Systematics and Ecology of New Zealand Central East Coast Plankton Sampled at Kaikoura

by

J. M. Bradford

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FOREWORD

Our knowledge of the composition and ecology of the New Zealand plankton fauna has, up to the present, been slight. Within recent years several studies have been made of regional faunas that will increase substantially the information available.

In this Memoir the author examines the environmental relationships and seasonal changes for the plankton sampled in the Kaikoura region of central New Zealand. She also discusses the taxonomic position of the copepod species sampled and provides a key to the pelagic copepods.

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CONTENTS

Systematics and Ecology of New Zealand Central East Coast Plankton Sampled at Kaikoura

by J. M. Bradford

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Abstract

Salinity, temperature, density, nitrate concentration, transparency, chlorophyll *a* concentration, and quantity of zooplankton (as weights and numbers) were measured every fortnight at 173° 48.5'E, 42° 26'S, off Kaikoura, New Zealand, over 13 months from April 1964 to May 1965. All these data were used to assess the seasonal, successive, and advective changes that might have taken place in the plankton.

Advective changes were the most important: invasions of oceanic subtropical water into a cold coastal situation, considered responsible for the extension of the phytoplankton bloom in spring; chlorophyll *a* maxima at depths expected of more transparent offshore waters; low average total zooplankton biomass (68 mg/m³); rapid fluctuations in zooplankton biomass and copepod numbers; increases in the number of oceanic copepod species captured; and the capture of euphausids with reduced fat reserves.

All adult copepod species occurring in plankton samples from an area off Kaikoura on the east coast, South Island, New Zealand, are recorded, and discussed taxonomically where appropriate.

Collections were made over a period of 13 months (April 1964 to May 1965) and represent samples taken inshore at the surface, over the continental slope to 200m, and in deeper water to 600m.

A key to the pelagic Copepoda is given.

SECTION 1

PELAGIC COPEPODA, WITH A KEY TO GENERA

INTRODUCTION

Until relatively recently contributions to knowledge of New Zealand marine copepod fauna had come almost exclusively from reports on material collected by various expeditions in the south-east Australia and New Zealand area (Fig. 1). Of these the British Antarctic *Terra Nova* Expedition contributed most to the knowledge of the Copepoda with 70 stations (64 north of Auckland) in New Zealand waters. Before this the *Challenger* Expedition occupied a few stations off eastern Australia, but Brady's (1883) report is of little taxonomic value as it has many errors.

Dakin and Colefax (1940) surveyed plankton off Sydney, and Vervoort (1957) has reported on British, Australian, and New Zealand Antarctic Research Expedition (BANZARE) material from two stations just south of Tasmania. Collections of copepods taken from other expedition ships that have visited the area, *Dana* 1928-30, *Discovery II* 1932-51, *Galathea* 1950-52, *Ob* 1955-58, *Vitiaz* 1957-58, *Eltanin* 1964- , have not yet been described.

Small collections of copepods have been dealt with by Kramer (1894) (from the Hauraki Gulf), Brady (1899) and Thomson and Anderton (1921) (both from Dunedin Harbour), and Bary (1951) (from the east coast of the South Island, particularly the south-eastern part). There has been no attempt at a comprehensive work on the New Zealand marine copepod fauna.

SOURCE OF MATERIAL

From April 1964 to May 1965 samples were taken from Mr R. Baxter's fishing boat *Virgo* at three Kaikoura stations (Table 1). The occurrence of each species (Table 2) was compiled from these records. Most of the samples were collected from Sta. 1 about 8 km east of the Kaikoura Peninsula. Two types of samples were taken: vertical hauls from 200 m to the surface with an N70 net, and horizontal hauls with a Clarke-Bumpus sampler, both with mesh aperture of 176μ. The maximum depth of the Clarke-Bumpus sampler hauls was determined approximately by a Kelvin tube on the wire just below the sampler. On two occasions vertical collections were taken below 200 m with the N70 net at Sta. 3. Hauls from 600 m to the surface on 29 October, 1964, and from 500 m to 200 m on 5 May, 1965, were secured. Horizontal surface samples were taken on other occasions at Sta. 2 very close to the peninsula.

Although the entire collection comes from one area, many species are probably typical of the nearshore plankton from Foveaux Strait to Castlepoint, Kaikoura being influenced by the north-flowing Southland and Canterbury Currents (Brodie, 1960). The New Zealand region presents contrasting environments from subantarctic to subtropical due to its geographical position and the nature of the current circulation. Cold subantarctic species, such as *Calanus simillimus* and *Clausocalanus laticeps,* found in the southern part of the New Zealand region, and strictly subtropical species

are not represented in the present collection. Though warm oceanic water encroached on the continental shelf at Kaikoura and brought with it oceanic species, none were subtropical species (such as *Canthocalanus pauper, Nannocalanus minor, Undinula vulgaris, Eucalanus attenuatus, Sapphirina* sp., *Corycella* sp., and *Corycaeus* sp.) typically found in the north of the New Zealand region and on the east Australian coast.

TABLE 1 Dates on which plankton samples were taken at Stations 1, 2, and 3

STATION 1 200m 173° 48.5′E, 42° 26′S

1.	14 Apr 64	13.	11 Oct
2.	30 Apr	14.	29 Oct
3.	16 May	15.	17 Nov
4.	1 Jun	16.	5 Dec
5.	15 Jun	17.	21 Dec
6.	26 Jun	18.	7 Jan 65
7.	12 Jul	19.	24 Jan
8.	2 Aug	20.	24 Feb
9.	16 Aug	21.	12 Mar
10.	29 Aug	22.	4 Apr
11.	13 Sep	23.	18 Apr
12.	26 Sep	24.	5 May

STATION 2 40m 173° 43.5′E. 42° 25′S

1.	14 Aug 63	3.	14 Apr 64
2.	22 Oct 63	4.	7 Jan 65

STATION 3 600m 173° 52′E. 42° 26′S

1.	29 Oct 64	2.	5 May 65

METHODS

Each copepod was dissected with fine needles and the parts mounted semi-permanently in Kaiser's Glycerine Jelly (Gatenby and Painter, 1937) for detailed microscopic examination. This mixture sets when cooled but may be melted by gentle heat. Thus a limb or a whole animal may be observed from several different angles. All small or delicate copepods were first left in a mixture of glycerine, alcohol, and water in the proportions 1 : 1 : 2 until the mixture concentrated, otherwise the integument collapsed and distorted the copepod form. More robust animals were transferred directly from preservative to Glycerine Jelly. A few specimens of each were measured from the anterior margin of the head to the posterior border of the furca. These measurements were used to check specific identity according to size ranges.

Genera were determined from Rose's (1933) key, the most useful for pelagic Copepoda. A translation of

it, prepared and modified in the light of recent publications, is given below.

Genera added to the key are: *Acrocalanus* (*see* Wilson, 1932); *Batheuchaeta* Brodsky (1950); *Benthomisophria* (*see* Hulsemann and Grice, 1964); *Bradycalanus* (*see* Sewell, 1947); *Bradyidius* (*see* Wilson, 1950, for discussion of priority of *Bradyidius* over *Undinopsis*)*; Calanoides* Brady (1883); *Calanopia* (*see* Wilson, 1932); *Canthocalanus* A. Scott (1909); *Chirundinella* Tanaka (1957); *Comantenna* (*see* J. Matthews (1964) for discussion on priority of *Comantenna* over *Bryaxis*); *Derjuginia* (*see* Brodsky, 1950); *Disco* Grice and Hulsemann (1965, *see also* 1967); *Epilabidocera* Wilson (1932); *Foxtonia* Hulsemann and Grice (1963); *Gaidiopsis* A. Scott (1909); *Gaussia* (*see* Sewell, 1932); *Ischnocalanus* Bernard (1963); *Macandrewella* A. Scott (1909); *Mesaiokeras* J. Matthews (1961); *Mixtocalanus* Brodsky (1950);
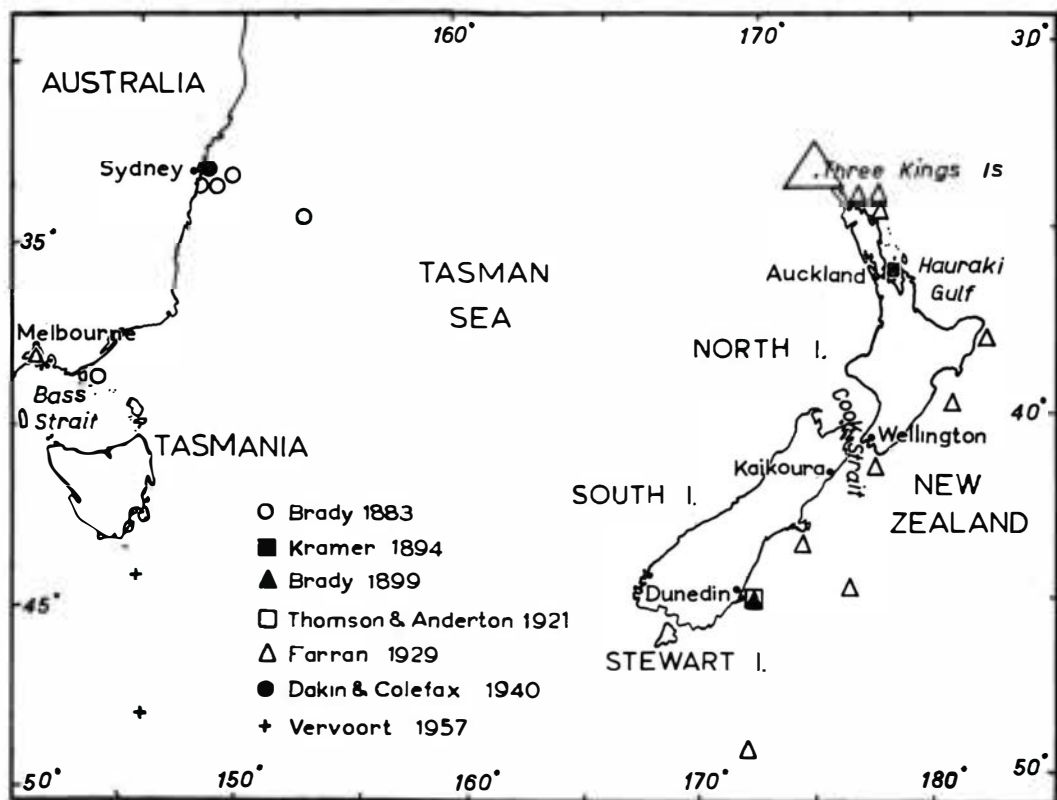
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FIG. 1. Map showing localities dealt with in previous work

Nannocalanus Sars (1925); *Neoaugaptilus* Brodsky (1950); *Neocalanus* Sars (1925); *Neopontella* A. Scott (1909); *Paivella* Vervoort (1965a); *Paracandacia* Grice (1963); *Paralabidocera* (*see* Wilson, 1932); *Parascaphocalanus* Brodsky (1955); *Parundinella* Fleminger (1957); *Pseudaetideus* (*see* Wilson, 1932); *Pseudodiaptomus* (*see* Wilson, 1932); *Racovitzanus* Giesbrecht (1902); *Ryocalanus* Tanaka (1956); *Scolecocalanus* Farran (1936); *Snelliaetideus* Vervoort (1949); *Sognocalanus* Fosshagen (1967); *Spicipes* Grice and Hulsemann (1965); *Teneriforma* Grice and Hulsemann (1967); *Undinothrix* Tanaka (1961); *Zenkevitchiella* (*see* Grice and Hulsemann, 1965).

The genus *Rhinomaxillaris* Grice and Hulsemann (1967) has not been included in the key. It has been placed tentatively in the family Bathypontiidae as it was described from a specimen without complete swimming legs.

Most of the figures are redrawn from Rose; Key-figs 56-9 are from Sewell (1947); Key-figs 27, 28 from Grice (1961); Key-fig. 259 from Grice (1963); Key-

figs 29, 31 from Giesbrecht (1892); Key-fig. 30 from Dakin and Colefax (1940); Key-fig. 179 from Fleminger (1957); and Key-figs 26, 33, 95 are original figures by the author.

Giesbrecht's obsolete division of the Copepoda, based on the position of the movable joint between the anterior (metasome) and the posterior (urosome) body, is used for convenience in this key as it fits the pelagic Copepoda well. (For general body and limb structure see Figs 2 and 3.)

Gymnoplea. The anterior division consists of the head and five thoracic segments, and the posterior division contains typically five abdominal segments in the male and fewer in the female, although fusions may reduce this number in both sexes to one or two.

Podoplea. The last thoracic segment with its rudimentary pair of legs is part of the posterior division.

Propodoplea. The body is divided as for the Podoplea, but the A1 has a large number of segments and A2 is biramous. The egg sac is single. *Benthomisophria* is the only genus in this group.

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TABLE. 2. Occurrence of Marine Copepod Species at Kaikoura

Species	14 April	30 April	16 May	1 June	15 June	26 June	12 July	2 Aug	16 Aug	29 Aug	13 Sept	26 Sept	11 Oct	29 Oct	17 Nov	5 Dec	21 Dec	7 Jan	24 Jan	24 Feb	12 Mar	4 April	18 April	5 May	14 Aug	22 Oct	14 April	7 Jan
									1964												1965				1963		1964	1965
Calanus australis	×	×	×	×	×	×		×		×	×	×	×	×	×	×	×	×	×			×	×	×	■		■	■
*C. tenuicornis		×	×		×		×			×	×	×					×	×	×	×	×			×				
*C. tonsus								×			×	×	×	×	×	×	×	×	×					×●				■
*Calanoides carinatus			×			×					×	×	×	×	×		×	×	×					×				
*Neocalanus gracilis			×			×										×						×	×	×				
*Eucalanus elongatus	×			×	×					×					×			×	×		×	×	×					
*E. longiceps	×		×		×		×				×	×	×	×	×			×	×		×	×	×					
*Rhincalanus nasutus				×																				●				
*Mecynocera clausi			×												×													
Paracalanus parvus	×	×	×	×	×	×	×	×	×	×	×	×	×	●	×	×	×	×	×	×	×	×	×	×	■	■	■	■
*Calocalanus styliremis		×		×	×			×								×												
*C. tenuis				×	×								×															
*Ctenocalanus vanus	×																											
Clausocalanus arcuicornis	×	×	×	×		×			×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		■	■	
C. pergens	×		×		×		×	×				×		×									×	●				
*Aetideus armatus	×							records incomplete							×							×		●				
*Euaetideus giesbrechti	×																							●				
*Aetideopsis sp.													×	●								×		●				
Bradyidius sp.														●										●				
*Chiridius gracilis				×							×			●										●				
Gaidius tenuispinus																								●				
Gaetanus minor														●										●				
*Euchirella rostrata														●		×	×							●				
*E. venusta														●						×				●				
*Pseudochirella sp.														●										●				
*Undeuchaeta plumosa														●						×				●				
*Euchaeta biloba				×										●										●				
E. exigua?														●										●				
E. acuta														●										●				
*Phaenna spinifera																							×					
Xanthocalanus sp.														●										●				
Scottocalanus persecans														●														
*Scaphocalanus echinatus																				×				●				
*Scolecithricella dentata						×																						
*S. glacialis	×	×												×					×			×		×				
*Metridia lucens	×		×	×	×	×		×	×	×	×	×	×	×	×	×		×	×	×		×	×	×				
*Pleuromamma abdominalis			×	×	×			×						●					×					●				
*P. gracilis	×	×	×	×	×	×		×	×		×	×	×	×	×	×		×	×		×	×	×	×				
*P. robusta				×	×	×		×						●					×					×				
*P. xiphias																			×									
Centropages aucklandicus	×		×		×	×		×	×	×	×	×	×	×				×	×	×	×	×	×	×	■	■	■	
*C. bradyi	×		×														×											
*Lucicutia flavicornis			×	×	×		×												×									
*Heterorhabdus papilliger			×																									
*Haloptilus oxycephalus														●					×					●				
*Candacia cheirura			×								×	×		●	×		×		×					●				
Labidocera cervi						×	×			×	×	×	×	×			×			×			×	×				
Acartia clausi	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×	■	■	■■	■
Oithona atlantica		×	×		×	×	×	×	×	×	×	×	×	×	×	×		×	×	×	×	×	×	×			■	■
O. similis	×			×	×		×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	■		■	
*Oncaea conifera								×						●										●				
*O. mediterranea	×	×	×	×	×			×				×	×	×	×	×		×	×	×	×	×	×	×			■	
Euterpina acutifrons				×				×																×				
Harpacticus sp.													×															
Clytemnestra rostrata						×																						
TOTAL AT STA. 1	18	12	19	20	18	15	12	19	8	10	17	17	16	12	16	16	12	17	22	12	15	15	12	15				
TOTAL AT STA. 2																									5	4	7	6
TOTAL AT STA. 3														13										14				
TOTAL OCEANIC SPECIES AT STA. 1	11	6	12	12	9	8	3	10	2	3	9	10	7	5	9	7	7	8	15	5	7	9	6	7				

* Oceanic species at Sta. 1; Sta. 1 (The Permanent Station) = ×; Sta. 2 = ■; Sta. 3 = ●
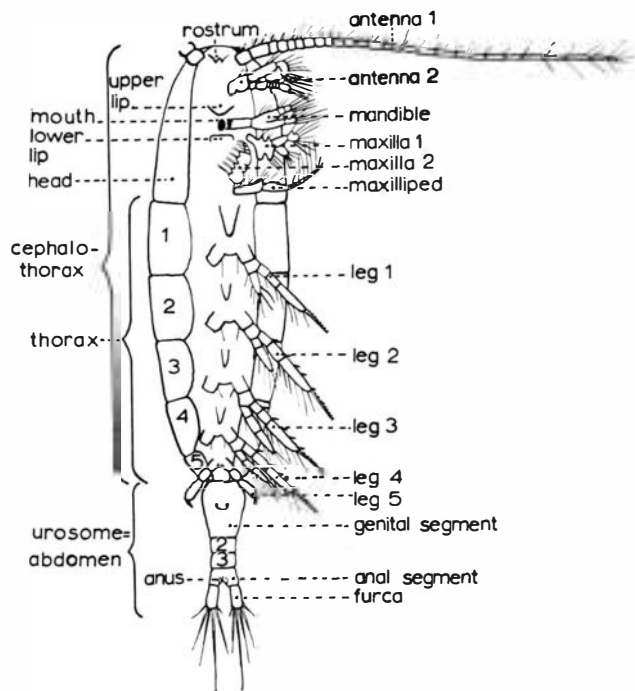
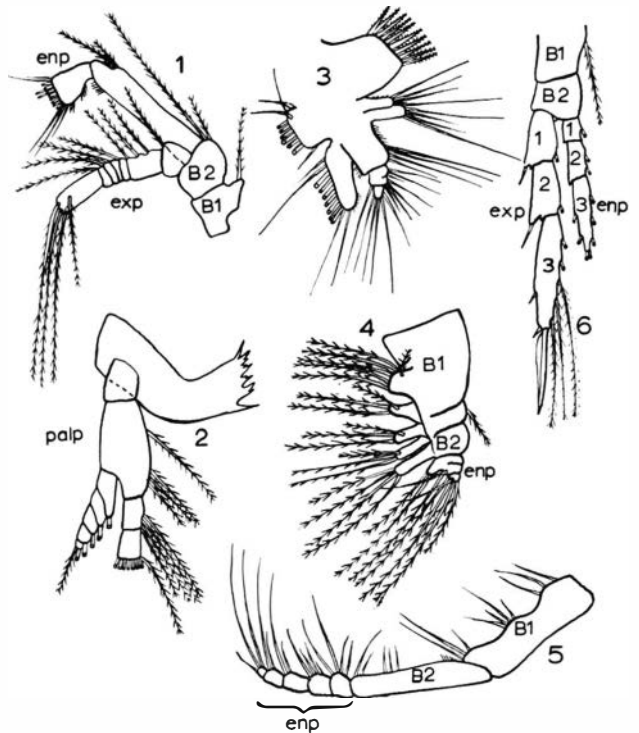FIG. 2. Diagrammatic representation of a calanoid copepod.

FIG. 3. Diagrammatic representation of normal copepod mouthparts. (1) antenna 2; (2) mandible; (3) maxilla 1; (4) maxilla 2; (5) maxilliped

KEY TO THE GENERA OF PELAGIC COPEPODA

To use the key begin with couplet 1, choose one of the alternatives, and proceed to the couplet indicated on the right.

1 No appendages between antenna 1 and leg 1 (Key-fig. 1) Fam. MONSTRILLIDAE

In this region, at least two and most frequently five pairs of appendages (Key-fig. 2) 2

2 Head with lenses which generally project on the anterior margin, sometimes placed ventrally or dorsally (Key-figs 3-12) 3

Head without lenses 8

3 Gymnoplea. Antenna 1 with more than 10 segments 4

Podoplea. Antenna 1 of three-six segments. Lenses always very noticeable (Key-figs 6-12) 7

4 Two enormous contiguous lenses, occupying all the anterior head; lenses triangular in dorsal view (Key-fig. 3)
Cephalophanes

Four lenses; two on each side of head; lenses round, sometimes difficult to see. Head with lateral hooks (Key-fig. 4)
Anomalocera

Two rounded lenses, sometimes very difficult to see. Head with or without lateral hooks (Key-fig. 5) 5

5 Endopod of leg 1 with two segments *Labidocera**

Endopod of leg 1 with three segments 6

6 Male leg 5 uniramous, three-segmented, asymmetrical, right leg without chela
Epilabidocera

Male right leg 5 with stout chela with sharp-pointed finger and thumb, left leg uniramous *Pontella*

* Some *Labidocera* have three segments on leg 1

11

7 Body flattened in the form of a leaf or slender scale; often iridescent or with metallic reflections when alive. Abdominal segments laterally enlarged. Furcae in form of two wide, flat plates (Key-figs 6, 7)   *Sapphirina*

Cephalothorax quadrangular; frontal lenses very protruding and widely separated. Furcae in form of two long rods frequently divergent (Key-fig. 8)   *Copilia* ♀

Body more or less conical; narrowed posteriorly; abdominal segments not enlarged laterally. Last thoracic segment always ends in a point. Abdomen of one or two segments. Furcae with two narrow branches or two short, thick plates. Lenses protruding little or not at all (Key-fig. 9-11)   Fam. CORYCÆIDÆ

Body tapers regularly towards the posterior, not flattened. No thoracic points. Abdomen without lateral expansions, with three segments. Lenses large and contiguous. Leg 5 reduced to three setae (Key-fig. 12)   *Corina*

8 Body flattened in the form of a leaf or scale, often iridescent when alive. Abdominal segments enlarged laterally. Furcae two parallel rods (Key-fig. 13)   *Copilia* ♂

These features absent   9

9 Maxilla 2 and the maxilliped with long clusters of slender setae arranged like brushes (Key-fig. 14)   *Augaptilina*

Maxilla 2 and the maxilliped otherwise armed   10

10 Endopod of leg 3 and leg 4 with three segments   12

Endopod of leg 3 and leg 4 with two segments   196

Endopod of leg 3 and leg 4 with one segment   11

Endopod of leg 3 with three segments, of leg 4 with two segments, one segment, or absent   221

Endopod of leg 3 with two segments, of leg 4 with three segments   *Foxtonia*

Endopod of leg 3 with one segment, of leg 4 with two segments   *Temorites discoveryae*

11 Gymnoplea. Leg 5 present, leg 1 exopod three segmented (Key-fig. 16)   *Heterocope*

Gymnoplea. Leg 5 present, leg 1 exopod one-segmented   *Spicipes* ♀

Podoplea. Leg 5 absent (Key-fig. 15)   *Mormonilla*

12 Endopod of leg 1 with three segments   13
Endopod of leg 1 with two segments   74
Endopod of leg 1 with one segment   87

13 Dark brown knob on thorax segment 1, on the right or left anterolateral corner (Key-figs 17, 18)   *Pleuromamma*

Knob absent   14

14 Endopod segment 1 of leg 2 with an internal hook bent back towards the base of the leg. Female abdomen narrow. Anal segment of male and female with no extensions (Key-fig. 19)   *Metridia*

Endopod segment 1 of leg 2 with an internal hook bent back towards the base of the leg. Female abdomen expanded. Anal segment of male and female has a backward directed process on each side   *Gaussia*

Endopod segment 1 of leg 2 without hook   15

15 Gymnoplea. Thorax and abdomen clearly distinct. Antenna 2 bifurcated with five-seven segments in the exopod; the two branches have plumose setae, without hooked spines (Key-fig. 20)   16

Propodoplea. A1 with more than 10 segments; A2 biramous; thoracic segment 5 contained in posterior body (urosome)   *Benthomisophria*

Podoplea. Antenna 2 with one or two branches. If biramous, exopod small, with at the most three segments; endopod with a few naked or hooked setae (Key-figs 21, 22)   65

16 Exopod segment 3 of leg 3 and leg 4 with two external spines, one of which is terminal, and a final seta (Key-fig. 23)   17

Exopod segment 3 of leg 3 and leg 4 with three external spines and a final seta (Key-fig. 24)   23

17 Terminal spine of exopod segment 3 of leg 3 and leg 4 flattened externally with a smooth margin, not toothed (Key-fig. 23)   19

Terminal spine of exopod segment 3 of leg 3 and leg 4 strongly toothed externally (Key-fig. 25)   18

18 Leg 5 biramous in both male and female. Male leg 5 endopods three-segmented   *Limnocalanus*

Female leg 5 uniramous, three- or four-segmented; biramous in male, endopods rudimentary or lacking, exopod two or three-segmented   *Pseudodiaptomus*

12
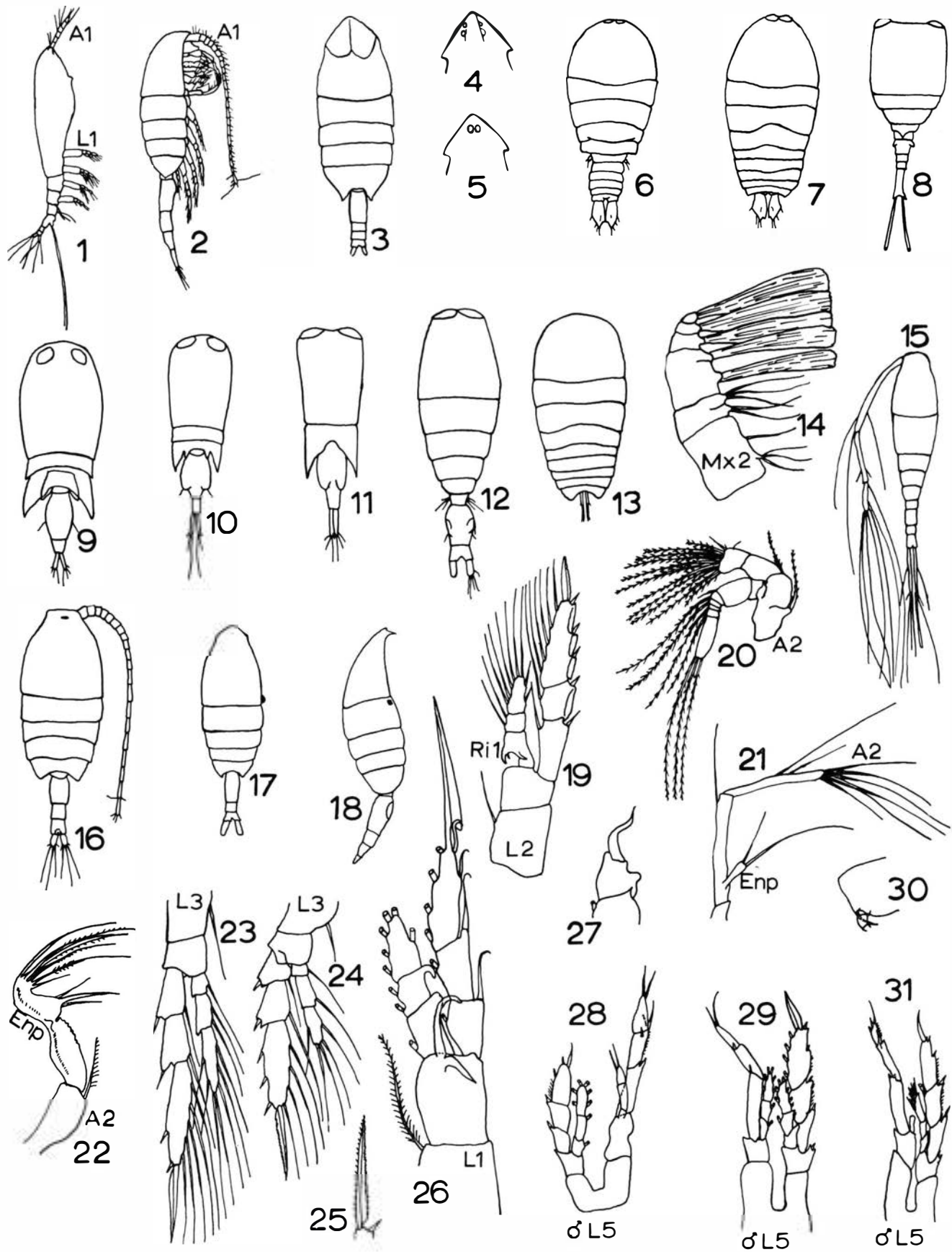
KEY-FIGS 1-31. ABBREVIATIONS: A 1,2=antenna 1,2; Enp (=Ri) =endopod; L 1,2,3,4,5,=legs 1,2,3,4,5,; Mx 1,2,=maxilla 1,2; ♂ =male

19 Basipod segment 2 of leg 1 with strong curved spine (Key-fig. 26) 20

Basipod segment 2 of leg 1 without spine 21

20 Leg 1 with anterior margin basipod segment 1 terminating in well defined hook (Key-figs 27, 28) *Canthocalanus**

Basipod segment 1 of leg 1 without hook. Exopod segment 1 of leg 2 with re-curved spine (Key-figs 26, 29) *Neocalanus**

21 Forehead conical; slightly crested. Male leg 5 prehensile. Left endopod one-segmented except in *C. acutus* (Key-figs 30, 31) *Calanoides**

Forehead not conical 22

22 Male leg 5 not prehensile, each ramus three-segmented. Left endopod segment 1 and 2 without setae. Basipod segment 1 of leg 5 inner margin serrate (Key-fig. 32) *Nannocalanus**

Basipod segment 1 of leg 5 with or without serrations. Male leg 5 not prehensile, each ramus three-segmented, left endopod segments 1 and 2 with short spines on the latero-distal border (not extending past the end of the next segment) (Key-fig. 33) *Calanus**

Female antenna 1 with joints 8 and 9 incompletely divided. Right male leg 5 has enlarged exopod with last segment converted into a powerful prehensile organ. Endopod of left leg 5 entirely absent or very rudimentary *Undinula*

23 Antenna 1 only reaching the hind margin of the head 24

Antenna 1 (at least the left) reaches at least the hind margin of the cephalo-thorax 25

24 Exopod of female leg 5 articulated (Key-figs 34, 35) *Pseudocyclops*

Exopod of female leg 5 not articulated (Key-figs 36, 39) *Paramisophria*

25 Neither of antenna 1 pair is modified as a prehensile organ 26

One of the antenna 1 pair is modified as a prehensile organ more or less obviously (Key-figs 40, 41) 47

26 Exopod and endopod of leg 5 has two segments (Key-fig. 37) *Euaugaptilus hecticus* ♀

Exopod and endopod of leg 5 with three segments (Key-figs 35, 38) 27

Exopod of leg 5 with three, endopod with two, segments 33

Exopod of leg 5 with three, endopod with one, segment (Key-fig. 49) 34

Leg 5 with one branch on each side (Key-figs 68-71) 44

27 Exopod segment 2 of leg 5 with a spine on the internal margin (Key-fig. 38) *Centropages* ♀

This margin has a rudimentary seta or a sabre-like spine (Key-figs 65, 66) 28

28 On left furca one seta is much stronger and longer than the others 29

Furcal setae symmetrical 36

29 Maxilla 2 without strong hook setae; one right furcal seta much longer than the others (Key-fig. 42) *Disseta* ♀

Maxilla 2 with strong hook seta; right furcal setae almost equal (Key-figs 43, 44) 30

30 Maxilla 2 short and thick-set, terminated by two very spiny, strong hook setae. Maxilliped slender and elongate (Key-fig. 43) *Hemirhabdus* ♀

Hook setae of maxilla 2 not spiny. Maxilliped shorter (Key-figs 44, 47) 31

31 Maxilla 2 with more than two hook setae; its proximal lobes very reduced; mandible asymmetrical; one tooth well apart from the others, much larger and sickle-shaped (Key-figs 44-6) *Heterorhabdus* ♀

Maxilla 2 with two hook setae only; teeth on mandible subequal (Key-figs 47, 51) 32

32 Proximal lobes of maxilla 2 and their setae little developed (Key-fig. 44) *Heterostylites* ♀

These lobes and setae well developed (Key-fig. 51) *Mesorhabdus* ♀

33 Rostrum present. Furca four times as long as wide (Key-fig. 52) *Lucicutia* ♀

Rostrum absent. Furca at the most two times as long as wide; often much shorter (Key-fig. 48) *Pontoptilus* ♀

34 Exopod segment 2 of leg 5 with one internal spine (Key-fig. 49) *Isias* ♀

Exopod segment 2 of leg 5 without internal spine 35

35 Mandible greatly enlarged at the tip; upper lip protruding greatly. Body very thick-set; rostrum bifurcated, very distinct (Key-fig. 50) *Pachyptilus* ♀

* Brodsky (1965) places these genera together under the genus *Calanus* so that the family Calanidae holds two genera, *Calanus* and *Undinula*
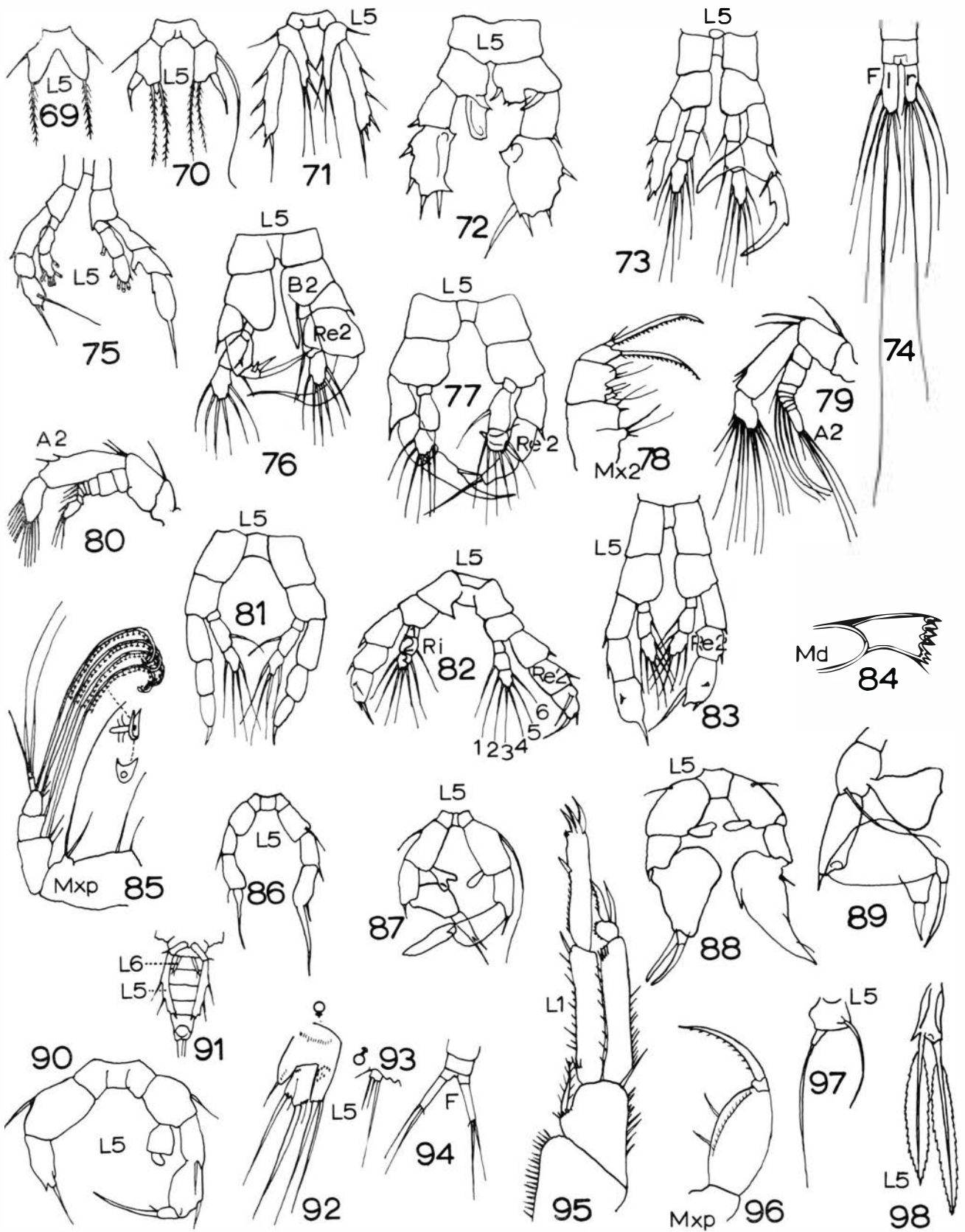
14
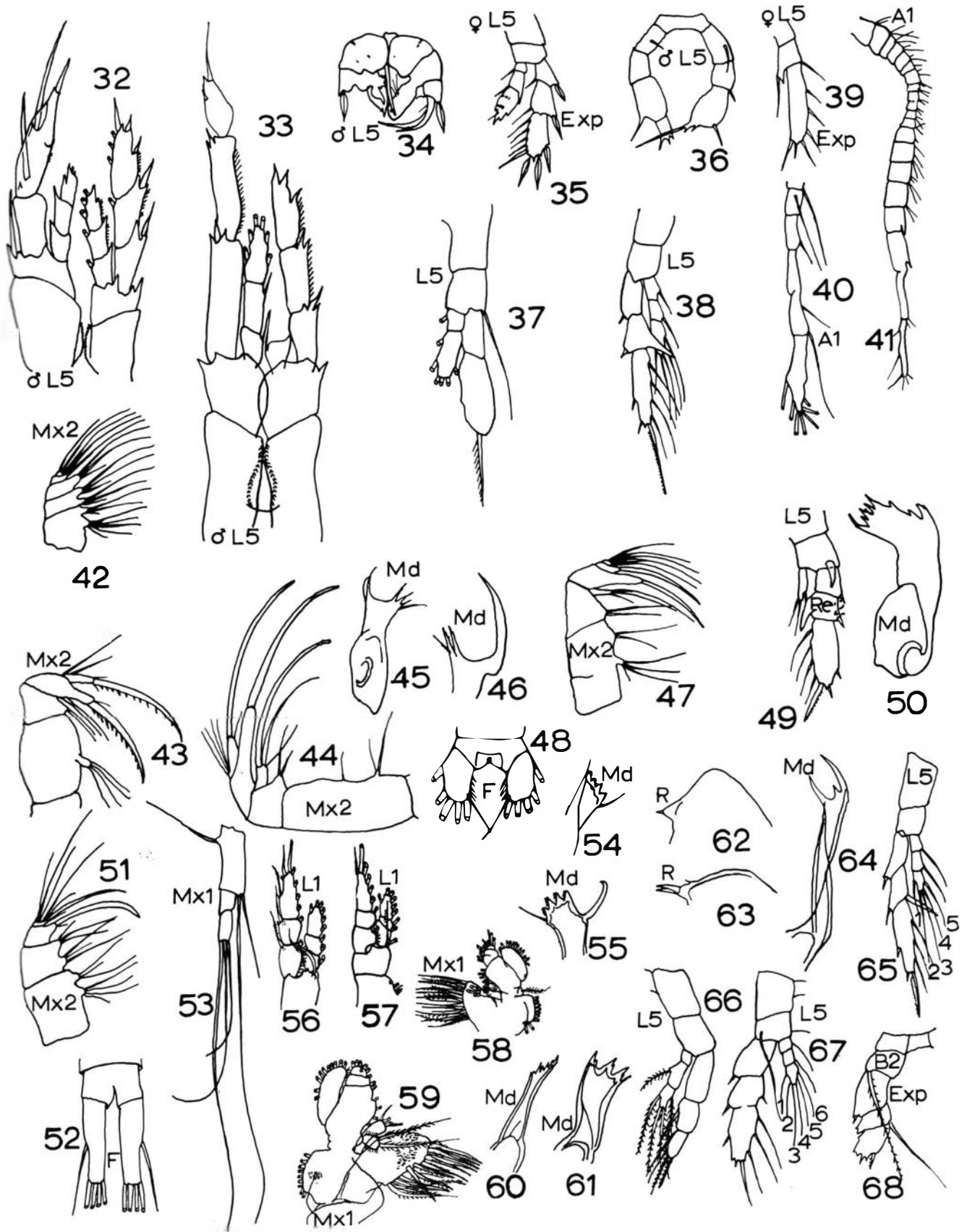
KEY-FIGS 32-68 ABBREVIATIONS: A 1,2=antenna 1,2; B 1,2=basipod segments 1,2; Exp (=Re) =exopod; F=furca; L 1,2,3,4,5,6,=legs 1,2,3,4,5,6; Md=Mandible; Mx 1,2=maxilla 1,2; R= rostrum; ♂ =male

Mandible very asymmetrical; one of them with a strong lateral curved tooth; lip protruding little. Body elongate. Rostrum absent (Key-figs. 54, 55)   *Heteroptilus* ♀

36   Thoracic segments 4 and 5 separated   37
      Thoracic segments 4 and 5 fused   39

37   Rostral filaments slender; exopod of leg 1 with 1, 1, 2 external setae (Key-fig. 56)   38
      Rostral filaments stout and sausage-like; exopod of leg 1 with 0, 0, 2 external setae; second inner lobe of maxilla 1 devoid of setae (Key-fig. 57)   *Bathycalanus*

38   Antenna 1 twice length of cephalothorax; second segment of maxilla 1 endopod bears four setae (Key-fig. 58)   *Megacalanus*
      Antenna 1 less than twice length of cephalothorax; second segment of maxilla 1 endopod bears one seta (Key-fig. 59)   *Bradycalanus*

39   Urosome with three segments   40
      Urosome with four segments   42

40   Maxilla 1 reduced to a three-segmented rod (Key-fig. 53)   *Augaptilus* ♀
      Maxilla 1 well developed   41

41   Mandible with numerous teeth, often cut obliquely. Rostrum most often small or absent, sometimes in the form of two long thin filaments (Key-figs 60, 61)   *Euaugaptilus* ♀
      Mandible very elongated, has two thin curved teeth, with one smaller tooth between them. Rostrum strong, bifurcate, projecting forward. Setae on maxilliped coiled, carrying special shields (Key-figs 62-4)   *Centraugaptilus* ♀

42   Exopod segment 2 of leg 5 with a long nude sabre-like seta on the internal margin. Endopod segment 3 of leg 5 with five setae (Key-fig. 65)   *Lucicutia* ♀
      Exopod segment 2 of leg 5 without sabre-like setae on the internal margin   43

43   Endopod segment 3 of leg 5 with four setae. Mandible a long rod finely toothed at the tip. Rostrum in the form of two long slender filaments (Key-fig. 66)   *Pseudaugaptilus* ♀
      Endopod segment 3 of leg 5 with six setae (Key-fig. 67)   *Haloptilus* ♀

44   Leg 5 with two segments in the basipod and three in the exopod (Key-fig. 68)   *Phyllopus* ♀

      Leg 5 of at the most three segments (Key-figs 69-71)   45

45   Leg 5 has one final seta and one lateral seta (Key-fig. 69)   *Paraugaptilus* ♀
      Leg 5 with three segments (Key-figs 70, 71)   46

46   Leg 5 final segment narrow and pointed (Key-fig. 70)   *Arietellus* ♀
      Leg 5 final segment not narrow and pointed (Key-fig. 71)   *Scottula* ♀

47   Right antenna 1 prehensile   48
      Left antenna 1 prehensile   50

48   The endopod of leg 5 with three segments, with plumose hairs (Key-figs 73, 75)   49
      This endopod rudimentary, without plumose hairs (Key-fig. 72)   *Isias* ♂

49   The two exopod segments of leg 5 unequal, with a pincer on the right (Key-fig. 73)   *Centropages* ♂
      These exopod segments nearly equal, without pincers (Key-fig. 75)   *Euaugaptilus hecticus* ♂

50   Exopod and endopod of leg 5 with three segments on each side (Key-figs 76, 77)   51
      Exopod of leg 5 with three segments, endopod rudimentary or absent (Key-figs 86-8)   62

51   One seta on the left furca much longer and thicker than the rest (Key-fig. 74)   52
      Furcal setae symmetrical   56

52   One seta on the right furca is much longer than the rest (Key-fig. 74)   *Disseta* ♂ *
      Right furcal setae subequal   53

53   Basipod segment 2 of right leg 5 with a long internal conical process, parallel to the endopod, exopod segment 2 of right leg 5 very enlarged, both exopod segments 3 of leg 5 terminated by a long point (Key-fig. 76)   *Heterostylites* ♂
      These features absent   54

54   Exopod segment 3 of right leg 5 terminated by a long seta, straight and naked; exopod segment 2 with a strong internal conical tooth (Key-fig. 77)   *Mesorhabdus* ♂
      Exopod segment 3 of right leg 5 terminated by a little tooth or a claw (Key-figs 81-3)   55

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* *Pontoptilus robustus* Sars has this character also (exception for the genus)

KEY-FIGS 69-98. ABBREVIATIONS: A 1,2=antenna 1.2; B 1.2=basipod segments 1.2; F=furca; L. 1.2.3,4.5,6=legs 1,2,3,4,5,6; l=left; Md=mandible; Mx 1,2=maxilla 1,2; Mxp=maxilliped; R=rostrum; r=right; Re=exopod; Ri=endopod; ♂=male; ♀=female

55 Maxilla 2 short and thick-set, with two strong hooked very spiny setae. Exopod of antenna 2 clearly shorter than the endopod (Key-figs 78, 80) *Hemirhabdus* ♂

Hooked setae on maxilla 2 not spiny. Exopod of antenna 2 hardly shorter than than the endopod (Key-fig. 79) *Heterorhabdus* ♂

56 Terminal setae on the maxilliped coiled, crook-shaped, with special shields. Rostrum strong, bifurcated, and projecting forward. Body thick-set (Key-figs 62, 63, 85) *Centraugaptilus* ♂

These features absent 57

57 Exopod of leg 5 smooth, without spines or setae, except for a final point (Key-fig. 81) *Pseudaugaptilus* ♂

The exopod of leg 5 has external spines 58

58 Endopod segment 3 of leg 5 with four setae; endopod segment 2 without internal setae 59

Endopod segment 3 of leg 5 with six setae; endopod segment 2 with one internal seta (Key-figs 82, 83) 60

59 Mandible symmetrical, with numerous equal teeth (Key-fig. 84) *Pontoptilus* ♂

Mandible asymmetrical, with one sickle-shaped tooth separated from the others (Key-figs 54, 55) *Heteroptilus* ♂

60 Right exopod segment 2 of leg 5 without internal point; never with shields on the maxilliped setae (Key-fig. 82) *Haloptilus* ♂

Right exopod 2 of leg 5 with at least one internal point, sometimes small. Numerous shields on the maxilliped setae (Key-fig. 83) 61

61 Maxilla 1 reduced to a three-segmented rod (Key-fig. 53) *Augaptilus* ♂

Maxilla 1 well developed *Euaugaptilus* ♂

62 Endopod of leg 5 present on both left and right legs (Key-figs 87, 88) 63

Endopod of leg 5 on one side only (Key-figs 89, 90) 64

Endopod of leg 5 absent on both sides. Exopod slightly asymmetrical with cylindrical segments (Key-fig. 86) *Scottula (inaequicornis)* ♂

63 Endopod of left leg 5 not bilobed; last segment of the leg 5 exopod very wide (Key-fig. 88) *Paraugaptilus* ♂

Endopod of left leg 5 bilobed; last segment of the leg 5 exopod not enlarged (Key-fig. 87) *Arietellus* ♂

64 Endopod of leg 5 large, in form of a leaf; exopod segments greatly enlarged (Key-fig. 89) *Phyllopus* ♂

Endopod has two small segments; exopod segments little enlarged (Key-fig. 90) *Scottula (abyssalis)* ♂

65 Exopod of leg 1 with one segment *Clytemnestra*

Exopod of leg 1 with two or three segments 66

66 Exopod of antenna 2 with one long narrow segment. A rudimentary leg 6 present (Key-fig. 91) *Aegisthus*

Exopod of antenna 2 with two or three segments. Leg 5 has two segments, in the form of a leaf: much smaller in the male than in the female (Key-figs 92, 93) 67

Exopod of antenna 2 absent. Leg 5 has one-three segments; elongated or in the form of a knob, a rod or replaced by setae. Leg 6 absent (Key-figs 97-9) 68

67 Exopod of antenna 2 with three segments; furca short *Microsetella*

Exopod of antenna 2 with two segments; furca long. Leg 1 exopod three-segmented (Key-fig. 94) *Halithalestris*

Exopod of antenna 2 with two segments; furca short. Leg 1 exopod two-segmented (Key-fig. 95) *Harpacticus*

68 Maxilla 2 and maxilliped alike, with long spiny setae (Key-fig. 100) 69

Maxilliped with or without short setae, and one terminal hook (Key-fig. 96) 70

69 Leg 5 very rudimentary, reduced to two setae on each side (Key-fig. 97) *Oithona*

Leg 5 with two or three segments (Key-fig. 99) *Cyclopina*

70 Leg 5 has one segment, ends in two toothed lancets, body very narrow (Key-fig. 98) *Lubbockia*

Leg 5 (with two or one segments, or a knob) has naked or plumose setae. Body thick set 71

71 Antenna 1 has special sensorial organs (Key-figs 101, 102) 72

Antenna 1 without such organs 73

72 Antenna 1 ends in a very long sensorial appendix (Key-fig. 101) *Ratania*

Antenna 1 has at the base some brush-like appendices (Key-fig. 102) *Pachos*

73 Hook setae of antenna 2 of average length. Endopod of posterior leg at least as long as the exopod. Endopod segment 3 of

18

leg 4 at least $1\frac{1}{2}$ times as long as endopod segments 1 and 2 together (Key-fig. 108) *Oncaea*

Hook setae on the last segment of antenna 2 very long. Endopod of posterior leg much shorter than the exopod; endopod segment 3 of leg 4 not longer than endopod segment 1 or 2 together (Key-fig. 111) *Conaea*

74 Leg 1 has both rami two-segmented. Exopod segment 1 of the other leg with 2 external spines. Antenna 1 very short with numerous segments (Key-fig. 103) *Platycopia*

These features absent 75

75 Antenna 2 has two branches with many-segmented exopod. Antenna 1 with at least 15 segments 76

Antenna 2 with one or two branches. When antenna biramous the exopod is small, of only one segment. Antenna 1 with at most nine segments ... 85

76 Right endopod of leg 5 two-segmented, left three-segmented (Key-fig. 104) *Lucicutia*

Both endopods of leg 5 two-segmented, with plumose setae *Disco* ♂

Both endopods and exopods of leg 5 three-segmented *Neoaugaptilus* ♀

Endopod of leg 5 without plumose setae or absent; often leg 5 entirely absent on one or both sides 77

77 Furca long and narrow, at least six times longer than wide (Key-fig. 105) *Temora*

Furca at most three times longer than wide 78

78 Surface of leg 3 and 4 endopods naked ... 79

Surface of leg 3 and 4 endopods with rows of small spines 82

79 Leg 3 and 4 endopod segment 2 with one seta, endopod segment 3 with three setae *Disco* ♀

Leg 3 and 4 endopod segment 2 with one seta, endopod segment 3 with five setae 80

Leg 3 and 4 endopod segment 2 with two setae, endopod segment 3 with seven setae *Temorites*

80 Exopod of leg 1 has three segments 81

Exopod of leg 1 has two segments. Female leg 5 present. Male leg 5 with left exopod (Key-figs. 106, 107) *Rhincalanus*

81 Female leg 5 present. Male leg 5 with left endopod (Key-figs 109, 110, 114) *Temoropia*

Female leg 5 absent. Male leg 5 without endopod on both sides (Key-fig. 112) *Eucalanus*

82 Exopod segment 3 of legs 2-4 bordered externally with row of small teeth 83

Exopod segment 3 of legs 2-4 without external teeth 84

83 Female leg 5 reduced to knobs or lacking, only left leg 5 present in male *Acrocalanus*

Female leg 5 two-segmented, leg 5 of male two-segmented on right, five-segmented on left *Paracalanus*

84 Female genital segment swollen projecting laterally. Male anal segment well developed and swollen *Calocalanus*

Female genital segment without lateral swellings but projecting ventrally. Anal segment of male as long as the two preceding segments *Ischnocalanus*

85 Anterior conical, rounded in front. Body very narrow. Exopod of antenna 2 absent (Key-fig. 121) *Macrosetella*

Anterior pointed. Body wide. Endopod of antenna 2 with one segment (Key-fig. 21) 86

86 Leg 5 in the form of a quadrangular leaf. No leg 6. Furca with separate narrow branches carrying setae (Key-figs 119, 122) *Euterpina*

Leg 5 very narrow, leg 6 present. Furca very short, fused in the mid-line. Furcal setae unequal, fused at the base (Key-figs 91, 120) *Aegisthus*

87 Endopod of leg 2 with three segments; leg 5 uniramous *Mecynocera*

Endopod of leg 2 with three segments; leg 5 biramous, endopods one-segmented *Zenkevitchiella*

Endopod of leg 2 with two segments ... 88

Endopod of leg 2 with one segment ... 175

88 Antenna 1 short, does not reach the hind margin of the head; first segment very big (Key-fig. 103) 89

Antenna 1 reaches past the head ... 90

89 Leg 5 has only one branch (Key-figs 123, 125) *Pseudocyclopia*

Leg 5 has two branches on each side (Key-figs 126, 127) *Platycopia*

90 The surfaces of the rami of legs 2, 3, 4 (particularly the endopod of leg 3 and leg 4) have numbers of spines (Key-fig. 128) 91

Hind surface of both rami of only leg 4 have spines *Derjuginia*

These legs without spines ... 127

19

2*

91 Body wide, almost globular (Key-fig. 124)
Phaenna

Body elongated elliptical ... 92

92 Leg 5 absent ... 93
Leg 5 present, sometimes small ... 98

93 Exopod segment 3 of legs 2, 3, 4 with five internal setae ... 94

Exopod segment 3 of legs 2, 3, 4 with four internal setae ... 95

94 Rostrum present, bifurcated, and thick (Key-figs 129, 130) *Monacilla* ♀ *

Rostrum absent (Key-fig. 131) *Spinocalanus* ♀

95 Genital segment projecting ventrally (Key-fig. 132) ... 96

Genital segment without such a projection ... 97

96 Posterior corners of thorax rounded
Scolecithrix (danae) ♀

Posterior corners of thorax pointed sometimes asymmetrical *Macandrewella* ♀

97 Rostrum without filaments or points (Key-fig. 133) *Diaixis* ♀

Rostrum with two small points. Maxilla 2 with special terminal appendages (Key-fig. 156) *Racovitzanus* ♀

Rostrum small, with two points. Maxilla 2 with only ordinary setae (Key-figs 134, 135) *Bradyidius* ♀

98 Abdomen with 5 segments, often with very short anal segment. Leg 5 asymmetrical with one or two branches on each side, often very elongated ... 99

Abdomen with five segments. Leg 5 absent
Scaphocalanus (curtus) ♀

Abdomen with four segments. Only left leg 5 present, represented by a basal joint carrying a curved spine *Scolecocalanus* ♀

Abdomen with four segments, often with very small anal segment. Leg 5 symmetrical with one branch on each side with one-three segments ... 113

99 Exopod segment 3 of legs 2, 3, 4 with five internal setae ... 100

Exopod segment 3 of legs 2, 3, 4 with four internal setae ... 101

100 Exopods of leg 5 with three segments, exopods ending in points. Both endopods styliform (Key-fig. 136) *Spinocalanus* ♂

Exopods of leg 5 with two segments, not pointed. Both endopods not styliform, the left one lamellate (Key-fig. 137)
Monacilla ♂

Leg 5 uniramous. left five-segmented. right four-segmented *Ryocalanus* ♂

101 Leg 5 biramous on one side only (endopod sometimes very small) ... 102

Leg 5 biramous on both sides (the endopods sometimes very small) or uniramous ... 104

Leg 5 uniramous on both sides (Key-fig. 205) *Bradyidius* ♂

102 Maxilla 2 with worm-like appendages, without spiny hooked setae ... 103

Maxilla 2 with two large tufted appendages (Key-fig. 153) *Mixtocalanus* ♂

Maxilla 2 without strong worm-like appendages often with strong spiny hooked setae (Key-fig. 138) *Xanthocalanus* ♂

103 Leg 5 long and thin, ending on the left in a long stylet (Key-fig. 139) *Scolecithricella* ♂

Leg 5 squat and thick without final stylet (Key-fig. 140) *Scolecithrix* ♂

104 Leg 5 uniramous on each side ... 105

Leg 5 with only one branch (Key-fig. 141)
Xanthocalanus (agilis) ♂

Leg 5 biramous on both sides (Key-figs 149, 150) ... 108

105 Leg 5 fat, with very irregular segments and many swellings (Key-fig. 142) *Diaixis* ♂

Leg 5 otherwise formed and very asymmetrical (Key-figs 143, 145) ... 106

106 Left leg 5 with five segments, right with three. Legs covered in hairs. Maxilla 2 ending in a strong claw, maxilliped normal (Key-figs 143, 144) *Onchocalanus* ♂

Left leg 5 very long, with five segments. Right leg 5 very short with five equal segments. Maxilliped terminated by two strong claws. Maxilla 2 with one claw (Key-figs 144, 146) *Cornucalanus* ♂

Right leg 5 less than five segments ... 107

107 Rostrum thick, swollen at the base, with two lobes terminated by two long thin filaments (Key-fig. 147) *Amallophora* ♂

Rostrum small, reduced to two filaments (Key-fig. 148) *Xanthocalanus* ♂

108 Leg 5 long and thin, its branches terminating in points or stylets. Right endopod very small, left endopod with one segment, extending past the exopod (Key-fig. 149) *Amallothrix*† *(obtusifrons)* ♂

* *M. typica* sometimes has a rudimentary leg 5
†Vervoort (1951, p.111) includes *Amallothrix* in *Scolecithricella*

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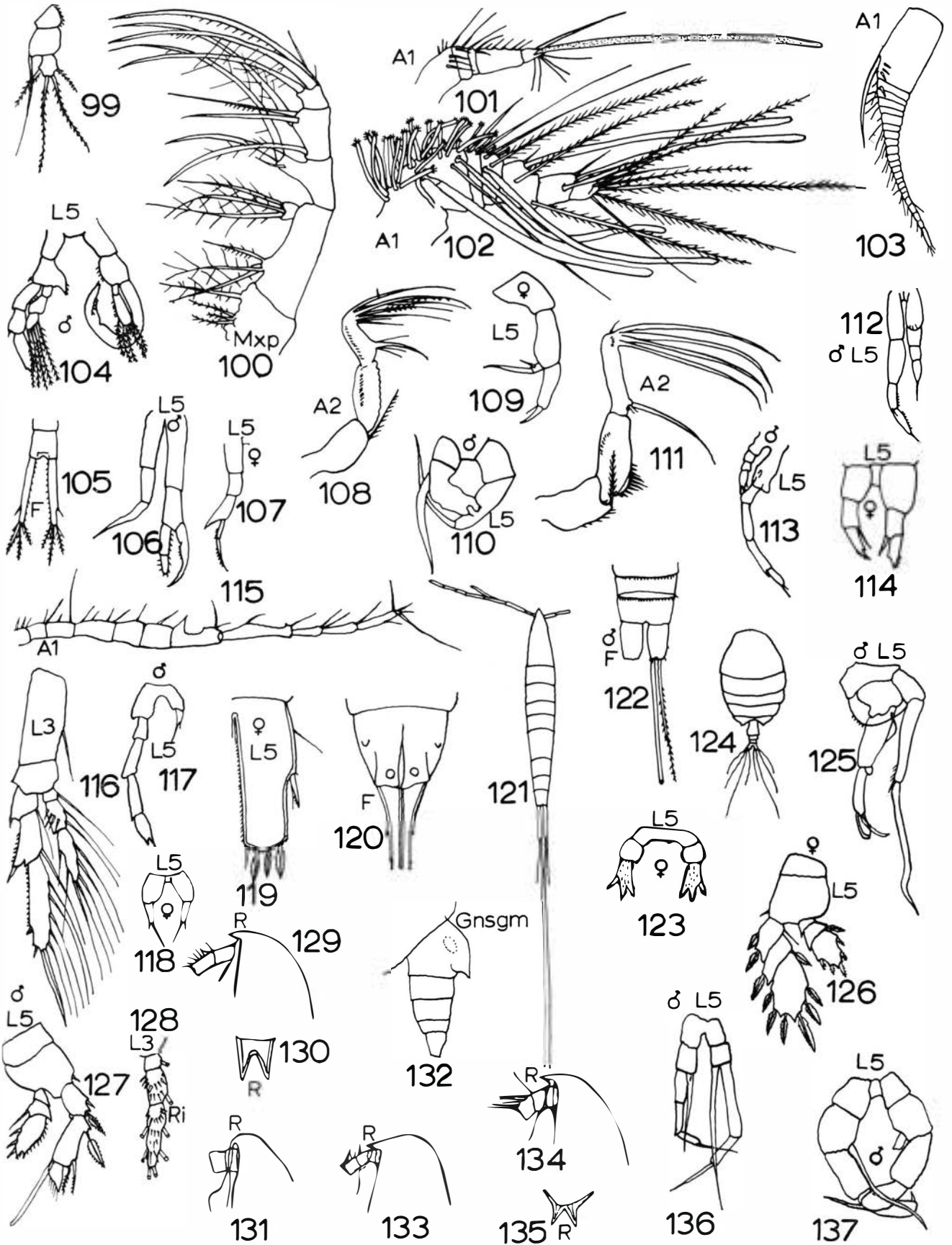
KEY-FIGS 99-137. ABBREVIATIONS: A 1,2=antenna 1,2; F=furca; Gnsgm=genital segment; L 1,2,3,4,5,6=legs 1,2,3,4,5,6; Mxp =maxilliped; R=rostrum; Ri=endopod; ♂=male; ♀=female

Leg 5 long and thin, right longer than the left. Both exopods three-segmented, both endopods small and one-segmented
Farrania ♂ *

Leg 5 otherwise formed 109

109 Endopod left leg 5 shorter than exopod ... 110
Endopod left leg 5 much longer than the exopod (Key-fig. 151) 112

110 Rostrum present 111
Rostrum absent *Parascaphocalanus* ♂

111 Right leg 5 third exopod segment usually bifurcate and held at right angles to the second exopod segment *Macandrewella* ♂
Right leg 5 third exopod segment neither bifurcate nor held at right angles to the preceding segment (Key-fig. 150)
Scottocalanus ♂

112 Left endopod of leg 5 with three segments, right endopod with one (Key-fig. 151)
Scaphocalanus ♂
Left endopod of leg 5 with two segments, right endopod with two (Key-fig. 152)
Lophothrix (frontalis) ♂
Left endopod of left leg 5 with one segment, right endopod with one *Racovitzanus* ♂

113 Maxilla 2 terminated by a strong curved claw (Key-fig. 144) 114
Maxilla 2 without this claw 115

114 Maxilliped thin and long, without spiny claws (Key-fig. 159) *Onchocalanus* ♀
Maxilliped with two strong claws more or less spiny (Key-fig. 146) *Cornucalanus* ♀

115 Maxilla 2 with two large appendages in the form of a tuft, surrounded by slender appendages terminated by a bristly button, worm-like appendages, and some ordinary setae (Key-fig. 153) *Heteramalla* ♀
Maxilla 2 with only one tuft, some worm-like appendages and ordinary setae (Key-fig. 154) *Amallophora* ♀
Maxilla 2 otherwise armed 116

116 Maxilla 2 has only ordinary setae and some hooked setae (Key-fig. 155)
Farrania ♀
Maxilla 2 carrying special appendages, worm-like, brush-like, besides normal setae, and sometimes hooked or spiny setae (Key-fig. 156) 117

117 Maxilla 2 has three worm-like appendages and five appendages terminated by a swollen knob 118
Maxilla 2 without these two types of appendages or in a different number ... 119

118 Leg 5 with one or two segments. Exopod segment 1 of leg 1 with an external spine *Amallothrix* ♀ †
Leg 5 with three segments. Exopod segment 1 of leg 1 without an external spine *Undinothrix* ♀

119 Antenna 1 very short, not extending past thoracic segment 3 and very thick at the base. Leg 5 with three segments covered in spines (Key-figs 157, 158)
Brachycalanus ♀
Antenna 1 usually longer than cephalothorax. When it is shorter it is not swollen at the base. Leg 5 with sparse spines 120

120 Leg 5 absent or quite rudimentary and asymmetrical (Key-fig. 160) *Scolecithrix* ♀
Leg 5 present and asymmetrical, three-segmented with an apical spine on one side *Mixtocalanus* ♀
Leg 5 present and symmetrical (Key-figs 161, 162) 121

121 Leg 5 with one segment (Key-figs 161, 162) 122
Leg 5 with two segments (Key-figs 163, 165) 124
Leg 5 with three segments (rarely four) (Key-figs 166, 167, 169, 170, 172) ... 125

122 Thoracic segments 4 and 5 fused 123
Thoracic segments 4 and 5 separate
Macandrewella ♀

123 Leg 5 plate-like, wide and flat, with some short spines on each edge (Key-fig. 161) *Scolecithricella* ♀
Leg 5 elongated with a long seta on the internal margin (Key-fig. 162)
Scaphocalanus ♀

124 Leg 5 terminated by three-four short spines and often covered with spinules (Key-figs 163, 167) *Xanthocalanus* ♀
Leg 5 carrying a long internal seta, a large apical point, and one short external spine; without spinules (Key-figs 162, 165, 172) *Scaphocalanus* ♀
Leg 5 with one very long seta directed backwards; without spinules (Key-fig. 164) *Scottocalanus* ♀
Leg 5 with one long internal seta and one terminal spine or with only one internal seta not directed backwards *Racovitzanus* ♀

*Farrania orbus* (see Tanaka, 1956); *F. frigida* (see Grice and Hulsemann, 1967)
†Vervoort (1951, p.111) includes *Amallothrix* in *Scolecithricella*

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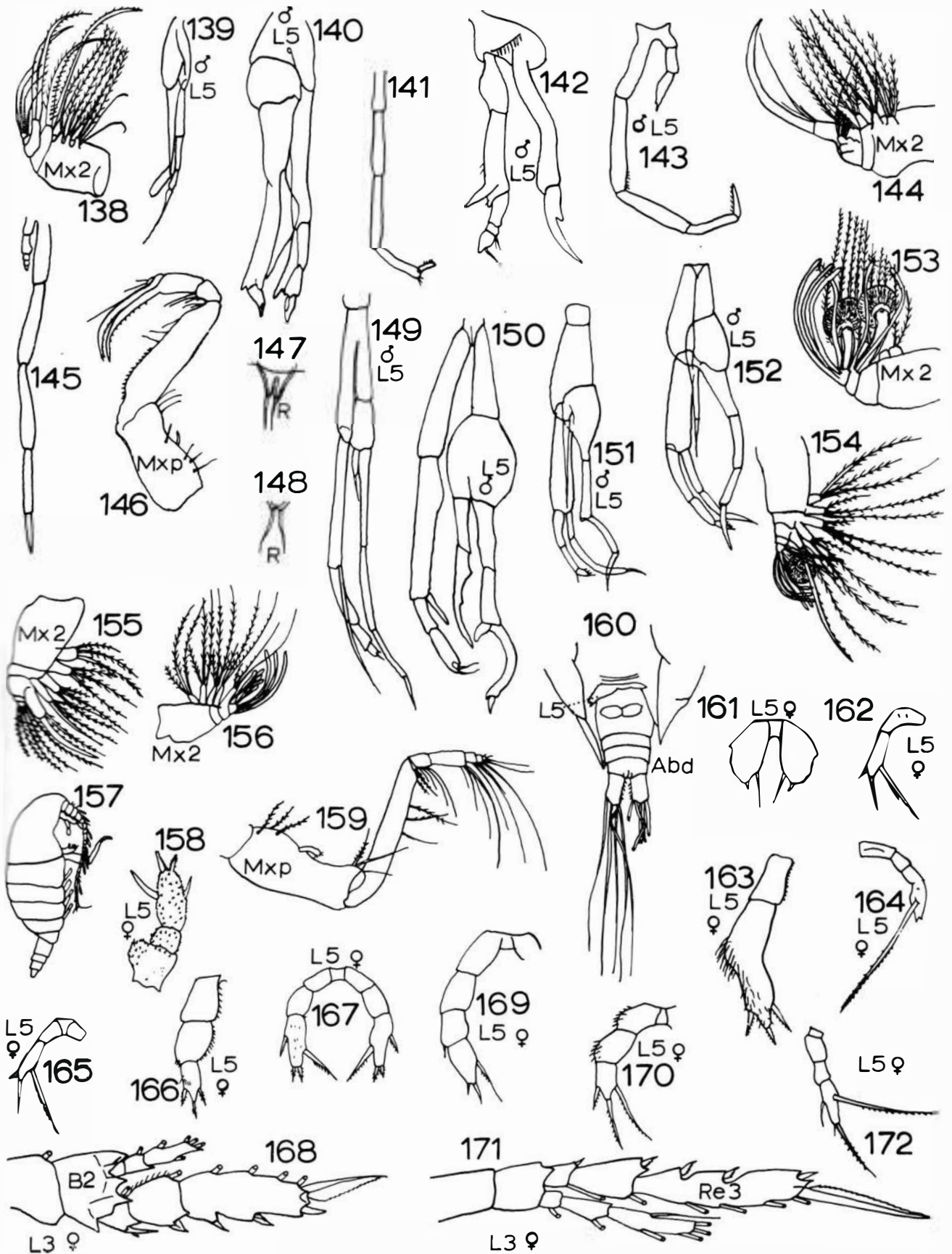
KEY-FIGS 138-172. ABBREVIATIONS: Abd=Abdomen; B 1,2=basipod segments 1,2; L 1,2,3,4,5,6=legs 1,2,3,4,5,6; Mx 1,2=maxilla 1,2; Mxp=maxilliped; R=rostrum; Re=exopod; ♂=male; ♀=female

125   Terminal segment of leg 5 much narrower often shorter than the other with three-four short spines. Leg 5 often bristling with spinules (Key-fig. 166)   *Xanthocalanus* ♀

Terminal segment of leg 5 as wide as or slightly narrower than the others, nearly always longer with two-four spines, of which at least the internal one is very long. Leg 5 smooth, or at the most with some small external spinules (Key-figs 169, 170)   126

126   Leg 5 ending in three well developed spines (Key-figs 169, 170)   *Lophothrix* ♀

Terminal segment of leg 5 with four spines (Key-fig. 172)   *Scaphocalanus* ♀

Terminal segment of leg 5 with two spines   *Parascaphocalanus* ♀

127   Basipod and exopod of leg 2 and leg 3 broader than in leg 4; their basipod segment 2 has a toothed edge enlarged like a calyx (Key-fig. 168)   *Clausocalanus*

Leg 2 and leg 3 without these features   128

128   External spines of exopod segment 3 of leg 3 and leg 4 in the form of combs set in deep notches (Key-fig. 171)   *Ctenocalanus*

These spines of the normal form   129

129   Leg 5 symmetrical or absent   130
Leg 5 asymmetrical   157

130   Leg 5 present   131
Leg 5 absent   136

131   Terminal segment of leg 5 claw-like or narrow and finger-like (Key-figs 173-6)   132
Not as above   135

132   Terminal segment of leg 5 claw-like (Key-fig. 173)   *Drepanopus* ♀
This segment straight or slightly curved (Key-figs 174-8)   133

133   Leg 5 wide at the base; terminal segment narrow and finger-like (Key-fig. 174)   *Parundinella* ♀
Leg 5 otherwise formed (Key-figs 175-8)   134

134   Leg 5 usually symmetrical; or at least having the two sides of nearly equal length (Key-fig. 175)   *Stephos* ♀
Left leg 5 much longer than the right (Key-fig. 176)   *Parastephos* ♀

135   Leg 5: see Key-fig. 177   *Oothrix* ♀
Leg 5: see Key-fig. 178   *Tharybis* ♀
Leg 5 two-segmented (Key-fig. 179)   *Parundinella* ♀

136   Head with a dorsal median spine (Key-figs 180, 181, 209)   *Gaetanus* ♀
Head without spine   137

137   Exopod segment 3 of leg 3 and leg 4 with five internal setae   138
Exopod segment 3 of leg 3 and leg 4 with four internal setae   139

138   Leg 1 exopod segment 1 without external spine   *Mimocalanus* ♀
All three exopod segments of leg 1 without external spines   *Sognocalanus* ♀
Leg 1 exopod segments 1 and 2 without external spines   *Teneriforma* ♀

139   Internal margin of basipod segment 1 of leg 4 naked or setose   141
This margin with spines (Key-figs 182, 183)   140

140   First and second segments of leg 1 exopod incompletely fused   *Pseudochirella* ♀
First and second segments of leg 1 exopod completely separate   *Chirundinella* ♀

141   Corners of thoracic segment 5 rounded or with an obtuse point (Key-figs 184, 185)   142
These corners terminated by a sharp point   147

142   Genital segment more or less asymmetrical (sometimes very little) with one lateral or ventral spine (Key-figs 184, 185)   *Undeuchaeta* ♀
Genital segment symmetrical without a spine   143

143   Terminal setae of antenna 1 thick and annulated (Key-fig. 188)   *Bradyetes* ♀
These setae of ordinary type, not thickened and annulated   144

144   Exopod segment 1 of leg 1 without external spine (Key-fig. 187)   145
Exopod segment 1 of leg 1 with an external spine (Key-fig. 186)   146
Exopod segments 1 and 2 of leg 1 without external spines   *Mesaiokeras* ♀

145   Endopod of leg 1 with four setae (Key-fig. 187)   *Microcalanus* ♀
Endopod of leg 1 with five setae   *Snelliaetideus* ♀

146   Maxilla 2 with some setae developed as spines   *Batheuchaeta* ♀
Maxilla 2 of ordinary type   *Pseudocalanus* ♀

147   Rostrum with two points   148
Rostrum with one point or absent   153

148   Exopod of leg 1 with two external spines (Key-fig. 187)   149

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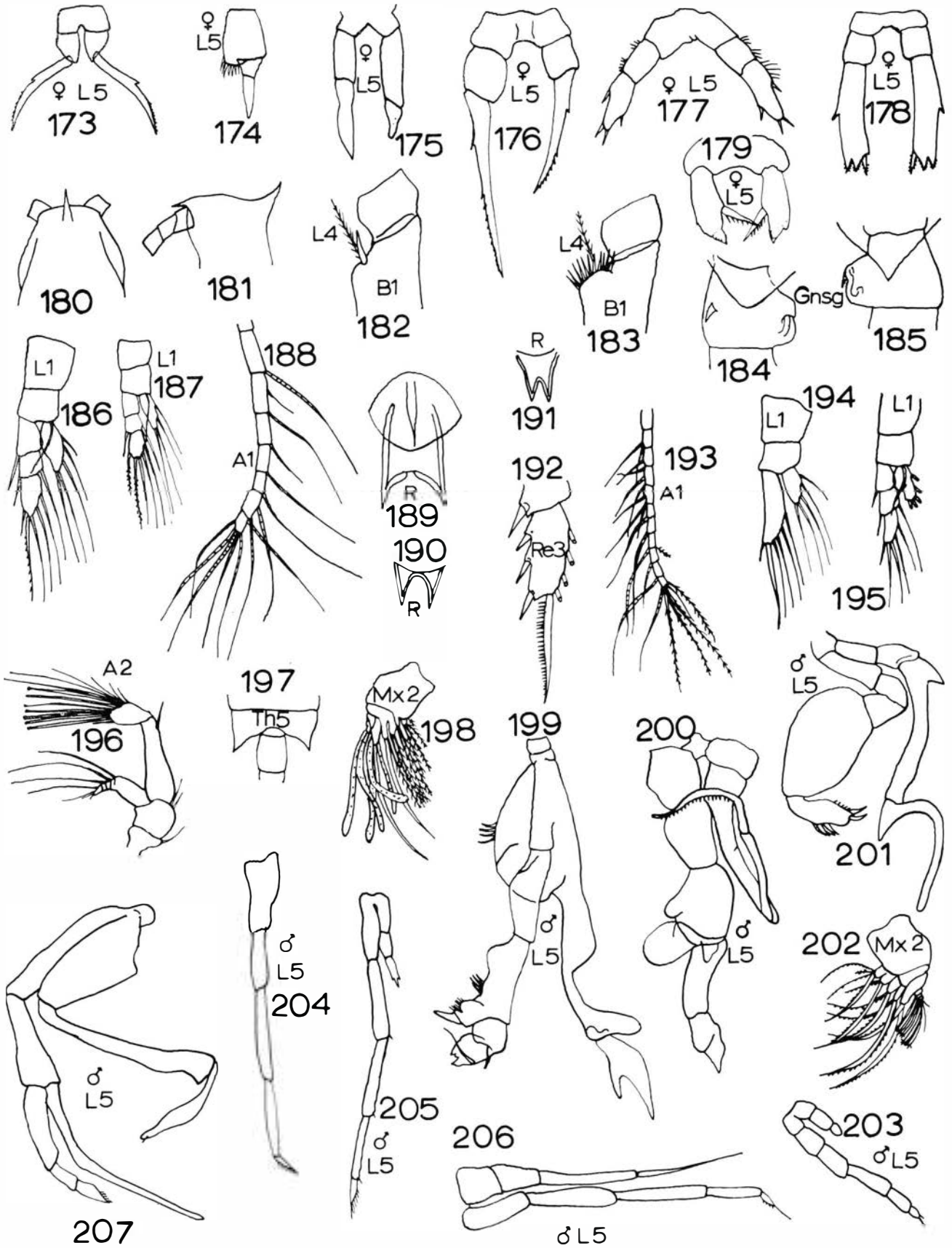
KEY-FIGS 173-207. ABBREVIATIONS: A 1,2=antenna 1,2; B 1,2=basipod segments 1,2; Gnsg=genital segment; L 1,2,3,4,5,6= legs 1,2,3,4,5,6; Mx 1,2=maxilla 1,2; R=rostrum; Re=exopod; Th=thorax; ♂=male; ♀=female
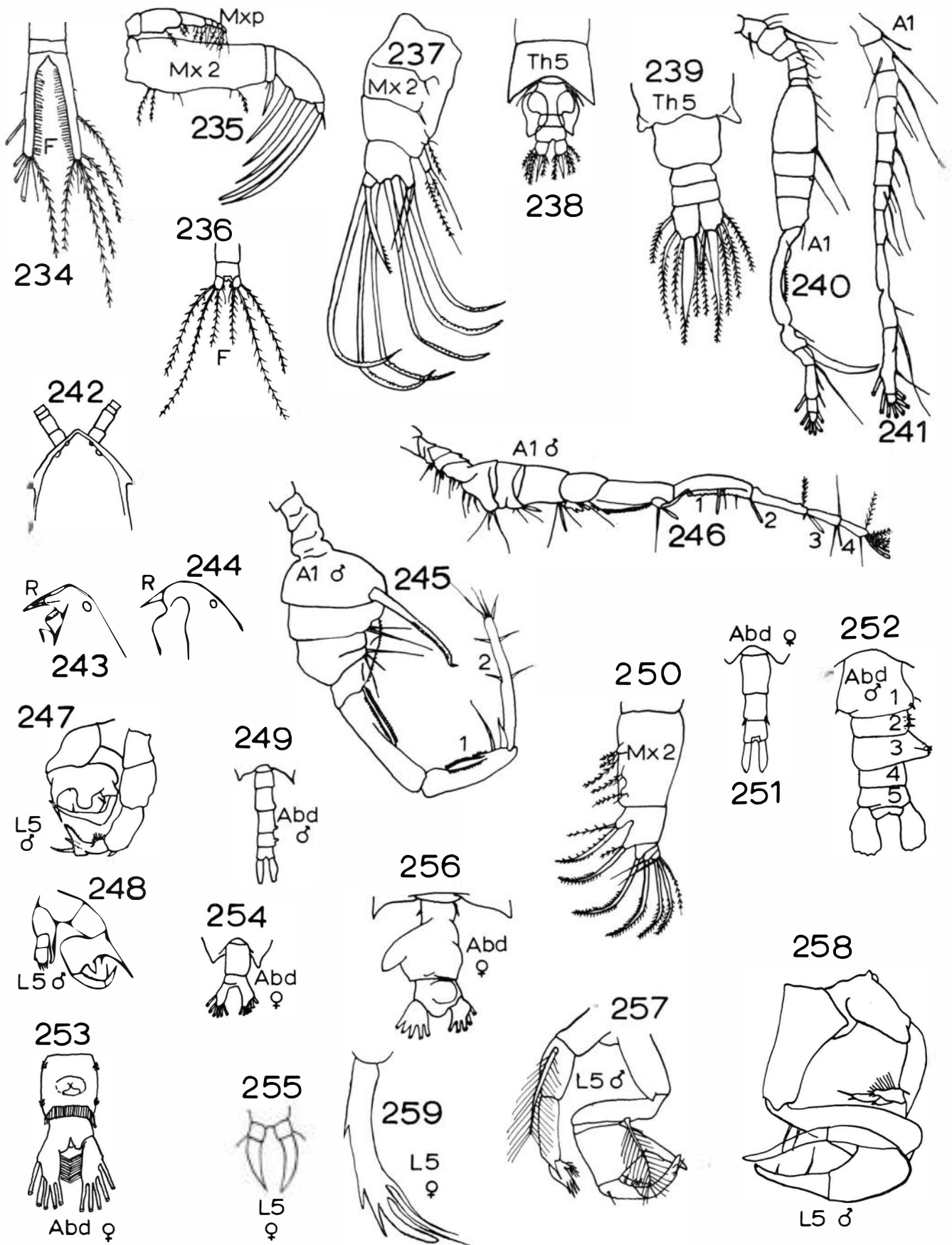
Exopod of leg 1 with three external spines (Key-fig. 186) — 150

149 Rostrum huge, with the two points fused at the base separated proximally by a large hollow (Key-fig. 189)   *Euaetideus* ♀

Rostrum thick, the two points separated down to the base (Key-fig. 190) *Aetideus* ♀

150 Rostrum large, with two strong points. Final seta of exopod segment 3 of legs 2, 3, 4 with numerous equal teeth (Key-figs 191, 192)   *Aetideopsis* ♀

Rostrum small, with two points — 151

151 Setae of last six segments of antenna 1 thick and annulated (Key-fig. 188)   *Bradyidius* ♀

These setae of ordinary form, not thick and annulated — 152

152 Maxilla 2 provided with very strong hooks. Exopod of leg 1 with one segment (Key-fig. 194)   *Chiridiella* ♀

Maxilla 2 without hooks; exopod of leg 1 with three segments (Key-fig. 195)   *Pseudaetideus* ♀

153 Exopod of antenna 2 longer than endopod   154
Exopod of antenna 2 half the length of the endopod (Key-fig. 196)   *Comantenna* ♀

154 Exopod of leg 1 with three external spines   155
This exopod with two external spines *Gaidius* ♀

155 Maxilla 2 with worm-like appendages. Corners of thoracic segment 5 pointed or undulated (Key-fig. 198)   *Diaixis* ♀

Maxilla 2 without worm-like appendages   156

156 Thoracic segments 4 and 5 fused   *Chiridius* ♀
Thoracic segments 4 and 5 separate *Gaidiopsis* ♀

157 Leg 5: see Key-fig. 175   *Stephos (fultoni)* ♀
Leg 5: see Key-fig. 176   *Parastephos* ♀
Leg 5 of another type — 158

158 Leg 5 very big and complex; its segments irregular, enlarged with lumps, but without endopods (Key-fig. 199) — 159

Leg 5 with its segments all narrow, often one or two endopods present (Key-figs 207, 211, 212) — 161

159 Exopod segment 1 of leg 1 with long thin external spine (Key-figs 195, 199) *Diaixis* ♂

This segment without external spine — 160

160 The penultimate segment of the left leg 5 cylindrical; last segment without appendages (Key-fig. 200)   *Parastephos* ♂

The penultimate segment of left leg 5 enlarged; final segment with two or many appendages (Key-fig. 201) *Stephos* ♂

161 Leg 5 without endopods. or with only one branch (Key-figs 203, 206) — 162

Leg 5 with at least one endopod, more or less rudimentary (Key-figs 207, 211, 212) — 168

162 Maxilla 2 with bush-like sensorial appendages (Key-fig. 202)   *Pseudophaenna* ♂

Maxilla 2 with only setae — 163

163 Exopod of leg 1 with two external spines   164
Exopod of leg 1 with three external spines   166

164 Leg 5 present on both sides, left five- or six-segmented, right three-segmented (Key-fig. 203) — 165

Leg 5 present on both sides, left five-, right two-segmented   *Teneriforma* ♂

Leg 5 present on both sides, left five-, right four-segmented   *Mimocalanus* ♂

Leg 5 five-segmented on left, right represented by a short stump   *Mesaiokeras* ♂

Leg 5 absent on the right (Key-fig. 204)   *Aetideus* ♂

165 Exopod segment 1 leg 1 without external spine, endopod leg 1 with four setae (Key-fig. 187)   *Microcalanus* ♂

Exopod segments of leg 1 devoid of external spines, endopod leg 1 with five setae   *Sognocalanus* ♂

166 Rostrum absent (Key-figs 131, 208) *Chiridius* ♂
Rostrum present — 167

167 Right leg 5 as long as the left; needle-like (Key-fig. 206)   *Pseudocalanus* ♂

168 Endopods leg 5 both present — 169
Right leg 5 without endopod. Left exopod three-segmented, half length styliform endopod. Sensorial filaments on maxilla 2 (Key-fig. 207)   *Tharybis* ♂

169 Endopods leg 5 often very shortened — 171
Endopods leg 5 well developed. Maxilla 2 with sensorial filaments — 170

170 Maxilla 2 bearing one enlarged spine-like seta   *Parundinella* ♂

Maxilla bearing two enlarged spine-like setae   *Batheuchaeta* ♂

171 Head with median dorsal spine (Key-figs 180, 181, 209)   *Gaetanus* ♂
Head without median dorsal spine — 172

172 Thoracic segment 5 with rounded corners   *Pseudochirella* ♂

Thoracic segment 5 extended into points (Key-fig. 197) — 173

173 Rostrum with one point. Exopod of leg 1 with two or three external spines (Key-fig. 210)   *Gaidius* ♂

26
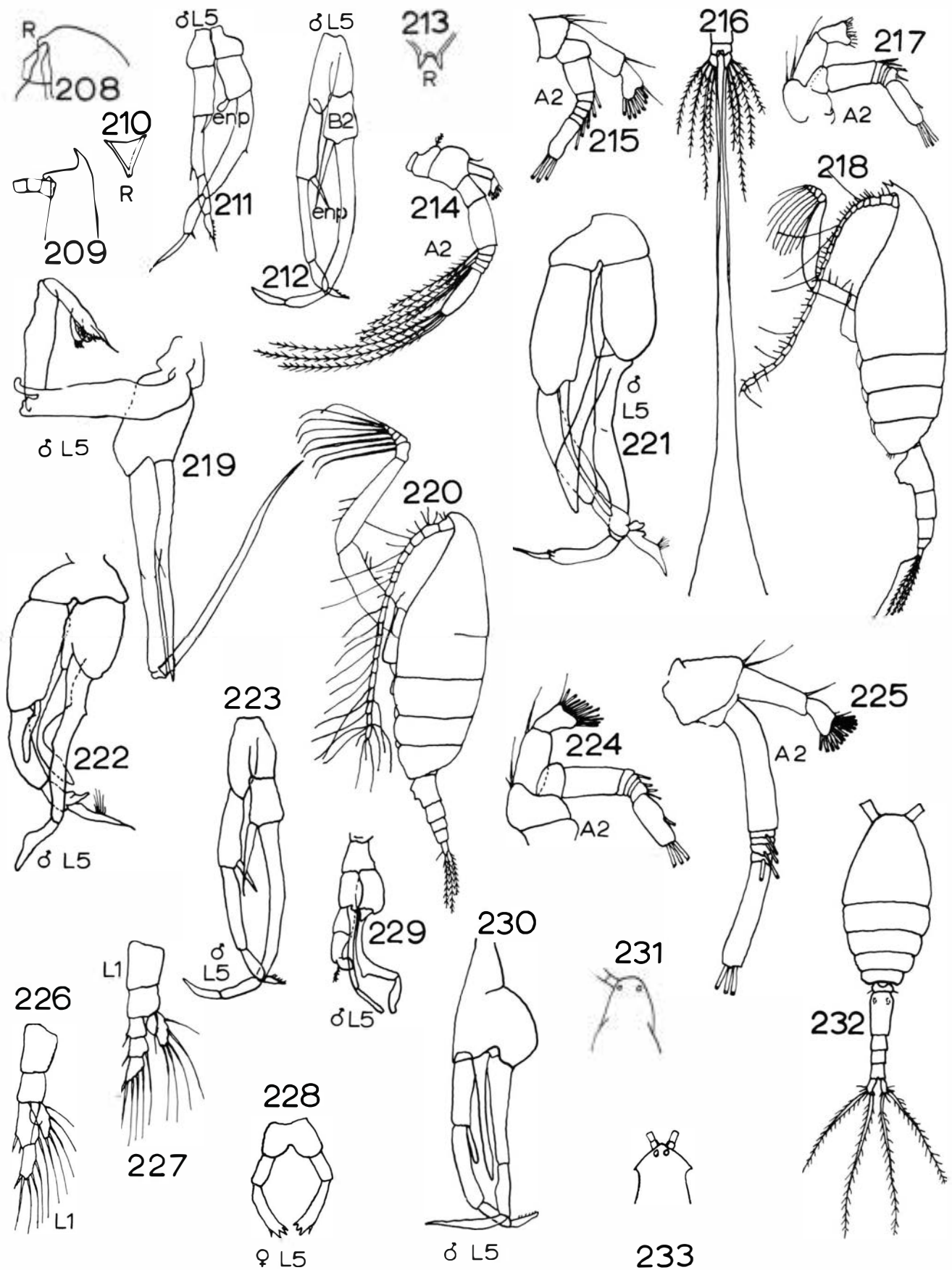
KEY-FIGS 208-233. ABBREVIATIONS: A 1,2=antenna 1,2; B 1,2=basipod segments 1,2; Enp=endopod; L 1,2,3,4,5,6=legs 1,2,3,4,5,6; R=rostrum; ♂=male; ♀=female

*Gaidius minutus ♀ (only sex known) Exopod of leg 1 has two segments fused.

28

KEY-FIGS 234-259. ABBREVIATIONS: A 1,2=antenna 1,2; Abd=abdomen; F=furca; L 1,2,3,4,5,6=legs 1,2,3,4,5,6; Mx 1,2= maxilla 1,2; Mxp=maxilliped; R=rostrum; Th=thorax; ♂=male; ♀=female

Exopod of leg 1 with two segments; sometimes with traces of the area of fusion in the first (Key-fig. 226)   195

195   Endopod of antenna 2 more than half the length of exopod (Key-fig. 224)
                    Pseudochirella ♂
Endopod of antenna 2 at most half the length of exopod (Key-fig. 225) *Euchirella* ♂

196   Endopod of leg 1 with one segment   197
Endopod of leg 1 with two segments   201
Endopod of leg 1 with three segments   209

197   Endopod of leg 2 with one segment   198
Endopod of leg 2 with two segments
                        Eurytemora

198   Leg 5 absent. Two egg sacs   *Valdiviella* ♀
Leg 5 present   199

199   Leg 5 with one three-segmented branch on each side; the last segment with three-four terminal teeth (Key-fig. 228)
                        Undinella ♀
Leg 5 large, of complex structure (Key-figs 229, 230)   200

200   Leg 5: see Key-fig. 229   *Undinella* ♂
Leg 5: see Key-fig. 230   *Valdiviella* ♂

201   Head with one pair of lenses (Key-figs 231, 233)   *Labidocera*
Head without dorsal lenses   202

202   Leg 5 uniramous   *Calanopia*
Leg 5 biramous   203

203   Endopod of leg 5 three-segmented (Key-figs 38, 73)   *Centropages*
Endopod of leg 5 with only one segment or absent   204

204   Podoplea. Furca short, with two plumose symmetrical setae (Key-fig. 232) *Paroithona*
Gymnoplea. Furca with three plumose setae, often asymmetrical. Maxilla 2 squat with very long hooked setae (Key-fig. 237)   *Bathypontia*
Gymnoplea. Furca with at least four symmetrical plumose setae   205

205   Maxilla 2 shorter than maxilliped. Furca long and narrow, at least six times longer than wide (Key-figs 105, 234)   *Temora*
Maxilla 2 longer than maxilliped. Furca short (Key-fig. 235)   206

206   Maxilla 2 very large, with large scythe-like setae (Key-fig. 235)   207
Maxilla 2 not greatly enlarged, with thin, long, very spiny setae   208

207   Female leg 5 end segment with terminal finger-like process which may be finely

serrate on one or both margins; two setae on the inner lateral margin of this segment. Male right antenna 1 has no teeth in the geniculate region between segments 18 and 19. Right leg 5 not chelate, ends in long feather-like seta (Key-fig. 259)   *Paracandacia*
Female leg 5 end segment not as above. Male right antenna 1 toothed on segments 17-20 in geniculate region. Right leg 5 chelate   *Candacia*

208   Female leg 5 uniramous, two- or three-segmented, end segment bearing an internal spine and an external plumose seta. Male leg 5 uniramous, four-segmented on right, five-segmented on left
                      Acartia
Female leg 5 biramous, one-segmented, endopod spine-like. Male leg 5 uniramous, four-segmented on right, three-segmented on left   *Paralabidocera*

209   Head with two or four lenses on the dorsal surface (Key-figs 5, 231, 233, 242-4)   210
Head without lenses or lateral hooks   215

210   Head with four lenses and lateral hooks (Key-fig. 242)   *Anomalocera*
Head with two lenses (Key-figs 243, 244)   211

211   Head without lateral hooks (Key-fig. 231)
                      Labidocera
Head with lateral hooks (Key-fig. 233)   212

212   Abdomen with two-three segments; neither antenna 1 with a knee-like joint   213
Abdomen with five segments; right antenna 1 with a knee-like joint   214

213   Rostrum swollen at the base, with one rostral lens (Key-fig. 243)   *Pontella* ♀
Rostrum not swollen at the base, without lens (Key-fig. 244)   *Labidocera* ♀

214   Terminal part of prehensile antenna 1 with two segments; no endopod on left leg 5 (Key-figs 245, 247)   *Pontella* ♂
Terminal part of prehensile antenna 1 with four segments. One endopod rudimentary on left leg 5 (Key-figs 246, 248)   *Labidocera* ♂

215   Maxilla 2 powerful with strong curved setae. Second segment female urosome with two dorsal spines. Leg 5 biramous. Male urosome five-segmented, third and fourth segments with extensions on their right (Key-figs 249-51)   *Parapontella*
Maxilla 2 powerful with strong curved setae. Female leg 5 uniramous. Male urosome four-segmented   *Neopontella*

30

These combinations of features absent ... 216

216 Abdomen with one, two, or three segments ... 217
　　 Abdomen with five segments ... 219

217 Leg 5 with only one two-segmented branch, terminating in a point (Key-fig. 255) *Tortanus* ♀
　　 Leg 5 with two branches on each side; endopod sometimes small ... 218

218 Antenna 1 with very plumose setae. Abdomen symmetrical. Furcae asymmetrical. Genital segment with four groups of lateral spinules (Key-figs 253, 254) *Pontellina* ♀

　　 Antenna 1 setae not very plumose. Abdomen not symmetrical. Furcae symmetrical. Genital segment without spinules (Key-fig. 256) *Pontellopsis* ♀

219 Prehensile antenna 1 little swollen, not globular in the middle. *Tortanus* ♂

Prehensile antenna 1 very swollen, globular in the middle (Key-fig. 245) ... 220

220 Third abdominal segment has lump on the right margin. External seta of basipod segment 2 of leg 5 small (Key-figs 252, 258) *Pontellopsis* ♂
　　 Third abdominal segment not lumpy. External seta of basipod segment 2 of leg 5 long and very plumose (Key-fig. 257) *Pontellina* ♂

221 Endopod of leg 4 with two segments (Key-fig. 12) *Corina*
　　 Endopod of leg 4 with one segment or knob-shaped, or replaced by one or two setae ... 222

222 Abdomen with one segment; setae on basipod segments 1 and 2 of antenna 2 branching (Key-fig. 11) *Corycella*
　　 Abdomen with two-three segments; setae on basipod segments 1 and 2 of antenna 2 not branching (Key-figs 9, 10) *Corycaeus (s.l.)*

SYSTEMATIC LIST OF SPECIES

Fifty-five species were recorded. Of these 48 were positively identified, 2 were uncertainly identified, and 5 were identified to genus only.

Two of the recorded species may not be typically pelagic: *Bradyidius* sp. is probably benthic (Sars, 1903 as *Undinopsis*), being captured in a haul which scooped the bottom, and *Harpacticus* sp. is probably a stray from the littoral environment.

Order CALANOIDA

Fam. CALANIDAE

Calanus australis Brodsky, 1959 (Fig. 4.1–4.3)

NEW ZEALAND RECORDS: Brodsky, 1961; Deevey, 1966.

MATERIAL EXAMINED: In all samples from Sta. 1. Also found at Sta. 2 on 4 Aug 63, 14 Apr 64; 7 Jan 65. Females were 2.4–3.5 mm and males 2.42–3.35 mm long (Deevey, 1966).

REMARKS: One of the most common species at Kaikoura. Almost absent at Sta. 1 on only two occasions, 29 Aug 64 and 21 Dec 64, and absent from Sta. 2 on 22 Oct 63. The validity of Brodsky's (1961) varieties, *pacificus* and *atlanticus,* was questioned by Deevey (1966).

Calanus tenuicornis Dana, 1849 (Fig. 4.4)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Deevey, 1966.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
30 Apr 64	N70	0–200m	1 ♀ 2.32 mm
16 May 64	N70	0–200m	1 ♀
15 Jun 64	N70	0–200m	3 ♀ ♀
12 Jul 64	N70	0–200m	4 juveniles
29 Aug 64	CB	150m	1 juvenile
13 Sep 64	CB	150m	1 ♀
26 Sep 64	CB	>80m	5 ♀ ♀, juveniles
21 Dec 64	CB	90m	1 ♀
24 Feb 65	N70	0–200m	1 ♂ 2.2 mm
12 Mar 65	N70	0–200m	1 ♀
5 May 65	N70	0–200m	1 ♀

REMARKS: Relatively uncommon at Kaikoura. Larger than the specimens recorded by Rose (1933) (females 1.8mm, males 1.5–1.8mm); Dakin and Colefax (1940) (female 2.0mm); and Farran (1929) (females 1.8–2.1mm). The proportional lengths of abdominal segments 2 and 3 (4.8 : 3.8) do not agree with Bowman's (1955) description of *C. lighti.*

31

Calanus tonsus Brady, 1883   (Fig. 4.5–4.7)

NEW ZEALAND RECORDS: Brady, 1883; Farran, 1929; Vervoort, 1957; Brodsky, 1964.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	2 Aug 64	N70	0–200m	♀ ♀ rare
		CB	20m	1 ♀
	13 Sep 64	N70	0–200m	♀ ♀ 3.8–4.1mm
	26 Sep 64	N70	0–200m	1 ♀, stage V rare
	11 Oct 64	N70	0–200m	♀ ♀ rare, stage V
	29 Oct 64	N70	0–200m	stage V rare
	17 Nov 64	N70	0–200m	stage V frequent
	5 Dec 64	N70	0–200m	many stage V at surface
	21 Dec 64	N70	0–200m	many stage V at 20m
	7 Jan 65	N70	0–200m	stage V common, ♀ ♀ rare
	24 Jan 65	N70	0–200m	stage V common, ♀ ♀ rare
	5 May 65	N70	0–200m	stage V rare
Sta. 2	7 Jan 65	N70	surface	many stage V
Sta. 3	5 May 65	N70	200–500m	stage V rare

REMARKS: Brady (1883) first described *Calanus tonsus* from material gathered in both hemispheres. Although Marukawa (Tanaka, 1956) described *C. plumchrus* from the northern hemisphere many authors perpetuated Brady's opinion that *C. tonsus* could be found in the north Pacific Ocean. Tanaka (1956) discussed *C. plumchrus* Marukawa and noted the differences from *C. tonsus,* which is now considered to be confined to the southern hemisphere, *C. plumchrus* being its northern analogue. Brodsky's (1964) description of the male confirms the relationship. The male fifth left leg of *C. tonsus* differs from *C. plumchrus* in having the endopod extending past the base of the third exopod segment. Brodsky recorded males from several localities (Tasman Sea, South of Australia, the southern tip of South America) all in hauls that reached below 500m.

Vervoort (1957, 1965b) considered *C. tonsus* to be a subantarctic surface species, although Heinrich's (1962) interpretation of the *C. plumchrus* life-history makes this seem unlikely. *C. plumchrus* females produce one brood a year in winter or spring at depths greater than 200m. The young, which rapidly reach stage V in the surface water layers, when there is maximum phytoplankton growth, store large reserves of fat until adult. Adult females, at least, have reduced mastication edges on the mandibles and do not feed (Heinrich, 1962). Stage V *C. tonsus* copepodite is the most common stage found at Kaikoura.

The first exopod segment of the female second leg is similar in form to that of *Neocalanus.* This was not figured by Vervoort (1957) and may be significant in any reconsideration of the taxonomy of *C. tonsus.*

Calanoides carinatus (Kroyer, 1849)   (Fig. 4.8–4.9)

NEW ZEALAND RECORDS: Farran, 1929 (= *Calanus carinatus*); Dakin and Colefax, 1940 (= *Calanoides brevicornis*); Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
13 Sep 64	N70	0–200m	♀ ♀ rare 3.18mm
26 Sep 64	N70	0–200m	stage V
11 Oct 64	N70	0–200m	stage V, ♀ ♀ rare
29 Oct 64	N70	0–200m	stage V
	CB	150m	stage V
17 Nov 64	N70	0–200m	stage V
5 Dec 64	N70	0–200m	stage V
	CB	86m	1 ♀
7 Jan 65	N70	0–200m	♀ ♀ rare
	CB	88m	1 ♀
24 Jan 65	N70	0–200m	stage V rare

REMARKS: Readily recognised by the shape of the head. Adults may be distinguished from *C. acutus* by their small size. Adult females were rarely captured at Kaikoura and were shown to be confined to a specific depth, never less than 86m, by Clarke-Bumpus sampler hauls. This species appeared mainly as stage V copepodites and seemed to be behaving like *Calanus tonsus* in this respect.

Neocalanus gracilis (Dana, 1849)   (Fig. 4.10–4.12)

NEW ZEALAND RECORDS: Brady, 1883; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
16 May 64	N70	0–200m	juvenile ♀ 2.91mm
26 Jun 64	N70	0–200m	♀
	CB	170m	♀
21 Dec 64	CB	90m	♀
24 Feb 65	N70	0–200m	♀
	CB	177m	♀
12 Mar 65	N70	0–200m	stage V
4 Apr 65	CB	180m	♀
5 May 65	N70	0–200m	♀

REMARKS: Readily recognised by the first swimming legs, the incurved hook on the first exopod segment of the second leg, and the long first antennae which are almost twice the body length. Only one specimen was taken on all occasions.

Fam. EUCALANIDAE

Eucalanus elongatus (Dana, 1848)   (Fig. 4.13–4.14)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
14 Apr 64	N70	0–200m	1 ♀ 7.1mm
1 Jun 64	CB	surface	1 ♀
26 Sep 64	CB	85m	1 ♀
29 Oct 64	N70	0–200m	1 ♀, 1 ♂ 4.2mm
17 Nov 64	CB	91m	2 ♂ ♂
7 Jan 65	CB	20m	1 ♂
24 Jan 65	CB	91m	1 ♂
12 Mar 65	N70	0–200m	1 ♀
	CB	81m	1 juvenile ♀
18 Apr 65	N70	0–200m	1 ♀
	CB	77m	1 juvenile ♂

SCALE

Scale mark
represents :

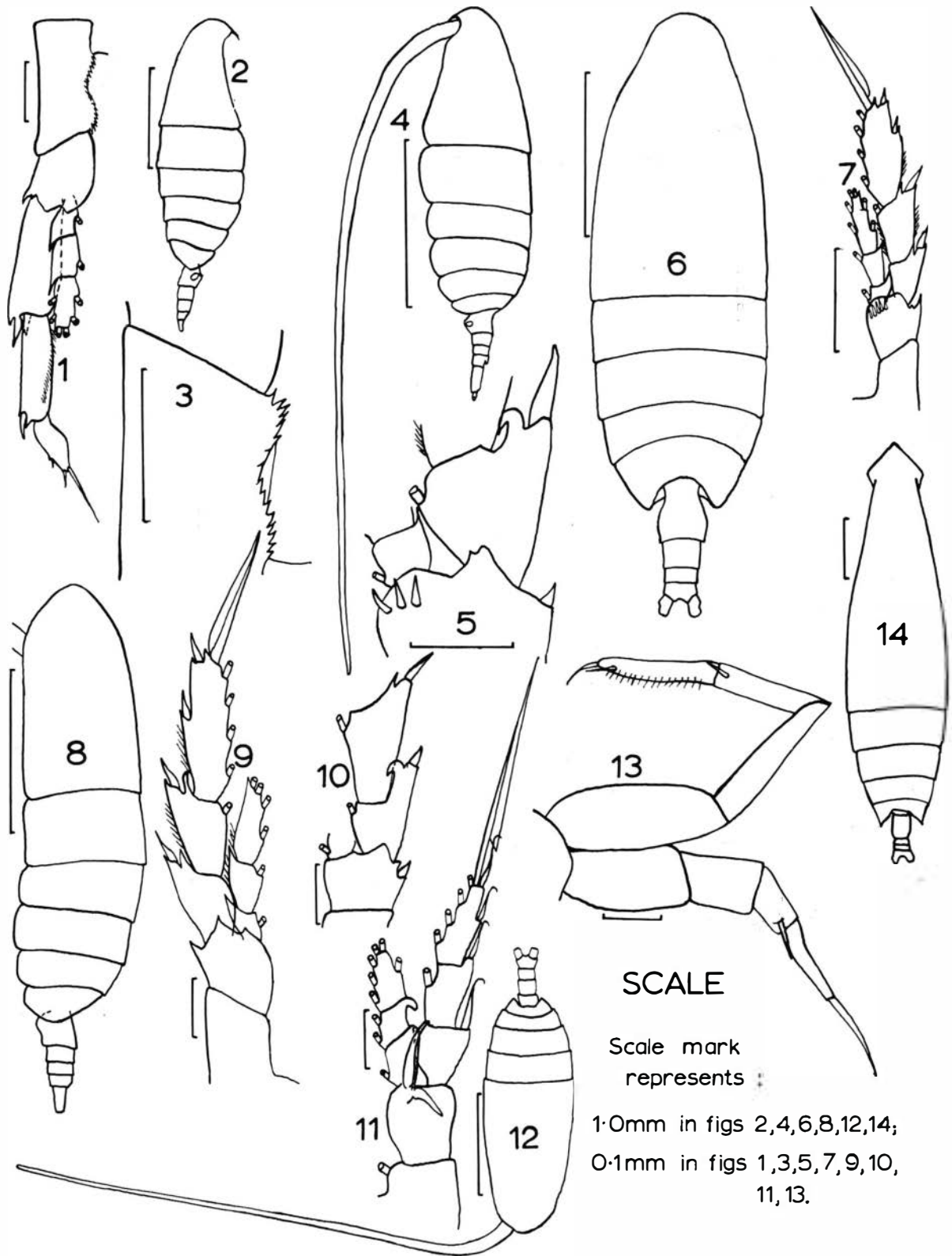1·0mm in figs 2,4,6,8,12,14;

0·1mm in figs 1,3,5,7,9,10,
11, 13.

FIG. 4 (1) *Calanus australis*, male, left leg 5; (2) female, lateral view; (3) basipod segment 1, leg 5; (4) *C. tenui-cornis*, female, lateral view; (5) *C. tonsus*, exopod segment 1, leg 2; (6) female, dorsal view; (7) leg 5; (8) *Calanoides carinatus*, female, lateral view; (9) leg 5; (10) *Neocalanus gracilis*, female, leg 2; (11) leg 1; (12) immature female, dorsal view; (13) *Eucalanus elongatus* male, leg 5; (14) female, dorsal view

REMARKS: Usually one specimen only was taken at a time. When it occurred in Clarke-Bumpus sampler hauls it was confined to depths below 80m, except on 1 Jun 64 and 7 Jan 65. In the Kaikoura plankton this species is readily recognised by its size.

Eucalanus longiceps Matthews, 1925 (Fig. 5.1–5.3)

NEW ZEALAND RECORDS: Farran, 1929 ($= E.\ acus$); Vervoort, 1957; Bary, 1959a ($= E.\ acus$).

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
14 Apr 64	N70	0–200m	♀ ♀	3.86mm
15 Jun 64	N70	0–200m	♀ ♀	
12 Aug 64	N70	0–200m	♀ ♀	
13 Sep 64	CB	22m	5 ♀ ♀	
26 Sep 64	N70	0–200m	10 ♀ ♀	
	CB	85m	2 ♀ ♀	
11 Oct 64	N70	0–200m	juveniles	
29 Oct 64	CB	77m	juveniles	
17 Nov 64	CB	24m	juveniles	
7 Jan 65	CB	20m	1 ♂	
		88m	4 ♀ ♀, 1 ♂	3.25mm
24 Jan 65	N70	0–200m	♀	
24 Feb 65	N70	0–200m	♀	
12 Mar 65	N70	0–200m	♀	
	CB	81m	juvenile	
4 Apr 65	N70	0–200m	♀	

REMARKS: This species, considered by Bary (1959a) to have subantarctic affinities, was captured quite often at Kaikoura.

Rhincalanus nasutus Giesbrecht, 1888 (Fig. 5.4–5.6)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth		
Sta. 1	1 Jun 64	N70	0–200m	juvenile ♂	3.1mm
Sta. 3	5 May 65	N70	200–500m	♀	5.18mm

REMARKS: A rare species, captured only twice, the adult specimen coming from below 200m. Easily recognised by the form of its head, the spines on the posterior border of the last three thoracic segments, and the dorsal surface of the genital segment.

Mecynocera clausii I. C. Thompson, 1888 (Fig. 5.7–5.8)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957; Dakin and Colefax, 1940.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
16 May 64	N70	0–200m	♀ ♀	1.20mm
5 Dec 64	CB	86m	♀ ♀	

REMARKS: This small species was captured twice and only females were taken. Vervoort (1963) suggests that Bernard (1958) has described a male as well as a female of *M. clausii* under the name *Dolichocera tenuis*.

Fam. PARACALANIDAE

Paracalanus parvus (Claus, 1863) (Fig. 5.9–5.12)

NEW ZEALAND RECORDS: Kramer, 1894; Brady, 1889; Thomson and Anderton, 1921; Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957; Bary, 1959a; R. M. Cassie, 1959; Deevey, 1966.

MATERIAL EXAMINED: *Paracalanus parvus* was taken in every sample. Length: female 0.86mm, male 1.0mm.

REMARKS: One of the most common species captured. Numbers were reduced only in December. Deevey (1966) noted that the largest specimens were caught in September.

Calocalanus styliremis Giesbrecht, 1888 (Fig. 5.13–5.14)

NEW ZEALAND RECORDS: Farran, 1929.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
30 Apr 64	N70	0–200m	♀ ♀	0.75mm
16 May 64	N70	0–200m	♀ ♀	
1 Jun 64	N70	0–200m	♀ ♀	
15 Jun 64	N70	0–200m	♀ ♀	
2 Aug 64	CB	92m	♀ ♀	
17 Nov 64	CB	100m	♀ ♀	
5 Dec 64	N70	0–200m	♀ ♀	
7 Jan 65	N70	0–200m	♀ ♀	
12 Mar 65	CB	81m	♀ ♀	
4 Apr 65	N70	0–200m	♀ ♀	
18 Apr 65	N70	0–200m	♀ ♀	
5 May 65	N70	0–200m	♀ ♀	

REMARKS: Only one or two specimens were captured at any one time. Recognised by the small size, shape of the female genital segment, and shape of the 5th legs.

Calocalanus tennis Farran, 1926 (Fig. 5.15–5.16)

NEW ZEALAND RECORDS: Nil

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
1 Jun 64	N70	0–200m	♀	1.25mm
15 Jun 64	N70	0–200m	♀	
26 Sep 64	CB	150m	♀	

REMARKS: These specimens fit Farran's original description and also that of Farran and Vervoort (1951a). The genus *Calocalanus* has been revised by Bernard (1958) who erected two new genera. She considered that *Calocalanus, Leptocalanus,* and *Dolichocera* form a family group (Calocalanidae) separate from the Paracalanidae. Her classification has not been followed here as her figures of *Dolichocera tenuis* do not agree with Farran's (1926) *Calocalanus tenuis*, which Bernard considered synonymous with *Dolichocera tenuis*. It is the first record of *Calocalanus tenuis* in the New Zealand region.
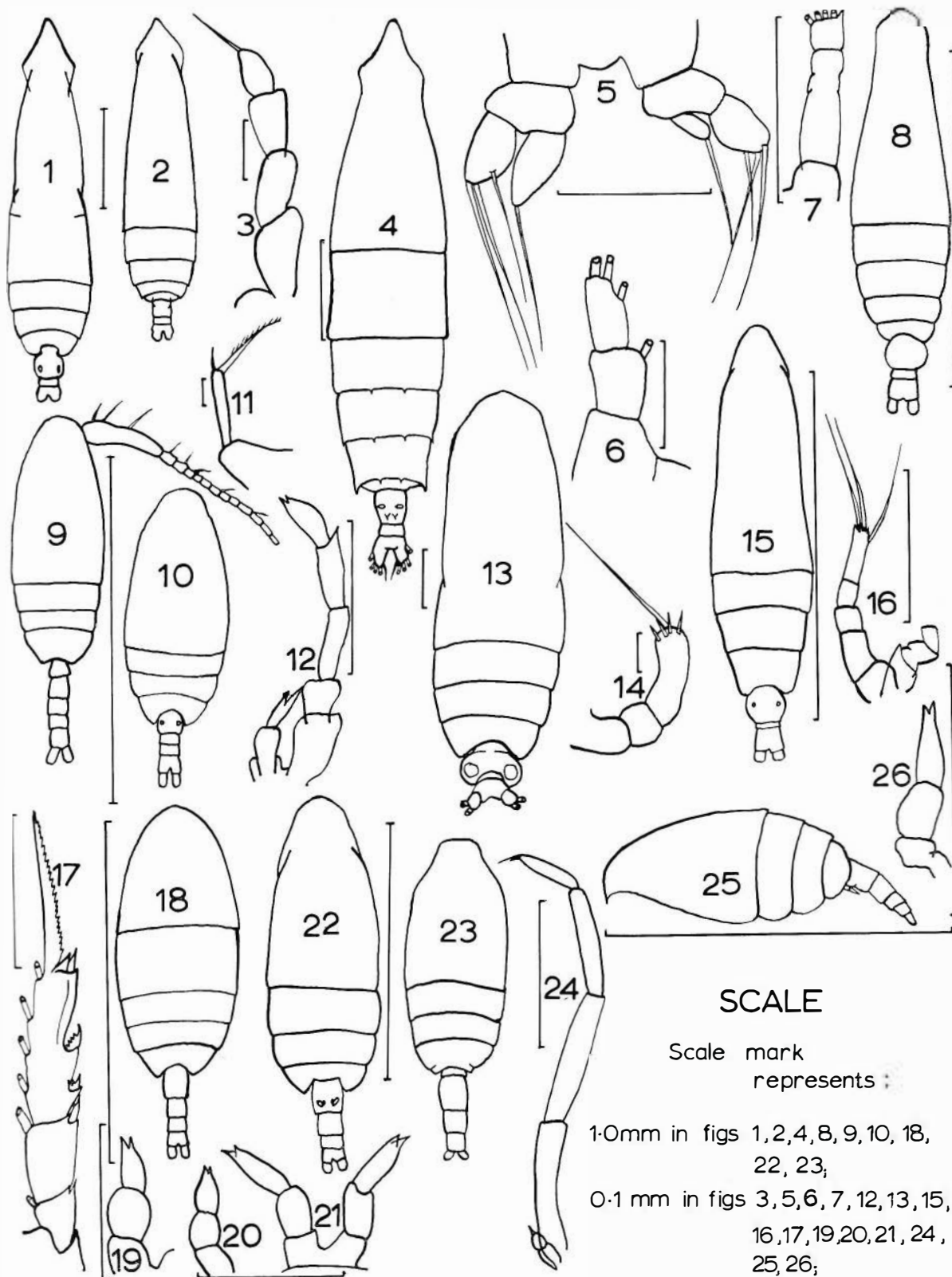
FIG. 5. (1) *Eucalanus longiceps,* female, dorsal view; (2) male, dorsal view; (3) leg 5; (4) *Rhincalanus nasutus,* female, dorsal view; (5) immature male, leg 5; (6) female, leg 5; (7) *Mecynocera clausi,* female, leg 5; (8) dorsal view; (9) *Paracalanus parvus,* male, dorsal view; (10) female, dorsal view; (11) leg 5; (12) male, leg 5; (13) *Calocalanus styliremis,* female, dorsal view; (14) leg 5; (15) *C. tenuis,* female, dorsal view; (16) leg 5; (17) *Ctenocalanus vanus,* female, leg 3 exopod; (18) dorsal view; (19) *Clausocalanus arcuicornis,* female, leg 5; (20) parasitised? female, leg 5; (21) female, leg 5; (22) dorsal view; (23) male, dorsal view; (24) leg 5; (25) *C. pergens,* female, lateral view; (26) leg 5

Fam. PSEUDOCALANIDAE

Ctenocalanus vanus Giesbrecht, 1888 (Fig. 5.17–5.18)

NEW ZEALAND RECORDS: Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
14 Apr 64	N70	0–200m	1 ♀ 1.02mm

REMARKS: A rare species, characterised by serration on the lateral spines of the third leg exopod.

Clausocalanus arcuicornis (Dana, 1849) (Fig. 5.19–5.24)

NEW ZEALAND RECORDS: Brady, 1883; (= in part *Scolecithrix minor* n.sp. female); Kramer, 1894; Brady, 1899; Thomson and Anderton, 1921; Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957; Deevey, 1966.

MATERIAL EXAMINED: Captured on every sampling day, except 14 Aug 63 at the inshore station. Females ranged in length from 1.25 to 1.65mm, and males from 1.0 to 1.4mm (Deevey, 1966).

REMARKS: One of the most common copepods in the Kaikoura collections. Most specimens belonged to the forma *maxima* of Grice (1961) and Tanaka (1956); that is, they had the last segment of the female fifth legs much longer than the preceding segment (Fig. 5.21). Nevertheless, some large specimens were found with female fifth legs as described by Farran (1936) (Fig. 5.19), but these were rare and could not always be separated from the common large form by superficial examination.

The opaque swollen appearance of the cephalothorax in some specimens suggests that this species may frequently be parasitised. One such large (1.8mm) opaque female did not have a fully developed genital segment, and the fifth legs (Fig. 5.20) had retained the juvenile proportions. Sewell (1951) found that *Clausocalanus arcuicornis* in the Arabian Sea parasitised by *Blastodinium* sp. were reduced in size, had modified fifth legs, and an incompletely developed abdomen.

Deevey (1966) recorded exceptionally small specimens of *C. arcuicornis* at Kaikoura in December, which she interpreted as an invasion by a different population.

Clausocalanus pergens Farran, 1926 (Fig. 5.25–5.26)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957; Deevey, 1966.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
14 Apr 64	N70	0–200m	♀ ♀	common 0.94mm
16 May 64	N70	0–200m	♀ ♀	rare
15 Jun 64	N70	0–200m	♀ ♀	rare
12 Jul 64	N70	0–200m	♀ ♀	rare
2 Aug 64	N70	0–200m	♀ ♀	rare

From 2 Aug 64 onwards *C. pergens* was not separated from *C. arcuicornis* because of the difficulty in distinguishing the two without detailed examination.

REMARKS: This species, which can be separated from *C. arcuicornis* by size alone, is probably constantly present in small numbers all year round.

Fam. AETIDEIDAE

Aetideus armatus (Boeck, 1872) (Fig. 6.1–6.3)

NEW ZEALAND RECORDS: Brady, 1883 (in part); Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	14 Apr 64	N70	0–200m	♀ 1.78mm
	26 Sep 64	N70	0–200m	♀
	24 Jan 65	N70	0–200m	♀, ♂ 1.56mm
	24 Feb 65	N70	0–200m	♀
	4 Apr 65	N70	0–200m	♀
	18 Apr 65	N70	0–200m	♀
Sta. 3	5 May 65	N70	200–500m	♀

REMARKS: Easily recognised by the shape of the rostrum and the pointed fifth thoracic segment.

Euaetideus giesbrechti (Cleve, 1904) (Fig. 6.4–6.6)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
14 Apr 64	N70	0–200m	♀ 1.96mm

REMARKS: Recognised by the shape of the head anterior margin (in dorsal view the rostral plate is not visible), the character of the rostrum (Fig. 6.6), and the posterolateral margins of the thorax (Fig. 6.4).

This specimen appears to be the first record for New Zealand.

Aetideopsis sp. (Fig. 6.7–6.10)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	11 Oct 64	N70	0–200m	1 ♀ 2.9mm
	4 Apr 65	N70	0–200m	juvenile ♀ ♀
Sta. 3	29 Oct 64	N70	0–600m	2 ♀ ♀
	5 May 65	N70	200–500m	many ♀ ♀ 2.76mm

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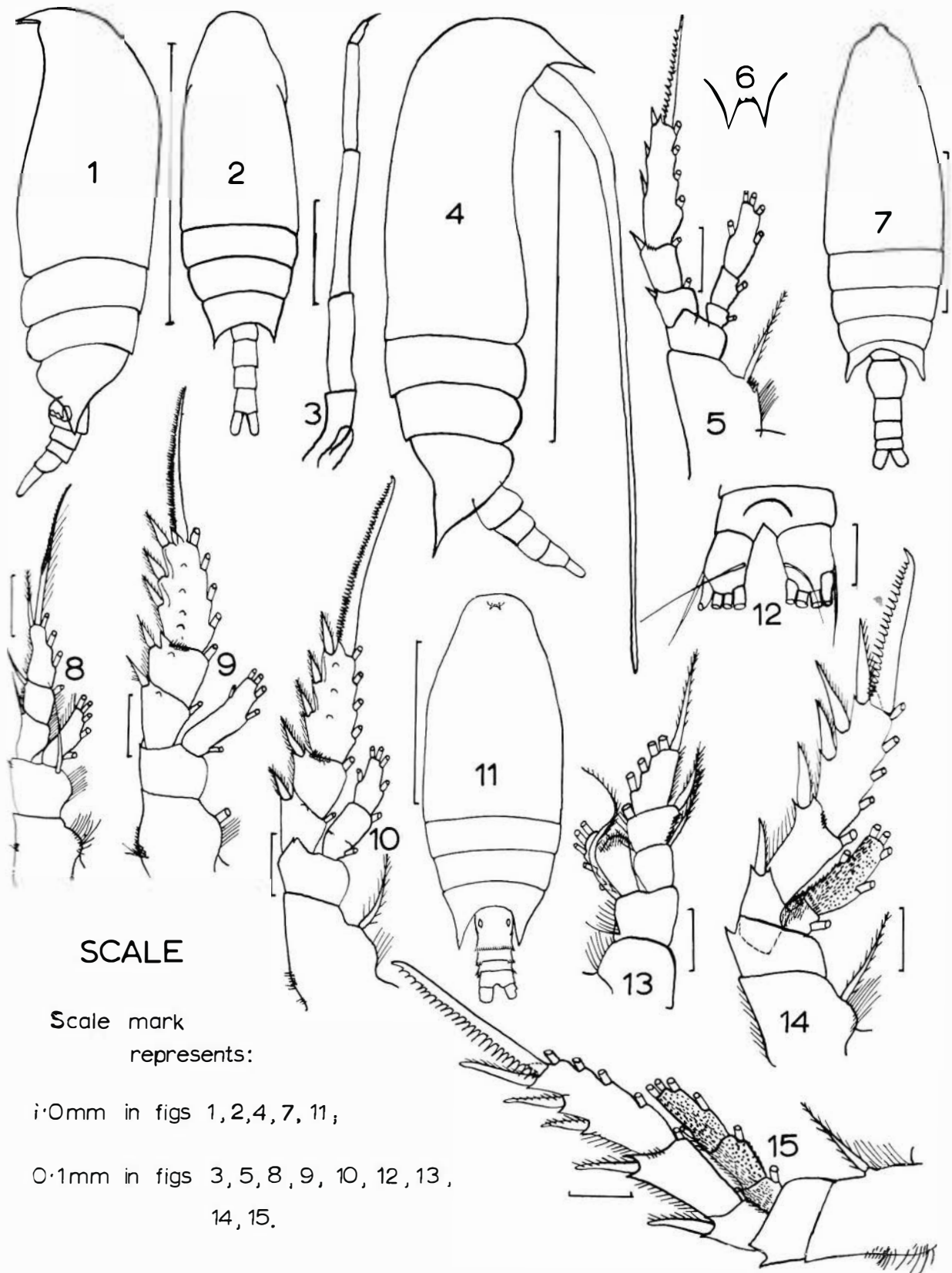0·1mm in figs 3, 5, 8, 9, 10, 12, 13,
  14, 15.

FIG. 6. (1) *Aetideus armatus*, female, lateral view; (2) male, dorsal view; (3) leg 5; (4) *Euaetideus giesbrechti*, female, lateral view; (5) leg 5; (6) rostrum; (7) *Aetideopsis* sp., female, dorsal view; (8) leg 1; (9) leg 2; (10) leg 3; (11) *Bradyidius* sp. female, dorsal view; (12) furca, ventral view; (13) leg 1; (14) leg 2; (15) leg 3

REMARKS: Kaikoura specimens do not entirely agree with descriptions of any of the following *Aetideopsis* species: *Aetideopsis rostrata* Sars, 1903 (= *A. pacifica* Esterly, 1911); *A. multiserrata* (Wolfenden, 1904); *A. antarctica* (Wolfenden, 1908); *A. minor* (Wolfenden, 1911); (see also Vervoort, 1951); *A. nasutus* (With, 1915); *A. modestus* (With, 1915); *A. divaricata* Esterly, 1911; *A. trichechus* Vervoort, 1949; *A. divergens* Tanaka, 1957; *A. cristata* Tanaka, 1957; *A. retusa* Grice and Hulsemann, 1967.

The body shape resembles *A. trichechus,* but the Kaikoura specimens are smaller. Distinctive features of the Kaikoura species are the genital segment, whose widest part, viewed dorsally, is anterior, and the first leg endopod, which has no outer swollen part furnished with bristles while the long seta on the second basipod segment is quite straight. Another distinct characteristic is the presence of glandular pores on the last exopod segments of legs 2, 3 and 4. These pores have not been mentioned by all authors so comparisons may not be made. The first antenna reaches approximately to the posterior border of the genital segment although usually held at right angles to the body.

Bradyidius sp. (Fig. 6.11–6.15)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth		
29 Oct 64	N70	0–600m	1 ♀	2.50mm

REMARKS: During this haul the net hit bottom at about 600m. According to Sars (1903) *U. bradyi* (= *Bradyidius bradyi*) lives close to the sea floor on a muddy bottom. It is likely that the Kaikoura specimen has a similar habitat.

Four species, *B. bradyi* (Sars, 1903); *B. similis* (Sars, 1903); *B. tropicus* (Wolfenden, 1905); and *B. augustus* (Tanaka, 1957), have been described. The present species is closest to *B. bradyi,* although there are several differences. The distal borders of urosome segments 1, 2, 3 have blunt spines, but only the genital segment is totally bordered. The endopods of the first, second, and third legs are densely covered with very small spines. The external spines of the second, third, and fourth leg exopods are very stoutly formed.

As only one specimen was captured, a new species is not proposed.

Chiridius gracilis Farran, 1908 (Fig. 7.1–7.2)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth		
Sta. 1	1 Jun 64	N70	0–200m	♀	2.61mm
	13 Sep 64	N70	0–200m	♀	
Sta. 3	29 Oct 64	N70	0–600m	♀	2.54mm

REMARKS: This rare species may be distinguished from *C. poppei* Giesbr. by the ratio of length of abdomen to cephalothorax (1 : 3 *C. poppei;* 1 : 3.5–4 *C. gracilis*) and the proportions of the second swimming legs (Vervoort, 1957).

Gaidius tenuispinus (Sars, 1900) (Fig. 7.3–7.4)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth	
5 May 65	N70	200–500m	♀ 2.92mm

REMARKS: This rare species may be distinguished from *G. pungens* Giesbr. by the two-segmented endopod of the second swimming legs. Taken once, in a haul from depths greater than 200m.

Gaetanus minor Farran, 1905 (Fig. 7.5–7.7)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth	
5 May 65	N70	200–500m	♀ 2.35mm

REMARKS: Captured only once, below 200m. Distinctive amongst the Kaikoura plankton in having a median dorsal spine on the head and very pointed hind corners to the fifth thoracic segment.

Euchirella rostrata (Claus, 1886) (Fig. 7.8–7.10)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth		
Sta. 1	5 Dec 64	CB	155m	♀	
	21 Dec 64	CB	90m	♀	
Sta. 3	29 Oct 64	N70	0–600m	♀	3.5mm

REMARKS: Easily recognised by its size and the number and form of the spines on the first basipod segment, fourth swimming legs. Not common.

Euchirella venusta Giesbrecht, 1892 (Fig. 7.11–7.12)

NEW ZEALAND RECORDS: Farran, 1929.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
24 Jan 65	N70	0–200m	♀ 5.06mm

REMARKS: Characterised by the genital segment and by the two spines on the fourth leg, first basipod segment, which reach its hind margin.
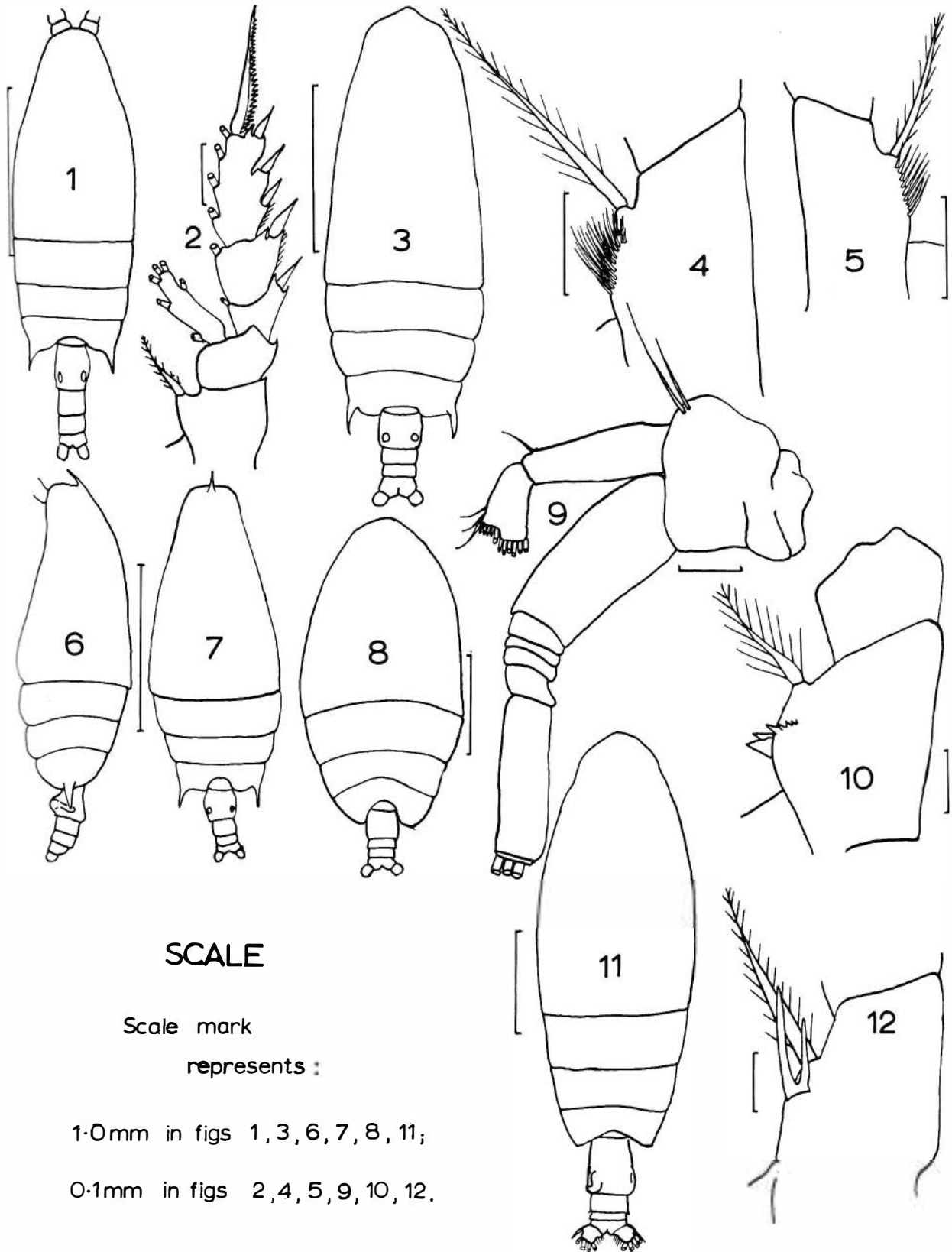
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FIG. 7. (1) *Chiridius gracilis,* female, dorsal view; (2) leg 2; (3) *Gaidius tenuispinus,* female, dorsal view; (4) basipod segments, leg 4; (5) *Gaetanus minor,* female, basipod segment 1, leg 4; (6) lateral view; (7) dorsal view; (8) *Euchirella rostrata,* female, dorsal view; (9) antenna 2; (10) basipod segment 1, leg 4; (11) *E. venusta,* female, dorsal view; (12) basipod segment 1, leg 4

Pseudochirella sp.   (Fig. 8.1–8.6)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth	
29 Oct 64	N70	0–600m	♀ 5.85mm

REMARKS: Apparently an undescribed species of *Pseudochirella*. It has 20 setae on the first maxilla endopod and is remarkable for the projections on the right side of the female genital segment and its ventral protuberance. As the only specimen captured had unequally developed spination on the fourth leg basipods, and may therefore be a deformed member of an already described species, it is not designated as new.

Undeuchaeta plumosa (Lubbock, 1856) (Fig. 8.7–8.8)

NEW ZEALAND RECORDS: Farran, 1929 *(= U. minor);* Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	24 Jan 65	N70	0–200m	♀ 4.06mm
Sta. 3	5 May 65	N70	200–500m	♀

REMARKS: Distinguishable from *U. major* Giesbr. by the lack of a sharp spine on the ventral surface of the genital segment.

Fam. EUCHAETIDAE

Euchaeta biloba (Farran, 1929)   (Fig. 8.9–8.13)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	1 Jun 64	N70	0–200m	♂ 4.66mm
Sta. 3	29 Oct 64	N70	0–600m	3 ♂♂ 5.04mm, 3 ♀♀ 5.37mm
	5 May 65	N70	200–500m	♀

REMARKS: The most common *Euchaeta* species caught. Easily recognised by its size, by the shape of the female genital segment, and the form of the male fifth legs. There was some variation in the number of teeth on one border of the spoon-shaped lamella of the second left exopod segment.

Euchaeta exigua ? Wolfenden, 1911   (Fig. 8.14–8.16)

NEW ZEALAND RECORDS: Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth	
29 Oct 64	N70	0–600m	♀ 6.95mm

REMARKS: This specimen agrees with the description of *E. exigua* Wolfenden except that its abdomen is very hairy.

Euchaeta acuta Giesbrecht, 1892   (Fig. 9.1–9.4)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth	
5 May 65	N70	200–500m	♀ 4.20mm

REMARKS: Has a distinctive female genital segment. Distinguishable from *E. media* Giesbr. by its larger size (over 3.80mm length) and the fact that the first antenna does not reach the hind border of the cephalothorax. (*See* Vervoort, 1957 p.84.)

Fam. PHAENNIDAE

Phaenna spinifera Claus, 1863   (Fig. 9.5)

NEW ZEALAND RECORDS: Farran, 1929.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
18 Apr 65	N70	0–200m	♀ 2.20mm

REMARKS: Easily identified by the shape of the thorax.

Xanthocalanus sp.   (Fig. 9.10–9.14)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth	
29 Oct 64	N70	0–600m	♀ 3.41mm

REMARKS: This specimen clearly belongs to *Xanthocalanus,* having the typical form of the second maxilla and female fifth legs. The third pair of swimming legs has a two-segmented exopod and a three-segmented endopod on one side whereas on the other side there are three segments in both rami. The fourth pair of swimming legs has a two-segmented exopod and endopod on one side and on the other side both are three-segmented. The unequal development of these legs suggests that this specimen could be deformed. The fifth legs are equally developed and adult in form in contrast to the copepodite-form of one of the pair on the third and fourth legs.

This specimen resembles *X. squamatus* Farran, 1936 in size, form of the female fifth legs, and spination on the second leg, but the second maxillae are not alike.

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FIG. 8. (1) *Pseudochirella* sp., female, dorsal view; (2) anterior head; (3) right side genital segment; (4) basipod segment 1, leg 4; (5) antenna 2; (6) exopod, leg 1; (7) *Undeuchaeta plumosa*, female, dorsal view; (8) abdomen, lateral view; (9) *Euchaeta biloba*, female, dorsal view; (10) lateral view; (11) male, lamella of exopodal joint 2, left leg 5; (12) distal part, left leg 5; (13) leg 5; (14) *E. exigua?* female, dorsal view; (15) exopod segment 3, leg 2; (16) genital segment, lateral view
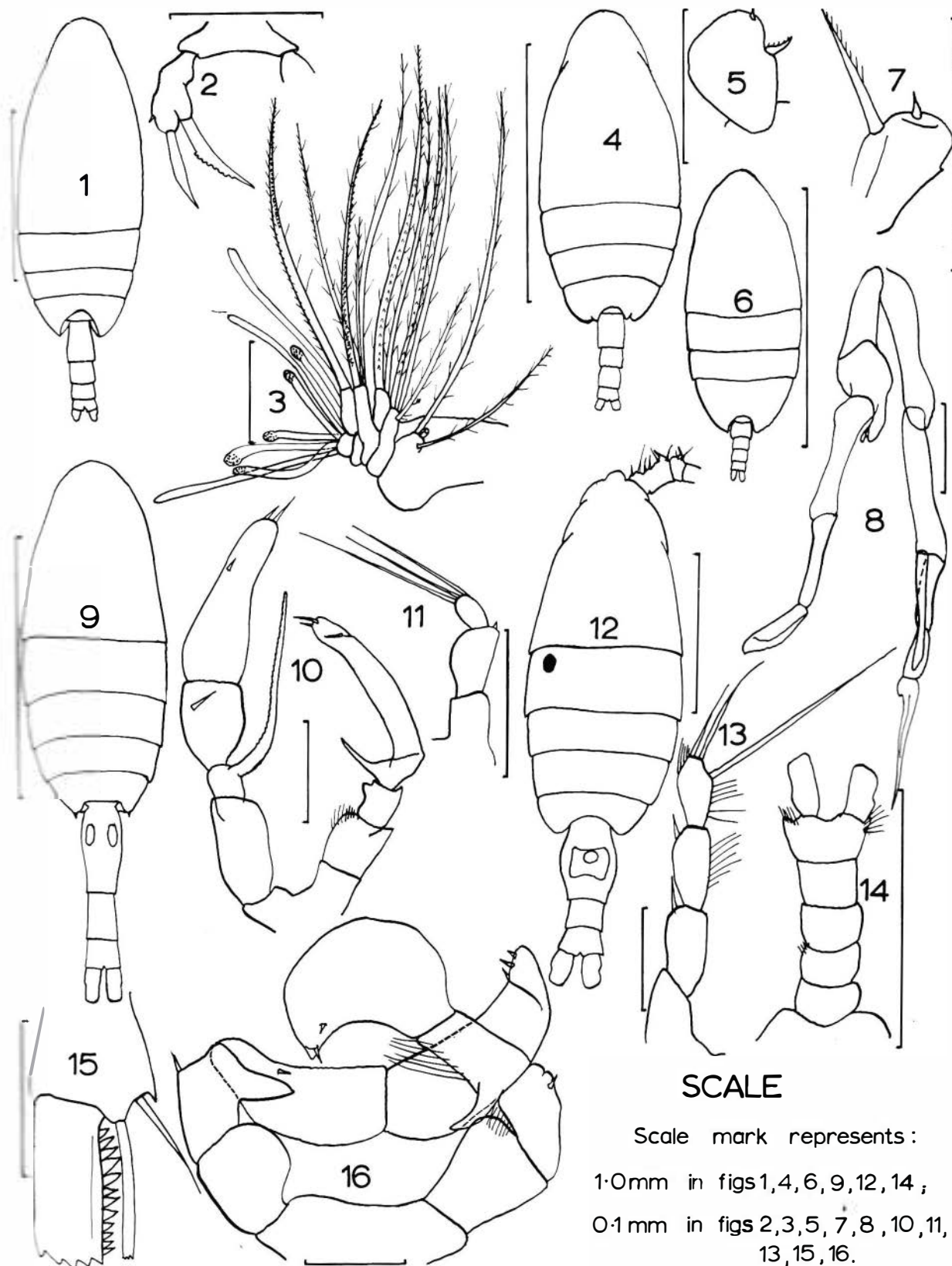
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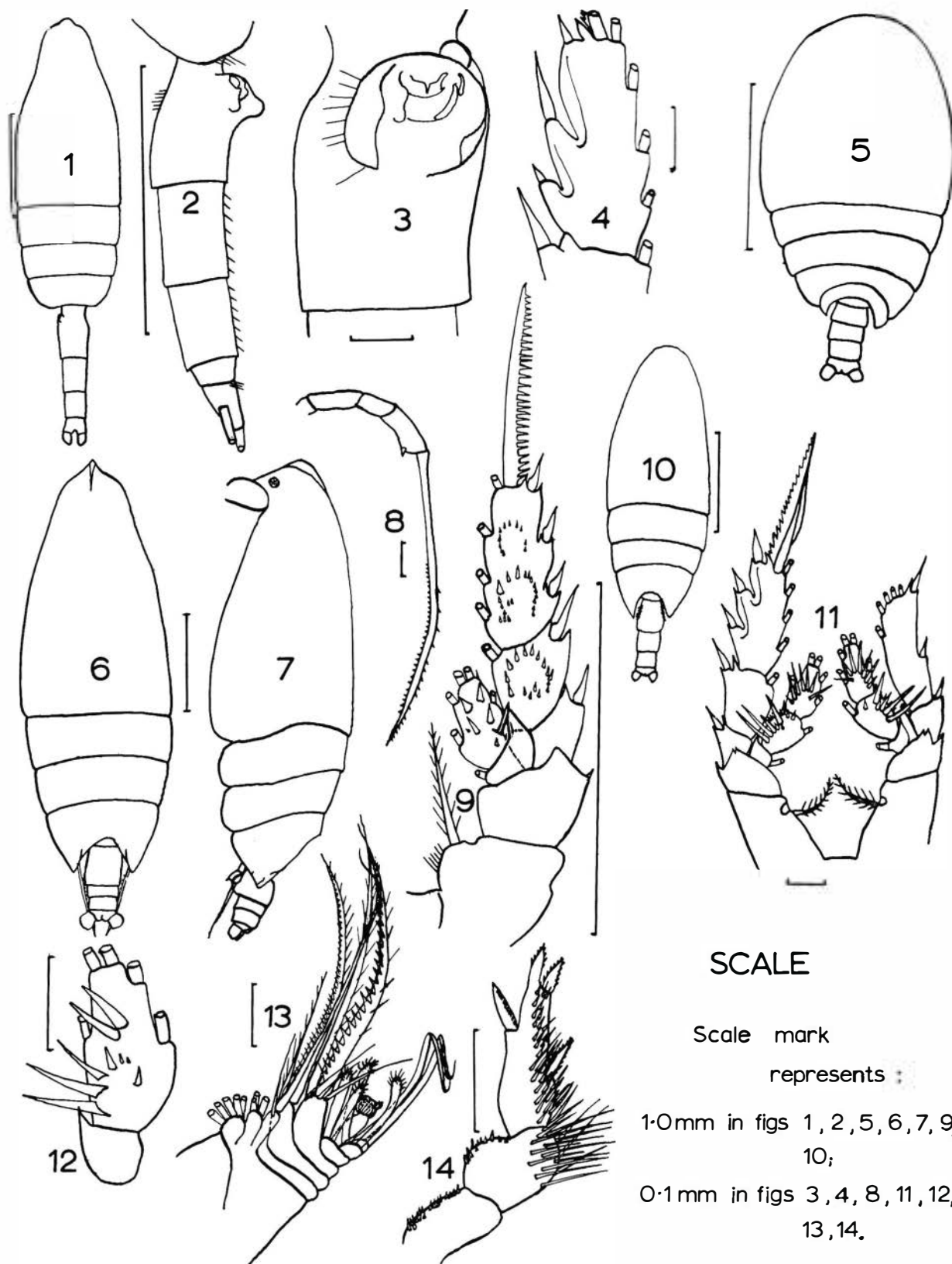
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13 , 14.

FIG. 9. (1) *Euchaeta acuta*, female, dorsal view; (2) abdomen, lateral view; (3) genital segment, ventral view; (4) exopod segment 3, leg 2; (5) *Phaenna spinifera*, female, dorsal view; (6) *Scottocalanus persecans*, female, dorsal view; (7) lateral view; (8) leg 5; (9) leg 2; (10) *Xanthocalanus sp.*, female, dorsal view; (11) leg 3; (12) endopod, leg 2; (13) maxilla 2; (14) leg 5

FIG. 10. (1) *Scaphocalanus echinatus,* female, dorsal view; (2) leg 5; (3) maxilla 2; (4) *Scolecithricella dentata,* female, dorsal view; (5) leg 5; (6) *S. glacialis,* female, dorsal view; (7) leg 5; (8) male, leg 5; (9) *Metridia lucens,* female, dorsal view; (10) male, leg 5; (11) female, leg 5; (12) *Pleuromamma abdominalis,* female, dorsal view; (13) leg 5; (14) male, abdomen; (15) right antenna 1, segments 17, 18; (16) leg 5

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0·1mm in figs 2,3,5,7,8,10,11, 13,15,16.

Fam. SCOLECITHRICIDAE

Scottocalanus persecans (Giesbrecht, 1895)   (Fig. 9.6–9.9)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 3)

Date	Net	Depth		
29 Oct 64	N70	0–600m	♀	4.8mm

REMARKS: Apparently the first record from New Zealand waters. The redescription of *S. persecans* by Vervoort (1965a) leaves no doubt about the identification of the present specimen.

Scaphocalanus echinatus (Farran, 1905)   (Fig. 10.1–10.3)

NEW ZEALAND RECORDS: Farran, 1929.

MATERIAL EXAMINED:

	Date	Net	Depth		
Sta. 1	24 Jan 65	N70	0–200m	♀	
Sta. 3	5 May 65	N70	200–500m	♀	2.4 mm

REMARKS: Characterised by the coarse, rounded teeth on the inner spine of the female fifth legs.

Scolecithricella dentata (Giesbrecht, 1892)   (Fig. 10.4–10.5)

NEW ZEALAND RECORDS: Farran, 1929.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
26 Jun 64	CB	170m	♀	1.55mm

REMARKS: The most notable characteristics are the notched posterolateral borders of the cephalothorax, which indicates the line of fusion between segments 4 and 5 (Fig. 10.4), and the female fifth leg.

Scolecithricella glacialis (Giesbrecht, 1902)   (Fig. 10.6–10.8)

NEW ZEALAND RECORDS: Farran, 1929 (= *Scolecithrix glacialis*); Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
14 Apr 64	N70	0–200m	♀	1.20mm
30 Apr 64	N70	0–200m	♂	1.24mm
24 Jan 65	N70	0–200m	♀	
4 Apr 65	N70	0–200m	♂, ♀	

REMARKS: These specimens agree with Giesbrecht's original description, but it is not clear how *S. glacialis* differs from *S. minor* (Brady, 1883).

Fam. METRIDIIDAE

Metridia lucens Boeck, 1863   (Fig. 10.9–10.11)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957; Deevey, 1966.

MATERIAL EXAMINED: Captured on all sampling days (except 30 Apr 64, 21 Dec 64, 24 Feb 65, 12 Mar 65 and not at Sta. 2). The length of a female on 1 Jun 64 was 2.16mm while two males on 2 Aug 64 were 1.50 and 1.82mm.

REMARKS: Consistently caught although never in great numbers.

Pleuromamma abdominalis (Lubbock, 1856)   (Fig. 10.12–10.16)

NEW ZEALAND RECORDS: Brady, 1883 (= *Pleuromma abdominale*); Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth		
Sta. 1	14 Apr 64	N70	0–200m	♀	
	16 May 64	N70	0–200m	♀ ♀	3.36, 3.88mm
	1 Jun 64	N70	0–200m	♀	2.96mm
	26 Jun 64	N70	0–200m	♀	
	2 Aug 64	N70	0–200m	♀	3.24mm
	24 Jan 65	CB	164m	2 ♀♀, ♂	3.16mm
Sta. 3	29 Oct 64	N70	0–600m	♀	3.44mm
	5 May 65	N70	200–500m	♂, ♀	

REMARKS: All females are of the forma *typica* (Steuer, 1932). The males captured are forma *abyssalis* subforma *thermophila* (Steuer, 1932), i.e., with an almost symmetrical abdomen. The presence of spines on the first two segments of the first antenna distinguish the females.

Pleuromamma gracilis (Claus, 1893)   (Fig. 11.1–11.3)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Deevey, 1966.

MATERIAL EXAMINED: Captured on all sampling days (except 12 Jul 64, 29 Aug 64, 21 Dec 64, 24 Feb 65, 18 Apr 65 and not at Sta. 2). Females measured 1.9–2.25mm on 16 May 64 and 2.40mm on 11 Oct 64, and males measured 1.86 and 1.90 mm on 16 May 64.

REMARKS: Like *Metridia lucens, Pleuromamma gracilis* consistently occurred in the Kaikoura plankton, although never in great numbers. The form was forma *maxima* (Steuer, 1932) which has two-segmented female fifth legs.

Pleuromamma robusta (F. Dahl, 1893)   (Fig. 11.4–11.7)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

FIG. 11. (1) *Pleuromamma gracilis,* female, dorsal view; (2) leg 5; (3) male, leg 5; (4) *P. robusta,* female, dorsal view; (5) male, leg 5; (6) female, leg 5; (7) male. abdomen: (8) *P. xiphias,* male, dorsal view; (9) leg 5; (10) *Centropages aucklandicus,* female, dorsal view; (11) leg 5; (12) male, leg 5; (13) female, abdomen, lateral view
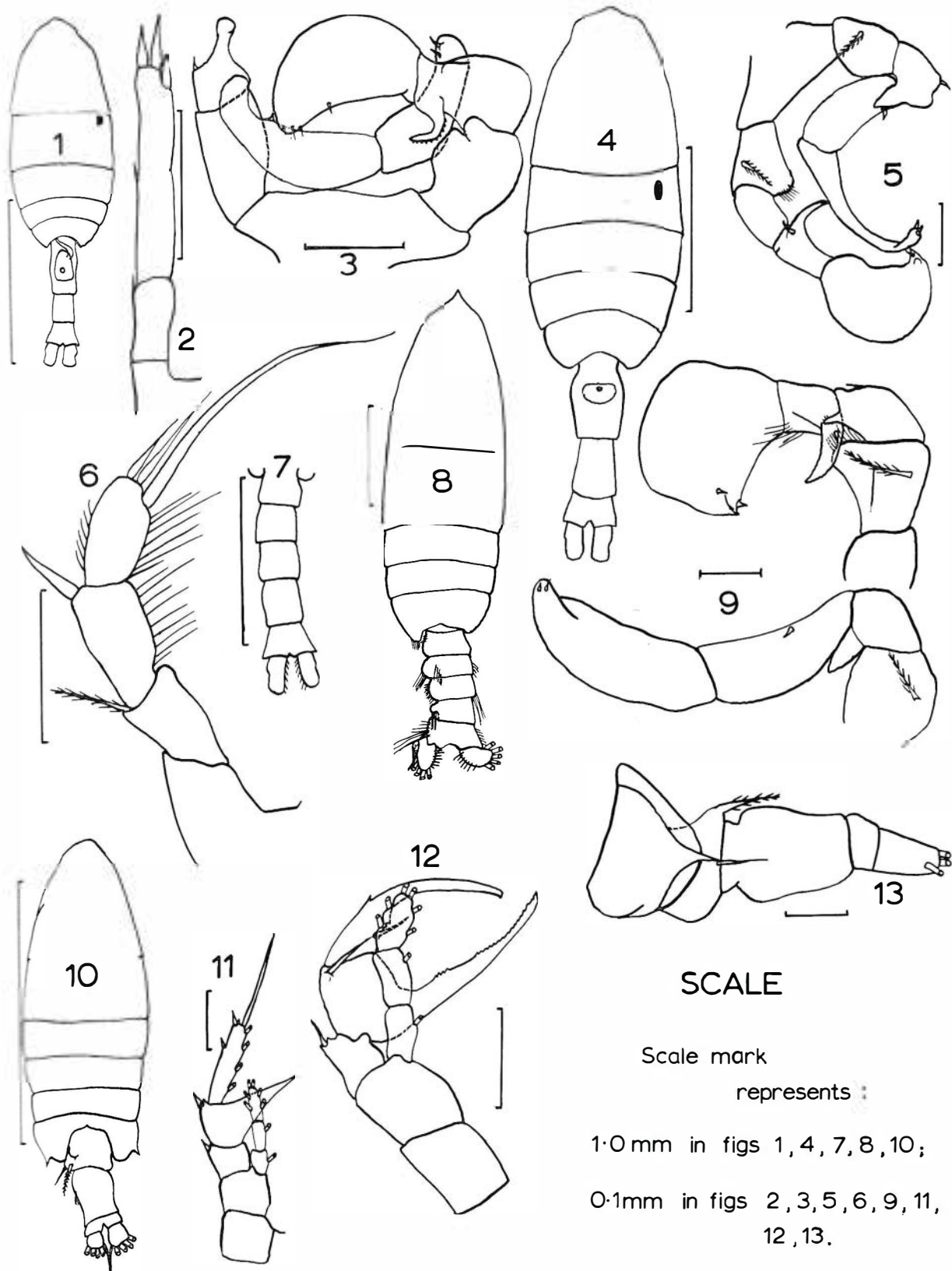
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        12, 13.

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MATERIAL EXAMINED:

	Date	Net	Depth		
Sta. 1	1 Jun 64	CB	200m	♀	3.69mm
	15 Jun 64	N70	0–200m	♀	
	26 Jun 64	N70	0–200m	♀	2.9mm
	2 Aug 64	N70	0–200m	♀	3.54mm
Sta. 3	29 Oct 64	N70	0–600m	4 ♀♀; 2 ♂♂	3.0, 3.3mm
	5 May 65	N70	200–500m	2 ♀♀, 1 ♂	

REMARKS: Most specimens were of the scantily haired forma *antarctica* (Steuer, 1932) but some forma *typica* were present.

Pleuromamma xiphias (Giesbrecht, 1889) (Fig.11.8–11.9)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth		
24 Jan 64	N70	0–200m	♂	4.90mm

REMARKS: Distinguishable from other species of *Pleuromamma* by the pointed head.

Fam. CENTROPAGIDAE

Centropages aucklandicus Kramer, 1895 (Fig.11.10–11.13)

NEW ZEALAND RECORDS: Kramer, 1894; Brady, 1899 (= *C. discaudatus*); Thomson and Anderton, 1921 (=*C. discaudatus*); Farran, 1929; Vervoort, 1957, 1964; Deevey, 1966.

MATERIAL EXAMINED: Captured on every sampling day (except 5 Dec 64, 21 Dec 64 at Sta. 1 and 7 Jan 65 at Sta. 2). Females were 1.25–2.05mm long, males 1.25–1.85mm (Deevey, 1966).

REMARKS: One of the most common copepods at Kaikoura. Its presence at Sta. 2 and smaller numbers in summer (absent in December) when oceanic water influence was greatest confirmed that *C. aucklandicus* is a coastal species.

Centropages bradyi Wheeler, 1899 (Fig. 12.1–12.3)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
14 Apr 64	N70	0–200m	♀
16 May 64	N70	0–200m	a few ♂♂ 1.87mm and ♀♀ 2.0mm
21 Dec 64	CB	161m	♀

REMARKS: Easily recognised by a peglike extension on the furca.

Fam. LUCICUTIIDAE

Lucicutia flavicornis? (Claus, 1863) (Fig. 12.4–12.6)

NEW ZEALAND RECORDS: Brady, 1883 (= *Leuckartia flavicornis*); Farran, 1929; Dakin and Colefax, 1940.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
16 May 64	N70	0–200m	♀ ♀
1 Jun 64	N70	0–200m	♀ ♀
15 Jun 64	N70	0–200m	♀ 1.8mm
2 Aug 64	N70	0–200m	♀ ♀
	CB	174m	2 ♀♀ 1.87mm, ♂ 1.68 mm
24 Jan 65	N70	0–200m	♀ ♀

REMARKS: It is uncertain which species of *Lucicutia* has been captured off Kaikoura. The male fifth legs fit *L. flavicornis* but the short internal spine on the second exopodal segment of the female fifth legs is like that of *L. gemina*. Hulsemann (1966) discusses these two species and places the range of *L. flavicornis* further south than that of *L. gemina* which has been recorded south to 34°S in the western Pacific.

Fam. HETERORHABDIDAE

Heterorhabdus papilliger (Claus, 1863) (Fig. 12.7–12.12)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
16 May 64	N70	0–200m	♀ 2.50mm

REMARKS: Easily recognised by the equal lengths of both spines on lobe 5 of maxilla 2 and by leg 5 second exopod segment inner spine which is longer than the third exopod segment.

Fam. AUGAPTILIDAE

Haloptilus oxycephalus (Giesbrecht, 1889) (Fig. 13.1–13.2)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
7 Jan 65	CB	5m	♀ 3.64mm

REMARKS: Easily recognised by the long slender extension of the forehead. The male is described by Vervoort (1957).

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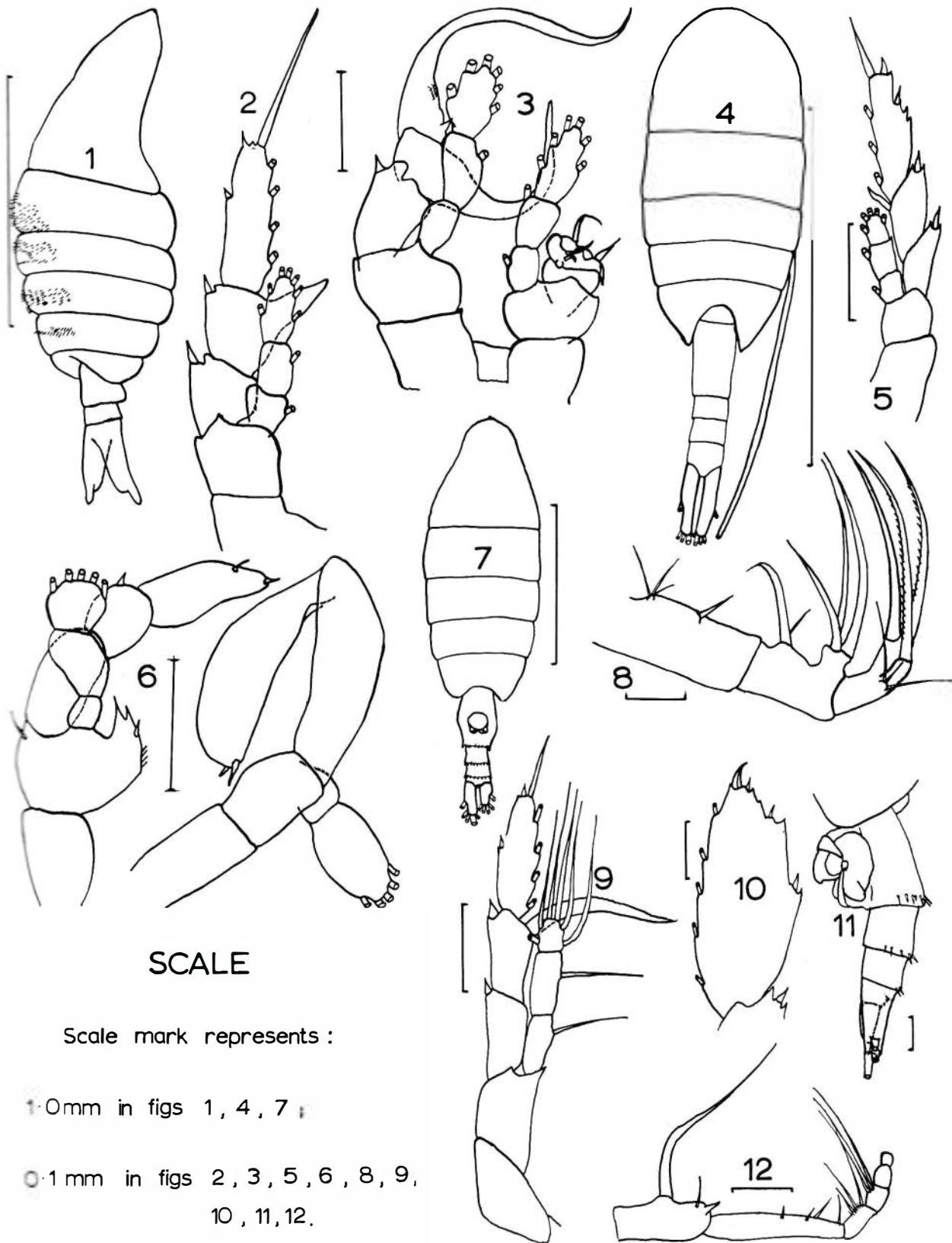
FIG. 12. (1) *Centropages bradyi,* female, lateral view; (2) leg 5; (3) male, leg 5; (4) *Lucicutia flavicornis,* female, dorsal view; (5) leg 5; (6) male, leg 5; (7) *Heterorhabdus papilliger,* female, dorsal view; (8) maxilla 2, (9) leg 5; (10) exopod segment 3, leg 3; (11) abdomen, lateral view; (12) maxilliped

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Fam. CANDACIIDAE

Candacia cheirura Cleve, 1905 (Fig. 13.3–13.6)

NEW ZEALAND RECORDS: Farran, 1929; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	30 Apr 64	N70	0–200m	♀
	16 May 64	N70	0–200m	♂ 2.45mm
	2 Aug 64	N70	0–200m	♀ 2.59mm
	13 Sep 64	N70	0–200m	♀
	26 Sep 64	N70	0–200m	♀
	17 Nov 64	N70	0–200m	♀
	21 Dec 64	N70	0–200m	♀ and ♂
		CB	90m	♀
		CB	161m	♂
	7 Jan 65	N70	0–200m	
Sta. 3	29 Oct 64	N70	0–600m	♀
	5 May 65	N70	200–500m	♂

REMARKS: Farran (1929) recorded seven species of *Candacia* off New Zealand. Only *C. cheirura* was captured at Kaikoura. Of this genus, only juveniles were captured on 26 Jun 64, 24 Jan 65, and 12 Mar 65. Easily recognised by a projection on the genital and second abdominal segments of the female and the male fifth legs.

Fam. PONTELLIDAE

Labidocera cervi Kramer, 1895 (Fig. 13.7–13.9)

NEW ZEALAND RECORDS: Kramer, 1894; Brady, 1899; Thomson and Anderton, 1921; Farran, 1929; Dakin and Colefax, 1940.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
26 Jun 64	N70	0–200m	
12 Jul 64	N70	0–200m	
	CB	70m	♂
29 Aug 64	N70	0–200m	
	CB	5m	juveniles
13 Sep 64	CB	5m	3 ♀♀ 3.34mm
	CB	22m	1 ♂ 3.08mm
11 Oct 64	N70	0–200m	
29 Oct 64	CB	77m	juveniles
5 Dec 64	N70	0–200m	♂ and ♀
12 Mar 65	N70	0–200m	
	CB	5m	2 juveniles
5 May 65	N70	0–200m	

REMARKS: Its general shape and the pair of lenses on the dorsal surface of the head distinguish this species from all others at Kaikoura.

Fam. ACARTIIDAE

Acartia clausi Giesbrecht, 1889 (Fig.13.10–13.12)

NEW ZEALAND RECORDS: ? Brady, 1883 (= *A. denticornis*); Kramer, 1894; Brady, 1899 (= *A. ensifera*); Farran, 1929; Dakin and Colefax, 1940; Deevey, 1966.

MATERIAL EXAMINED: Captured on every sampling day except 21 Dec 64. On 14 Apr 64 females measured 0.77–0.98mm, and a male measured 0.86mm on 1 Jun 64.

REMARKS: One of the most common copepods, nearly always concentrated in greatest numbers at the surface.

The external plumose setae on the female fifth leg is proportionally much longer than has been recorded on specimens from elsewhere (Fig. 13.11). Australian specimens (Dakin and Colefax, 1940) have an external plumose seta ¼ longer than the inner spine, while in northern Atlantic specimens these parts are of equal length (Sars, 1903).

Order CYCLOPOIDA

Fam. OITHONIDAE

Oithona atlantica Farran, 1908 (Fig.14.1–14.3)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: Captured on all sampling days at Sta. 1 except 14 Apr 64, 16 Aug 64, 29 Aug 64, 29 Oct 64, 4 Apr 65, and 18 Apr 65. It was at Sta. 2 on 14 Apr 64. A female measured 1.32mm on 14 Apr 64.

REMARKS: The shape of the rostrum and the hairless genital segment distinguish this species (Rosendorn, 1917). Although *Oithona atlantica* occurred in nearly all samples it was not always in great numbers and its main concentration was often at about 100m. This is the first record for the area.

Oithona similis Claus, 1866 (Fig.14.4–14.6)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Cassie, 1959.

MATERIAL EXAMINED: Captured on all sampling days at Sta. 1 except 30 Apr 64, 16 May 64, and 26 Jun 64. Found at Sta. 2 on 14 Aug 63 and 7 Jan 65. On 14 Apr 64 a female measured 0.84mm and a male measured 0.65mm.

REMARKS: The shape of the anterior part of the head and the external spines on the first and second leg exopods distinguish this species (Rosendorn, 1917). *Oithona similis,* along with *Acartia clausi* and *Paracalanus parvus,* was one of the most common copepods in the Kaikoura plankton. *Oithona* was also plentiful at Sta. 2.

48

SCALE

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0·1 mm in figs 2, 4, 5, 6, 8, 10, 11, 12.
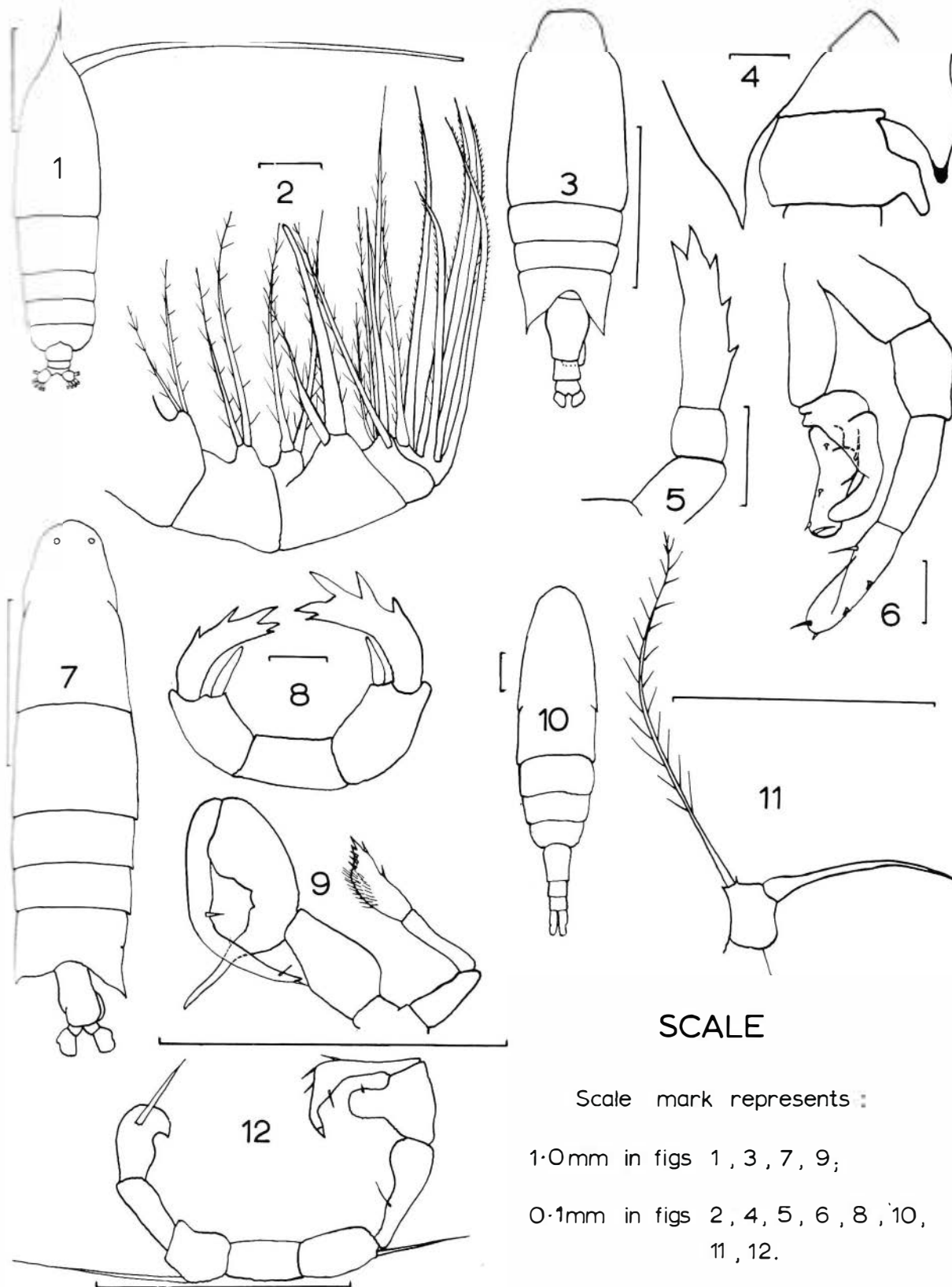
FIG. 13. (1) *Haloptilus oxycephalus*, female, dorsal view; (2) maxilliped; (3) *Candacia cheirura*, female, dorsal view; (4) male, genital segment; (5) female, leg 5; (6) male, leg 5; (7) *Labidocera cervi*, female, dorsal view; (8) leg 5; (9) male, leg 5; (10) *Acartia clausi*, female, dorsal view; (11) leg 5; (12) male, leg 5

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Fam. ONCAEIDAE

Oncaea conifera Giesbrecht, 1891   (Fig. 14.7–14.14)

NEW ZEALAND RECORDS: Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED:

	Date	Net	Depth	
Sta. 1	2 Aug 64	N70	0–200m	♂ ♂ and ♀ ♀, few
		CB	92m	♀ 1.09mm
Sta. 3	29 Oct 64	N70	0–600m	
	5 May 65	N70	200–500m	♀ ♀ 1.05mm, ♂ ♂

REMARKS: Usually identified by a dorsal projection on the second thoracic segment and by the length of the furca, but some specimens (5 May 65) agreed with Farran's (1936) form (c), which hardly shows this characteristic. The remainder belonged to Farran's form (b), which has more slender legs than form (c) and slightly different body proportions.

Oncaea mediterranea (Claus, 1863)   (Fig. 14.15–14.17)

NEW ZEALAND RECORDS: ? Brady, 1883 (= *O. obtusa*); Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957.

MATERIAL EXAMINED: Captured on all sampling days at Sta. 1, except 12 Jul 64, 16 Aug 64, 29 Aug 64, and 29 Oct 64. Found at Sta. 2 on 14 Apr 64. On 14 Apr 64 a female measured 1.12mm.

REMARKS: Easily recognised by the female fourth leg endopod, second antenna, length and width of the furca, size of the genital segment, and red-orange colour on the ventral surface.

Nearly always present but never in great numbers.

Order HARPACTICOIDA

Fam. TACHIDIIDAE

Euterpina acutifrons (Dana, 1852)   (Fig.15.1–15.2)

NEW ZEALAND RECORDS: Kramer, 1894; Brady, 1899 (= *Euterpe gracilis*); Farran, 1929 (= *Euterpe acutifrons*); Dakin and Colefax, 1940.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
1 Jun 64	N70	0–200m	♀ 0.81mm
2 Aug 64	N70	0–200m	♀

REMARKS: Recognisable from its general shape and the form of its fifth legs. Found by Farran (1929) to be common in the Bay of Islands neritic waters and by the author in Port Underwood. Considered to be a species more commonly associated with the sheltered water environment.

Fam. HARPACTICIDAE

Harpacticus sp.   (Fig. 15.3–15.9)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
11 Oct 64	N70	0–200m	1 ♂ 0.58mm

REMARKS: One New Zealand species has been described from one female specimen caught in Otago Harbour (*H. glaber* Brady, 1899). It does not seem likely, from Brady's drawings, that the single Kaikoura male specimen belongs to that species, neither does it belong to any mentioned by Lang (1948).

Several characteristics are quite distinctive. The second antenna, second endopod segment, bears four naked, jointed setae, two large saw-edged spines, and one large, external, naked spine. A row of small spines extends from the base of the large naked spine. The end border of the second endopod segment has a short, finger-like projection at the base of the jointed setae. The maxilliped has an elongated basal segment (not figured), slightly constricted near each end, and the endopod bears long slender spines on the concave part of the inner margin. The male fifth leg exopod bears five setae, the innermost of which is plumose. The outer border is more densely covered with small spines than the inner border. The small external extension of the basal segment carries one seta and a few small spines.

This one male specimen must be a new species, but until more of both male and female individuals are available it will not be described as such.

Fam. PSEUDOPELTIDIIDAE

Clytemnestra rostrata (Brady, 1883)   (Fig. 15.10–15.11)

NEW ZEALAND RECORDS: Nil.

MATERIAL EXAMINED: (Sta. 1)

Date	Net	Depth	
15 Jun 64	N70	0–200m	♀ 0.97mm

REMARKS: Of the two known species of *Clytemnestra*, the description of *C. rostrata* agrees very well with the present specimen, although the species has not been recorded previously in this area.

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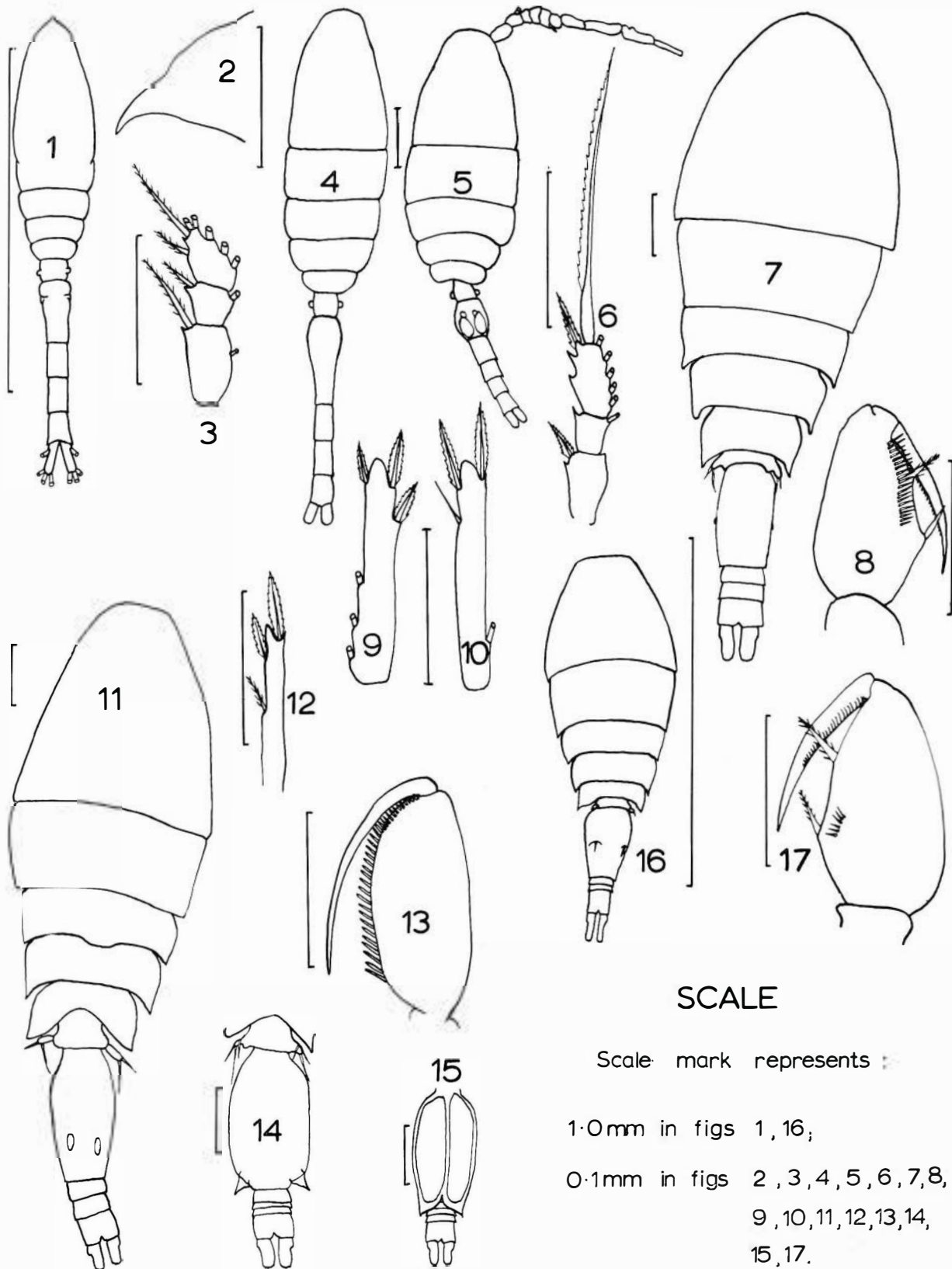
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FIG. 14. (1) *Oithona atlantica*, female, dorsal view; (2) rostrum; (3) exopod, leg 1; (4) *O. similis*, female, dorsal view; (5) male, dorsal view; (6) female, exopod, leg 2; (7) *Oncaea conifera*, female, dorsal view; (8) maxilliped; (9) endopod segment 3, leg 2; (10) endopod segment 3, leg 4; (11) female, type (b), dorsal view; (12) endopod segment 3, leg 4; (13) male, maxilliped: (14) abdomen, dorsal view; (15) *O. mediterranea*, male, abdomen; (16) female, dorsal view; (17) maxilliped

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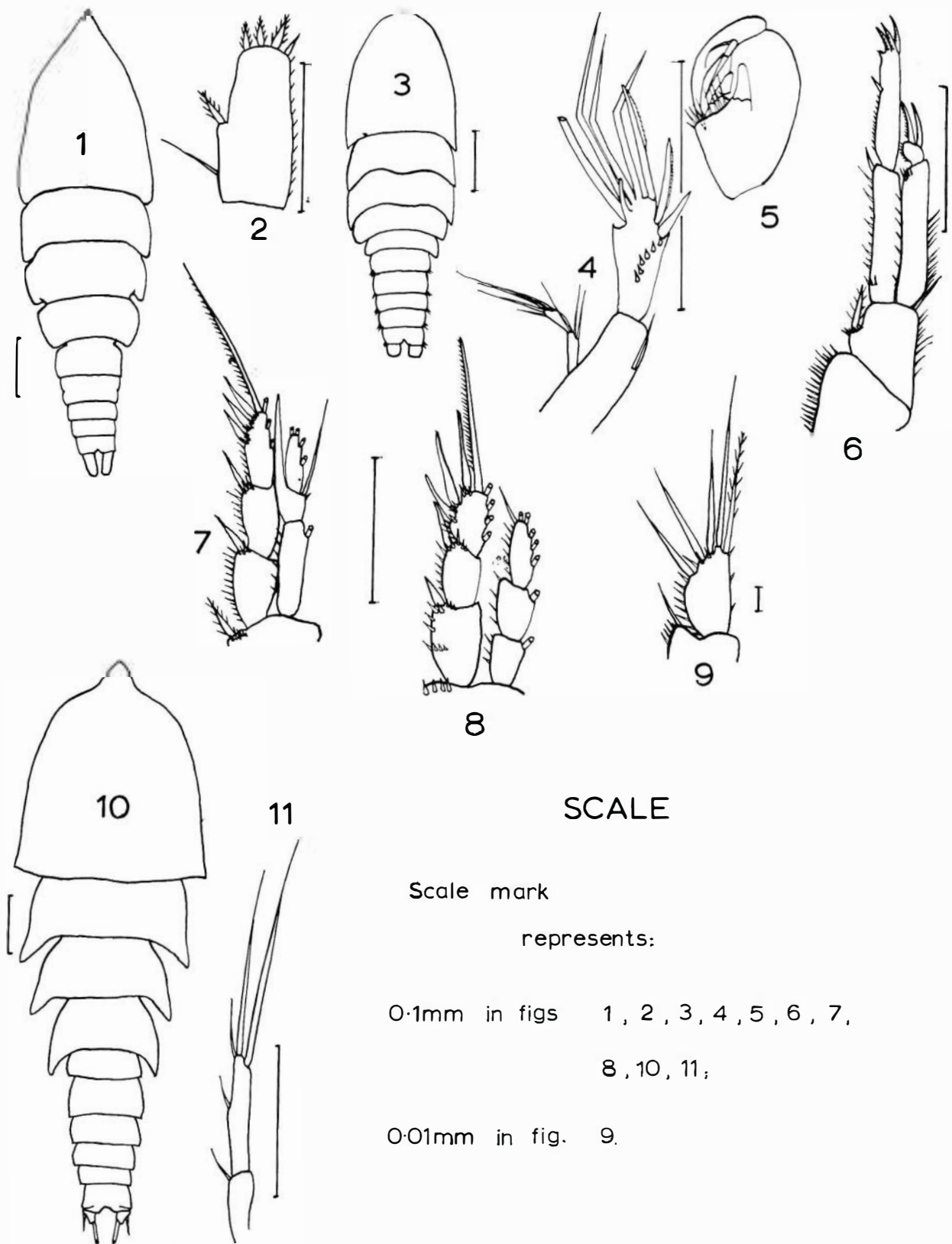
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8 , 10 , 11 ;

0·01mm in fig. 9.

FIG. 15. (1) *Euterpina acutifrons,* female, dorsal view; (2) leg 5; (3) *Harpacticus* sp., male, dorsal view; (4) antenna 2; (5) maxilliped; (6) leg 1; (7) leg 2; (8) leg 3; (9) leg 5; (10) *Clytemnestra rostrata,* female, dorsal view; (11) leg 5

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THE COPEPOD POPULATION

Throughout the year a basic assemblage of common species consisting of *Acartia clausi, Oithona similis, Paracalanus parvus,* and *Clausocalanus arcuicornis,* and less plentifully *Centropages aucklandicus* and *Calanus australis,* could be recognised. These species were also found at Sta. 2 with few additions. At Sta. 1 *Pleuromamma gracilis* and *Metridia lucens* were also constantly present.

Two groups additional to this basic near-shore community were observed. The first is represented by *Calanus tonsus,* the copepodites of which are believed to enter the near-shore environment in response to the maximal phytoplankton growth there to store up large reserves of oil before returning to deeper waters for winter spawning (as with the closely related *C. plumchrus* (Heinrich, 1962)). *C. tonsus* appeared off Kaikoura in August 1964 and disappeared in May 1965. During this time the numbers of stage V copepodites gradually increased until, in December, the near-surface plankton was completely dominated by *C. tonsus.*

The second additional group was introduced into the Kaikoura region with water of oceanic origin. However, the small numbers of each species captured indicate that the environment at Kaikoura is only marginally suitable for such species.

SECTION 2

PLANKTONIC AND ENVIRONMENTAL VARIATION 1964-65

INTRODUCTION

The Kaikoura region is influenced by several interesting hydrological phenomena. These include the upwelling of cold water in summer over the Conway Trough (Garner, 1961), the appearance of warm water at the same place in winter (Houtman, 1965), and surface intrusions of subtropical water (Garner, 1961). From the occurrence of upwelling and the fact that the Kaikoura region offers breeding and feeding grounds for large numbers of fish, sea birds, seals, and other marine mammals (Stonehouse, 1965) one could expect that nutrient enrichment of surface waters had enhanced production in the plankton populations.

Because changes in plankton and the environment could come from *in situ* or advective effects the aim of this study was to establish the role of seasonal successive and advective changes in the plankton and to determine the importance of each in forming the locally sampled situation. Fortnightly samples were collected for 13 months from April 1964 to May 1965 from a position almost due east of Kaikoura Peninsula (173°48.5′E, 42°26′S), over the broader part of the shelf and slope north of Kaikoura Canyon. This position was chosen rather than one south of Kaikoura Peninsula as the hydrology of the region, supposedly complicated by Kaikoura Canyon, could make it difficult to interpret planktonic changes. The series of stations occupied during the collection of water samples and plankton net tows over 13 months are grouped together as "The Permanent Station" (Fig. 17). All stations fell within a rectangular area 3.2 × 6.4 sq. km, and the greatest concentration of stations was over the 200m contour, so an oceanic rather than a neritic situation was sampled. The distance of "The Permanent Station" from Kaikoura Peninsula was approximately 8 km.

Before the work of Bary (1951) there were few attempts to relate zooplankton distribution to hydrological conditions in New Zealand waters. Garstang (1933), in his discussion of the doliolids, appears to have been the only author of a *Terra Nova* report to recognise that upwelling south of Three Kings Island might explain plankton distribution in that area. A progression of events in the zooplankton over a year has been studied in New Zealand waters by Wear (1965) in Wellington Harbour and by Fuller (1953) in Hauraki Gulf. Seasonal data have been collected on phytoplankton by Crawford (1949) in Cook Strait; Brewin (1952) in Otago Harbour, and Cassie (1960) in Hauraki Gulf, Wellington Harbour, and Cook Strait. None of these authors used the quantitative techniques employed in this study, so it is not possible to compare their results directly with the data collected at Kaikoura.
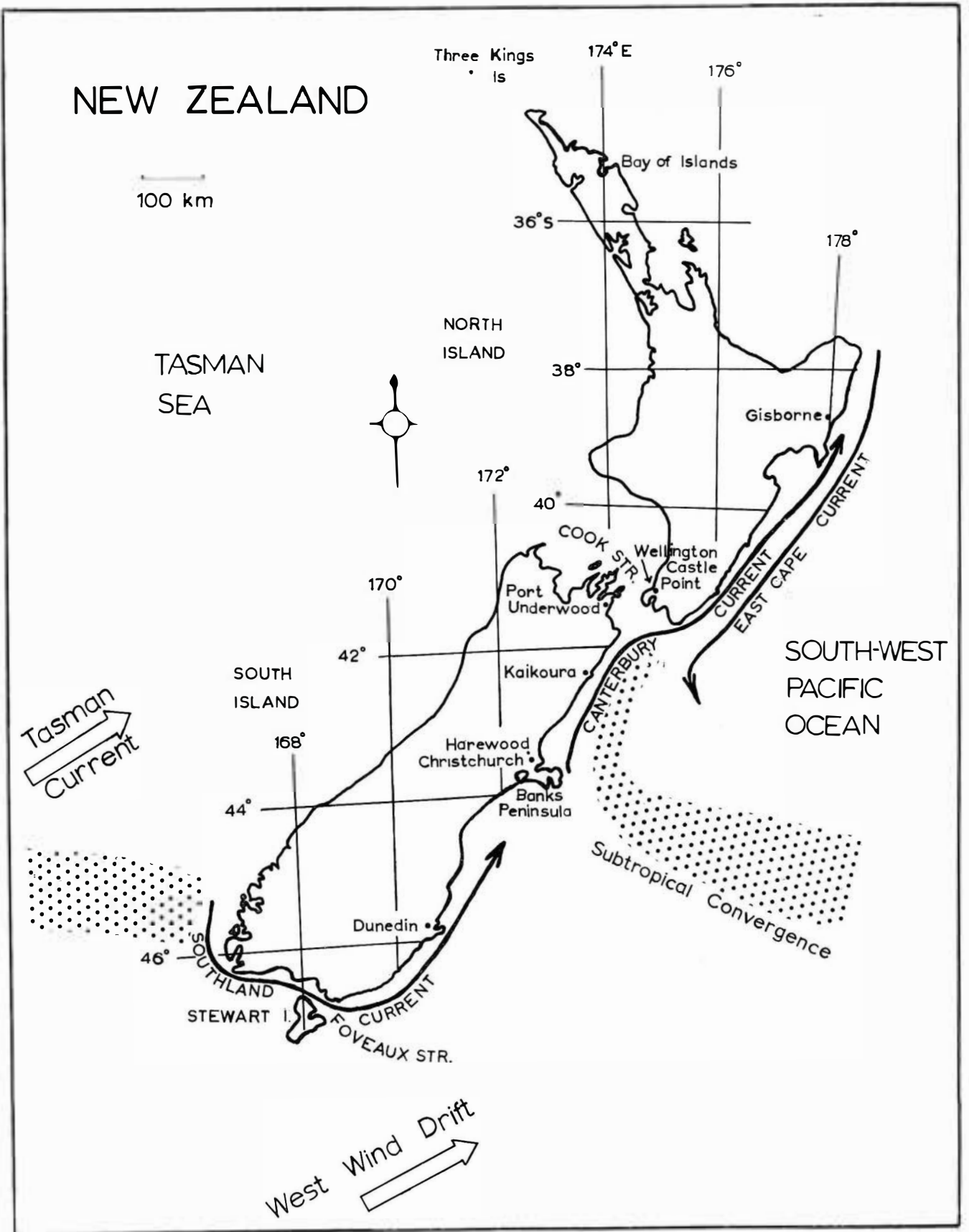
FIG. 16. Locality map showing currents east of New Zealand (after Brodie, 1960)
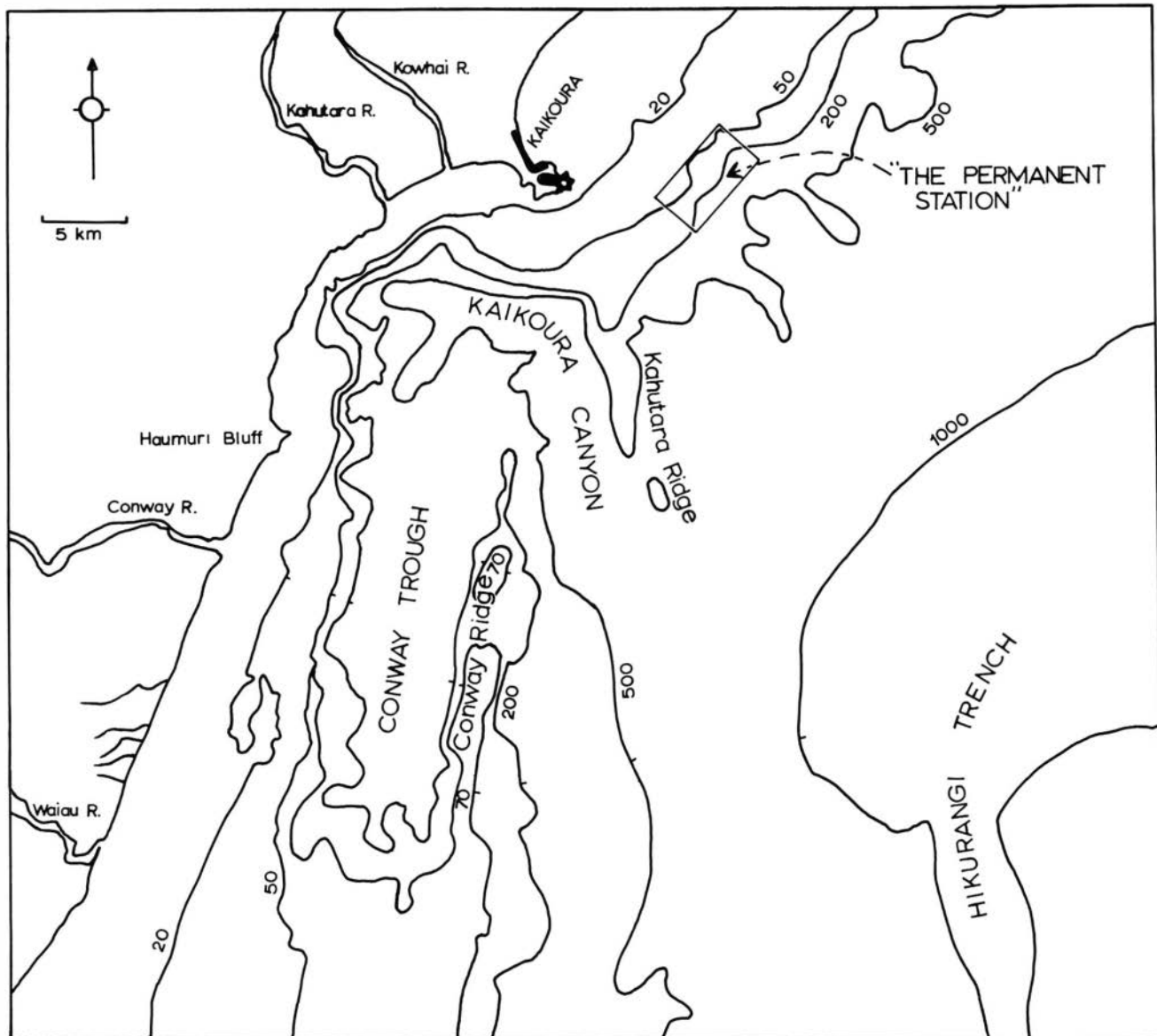
FIG. 17. Kaikoura area showing the position of "The Permanent Station." Bathymetry in fathoms (Cullen and Brodie, 1966)

AREA OF STUDY

Kaikoura Peninsula is situated on the east coast of the South Island of New Zealand approximately half way between Christchurch and Wellington (Fig. 16). The coastal plains immediately to the north and south, composed of alluvium and outwash deposits, are backed by the precipitous Seaward Kaikoura range (whose peaks reach 1,200–2,500 m within 12–16 km of the coast) built of massive Mesozoic greywacke formations. (Lensen, 1962.)

Several rivers flow from the Seaward Kaikoura range; Hapuku River north of the Peninsula (north of the area in Fig. 17), and the Kowhai, Kahutara, and Conway Rivers south of the Peninsula. Further south, draining water from the Southern Alps, is the Waiau River.

The continental slope off the Kaikoura coast is bounded by the southern part of Hikurangi Trench, a wide depression reaching depths greater than 2,000 m (Brodie and Hatherton, 1958). Into this trench extends Kaikoura Canyon (Fig. 17), which brings depths of 1,000 m to within 3.5 km of the coast south of the Peninsula. A southerly extension of the canyon approximately 400 m deep is separated from Hikurangi

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Trench by Conway Ridge, which rises to depths of just over 110 m (Cullen and Brodie, 1966).

Sediments of Hikurangi Trench are predominantly mud, but in the vicinity of "The Permanent Station" medium and fine sand comprise over 20% of the muddy bottom sediment. The gently sloping shelf around Kaikoura Peninsula. and adjacent to "The Permanent Station". is covered by gravels which pass northward into a belt of sand along the coast (Cullen and Gibb, 1966).

FIELD AND LABORATORY METHODS

SAMPLING PROCEDURE

So that all the data (temperature, salinity, transparency, nitrate, and chlorophyll *a,* and zooplankton weights (see Appendices) and numbers) could be processed, samples were taken fortnightly at "The Permanent Station". Information was collected from Mr R. Baxter's *Virgo,* a 12 m fishing boat (Fig. 18). Sampling was begun between 08.30 and 10.00 hrs on one day every fortnight and the records were taken in exactly the same order:

A Clarke-Bumpus sampler (Fig. 19) was first attached to the wire above a 55 lb weight and an oblique haul taken from 200 m to the surface using a portable winch (Fig. 20). Four horizontal hauls were then made with the same net with 5 m, 22 m, 100 m, and 180 m of wire out respectively. The maximum depth sampled was measured by attaching a Kelvin Tube, in its holder, to the wire just below the Clarke-Bumpus sampler. Each zooplankton collection was added to enough formalin for the resulting solution to be 5% formalin in sea water. A small phytoplankton net, 200 meshes to the inch with aperture size 61 microns, was trailed from the Clarke-Bumpus frame during the horizontal hauls.

Also, 5-litre water samples were taken with a Van Dorn water sampler (Fig. 21) at depths of 0, 10, 25, 50, 75, 125, and 200 m. Most of this sea water was used for the extraction of plant pigments from the phytoplankton in it, but a small quantity was used for salinity and nitrate determinations.

A bathythermograph was lowered to 140 m while the surface temperature was being recorded by thermometer, a vertical zooplankton haul was made with an N70 net, and finally a Secchi-disc reading was taken.

SALINITY

On each sampling day approximately 300 ml of sea water from all depths sampled was stored in medicine bottles, stoppered with waxed corks, and sealed with more wax. Salinity was determined subsequently by the Knudsen method (Oxner, 1920). Copenhagen Normal Sea Water was used as the primary standard, and from it a substandard reference solution, chlorinity 19.15‰, was established. Knudsen's tables require a substandard with chlorinity 19.31–19.45‰. His "Table of Titration" was therefore not used, the method of McGary (1954) being employed instead, as it may be used with a reference solution of natural sea water of any chlorinity.

TEMPERATURE

Surface water temperatures were recorded with a Celsius thermometer to the nearest 0.1° and subsurface temperatures were recorded with 140 m bathythermograph.

DENSITY

Density (σ_t) was calculated from Matthews's tables (1932) at all depths sampled. In considering the values of σ_t, it should be noted that all temperatures apart from surface ones were taken by a bathythermograph and the salinity and temperature observations were not taken simultaneously.

FIG. 18. Mr R. Baxter's *Virgo,* a 12m fishing boat, from which sampling was done
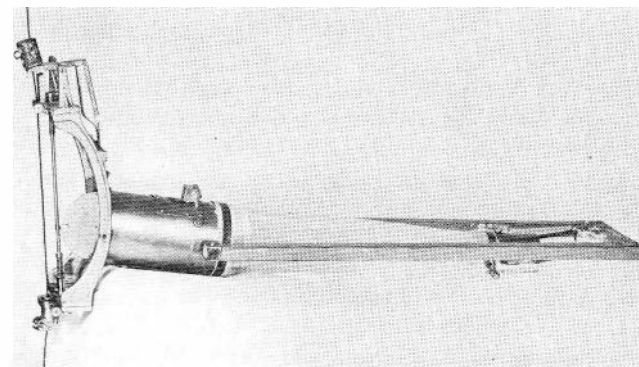
FIG. 19. Clarke-Bumpus plankton sampler used throughout the study

Fig. 20. Portable winch

Fig. 21. Modified Van Dorn 5-litre water bottle
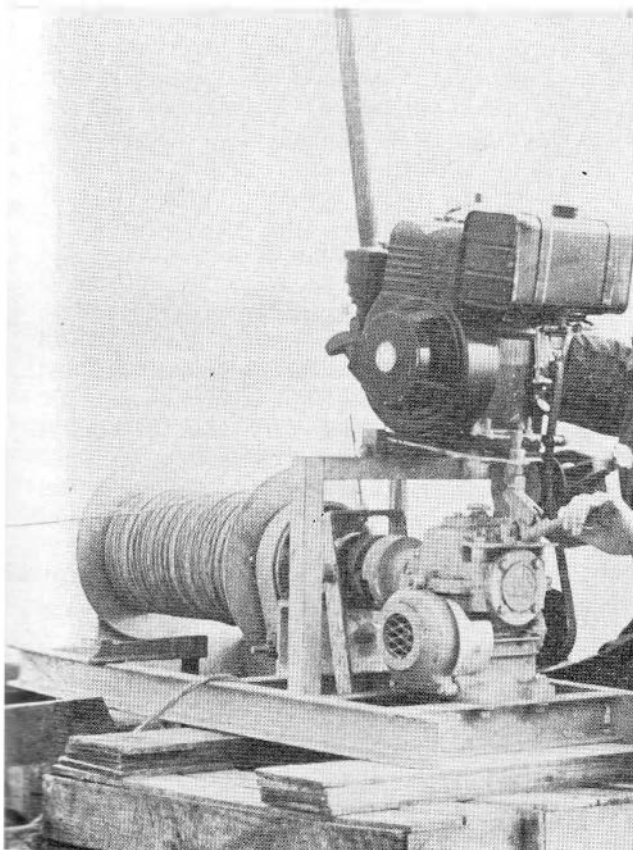
NITRATE

About 150 ml of sea water from all depths sampled was processed not more than 8 hours after collection. The method used for the determination of nitrite-nitrate nitrogen was that of Strickland and Parsons (1960). Calibration was carried out on each batch of seven samples using a $30\mu g$ at/L (atoms/litre) standard nitrate solution. The extinction of the pink dye formed was measured with a Spectronic 20 colorimeter-spectrophotometer. Nitrite-nitrate is hereafter referred to as nitrate.

PHYTOPLANKTON

Chlorophyll a

The bulk of the water collected in the modified Van Dorn 5-litre water sampler was used for the extraction of pigments from the phytoplankton. The method employed was that of Strickland and Parsons (1960). All samples taken before 16 August 1964 were filtered through an HA Millipore filter (pore size 0.45μ), but as these filters tended to clog very quickly a change was made to the AA Millipore filter (pore size 0.8μ). A considerable amount of pigment was often left unextracted. On 12 July 1964, particularly, it was noticed that all the pigment was not extracted from the phyto-

plankton; examination of the net plankton showed a bloom of *Ceratium* sp. Gardiner (1943) reported that *Ceratium* spp., which were present to a greater or lesser extent over the whole sampling period at Kaikoura, were far from completely decolourised by 80% acetone. All samples filtered on or before 26 June 1964 were stored in a desiccator and frozen until the pigments were extracted on 3 July 1964. Thus the April and May 1964 samples were stored longer than the 4 weeks recommended by Humphrey (1960). All other filtered samples were not stored but treated immediately. The extinction of the plant pigments dissolved in acetone was measured on a Spectronic 20 colorimeter-spectrophotometer.

"Gross" Primary Production

"Gross" primary production was calculated from radiation, transparency, and chlorophyll data by the method of Ryther and Yentsch (1957). This method assumes a constant assimilation number (phytosynthesis/unit chlorophyll at optimal light intensity) which in fact does not exist. Although an average assimilation number, 4, has been calculated, values between 1 and 10 have been found (Strickland, 1960). Predictions of gross primary production may be within 20% but differences are often 2- or 3-fold (Ryther and Yentsch, 1957). Strickland (1960) points out why a precise relationship between chlorophyll *a,* light intensity, and gross primary production is not to be expected. He shows the importance of taxonomic position and prehistory of cells, ratio of chloroplast volume to total cell volume, and correct estimation of chlorophyll in live healthy cells and pigments other than chlorophyll *a* in determining photosynthetic rate. None of these factors are accounted for in Ryther and Yentsch's method (1957) but it is used here so that the Kaikoura results may be compared with their figures.

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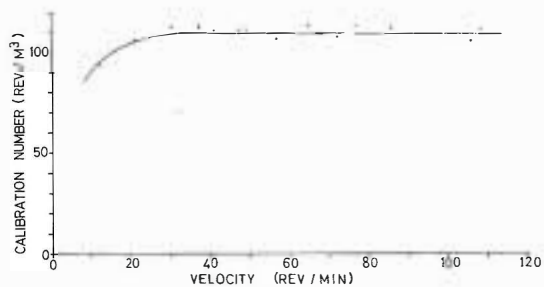
Fig. 22. Calibration curve for Clarke-Bumpas sampler flowmeter

Secchi-disc readings were taken from 16 August 1964 onwards, and radiation figures (data from N.Z. Meterological Service) from Harewood Airport (160 km south of Kaikoura) were used as an estimate of surface radiation. Daily photosynthesis below a square metre of sea surface (gm carbon/m²/day) was then calculated by graphic integration of the values of daily photosynthesis (gm carbon/m³) obtained for each depth.

ZOOPLANKTON

The Clarke-Bumpus sampler used was calibrated using a forced flow through the barrel of the sampler into a calibration pit. A calibration curve (Fig. 22) was obtained by plotting the number of meter revolutions (rev/m³) against velocity (rev/minute). Calibration was carried out at the beginning and end of every 3-month period to ascertain whether any appreciable change occurred. Differences in calibration were small and therefore ignored. Hauls were made at about 2 knots so that the flow meter would revolve faster than 40 rev/min, at which rate the calibration curve became flat (Fig. 22). The Clarke-Bumpus sampler was used to estimate the quantity of zooplankton and, as it is difficult to separate phytoplankton from zooplankton, a net was chosen with an aperture size (72 meshes to the inch and an aperture of 176 microns) small enough to catch most adult copepods but large enough not to catch the phytoplankton. When the Clarke-Bumpus samples were compared with the fine net samples it was clear that the Clarke-Bumpus sampler missed much of the smaller zooplankton. As sampling was carried out between 08.30 and 10.00 hr the effects of diurnal migration are ignored. Many planktonic animals reach a maximum depth in their migratory cycle on each side of mid day (Marshall and Orr, 1955; Raymont, 1963).

Two types of haul, oblique and horizontal, were made with the Clarke-Bumpus sampler.

OBLIQUE HAUL

An oblique haul was made by lowering the net, when the boat was under way, to 200 m. The net was opened by a messenger and hauled in at a constant speed that allowed the haul to last 10-15 minutes. Since the tunicate *Pyrosoma* was often found wrapped round the wire, preventing messengers operating, a double oblique haul was taken from 16 August, when the net was sent down open so that it sampled on the way down as well as on the way up. The time available for collecting and processing the zooplankton permitted only single samples to be taken. One one occasion, 14 April 1964, a set of six consecutive oblique hauls was taken from 100 m to check the variability inherent in this single-sampling. Various planktonic groups were counted and the coefficients of variation of a single haul determined by Windsor and Clarke's method (1940). The Kaikoura set of replicate samples gave a coefficient of variation of 30%, which is very close to Windsor and Clarke's 31%. The total zooplankton collected during an oblique haul was used to determine wet weight or biomass, dry weight, and organic matter content.

Wet Weight (Biomass)

The wet weight was determined by filtering the zooplankton under suction on No. 42 Whatman ashless filter paper (5cm diameter) while rinsing with 70% alcohol (an adaptation of the method described by Riley *et al.* 1956, p. 317). This method was chosen as, after wetting, removal of excess moisture, and weighing six times, a coefficient of variation of 1.47% resulted. Nakai and Honjo (1961) did not use a suction pump but rolled the plankton on filter paper to remove the excess moisture. This method gave coefficients of variation ranging from 0.31 to 2.01%. The method used at Kaikoura gave results that compared favourably with these results. Tranter (1962) separated his zooplankton samples from their preservative by using a perspex weighing dish fitted with a bottom of fine gauze to drain off the liquid, then washing the sample with 50% alcohol. Excess moisture was removed by standing the weighing dish on filter paper for a few minutes. Tranter obtained coefficients of variation from 0.57 to 7.56% after weighing six samples six times. At Kaikoura trials of this method gave coefficients of variation of 6 and 11% and it was therefore not employed.

The zooplankton on the filter paper was rinsed with 70% alcohol and left under suction until the alcohol had stopped visibly vapourising under the glass filter holder. The sample plus the damp filter paper was then placed in a porcelain crucible and weighed on a Mettler H 15 balance to 4 decimal places of a gramme. By subtracting the pre-determined weights of crucible and damp filter paper the wet weight of the zooplankton was found. The wet weight values were then related to the volume of water filtered. The figures thus obtained represented the mean biomass/m³ in the surface 200 m at the sampling place and instance. Large specimens, for example salps and euphausids longer than 1.5 cm, were removed and processed separately.

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Dry Weight

The crucible with its contents was then dried in an oven at 95°C (Riley *et al.* 1956, p. 317; Naki and Honjo, 1961). Curl *in* Lovegrove (1962) has subsequently suggested that drying the zooplankton at temperatures higher than 80°C would volatilise some lipids and amines as well as denature some proteins, so the weights obtained from the Kaikoura specimens may be too low.

Organic Matter Content

The contents of the crucible were ignited. The weight lost is considered to be an estimate of the organic matter content of the zooplankton. The organic matter values may be too large as the temperature of ignition was greater than 450°C, above which bicarbonates volatilise (Curl *in* Lovegrove, 1962).

HORIZONTAL HAUL

Four horizontal hauls were taken at depths of about 5, 22, 70, and 120 m. The hauls were made at a speed of about 2 knots and the number of meter revolutions noted. The numbers in the main taxonomic groups in the horizontal samples were counted. Molluscs, ostracods, and larvae were never very abundant so were not recorded. Most of the samples were too large to count entirely, so a sample divider (Kott, 1953) was used. Kott found that small differences in compartment size did not give differences in plankton counts for each compartment, but there was a tendency for some animals to "clump," especially those present in large numbers. Tests confirmed Kott's conclusions. A fraction of the sample, usually $\frac{1}{10}$, was counted on a perspex tray 8 cm by 3 cm marked in 5 mm squares. The rarely occurring species were also noted.

As it was not possible to replicate conditions in consecutive hauls no attempt was made to determine the variation involved in taking single horizontal hauls. Windsor and Clarke (1940) calculated a 93% variation for a single haul, but they thought that imprecise sampling of a vertically stratified zooplankton population could have been the cause of variation.

THE ENVIRONMENT

To define the basic physical and chemical properties at "The Permanent Station", salinity, temperature, and nitrate data were collected from April 1964 to May 1965.

SALINITY AND TEMPERATURE

Over the period 1964-65 the surface temperature reached a minimum during the winter months July and August and a maximum at the beginning of January (Fig. 23). Surface salinities reached a low point in July 1964, a maximum from November 1964 to January 1965, but from April to June 1964 and February to May 1965 they fluctuated irregularly (Fig. 24).

Essentially, the salinity in the water column increased with depth (Fig. 25), although during summer (November 1964 to January 1965), the water column was almost isohaline. In winter this general pattern of salinity increasing with depth was disturbed by subsurface invasions of high-salinity, high-temperature water (Figs 25, 26).

On one occasion (at the end of August 1964) the water column was completely isothermal. During summer the position of the isotherms fluctuated considerably and not in the same way as the isohalines. For example, the water column at the beginning of January 1965 exhibited an increase of temperature at depth while the salinities remained much the same as they were on the previous sampling day. During March 1965 a similar increase of temperature at depth was accompanied by greatly lowered salinities.

Salinity and temperature data were taken in a section across part of the shelf at the end of April. The results (Figs 27, 28) show typical warm, low-salinity coastal water lying over the shelf with oceanic water extending towards the coast increasing the salinity and reducing the temperature.
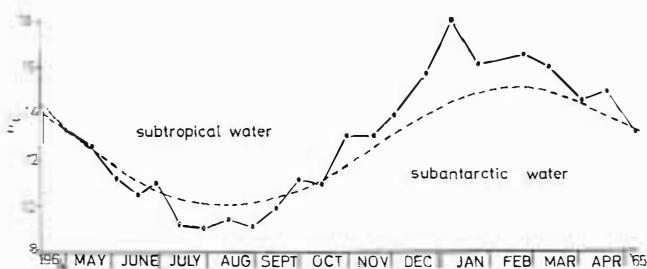
FIG. 23. Surface temperature (solid line) at "The Permanent Station" and mid-temperature (broken line) of the Subtropical Convergence (Garner, 1959)
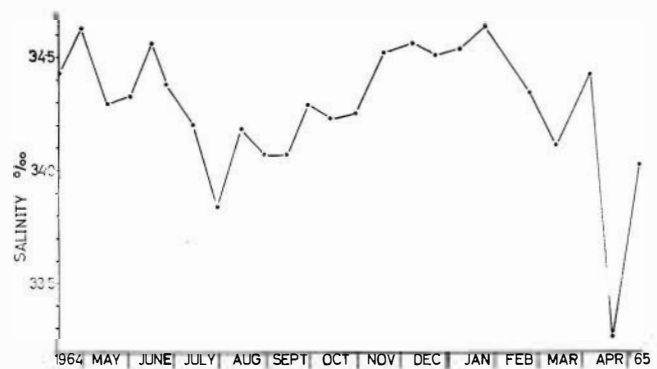
FIG. 24. Surface salinity, ‰, at "The Permanent Station"

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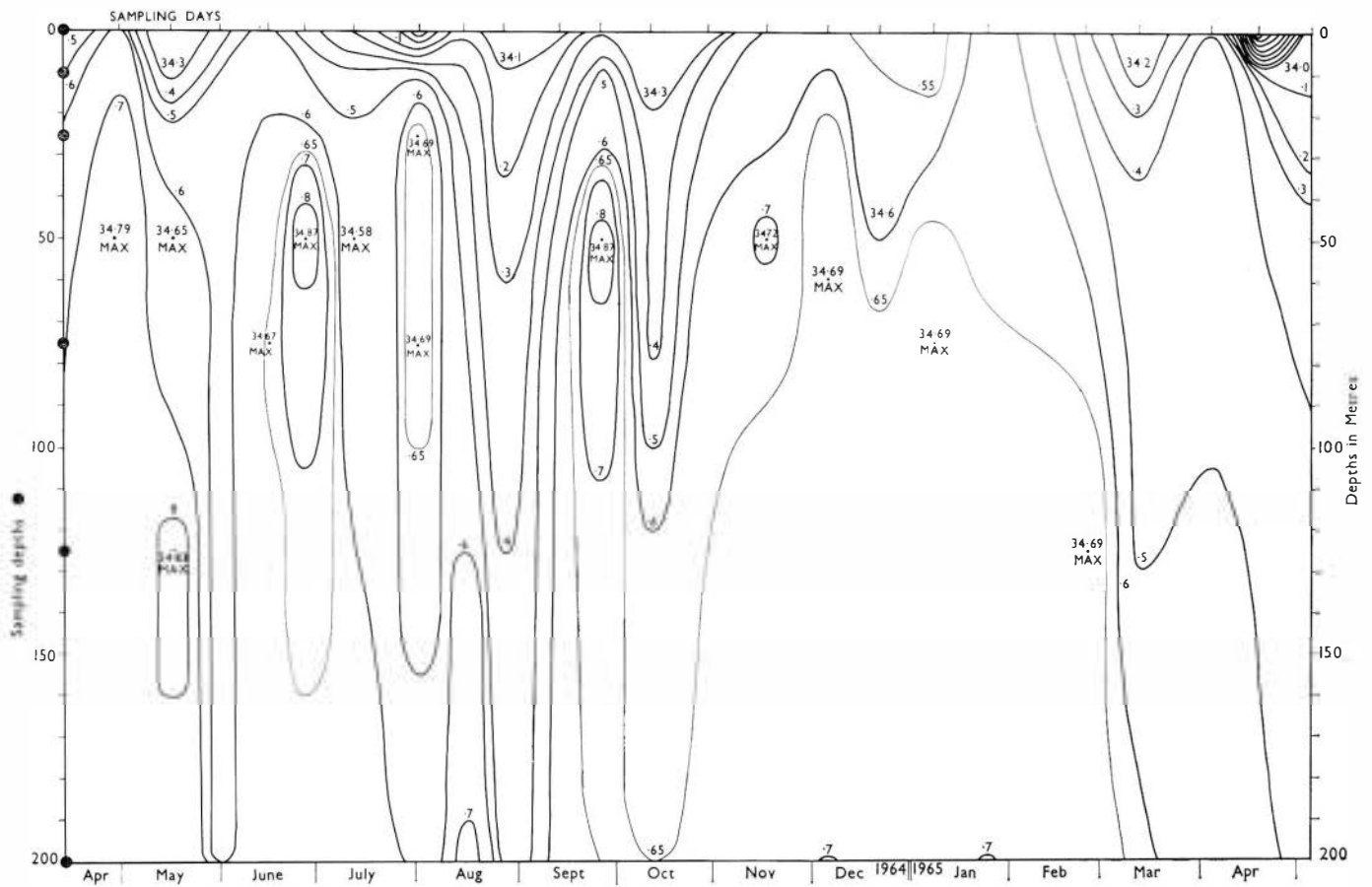
FIG. 25. Seasonal depth profile of salinity, ‰, at "The Permanent Station"
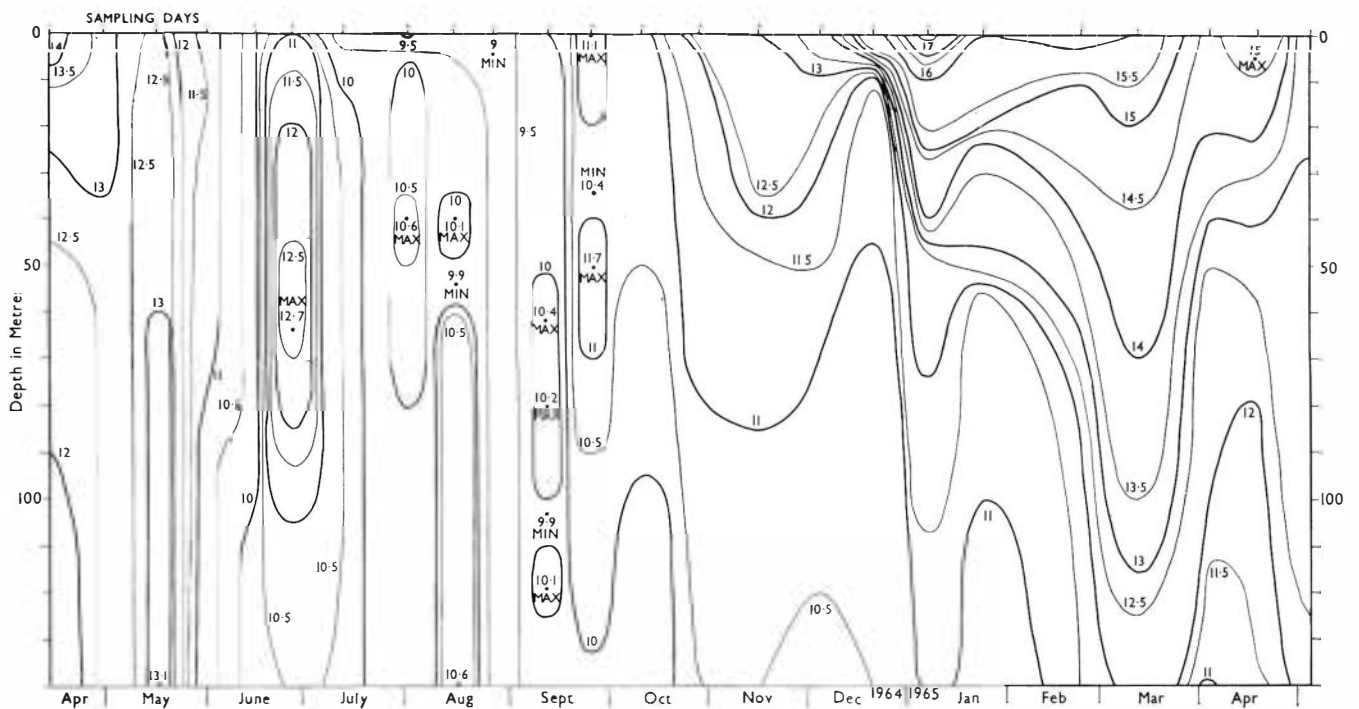
FIG. 26. Seasonal depth profile of temperature, °C, at "The Permanent Station"

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DENSITY

The winter invasions of high-salinity warm water and the summer fluctuations in surface and subsurface temperatures had a marked effect on the density. The invasions in May and at the end of June 1964, and the warming of subsurface layers at the beginning of January and in March 1965, resulted in drops in the average density (Fig. 29).

Seasonal changes in stratification are best shown by the seasonal depth profile of density (σ_t) (Fig. 30). The water column in June was almost homogeneous and remained so until October 1964 except for slight stratification because of diluted surface waters (Fig. 25). Mixing had been taking place over that period, June to October, temperature stratification not being observed until October 1964 (Fig. 26). Summer density stratification (Fig. 30) was at its greatest at the beginning of January 1965, corresponding with a strong surface invasion of subtropical water (Fig. 26).

NITRITE-NITRATE NITROGEN

The greatest nitrate values were found in winter (Fig. 31); the first average amount reliably detected was $20.0 \mu g$ at/L at the end of June 1964. From then until the end of August 1964 there was a rapid decrease to $3.7 \mu g$ at/L, then a small increase in September, and a decrease to a minimum of $3.0 \mu g$ at/L in mid-October. The average amount of nitrate then rose slowly but irregularly until sampling finished. Peaks were reached at the end of December 1964 and January 1965, and in mid April 1965.

The above-mentioned peak concentrations of nitrate (Fig. 31) were concurrent with increased nitrate concentrations in the upper layers (Fig. 32). This increase in surface layers was particularly marked in September 1964. The winter was notable for the rich nitrate concentration; at least $34.5 \mu g$ at/L was found at 200 m in mid June 1964. From September 1964 to January 1965 there was less than $1 \mu g$ at/L at the surface and down to 75 m. This meant that the nitrate was almost exhausted in the surface layers.

PREVIOUS WORK

The Kaikoura region is influenced by two coastal currents (Fig. 16). Water predominantly derived from the modified subtropical water of the Tasman Sea, and probably further cooled by mixing with subantarctic water, flows northwards along the east coast as the Southland Current (Garner, 1961). This flow merges with the north-flowing *Canterbury Current* (Burling, 1961; Brodie, 1960), which occupies a major portion of the east coast shelf and which occasionally extends as far north as Gisborne (Brodie, 1960; Garner, 1961). The *East Cape Current*, which bounds the Canterbury Current on the east, is a south-flowing tongue of sub-tropical water (Fleming, 1952; Garner, 1953, 1954, 1961; Brodie, 1960). The influence of the East Cape Current varies considerably from year to year. For example, Garner (1954) showed that it extended the length of New Zealand in 1951, but its influence did not extend much past Cook Strait the following summer.

The boundary between subantarctic and subtropical water masses in the south-west Pacific has been described by Deacon (1937) as the *Subtropical Convergence*. More relevant to this study is its character in New Zealand waters where it results from the confluence of the Canterbury and East Cape Currents in the coastal region (Fig. 16). Its relationship to New Zealand has been considered by Fleming (1952) and Garner (1954, 1959). Garner (1959) defines the Subtropical Convergence as following "approximately the isotherms of 15°C in February and 10°C in August and the isohalines of 34.7 to 34.8‰ with little seasonal variation". However Garner (1954) noted that, because of the fluctuations in the East Cape Current, seasonal and yearly fluctuations in the position of the Convergence are to be expected.

Garner (1961) described invasions of subtropical water off the Kaikoura coast at two-monthly intervals in 1955 and noted two occasions when the invasions were particularly strong. These seemed to be connected with pulses of cold water upwelling in southern Cook Strait. He also noticed that cold water upwelled over the Conway Trough in summer. Houtman (1965) found warm water at the surface there in winter.

RELATIONSHIP OF 1964-65 EVENTS TO PREVIOUS FINDINGS

The most obvious occurrence in the salinity and temperature data (Figs 25, 26) was the periodic invasion of warm, high-salinity water into the Kaikoura region. There is no doubt that these invasions must be equated with Garner's (1961) two-monthly intrusions of sub-tropical water, interpreted from daily records. However the intrusion intervals in this study were not as regularly spaced; possibly the measurements were influenced by the less frequent (fortnightly) sampling.

Even though the surface temperatures (Fig. 23) often rose above Garner's (1959) lower limits for sub-tropical water the salinities recorded were never great enough to confirm an entirely subtropical origin for the warm water discovered off Kaikoura during 1964-65. On only three occasions did the salinity rise above 34.8‰: at 125 m in May, and at 50 m in June and September 1964. Nevertheless during 1964-65 slight summer salinity maxima were observed at Kaikoura which were similar to those noted by Sdubbundhit and Gilmour (1963) in subtropical oceanic water off the south-east coast of the North Island. The almost iso-haline water column, present at the same time and greatest at the end of February 1965, indicated the

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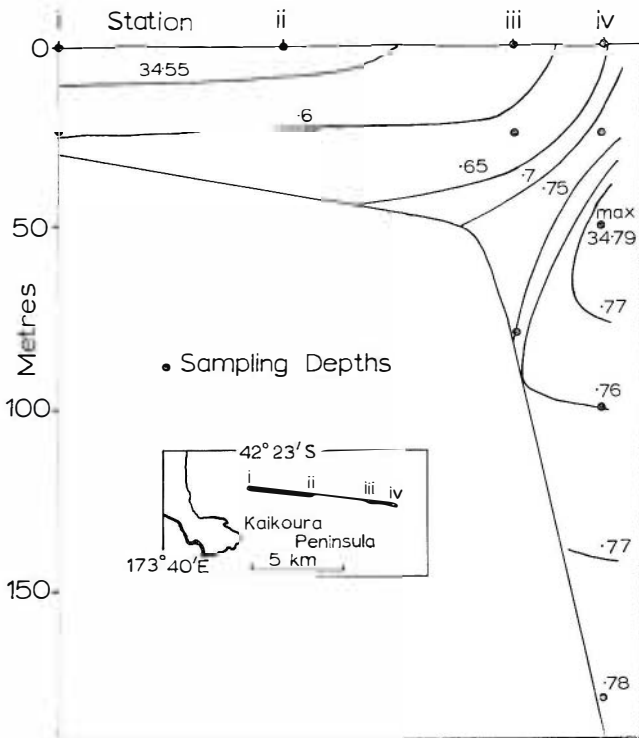
FIG. 27. Salinity, ‰, profile across shelf and slope 30 April 1964

FIG. 29. Average density (σ_t) above 125m (from depths of 0, 10, 25, 50, 75, and 125m) at "The Permanent Station"
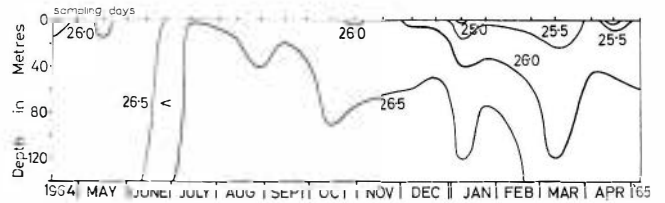
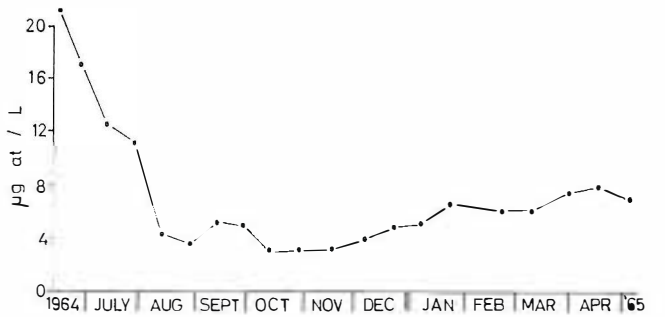FIG. 30. Seasonal depth profile of density (σ_t) at "The Permanent Station"

FIG. 31. Average nitrite-nitrate nitrogen, μg at/L, above 200 m (from depths of 0, 10, 25, 50, 75, 125, and 200m) at "The Permanent Station"
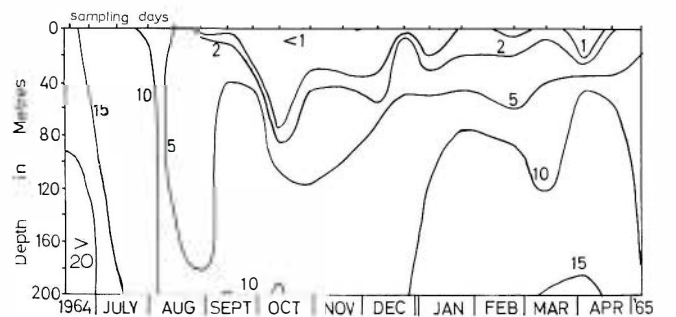

FIG. 28. Temperature, °C, profile across shelf and slope 30 April 1964

FIG. 32. Seasonal depth profile of nitrite-nitrate nitrogen μg at/L at "The Permanent Station"

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more oceanic nature of the sea water. During winter river water was the main diluting agent of surface waters.

The data collected at "The Permanent Station" indicate the *Convergence Region* nature of the Kaikoura area. This fact is clearly underlined when the surface temperatures for 1964-65 are superimposed on a sine curve containing the summer maximum and winter minimum temperatures for the Subtropical Convergence (Garner, 1959) (Fig. 23).

Little may be concluded about the way in which warm water is introduced into the vicinity of "The Permanent Station", presumably from the East Cape Current. Houtman (1965) recorded warm water in June over the Conway Trough and indicated how it may occur. He found water of subtropical origin in two forms: as a tongue at about 200 m reaching from Hikurangi Trench into Kaikoura Canyon; and as "Canyon Water", which originated from the above tongue, was modified by mixing with river discharge, and flowed out of the Canyon at the surface, moving over the deepest part in a seaward direction. In the present study, during winter, warm water influenced the surface layers on only two occasions, but caused temperature and salinity maxima at depths varying from 50 to 200 m.

In summer the highest surface temperature was observed at the beginning of January 1965. The situation in the water column at that time is presumed to be the result of an invasion of subtropical water. It is expected that the normal situation would be reinstated after the pulse of warm water had retreated, and such was probably the position at the end of January and during April.

At the end of December 1964 cold water found much nearer the surface than on the previous or following sampling days formed a surface thermocline in which the temperature decreased 4°C in 8 m (Fig. 33). At the same time the surface temperature itself had increased by 4°C in just over 4 weeks. It is more likely that an upwelling situation was recorded on this day, similar to that noted in summer south of the Kaikoura Peninsula (Garner, 1961), rather than the results of horizontal water movements only. This hypothesis is substantiated by the fact that nitrate enrichment of the surface layers took place at the end of December 1964 (Fig. 32). There is no record of cold water reaching the surface over the Conway Trough at the beginning of 1965.

The situation observed in March 1965 was interesting in that the water at depth became several degrees warmer than it had been all summer while the surface water continued to cool. Salinities at this time were lower than they had been during the summer. The whole water column had become coastal in character with lower salinities and higher temperatures (cf. Figs 27, 28).

In summary, samples taken at "The Permanent Station" from April 1964 to May 1965 off Kaikoura represent a series of events occurring in the Canterbury Current which flows north at up to 15 km/day (Garner, 1961; p. 36). Three types of water masses were introduced into the Kaikoura region, altering some characteristics of the Canterbury Current. River outflow, especially in winter, lowered surface salinities to a marked extent and temperature to a lesser degree. Subtropical water, probably from the East Cape Current, invaded the region at approximately 2-monthly intervals, producing salinity and temperature maxima in the water column. Cold water found near the surface was presumed to have upwelled against the shelf (Garner, 1961; Burling, 1961).
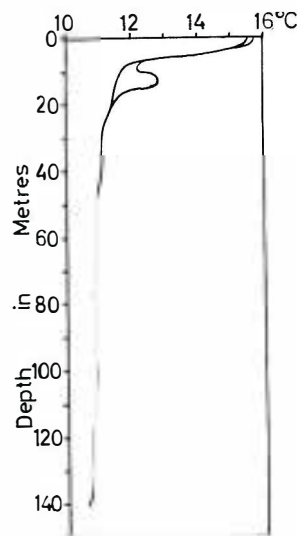
FIG. 33. Bathythermograph trace, 21 December 1964, at "The Permanent Station"

FIG. 34. Average chlorophyll *a*, mg/m³, above 50m (from depths of 0,10,25, and 50m) at "The Permanent Station"

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PHYTOPLANKTON OBSERVATIONS

Average Concentrations of Chlorophyll *a*

Sampling started after the last of the 1964 autumn phytoplankton growth (Fig. 34). Average concentrations of chlorophyll *a* above 50 m remained low throughout the period sampled except for the spring increase in September and October.

Distribution of Chlorophyll *a* with Depth

In general, a concentration greater than $0.5 \ mg/m^3$ of chlorophyll *a* was found above 80 m at "The Permanent Station", except in the period from July to the end of October 1964 (Fig. 35). At the end of August 1964 a concentration as great as $1.21 \ mg/m^3$ was found at 125 m. The period from July to the end of October 1964 corresponded to the time over which the spring phytoplankton bloom took place.

Yentsch (1963) showed from a number of observations that the depth of the euphotic zone was from four to nine times the depth at which maximum photosynthesis (maximum productivity) occurs (Table 3).

TABLE 3. Depth of maximum photosynthesis in relation to the depth to which photosynthesis occurs (Yentsch, 1963)

Depth of maximum photosynthesis (m)	Depth to which photosynthesis occurs (m)
3	25
5–10	45
10–20	83

Jitts (1965) has, however, shown that chlorophyll maxima corresponded approximately to the productivity maxima in waters off Australia ranging from tropical to subantarctic. On this basis, Yentsch's photosynthetic maxima were equated with the chlorophyll maxima observed at Kaikoura, and the depth of the euphotic zone was calculated. The depth of the euphotic zone at Kaikoura was calculated independently by multiplying the Secchi Disc reading by three (Riley, 1941). The results of the two methods are compared in Table 4.

Thus the distribution of chlorophyll found at "The Permanent Station" was not a product of the transparency conditions recorded there by the Secchi Disc, except for perhaps late December 1964 and early January 1965 (Table 4). It appears that more transparent oceanic water had moved close to the coast and become overlaid and mixed with more turbid coastal water.

TABLE 4. Depth of the euphotic zone at "The Permanent Station" calculated from Secchi Disc readings and from chlorophyll *a* maxima

Date	Depth from Secchi Disc readings (m)	Depth from chlorophyll maxima (m)
1964		
16 Aug	18	45
13 Sep	16	45
26 Sep	19	45
11 Oct	17	45
29 Oct	13	45
7 Nov	21	83
5 Dec	27	83
21 Dec	18	25
1965		
7 Jan	36	45
24 Jan	27	83
24 Feb	17	45
12 Mar	12	25
4 Apr	41	83
18 Apr	17	83
5 May	9	45

"Gross" Primary Production

(Calculated from Chlorophyll, Radiation, and Transparency Data)

The annual pattern of "gross" primary production (Fig. 36) found at Kaikoura was similar to that of the biomass as represented by chlorophyll *a* (Fig. 34). The range of values found was 0.09–$1.05 \ gmC/m^2/day$ (Fig. 36). The "gross" annual primary production at "The Permanent Station" off Kaikoura was $157 \ gmC/m^2/year$.

FIG. 35. Seasonal depth profile of chlorophyll *a*, mg/m^3, at "The Permanent Station"
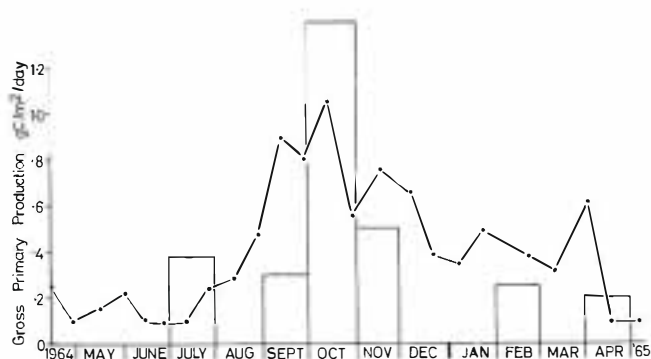
FIG. 36. "Gross" primary production at "The Permanent Station" (line graph) and at New York (histogram) (Ryther and Yentsch, 1958)

ZOOPLANKTON OBSERVATIONS

Biomass (Wet Weight)

The biomass of zooplankton in mg/m³, omitting salps, fluctuated during the sampling period (Fig. 37). As was previously stated, the coefficient of variation of a single oblique haul was 30%, so it is likely that most of the observed fluctuations in biomass were real and not due to errors in observation. The lowest average biomass in the surface 200 m (10.3 mg/m³) occurred at the beginning of August 1964 and the highest average amount (403.1 mg/m³) at the end of December 1964, but there was no steady rise and fall. There were only seven occasions when the zooplankton biomass without salps was greater than 100 mg/m³ and these were spread fairly evenly over the whole year: April, July, October, and December 1964, and April 1965. The maximum biomass recorded (at the end of December 1964) was almost entirely due to huge numbers of stage V *Calanus tonsus* copepodites at 5 m on 5 December and at 22 m on 21 December 1964. On both occasions they must have been concentrated in a narrow band as on the latter date a biomass of 6,200 mg/m³ was found at 22 m. *Calanus tonsus* was not always present in the Kaikoura plankton. An occasional female was captured during August and September, then from October to January, with a peak in December, numbers of stage V copepodites were found. They disappeared completely from February onwards.

An average biomass of 68 mg/m³ was calculated for the 13 months of fortnightly sampling.

Dry Weight and Organic Content

From observations made during 1964-65 at Kaikoura, it is obvious (Table 5) that different groups of planktonic animals contain different amounts of water.
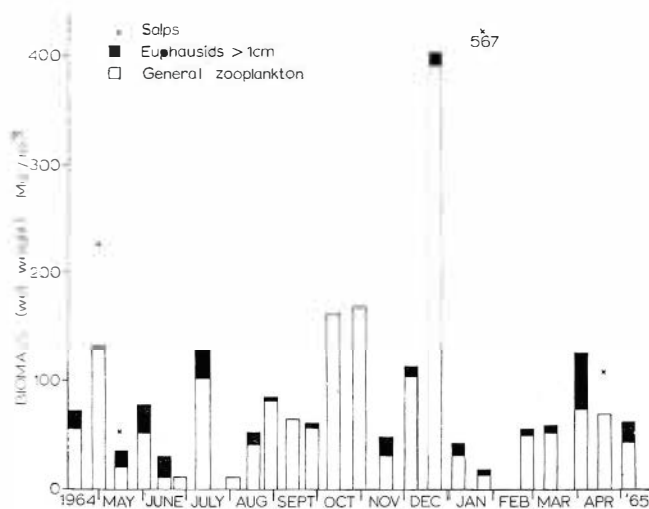
Dry weight, by itself, is a more meaningful measure of "biomass" since heavy salps do not represent a great amount of organic matter. Peaks in wet weight (Fig. 37) caused by salps are depressed in dry weight (Fig. 38), especially at the end of January 1965. Tranter (1962), on the other hand, found that salp swarms represented a high concentration of organic matter evident as peaks in both wet and dry weights.

Organic matter is important when zooplankton is being considered as a source of food. Because of the varying proportions of water in different species, organic matter in the zooplankton is best expressed as a percentage of dry weight. Fig. 39 shows how % (organic matter/dry weight) varied at Kaikoura. These values indicate the better condition of most animals during the spring and summer when the food supply was good. Most of the organic matter is found as fat reserves (Riley *et al.* 1949). Marshall and Orr (1955) found an increased fat content in males, females, and stage V *Calanus finmarchicus* copepodites in April and a decrease at the end of July. They also reported a maximum fluctuation in the percentage fat of 20% in males and stage V copepodites and 13% in females.

TABLE 5. Percentage (dry weight/wet weight) of the general zooplankton and separate groups

Group	% Dry Weight / Wet Weight
Salps	6
Euphausids	12
Copepods (*Calanus tonsus*)	19
Plankton, miscellaneous	14
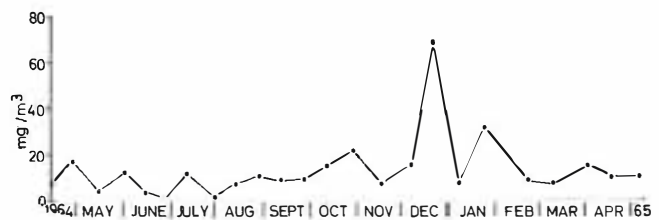
Fig. 38. Mean dry weight of total zooplankton above 200 m on each sampling day at "The Permanent Station"
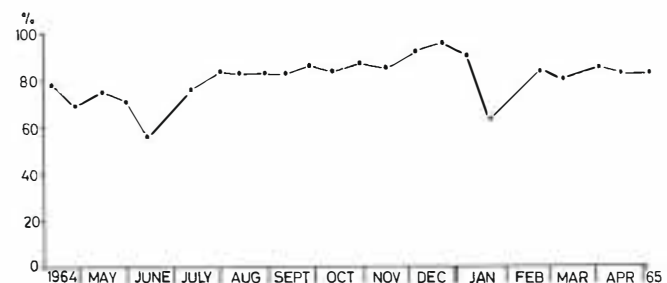
Fig. 39. Percentage (organic matter/dry weight) of plankton excluding salps and euphausids at "The Permanent Station"

Fig. 37. Mean zooplankton biomass above 200m (from Clarke-Bumpus sampler oblique haul from 200m) on each sampling day at "The Permanent Station"

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Several workers have related organic matter content to wet weight. Valid comparisons of results may be made if single species, or plankton samples of similar species composition, are referred to. Nakai's (1942) determinations of the fat content of seven copepod and three euphausid species between 32°22'N and 42°22'N near Japan were interpreted by Riley and Gorgy (1948) as showing a latitudinal effect on the amount of fat stored by crustacean species. At Kaikoura (Fig. 40) there were three occasions (April to early May 1964, June 1964, January to April 1965) when % (organic matter/wet weight) of the euphausids was below 10%. Except perhaps in the middle of June, these were also occasions when subtropical water influence was strong at "The Permanent Station" (Fig. 26). Sheard (*in* Thompson, 1942) noted an apparent increase southwards in the south-east Australian region in oil content of copepod species and euphausids (*Euphausia similis, E. recurva,* and *Thysanoessa gregaria*). By analogy with the work of Sheard, (*in* Thompson, 1942) and Riley and Gorgy (1948) it seems that subtropical water may have occasionally carried euphausids from the north towards

Kaikoura. Percentage (organic matter/wet weight) for total zooplankton varied irregularly (Fig. 41) except that from April to July 1964 most values were below 10% and a peak percentage did occur during December.

ZOOPLANKTON NUMBERS

Results from the enumeration of the zooplankton are presented in the figures in three forms: numbers/m^3, percentage distribution with depth, and percentage of the non-copepod zooplankton. The numbers/m^3 have been obtained by taking the average of numbers/m^3 from four depths (approximately 5, 22, 70, and 120 m). The horizontal hauls from which the numbers of animals have been counted have an unknown variability, possibly large (see page 59). Thus one should not draw conclusions in too great detail from these figures. Figures representing percentage distribution with depth are based on information from the above four depths, the sum of concentrations at each of these depths representing 100%. Distribution outside the sampling range of depths has not been considered.

Animals were identified mainly from the following sources: Ctenophora (Benham, 1906; Ralph and Kaberry, 1950); Copepoda (Wilson, 1932; Rose, 1933; Farran, 1948a, b, c, d, e, f; Farran and Vervoort, 1951a, b, c, d, e, f, g, h, i; Vervoort, 1952a, b, c, d, e, f, g, h, i); Amphipoda (Hurley, 1955), Euphausiacea (Sheard, 1953); Chaetognatha (Thompson, 1947; David, 1955); Tunicata (Thompson, 1948).

FIG. 40. Percentage (organic matter/dry weight) of euphausids
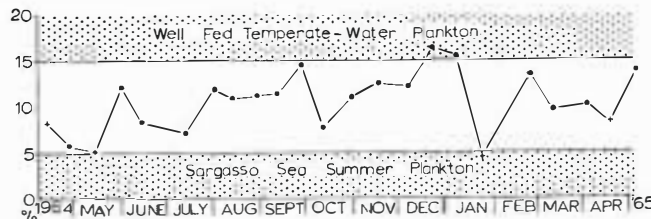
FIG. 41. Percentage (organic matter/wet weight) of total zooplankton. Limits for "well fed temperature-water plankton" and "Sargasso Sea summer plankton" from Riley *et al.* (1949)
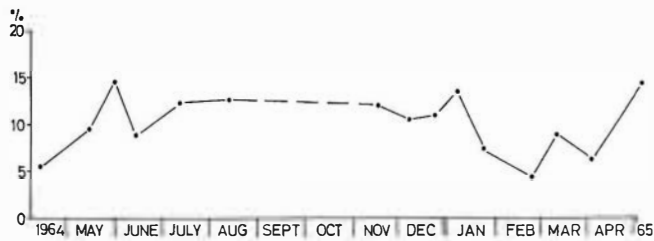
FIG. 42. Ctenophora per cubic metre (average of four depths) on each sampling day.
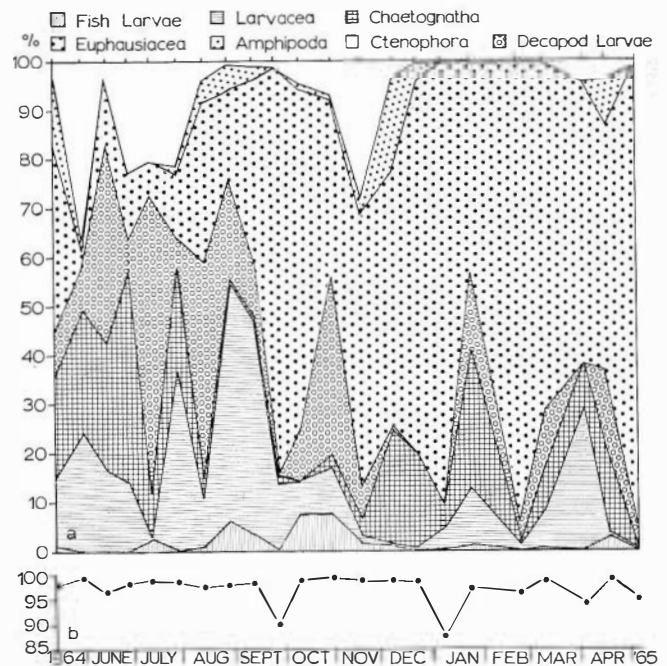
FIG. 43. a) Percentage composition of non-copepod zooplankton. b) Copepod as a percentage of the total zooplankton

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Ctenophora

Representatives of this group were not well preserved, and they were often broken into unrecognisable pieces. Thus they were difficult to identify and count. The most abundant species was *Pleurobrachia pileus* (O. F. Muller, 1776) which occurred all year round. *Pleurobrachia australis* (Benham, 1907) was found in October, November, and December 1964. No other species were recognised but there may have been others present as Ralph and Kaberry (1950) recorded seven species from Cook Strait.

The numbers of Ctenophora/m³ fluctuated during the year (Fig. 42). The most noticeable feature was their almost complete absence in December 1964, January, February, and part of March 1965, whereas in autumn and late spring they represented over 25% of the non-copepod zooplankton (Fig. 43). Ctenophora are feeble swimmers, easily aggregated by tides and currents into dense swarms (Hyman, 1940), so the recorded increases in numbers may not necessarily represent increase in total population.

Ctenophora are found in greatest numbers most often below 100 m and only occasionally at the surface during the day (Fig. 44).

Copepoda

This group represents the bulk of the zooplankton, and at Kaikoura from 87% to more than 99% were Copepoda (Fig. 43). The most plentiful species (in order of abundance) were:

> *Acartia clausi* Giesbrecht, 1889
> *Oithona atlantica* Farran, 1908
> *O. similis* (Claus, 1863)
> *Centropages aucklandicus* Kramer, 1892
> *Calanus australis* Brodsky, 1959
> *Clausocalanus* sp.
> *Paracalanus parvus* (Claus, 1863)

These species were found nearly all year round, the genera *Acartia* and *Oithona* being particularly abundant at the surface. Another copepod, *Calanus tonsus* Brady, 1883, was also found; a few adult females in August and September 1964 and, from then until January 1965, large numbers of stage V copepodites which reached peak concentrations of 3,140/m³ at 5 m and 4,425/m³ at 20 m on 5 and 21 December 1964 respectively. From February to May 1965 *C. tonsus* disappeared. The swarms of *C. tonsus* that occurred during December 1964 and December 1965 were important as food to schools of basking sharks (*Cetorhinus maximus*) recorded near Kaikoura Peninsula on both occasions.

FIG. 44. Distribution of Ctenophora with depth. At each of the depths sampled the quantity of Ctenophora is expressed as a percentage of the total occurrence
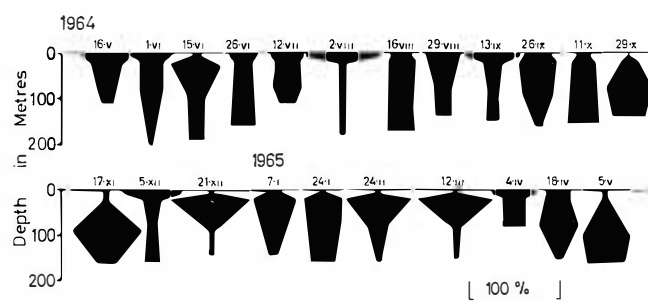
FIG. 46. Distribution of Copepoda with depth. At each of the depths sampled the quantity of Copepoda is expressed as a percentage of the total occurrence

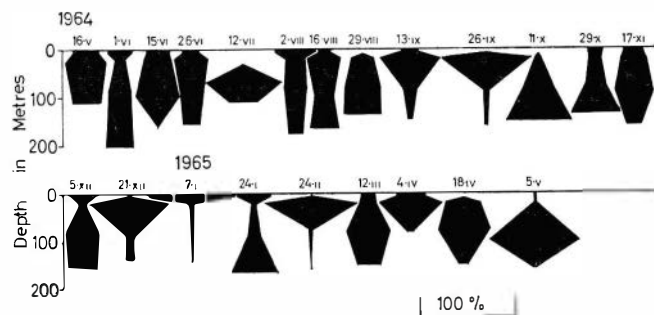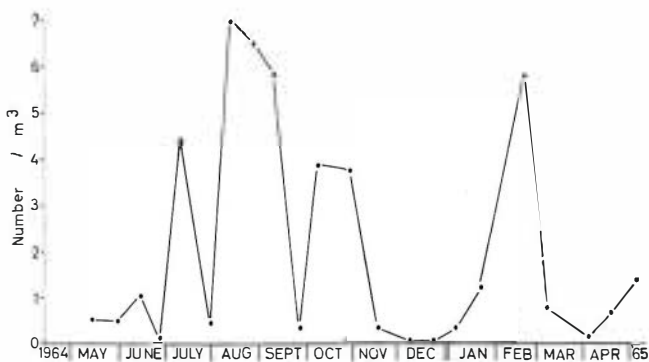FIG. 45. Copepoda per cubic metre (average of the depths sampled) on each sampling day
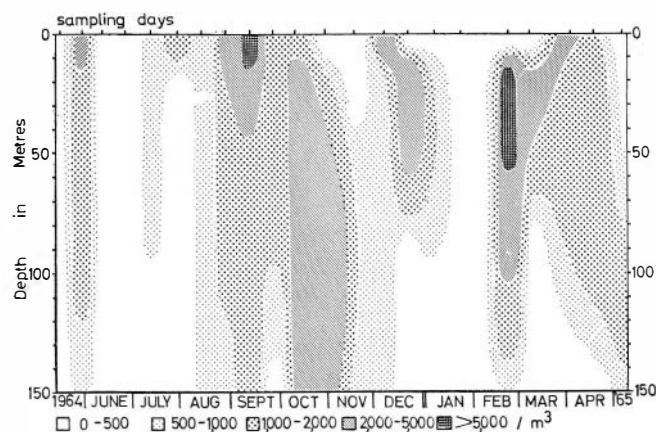
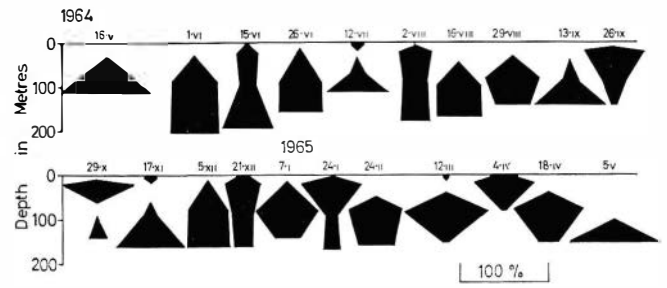FIG. 47. Seasonal depth profile of copepod numbers per cubic metre

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Besides the common copepods there were other less frequently occurring species characteristic of oceanic water (Table 2). Species most consistently captured were *Metridia lucens* and *Pleuromamma gracilis*.

Numbers of Copepoda/m³ fluctuated greatly during the year, the highest numbers occurring in September and October 1964 and February 1965. During December 1964, when the greatest total biomass was found (Fig. 37), there was a relatively low count of Copepoda/m³ (Fig. 45). The large *Calanus tonsus*, which reaches 4mm in length, was present in a narrow band around 22m in December 1964. Its size had considerable effect on biomass. (When the small *Oithona* spp. (length 1mm) and *Acartia clausia* (length 1mm) were present in large numbers near the surface, there was no corresponding high biomass.)

As would be expected of a group of mainly herbivorous animals, the maximum number of Copepoda is nearly always found at or near the surface (Fig. 46). Very small concentrations (less than 500/m³) were found on several occasions (Fig. 47). From June to the beginning of August low numbers accompanied the main winter mixing process. Low numbers of Copepoda were also recorded during November at the surface, in December below 90m, and in January throughout the water column. Small numbers of Copepoda were found nearer the bottom during March and April.

The short-term fluctuations in mean numbers recorded at Kaikoura were similar to those noted by Tranter (1962), who regarded such fluctuations as indicating a lack of stability in the environment. Humphrey (1960) figures the occasional presence of surface, high-temperature and high-salinity water of northern origin (Newell, 1966), (not unlike that recorded at Kaikoura 1964-65 and interpreted as incursions of offshore warmer water). This could have caused the lack of environmental stability deduced by Tranter from the short-term fluctuations in copepod numbers and zooplankton biomass.

TABLE 6. Occurrence of six species of amphipods at "The Permanent Station" April 1964—May 1965

	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Parathemisto australis	X	X	X	X	X	X	X	X	X	X	X			
P. gracilipes				X						X			X	
Vibilia stebbingi?	X	X											X	
Primno macropa					X		X			X				
Phronima sedentaria					X	X							X	X
Cyllopus magellanicus	X	X								X			X	

TABLE 7. Occurrence of six species of euphausids at "The Permanent Station" April 1964—May 1965

	A	M	J	J	A	S	O	N	D	J	F	M	A	M
Nyctiphanes australis	X			X			X	X	X	X				X
Euphausia lucens			X	X		X	X	X	X	X	X	X	X	X
E. similis					X	X			X	X				
E. vallentini				X		X								
Thysanoessa gregaria		X	X	X			X	X	X	X			X	X
Nematoscelis megalops?		X	X	X		X		X		X		X		

Amphipoda

The main species of amphipoda present and their occurrence are shown in Table 6.

Amphipoda represented up to 15%, but usually a much smaller proportion, of the non-copepod zooplankton (Fig. 43). The greatest numbers of Amphipoda found in August, September, and December 1964 (Fig. 48) were mainly juveniles of the coastal species *Parathemisto australis*. The greatest concentration of Amphipoda, mainly juveniles, was found most often at or just below the surface. Bousfield (1951) suggested that the young stages were dependent on the phytoplankton for food, which would explain the large concentrations of juveniles at the surface. Bary (1959b) also found *P. gracilis* and *P. australis* consistently present at the surface in daytime. Adult Amphipoda, however, are carnivorous. Hardy and Gunther (1935) reported that *P. gaudichaudii* fed mostly on young Euphausiacea, and Bousfield (1951) reported that *Themisto* sp. fed on Copepoda and other planktonic forms and was even cannibalistic. Probably representative adult Amphipoda were not caught because they are very efficient swimmers. Amphipoda sometimes swarm and become important as food for sea birds and fish as, for example, on 18 April 1965 (personal observation).

Euphausiacea

The main species of Euphausiacea present and their occurrence are shown in Table 7.

Euphausiacea were the second most important constitutent (after Copepoda) of the zooplankton. On half the sampling days over 50% of the non-copepod zooplankton belonged to this group (Fig. 43). As with the Copepoda, the total numbers of Euphausiacea fluctuated over short periods. The peak concentrations (Fig. 49) were entirely due to calyptopis and furcilia larvae. Adult Euphausiacea were only a small proportion of the total numbers, and peaks in their numbers did not correspond with the peaks in the total numbers (Fig. 50). The low total Euphausiacea numbers from May to August 1964 may be accounted for by the life cycle of *Nyctiphanes australis* females. Sheard (1953) found ovigerous *N. australis* females between latitudes 31°S and 43°S throughout the year except for May and June, but nauplii were absent from February to June. He found other larval stages of *N. australis* all year round.

The decrease in numbers of adult *N. australis* at the end of December and January and their disappearance from samples in February, March, and April (Table 7) was associated with an almost complete disappearance of shoals of kahawai, *Arripis trutta*, from the beginning of January until the end of March 1965. Kahawai in the Kaikoura region depend for much of their diet on *Nyctiphanes australis, Munida gregaria*, and small fish, pilchards, *Sardinops neopilchardus*, and sprats, *Mauge-clupea antipodum* (Graham, 1953). These small fish,

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in turn, feed upon smaller planktonic organisms, which were reduced in quantity during January, February, and March 1965 at Kaikoura (Fig. 37).

The maximum concentration of all stages of Euphausiacea was found between 22 and 100m. On all but five occasions they were found at the surface (Fig. 51). Euphausiacea, according to Sheard (1953), inhabit the detritus-bearing water layers near the bottom over the continental shelf, except for brief periods of surface swarming by neritic species. Sheard shows that Euphausiacea tend to concentrate below the Copepoda and feed extensively on copepod faecal pellets and live diatoms. At Kaikoura the main concentration of Euphausiacea was below that of the Copepoda (Figs 46, 51).

The swarming of *Nyctiphanes australis* during breeding is well developed, and some species of birds (*Larus novaehollandiae scopulinus*) and fish (*Arripis trutta*) depend on this aggregation for food at Kaikoura.

Decapod Larvae

Decapod larvae were occasionally an important part, up to 60%, of the non-copepod zooplankton (Fig. 43). They have not been identified in this study, except for *Munida* sp. which is discussed later.

Larval decapod numbers began to increase in July, but there were great fluctuations in the numbers recorded (Fig. 52). This was probably due to the appearance and disappearance of different species in the plankton. The greatest concentration was most often found at 22m (Fig. 53).

The larvae included species of Galatheidae and Paguridae. Paguridae were present from mid August 1964 until the end of February 1965, and only an occasional one appeared after this. The Galatheidae consisted of two *Munida* species and one other species in which the stage III, IV, and V zoea were very like *Munida* but stages I and II had a telson that was not typical of that genus.

Larvae of one of the *Munida* species were captured on the following dates:

Stage I	29 August 1964
Stage II	13 and 26 September 1964, 24 January 1965
Stage III	7 January 1965

FIG. 48. Amphipoda per cubic metre (average of the depths sampled) on each sampling day

FIG. 49. Total Euphausiaceae per cubic metre (average of the depths sampled) on each sampling day

FIG. 51. Distribution of Euphausiaceae with depth. At each of the depths sampled the quantity of Euphausiaceae is expressed as a percentage of the total occurrence

FIG. 50. Adult Euphausiaceae per cubic metre (average of the depths sampled) on each sampling day

FIG. 52. Decapod larvae per cubic metre (average of the depths sampled) on each sampling day

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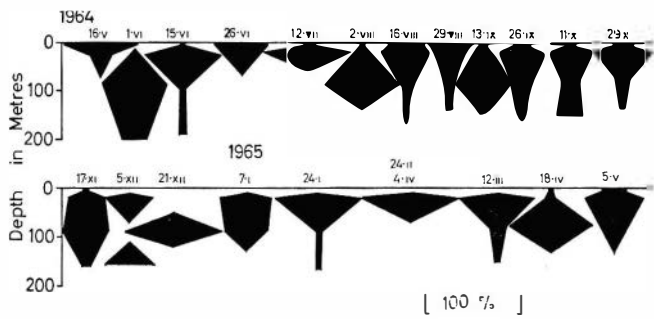
FIG. 53. Distribution of decapod larvae with depth. At each of the depths sampled the quantity of decapod larvae is expressed as a percentage of the total occurrence
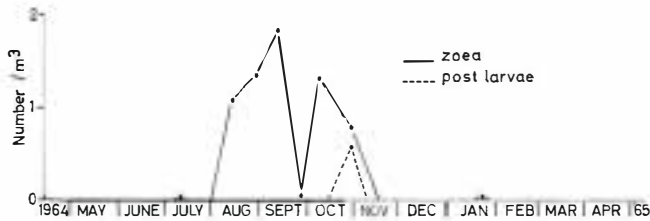
FIG. 54. *Munida* larvae per cubic metre (average of the depths sampled) on each sampling day
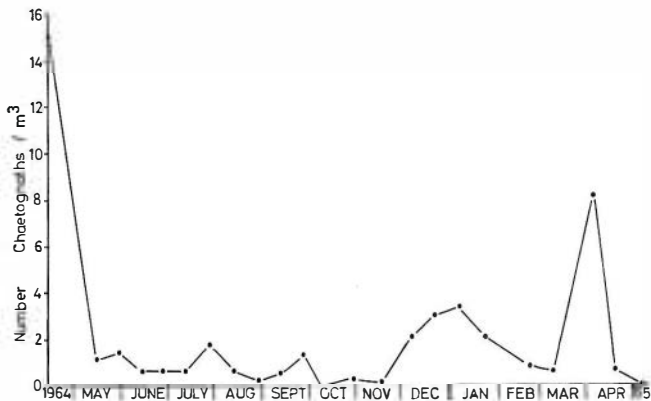
FIG. 55. Chaetognatha per cubic metre (average of the depths sampled) on each sampling day

FIG. 56. Distribution of Chaetognatha with depth. At each of the depths sampled the quantity of Chaetognatha is expressed as a percentage of the total occurrence
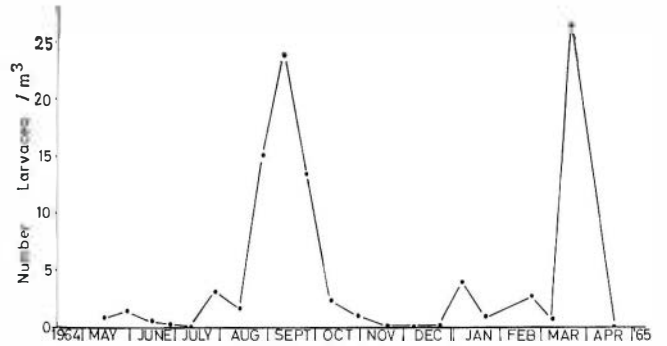
FIG. 57. Larvacea per cubic metre (average of the depths sampled) on each sampling day
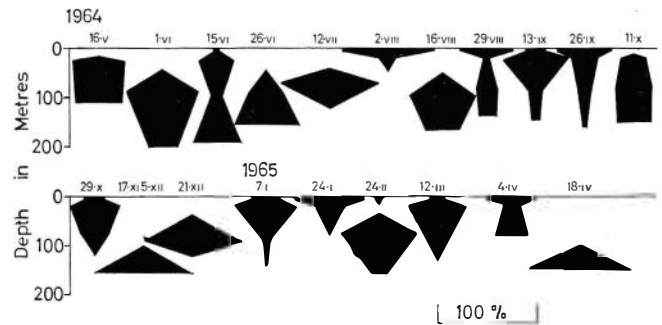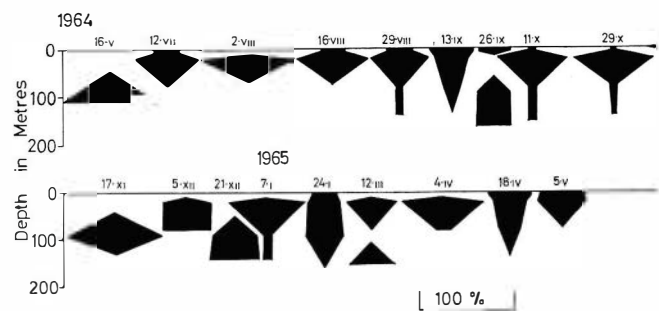

FIG. 58. Distribution of Larvacea with depth. At each of the depths sampled the quantity of Larvacea is expressed as a percentage of the total occurrence

The larvae of this species are similar to the one recorded by Gurney (1924) from 5 miles south-west of Three Kings Islands, New Zealand. The remaining *Munida* young belong to the *Munida subrugosa/gregaria* complex. In the Kaikoura samples zoeae were found from August to November 1964 with a few occurring in July 1964 and January 1965 (Fig. 54). The only catch of post-larvae was in October.

The identity of the zoea larvae is uncertain, it being impossible to distinguish between zoea stages in *M. subrugosa* and *M. gregaria* (Rayner, 1935). Adult *M. gregaria* are distinguished from *M. subrugosa* only by eye-stalk length and maxilliped modifications which tend to disappear once sexual maturity is attained.

Some post-larvae (presumably *M. gregaria*) retain the pelagic habit and in this form often swarm in shallow places and even reach maturity without settling (Chilton, 1909).

Chaetognatha

Chaetognatha sometimes formed up to 43%, but usually a smaller proportion, of the non-copepod zooplankton (Fig. 43).

The most abundant species at "The Permanent Station" was *Sagitta serratodentata* Krohn, 1853, var. *tasmanica* Thomson, 1947, which appeared all year round. *Sagitta gazellae* Ritter-Zahony, 1909 appeared in considerable numbers from November to January

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1965, and a few appeared at other times. *Sagitta gazellae* appeared in water cooler than 11°C (Fig. 26) and when a salinity of 34.65‰ was found above 150m (Fig. 25) indicating a degree of oceanic influence. This information falls within the range of figures from which David (1955) concluded that *S. gazellae* is limited to the north by the Subtropical Convergence. One specimen of another *Sagitta* species was present but because of its damaged condition was not identified.

The greatest numbers of Chaetognatha were found during summer and autumn (Fig. 55). Dakin and Colefax (1940) also found *Sagitta* species "most abundant in late summer and in autumn" off the Australian New South Wales coast.

The greatest concentrations were most often found below 100m, never at the surface (Fig. 56).

Larvacea

Larvacea were not identified to the level of species. Bary (1960) found both *Oikopleura fusiformis* and *O. dioica* off the South Island, so it is probable that these two species, at least, were present.

Up to 48% of the non-copepod zooplankton was larvacean, but on some days the proportion was very small (Fig. 43). They were most abundant in August and September 1964 and March 1965 (Fig. 57), their appearance at the surface being apparently related to their peak mean numbers. At different times they were found in maximum concentration at all depths sampled (Fig. 58).

Pyrosomatidae

Pyrosoma sp. were captured during April, May, June, August, and September 1964, and April 1965; juvenile stages were present on 14 April, 16 May, and 26 September 1964.

The species recorded was probably *Pyrosoma atlanticum* (Peron, 1804). Bary (1960) found *P. atlanticum* in large numbers to the east of Stewart Island in January and February and off Dunedin during March. The only other species recorded off New Zealand was a single specimen of *P. spinosum* from near Kaikoura (Bary 1960).

Salpidae

Salps found at "The Permanent Station" are shown in Table 8. *Ihlea magalhanica* was found in the largest numbers, occurring only in April and May samples. The other three species appeared with the warmer water. Tranter (1962) noticed that salps reached swarm proportions more commonly in the region of the region of the Subtropical Convergence.

TABLE 8. Occurrence of four species of salps at "The Permanent Station" April 1964—May 1965

	Apr	May	Jan	Mar	Apr
Ihlea magalhanica	X	X			X
Salpa thompsoni			X		
Iasis zonaria			X	X	
Thalia democratica			X		

Larval Fish

Larval fish formed a very small proportion of the non-copepod zooplankton, never more than 8% being found (Fig. 43). Largest numbers were found between August and October 1964 (Fig. 59), the period of the phytoplankton bloom (Fig. 34). The maximum concentration was found most often at 22m (Fig. 60). This, and their time of peak abundance, indicates that they were feeding on the phytoplankton and small copepods (Fig. 46).

THE ZOOPLANKTON COMMUNITY

All the planktonic groups, except the predators (Ctenophora and Chaetognatha), tended to have their initial or main increase at the time of the greatest phytoplankton growth in August and September (Fig. 34). The depth distribution of each group was such that the carnivores (Ctenophora and Chaetognatha) had their maximum concentration most often below 100 m, and those grazing mainly on phytoplankton (Copepoda, larval fish, and juvenile Amphipoda) had main concentrations near the surface. The feeding habits of the Euphausiacea (see p.69) caused their maximum concentrations to be always deeper than the Copepoda concentrations.

FIG. 59. Fish larvae per cubic metre (average of the depths sampled) on each sampling day

FIG. 60. Distribution of fish larvae with depth. At each of the depths sampled the quantity of fish larvae is expressed as a percentage of the total occurrence

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No attempt was made to identify every species in the plankton. Nevertheless, since the most common species were identified, it is possible to generalise about the zooplankton population composition.

When the population at "The Permanent Station" from April 1964 to May 1965 is compared with populations recorded in Block Island and Long Island sounds (Riley et al., 1952, 1956) and Delaware Bay (Deevey, 1960), several important differences appear. Deevey recorded Cladocera, many larval forms (crustacean, polychaete, echinoderm and molluscan), medusae, and certain neritic genera of Copepoda (Eurytemora, Temora, Tortanus, Pseudodiaptomus, and the harpacticoid Euterpina acutifrons). In contrast, Cladocera were not found at Kaikoura and very few medusae and larval forms were recorded. None of the copepod genera mentioned above were found at Kaikoura, although Temora turbinata and Euterpina acutifrons have been recorded from the Bay of Islands by Farran (1929). These differences between the zooplankton populations at Kaikoura and the American location are probably due to the American collections being made in enclosed bodies of low-salinity water.

The Kaikoura zooplankton, excluding those that indicate coastal influence, form a community not unlike the Calanus community of the North Atlantic (Table 9). The genera of Copepoda are identical except that Pseudocalanus of the North Atlantic community is replaced by at least two species of Clausocalanus at Kaikoura. Both genera belong to the Pseudocalanidae. The copepod Euchaeta was not important at Kaikoura and Metridia shared equal status with Pleuromamma.

TABLE 9. Comparison of Kaikoura and North Atlantic Calanus zooplankton communities (Raymont, 1963, pp. 336-8)

Kaikoura Zooplankton Community	North Atlantic Calanus Community
Calanus australis	Calanus finmarchicus
Clausocalanus arcuicornis	Pseudocalanus
Clausocalanus sp.	
Metridia lucens	Metridia
Pleuromamma gracilis	
Euchaeta sp.	Euchaeta
Parathemisto sp.	Euthemisto
Euphausia lucens	Thysanoessa spp.
Sagitta serratodentata var. tasmanica (low no. in winter)	Sagitta serratodentata (absent in winter)
COASTAL ADDITIONS	POSSIBLE COASTAL ADDITIONS
Centropages aucklandicus	Centropages typicus
Oithona similis	Oithona similis
Acartia clausi	
Paracalanus parvus	
Nyctiphanes australis	Meganyctiphanes
Pleurobrachia pileus	Ctenophora
	Sagitta elegans

The generalised population at Kaikoura listed in Table 9 was not always fully represented. During the period of greatest oceanic influence it was particularly evident that the dominant species in the community changed. In November and December 1964 and January 1965 Calanus tonsus stage V copepodites became plentiful, completely dominating the community in December. Accompanying C. tonsus in the subsurface water was the chaetognath Sagitta gazellae, and the ctenophore Pleurobrachia pileus was to a considerable degree replaced by P. australis.

COMPARISON WITH OTHER REGIONS

In a number of aspects the Kaikoura "Permanent Station" was similar to other areas.

Nitrate concentrations were generally the same as those over the continental slope off New York (Ketchum et al., 1958) and at a 100m station off Sydney, Australia (Humphrey, 1960). Differences were evident especially in winter when surface nitrate concentration ($7\mu g$ at/L off New York and less than 1 μg at/L off Sydney) did not reach the Kaikoura concentration of $16\mu g$ at/L. The Sydney concentration is explained by the facts that the 100 m station was about $8°$ further north than Kaikoura and the stability of the water column did not break down in winter so that mixing could not take place. Off both New York and Sydney a summer nitrate concentration of $2\mu g$ at/L was not found above 30 m. At Kaikoura during late December 1964 and late January to March 1965 (mid-late summer) this same nitrate concentration was found nearer the surface.

So that the Kaikoura chlorophyll a concentration could be compared with Humphrey's (1960) data the weighted mean concentration, X, above 125m was calculated from:

$$X = \frac{5C_0 + 12.5C_{10} + 20C_{25} + 37.5C_{75} + 25(C_{50}+C_{125})}{125}$$

where C_0, C_{10}, C_{25} . . . are chlorophyll a concentrations at 0, 10, 25 . . . m respectively. The general levels of chlorophyll a were in accord (Fig. 61) at both places. Off Sydney greater stability of the water column, through the shallower depth (100m) and lower latitude, contributed to the earlier manifestation and greater magnitude of the spring phytoplankton bloom. The extended nature of the Kaikoura spring bloom, compared with that at Sydney in 1958, was concurrent with an increase of nitrate in the upper layers during September 1964, accompanying the invasion of oceanic water with its later phytoplankton season.

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TABLE 10. Primary production at Kaikoura compared with values obtained by Ryther and Yentsch (1958)

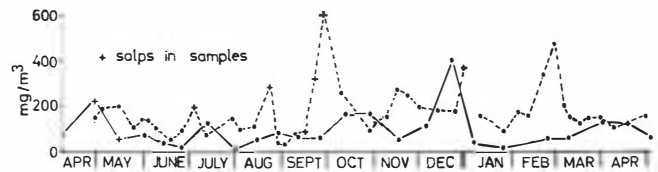|	Total depth (m)	Production gmC/m²/year
Long I. Sound 41°N	25	380
Continental Shelf	25-50	160
	50-1,000	135
	1,000-2,000	100
North Central Sargasso Sea	5,000	78
Kaikoura, N.Z., 42°S	200	157

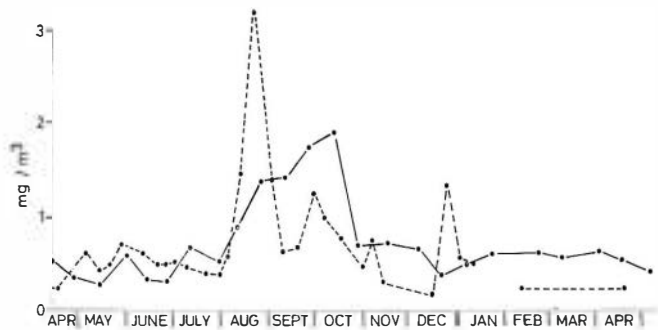FIG. 61. Weighted mean amounts of chlorophyll *a* at "The Permanent Station" (solid line) and Sydney (Humphrey, 1960) (broken line)

FIG. 62. Mean zooplankton biomass at "The Permanent Station" (solid line) 1964-65 and at Port Hacking (Tranter, 1962) (broken line)

"Gross" primary production at Kaikoura 1964-65 covers a range 0.09–1.05 gmC/m²/day (Fig. 36), comparable with Ryther and Yentsch's (1958) values of 0.20–0.85 gmC/m²/day for an inshore station and 0.10–1.10 gmC/m²/day for an offshore location. Even Riley's (1957) values for gross primary production in the central Sargasso Sea of 0.09–0.89 gmC/m²/day have a similar range. Nevertheless total annual production in different regions may be quite dissimilar (Table 10).

The "gross" annual primary production at "The Permanent Station" off Kaikoura (42°S) was little higher than the average value for a comparable position off New York (41°N).

Tranter (1962) studied the zooplankton off Sydney with methods and equipment similar to those used in this study. Tranter's Port Hacking 100m station exhibited biomass quantities comparable with those at Kaikoura 1964-5 (Fig. 62), although the yearly average was twice as high; 151 mg/m³ without salps at Port Hacking and 68 mg/m³ at Kaikoura.

Several generalisations may be made concerning zooplankton productivity with respect to locality. Coastal areas are generally more productive than adjacent oceanic areas. Between November and April Tranter (1962) found a biomass of 25-50 mg/m³ adjacent to the south-east coast of Australia, and further offshore a biomass of less than 25mg/m³. The waters of low latitudes are less productive than those of higher latitudes (Raymont, 1963, Ch. 14). Ponamereva and Lubni, and Bogorov and Vinogradov (*in* Tranter, 1962) give values of 0-50 mg/m³ for the north and south oceanic subtropical zones compared with 1,000 mg/m³ for polar regions. Warm-water plankton also exhibits very little seasonal fluctuation compared with temperate region plankton (Raymont, 1963, Ch. 14), and winter quantities may be often greater than those observed in higher latitudes (Tranter, 1962).

Although subtropical water influence at Kaikoura was marginal, the yearly average biomass of 68 mg/m³ agrees more nearly with the values for subtropical oceanic areas than with those for southern waters. The winter biomass greater than 100 mg/m³ and the low concentration from November 1964 to February 1965 are explained when they are considered to have been contained in subtropical water. The Port Hacking station, although shallow and thus exhibiting a higher yearly average biomass than the Kaikoura station, was also subject to periodic invasions of warm water (Humphrey, 1960). Tranter (1962) considered lack of environmental stability was responsible for the rapid fluctuations in copepod numbers and zooplankton biomass.

The organic composition of the Kaikoura plankton falls within previously described limits (Fig. 41). Riley *et al*. (1949) described a range of values of % (organic matter/wet weight) from 3% in summer Sargasso Sea populations to 15-25% for well fed temperate-water zooplankton. It is significant that the two maxima (in late September and late December to early January) were concurrent with the spring bloom and the swarming of oil-bearing *Calanus tonsus* respectively.

Changes in the plankton at any one place may be brought about in several ways.

In temperate regions there may be a distinct seasonal cycle which includes a winter minimum and a spring maximum rate of increase. Many types of seasonal cycle have been described that depend to a great extent on geographical position. Colebrook and Robinson (1960) found that shallow waters supported a phytoplankton season of longer duration than offshore waters. In a similar environment off New York, Ryther and Yentsch (1968) found that the yearly total productivity was greater in water shallower than 50m than in offshore areas deeper than 100m. They also found the peak in production occurred a month earlier at a depth of 100-200m than in offshore regions deeper than 1,000m.

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SEASONAL, SUCCESSIVE, AND ADVECTIVE CHANGES IN THE PLANKTON

The zooplankton maximum nearly always follows the phytoplankton maximum (Colebrook and Robinson, 1960; Heinrich, 1962), since the vernal increase is almost entirely due to an increase in the mainly herbivorous Copepoda (Deevey, 1960; Harvey *et al.* 1935). Even in neritic waters the Copepoda form a greater part of the spring increase than do the temporary plankton. Amongst the herbivorous Copepoda, Heinrich (1962) defined three types of life history, all depending on the spring phytoplankton bloom:

(1) Species that cannot begin breeding before the vernal development of phytoplankton (*Calanus finmarchicus, Paracalanus parvus,* and *Acartia clausi*).

(2) Species in which breeding may occur in and out of the period of phytoplankton growth (*Calanus plumchrus*). However the maximum biomass of *C. plumchrus* occurs at the surface in the spring when copepodite stage V begins to dominate. Adult females of this species have reduced masticatory edges of the mandibles and are presumed not to feed but to subsist on fat stored in their bodies. They live at depths greater than 200m.

(3) Species that reproduce all year round (*Oithona similis* and *Acartia longiremis*). The size of their broods is greatly affected by the supply of phytoplankton.

In contrast to temperate regions, tropical oceanic areas show only slight, if any, seasonal change, and there is little delay between the phytoplankton and zooplankton maxima (Heinrich, 1962).

"Succession" often occurs within the seasonal cycle. Some species reproduce rapidly in optimal conditions and even dominate a community, then condition the environment so that it becomes unfavourable for their growth but very suitable for the multiplication of some other species (Lucas, 1955). The Kaikoura "Permanent Station" was situated in an area influenced by the north-flowing Canterbury Current. Drift cards released at Timaru (Garner, 1961; p. 36) were recovered in the vicinity of Wellington after varying times that indicated rates of drift from 5 to 15 km per day, assuming the shortest course between points. In view of the distance (70-210km) a body of water could have moved in a fortnight from the Kaikoura "Permanent Station", it is assumed that temporal successional sequences were not observed. But it is clear that various time sequences within the individual stages of spatial succession taking place in the water body moving past "The Permanent Station" were sampled. The appropriateness of the sampling interval to the timing of events in a succession is not known.

By far the greatest changes in the plankton may be brought about by advective processes. These are large-scale movements of water, induced by ocean currents or by vertical movements (upwelling or sinking of water masses), which bring with them their dissolved and suspended matter. As well as the long-shore movement of the Canterbury Current, the Kaikoura region is influenced by invasions of oceanic water of subtropical origin (Garner, 1961), probably from the East Cape Current. Vertical water movements are known to occur along the shelf edge of the north-east part of the South Island (Garner, 1961). Whether the advection of external water masses masked seasonal changes in the plankton is discussed below.

Although the animals sampled were not in one population, a series of planktonic events were recorded which may indicate the situation over a large part of the east coast of New Zealand, since, especially in summer, the east coast environment is relatively uniform.

WINTER MINIMUM

Minimal quantities of both phytoplankton and zooplankton were found at "The Permanent Station" during the winter months of June and July 1964. From comparisons made with other temperate regions (Deevey, 1960; Heinrich, 1962; Colebrook and Robinson, 1960), a winter minimum is to be expected in a temperate region seasonal cycle. The winter minimum is formed by water column instability and the influence of minimal surface radiation. At Kaikoura the winter minimum in the phytoplankton is one of the few seasonally controlled events in the plankton calendar.

The principal environmental factors that control the seasonal growth of phytoplankton in temperate and high latitudes at the beginning of the spring are increasing light and length of day (Raymont, 1963). Nevertheless, it is unlikely that surface radiation was the main limiting factor in the start of the spring phytoplankton bloom at Kaikoura, the lowest mean surface radiation (0.09 g cal/cm²/min on 12 July) being three times larger than the critical value 0.03 g cal/cm²/min given by Ryther (1963) for plant production. Riley (1942) stated that the beginning of the spring increase in the rate of phytoplankton multiplication is roughly proportional to the reciprocal of the depth of turbulence. As the mixing processes at Kaikoura were carrying much of the phytoplankton out of the euphotic zone (Fig. 35) from July to October, the degree of stability in the water column must have been important in determining the extent of the phytoplankton minimum in winter and when the phytoplankton bloom would begin.

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The winter minimum in phytoplankton biomass at Kaikoura and the initiation of the spring bloom were the only events that could be said to follow a seasonal cycle, the phytoplankton at the beginning of 1965 not being limited by any of the factors measured. Nutrients, as indicated by nitrate content, were richer then than in September 1964, when the largest quantities of phytoplankton were found.

Winter minima did occur in the zooplankton, but in such a way as to make it impossible to predict for any other year.

In July, between days when the two smallest biomasses were recorded, a biomass was noted that exceeded many of the standing crops recorded in spring and summer.

Fig. 63. Mean zooplankton biomass and chlorophyll a

Fluctuations in Zooplankton Abundance

Several indications of the dependence of zooplankton on phytoplankton at Kaikoura were obtained. It was obvious that the drop in chlorophyll a concentration observed at the end of December was associated with tremendous numbers ($4,425/m^3$) of *Calanus tonsus*. More subtle and interesting associations were brought to light in a study of several Kaikoura copepod species in 1964-65 (Deevey, 1966), which showed that the length measurement of each species was correlated significantly with the phytoplankton cycle. Thus *Centropages aucklandicus, Acartia clausi,* and *Paracalanus parvus* were longer in spring than in the rest of the year. *Calanus australis* and *Clausocalanus arcuicornis* followed the same pattern of size except that they were much longer in summer than was expected from the chlorophyll a data. The observed influx of larger specimens of these last two species were supposed by Deevey to have been contained in particularly strong invasions of subtropical oceanic waters.

Only the two neritic species *Acartia clausi* and *Centropages arcuicornis* had sizes related to the temperature cycle as well as to the phytoplankton cycle.

The dependence of Copepoda, the major group in the plankton, on the phytoplankton during the breeding season was demonstrated by the occurrence of large numbers in late spring (September and October) (Fig. 45). The organic matter content of the zooplankton (excluding Euphausiacea and salps) expressed as a percentage of the dry weight also showed a maximum during spring which continued until mid summer (December) (Fig. 39), indicating the growth of animals during the summer when the food supply was good.

Contrary to the evidence of a constant relationship of the most plentiful Copepoda in the Kaikoura region to the phytoplankton, the zooplankton biomass did not follow the cyclic pattern shown by other workers. The interruption of the winter minimum by a biomass value of over $100 \ mg/m^3$ (Fig. 63) in mid July was only one instance of frequent fluctuations over the remainder of the year. There were great fluctuations not only in the biomass but also in the numbers of Copepoda which are 90% of the total zooplankton population. At Port Hacking, Tranter (1962) observed similar fluctuations and associated them with an unstable environment where warm surface water occasionally invaded the region (Humphrey, 1960), as at Kaikoura. An overall effect of these fluctuations was the reduction of the average biomass to $68 \ mg/m^3$ at Kaikoura, comparable to the values of $0.50 \ mg/m^3$ recorded for oceanic subtropical regions (Tranter, 1962).
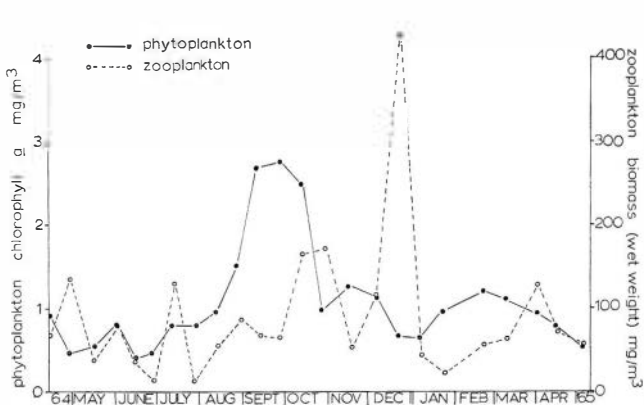
The gross progression of events in the zooplankton from April 1964 to May 1965 was not related to the seasons. Minima did occur in winter and an isolated maximum was observed in December, but the whole form of the zooplankton pattern of events was due to movements of oceanic water into the region. During October the biomass observed (Fig. 63) was capable of forming a spring zooplankton peak dependent on the phytoplankton bloom, had not the whole water column become more oceanic and the zooplankton community dominated by *Calanus tonsus,* which later caused the summer maximum biomass.

Events Associated with the Invasion of Oceanic Waters

During this study there were indications that oceanic water with its contained fauna was invading the region.

The number of oceanic species of Copepoda captured during the year (Table 2) fluctuated from a minimum at the end of August, when the water column showed the strongest coastal characteristics, to a maximum at the end of January, when oceanic influence was strong. This water was both oceanic and subtropical in origin. The organic matter content of the Euphausiacea expressed as a percentage of the wet weight was sometimes reduced, as in lower latitudes off Japan (Riley and Gorgy, 1948) and Australia (Thompson, 1942) as well as the three occasions

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(April to May, and June 1964, and January to April 1965) when the % (organic matter/wet weight) was below 10%. These were nearly all instances when subtropical water was influencing "The Permanent Station".

Of the characteristics of the phytoplankton population noted at Kaikoura, only the vertical distribution of chlorophyll *a* maxima indicated oceanic influence. From the end of December to the beginning of January a vertical maximum concentration of chlorophyll *a* occurred, which could be correlated with the transparency conditions. For the remainder of the period sampled (early January to April 1965) the chlorophyll *a* maxima were deeper than would have been expected from the observed sea-water transparency.

Quantities of zooplankton found in offshore subtropical waters are generally less than in inshore waters, but in winter the levels of zooplankton abundance in subtropical regions are often greater than in colder regions (Tranter, 1962). Some of the zooplankton biomass fluctuations, the winter biomass greater than 100 mg/m³ in July and the low zooplankton concentrations from November 1964 to February 1965, may be explained by the fact that subtropical oceanic populations were introduced into the Kaikoura region.

The rapid changes in numbers of Copepoda were expected as this group is numerically always the greatest constituent of the plankton. Fluctuations in copepod numbers could not be correlated with the changes in zooplankton biomass; the small copepods *Acartia* and *Oithona*, when plentiful, did not contribute much to the biomass whereas *Calanus tonsus* contributed little to the numbers but greatly to the biomass. The biomass was not always reduced in summer when oceanic influence was great. On one occasion, late December 1964, the biomass reached a maximum for the year, entirely due to the presence and characteristics of the copepod *C. tonsus*. This wide-spread species is particularly characteristic of the subantarctic epiplankton (Vervoort, 1957), although its stage V copepodites aggregate in nearshore waters (Bary, 1951).

On the average, the total zooplankton biomass was reduced to a quantity not out of keeping with the levels described (Tranter, 1962) for subtropical oceanic regions.

As discussed previously, the offshore phytoplankton season begins later than that over the shelf (Ryther and Yentsch, 1958), so the increase in surface nitrate at Kaikoura during September and the extended phytoplankton bloom is attributed to the invasion of oceanic water at that time.

EVENTS ASSOCIATED WITH VERTICAL WATER MOVEMENT

Hydrological data collected during 1964-65 at Kaikoura showed that vertical mixing in the water column, other than the mixing in winter, had taken place once during the year. At the end of December (mid summer) the nitrate content of the surface layers was increased by the mixing of nitrate-rich water from lower levels.

This instance of upwelling does not appear related to events in the phytoplankton, although an increased concentration of chlorophyll *a* was found from January 1965 onwards (Fig. 34), which never managed to deplete the surface nitrate (Fig. 32) to the level found in October and November 1964. The higher nitrate concentration suggests there could have been a greater quantity of phytoplankton, but some additional factor prevented increased plant production. A comparable situation was found off the south-west coast of Africa, with supposedly recently upwelled water which contained little phytoplankton (Steeman Nielsen and Aabye Jensen, 1957). Andersen and Banse (1961) considered this situation and concluded that the difficulty of seeding cool water, the physical effects of dilution of the initial population by newly upwelled water, and vertical instability were significant components of the problem.* It is possible that a similar situation existed at Kaikoura with the added complication of surface invasions of subtropical oceanic water.

DISTINCTIVENESS OF THE EVENTS OBSERVED AT KAIKOURA 1964-65

Shoals of kahawai (*Arripis trutta*) disappeared almost completely from the Kaikoura region from the beginning of January to the end of March 1965. The disappearance of adult *Nyctiphanes australis* from the Kaikoura plankton collections at the same time (Fig. 50) and a study of the gut contents of the fish demonstrated the dependence of the kahawai on the Euphausiacea for food. The situation recorded during 1964-65 appears to have been unusual as far as the kahawai are concerned, according to local fishermen, and it was certainly different from the previous year when Stonehouse (1965) recorded shoals of fish off Kaikoura all through summer. As kahawai are reliant on the plankton for food and the fish were scarce one year but abundant the next, there is some indication that a major change in zooplankton quantities occurred from 1963 to 1964-65, and that no two consecutive years will necessarily be alike.

It is clear that the most important hydrological phenomenon influencing the area of "The Permanent Station" 1964-65 was the invasion of subtropical oceanic water. In general these invasions accompanied an overall reduction in plankton biomass, but the adventitious incursion in September of high nitrate water, in which the phytoplankton season was probably behind that of coastal waters, resulted in an extended phytoplankton season at Kaikoura. Assuming that the same

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*More recently Tranter and Newell (1963) have shown that iron can be a limiting factor in organic production in areas of upwelling.

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type of water movements (northward flow of the Canterbury Current, inshore invasions of oceanic water, and upwelling of subsurface water) occur every year at Kaikoura, a particular magnitude and timing of the water movements must be optimal to plankton growth to explain the "good" plankton and fish years.

Even though the events recorded at Kaikoura are different when compared with the previous year, they are possibly not unusual geographically because part of the east coast of New Zealand is under the influence of the north-flowing Southland and Canterbury Currents, which are flanked by the southward flow of warmer subtropical water at least as far south as Banks Peninsula.

SUMMARY

The Subtropical Convergence Region nature of the Kaikoura, New Zealand, "Permanent Station" from April 1964 to May 1965 is demonstrated. Surface dilution by river water occurred in winter but waned in summer.

The dominant water movement modifying the environment during 1964-1965 was the invasion of subtropical oceanic water.

Winter mixing produced high nitrate concentrations: 17.9 μg at/L and 34.5 μg at/L were recorded at 0m and 200m respectively in the middle of June.

Upwelling and subsequent nitrate enrichment of the surface layers were recorded in late December 1964.

The phytoplankton had a "gross" annual primary production of 157gmC/m²/year.

The only seasonally controlled events in the plankton calendar were the winter phytoplankton minimum and the initiation of the late-winter phytoplankton bloom.

The invasions of oceanic subtropical water masked most seasonal changes, and they are considered responsible for:

> The extension of the phytoplankton bloom in spring through the September introduction of nitrate-rich water, the phytoplankton season being later in offshore waters compared with coastal waters.

> Chlorophyll a maxima at depths that would have been expected from more transparent offshore waters.

> The low average total zooplankton biomass of 68 mg/m³.

> The rapid fluctuations in zooplankton biomass and copepod numbers.

> Increases in the number of oceanic copepod species captured.

> The capture of euphausids with reduced fat reserves.

> Upwelling at the end of December (mid summer), although increasing nitrate concentrations in the surface layers did not enhance plankton production.

Copepods dominated the zooplankton population, forming 87-99% of the total numbers. Euphausids were the next most numerically abundant group, forming over 50% of the non-copepod zooplankton on half the sampling days.

The quantity of plankton found at Kaikoura probably varies considerably from year to year and must depend primarily on the degree of subtropical oceanic water influence.

ACKNOWLEDGMENTS

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APPENDIX

FIELD DATA

Salinity, temperature, density, chlorophyll *a* concentration, and nitrate concentration at "The Permanent Station", 1964-65

DATE	Sal. °/oo	Temp. °C	σ_t g/L	Ca mg/m³	NO_2-NO_3 ug at/L	Depth m
14 Apr	34.43	14.3	25.70	1.21	6.4*	0
	34.49	13.6	25.89	1.50	5.8*	10
	34.63	13.0	26.13	0.57	13.8*	25
	34.63	12.3	26.27	0.28	15.9*	50
	34.67	12.0	26.33	0.47	19.1*	75
	34.76	11.8	26.46	0.20	14.8*	100
30 Apr	34.63	13.3	27.07	0.61	14.8*	0
	34.74	13.3	26.15	0.46	17.5*	25
	34.79	12.9	26.27	0.42	17.5*	50
	34.76	12.8	26.26	0.39	19.0*	100
	34.78				22.3*	200
16 May	34.29	12.6	25.94	0.87	12.7*	0
	34.29	12.6	25.94	0.49	12.2*	10
	34.54	12.9	26.08	0.38	12.7*	25
	34.65	12.9	26.16	0.38	13.2*	50
	34.63	13.1	26.11	0.39	12.2*	75
	34.83	13.1	26.26	0.42	13.2*	125
	34.76			0.19	14.8*	200
1 Jun	34.33	11.2	26.23	1.05	13.0*	0
	34.51	11.5	26.32	0.83	10.6*	10
	34.52	11.3	26.37	0.77	11.6*	25
	34.56	11.1	26.43	0.51	19.3*	50
	34.56	11.0	26.45	0.45	22.8*	75
	34.56	10.8	26.49	0.51	19.3*	125
	34.60			0.26	20.7*	200
15 Jun	34.56	10.5	26.54	0.42	17.9*	0
	34.58	10.5	26.56	0.44	16.5*	10
	34.61	10.5	26.59	0.35	17.9*	25
	34.61	10.5	26.59	0.42	17.9*	50
	34.67	10.5	26.63	0.36	15.2*	75
	34.63	10.3	26.63	0.19	29.0*	125
	34.61			0.26	34.5*	200
26 Jun	34.38	11.0	26.32	0.47	13.3	0
	34.52	11.6	26.31	0.50	12.0	10
	34.61	12.2	26.27	0.44	13.3	25
	34.87	12.6	26.39	0.37	15.5	50
	34.72	12.5	26.29	0.26	18.3	75
	34.69	10.7	26.42	0.13	19.7	125
	34.61			0.17	26.8	200
12 Jul	34.20	9.2	26.48	1.28	13.2	0
	34.43	9.9	26.55	0.53	11.7	10
	34.52	10.2	26.56	0.61	13.0	25
	34.58	10.2	26.61	0.68	11.7	50
	34.56	10.2	26.59	0.65	11.7	75
	34.61	10.2	26.62	0.75	13.0	125
	34.63			0.80	15.6	200
2 Aug	33.84	9.0	26.23	0.95	6.0	0
	34.49	10.2	26.53	1.15	9.1	10
	34.69	10.4	26.65	0.61	12.2	25
	34.67	10.5	26.63	0.47	11.0	50
	34.69	10.1	26.71	0.44	12.9	75
	34.61	9.7	26.73	0.27	12.9	125

* Unreliable results

DATE	Sal. °/oo	Temp. °C	σ_t g/L	Ca mg/m³	NO_2-NO_3 ug at/L	Depth m
2 Aug	34.58			0.62	14.1	200
16 Aug	34.18	9.4	26.44	0.82	4.8	0
	34.33	9.8	26.48	1.11	2.7	10
	34.40	9.8	26.54	0.94	2.7	25
	34.45	9.9	26.56	0.98	2.5	50
	34.54	10.6	26.51	0.87	3.7	75
	34.60	10.6	26.55	0.66	4.3	125
	34.72			0.41	9.2	200
29 Aug	34.07	9.1	26.40	1.72	2.0	0
	34.36	9.2	26.40	1.21	3.3	75
	34.40	9.2	26.63	1.21	3.4	125
	34.47			0.93	6.0	200
13 Sep	34.07	9.9	26.27	3.18	0.6	0
	34.25	9.8	26.42	4.45	2.2	10
	34.38	9.8	26.53	2.11	3.5	25
	34.54	9.8	26.65	0.97	6.2	50
	34.63	10.0	26.69	0.47	6.6	75
	34.63	10.0	26.69	0.66	7.1	125
	34.63			0.29	10.0	200
26 Sep	34.29	11.1	26.22	1.88	0.3	0
	34.54	11.1	26.42	3.98	0.3	10
	34.56	10.9	26.47	3.62	0.5	25
	34.87	11.7	26.56	1.49	6.6	50
	34.76	10.9	26.61	0.99	8.7	75
	34.67	10.9	26.56	0.40	9.3	125
	34.65			0.37	9.9	200
11 Oct	34.23	10.9	26.22	2.66	0.3	0
	34.25	10.7	26.26	3.06	0.5	10
	34.34	10.6	26.36	2.44	0.6	25
	34.34	10.5	26.38	1.89	0.8	50
	34.38	10.4	26.42	2.08	0.8	75
	34.63	9.8	26.72	0.47	8.1	125
	34.65			0.29	10.2	200
29 Oct	34.25	13.0	25.83	1.17	0.5	0
	34.47	11.9	26.22	1.51	0.9	10
	34.51	11.6	26.30	0.77	0.5	25
	34.61	11.1	26.48	0.45	2.4	50
	34.65	11.1	26.50	0.71	2.4	75
	34.67	10.6	26.61	0.36	6.0	125
	34.69			0.22	9.2	200
17 Nov	34.52	13.0	26.04	1.13	0.1	0
	34.52	12.9	26.06	1.69	0.1	10
	34.58	12.7	26.15	1.71	0.1	25
	34.72	11.4	26.50	0.52	2.8	50
	34.63	11.1	26.49	0.24	3.8	75
	34.69	10.6	26.62	0.26	6.9	125
	34.69			0.23	8.9	200
5 Dec	34.56	13.9	25.88	1.32	0.5	0
	34.61	12.8	26.16	0.95	0.2	10
	34.67	12.2	26.31	1.53	0.6	25
	34.69	11.5	26.46	0.62	1.7	50
	34.69	10.8	26.58	0.36	5.8	75
	34.67	10.5	26.63	0.19	8.8	125
	34.70			0.27	9.7	200

	°/oo	°C	g/L	mg/m³	µg at/L	m
21 Dec	34.51	15.6	25.48	1.06	0.2	0
	34.56	11.7	26.32	0.84	3.1	10
	34.58	11.5	26.38	0.52	3.8	25
	34.60	10.9	26.50	0.24	5.0	50
	34.67	10.8	26.57	0.17	7.4	75
	34.67	10.7	26.59	0.33	7.5	125
	34.69			0.52	7.3	200
7 Jan	34.54	17.9	24.97	0.29	0.1	0
	34.54	16.0	25.42	0.91	0.1	10
	34.58	15.0	25.67	0.66	1.1	25
	34.67	12.4	26.27	0.69	5.0	50
	34.69	12.0	26.36	0.43	5.1	75
	34.67	11.1	26.52	0.13	11.1	125
	34.67			0.13	12.9	200
24 Jan	34.63	16.0	25.48	0.94	1.1	0
	34.61	15.7	25.54	0.98	1.3	10
	34.63	13.9	25.94	1.15	2.5	25
	34.63	12.8	26.17	0.77	5.9	50
	34.69	11.1	26.53	0.32	11.4	75
	34.69	10.8	26.58	0.25	12.7	125
	34.70			0.26	12.2	200
24 Feb	34.34	16.4	25.17	1.32	0.8	0
	34.40	15.3	25.46	1.85	1.2	10
	34.49	14.6	25.68	1.14	2.5	25
	34.58	13.7	25.94	0.49	2.9	50
	34.63	12.6	26.21	0.19	9.6	75
	34.69	11.7	26.42	0.27	13.0	125
	34.65			0.17	13.3	200
12 Mar	34.11	15.9	25.11	1.82	1.1	0
	34.16	15.7	25.19	1.17	2.5	10
	34.33	14.8	25.56	0.91	4.0	25
	34.43	14.3	25.70	0.51	5.4	50
	34.45	13.9	25.80	0.26	5.9	75
	34.49	12.9	26.03	0.27	10.5	125
	34.65			0.18	15.3	200
4 Apr	34.40	14.4	25.66	0.78	0.2	0
	34.42	14.3	25.68	0.70	0.2	10
	34.43	13.9	25.79	1.62	0.2	25
	34.45	12.6	26.06	0.63	11.7	50
	34.47	12.2	26.16	0.35	11.7	75
	34.52	11.3	26.37	0.26	13.5	125
	34.52			0.15	15.6	200
18 Apr	33.26	14.8	24.65	0.55	1.3	0
	34.27	14.4	25.54	0.58	3.8	10
	34.34	13.9	25.70	1.39	2.3	25
	34.43	12.8	26.01	0.65	9.3	50
	34.47	12.1	26.18	0.18	11.8	75
	34.49	11.7	26.26	0.21	13.5	125
	34.52			0.17	13.8	200
5 May	34.02	13.1	25.64	0.50	2.8	0
	34.09	13.1	25.68	0.58	3.1	10
	34.11	13.0	25.72	0.55	6.6	25
	34.42	12.8	25.99	0.36	9.3	50
	34.42	12.7	26.01	0.35	8.0	75
	34.42	12.5	26.05	0.38	9.0	125
	34.49			0.35	10.4	200

Surface radiation, Secchi Disc readings, and "gross" primary production, 1964-65

	Surface Radiation g cal/cm²/day	"Gross" Production g C/m²/day	Secchi Disc Readings m
14 Apr	209	0.25	–
30 Apr	231	0.10	–
16 May	183	0.15	–
1 Jun	174	0.22	–
15 Jun	156	0.10	–
26 Jun	070	0.09	–
12 Jul	049	0.10	–
2 Aug	129	0.24	–
16 Aug	277	0.28	6.0
29 Aug	320	0.48	6.7
13 Sep	247	0.89	5.3
26 Sep	355	0.80	6.3
11 Oct	454	1.05	5.5
29 Oct	625	0.55	4.3
17 Nov	667	0.75	7.0
5 Dec	606	0.65	9.0
21 Dec	561	0.39	6.0
7 Jan	345	0.35	12.0
24 Jan	458	0.49	9.0
24 Feb	221	0.38	5.5
12 Mar	209	0.31	4.0
4 Apr	230	0.61	13.5
18 Apr	230	0.09	5.5
5 May	220	0.09	3.0

Weights of zooplankton in quantitative hauls from 200 m, 1964-65

	Plankton	Wet Wt mg/m³	Dry Wt mg/m³	% Organic Matter Dry Weight
14 Apr	General	55.4	6.68	96.7
	Euphausids	15.9	1.27	64.2
30 Apr	General	132.4	9.98	68.5
	Salps	94.2	9.37	72.3
16 May	General	20.6	2.96	75.4
	Euphausids	14.5	0.43	32.2
	Salps	17.9	0.95	33.3
1 Jun	General	52.1	7.85	72.4
	Euphausids	26.1	4.36	87.5
15 Jun	General	11.9	1.52	56.1
	Euphausids	19.9	2.36	74.8
26 Jun	General	10.9		
12 Jul	General	102.2	7.94	75.8
	Euphausids	26.1	3.68	85.2
2 Aug	General	10.3	1.44	84.2
16 Aug	General	41.3	5.13	82.6
	Euphausids	11.7	1.97	89.5
29 Aug	General	81.5	10.74	83.4
	Euphausids	3.5		
13 Sep	General	64.7	8.65	82.8
26 Sep	General	56.8	9.60	86.2
	Euphausids	5.2		
11 Oct	General	162.5	15.00	83.5
29 Oct	General	167.5	21.98	86.9
17 Nov	General	31.2	4.60	86.2
	Euphausids	17.9	2.44	87.4
5 Dec	General	104.4	14.01	91.6
	Euphausids	9.1	1.06	88.7
21 Dec	General	392.0	67.50	95.8
	Euphausids	11.1	1.30	93.2
7 Jan	General	30.7	5.40	90.0
	Euphausids	10.6	1.68	85.0
24 Jan	General	13.4	2.75	63.0
	Euphausids	5.7	0.62	64.8
	Salps	567.0	28.20	85.4
24 Feb	General	50.0	8.38	84.5
	Euphausids	4.6	0.34	57.9
12 Mar	General	52.6	6.33	79.7
	Euphausids	6.9	0.81	76.1
4 Apr	General	74.8	11.09	85.0
	Euphausids	51.5	3.98	80.7
18 Apr	General	69.5	8.54	82.7
	Salps	38.7	1.78	68.4
5 May	General	44.4	7.31	82.4
	Euphausids	18.2	3.04	83.9

Inset

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