, eastern side of Andaman and Nicobar Islands, Gulf of Martaban and the mouths of river Irravadi, off Gangetic delta area and Vizianagaram on the east coast of India, a continuous broad stretch around south India and Ceylon, extending from Nellore on the east to Mangalore on the west, around Goa and southwest of Bombay, southwest of Diu, off Karachi, and a continuous area stretching from off Arabian coast covering Socotra and Tamida Islands to south Somali coast. Coastal area between Obbia on Somali coast and Mombasa and a small area off Port Elizabeth on South African coast are also very rich in decapod larvae. Off and around Aden, in the middle of Red Sea and also off Mecca, small patches of high values are noticed.

In majority of the areas south of Java, between 10° S - 35° S latitude and 105° E - 115° E as well as most parts of the Bay of Bengal, west coast of India, to the extent of 65° E longitude and north of equator, south coast of Pakistan and Iran, southwest coast of Saudi Arabia, west and south Arabian Sea, there are concentrations of decapod larvae, between 101 - 300 per standard haul. Varying numbers of larvae, from 1-100 were obtained from collections from all other areas in the Indian Ocean, down to 45° south. Surprisingly, west coast of Sumatra, Central Bay of Bengal, Central Arabian Sea and parts of equatorial Indian Ocean, coast of Mozambique, around Madagascar and east and south of South Africa, are





within this belt. Thus it could be noticed that though the main concentration of the larvae are in the proximity of land masses, decapod larvae are invariably met with in almost every collection from any area in the Indian Ocean.

Data on decapod larvae excluding those of Brachyura showed some interesting results (Fig. 2). This was attempted as brachyuran larvae were quite a common factor in almost all collections. While the general pattern of distribution remained fairly unaltered from that of the total decapod larvae (Fig. 1), the high concentrations off the Gangetic delta area, Andamans and Nicobar islands and mouth of river Gascoyne in northwest Australia were proved to be due to brachyuran larvae. The area of high abundance along Somali coast, off Mangalore and Cochin and around Ceylon were also mostly due to these larvae. None the less, it is evident that decapod larvae other than brachyuran larvae have fairly wide and dense distribution in the Indian Ocean, nearer the coastlines.

Maximum sampling was carried out during the southwest monsoon period (April 16 - October 15) (Fig. 3). During this period the maximum (over 2700 larvae per haul) is seen at two small areas, one off Port Elizabeth, and the other south of Central Java. High values (301-2700 larvae per haul) are also seen northeast of Madagascar, off Mombasa, off and around the central and the northern point of Somali coast, Central and northeast of Arabian coast, Gulf of Cambay, south of Bombay to Kozhikode on the west coast of India, from around Ceylon to the mouths of Ganges and Brahmaputra, a large area south of Andamans, and small areas off Penang and Java head. Concentrations varying from 101 - 300 larvae per standard haul are met with off and along all the coasts of the land masses around Indian Ocean, right north from 20°S on the East African coast to west of Australia. The south and central Indian Ocean together with central part of Arabian Sea and mouth of Irravadi river, seem to have little representation of these larvae in this season.

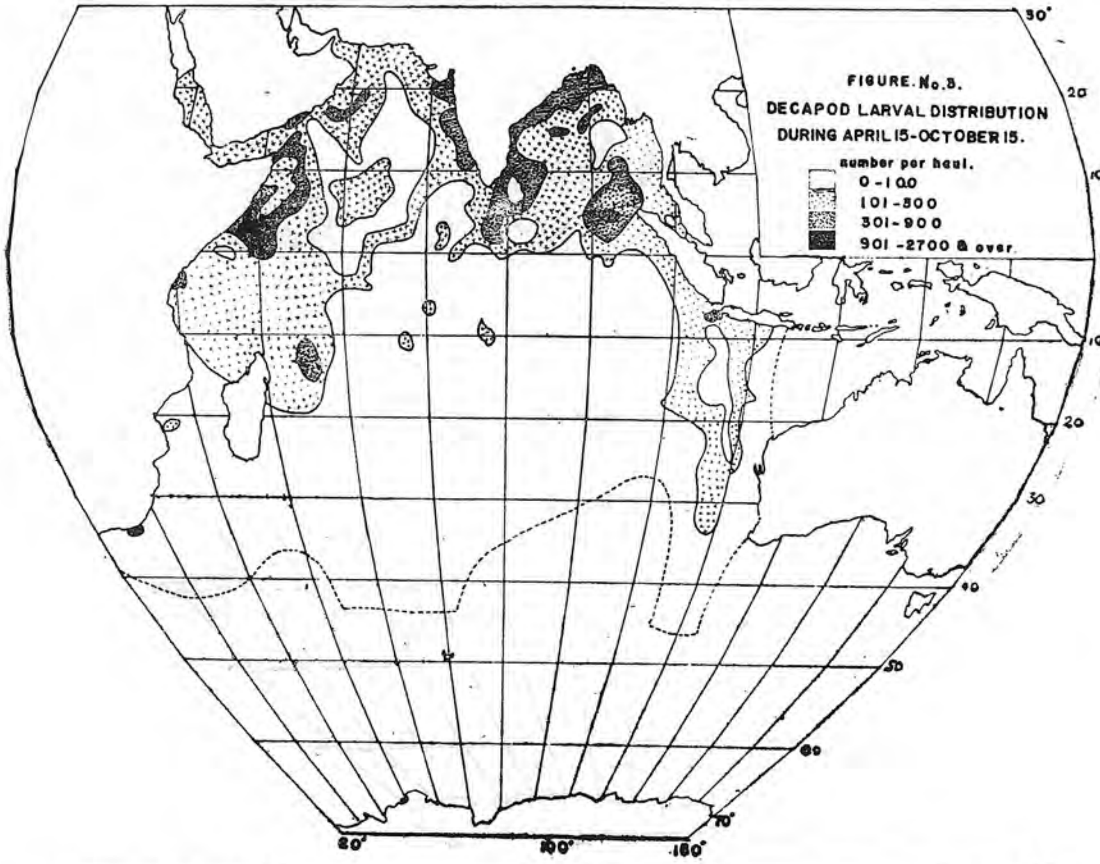
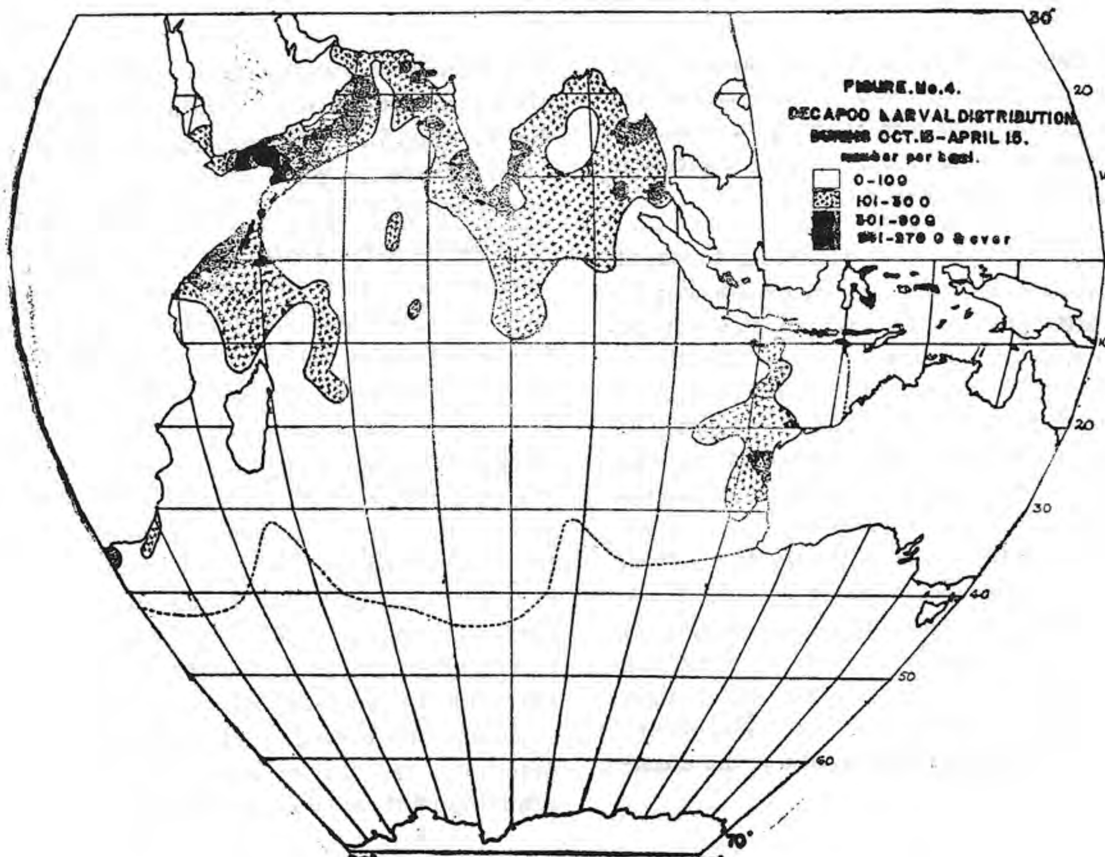


FIGURE. No. 3.
DECAPOD LARVAL DISTRIBUTION
DURING APRIL 15-OCTOBER 15.
number per haul.
0-100
101-300
301-900
901-2700 & over.
30°
0°
80°
100°
180°
70°


DECAPOD LARVAL DISTRIBUTION
OCT. 15-APRIL 15.
0-100
101-300
30°
0°
80°
180°
70°

During northeast monsoon (October 16 - April 15) (Fig. 4), on the other hand larger numbers of the larvae are recorded from a small area south of Cape of Good Hope, north of Mombasa to middle of Somali Republic on the east coast of Africa, in the Gulf of Aden, off Muscat and Oman, small areas each south of Karachi, off Diu, off Bombay, around South Indian coast from Mangalore on the west coast to Madras on the east, mouth of Irravadi river and very small areas south of Andaman Islands, around Phuket and mouth of river Gascoyne on the Australian coast. Fair numbers of larvae (101 - 300) are distributed south of Durban, north and northeast of Madagascar, Somali coast, Arabian coast, coasts of Iran, Pakistan, west and east coasts of India, Bay of Bengal excepting a large central area, a small area each off Madras and Andaman Islands and northwest of Malaya and Sumatra. South of India, this concentration extends upto lat. 10°S.

The analysis of the data relating to day and night collections does not give any clear sign of a diurnal migration for these larvae, although in certain areas maximum catches were during night. This is especially noticeable around southern India and northern part of the Bay of Bengal (Fig. 5 & 6). Particularly the Bay of Bengal and adjacent areas are rich in decapod larvae during night. The Arabian Sea areas and east African coasts do not show much difference in density between night and day except for the difference in the distribution of maximum value areas. South of Cape Comorin and in the Gulf of Mannar high concentration of larvae are in the night collections.

Analysis of the standard samples on the basis of the intensity of larvae, and comparison of the data with the total zooplankton biomass in the Indian Ocean (Panikkar, Ed., 1968), gives interesting results. Almost 90 per cent of the 30 samples without representation of decapod larvae were from the western half of the Indian Ocean, south of 20° S, although the area is not very poor for zooplankton. The general pattern of distribution and abundance of the zooplankton biomass and that of the decapod larvae agree fairly well, in both cases maximum concentrations being along coast lines and low values particularly in the mid-ocean. Corresponding areas of high values also coincide for both cases, for the total, the two seasons and the day and night collections. Abundance ranging from 1-100 decapod larvae per standard haul were seen for 866 samples, 101 - 300 for about 450 stations and 301 - 2700 for 164 stations. Four samples collected, one each off Port Elizabeth, Karachi, Alleppey, Java and two off Cochin yielded larvae numbering over 2700 per standard haul, varying to 4800. The stations off Port Elizabeth and south of Java were sampled during southwest as well as northeast monsoons; the maximum abundance being during the southwest monsoon period. On the contrary the collections from off Karachi, off Cochin and Alleppey were swarming with decapod larvae during northeast monsoon; the major component being Brachyura. It is also observed that while the abundance in stations off Karachi and west coast of India is brought about by the brachyuran larvae, it is solely due to non-brachyuran decapod larvae, mainly sergestids and carideans, off Port Elizabeth and Java.

The east coast of Africa, north of Mombasa to about 7° N, shows higher density of decapod larvae, during both the monsoons, as also day and night. It is evident that this area is rich in brachyuran and non-brachyuran decapod larvae. However, the abundance in a narrow stretch of the coast line from north of Mombasa to about 2° S is considerably influenced by the presence or absence of brachyuran larvae. Low values are obtained during northeast monsoon in this area and the extent of such low intensity area expanded north to off Mogadiscio during southwest monsoon. The immediate coast line of the northeastern part of Somali Republic is not very rich in these larvae anytime, though areas of high abundance are noticed off the coast during southwest monsoon and mainly in day collections.

In general, the southeast coast of Arabia is rather poor in these larvae. A tongue of low density area from the central Arabian Sea reaches to the proximity of the coast in southwest monsoon period and extends to the middle of the coast especially in night collections. Higher density is noticed during certain periods, off the coast.

West coast of India has swarms in stretches along the coast line; though considerable reduction in numbers in the south and southwest coast region is seen during southwest monsoon period and very low values during day collections. This, to some extent seems to be coupled with the fact that the larvae encountered at this area are mainly non-brachyuran.

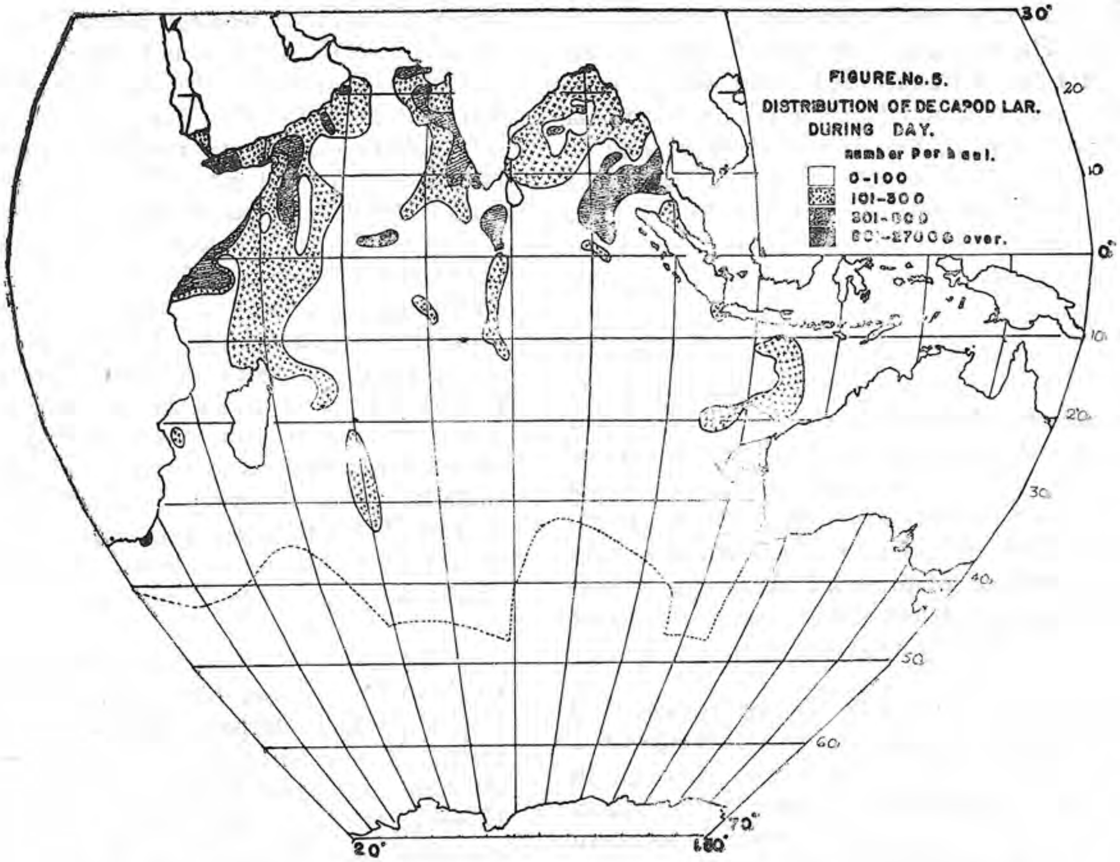


FIGURE.No.5.
DISTRIBUTION OF DECAPOD LAR.
DURING DAY.
0-100
101-500
30°
20
10
0°
10
20
30
40
50
60
70°
20°
180°

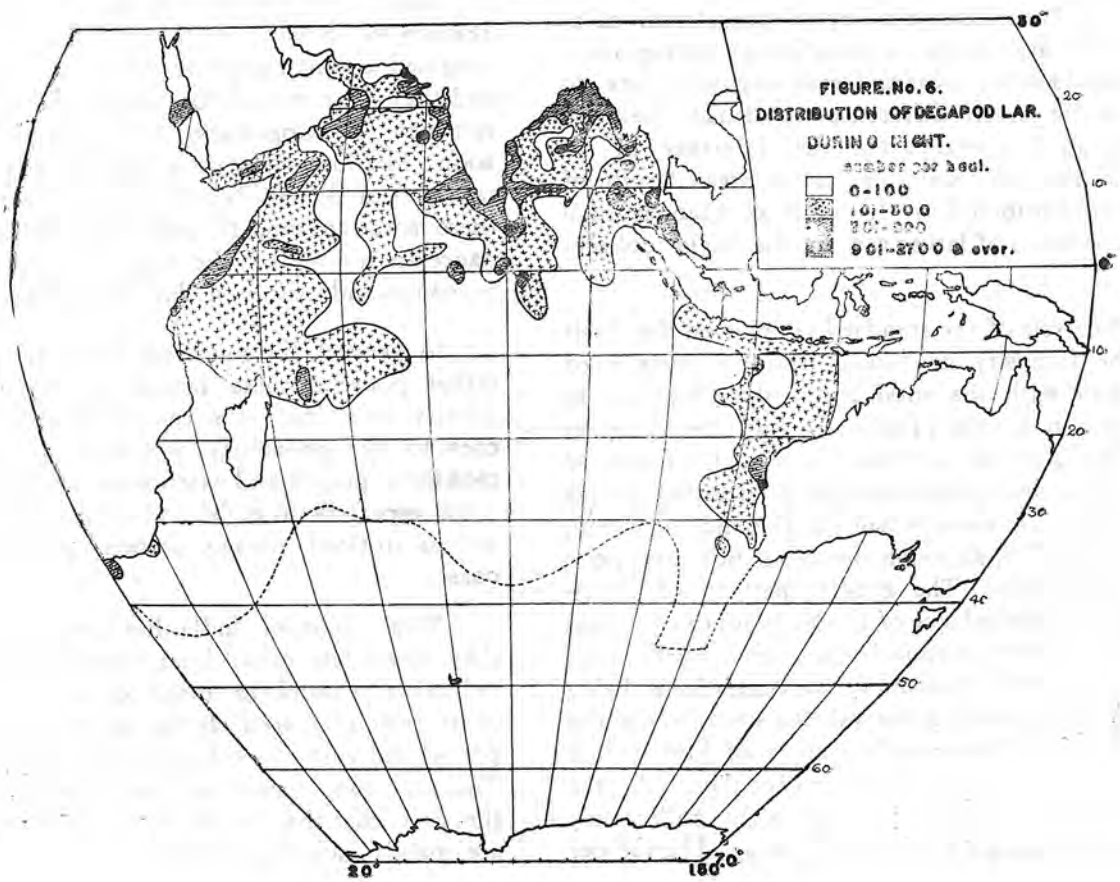


FIGURE.No.6.
DISTRIBUTION OF DECAPOD LAR.
0-100
901-2700 & over.
30°
20
10
0°
10
20
30
40
50
60
70°
20°
180°

East coast of India including Gangetic delta has a continuous stretch of very abundant area, along the coast during southwest monsoon. This abundance is mainly due to non-brachyuran larvae largely during night collections and not occuring in this area during northeast monsoon. At the mouth of Ganges, brachyurans are also abundant. The area off the mouth of Irravadi is abundant with decapod larvae other than Brachyura, mostly during northeast monsoon and night collections.

Off the west coast of Australia along 110°E, there is a fairly rich area, principally due to brachyuran larvae, abundant closer to the coast during northeast monsoon and away from the coast during southwest monsoon, mainly during night collections. Near the coast of western Australia, northwestern part only has a small area of higher abundance. This area is at the mouth of certain rivers, and the abundance is caused by the brachyuran larvae present in night collections during northeast monsoon.

It has been possible to assess the groupwise abundance of the decapod larvae from different stations. As a single family, sergestids dominated the collection. They seem to have a very wide distribution in the Indian Ocean as they had been separated from 98% of the total samples (1927) and from about 95.5% of the standard samples. Among the few samples with no representation of sergestids, majority were from the South African coast. In terms of the number of larvae represented also, sergestids out-numbered almost five times all other decapod larvae put together. Among the other more important components of the decapod group, the larvae of the penaeid subfamily Aristaeinae were recorded from 518 stations, and forms 4.8% of the total decapod larvae collected. Sub-family Solenocerinae were represented in 11.3% of the standard collections. The larvae of other penaeids were separated from 321 stations and the number corresponded to 4.3% of the total number of decapod larvae. Amphionids were obtained from 136 collections. Among the carideans, pandalids dominated the collections, by a representation from 665 stations and more than 22% of the larvae. Oplophorids were represented from 304 stations, alpheids from 298, palaemonids from 200, pasiphaeids from 100, hippolytids from 90 and crangonids from 45 stations. They each formed 1-4.7% of the total decapod larvae collected. Stenopids have only 2.6% distribution. Among the anomurans, the axiids were recorded from 318 stations, pagurids from 156, galatheids from 151, callianassids from 102 and albuneids from 86 stations. Incidentally, these groups were represented in small numbers, varying from 0.7-3.6% of the total number of decapod larvae. As was mentioned before, brachyuran larvae are quite common in more than half of the samples and when present they are often so abundant as to form the major component of the decapod larvae.

DISCUSSION

As pointed out by Menon *et al.* (1967) these larvae are more abundant along the coasts and their vicinity (Fig. 1). In the open sea they have a scanty distribution. This is especially so, south of the equator, in the central Indian Ocean, between longitude 20°E and 120°E. This area, any way, is not adequately sampled. But in spite of intense sampling, much of the east coast off South Africa seems to be barren of decapod larvae. At the same time it is interesting to note that the maximum number of larvae (excluding Brachyura) from a single haul has been recorded from a station off Port Elizabeth. It is rather difficult to say whether the Agulhas current and Mozambique current has got some influence on this situation.

In general, it may be noted that the larvae are more abundant in less disturbed coastal waters. For instance, during the southwest monsoon the Bay of Bengal appears to be calmer and richer in decapod larvae and that during northeast monsoon due to the turbulence of the Bay, east coast has less density and the west coast of India is richer with them (Figs. 3 & 4). However, there are certain regions like the region west off Phuket, northeast African coast from Mogadiscio to about 8°N, which are found to be richer areas throughout the year. It may be due to the fact that the Somali coast is very rich in phytoplankton and detritus, due to upwelling, and these larvae have a good pasture there. Off Phuket and around, however, there are many smaller islands which provide ample shelf region, where adults of most of the decapods thrive very well.

On the whole, the coastal waters of India are noticed to be comparatively richer in decapod larvae. Taking the total samples into consideration, the midcentral region of the west coast, southwest coast, southeast and the coastal waters off the Gangetic delta area especially, have fairly high abundance of these larvae. It is of particular interest to note that during the southwest monsoon season while southwest coast of India has very little representation of decapod larvae in the plankton samples, the entire east coast waters is very rich in these larvae. The upwelling of the waters during the monsoon season reported along the southwest coast of India (Banse, 1959; Sharma, 1966) may probably be one of the reasons for this poor representation of the larvae here at the time.

The coasts of Somalia south of about 8°N, the west, south and southeastern coasts of India and the Andaman Sea near the coast of Malaysia are found to be rich areas having plenty of decapod larvae. It may also be noted that the areal distribution of samples is fairly good, the Bay of Bengal and Arabian Sea having received the best coverage.

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DISTRIBUTION OF *HALOPTILUS ACUTIFRONS* (COPEPODA, CALANOIDA) IN THE INDIAN OCEAN WITH A DESCRIPTON OF THE HITHERTO UNKNOWN MALE

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ABSTRACT

In the genus *Haloptilus* the males are usually rare and are unknown in some species. The present paper describes the male of *H. acutifrons* (Giesbrecht, 1892), a species so far considered to be Arctic in origin and inhabiting deep waters. Out of the 315 samples from the upper 200 metres analysed from the International Indian Ocean Expedition collections, it was encountered only in 24 samples. The species was also obtained in large numbers from a deep water haul (880-0m) from the Red sea. The species is here reported for the first time from the Bay of Bengal.

A positive correlation between number of specimens and total biomass is found. The correlation coefficient is 0.87.

INTRODUCTION

Haloptilus acutifrons was originally described by Giesbrecht (1892) based on females collected from the Mediterranean sea. In the Indian Ocean it was first recorded by Sewell (1947) and later by De Decker and Mombeck (1964). The male of this species is as yet undescribed. A careful study of the samples of the International Indian Ocean Expedition analysed so far, revealed the presence of ten males and a number of females. The present report gives a description of the male and the distribution of the species in the Indian Ocean, based on the available specimens.

MATERIAL

One male specimen was observed in a night sample taken off the Somali coast, Lat. 02°02'N, Long. 56°03'E from 200-0m haul (Discovery 5412A); 9 males and 540 females were found in a 880m haul taken from the Red Sea (Discovery 5002A). 85 females were present in 24 samples out of the 315 samples from the upper 200 metres of water examined so far.

Haloptilus Acutifrons Giesbrecht (1892)

Description of Male

Length of Specimen

Indian Ocean	2.4mm
Red Sea	2.1 to 2.3 mm

Head roughly triangular with corners smoothly rounded (Fig.1, a); proportion of prosome to urosome 5:1. First metasomal segment separate, segments 4 and 5 fused. Urosome 5-segmented in the proportion 30:20:18:12:20. Caudal rami about 1/3 length of preceeding 5 segments.

Antennule. (Fig. 1, b) Extends beyond body by about last 5 segments. Right antennule 25 and left 23 segmented. Left antennule geniculated, with a knee joint between segments 18 and 19. Anterior border of segments 17 and 18 serrated. Sensory setae with bulbous basal portions, especially on segments 6 to 12 (Fig.1, c).

Antenna. (Fig. 1, d) Biramous with 2-segmented endopod, twice as long as 8-segmented exopod.

Mandible. Palp slender, exopod slightly shorter than endopod. Gnathal lobe of mandible (Fig. e & f) with 2 teeth, posterior tooth bifurcate at tip, with an additional spine on the outer border.

Maxillule. (Fig. 1, g). First inner lobe with 6 setae 2 of which are spiniform. Second inner lobe with 1 and 3rd with 3 setae. Second basis with 5 and exopod with 10 setae. Outer lobe with 6 long and 4 short setae. Endopod 1-segmented and with 4 setae.

Maxilla (Fig. 1, h) First lobe with 3 setae, the next three lobes with 2 setae and 5th lobe with one seta and one thickened spine.

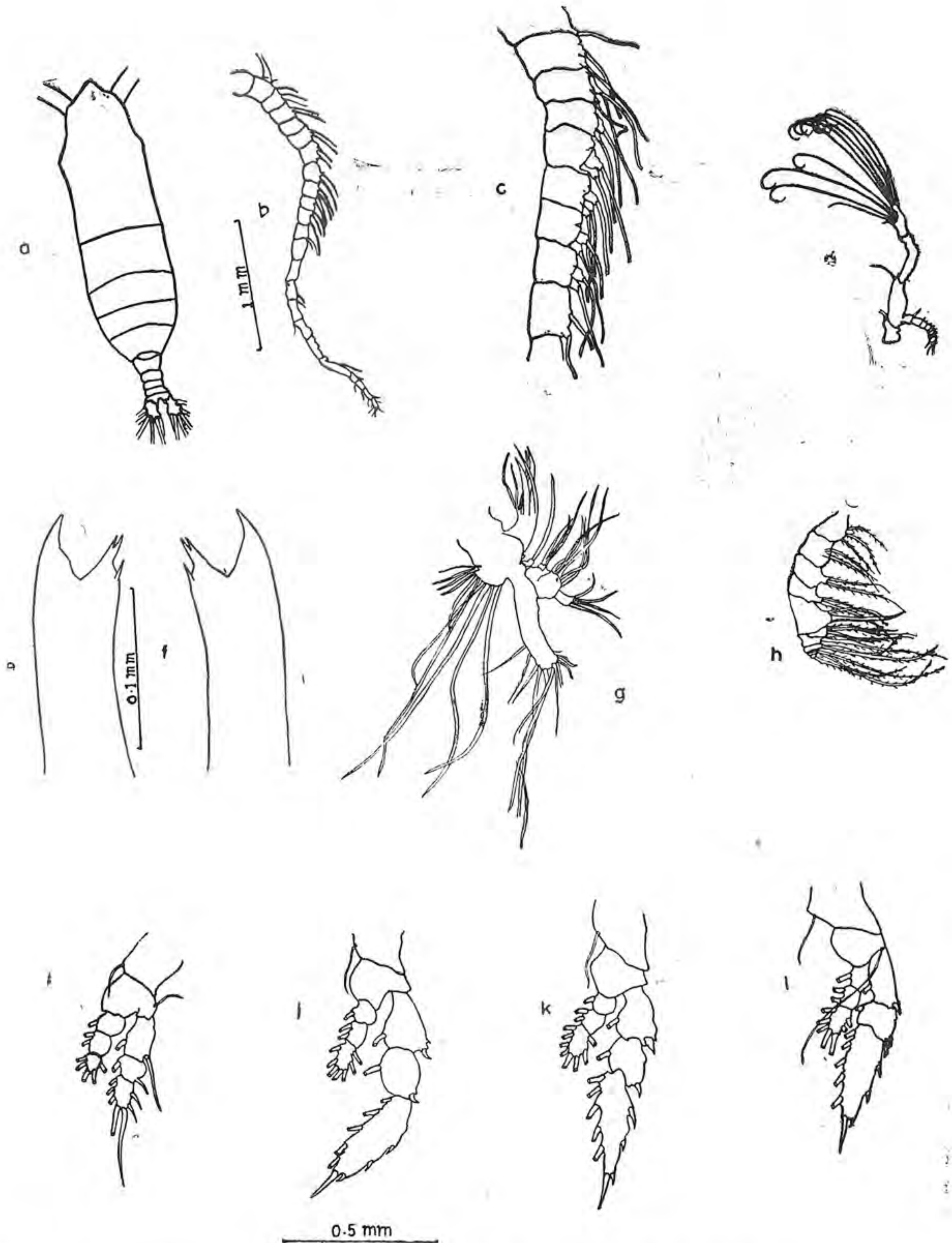

Fig. 1. (a) *Haloptilus acutifrons*, male, dorsal view, (b) left antennule, (c) 4th to 12th segment of left antenule enlarged, (d) antenna, (e) left mandible, (f) right mandible, g) maxillule, (h) maxilla, (i—l) legs 1—4.

Maxilliped. Greatly elongated.

Swimming legs. Biramous, both rami 3-segmented. 1st to 4th pairs symmetrical. First pair of legs reduced (Fig. 1, i) Basipod 1 with 1 internal seta; basipod 2 with 1 external seta. Exopod segments 1 and 2 with 1 internal seta and 1 external spine; spine on segment 1 extends much beyond spine on segment 2. Exopod segment 3 with 4 internal setae, 1 terminal spine and 2 external spines. Endopod with 1 seta on segment 1, 2 on segment 2 and 5 on segment 3.

Second to 4th pair of legs alike (Fig. 1, j-1). Basipod 1 with 1 internal seta in all 3 legs, basipod 2 in 2nd and 3rd naked, basipod 2 on leg 4 with a long and curved external seta. Exopod segments 1 and 2 with 1 internal seta and 1 external spine. Third segment with 3 internal setae, 1 terminal spine and 3 external spines. First and 2nd segments of endopod in legs 2, 3 and 4 with 1 and 2 setae; third segment with 7 setae on legs 2 and 4, but 8 setae on leg 3.

Fifth pair of legs asymmetrical and curved inward (Fig. 1. m). Basipod 1 of left leg with short stout inner spine. Bosipod 2 on both sides with 1 long plumose external seta. First exopod segment with 1 external spine. Second exopod segment of right leg with an internal conical protrusion towards the proximal end, and that of left leg with a serrated inner distal margin; external spine on right not terminal as on left leg. Exopod segment 3 of right leg with 2 terminal spines one of which is longer than the other; another long, stout spine is located proximally. Spine at the same position on left leg smaller and arises from middle of segment; terminal spines less pronounced than on right leg. Endopod similar on both sides, first segment naked, 2nd with 1 and 3rd with 6 setae.

Remarks

H. acutifrons males show the same degree of sexual dimorphism as do *H. oxycephalus* and *H. ocellatus* males. Similarity between females of *H.*

m

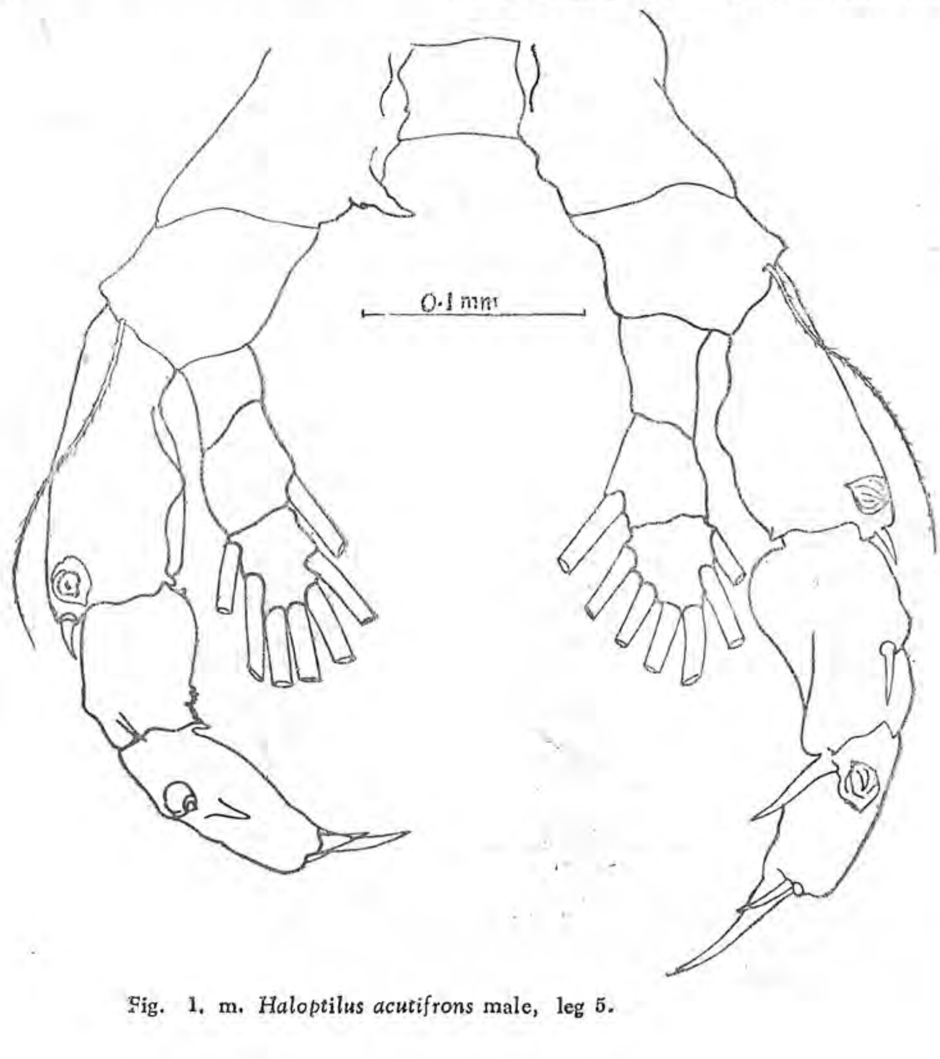

Fig. 1. m. *Haloptilus acutifrons* male, leg 5.

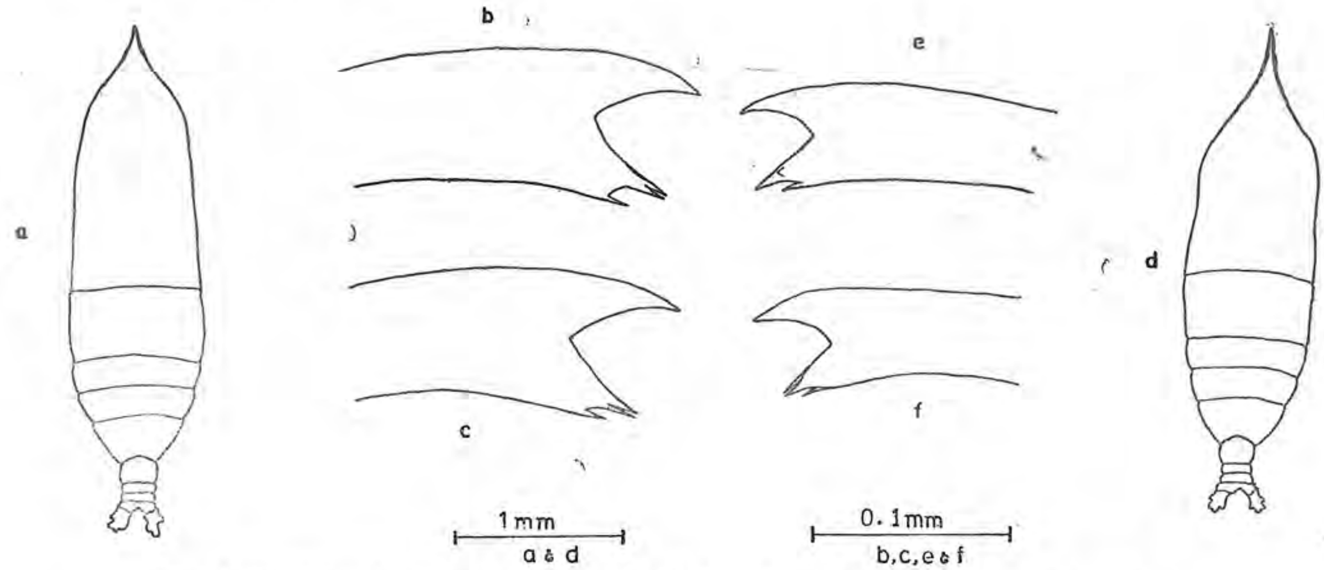

Fig. 2. (a) *Haloptilus acutifrons*, female, dorsal view, (b) left mandible, (c) right mandible, (d) *Haloptilus oxycephalus*, female, dorsal view, (e) left mandible, (f) right mandible.

acutifrons and *H. oxycephalus* has been pointed out by Bradford (1970), though no comparison was made because of absence of *H acutifrons* in her collections. In the IIOE collection both species were available. *H. acutifrons* differs from *H. oxycephalus* in the following characters.

Female	*H. acutifrons*	*H. oxycephalus*
Total length mm.	2.8—3.4	2.5—4.3
Anterior Head spine	short & stout	long, slender & slightly curved
Antennule length mm.	3.3—3.9	2.9—3.6
Mandible	Right & left similar	Variable
Male		
Total length mm.	2.1—2.4	2.85
Mandible	Right & left similar	variable
Glandular pores	Re 1—one Re 2—nil Re 3—one	At the base of exopod spine
Left leg 5-distal inner margin of Re 2.	Serrated	Not serrated

[Details of *H. oxycephalus* male taken from Bradford (1971)]

There is great resemblance between the mouthparts of *H. acutifrons* and *H. oxycephalus* male. But the arrangement of mandibular teeth in *H. oxycephalus* male (see Bradford 1971 figs. 122 & 123) is different from that described here. The serrated inner margin of exopod segment 2 of left leg 5 is a unique character not seen in any other males of this genus.

Distribution

Location of stations from where *H. acutifrons* was observed are shown in Fig. 3. The asterisk indicates the location of the station from which the male was recorded. Two female specimens were also observed in the same sample. The north Indian Ocean shows greater number as compared to the south. The highest density is observed between 10°N and 10°S lat. and 40°E to 65°E long. Maximum number (8/std. haul) is observed at two stations one at the mouth of Gulf of Aden (Me 93B, Table 1) and the other located off Kenya (Me 153, Table 1). *H. acutifrons* is moderately represented in the Bay of Bengal and is here recorded for the first time. In the southern Indian Ocean only isolated records are observed. In a non standard sample (Fig. 3 point Q) taken from the Red Sea from 880-0m, 549 specimens of *H. acutifrons* were observed including nine males. Based on the hydrographic conditions the stations can be grouped into five areas as shown in fig. 3.

A. Upwelling area. B. Upwelling not reaching the surface C. Southern Indian Ocean D. Equatorial E. Bay of Bengal

TABLE 1.

Ship	Cruise	St. No.	Latitude	Longitude	Date	Time	Zooplankton volume (ml)	Number of *H. acutifrons*/haul	
Anton	1	52	18°55'N	91°59'E	6-4-63	N	10.0	5	f
Bruun	,,	74	13°36'N	90°48'E	18-4-63	D	3.0	3	,,
	,,	79	14°58'N	91°17'E	19-4-63	D	13.5	3	,,
	,,	96	13°43'N	85°47,E	30-4-63	D	9.0	5	,,
	4A	189	24°00'N	62°04'E	1-11-63	N	7.5	3	,,
	5	303	26°00'S	54°52'E	5-3-64	D	2.2	3	,,
	,,	305	30°50'S	55°02'E	7-3-64	D	1.0	1	,,
	,,	318	16°43'S	74°53'E	17-4-64	D	1.2	1	,,
	6	355	29°38'S	49°23'E	12-7-64	D	2.0	1	,,
Argo	Lusiad	53	00°05'N	62°20'E	18-8-62	D	5.0	3	,,
Discovery	1	5002A*	20°19'N	38°21'E	16-6-63	N	128.0	549 (540f & 9m)	
	3	5267B	06°44'N	57°59'E	15-3-64	N	8.0	2	f
	,,	5412A	02°02'N	56°03'E	2-6-64	N	14.5	3 (2f & 1m)	
	,,	5437B	00°57'S	59°59'E	15-6 64	D	9.5	4	f
	14	Rs 3A	32°38'S	111°50'E	15-1-63	N	2.0	1	,,
Meteor	1	93B	12°43'N	48°31'E	17-12-64	D	25.0	8	,,
	,,	130A	04°54'N	50°47'E	31-12-64	D	10.0	4	,,
	,,	135	02°34'N	48°16'E	3-1-65	N	18.1	6	,,
	,,	149	00°12'S	46°15'E	9-1-65	N	12.0	5	,,
	,,	153	02°01'S	43°22'E	12-1-65	N	25.2	8	,,
	,,	165	04°41'S	41°22'E	23-1-65	D	4.0	3	,,
	,,	166	04°50'S	41°40'E	24-1-65	N	8.5	5	,,
Vitiaz	35	5198A	28°01'S	91°27'E	22-8-62	N	2.0	4	,,
	,,	5208	09°16'S	91°27'E	30-8-62	D	2.4	1	,,
	,,	5278	05°55'S	84°03'E	22-10-62	D	4.5	3	,,

* Non standard haul from Red Sea

N – Night. D – Day.

f – Female. m – Male.

DISCUSSION

The hydrographical data for the stations from which the species was observed show that it has a preference for salinity around 35 °/oo. However, they can tolerate a range of 34.9 or lower to 35.8 °/oo. The dissolved O_2 content of the water column in these stations was usually high but in the deeper layers sampled, it was in some cases as low as 0.1—0.5 ml/1. It is impossible to state the range of tolerance of this species for dissolved O_2 content. It prefers cold waters but may be found in temperatures higher than 19°C. Since our samples were all from the surface layer and the species appears to be concentrated in lower layers, we cannot indicate precisely the limits of tolerance for this species.

The first record of this species in the Indian Ocean is by Sewell (1947). In the John Murray collections, only two females were present, one taken from the Gulf of Oman in a 600m to surface haul and the other from northern Arabian Sea in a 200-0m haul. He explains the probability of the occurrence of the species in the North Atlantic and Indian Ocean while discussing the distribution of certain Arctic species. He suggests that in the more southerly latitudes they are most often found in great depths where the temperature is low, whereas in the Arctic seas they are often found in the upper layers. DeDecker and Mombeck (1964) in their account of the planktonic copepoda of South Africa gives only a passing remark to the species, but their table shows its presence at 2 stations taken off the south east coast of Africa in a 250-100 m haul and in a 1500 – 1000m haul. In their study they have traced a distribution pattern defined as "dichotopy" ie. occurring in two or more rather widely separated areas and being conspicuously absent between them. This pattern is found to occur in species that were encountered both in the Atlantic and in the Indian Ocean. Their conclusion was that in this area the population in the deeper layers are brought by the incoming Atlantic water through the Cape of Good Hope and those found in the surface layers are autochthonous Indian Ocean population of the same species. According to Grice and Hulsemann (1967) the distribution of bathypelagic copepods is extremely widespread. They further found that 92% of the deep living copepods of the Arabian sea are also recorded from the North Atlantic. The distribution of *Haloptilus acutifrons* in the Indian Ocean (Fig. 3), illustrates this point.

Van Breeman (1908) recorded this species from Mediterranean, North Atlantic and Polar seas. The species has been considered to be of Arctic origin and details of its geographic distribution is given by Sewell (1948). More recent reports are from Florida current (Owre & Foyo, 1967) and from Japanese waters (Mori 1937, Tanaka 1964). Scott (1895) observed this species in the Atlantic region of the southern ocean, but according to the investigation of Wolfenden (1908), there exists a

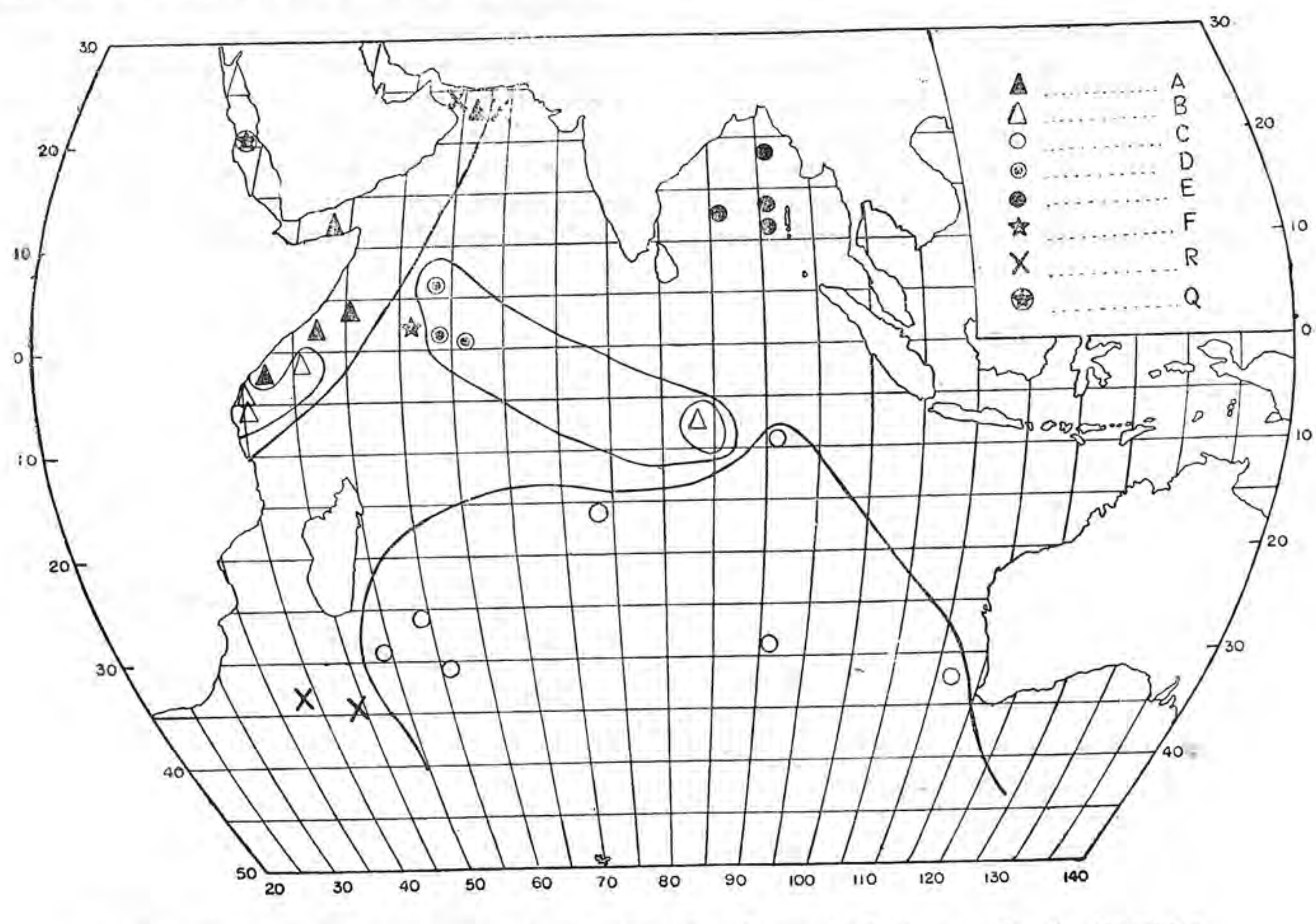

Fig. 3. Distribution of *Haloptilus acutifrons* in the Indian Ocean. R, Earlier records; A, Upwelling areas where upwelled water reached the surface; B, Upwelling area where stratifications were found; C, Southern Indian Ocean; D, equatorial water outside of upwelling area; E, Bay of Bengal; F, Station at which male specimen was taken; Q, Deep haul from the Red Sea.

barrier between the copepod fauna of the Indian Ocean and the Antarctic Ocean at the subtropical convergence which prevents the southward extension of the Indian Oeean subtropical species beyond lat. 30°S. Hence *H. acutifrons* appears to be replaced in the southern ocean by *H.ocellatus*.

Anraku and Omori (1963) showed experimentally that the morphology of the mouth parts is related to the food habits of copepods. Mullin (1966) supported this view and confirmed that the abundance of fine setae on the cephalic appendages indicates herbivorous habits, but the presence of strong spines and of long prehensile setae in the maxillule and strong mandibular blades suggest that the species is carnivorous. The examination of the mouth parts of *Haloptilus acutifrons* reveals an intermediate structure, thus showing euryphagous mode of feeding.

The samples studied were taken during the 11 OE with the Indian Ocean standard net that has a mesh size of 0.33 mm. Thus the small zooplakton and the phytoplankton escaped through the mesh and were not available in the IOBC samples and could not be computed in the biomass values neither as volume nor as number of animals present per sample. Judging from the shape of the mouth parts and from the vertical distribution, this species appears to be omnivorous. Hence for a study of the relationship between number of specimens and total biomass, consideration should be given to, the fact that fractions of the association were lost during sampling at sea.

In spite of the bias introduced by this loss the relationship between number of *Haloptilus acutifrons* and total biomass was studied (Fig. 4) The regression factor was found to be 0.87 and the line drawn was calculated. The calculated regression line indicates that *Haloptilus acutifrons* specimens are present when biomass is zero. This confirms the omnivorous habit of *H. ocutifrons*.

In the graph the data from different ecosystems are marked with different symbols. The same symbols are used on the map to show the geographical position of the stations from where they were taken. If we consider separately the grouping by ecosystem, it may be seen that they show a consistent arrangement and distribution. The point 'Q' represents the nonstandard sample from the Red sea. But this sample is not comparable to the others since it was a deep haul and was filtered through different water masses.

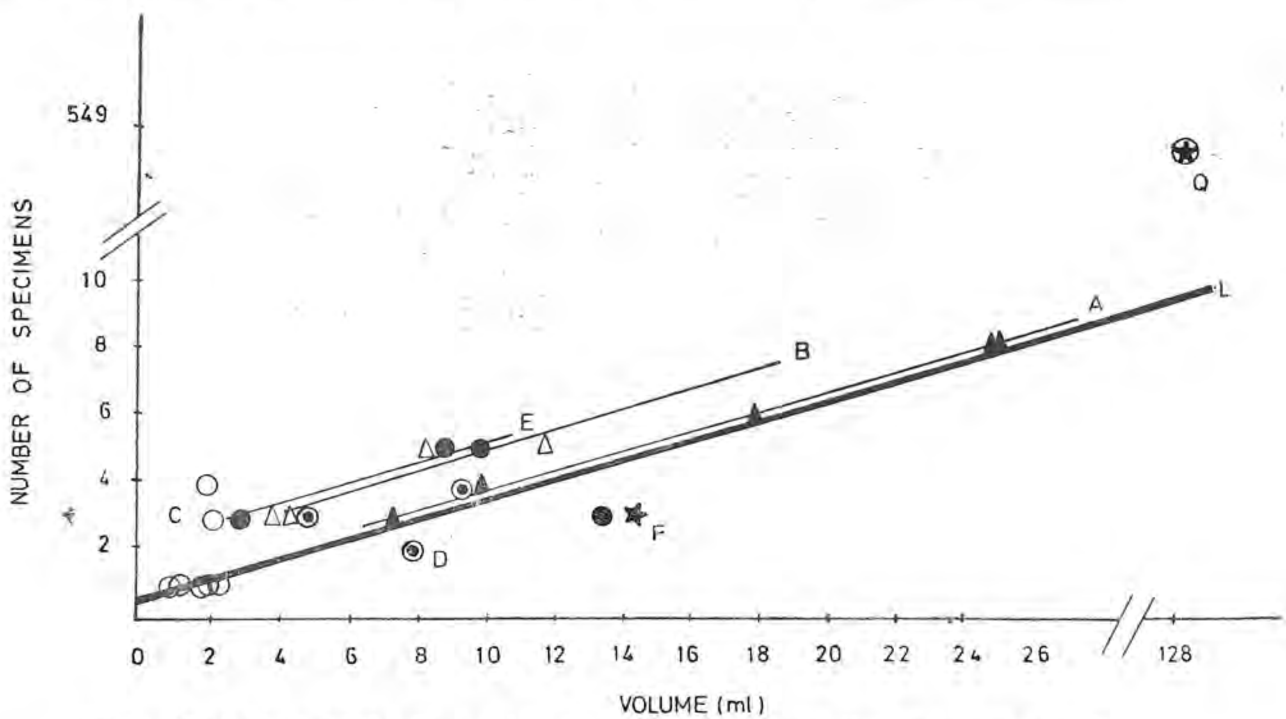

Fig. 4. Distribution of *Haloptilus acutifrons* in relation to total zooplankton volume of sample. Symbols as in Fig. 3. L, Regression line for all the points

SUMMARY

1. During the study of the genus *Haloptilus* from the Indian Ocean, the unrecorded male of *H. acutifrons* was observed in a night sample taken off the Somali coast from 200-0 m.

2. A deep water sample from the Red Sea revealed the presence of 9 males and 540 females of *H. acutifrons*.

3. A positive correlation was found between the number of *H. acutifrons* and total biomass. The regression factor was 0.87.

4. The morphology of the mouth parts of *Haloptilus acutifrons* suggests that it has an omnivorous habit.

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A NEW SPECIES OF MACANDREWELLA (COPEPODA: CALANOIDA) FROM OFF COCHIN, SOUTH WEST COAST OF INDIA

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ABSTRACT

Macandrewella cochinensis is described and compared with other species of the genus. Examination of the specimens revealed that they cannot be assigned to any of the known species of the genus though they had similarities with *M. joanae* and *M. scotti*.

INTRODUCTION

During the course of the studies on the copepod family Scolecithricidae from the International Indian Ocean Expedition collections, some specimens of both sexes belonging to the genus *Macandrewella* were observed in a sample taken by "R. V. Conch" from a station at Lat. 10°10'N, Long. 75°46'E (IOBC Hand book Vol.I, 1969). They were different from the seven known species of the genus and are hence described as new. Specimens belonging to the same species were later collected from a sample taken by "Blue Fin" at Lat. 09° 48'N, Long. 75°39' E (N. I. O., 1969-70).

DESCRIPTION OF SPECIES

Macandrewella cochinensis n. sp.

Female (Fig. 1a): Head and the first thoracic segment fused together with a faint line of demarcation laterally. Forehead with a lens-like organ at the base of the rostrum. Fourth and fifth thoracic segments completely separated. Posterolateral corners of the last thoracic segment asymmetrical, each side drawn out into a stout curved spine with a distinct tooth at the base. Spine on the left side longer than the spine on the right side reaching the level of the distal margin of the first urosome segment (Fig. 1b). Rostrum with a bifurcate base and one filament attached to each ramus.

Abdomen four segmented, genital segment asymmetrical in outline in dorsal view and with a ventral backwardly directed protuberance (Fig. 1c). Posterior margin of the second and the third abdominal segments fringed with fine spines. Fourth abdominal segment shortest. Caudal furca almost as long as wide. Five caudal setae attached to each furcal joint. Middle caudal seta on the left side elongated.

Antennules with 23 separate segments. Antennae, mandibles, maxillae and maxillipeds in general structure almost similar to those of the other species of the genus with the following differences. Chewing blade of each mandible carries 8 teeth; inner tooth long, curved and serrated (Fig. 2c). First basal of the maxilliped with a short row of fine curved spines at its proximal end on either side. Second basal just behind the anterior margin, on either surface carries a long row of fine spines along its entire length. Spines at the centre of this row are short and those at the ends are long (Fig. 2f).

Segmentation of legs 1-4 (Figs. 3a,b,c,d) as in *M. scotti* Sewell, with the following differences. Outer border of exopod 3 of leg 1 even and straight, external spines on the three exopod segments almost subequal. First basal segment of leg 2 with a small spine behind the distal external angle. Exopod segment 2 of leg 2 and 3 with a transverse, crescent-shaped row of spines towards the distal border, segment 3 provided with a group of small spines on the surface towards the middle. Endopod 1 of leg 2 drawn out into a spine at the distal external angle. Endopod 2 of leg 2 with two rows of three spines each. Spines in the outer row almost equal. Spines in the inner row unequal. Endopod segments 1 and 2 of legs 3 and 4 drawn out into spines at their distal external angle, segments 2 and 3 with stout sharp spines on the surface. Spines on the sur-

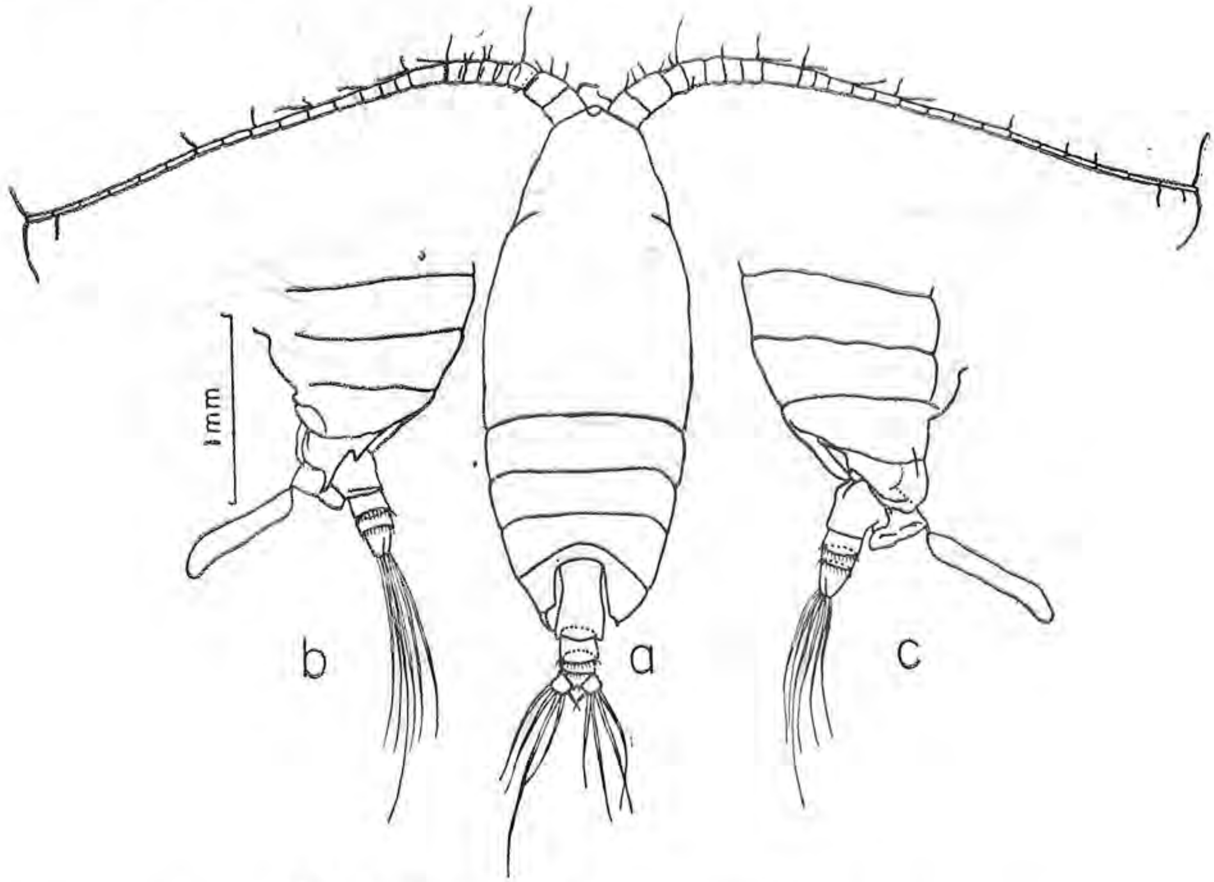

Fig. 1. *Macandrewella cochinensis*. n. sp. Female.
(a) Dorsal view, (b) Lateral view of posterior part from left side, (c) Lateral view of posterior part from right side.

face of segments 2 and 3 of both exopod and endopod of leg 4 arranged in vertical rows. Leg 5 absent.

Material examined: Total 25 specimens from the two samples.

Length range: 3.0–3.15mm.

Male (Fig.4a):- Head and first thoracic segment fused together, forehead carries lens-like organ. Posterolateral corners of the last thoracic segment symmetrical, each side with stout curved spines. Abdomen five segmented. Posterior margin of second, third and fourth abdominal segments fringed with fine spines. Four caudal setae on each caudal rami. Antennules with 20 segments on the right side and 21 on the left side. Mouth parts as in female. Legs 1-4 as in female but with reduced armature. Leg 5, in general structure resembles that of the other species in the genus. Right leg with the first basal with an angular expansion towards the proximal one-third; the second basal segment dilated, proximal part of endopod with a curved and blunt distally directed process, a median conical protuberance and a curved tapering distal end; first exopod segment bearing an irregular wing like expansion at the proximal part, a small rounded prominence in the middle and an evenly curved prominent process towards the distal end, second segment with an internally directed club-shaped process almost as long as the entire segment, third segment bent on itself at about the middle with a thin transparent web-like structure connecting the two halves. In left leg second basal longer than first, endopod one-segmented and almost straight, with two triangular expansions and a row of strong teeth distally; exopod two-segmented, tip of second segment with a thin plate-like structure covered with a dense tuft of long cilia and with a thin pointed claw (Fig.4b.).

Material examined: Total 31 specimens from the two samples.

Length range: 2.9 – 2.95 mm.

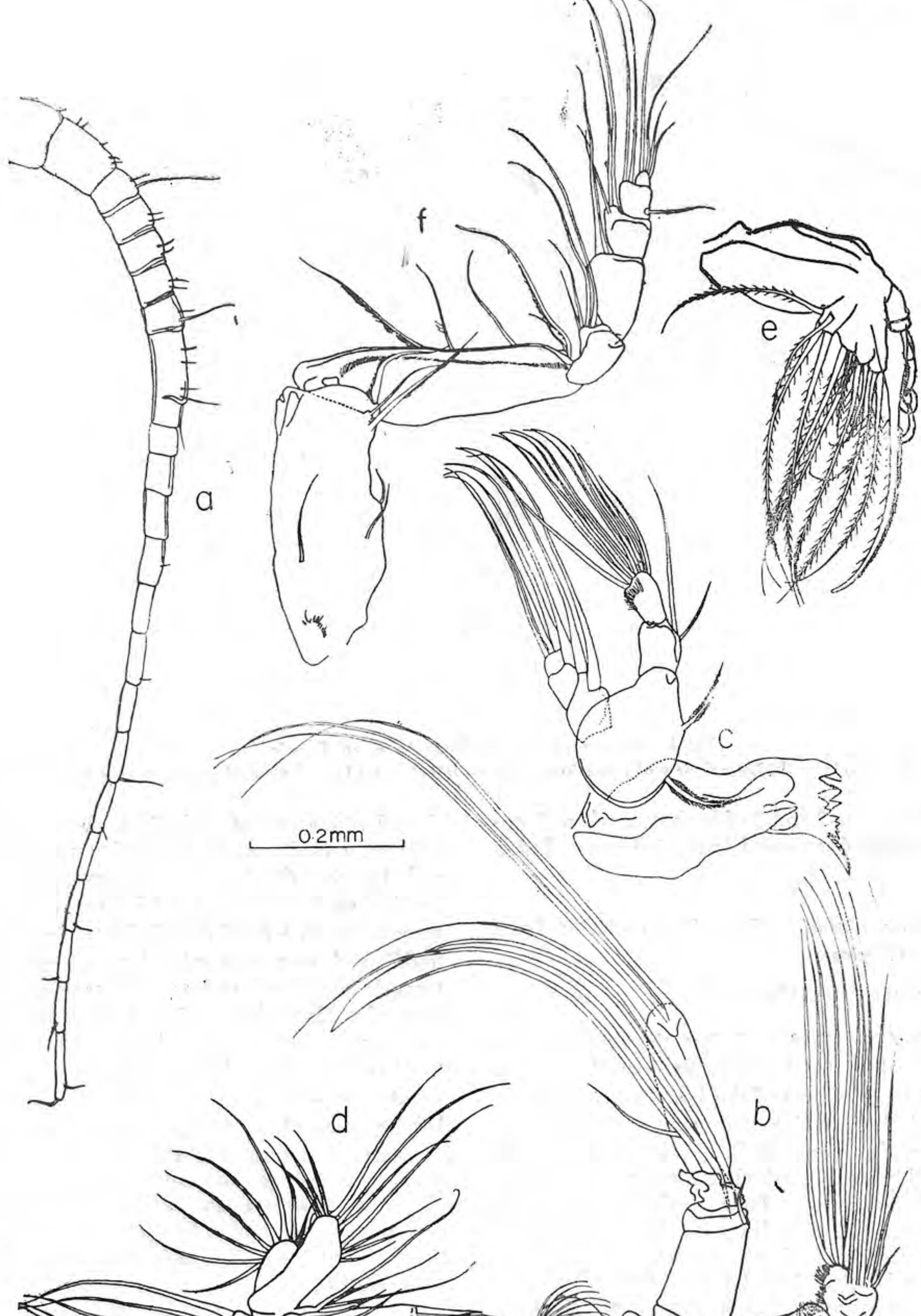

Fig. 2. ***Macandrewella cochinensis*** *n. sp. female.*
(a) Antennule, (Magnification double that of the other appendages), (b) Antenna, (c) Mandible, (d) 1st maxilla, (e 2nd maxilla, (f) Maxilliped.

Fig. 3. ***Macandrewella cochinensis***, n. *sp. female*.
(a) — (d) legs 1 — 4.

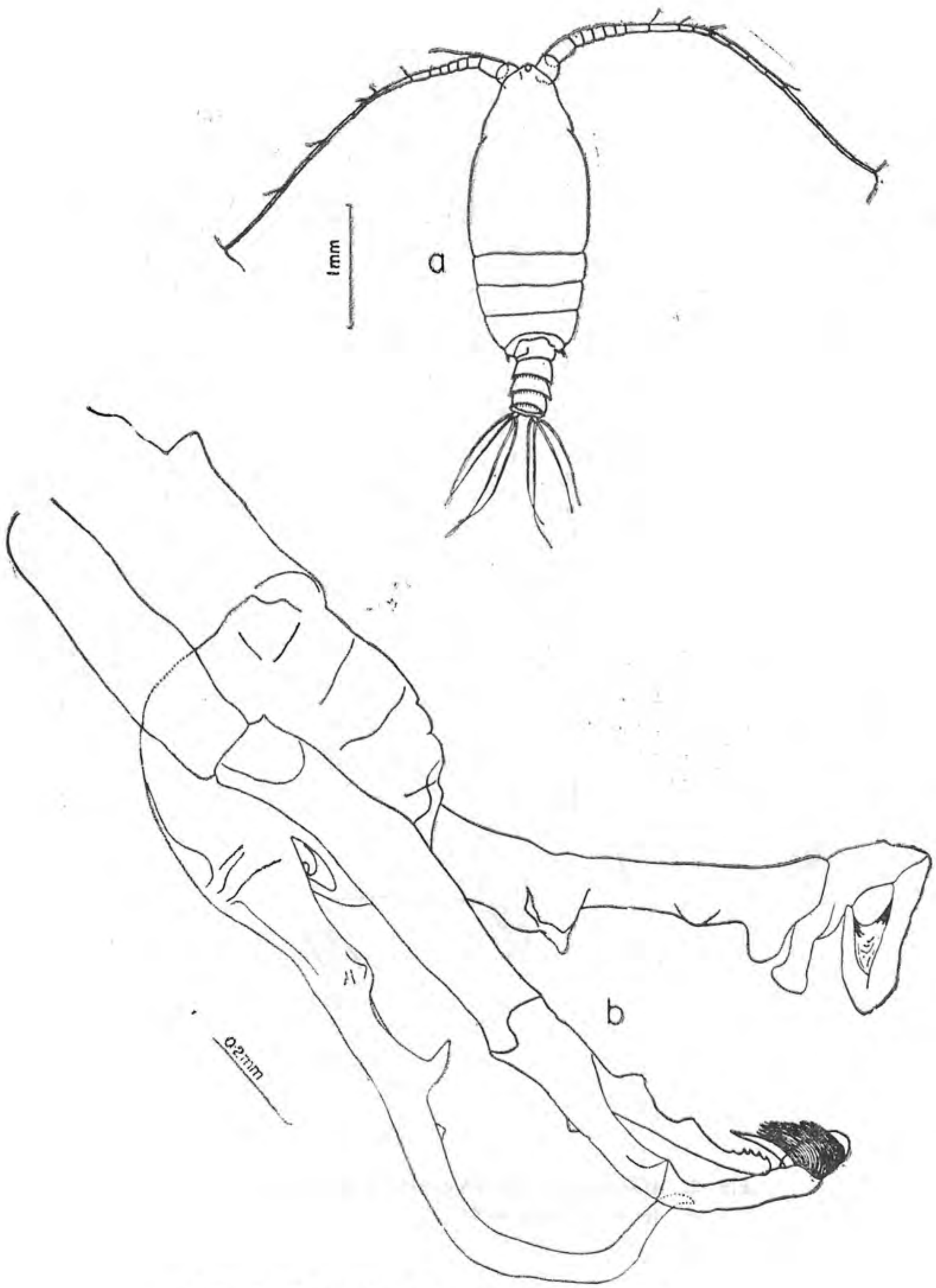

Fig. 4. ***Macandrewella cochinensis*** *n. sp.* **male.**
(a) Dorsal view (b) Leg. 5.

Table: Comparison of *Macandrewella* species

	M. joanae	*M. scotti*	*M. chelipes*	*M. Sewelli*	*M. asymmetrica*	*M. mera*	*M. agassizi*	*M. cochinensis*
Female								
Length (mm)	3.6	3.2	3.5	3.5 - 3.7	3.5 - 3.7	3.84	3.0	3 - 3.15
Posterolateral corners of the last thoracic segment	Asymmetrical with the spine on the left side extending beyond the middle of the genital segment	Symmetrical	Symmetrical	Symmetrical	Asymmetrical with the spine on the left side bent outwards at an angle of about 45°.	End laterally in short sharp points directed slightly inwards. Dorsal to the point on the right side the margin of the segment is produced into a short tooth which bears a few spinules on its margin.	Symmetrical	Asymmetrical with the spine on the left side reaching the level of the distal margin of the first urosome segment.
Genital segment	Asymmetrical in dorsal view. Ventral surface produced posteriorly into a small blunt lobe.	Symmetrical in dorsal view.	Symmetrical in dorsal view.	Asymmetrical with a lobe at the right posterior corner overlapping the next abdominal segment.	Asymmetrical with a swollen lateral projection on the right side slightly overlapping the following segment dorsally and with a ventral backwardly directed thumblike process projecting from the genital boss.	Asymmetrical with a swelling on the right side, a ventral thumblike projection directed backwards from the genital plate.	Dorsal surface strongly elevated along mid line and armed with a stout spine at the posterior end.	Asymmetrical in dorsal view, prominent backwardly directed protuberance on ventral side.
Spines on the posterior margin of abdominal segments	Present on lst, 2nd and 3rd segments.	Present on 2nd and 3rd segments	Absent	Absent	Absent	Absent	Absent	Present on 2nd and 3rd segments.
Caudal furca	As long as broad	Short and broad	Wider than long	Wider than long	As broad as long	—	Wider than long	As long as broad

Table (Contd)

	M. joanae	*M. scotti*	*M. chelipes*	*M. sewelli*	*M. asymmetrica*	*M. mera*	*M. agassizi*	*M. cochtnensis*
Caudal setae	5 on each side, asymmetrical with middle seta on left side eolngated.	5 on each side, symmetrical.	4 on each side, symmetrical.	4 on each side, symmetrical.	5 on each side, symmetrical	Symmetrical	4 on each side, asymmetrical with 2nd inner seta on left side elongated.	5 on each side, asymmetrical with middle seta on left side elongated.
Leg 5	Present	Absent	Absent	Absent	Absent	Absent	Present	Absent
Male								
Length (mm)	3.4	—	Smaller than female	3.25	3.7	Male not recorded.	2.95	2.9 - 2.95
Spines on the posterior margin of abdominal segments	Present on 2nd, 3rd and 4th abdominal segments.	Present on 2nd and 3rd abdominal segments.	Absent	Absent	Absent	—	Absent	Present on 2nd, 3rd and 4th abdominal segments.
5th leg Right								
Exopod	2 segmented	3 segmented	3 segmented	3 segmented	Similar to that figured by Scott for *M. joanae* and differ only in small details which can be best seen by comparison of the figures.	—	3 segmented	3 segmented.
Exopod 1	Produced internally into a strong curved claw which exceeds the length of the joint, middle inner margin produced into stout tooth.	Fused with second basal, a wing-like projection at proximal end, about the junction of the middle and distal thirds a small rounded lobe, a club-shaped prominence at the distal end.	An angular swelling on the outer margin at the centre, a small knob at the inner distal corner.	Extends beyond the articulation with the second segment as a curved finger-like process.	—	—	A knob at the inner distal corner.	An irregular wing like expansion at the proximal part, small rounded prominence in the middle and an evenly curved prominent process at the distal end.

Table (Contd.)

	M. joanae	*M. scotti*	*M. chelipes*	*M. sewelli*	*M. asymmetrica*	*M. mera*	*M. agassizi*	*M. cochinensis*
Exopod 2	Forked at the apex.	A strong inwardly directed blunt process at the base equal in length to the whole segment.	A curved process at the base and a small straight process near the centre of the inner margin.	Outer side articulated with the inner side of Ist segment, proximal end enlarged into a trilobed knob which extends behind the articulation.	—	—	A sickle shaped process on the inner margin at the base, projects distally beyond the joint with the third segment.	An internally directed club-shaped process almost as long as the entire segment.
Exopod 3	—	Sickle shaped.	Sickle shaped; a knob on the convex margin, point of sickle overlaps the base of the second segment.	Bent at right angles near its centre with a long process, toothed at the tip on the outer angle of the bent.	—	—	Bent at right angles near its centre and the terminal claw-like part overlaps the sickle-like process at the base of the 2nd segment.	Bent on itself at the middle with a thin transparent web-like structure connecting the two halves.
Endopod	One jointed long curved.	One jointed long curved.	Slender, reaches the distal end of exopod 2.	Extends beyond exopod 2, curved and blunt at the tip, a sharp process on the inner margin near the base and another towards the tip.	—	—	One jointed, a single knob near the centre of the outer margin.	One jointed, proximal part with a curved and blunt distally directed process, a median conical protuberance and a curved tapering distal end.
Left leg								
Exopod	2 jointed.	2 jointed	3 jointed	2 jointed.	—	—	3 jointed	2 jointed.
Exopo d2	Short, dilated, apex furnished with a pad of hairs and a spine.	Terminates in a claw-like process with a tuft of hairs.	Equal in length to exopod 1.	Enlarged at its distal end with an outer setose process.	—	—	Somewhat widened.	A thin plate-like structure at the tip covered with dense tuft of long cilia and with a thin pointed claw.

Table (Contd.)

	M. joanae	*M. scotti*	*M. chelipes*	*M. sewelli*	*M. asymmetrica*	*M. mera*	*M. agassizi*	*M. cochinensis*
Exopod 3	—	—	Short and claw shaped.	—	—	—	With a rounded process and a soft pointed filament on its inner surface, rounded tip covered with hairs.	—
Endopod	One jointed, sickleshaped, as long as exopod, distal half of inner margin serrated.	One jointed, curved and with a row of serrations at the distal end. Shorter than exopod.	One jointed, nearly as long as exopod, dentate on its inner margin.	One jointed, shorter than exopod, laminate and truncate at its tip, with a sharp spine at the centre and a row of coarse teeth distal to the spine.	—	—	One jointed, nearly as long as exopod, two angular processes on the outer margin, three minute teeth at the tip.	One jointed, shorter than exopod, almost straight, two triangular expansions, a row of strong teeth distally.

Types:- Holotype 1 female, allotype 1 male and paratypes 2 females and 2 males are deposited in the reference collection at the Regional Centre of N. I. O. (CSIR), Cochin-18, India, Reg. Nos: I. O. B. C. 0146, 0147, 0148 respectively. In the table the distinctive features of the species in the genus *Macandrewella* are summarised.

DISCUSSION

Scott (1909) created the genus *Macandrewella* to accommodate the new species *M. joanae* collected by "Siboga" in the Malay Archipelago. Scott also included in the genus the copepod that Giesbrecht (1896) had described from the Red Sea under the name *Scolecithrix chelipes*. There are seven established species of the genus; *M. joanae*, *M. chelipes* (Giesbrecht 1896), *M. scotti* Sewell (1929), *M. sewelli*, *M. asymmetrica*, *M. mera* Farran (1936) and *M. agassizi* Wilson (1950). Female of *M. cochinensis* resembles *M. joanae* in the extreme asymmetry of the posterolateral corners of the last thoracic segment with the spine on the left side reaching the level of the distal margin of the first urosome segment and in the asymmetrical caudal setae with the middle seta on the left side elongated. But the absence of leg 5 is an important character distinguishing it from the latter species. Leg 5 of male in *M. cochinensis* is distinct, in the structure of the different parts, from the other species, though retaining the basic form in the genus. Sewell (1929) while describing females of *M. scotti* refers in the text to the similarity with *M. joanae* in the shape of the posterolateral corners of the thorax, but from figures it has to be assumed that though there are spinous projections they are not comparable to the distinctly asymmetrical spines of *M. Joanae*. Moreover, Sewell makes special mention of the symmetrical caudal setae. They are asymmetrical in *M. cochinensis* as well as in *M. Joanae*. Apart from the variations in the distribution of spines on the maxilliped and legs 1–4, the straight outer border of exopod 3 of leg 1, instead of a notched border in *M. scotti* is a well marked feature of *M. cochinensis*. Thus *M. cochinensis* though possessing certain characters in common with *M. joanae* and *M. scotti* is quite distinct from them and also from the other species in the genus.

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THE GENUS *GAUSSIA* (COPEPODA-CALANOIDA) WITH A DESCRIPTION OF *G. SEWELLI* SP. NOV. FROM THE INDIAN OCEAN

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ABSTRACT

The genus *Gaussia* (Copepoda - Calanoida) which had so far been considered monospecific has now been found to consist of two distinct species. An error in nomenclature of the type species has been corrected and the new species endemic in the northern areas of the Indian Ocean has been described. Examination of specimens from the Atlantic, Indian and Pacific oceans lead to the findings.

INTRODUCTION

A study of the genus *Gaussia* based on specimens collected from Indian, Atlantic and Pacific Oceans has shown that the genus which was hitherto considered monospecific, comprises two distinct species, *G. scotti* (Giesbrecht), a species found in all oceans and a second species *G. sewelli* sp. nov. which has so far been observed only in the northern Indian Ocean.

Detailed examination of the specimens has lead to a redefinition of the genus. This, and notes on the distinctive characters of both species are given in this paper. In the synonymy, I have included only those records which I was able to verify from descriptions and illustrations or by re-examining specimens.

GENUS *GAUSSIA* WOLFENDEN 1905

Wolfenden (1905) created the genus *Gaussia*, briefly defining it as "resembling *Metridia* in the structure of the feet and *Pleuromamma* in the form of the body, but no trace of pigment ocellus". Brodskii (1950) is the only other person to attempt a definition of the genus although he had not seen any specimens. Davis (1949) who had seen only the female, expressed the doubt whether *Gaussia* is a valid genus, but there is no doubt either about the distinctiveness of the genus or about its position in the family Metridiidae.

Redefinition of Genus *Gaussia*

Head with small conical knob at anterior end; posterolateral corners of last metasome segment produced into spines, more prominent in female, genital segment symmetrically or asymmetrically inflated in female, some times with black mass ventrally; distolateral border of segment 2 of urosome produced into small flaps; anal segment in both sexes with posterolateral corners produced into large pterygoid processes terminated by a pore and with fine hairs on both sides of the segment, arising from the ventral surfaces. Caudal rami with a blunt process on the distal border. Right antennule of male geniculate, 12th segment with a small rounded glandular structure in addition to an aesthetask and a seta. Maxillule with a small but distinct 2nd outer lobe bearing a single plumose seta. Leg 5 in female 4-segmented, 3rd segment with a very long plumose seta, 4th with 2 shorter plumose setae. Leg 5 in male 3-segmented; terminal segment indistinctly divided into 2; proximal half of 3rd segment of left leg with 2 strong processes, 1 directed distally and the other proximally, 3rd segment of right leg with 4 setae, distal half of the segment with undulating inner margin.

Apart from the many obvious morphological peculiarities which can be noticed without close examination, the peculiar glandular structure noticed on the right antennule of male is unique for this genus and needs detailed study (Fig 1a, b). A small second outer lobe for the maxillule seems to be a character which *Gaussia* shares with the two other genera of the family Metridiidae in which various degrees of development can be noticed.

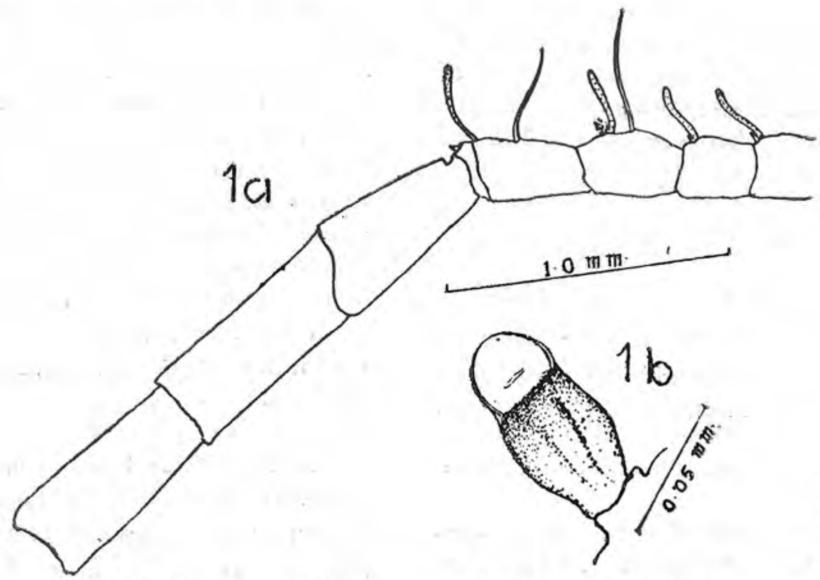


Fig. 1 a - *Gaussia scotti* male: segments 10 to 16, right antennule
1 b - Glandular structure on segment 12.

Gaussia scotti (Giesbrecht)

Pleuromma princeps T. Scott, 1894: 42, pl.3.

Metridia scotti Giesbrecht, 1897:254; Giesbrecht & Schmeil, 1898: 107.

Gaussia melanotica Wolfenden, 1905:5 pl.2.

Gaussia scotti Wolfenden, 1905 (amended copy): 5, pl.2.

Metridia atra Esterly, 1906: 70, pls. 9, 11, 13, 14.

Gaussia scotti Wolfenden, 1911: 290, pl.33.

Gaussia princeps Wilson, 1950:235, pl.11.

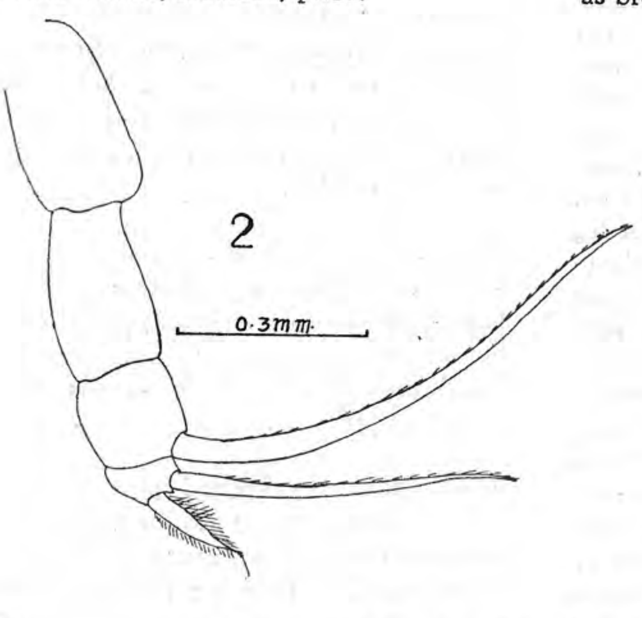
Metridia atra Wilson, 1950:263, pl.25.

Gaussia princeps Grice, 1963:496; Grice & Hulsemann, 1967: 17 (part).

Gaussia princeps Vervoort, 1965:103.

Material examined: 18 females and 19 males from Indian Ocean, 14 females and 13 males from the Atlantic, 28 females and 12 males from the Pacific.

Female: Spinous prolongations of posterolateral corners of last metasome segment divergent; proximal part of genital segment asymmetrically inflated, with a very prominent curved process usually on right side. Blunt process on caudal rami prominent. Penultimate segment of leg 5 as broad as long. (Fig. 2).



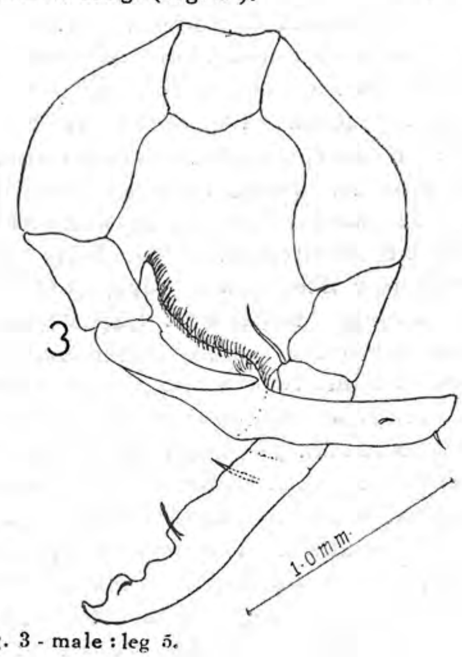


Fig. 2 *Gaussia scotti* female: leg 5; Fig. 3 - male : leg 5.

Male: Process on caudal rami as in female. Proximally directed spine on 3rd segment of leg 5 blunt, short and stumpy. Terminal segment of right leg with prominent undulating inner border, and four setae; distance between 1st and 2nd and 2nd and 3rd setae almost equal (Fig. 3).

Length range of specimens examined.

	Female	Male
Indian Ocean	10.5 - 11.4 mm.	9.6 – 10.6 mm.
Atlantic Ocean	10.0 - 10.7 mm.	9.1 - 10.4 mm.
Pacific Ocean	10.0 - 11.6mm.	10.1 – 11.1 mm.

Distribution: Indian, Atlantic and Pacific Oceans.

Remarks: There is no doubt that this is the species described by T. Scott (1894). This species, originally described by T. Scott as *Pleuromma princeps* was placed in the genus *Metridia* by Giesbrecht (1897), where *M. princeps* (T. Scott, 1894) is a secondary homonym of *M. princeps*(Giesbrecht, 1889). According to the provisions of Article 59 C of the "Code" T. Scott's name must remain rejected and Giesbrecht's name should be used as the valid name for the species. Dr. T. E. Bowman, Dr. F. A. Chace, Jr. and Dr. C. W. Sabrosky of the U.S. National Museum gave authoritative opinion concerning nomenclature. This was further confirmed by Dr. W. Vervoort, Rijksmuseum van Natuurlijke Historie, in consultation with Dr. L. B. Holthuis. Previous records of *Gaussia* are nearly all of *G. scotti* except for those of Sewell (1932, 1947), Chiba (19o5) part, Grice and Hulsemann (1967) part and Saraswathy (1971). It has been previously collected from the Indian Ocean on possibly two occasions (Chiba, 1965 part; Grice and Hulsemann, 1967 part). A review of literature on this species brings forth certain confusions, probably owing to some inaccuracies. Sewell (1932) noticed that the illustrations of leg 5 of female by Wolfenden (1905, 1911) and Esterly (1906) were like those of copepodite 5 female of his collections. I agree with this statement with regard to Esterly but not to Wolfenden. Esterly mentions that one female and 3 males were collected, but gives 9 mm. as length of male and 11.5 mm. to 12 mm. as length of female. 9 mm. is probably the length of the single female specimen, which, as can be judged from the figure of leg 5, is copepodite 5. This is also supported by the absence of any description of the very peculiar nature of the genital segment in the adult female. I consider the leg 5 figured by Wolfenden (1905, 1911) as that of an adult female. The lack of demarkation between the two terminal segments probably prompted Sewell (1932) to conclude that it was a juvenile limb. I have examined specimens identified by Wilson (1950) as *Metridia atra* and found them to be copepodites of *Gaussia scotti*. Sewell (1932) had vaguely indicated the possibility to separate a Pacific variety of *Gaussia* and Broadskii (1950) was emphatic in his suggestion that the specimens from the Pacific should be named *Gaussia princrps v. atra* Esterly. But my examination of specimens from the three Oceans has shown that the Pacific and Altantic specimens are identical.

Johnson (1942), Lysholm and Nordgaard (1945), Davis (1949), Owre & Foyo (1967), Tanaka & Omori (1967), Fleminger (1967), Gueredrat (1969) and Morris (1970) have recorded the genus *Gaussia* from various localities in the Pacific and Atlantic. It is probable that all these records are of *G. scotti* (Giesbrecht).

Gaussia sewelli sp. nov.

Metridia Scotti Sewell, 1913 : 354.

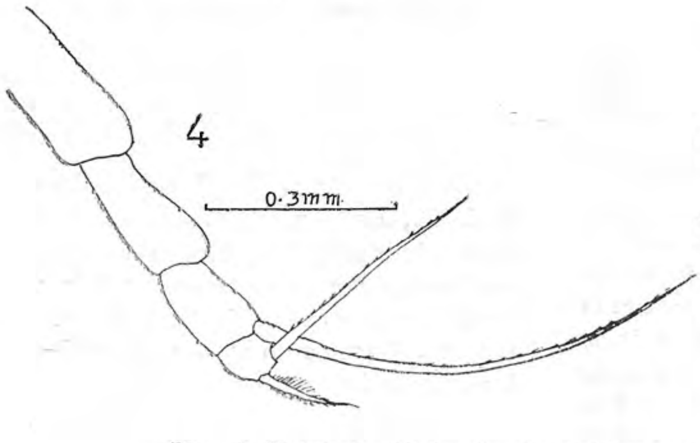
Gaussia princeps Sewell, 1932:270, pls. 5, 6; 1947: 173; Grice & Hulsemann, 1967:17 (part); Saraswathy, 1971.

Material examined: 57 females and 67 males from Indian Ocean.

Holotype 1 female Z. S. I. Reg no. $\frac{c1003}{2}$ and allotype 1 male Z. S. I. Reg. no. $\frac{c\ 1004}{2}$ in Indian Museum, Calcutta. Paratypes 1 female and 1 male at U. S. National Museum; USNM Cat. No. 138901. Paratypes 1 female and 1 male at British Museum Natural History; Reg. nos. 1971-9-30-184 and 1971-9-30-185.

Female: Posterolateral corners of last metasome segment backwardly directed; genital segment laterally inflated, symmetrical; projection on distal border of caudal rami not very prominent. Penultimate segment of leg 5 tends to be longer than broad (Fig. 4).

Male : Proximally directed spine on 3rd segment of leg 5, thin, tapering and long, extending beyond proximal border of segment 2. Distal inner corner of segment 2 of right leg produced into a small rounded process, undulations of terminal half of segment 3 not very prominent; distance between 1st and 2nd and 2nd and 3rd seta unequal (Fig. 5).



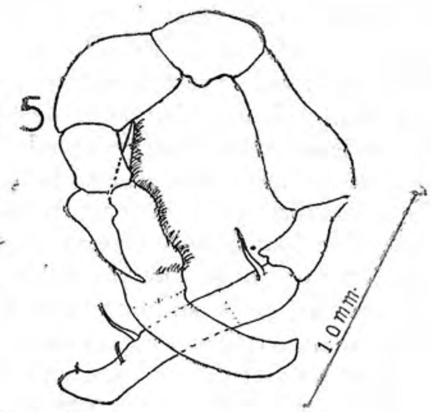


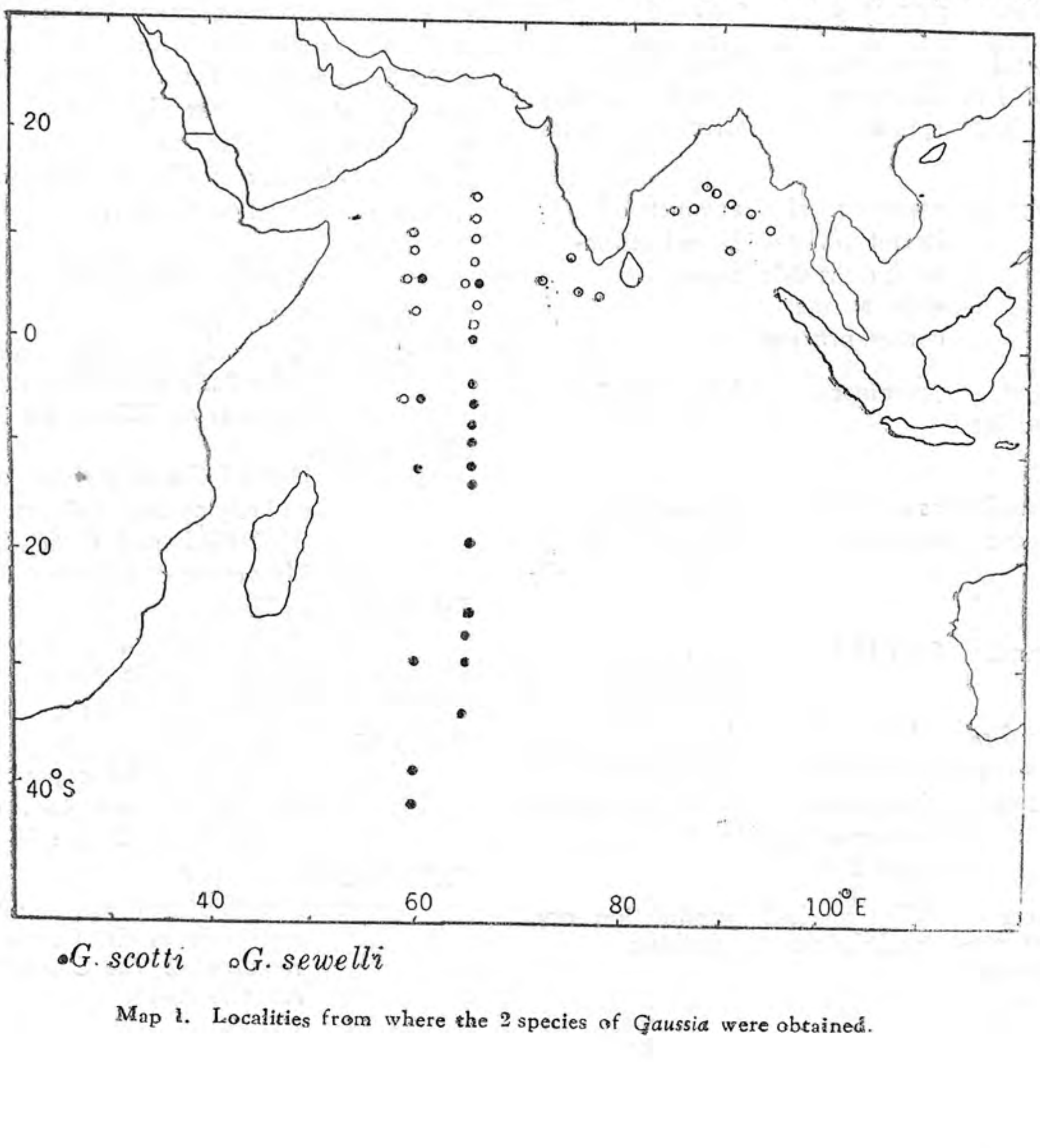
Fig. 4 *Gaussia sewelli* female : leg 5; Fig. 5 - male. leg 5

Length range of specimens examined:

	Female	Male
Indian Ocean	9.4 - 9.9 mm.	8.4 - 9.6 mm.

Distribution : Indian Ocean, mainly in the Arabian Sea and Bay of Bengal.

Remarks: The first record of the genus *Gaussia* from the Indian Ocean was that of Sewell (1913). There is an erroneous statement in Wolfenden (1911), that *Gaussia* was obtained in Gardiner's collection from the Indian Ocean. The drawings of Sewell (1932) are clear enough



Map 1. Localities from where the 2 species of *Gaussia* were obtained.

to recognise them as identical with specimens obtained during the present study from the northern areas of the Indian Ocean. I have also examined Sewell's specimens, deposited at the British Museum (Natural History). The species is named after Sewell who first recorded them. It is likely that specimens recorded by Chiba (1965) from the Indian Ocean are in part specimens of *G. sewelli*. The distribution pattern as indicated by the station locations from where this species is collected (map 1), gives an impression that it is isolated in the northern areas of the Indian Ocean. A detailed account of distribution will be published later. All specimens from the Indian Ocean included in this study were collected during the IIOE.

G. scotti differs from *G. sewelli* in the following characters:

	G. scotti	*G. sewelli*
Female.		
Length (mm)	1·00–11.6	9.4 - 9.9
Posterolateral corners of last metasome segment	strong sharp divergent spines.	Backwardly directed hardly divergent spines
Genital segment	asymmetrical lateral inflations, right side with strong conical process	symmetrical lateral inflations.
Caudal rami distal protuberance	prominent	barely evident
Leg 5, penultimate segment	as broad as long	tends to be longer than broad
Male.		
Length (mm).	9.1 - 11.1	8.4 - 9.6
Leg 5		
Proximally directed spine on segment 3 of left leg.	short and blunt, not reaching distal border of segment 2	long and tapering, reaching distal border of segment 2.
Distal inner border of terminal segment of right leg	Well marked undulations	undulation not striking.

Halftone reproductions of the posterior part of males and females of both species (Plate I) would clearly illustrate the differences.

ACKNOWLEDGEMENTS

I am grateful to Dr. N. K. Panikkar, Director N. I. O., India and Dr. M. Vannucci, Unesco Expert, Indian Ocean Biological Centre, for giving me the opportunity to carry out this work. The work was done at the National Museum of Natural History, Washington D. C. with financial support from Unesco.

To Dr. T. E. Bowman, I am thankful for placing at my disposal the *Gaussia* specimens in the Museum, for his interest in the work and for reading the manuscript. My sincere thanks to Dr. G. D. Grice, Woods Hole Oceanographic Institution, Dr. H. A. Fehlmann, Smithsonian Oceanographic Sorting Centre, Dr. K. G McKenzie, British Museum N. H. and Dr. W. Vervoort for giving me the specimens in their custody for study. I record my appreciation for the assistance rendered to me by Dr. Janet M. Bradford while at the S. O. S. C. and at the Museum of Natural History. My thanks are also due to Ms. Carolyn Barlett Gast of the National Museum of Natural History, Washington D. C. for drawing the figures reproduced on plate I.

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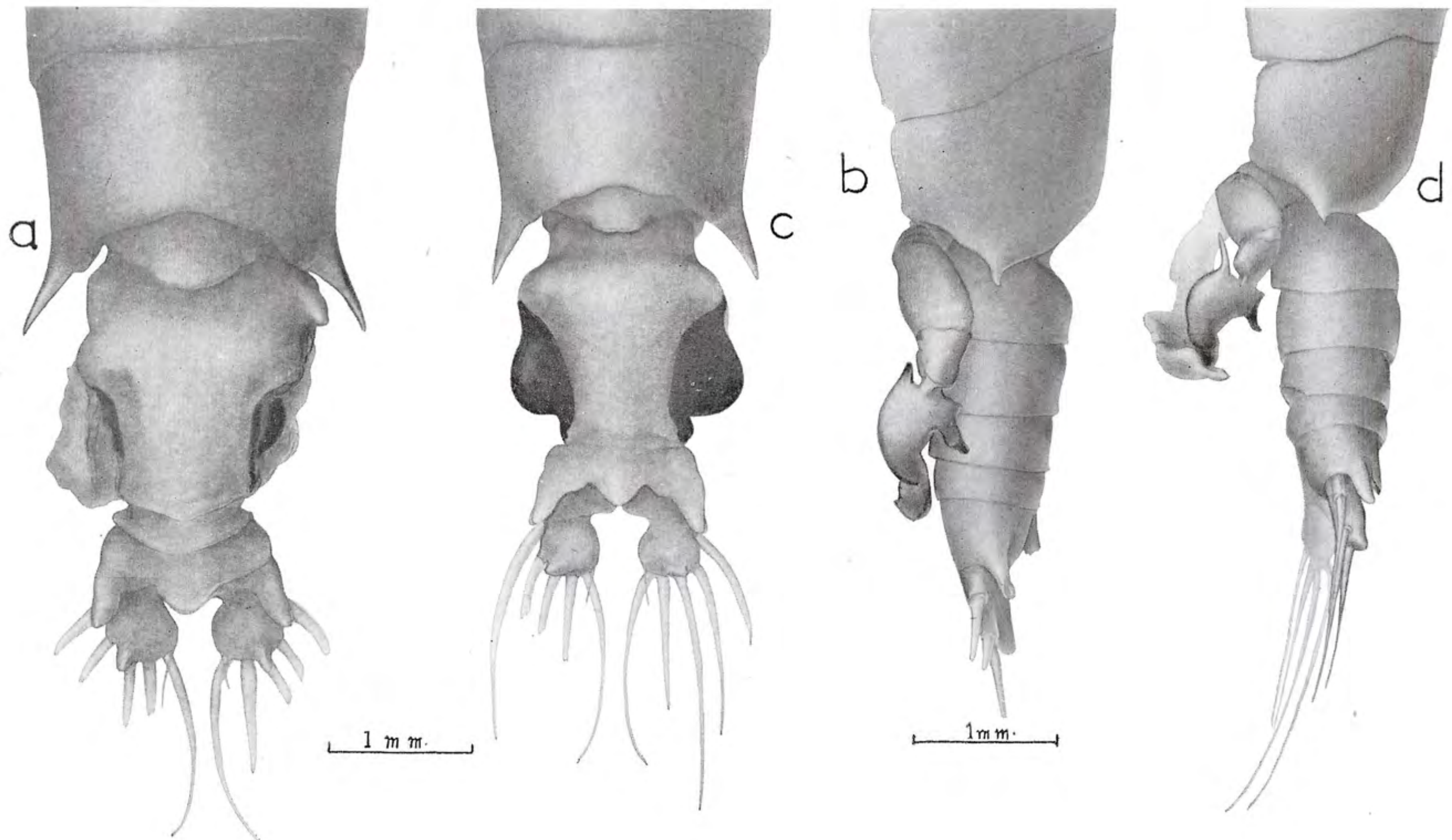

Plate 1.

Posterior region of : *Gaussia scotti* - a female (dorsal view), b male (lateral view); *Gaussia sewelli*- c female (dorsal view), d male (lateral view).

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LEPTOCHELA ROBUSTA STIMPSON (DECAPODA, CARIDEA, PASIPHAEIDAE) FROM THE SOUTHWEST COAST OF INDIA AND ITS LARVAL DEVELOPMENT

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ABSTRACT

One of the pasiphaeid shrimps *Leptochela robusta*, which is an important forage species of pelagic fishes, is recorded for the first time from the coastal waters of India, off the south-west coast. Its larval development is traced through 5 larval and 2 postlarval stages with detailed descriptions and figures. Features of differences from the larval stages of other species of the genus are mentioned. Unlike in the allied species *L. aculeocaudata* in which the larval development is restricted to 4 stages, the present species passes through 5 larval stages. The delayed development of the third to fifth pereopods and the suppression of the first pleopod in the earlier stage are features of probable phylogenetic significance.

INTRODUCTION

A series of plankton samples collected during two cruises made in the fishing-cum-training vessel BLUE FIN under a joint project of the National Institute of Oceanography and the Central Institute of Fisheries Operatives, off Cochin, Alleppey and Quilon coasts in depths ranging upto 1000 m form the basis of the present contribution. On analysis of the planktonic decapods sorted out from these samples it was found that both adults and different developmental stages of a pasiphaeid (Decapoda, Caridea) *Leptochela robusta* Stimpson were represented in large numbers. The species being a new record from this region, opportunity is taken to report about it and describe the complete larval history of the same, in view of its importance as a forage species of the locality, forming a significant part of the food of some of the pelagic fishes.

Among the eight or nine species of *Leptochela* recorded so far, larval development of four species are either partly or fully known. Gurney (1935) described five larval and two postlarval stages of two species together, namely, *L. bermudensis* (as *L. carinata*) and *L. pugnax*. Larval and post-larval development of *L. aculeocaudata* was traced by Menon (1937) from the east coast of India. Dakin and Colefax (1940) while describing the new species *L. sydniensis* reported the larval stages also, although detailed descriptions are lacking. Pillai (1955) repeated the description of *L. aculeocaudata* from the plankton collections from Trivandrum coast. The occurrence of large numbers of various stages of larvae along with juveniles and adults of *L. robusta* in the present collections has made it possible to trace the complete larval and post-larval development through all the stages reported here.

TRIBE CARIDEA

Family Pasiphaeidae

Leptochela robusta Stimpson

Leptochela robusta Stimpson 1860: p. 43; de Man 1920: p. 19; Rathbun 1903: p. 929; Balss 1915: p. 17; 1920: p. 7; Borradaile 1917: p. 398; Kemp 1925: p. 252; Gurney 1939: p. 428; Hayashi and Miyake 1969: p. 5.

Material: Several specimens of various sizes of juveniles and adults obtained from plankton samples collected from 200m up. Specimens in different stages of digestion were obtained from the stomachs of flying fishes and tunas.

Locality: Southwest coast of India, off Quilon, Alleppey and Cochin in waters of depth ranging from 20 m to 1000 m.

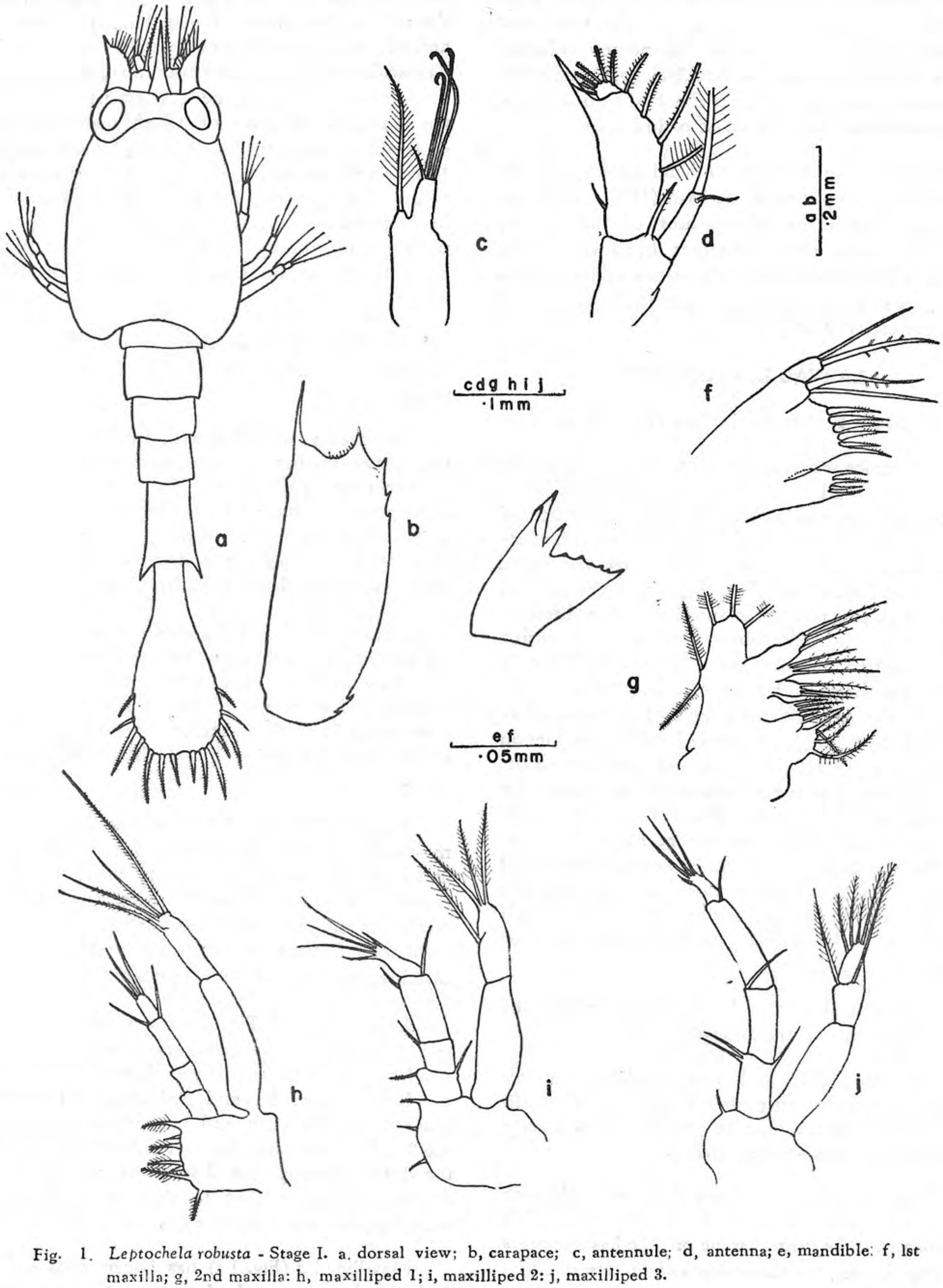

Fig. 1. *Leptochela robusta* - Stage I. a, dorsal view; b, carapace; c, antennule; d, antenna; e, mandible; f, lst maxilla; g, 2nd maxilla: h, maxilliped 1; i, maxilliped 2: j, maxilliped 3.

Distribution: The species has a distribution in the Indo-Pacific region in Hawaii Islands, north-east coast of Australia, Chinese Sea, numerous localities in the East Indian Archipelago, Maldive Islands and Red Sea. This is the first record of the species from nearer the coast of India.

Remarks: The material on hand agrees with the detailed descriptions of de Man (1920) and Kemp (1925). The diagnostic features of the species, namely the three pairs of spines in advance of the apex of the telson and the presence of more than 35 spines on the fingers of the chela of the 2nd leg are clearly seen.

LARVAL DEVELOPMENT

Stage I – Length 1.8 mm (Fig. 1a- j)

Carapace with long straight rostrum extending slightly beyond antennal scale; with two small protuberances on the mid-dorsal line, one behind eye and the other towards the posterior end, ventral margin with a large anterolateral spine and three small teeth behind it, (Fig. 1b) posterolateral angle with two teeth; the anterior margin between the eye and the anterolateral spine beset with a fringe of stiff minute teeth. Gurney (1935) calls them stiff hairs in his stage III *L. pugnax* and he records the posterolateral angle of the carapace as smooth. In *L. aculeocaudata* according to Menon (1937) the anterolateral spine and the 3 teeth behind it as well as the minute teeth at the anterior margin appear at stage II and the teeth at the posterolateral margin appear at stage III only. Dakin and Colefax (1940), however, describe all these characters of the carapace including the "fringe of very small stiff processes like small spinelets" at the anterior margin in stage I *L. sydniensis*.

Eyes well developed but not separate from the anterior margin of the carapace.

Antennule (Fig. 1c) has an unjointed peduncle with a long and stout plumose seta and the rudiment of one of the flagella possessing 3 long aesthetes and a short seta terminally.

Antenna (Fig. 1 d) has a short peduncle with a stout ventral spine as in *L. bermudensis* and *L. sydniensis*. The ventral spine on the basis appears in stage II only in *L. aculeocaudata* described by Menon (1937). The endopod which is the rudimentary flagellum is a slender rod, less than half the scale in length carrying a long plumose seta apically and a small seta laterally near the tip. The scale with a straight outer margin produced distally into a sharp spine. Along its inner margin and tip are 10 setae of which 6 are borne on a terminal segment; 9 setae are plumose and the 10th is a reduced seta present just internal to the spine. On the outer margin there is a small hair in the proximal half. In *L. bermudensis* in the figure given by Gurney (1935) this small hair on the outer margin of the scale is shown in the distal half.

The incisor part of the mandible (Fig. 1 e) is tridentate and the molar part is broad with few teeth.

1st maxilla (Fig. 1 f) with two endites and a stout, two-segmented palp, each segment carrying two setae at the distal ends. Menon's (1937) description of stage I *L. aculeocaudata* shows a single seta in each joint of the palp while in same stage of *L. bermudensis* two setae are shown in each joint in the figure given by Gurney (1935).

2nd maxilla (Fig. 1 g) with 4 well-marked endites carrying 3 to 5 setae; endopod unsegmented with two inner lobes carrying 3 setae each at the tips; exopod or scaphognathite small, with 5 plumose setae, 3 anteriorly and 2 posteriorly of which one is directed anteriorad and the other posteriorad.

Maxilliped 1 (Fig. 1 h) has a well developed masticatory basipodite bearing 5 plumose setae and 2 smaller spine-like setae; endopod 4-segmented with the 3rd segment longest and carrying one outer and one inner seta distally, distal segment with 3 setae at the tip; exopod 2-jointed, distal segment tipped with 4 plumose setae.

In maxilliped 2 (Fig. 1 i) the masticatory lobe of the basipodite has only 3 small setae; endopod similar to that of maxilliped 1, except for the number of setae; 1st and 3rd segments have one seta each on the outer and inner margins distally, the 2nd has 1 seta on the outer distal margin and the distal segment has 5 setae of which 2 are shorter; exopod similar to that of maxilliped 1 with 4 plumose setae at the tip.

Maxilliped 3 (Fig. 1 j) has 4-segmented endopod with 3 setae on the 1st segment, 1 each on

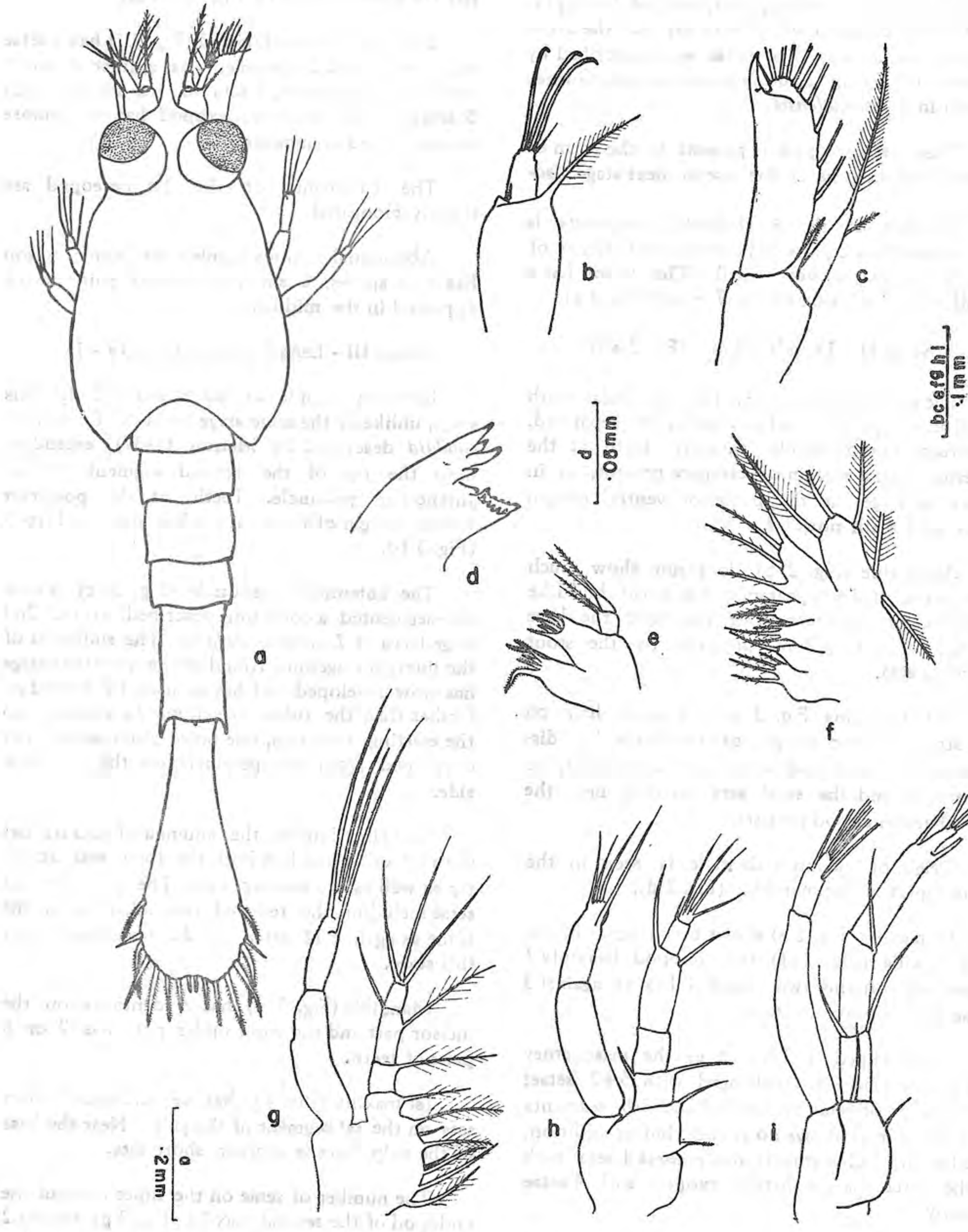

Fig. 2. *L. robusta* - Stage II a, dorsal view; b, antennule; c, antenna; d, mandible; e, 1st maxilla; f, 2nd maxilla; g, maxilliped 1; h, maxilliped 2; i, maxilliped 3.

2nd and 3rd segments and 5 setae of which 2 are shorter on the distal segment; exopod has 6 plumose setae arranged asymmetrically on the distal segment as against 5 plumose setae described by Menon (1937) in *L. aculeocaudata*, and Gurney (1935) in *L. bermudensis*.

The first pereopod is present in the form of a small rudiment as is the case in next stage also.

The last of the 5 abdominal segments is thinner and has 2 pairs of posterolateral spines of which one pair is very small. The telson has a small median incision and 7+7 spines (Fig, 1 a).

Stage II - Length 2.2 mm (Fig. 2 a-i)

The eyes are completely free, globular with small inner papilla and corneal part separated. Rostrum comparatively shorter, teeth at the anterior ventral margin of carapace present, as in previous stage; at the posterior ventral margin there are 3 teeth now.

Antennule (Fig. 2 b) does not show much change except the appearance of a small bud-like rudiment of the internal flagellum near the base of the outer flagellum, opposite to the stout plumose seta.

In the antenna (Fig. 2 c) the small hair on the straight outer margin of the scale has disappeared; the endopod as well as the ventral spine are stouter and the small seta laterally near the tip of the endopod persists.

Origin of one more denticle is seen in the incisor part of the mandible (Fig. 2 d),

Ist maxilla (Fig. 2 e) shows no change. In the 2nd maxilla (Fig. 2 f) the endopod has only 2 setae each on the two inner lobes as against 3 setae in the previous stage.

In maxilliped 1 (Fig. 2 g) the masticatory basipodite remains unchanged with 5+2 setae; the number of setae on the 3rd and 4th segments of the endopod shows no change, but in addition, the 1st and 2nd segments also possess 1 seta each at the outer margin distally; exopod with 4 setae apically.

The basipodite of maxilliped 2 (Fig. 2 h) has only 2 setae and the second segment of the endopod has no seta on it in this stage; exopod has the same number of 4 plumose setae.

Endopod of maxilliped 3 (Fig 2 i) has 2 setae each on 1st and 2nd segments as against 3 and 1 seta in previous stage, 1 seta on 3rd segment and 5 setae on 4th segment; exopod has 6 plumose setae arranged asymmetrically.

The rudiments of the 1st pereopod are slightly elongated.

Abdominal somites number the same; telson has 8+8 spines, a small additional pair having appeared in the middle.

Stage III - Length 2.8 mm (Fig. 3 a - 1)

Rostrum is not so much reduced in this stage, unlike in the same stage larva of *L. aculeocaudata* described by Menon (1937), extending upto the tip of the second segment of the antennular peduncle. Teeth at the posterior ventral margin of the carapace has increased to 5 (Fig. 3 b).

The antennular peduncle (Fig. 3 c) is now two-segmented, a condition described in the 2nd stage larva of *L. aculeocaudata*. The rudiment of the internal flagellum found in the previous stage has now developed and has an acute tip extending farther than the other flagellum. In addition to the existing stout seta, one more plumose seta has developed from the peduncle on the opposite side.

The flagellum of the antenna (Fig. 3 d) has grown stouter and lost both the long seta at the tip as well as the smaller one. The scale has 11 setae including the reduced one adjacent to the spine as against 12 setae in *L. aculeocaudata* at this stage.

Mandible (Fig. 3 e) has 4 denticles on the incisor part and the stout molar part has 7 or 8 pairs of teeth.

1st maxilla (Fig. 3 f) has an additional short seta on the 1st segment of the palp. Near the base of the palp there is another short seta.

The number of setae on the inner lobes of the endopod of the second maxilla (Fig. 3 g) remain 2 each as in previous stage; the scaphognathite has 7 plumose setae in this stage as in the case of

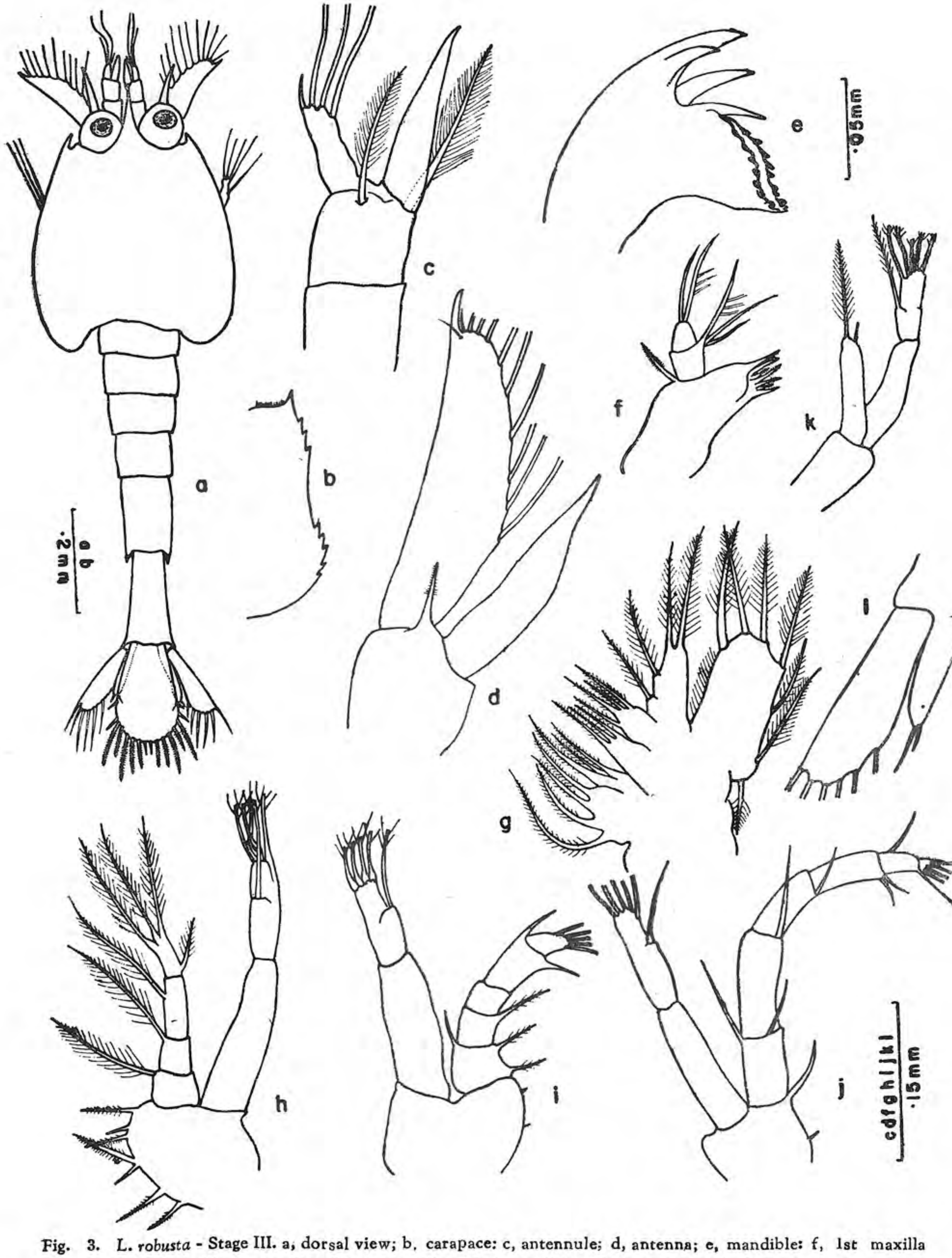

Fig. 3. *L. robusta* - Stage III. a, dorsal view; b, carapace: c, antennule; d, antenna; e, mandible: f, 1st maxilla g, 2nd maxilla; h, maxilliped 1; i, maxilliped 2; j, maxilliped 3; k, pereopod 1: l, uropod.

L. aculeocaudata; its inner margin beset with a fringe of small hairs.

The basipodite of maxilliped 1 (Fig. 3 h) has 5+2 setae: endopod also shows no change; exopod has now 5 plumose setae arranged asymmetrically at the tip.

The endopod of both maxillipeds 2 and 3 are 5 - segmented, a condition noticed in the 2nd stage of *L. aculeocaudata* by Menon (1937). In maxilliped 2 (Fig. 3 i) the 1st segment has 3 setae, one seta each proximally and distally on the outer margin and 1 seta in the inner margin; 1 seta on the outer margin in 2nd segment; no seta on 3rd segment; 1 seta each distally on the outer and inner margins in 4th segment and 5 setae at the tip of the 5th segment. Exopod has 5 plumose setae as against 4 in the previous stage.

Endopod of maxilliped 3 (Fig. 3 j) has 2 setae on the 1st segment; 1 seta each on the outer margin of 2nd and 3rd segments; 3 setae, 2 on the outer and 1 on inner margin distally on the 4th segment and 5 setae at the tip of the 5th segment. Exopod has 6 plumose setae distally.

1st pereopod (Fig. 3 k) has developed into a biramous appendage with an unsegmented endopod bearing 2 setae at the tip, one long and the other short; the exopod similar to that of the maxillipeds with 6 plumose setae at the tip of the second segment.

Abdomen has 6 segments in this stage with the uropods developed from the 6th segment; uropods (Fig. 3 l) biramous, the endopod having 2 setae at the tip and the exopod with 6 setae along the inner margin; no pleopods.

Telson has 8+8 spines as in the previous stage.

Stage IV – Length 3.4 mm (Fig. 4 a – 1)

The median dorsal tubercles present on the carapace (Fig. 4 a); rostrum shorter, extending just beyond the anterior extremity of the eye.

Both the flagella of the antennule (Fig 4 b) are longer and stouter; the three aesthetes on the outer flagellum arise from the middle on the inner side, with the short seta remaining at the tip; 1 or 2 minute hair-like setae are found on the inner margin of the internal flagellum; one more plumose, stout seta is now present opposite to the flagella, raising the number to 3.

Antennal scale (Fig. 4 c) with 11 setae as in previous stage.

Mandible and 1st maxilla show no change (Figs 4 d, e).

In the 2nd maxilla (Fig. 4 f) the scaphognathite has 8 plumose setae, one additional seta having appeared on the inner margin where there was a fringe of small hairs in the previous stage; the inner lobes of the palp has 5 setae.

Maxillipeds do not show much change from previous stage except for one or two additional setae in certain segments of the endopods. The endopod of the 3rd maxilliped possesses an additional seta on the distal internal margin of the 4th segment; exopods of maxillipeds 1 to 3 with 5, 5, 6 setae respectively, as in previous stage (Fig. 4 g, h, i).

Pereopod I (Fig. 4 j) has an endopod which is 4-segmented, 3rd segment being the longest; the origin of the chela is slightly evident by the slight elongation of the distal tip of the penultimate segment; 2 setae present on this segment one on each side distally; 1 seta present at the tip of last segment; exopod similar to that of last stage with 6 plumose setae at the tip.

Pereopod II (Fig. 4 k) is also biramous; endopod bud-like, unsegmented; exopod much smaller and finger-shaped.

Bud-like rudiments of pleopods present on the 2nd to 5th abdominal somites.

Uropods (Fig. 4 l) segmented; exopod with terminal spine and 8 setae, outer margin smooth; endopod with 5 setae, as against 9 and 6 setae respectively in the same stage of *L. pugnax* described by Gurney (1935).

Telson (Fig. 4 l) with a pair of lateral spines and 6 + 6 terminal spines.

Stage V – Length 3.9 mm (Fig. 5 a – m)

The number of teeth on the ventral margin of the carapace has increased by 1 or 2, both at the anterior and posterior regions. The median dorsal tubercles more prominent; rostrum extends beyond the eye.

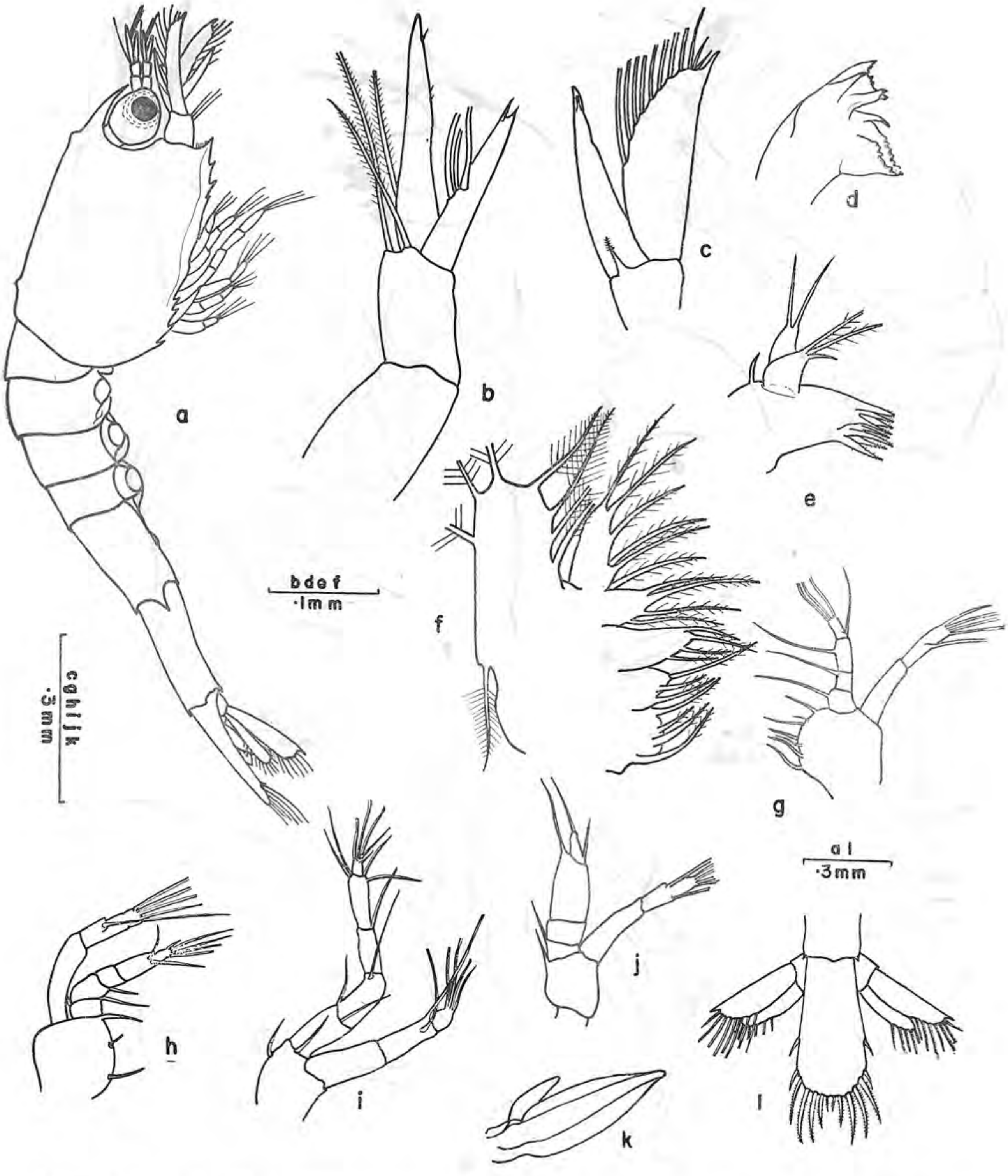

Fig. 4. *L. robusta* - Stage IV. a, lateral view; b, antennule; c, antenna; d, mandible; e, 1st maxilla; f, 2nd maxilla; g, maxilliped 1; h, maxilliped 2; i, maxilliped 3; j, pereopod 1; k, pereopod 2; l, telson and uropods.

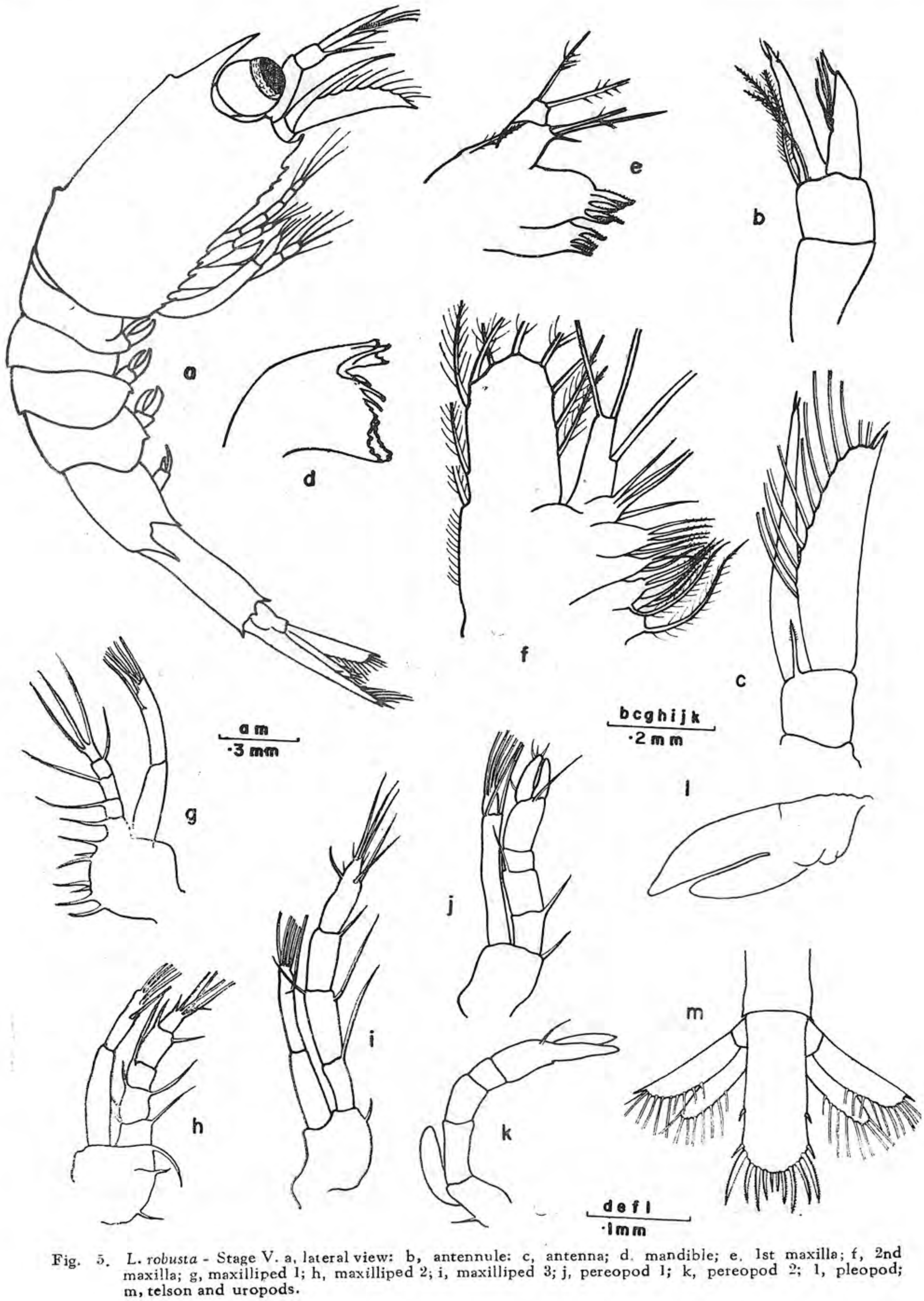

Fig. 5. *L. robusta* - Stage V. a, lateral view: b, antennule: c, antenna; d, mandible; e, 1st maxilla; f, 2nd maxilla; g, maxilliped 1; h, maxilliped 2; i, maxilliped 3; j, pereopod 1; k, pereopod 2; 1, pleopod; m, telson and uropods.

Antennular peduncle (Fig. 5 b) longer, 2- segmented; 2 short setae present at the tip of the endopod or internal flagellum which is longer than the exopod carrying the 3 aesthetes arising from the middle. In the figure of the stage V larva of *L. burmudensis* only 2 aesthetes are shown by Gurney (1935); 3 long plumose setae surrounding the internal flagellum.

Flagellum of the antenna (Fig. 5 c) longer than scale which has 13 setae as in *L. pugnax*.

Mandible and 1st maxilla as shown in figures 5 d, e.

2nd maxilla (Fig. 5 f) with 10 plumose setae on the scale. Both in *L. pugnax* and *L. aculeocaudata* there are only 9 setae in the scale of the last stage larva, stage V in the former and stage IV in the latter; palp with 7 setae.

Maxilliped I (Fig. 5 g) without any change; exopod has 5 setae apically.

Maxilliped 2 (Fig. 5 h) has 5 setae on the exopod; in the endopod, for the first time, there is a seta anteriorly on the inner margin of 3rd segment, second segment also shows an additional seta.

In maxilliped 3 (Fig. 5 i) the 2nd segment of the endopod has an additional seta on the internal distal margin; exopod with 6 setae apically.

Pereopod I (Fig. 5 j) with 5-segmented endopod, chelate terminally; tip of the chela with 3 setae; all segments except the third with 1 seta each; exopod as in previous stage, having 6 setae terminally.

Pereopod 2 (Fig. 5 k) also has a well-developed, 5-segmented endopod with terminal chela; only 1 seta present on the palm; exopod small, unsegmented and finger-shaped.

The other pereopods are rudimentary. Pleura of the abdominal segments developed; pleopods present on all abdominal segments except 1st; all biramous (Fig. 5 l) progressively decreasing in size posteriorly.

Uropod (Fig 5 m) has exopod with terminal spine and 10 setae; endopod with 8 setae.

Telson almost parallel sided, with lateral spine and 6 + 6 terminal spines.

POST-LARVAL DEVELOPMENT

Post-larva, stage I - length 4.1 mm (Fig. 6 a - o)

Rostrum basally broad and reaching beyond the 1st segment of antennular peduncle; the teeth at the ventral margin of carapace as in stage V larva. In *L. bermudensis* carapace has small median dorsal prominence behind the eye but without posterior papilla according to Gurney (1935). But in *L. robusta* both are present as in the last stage larva. Both Menon (1937) and Pillai (1955) do not make any mention about these tubercles in post-larval stage I of *L. aculeocaudata*.

Segment 1 of antennular peduncle (Fig. 6 b) with stout stylocerite reaching the tip of the segment; both flagella multisegmented; the 3 aesthetes are still seen in the second segment of the outer flagellum.

Antennal flagellum (Fig. 6c) well developed, multisegmented, about 3 times longer than the scale.

Mandible (Fig. 6 d) approaching adult form; with a series of about 10 teeth; small unsegmented, bud-like palp without seta.

Endopod of 1st maxilla faintly bifid with a seta on the inner lobe (Fig. 6e).

2nd maxilla (Fig. 6 f) with three inner lobes, endopod small, unsegmented and devoid of setae; exopod large, leaf-like fringed with many setae.

Maxilliped 1 (Fig. 6 g) with small, unsegmented endopod devoid of setae; exopod 2- segmented with the smaller distal segment fringed with setae; small bilobed epipod present. In *L. bermudensis* and *L. pugnax* large bilobed epipod is recorded in this appendage by Gurney (1935). Pillai (1955) records an epipod, long but not bilobed, in maxilliped 1 of the post-larva of *L. aculeocaudata* while Menon (1937) in his figure of the appendage of the same species does not show the epipod in this stage.

Maxilliped 2 (Fig. 6 h) of adult form, the last two segments of the endopod sharply bend downwards, the last segment with 4 setae distally and the penultimate segment with 2 setae on the outer margin; exopod long, 2-segmented and bearing 2 small terminal setae as against 4 in *L. bermudensis* and 3 shown in the figure of *L. aculeocaudata* by Menon (1937).

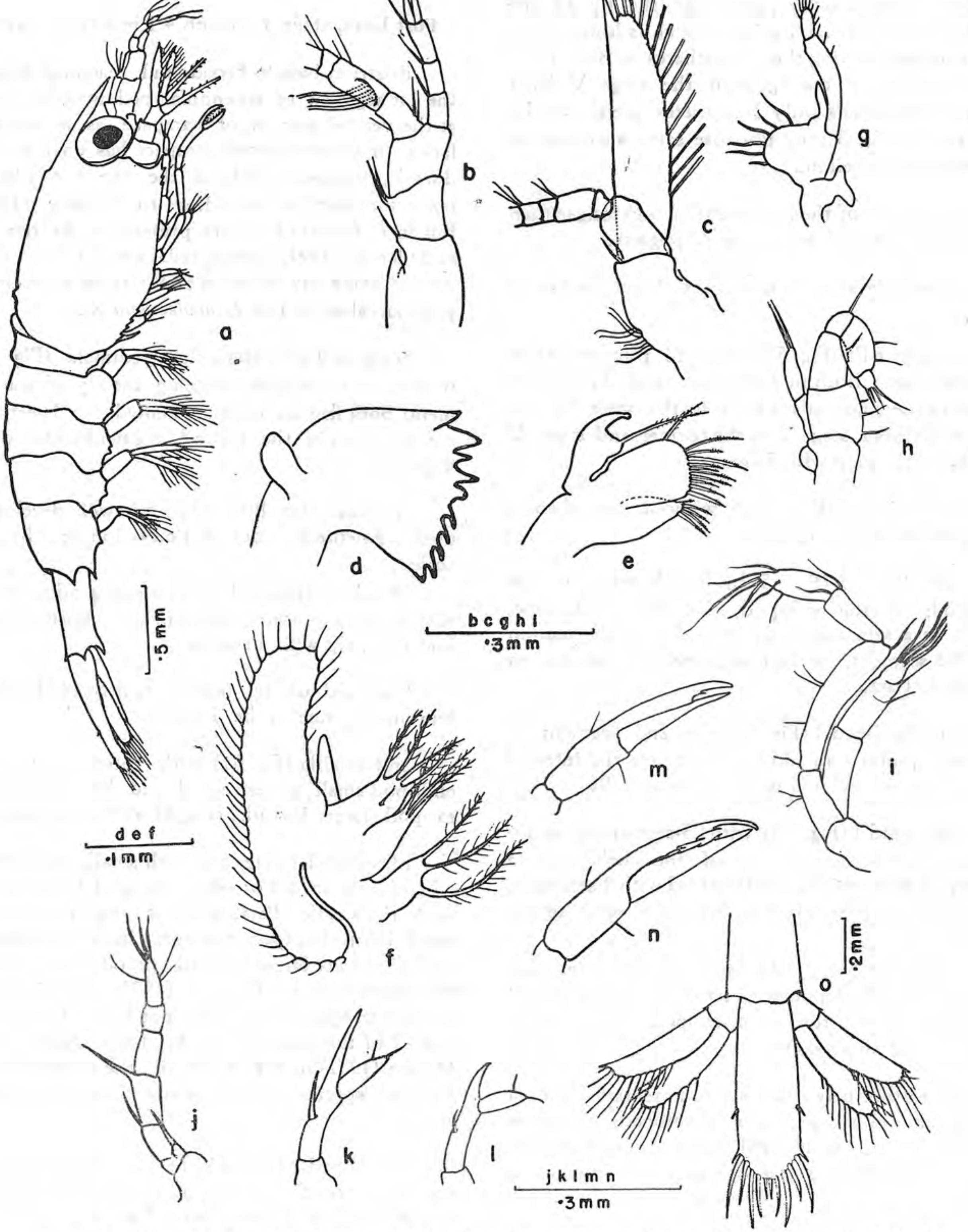

Fig. 6. *L. robusta* - Postlarva I. a, lateral view: b, antennule; c, antenna: d, mandible; e, 1st maxilla; f, 2nd maxilla; g, maxilliped 1; h, maxilliped 2; i, maxilliped 3; j, pereopod 3; k, pereopod 4; l, pereopod 5; m, chela of pereopod 1; n, chela of pereopod 2; o, telson and uropods.

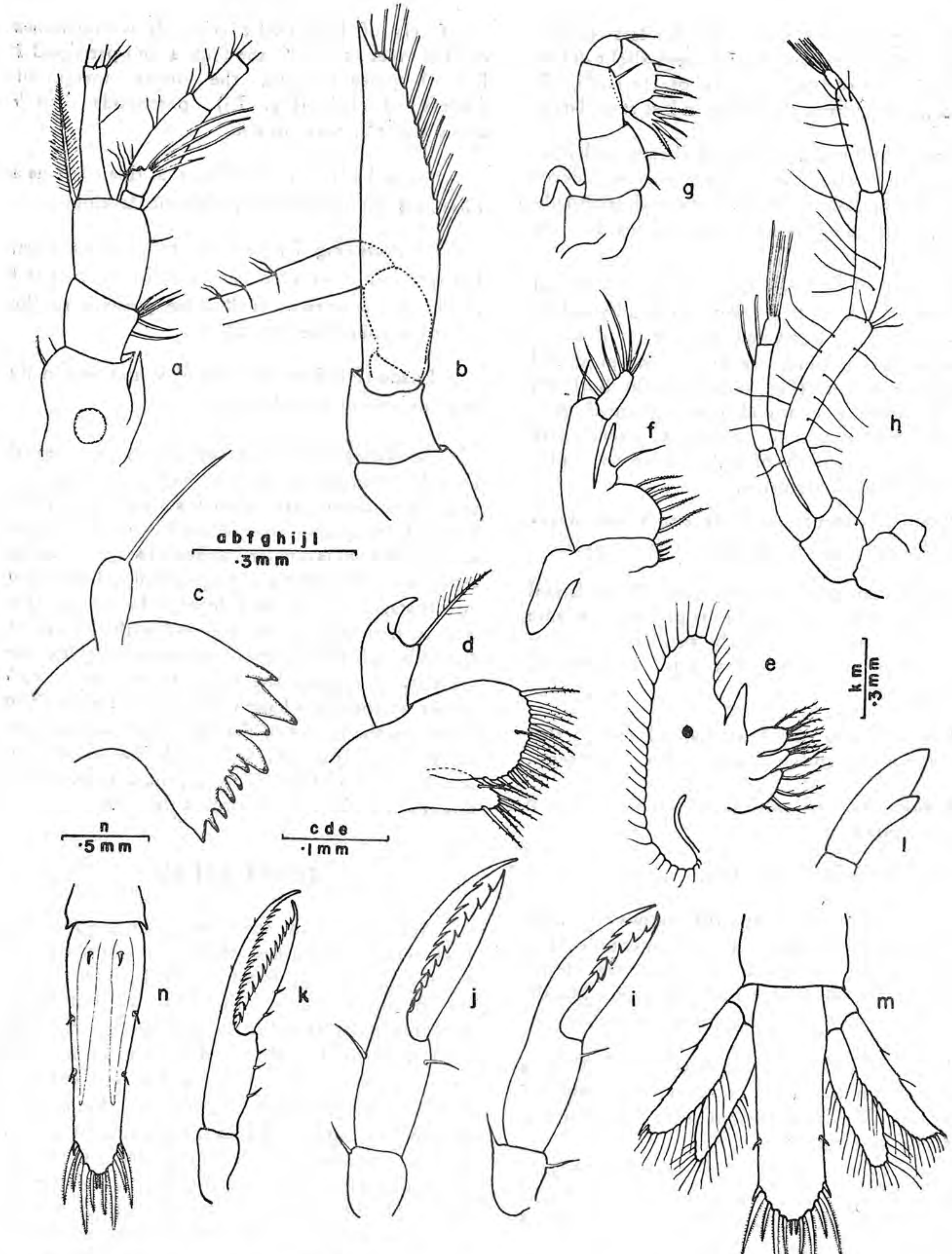

Fig. 7. *L. robusta* - Postlarva II. a, antennule; b, antenna; c, mandible; d, 1st maxilla; e, 2nd maxilla; f, maxilliped 1; g, maxilliped 2; h, maxilliped 3; i, chela of pereopod 1; j, chela of pereopod 2; k, chela of pereopod 2 of specimen of 7 mm length: l, pleopod 1 of postlarva II; m, telson and uropods of postlarva II; n, telson of specimen of 7 mm length.

Maxilliped 3 (Fig. 6 i) more or less similar to that of the previous stage, except slight differences in the size of the segments of the endopod; exopod has the terminal setae as in last stage larva.

Pereopods 1 and 2 large and chelate with exopods bearing 6 setae terminally; chelae well developed in both, fingers with 1 spine each internally in the 1st leg and 3 spines each in the 2nd leg (Fig. 6 m, n).

Pereopods 3 to 5 are short, especially 4 and 5; rudimentary exopod present on 3rd leg while exopods absent in legs 4 and 5, in each of which the basis and ischium are fused and produced into a large spine. (Fig. 6 j, k, l). In both 4th and 5th legs the endopod is unsegmented as in *L. bermudensis*, but differing from *L. pugnax* and *L. aculeocaudata*, both of which have the endopod divided into 2 segments.

Pleopod 1 absent; pleopods 2 to 5 well developed, the endopods nearly as large as exopods.

Abdominal somite 5 with large dorso-lateral and smaller ventrolateral spinous processes; somite 6 also with similar but slightly smaller processes; abdominal pleura of somites 3 to 5 with small ventral points.

Uropods (Fig. 6 o) unchanged except that both exopod and endopod show a few more setae.

Telson (Fig. 6 o) with lateral spine and 6+6 terminal spines.

Post-larva, stage II 5.0 mm (**Fig.** 7 a-n)

The second stage post-larva shows very little progress in development. In the antennule (Fig. 7a) the stylocerite and the statocyst are clearly seen in the 1st segment of the peduncle. Mandibular palp (Fig. 7 c) has developed a seta.

Endopod of maxilliped 1 (Fig. 7 f) with a single seta on the inner side; terminal smaller segment of the exopod fringed with 8 setae on the outer side and tip.

Maxilliped 2 (Fig. 7 g) has unsegmented exopod devoid of setae; last segment of endopod with 5 stout setae and penultimate segment with 4 setae; previous 2 segments have 1 seta each.

Maxilliped 3 (Fig. 7 h) shows not much change except in the number of setae on the segments of endopod.

Chela of Pereopod 1 (Fig. 7 i) with 6 spines on the inner side of the fingers and pereopod 2 has 10 spines each on the inner margin of fingers of chela (Fig. 7 j) ; pereopods 3 to 5 show slight increase in size.

Pleopod 1 (Fig. 7 1) appears at this stage as a biramous bud; other pleopods well developed.

Uropods (Fig. 7 m) similar to previous stage, but with addition of setae on both exopod and endopod; one or two small setae present on the outer margin of the exopod.

Telson (Fig. 7 m) with 6+6 spines terminally and one pair of lateral spines.

According to Gurney (1935) in the case of both *L. bermudensis* and *L. pugnax* it is hardly possible to distinguish different stages in their post-larval development after stage II. In the present species also it is similar, although stage III can be separated, as the first pleopod becomes functional at this stage. At 7.0 mm length the telson (Fig 7 n) is narrower at the tip and with 3 pairs of spines in advance of apex, where 6+6 spines are present. It reaches the adult form, with 5+5 spines at apex, at a length of about 19 mm. The spines on the fingers of the chela increase in number gradually (Fig. 7k) and reach the adult form at a length of 19 mm. The appendix masculina is noticed in rudimentary form at this time.

DISCUSSION

While recording specimens from the Red Sea, Balss (1915) suggested that *L. aculeocaudata* is synonymous with *L. robusta*. De Man (1920) also was inclined to agree with this view. But Kemp (1925) regarded these as distinct species, based on the important characters of differences in the number of spines on the telson as well as number of spines on the dactylus of 2nd leg. Among the two species, so far the developmental stages of *L. aculeocaudata* only was known from the works of Menon (1937) and Pillai (1955). The present study of the larval development of *L. robusta* shows some marked differences in the number of larval stages as well as other distinct characters in the different stages. This would give added evidence to support Kemp's point of view and to establish that the two species are quite distinct.

In his description of the larval development of *L. aculeocaudata,* Menon (1937) has come across only 4 stages, the 4th stage larva developing into 1st post-larva. However, Gurney (1935) found that both *L. pugnax* and *L. bermudensis* (as *L. carinata*) pass through 5 larval stages before reaching the first post-larval stage. Dakin and Colefax (1940) also recorded 5 stages in the development of *L. sydniensis*. 5 stages of larvae are found in *L. robusta* of the present study too.

One of the interesting features in the development of *Leptochela robusta*, as in other species of the genus, is the delayed development of legs 3-5, the 3 legs being developed only in the first post-larval stage. Even at this stage legs 4 and 5are comparatively less developed with complete absence of exopods, the 3rd leg having a bud-like rudiment of an exopod. The suppression of pleopod 1 in the larva and its gradual appearance in later post-larval stages is another interesting feature in the development of the species. According to Gurney (1942) the occurrence of these features "especially in a genus belonging to a family supposed to be primitive" is remarkable. Based on an extensive study of adult morphological comparison in Section Caridea, Thompson (1966) concluded that Superfamily Pasiphaeoida left the main carid stem early in the evolution of the section and got adopted for pelagic existence. The above features in the larval development of the genus confuse rather than aid phylogenetic interpretation along this line.

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