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ZOOPLANKTON OF EAST AUSTRALIAN WATERS

1945 - 1954

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Cronulla, Sydney
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SUMMARY

The zooplankton discussed in this report was collected in New South Wales coastal waters during 1945 to 1954; supplemented by collections made in the Tasman Sea by R.R.S. "Discovery II" in 1950 and F.R.V. "Derwent Hunter" in 1954.

The occurrence of fifty-nine species in the major groups of Copepoda, Cladocera, Acopa, Appendicularia, Mollusca, and Chaetognatha has been considered and the populations in the coastal waters of the area have been classified according to their origin.

The succession of organisms through the year was found to be comparable over the greater part of the coast, but at the northern and southern extremes, the faunal changes throughout the year were found to be not so great and the zooplankton to be more uniform.

Species from the northern coastal area were found to invade New South Wales coastal waters from January to June. From April to September species including deeper sub-Antarctic species, surface sub-tropical species, and tropical species from the surface oceanic waters to the north, appeared from offshore waters. From October to December southern coastal species were found to move north and to invade the more northern areas. These seasonal changes are discussed and the annual variations of the movements of different species are examined. Geographical groups of species have been identified which may, in the future, be associated with water masses circulating in the Tasman Sea and affecting the New South Wales coastal area.

In citing this report, abbreviate as follows:
C.S.I.R.O. Aust. Div. Fish. Oceanogr. Rep. No. 14.

I. INTRODUCTION

Zooplankton has been collected previously in east Australian waters by various visiting expeditions (Dakin & Colefax 1940, pp. 7-14). The reports of these expeditions are concerned mainly with the systematics of the major groups of zooplankton. The geographic distribution and seasonal succession of zooplankton have been discussed by Dakin and Colefax (1933, 1940) who maintained a station off North Head, Sydney, during 1929 and 1931, and by Sheard (1949) from collections made during 1943-46 off Jibbon, Port Hacking. Thompson (1942, 1948) has dealt with the pelagic tunicates of Australia and Thomson (1947) has published an account of the chaetognaths of the south-east Australian area. Sheard and Fairbridge prepared in 1943, but did not publish, an account of some copepods of east Australian waters.

The present report deals with the Division's collections of plankton made during a period of nine years from 1945 to 1954. This is a longer period than any covered by previous workers and in the discussion of various species in Section III(b) reference has been made to the findings published by the workers listed above, where these differ markedly or support strongly, the conclusions of this report.

II. COLLECTION AND HANDLING OF DATA

The zooplankton collections were taken at 50 m, 100 m, and at oceanic stations. Unfortunately sampling during the nine-year period was not always carried out regularly.

The 50 m coastal stations (Fig. 1) were situated from Port Phillip Bay in Victoria to Evans Head in northern New South Wales. Sampling at the Jibbon station was the most regular, usually monthly, sometimes twice monthly, occasionally once every two months, but with gaps from November 1947 to October 1948 and from June 1950 to February 1952, when no hauls were taken. All other coastal stations were occupied monthly, but there are gaps when no hauls were made.

The 100 m stations are beyond the coastal stations at Eden and Ulladulla in 100 m of water. These were occupied occasionally in 1952 - 54. In January 1954, F.R.V. "Derwent Hunter" occupied stations on the continental slope at Nobby's Head, Norah Head, and Barrenjoey Head. (C.S.I.R.O. Aust. 1954. DH8-9/54 and DH11-19/45).

Hauls were made at ocean stations by R.R.S. "Discovery" in October 1950, on a line east from Green Cape (N.S.W.) to a point, 153°04'E, in the Tasman Sea, and by F.R.V. "Derwent Hunter" in February and November 1945 at stations in the Tasman Sea (Fig. 1).

Discovery N70 nets were used for hauls except those taken by R.R.S. "Discovery" in 1950 when a Discovery type N100 net was used. Before 1952 nets were hauled horizontally at the surface for 15 minutes, and from 1952 duplicate vertical hauls were also made at 50 m stations. Originally, at the deeper offshore stations, the vertical hauls were taken with a closing net similar to that described by Kemp and Hardy (1929). Due to loss of catch as discussed by Barnes (1949) and Wiborg (1954), the methods used for vertical hauls in this survey were changed in 1954 and all hauls were taken from particular depths to the surface not using a closing net.

Inefficient sampling by N70 nets has been discussed by Gardner (1931) and Winsor and Walford (1936). The non-random distribution of plankton has been noted and discussed by Winsor and Clarke (1940), Baldi, Cavalli and Perocchi (1945), and Barnes and Marshall (1951). However, despite these disadvantages, it was found during this survey that the quantitative and qualitative sampling were comparable from station to station at any one time and from week to week, and the relative content of the catches was consistent.

Most of the hauls at coastal stations were taken during daylight hours. Stations in the Tasman Sea were occasionally worked at night.

Hauls were received at the laboratory preserved in 5-10 per cent. formalin. Larger and less common organisms were recorded. If the haul was small, as was usual with vertical hauls, particularly those from a great depth, the organisms in each group were counted. Usually a tenth though occasionally a hundredth of the larger horizontal hauls was examined (Kott 1953). Count trays (Russell and Colman 1931) were used to count individuals. Each species of Cladocera, Acopa, Mollusca, and Appendicularia was counted; each individual species of Copepoda was not counted separately but the group as a whole was counted and the numerical relationships of species were noted. During the earlier years of the survey the volume of each haul was measured by the displacement method (Sheard 1947). This was later discarded in favour of counts since the varying size of organisms prevented volume giving any real indication of the quantities of zooplankton present.

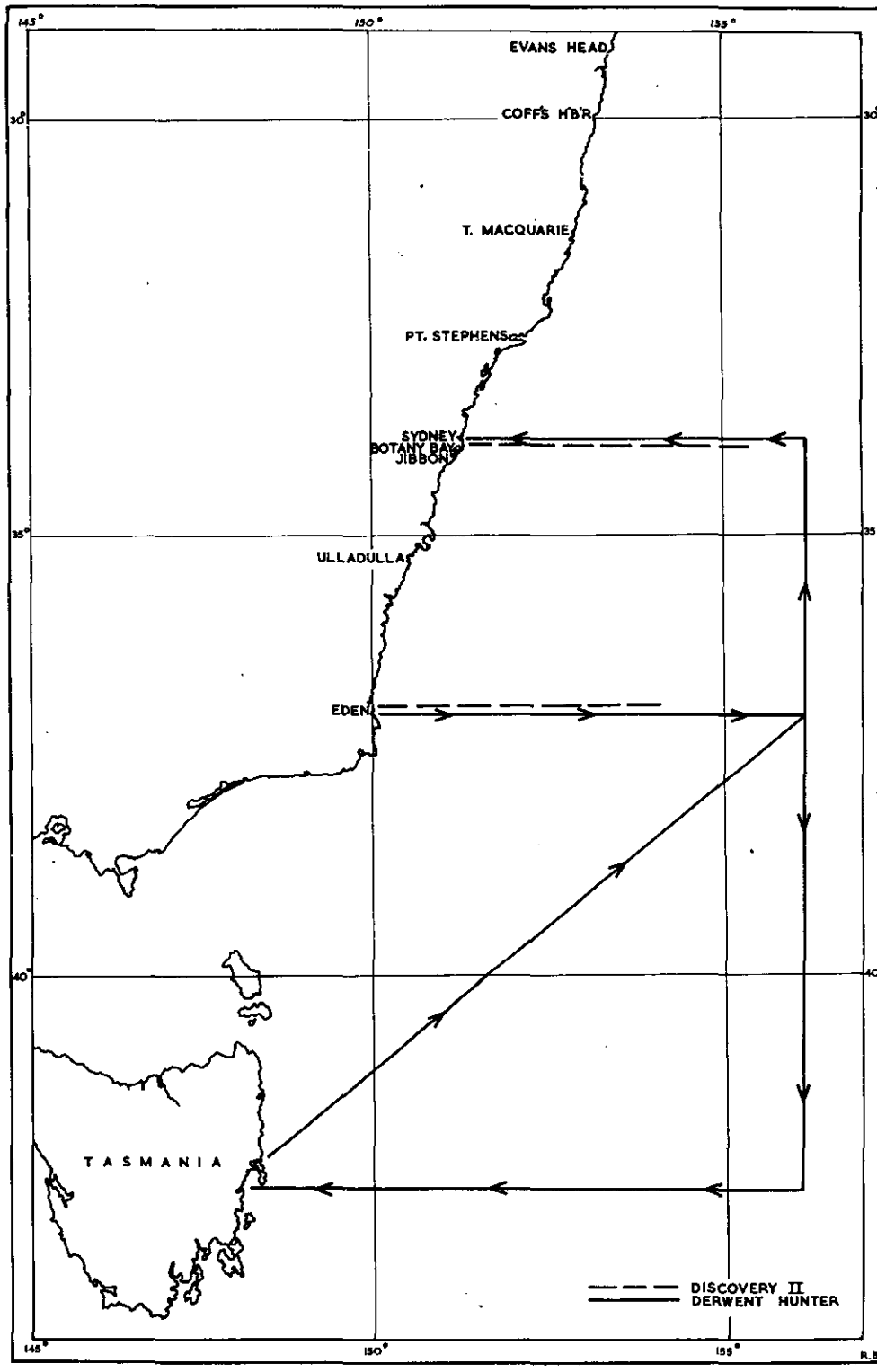


Fig. 1. Map showing coastal stations, direction of Tasman Sea Cruise by F.R.V. "Derwent Hunter," and R.R.S. Discovery II.

Some of the data used in this survey are available in Oceanographical Station List 19 (C.S.I.R.O. 1954). Detailed information, particularly on the copepod populations and on comparable numbers of all species, is from the unpublished records of this Laboratory.

III. RESULTS

(a) List of Species

The species dealt with in the survey are listed below.

COPEPODA

(Dakin and Colefax 1940; Brady 1883; Farran 1929; Farran 1936; Scott 1909; Seymour Sewell 1932)

Calanidae

Calanoides carinatus (Lubbock), Calanus finmarchicus (Gunner), Nannocalanus minor (Claus), Undinula darwinii (Lubbock), Undinula vulgaris (Dana).

Metridiidae

Pleuromamma abdominalis (Lubbock), Pleuromamma gracilis (Claus).

Centropagidae

Centropages bradyi Wheeler, Centropages furcatus (Dana), Centropages kroyeri Giesbrecht, Centropages orsinii Giesbrecht.

Temoridae

Temora discaudata Giesbrecht, Temora turbinata (Dana).

Lucicutiidae

Lucicutia flavicornis (Claus).

Scolecithricidae

Scolecithrix danae (Lubbock).

Aetideidae

Aetideus sp.

Eucalanidae

Eucalanus crassus Giesbrecht, Rhincalanus nasutus Giesbrecht.

Paracalanidae

Paracalanus aculeatus Giesbrecht, Paracalanus parvus (Claus).

Pseudocalanidae

Clausocalanus arcuicornis Dana.

Euchaetidae

Euchaeta spp., Paraeuchaeta sp.

Pontellidae

Pontella securifer Brady.

Labidoceridae

Labidocera cervi Kramer.

Acartiidae

Acartia clausei Giesbrecht, Tortanus barbatus (Brady).

Candacidae

Calanopia elliptica (Dana), Candacia bipinnata (Giesbrecht), Candacia pectinnata Brady ?

Sapphirinidae

Sapphirina spp. Large numbers of Oithona spp., Oncoea spp., and Copilia spp. were also present in the hauls from time to time but variations in their occurrence have not been taken into account during this survey.

CLADOCERA

(Dakin and Colefax 1940)

Evadne nordmanni Loven, Evadne spinifera Muller, Evadne tergestina Claus, Penilia schmackeri Richard, Podon polyphemoides Leuck.

MOLLUSCA

(Dakin and Colefax 1940)

Creseis acicula Rang, Creseis virgula Esch, Firoloida desmaresti Vayssiere.

TUNICATA

(Thompson 1948)

Acopa

Doliolum denticulatum Q & G, Doliolum gegenbauri Uljanin, Iasis zonaria Pallas, Ihlea magalhanica Apstein, Pyrosoma atlanticum Peron, Salpa fusiformis Cuvier, Thalia democratica Forskal.

Appendicularia

Fritillaria borealis Lohmann, Fritillaria megachile Fol, Fritillaria formica Fol, Fritillaria haplostomata Fol, Fritillaria pellucida Busch, Oikopleura fusiformis Fol, Oikopleura longicauda Vogt, Oikopleura rufescens Fol, Tectillaria fertilis Lohmann, Kowalewskaia tenuis Fol, Stegasoma magnum Langerhans.

CHAETOGNATHA

(Thomson 1947)

Occasionally the following species were identified in the collections.

Krohnita pacifica (Aida), Pterosagitta draco (Krohn).

(b) Local Occurrences of Species

In the following accounts species are divided into groups according to the area in which they flourished throughout the year. Under the headings of these geographic areas the major taxonomic groups are set out and within these the species are arranged according to their relative numerical importance. Here "northern coastal" is defined as the area north of Port Stephens, "southern coastal" as the area south of Eden, the area between these two is considered as a transition area, and the

"offshore area" as that from which deep vertical hauls of 100 m or more were taken.

(i) The Northern Coastal Area.- The main stations where hauls were taken in this area are at Evans Head, Coff's Harbour, Port Macquarie, and Port Stephens. Many of the species collected at these stations have a wide distribution in the tropical and temperate waters of both hemispheres.

1. Temora turbinata.- This species was found in 1945-54 to be the most numerous at Port Stephens and stations to the north where it was the dominant copepod during the greater part of the year. At Jibbon, in the transition area, the species gradually increased from November to March and persisted in large numbers until the appearance of the salp swarm in July and August. This species was less numerous at Ulladulla and at Eden occurred rarely and then only in small numbers from January to May. In August 1952 T. turbinata was taken at the Eden 100 m station with other northern coastal species, but these were not taken at the Eden 50 m station.

Temora turbinata is thus one of the most important copepods in the coastal waters off Jibbon and to the north. Its occurrence may be taken to indicate the presence of waters of the northern coastal area. The large numbers of this species at the Eden 100 m station in August 1952 suggest that the northward moving southern coastal waters caused the northern coastal waters to be deflected away from the coast in their southern limits.

2. Undinula darwinii 3. Undinula vulgaris.-

These two species occurred together in this area and decreased in number from north to south exactly as Temora turbinata, though this latter species far exceeded the numbers of Undinula spp. The species were found to flourish throughout the year from Port Stephens to the north and to occur further south in the coastal plankton only for a limited period. U. vulgaris was the more common of the two species as also reported by Dakin and Colefax (1940). The latter authors found U. darwinii a rare component of the plankton hauls during the late winter months. However during the present investigation neither of these two species could be described as rare. They may be used with T. turbinata as indicators of northern coastal waters.

4. Centropages furcatus.- This species was usually taken at Jibbon station from February to May. However, in 1945 when Calanus finmarchicus persisted in coastal waters until March, C. furcatus did not occur until May, in a copepod population of Undinula spp. and Temora turbinata. In 1946, 1950, and 1953 this species did not occur in the plankton from Jibbon station and in 1949 it did not occur until August. There were, however, in 1949 irregularities in the zooplankton, which may have been related to the absence of the usual huge swarm of Thalia democratica, resulting in the persistence in the area of species which would otherwise have been excluded. It was never a plentiful species, but it occurred consistently from November to July to the north of Port Stephens in the coastal area. It extended south to Ulladulla in April in company with other northern coastal species. It did not occur at offshore or Tasman Sea stations and only once, in April 1953, at Eden. It is not regarded as an ideal indicator species because its numbers in the plankton were too few to ensure its regular collection, and its absence from any haul could not be regarded as significant.

5. Eucalanus crassus.- This species was plentiful throughout the year at the more northerly stations and appeared at the Jibbon station with Temora turbinata and Undinula spp. during April to June and sometimes persisted until October. Juvenile specimens were particularly common. This species was present off Ulladulla and Eden. It was taken offshore usually in surface hauls. It was most numerous in the plankton of the northern coastal region but it occurred frequently with other northern species when they invaded southern coastal areas. When it was not with other northern species its presence might indicate an invasion of offshore plankton into coastal regions.

6. Centropages orsinii.- This species was taken regularly at Jibbon station in March and April. In 1950 it was present from January to April. At stations in the northern coastal area it was taken in large quantities in June 1954. It occurred at Ulladulla from March to April but was present at Eden only in November 1953. Its occurrence during the years under review appeared to be spasmodic and discontinuous, and at no time were the numbers high.

7. Evadne tergestina (Fig. 2).- This species appeared at Jibbon station usually during October, and gradually increased to a maximum in January to April and eventually disappeared by June. In 1949 when there was no salp swarm it appeared in August. At Port Stephens it appeared during the same months except in 1953 when it occurred throughout the year. Further north it appeared to persist

throughout the year but never in such great numbers as at Jibbon station. Its distribution at southern stations appeared similar to that of Temora turbinata. This species was particularly characteristic of Jibbon plankton, where numbers increased gradually and did not occur suddenly in high numbers as did most of the species which invaded from another area.

8. Penilia schmackeri (Fig. 3).- This species, after E. tergestina, was the most common cladoceran in the coastal plankton. At Jibbon station it appeared usually in March or April and disappeared in June although in 1949 and 1953 it made an isolated appearance later in the year as did Evadne tergestina. It was usually present in association with Fritillaria pellucida. Dakin and Colefax (1940) recorded it throughout the year, breeding in April and May, and in highest numbers in the summer months. This species occurred in equally high numbers from Evans Head to Ulladulla at the same time of the year but at Eden the numbers were much reduced. It was not found in Bass Strait nor off the east coast of Tasmania and very rarely offshore. Although the species appeared later and flourished further to the south, it behaved in a similar manner to E. tergestina.

9. Evadne spinifera (Fig. 2).- This species occurred in coastal waters north of Eden. It behaved like Evadne tergestina although its maximum numbers occurred further to the north. At Jibbon station it was present in considerable numbers during December and persisted until the following June, though in much reduced numbers. Dakin and Colefax (1940) found this species present throughout the year with highest numbers in January and its lowest in the winter. At Port Stephens and Port Macquarie it occurred during the same months as at Jibbon although in 1953 it appeared at Port Stephens in September. At Coff's Harbour it was very much more plentiful and exceeded the numbers of E. tergestina. It was a rare component of the plankton at Ulladulla and Eden.

10. Cressis acicula.- This species behaved as Evadne tergestina but was more persistent through most of the year at Jibbon station and to the north, but decreased in the south. Cressis virgula also occurred but was not so common.

11. Thalia democratica (Fig. 5).- This was the most important salp in the area and appeared in large numbers usually twice a year in February or March until May and again in July or August until November and it did not always

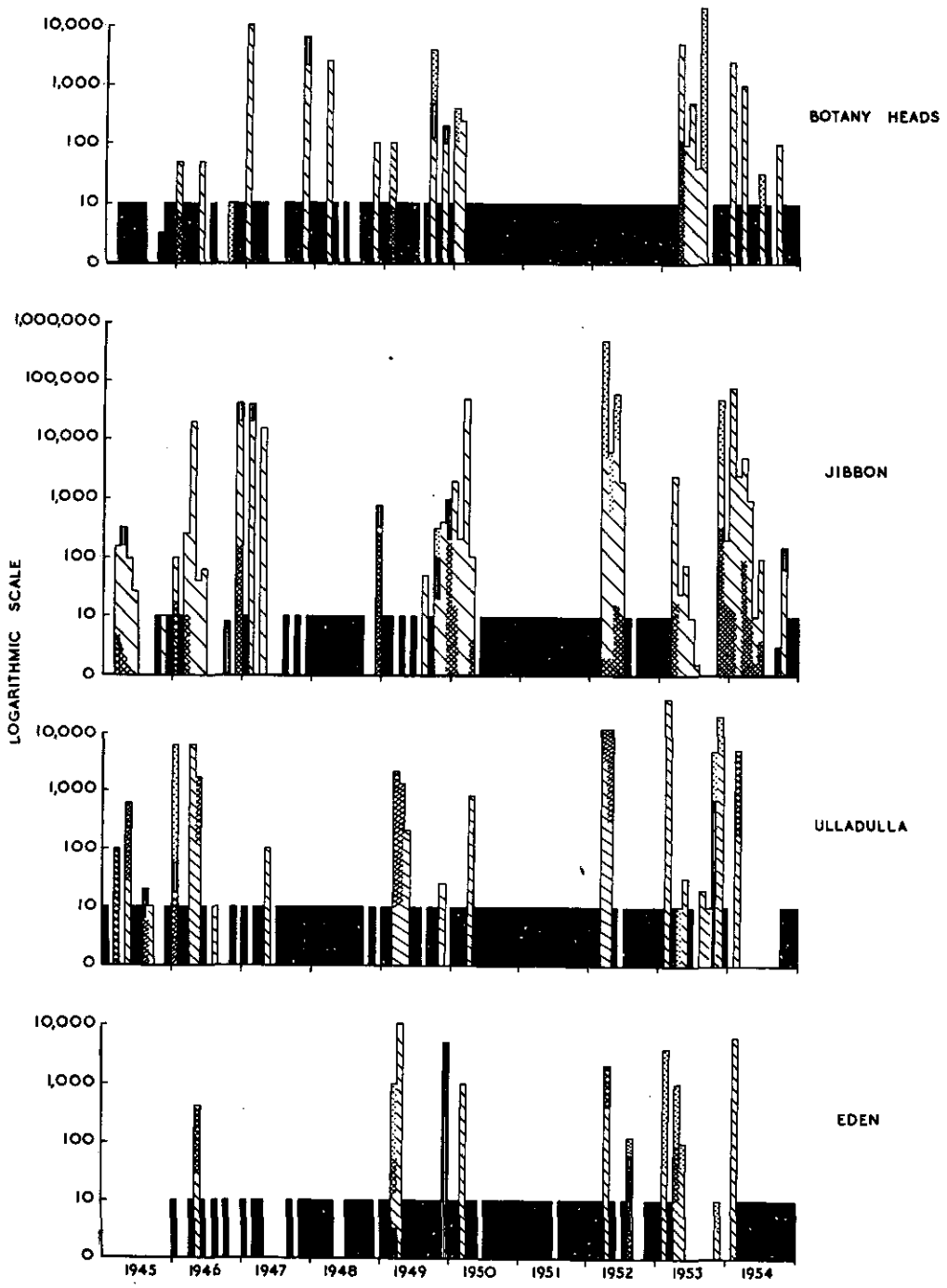


Fig. 2. Numbers of Evadne spp. and Podon polyphemoides from 15 minutes, horizontal, N70 hauls.

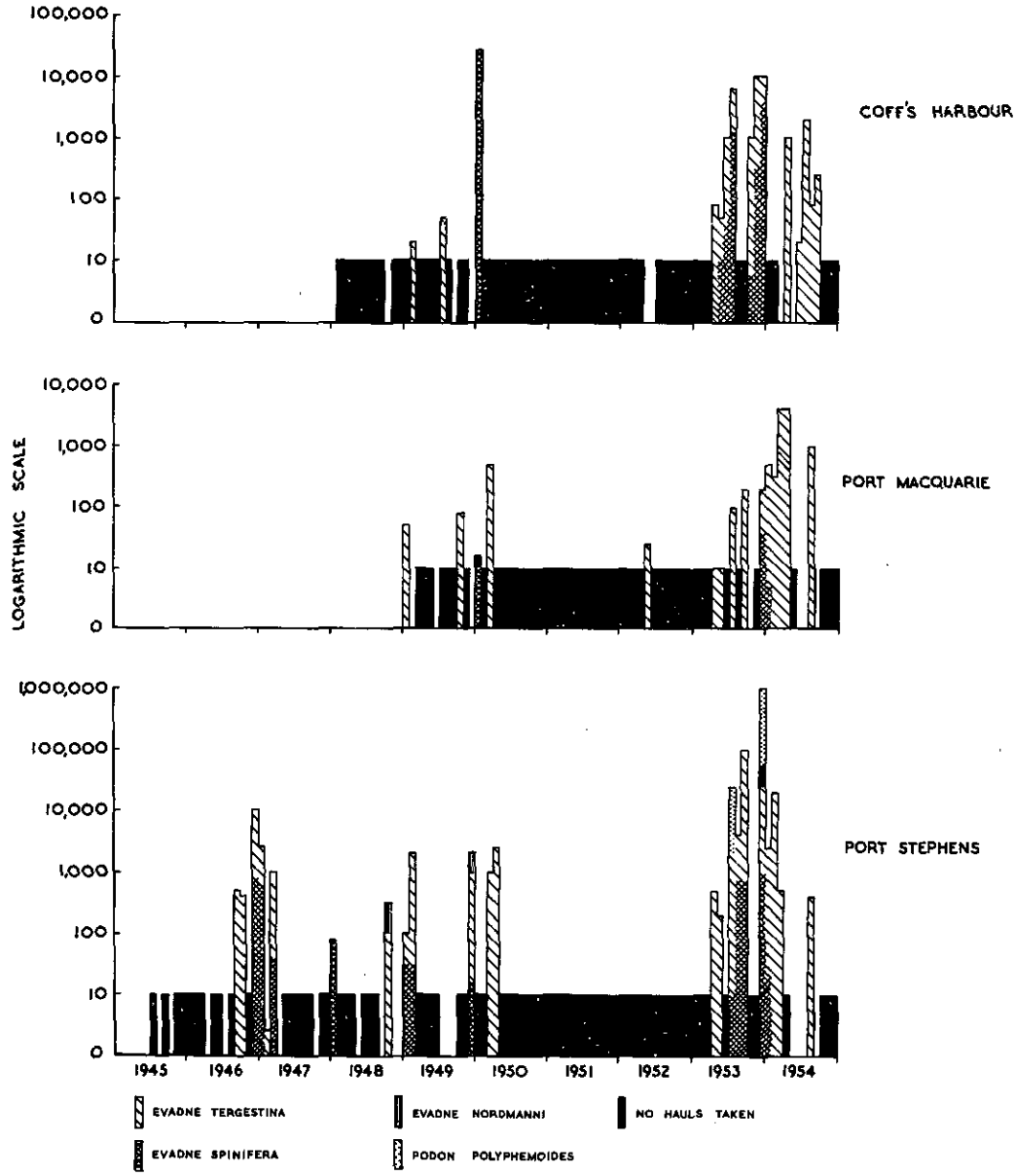


Fig. 2. Numbers of Evadne spp. and Podon polyphemoides from 15 minutes, horizontal, N70 hauls.

disappear between these maxima. In 1949 there was no major swarming of Thalia democratica and at Jibbon station the species was taken only twice in very small numbers in March and in August coinciding with the time of the usual swarm. In 1952 there was only a very small summer swarm and in 1953 and 1954 the summer swarm was missed and the species appeared earlier and gradually rose to the huge numbers of the winter swarm. Dakin and Colefax (1940) recorded huge numbers present in October and November and suggested that these numbers persist through until the following summer.

At stations to the north and south of Jibbon this species was found in similar numbers in the same months except at Eden and Coff's Harbour which were the two extremes of the area sampled, and there numbers were smaller, possibly due to insufficient sampling. The species, after its appearance in the surface, gradually spread into the deeper coastal waters. It occurred in large numbers in offshore surface waters but very rarely in deeper offshore hauls. Russell and Colman (1935) detected a secondary outburst of this species in April and May in the Great Barrier Reef area, indicating that Coff's Harbour is by no means the northern limit of the coastal distribution of this species.

It is suggested that the appearance in coastal waters of such huge numbers of this species was due to an invasion from offshore waters. When this species was swarming it was associated with Sapphirina sp. and very little else, suggesting the exclusion of all other zooplankton. In 1949 when the swarms of the species did not appear, species from the northern coastal area persisted longer in the Jibbon area and the species from the south appeared earlier. This was probably not the effect of the absence of salps but of the absence of the water carrying the salps. Although there was evidence that this species originated from offshore waters, its density achieved extremely high levels in the onshore shelf area.

12. Oikopleura longicanda

13. Oikopleura fusiformis

14. Oikopleura rufescens

These species were common in these waters, both coastal and oceanic, over the greater part of the year. Thompson (1948) has discussed their distribution.

15. Fritillaria pellucida (Fig. 4).- This species was present at the Jibbon station usually during April - June. Sheard (1949) took it from April to June in 1944 but during 1943 it was present from time to time during the year. Thompson (1948) found it especially off the extreme southern corner of New South Wales, particularly from January to May, and again in September. From this evidence it is clear that the species occurred along the whole coastal area concerned in this survey. For part of the year, during August and November, it was present only in deeper hauls. This may indicate a particular diurnal migratory habit of the species so that it was absent from the surface when hauls were taken, or that this species with other forms was pushed into the deeper layers when surface offshore waters bearing the salps flowed into the area.

(ii) The Southern Coastal Area.- The species characteristic of this area are found generally in the colder waters of the world. It is only in this group that there are Antarctic species.

1. Acartia clausii.- This species was one of the most common copepod species. At Jibbon and stations to the north numbers increased from October to March and were consideraly reduced during April - June with the advent of many other copepod species. This occurrence agrees with Dakin and Colefax (1933, 1940) who indicated two maxima, one in October - November and another, to a lesser extent, in January, both of which might have been parts of the same swarm. In May 1945 the species was completely absent from the Jibbon hauls. In July with the appearance of swarms of Thalia democratica, A. clausii, together with most other species of the zooplankton, usually disappeared completely. In 1949, when the salp swarms were absent from coastal waters, Acartia persisted throughout the year, though in reduced numbers from April to October (C.S.I.R.O. 1945 p. 22, 35, 42).

At Port Stephens and Port Macquarie the April - June decrease in numbers sometimes commenced earlier but more often there was a complete disappearance of the species during those months. At Coff's Harbour the species was never present in the large numbers which occurred further south.

To the south of Jibbon at Ulladulla and Eden stations the species persisted in large numbers throughout the year and always as one of the dominant species of copepod.

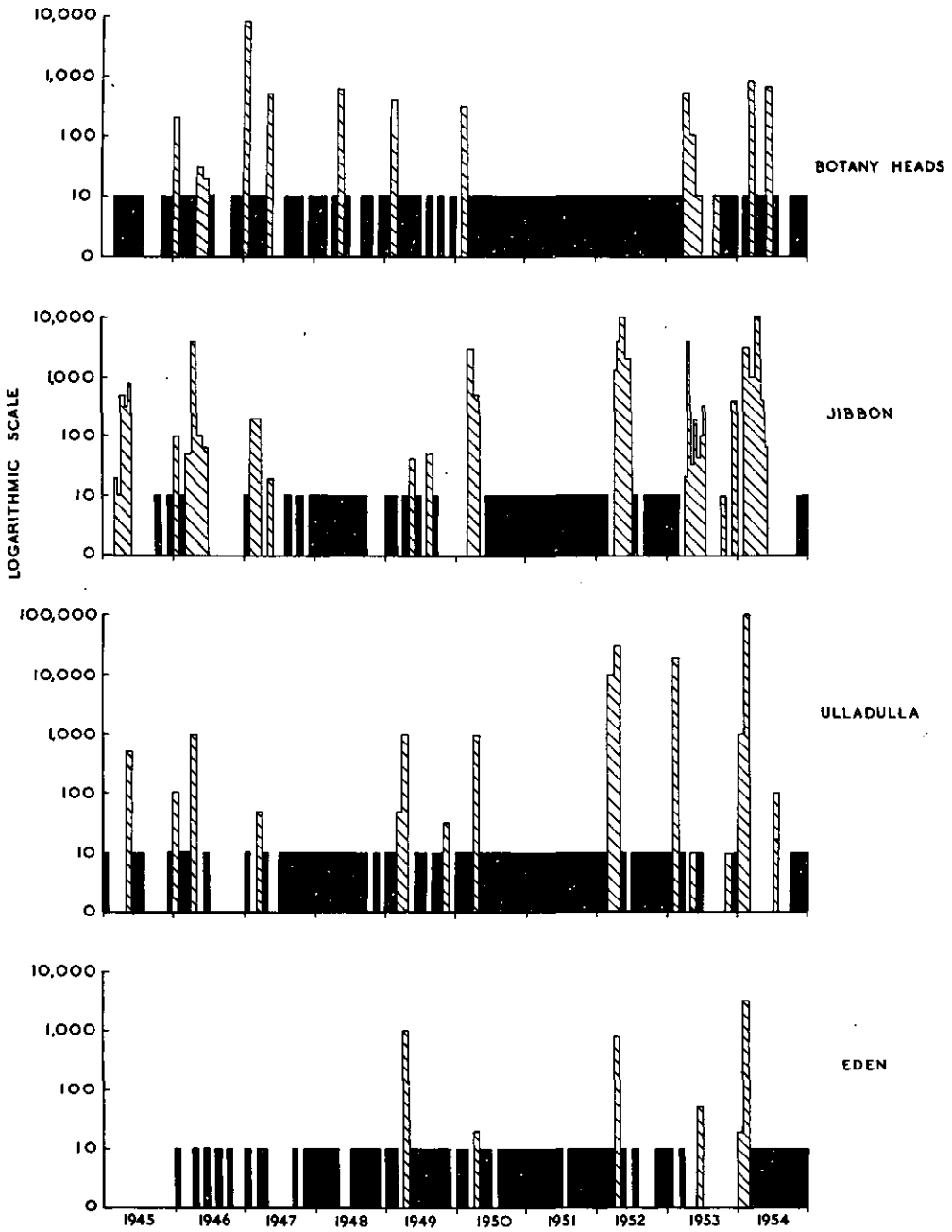
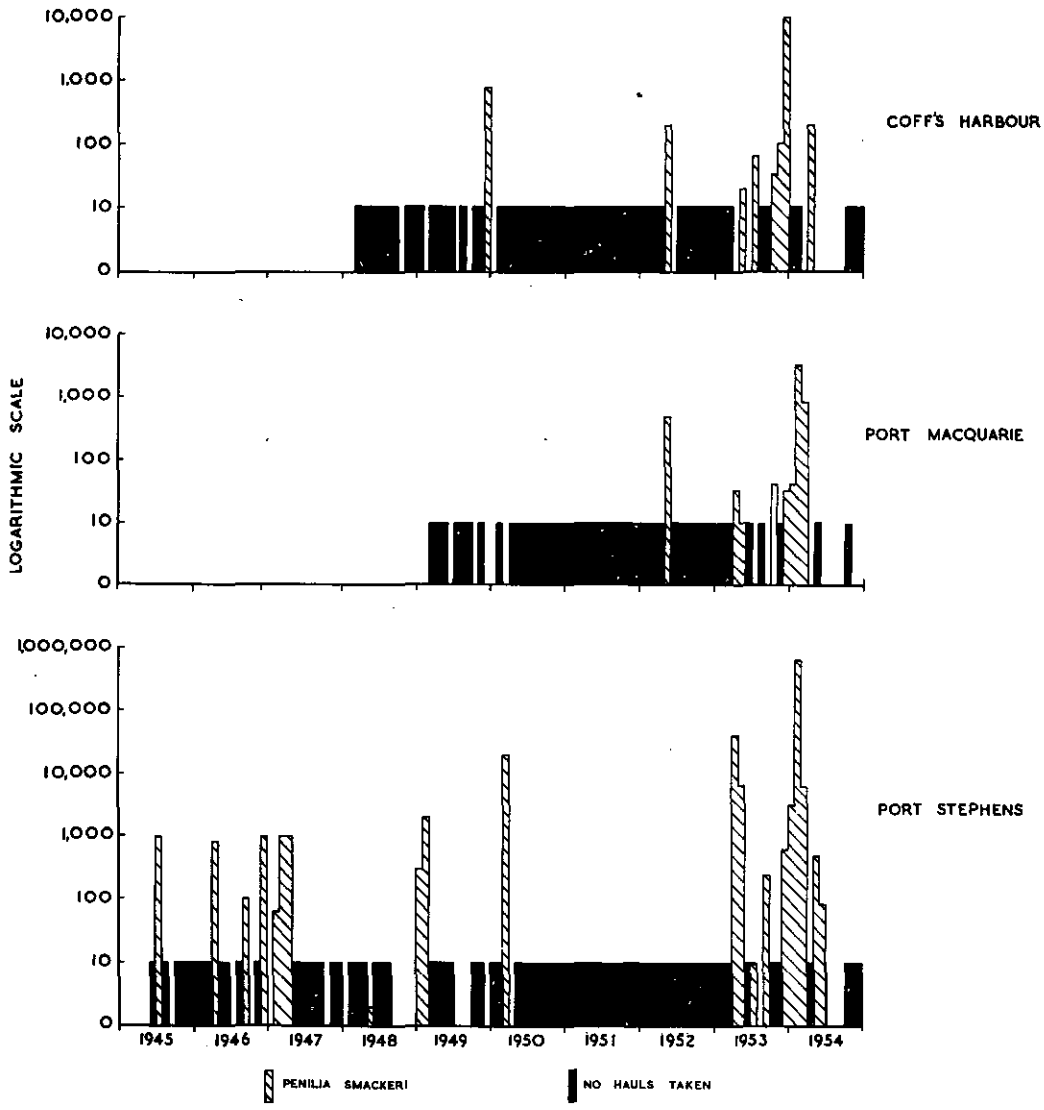


Fig. 3. Numbers of Penilia schmackeri from 15 minutes, horizontal, N70 hauls.



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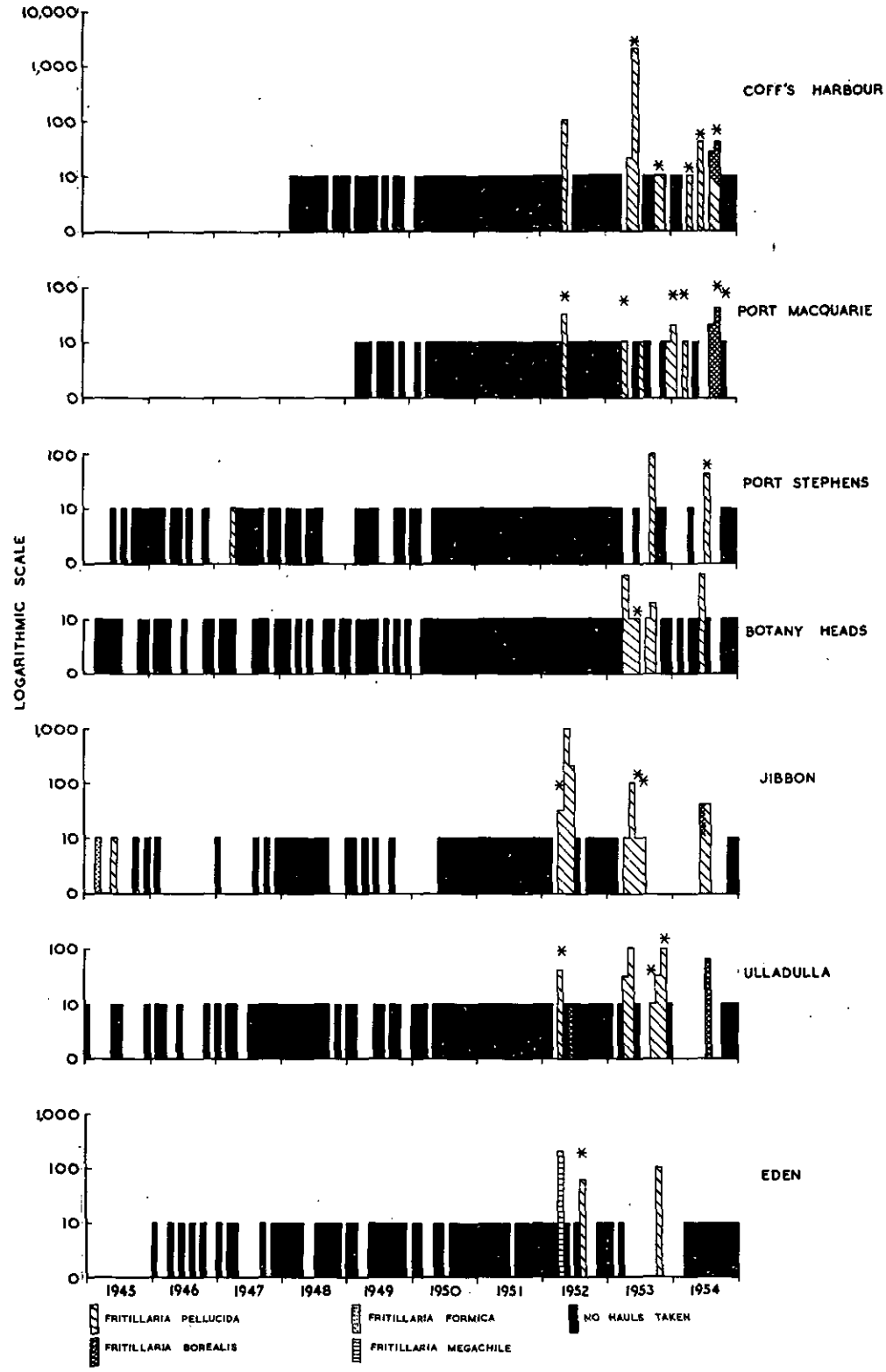

Fig. 4. Numbers of Fritillaria spp. from N70 hauls. (15 minute horizontal hauls, except where *indicates species in deeper vertical haul).

Collections in Bass Strait in March 1954 showed A. clausii in the coastal waters off the Victorian coast and extending south into the centre of Bass Strait. Offshore collections indicated that the species occurred in appreciable numbers only in the coastal "shelf" area. This species may be regarded as a coastal form with its main centre of abundance south of Jibbon, flourishing from October to March between Ulladulla and Port Stephens, and for a longer period at Ulladulla and Eden. Dominance of this species is thus indicative of southern coastal waters.

2. Paracalanus aculeatus and Paracalanus parvus.-

These two species were common in these waters. They were usually present throughout the year at all stations on the coast but plentiful in the Bass Strait and at Eden and Ulladulla, in association with Calanus finmarchicus, Acartia clausii, and Clausocalanus arcuicornis. They were especially plentiful from November to March and numbers increased further and persisted longer in the south and decreased in numbers in the northern coastal area. Their dominance may be regarded as indicative of southern coastal waters.

3. Calanoides carinatus.- This species was observed to arrive in coastal waters from Eden to Evans Head during October and to persist in decreasing numbers until December and rarely into January. It was most rich at the southern stations and became progressively less so in the north. Dakin and Colefax (1933, 1940) record this species as "rare except for one big catch in September. It is however the most common copepod in the stomach of the fish Apogonops caught in October off Newcastle." This September catch was probably part of the October invasion noted above. The species was absent at Jibbon and all stations north in 1945 and 1947. It was present in the slope and deeper oceanic waters off the New South Wales coast during January 1954 but did not appear at any of the Tasman Sea stations in February 1954 but was taken at most of the Tasman Sea stations at the surface in November 1954.

Despite the fact that this species was usually present at the coastal stations in association with Calanus finmarchicus it is not regarded, as is that species, as an indicator of waters from the southern coastal areas because it was not taken in the Bass Strait except during October to January. It occurred at stations further north than did C. finmarchicus and its wider oceanic distribution suggests that its introduction into the area must have been due to some wider oceanic influence over the whole region.

4. Calanus finmarchicus.- This species was recorded at Tasmanian coastal stations in the Bass Strait and in Victorian coastal waters throughout the year. It was not taken at any of the offshore stations in the Tasman Sea, nor at the 100 m stations off the New South Wales coast. At the Eden 50 m station it was present in fair numbers for most of the year. It occurred in the plankton from Ulladulla and Jibbon stations from October to December at the same time as Calanoides carinatus. C. finmarchicus was taken rarely and in smaller numbers at northern stations. This species is regarded as characteristic of coastal waters off Eden in Bass Strait and off the Tasmanian coast and may therefore be used as an indicator of southern coastal waters.

5. Centropages kroyeri.- This was a common component of the plankton in southern coastal waters. It was never present in very great numbers and seemed to occupy the same relationship to Acartia clausii and Paracalanus spp. in the south as did Centropages furcatus to Temora turbinata and Undinula spp. in the north. It was never taken at Coff's Harbour, Port Macquarie, or Evans Head stations, occurred rarely at Port Stephens except in August 1953 with a strong occurrence of Calanus finmarchicus and Calanoides carinatus. At Jibbon station it was present in March 1945, during the late persistence there of Calanus finmarchicus, and in January and February 1947, January 1950, April 1953, and September 1954. At this station its appearances were limited to periods when Acartia and Paracalanus were present and at a time when species characteristic of the northern coastal area were at a minimum. At Ulladulla it was regularly present from October to January and at Eden over most of the year. It was present along the north coast of Tasmania and down the east Tasmanian coast in March 1954 with Calanus finmarchicus and Salpa fusiformis. It was not taken in Tasman Sea hauls. This species cannot be considered as dependable an indicator as Calanus finmarchicus because it was not as conspicuous and it occurred in much smaller numbers in the plankton.

6. Centropages bradyi.- From Bass Strait area to the most northerly station in this survey, this species occurred spasmodically and in small numbers throughout the year. It was usually present from March to July but it also occurred from August to January after the salp swarm. It was sampled from the Tasman Sea at some stations in November 1954 and it was taken in large numbers at both the east and west ends of the Bass Strait in March 1954. The distribution appeared to be fairly general in both coastal and

oceanic waters, although the March to July occurrences did come at a time when there were species from offshore regions in the coastal waters. Data on this species were too limited for its use as an indicator of any particular water mass.

7. Labidocera cervi.- In association with Calanus finmarchicus, Centropages kroyeri, and large numbers of Acartia clausii and Paracalanus spp., Labidocera cervi was particularly plentiful in Bass Strait and in Victoria and Tasmanian coastal waters. It also occurred from time to time throughout the year in the New South Wales coastal area. It is possible that the specimens of this species present in the Bass Strait and off the Victorian and Tasmanian coasts may have been distinct from the form found at Jibbon station and off North Head, Sydney, by Dakin and Colefax (1940).

8. Tortanus barbatus.- This species was found at Port Phillip Heads and Eden stations in fair numbers in May and June, but rarely extended further north.

9. Evadne nordmanni (Fig. 2).- This species was comparatively rare in the plankton at Jibbon station where it usually occurred in October to December in association with large numbers of Evadne spinifera and Evadne tergestina. In 1945 it was still present in March and it persisted until February in 1946. Sheard (1949) working on plankton hauls from Jibbon Station found this species during June to August in 1943 - 1944. During the years of the present survey (1945-54) the occurrence of this very rare species did not vary greatly except in the duration of its stay in the area.

At Port Stephens it appeared in the hauls only during November and in small numbers. It was recorded once from Port Macquarie and never from stations further north. Off Ulladulla it seemed to appear earlier and to persist for longer (September to March). At Eden it was present in very much greater numbers. In December 1949 it was the only cladoceran in the plankton off Eden. It was not taken in the Tasman Sea off the continental slope of the New South Wales coast but was common off the east coast of Tasmania and in Bass Strait. However it was found to be the dominant cladoceran in the waters of Lake Macquarie, some miles north of Jibbon station (Kott 1955).

The distribution of this species was the same as that noted for Centropages kroyeri and Calanus finmarchicus. Unfortunately this species is not easily identified and it is therefore not ideal as an indicator species. It is

superficially like Evadne tergestina which is distributed in northern coastal waters. In association with other species, however, it is useful since it arrived at Jibbon station at the same time as other species which it is suggested are autochthonous, belonging to the southern coastal area all the year.

10. Podon polyphemoides (Fig. 2).- This species was found to be more plentiful in the estuaries than at coastal stations (Kott 1955). Sheard (1949) recorded it at regular intervals during the year with Penilia schmackeri. His records of its occurrence at Jibbon from March to June in 1943-44 may have been due to a contamination from the Port Hacking estuary. Its occurrence was spasmodic but it was most plentiful at Ulladulla and Eden in February and March, but it was also taken in October.

11. Iasis zonaria.- This species was taken in hauls from the east coast of Tasmania. Thompson (1948) recorded the species most commonly between Sydney and the southern tip of Tasmania with maximum numbers in August to December. This is the period during which other southern waters species invade the New South Wales coast.

12. Ihlea magalhanica (Fig. 5).- This species was recorded by Thompson (1948) as particularly intolerant of warmer waters and its distribution is circumpolar. He found it in the upper 50 m in south east Australian waters. In this survey it appeared off Jibbon in May 1953 and was present in large numbers at Ulladulla and Eden in September with Salpa fusiformis and Pyrosoma atlanticum. It was present in the Bass Strait in March 1954 and off the east coast of Tasmania in February 1954. It is the counterpart in southern offshore waters of Thalia democratica in the north.

(iii) The Offshore Area.- Certain of the species from the offshore area have a wide distribution in the tropical and temperate waters of the world; a group of species from the deep offshore waters is of sub-Antarctic origin.

1. Nannocalanus minor occurred particularly in April to June at most southern stations from Jibbon to Ulladulla. It was also generally distributed in the offshore Tasmanian region and in the Tasman Sea. This species appeared to bear the same relationship to the southern coastal area as did Eucalanus crassus in the north. This latter species however invaded the onshore waters to the north of Jibbon when there was a general movement of these waters to the

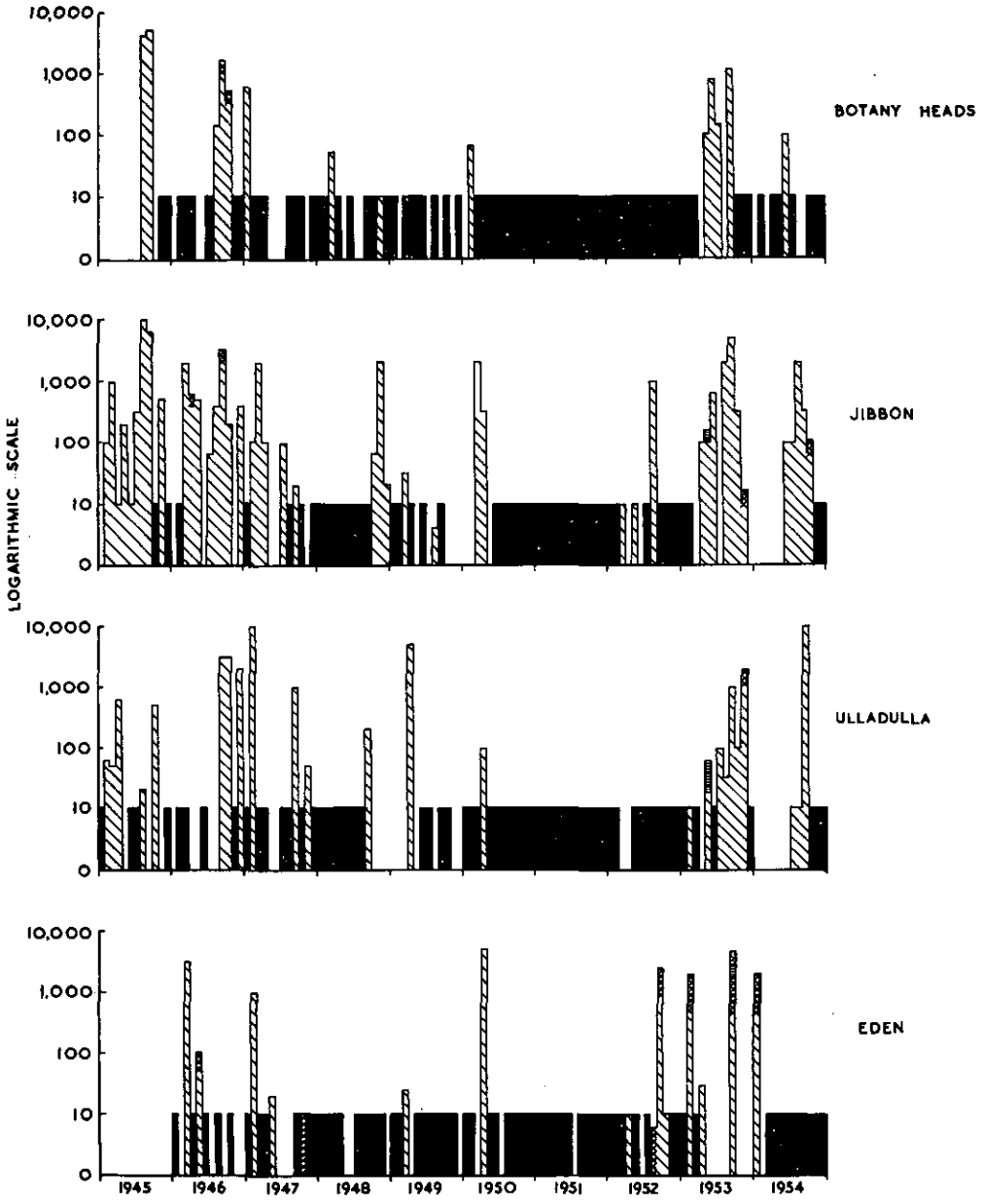

Fig. 5. Numbers of Acopa from 15 minutes, horizontal, N70 hauls.

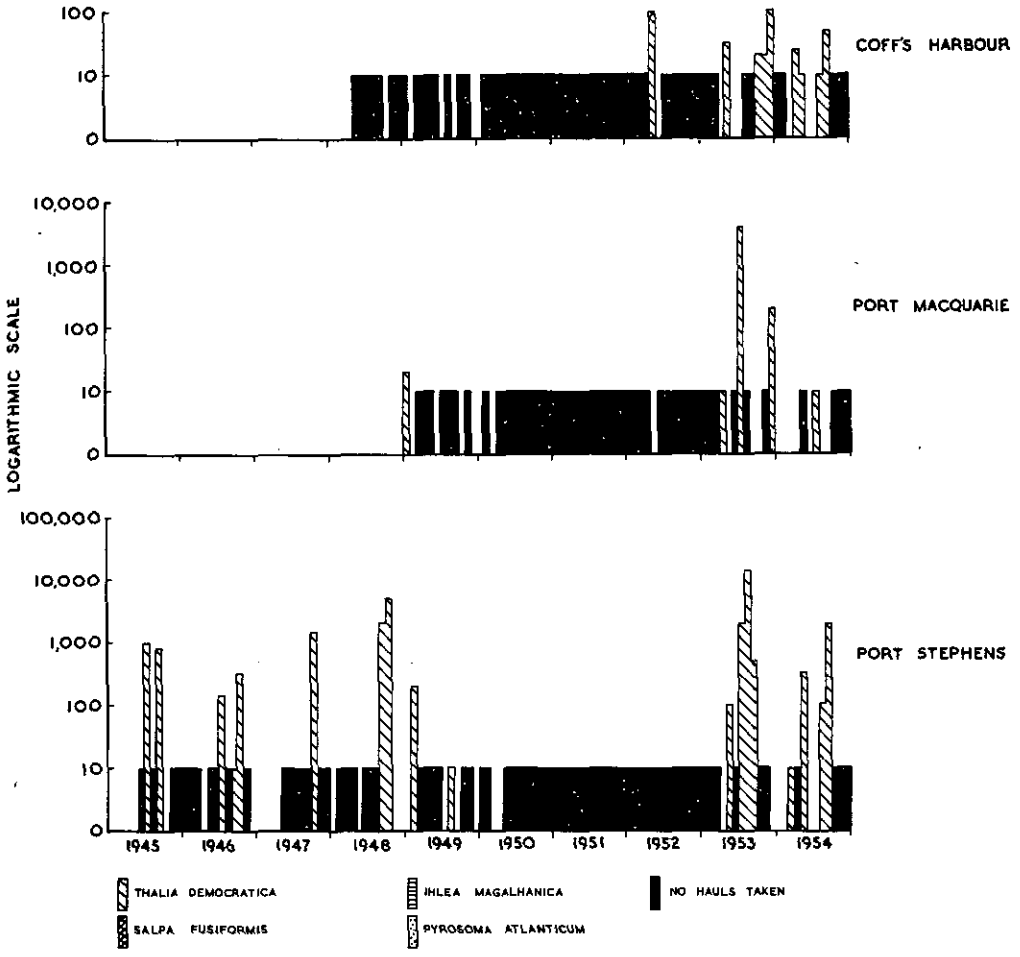

Fig. 5. Numbers of Acopa from 15 minutes, horizontal, N70 hauls.

south and the species was therefore significant as an indicator of the southward movement of the northern coastal water. Nannocalanus minor was present at the more southern coastal stations when this area was being invaded from the north, so it was not usually carried into the northern coastal area. Its ubiquitous offshore distribution limits its use as an indicator.

2. Pleuromamma gracilis was present off Jibbon in the deeper hauls from April to October 1953 but was taken at the surface only during May. At Port Macquarie it was taken in deeper hauls during July, August, and December of 1953 and 1954. It occurred in both the surface and deeper hauls at Eden during October to December. The absence of records of this species during the early years of this survey may be explained by the fact that very few deep hauls were made before 1953. It was present at most stations in the Tasman Sea worked in February and November 1954. In February it was taken in surface waters south of latitude 41°S and to the north of that latitude it was usually found between 300 - 100 m. During November the appearance of the species in the surface waters occurred slightly further south.

The species is therefore a useful indicator of offshore waters from the 300 - 100 m layers off the New South Wales coast.

3. Rhincalanus nasutus was present at Jibbon station generally from April to June. It also occurred later in August and September. It occurred at stations north of Jibbon but further south its numbers decreased. Like Pleuromamma gracilis it was taken more often in the vertical hauls from 50 m to the surface than in surface hauls. It has a similar distribution to that of Eucalanus crassus but was much less important in the onshore region; offshore it was common in surface waters.

4. Euchaeta marina was present off Jibbon during April to June in the surface hauls and it persisted until October in the deeper hauls from 50 m. In 1953 it was not taken at the surface but was present in the 50 m hauls. At Eden and Ulladulla it rarely occurred at the onshore station. Offshore it was usually present in hauls from 100 m to the surface, and at the Tasman Sea stations it was occasionally present in deeper waters, and as far as can be ascertained from the few hauls available it occurred throughout the year. Its distribution was principally offshore with only an occasional invasion of the northern onshore area.

5. Sapphirina spp.- This genus was usually associated with the salp swarm (Thalia democratica).

6. Scolecithrix danae occurred in June and July in the deeper hauls with Pleuromamma gracilis at all the coastal plankton stations when other offshore species were present. Although associated with other offshore plankton species which had invaded coastal waters it was not found at Tasman Sea stations. It is one of the few species occurring in the Australian area which is also taken in the tropical Pacific region.

7. Calanopia elliptica occurred spasmodically in hauls from Jibbon to Port Macquarie. It was present in the surface hauls at Jibbon and Botany Heads stations in June 1946, April 1952, April to July 1953, and in June 1954. When deeper hauls had been taken on these occasions, the species was present in the deeper haul before it was evident at the surface. It occurred at Port Stephens in July and March 1954, at Port Macquarie during January 1949, October 1953 and March 1954, and at Evans Head during June and July 1954. It usually occurred with Scolecithrix danae and occasionally with other offshore species. It was not taken at any of the offshore or Tasman Sea stations, but these stations were not sufficiently far north to sample plankton from tropical Pacific areas, where, as with S. danae, this species has been recorded.

8. Candacia bipinnata 9. Candacia pectinata.-

These species were found often in the plankton but always in small numbers. They occurred at all offshore stations, usually during March to May and again in November to January. The species were also present at onshore stations.

10. Lucicutia flavicornis occurred constantly off the New South Wales coast in water layers below 100 m; and in hauls taken off the continental shelf in hauls from 100 m to the surface. At onshore stations it was taken in the 50 - 0 m hauls in March and August 1954 at Coff's Harbour, in December 1953 at Port Macquarie, and at Jibbon in May and September 1953. In the Tasman Sea it occurred with Pleuromamma gracilis and with that species is indicative of deeper offshore waters.

11. Pontella securifer was common in the Bass Strait. It was also taken at more northerly stations but never in appreciable numbers and it is regarded as a rare and spasmodic member of the copepod population studied in this survey.

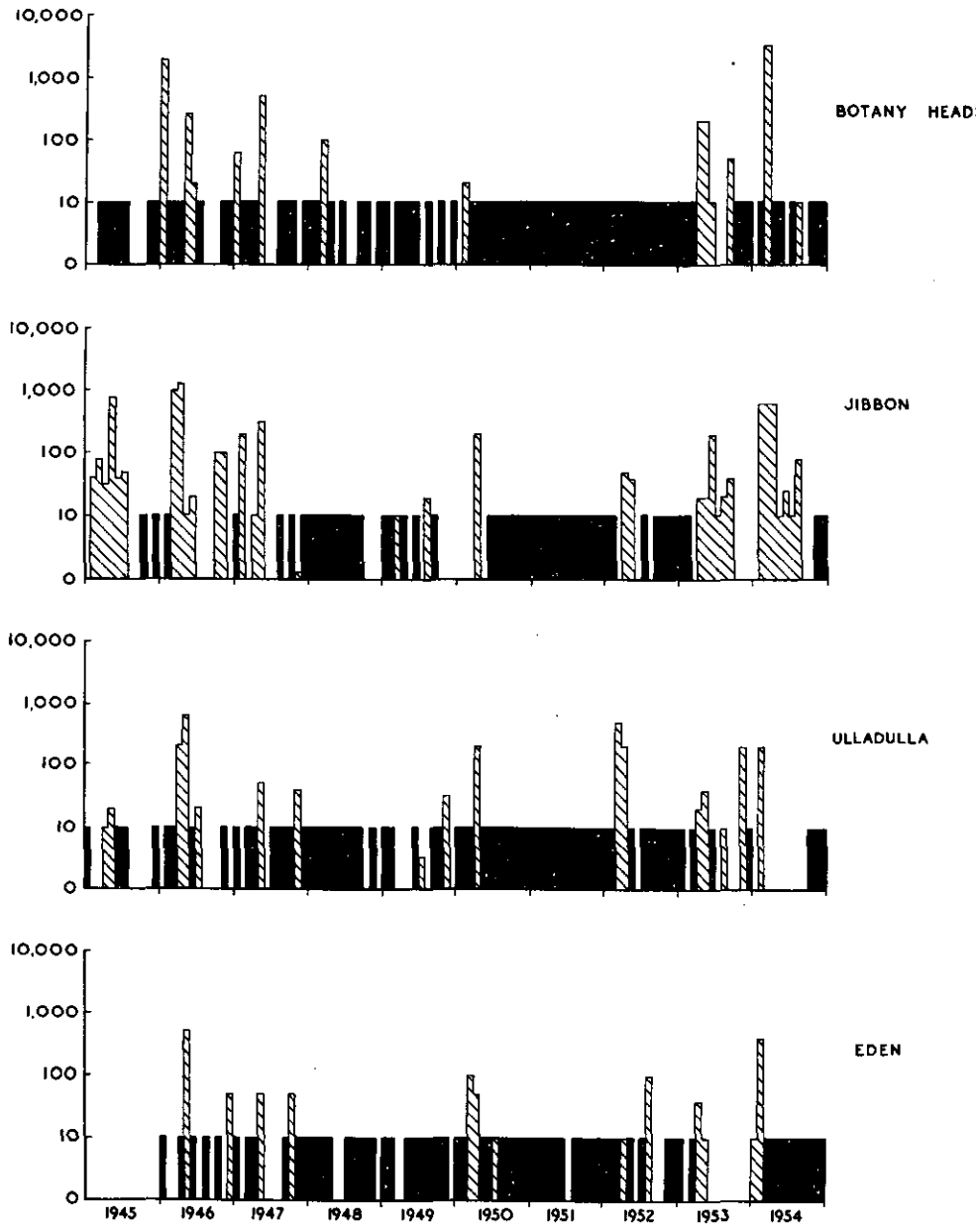

Fig. 6. Numbers of Doliolum denticulatum from 15 minutes, horizontal, N70 hauls.

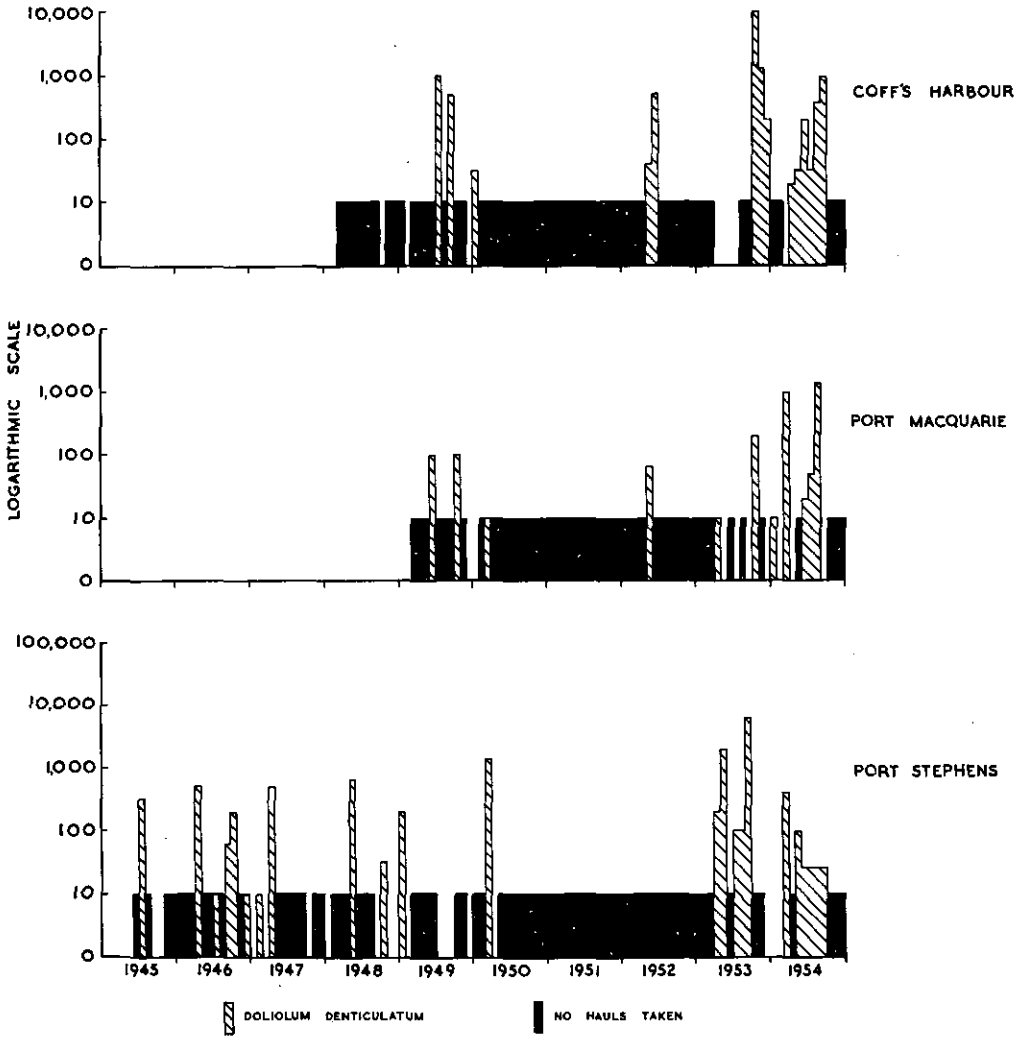

Fig. 6. Numbers of Doliolum denticulatum from 15 minutes, horizontal, N70 hauls.

12. Pleuromamma abdominalis was not taken in any of the surface hauls but was taken in a haul at the offshore Eden station in the haul from 500 m in August 1952. It was common in the Tasman Sea at 500 - 300 m and it became more common further to the south off the coast of Tasmania.

13. Aetideus sp. was taken off Eden in hauls from 500 m and off the coast of New South Wales from 500 - 400 m at all stations off the continental shelf. It was also taken once in a haul 100 - 0 m at the Jibbon station. It was present, though only in very small numbers, at the deep stations in the Tasman Sea.

14. Firoloida desmaresti was occasionally found in coastal waters but was more common offshore. It was taken in hauls off Jibbon from May to July which is the time of the invasion of coastal waters by the offshore surface plankton. Further to the north and offshore it was present over many more months. Its distribution was similar to that of Rhincalanus nasutus.

15. Doliolum denticulatum (Fig. 6) appeared in the Jibbon plankton from February to July and sometimes persisted until September. In 1949 it was present in small numbers and for a very short time. At other stations it occurred at corresponding times and in similar numbers. Thompson (1942, 1948) found this species evenly distributed over the whole New South Wales and south Queensland coasts with the greatest concentrations between Montague I. and Cape Byron, but absent from Bass Strait. He also found that it did not occur below a depth of 100 m. It may be assumed that the coastal population of this species was derived from the offshore region since, in 1949, when there was an absence of other offshore forms, only a small number of this species occurred in coastal waters.

16. Doliolum gegenbauri (Fig. 7) decreased in numbers from Coff's Harbour to Eden but always occurred less frequently and in smaller numbers than D. denticulatum. At the northern stations they appeared together but in the south D. gegenbauri appeared when D. denticulatum had disappeared. D. gegenbauri was common off the east coast of Tasmania and in the southern Bass Strait area and was occasionally taken in deep hauls at Tasman Sea stations.

With this distribution it is difficult to explain the sometimes great numbers found in coastal waters to the north of Jibbon. It appeared at these stations at the same time of the year as Calanoides carinatus. D. gegenbauri and D. denticulatum appear to have been brought into this coastal

area by entirely different agencies.

17. Pyrosoma atlanticum (Fig. 5).- During the period under discussion this species was taken in coastal waters off Eden only in September 1953; in the Tasman Sea in February 1954 at the more southern stations, and in Bass Strait along the north coast of Tasmania in March 1954, and again at the southern stations in the Tasman Sea in November 1954. Thompson (1948) found it most plentiful from Sydney to the south of Tasmania. Off the Tasmanian coast the species was abundant throughout the year, and he found it common in deeper hauls. He found off the Australian coast a rise in numbers during May and June and found they disappeared during October and November. This survey did not find the maximum numbers recorded by Thompson for May and June in the New South Wales coastal area. It is possible that the high May and June numbers which Thompson found were well offshore, and may have been related to a population with its origins in some other part of the Pacific rather than the population off the east coast of Tasmania, which would be expected in coastal New South Wales waters with other southern species from October - December; a period when Thompson found them absent completely from the Australian coast.

18. Salpa fusiformis (Fig. 5) occurred in the coastal plankton at Jibbon station with the summer and winter swarms of Thalia democratica, but only in small numbers. At Ulladulla this was repeated but at Eden the numbers were higher and the occurrences lasted longer. North of Jibbon the species has not been taken. In the Tasman Sea the species was more common at the stations off the mainland than off the coast of Tasmania, and it was especially common in November. It was taken in the Bass Strait along the north and east coasts of Tasmania in March 1954.

This species has a very general distribution over the whole offshore area but is present in the greatest numbers in the south. Its presence in Bass Strait could be due to the movement of water into that area from the Tasman Sea, when generally offshore species appear in the onshore area.

19. Fritillaria borealis (Fig. 4) was taken in small numbers at all stations except Eden from June to August and sometimes until October. It was most consistently present in 1954 from August to October. It was generally present with other species of Fritillaria. It was not taken at the offshore stations. However Thompson (1948) recorded the species in south-east Australian waters all the year round, but most common from August to October, followed by a maximum in January

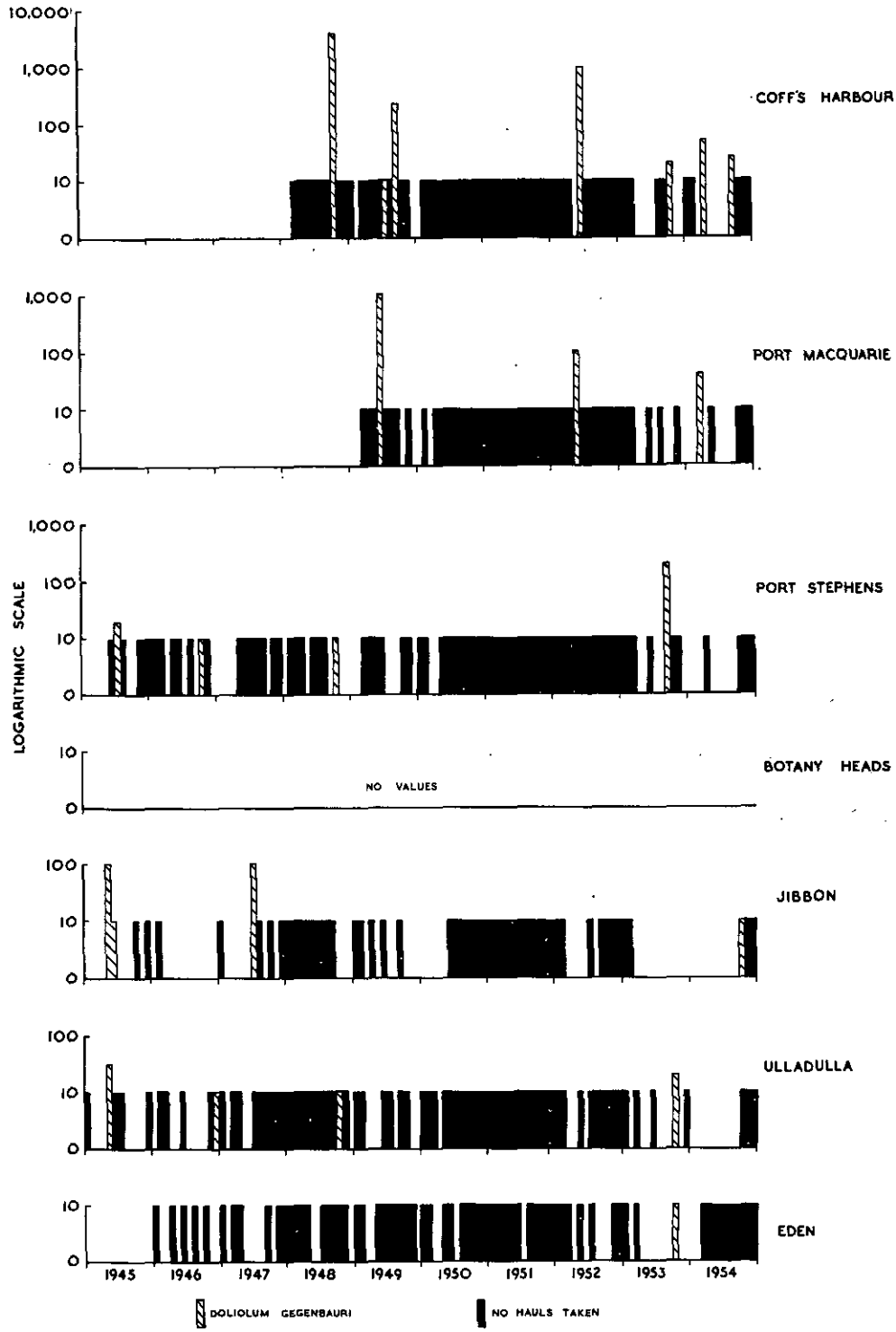

Fig. 7. Numbers of Doliolum gegenbauri from 15 minutes, horizontal, N70 hauls.

and a secondary maximum in May. He found the species was typical of oceanic waters off the coast of New South Wales.

A number of species of Appendicularia was present in the hauls on only a few occasions at northern stations and at Jibbon. Fritillaria megachile appeared once in the coastal plankton, during April 1952 at Eden. Thompson (1948) has recorded the species at different months during the year along the New South Wales coast, and he suggested that it occurred generally in warmer oceanic waters. Sheard recorded this species at Jibbon during May 1943. Fritillaria haplostomata was found off Jibbon during June 1945. Thompson (1948) recorded it in April, May, and November from the New South Wales coast. Fritillaria formica and Kowalewskaia tenuis were present off Jibbon during March 1945. Thompson (1948) found both of them from April to September. Stegosoma magnum appeared in small numbers from March to May particularly in 1945, 1953, and 1954 at stations from Jibbon to Coff's Harbour. Thompson (1948) found this species rarely south of Sydney but in offshore waters north of Sydney it was present in all months but November and December. Tectillaria fertilis appeared off Coff's Harbour in August 1954 and off Port Stephens in July 1954. Thompson (1948) recorded the species in January, May, and July.

All of these species of Appendicularia are regarded as typical of the warmer offshore waters but as they occurred in such small numbers and so rarely they can be used only as supporting evidence with those species occurring more regularly and in larger numbers which move from offshore to coastal areas and may be regarded as indicators of water mass movement. It is significant that they were taken during the same periods as Calanopia elliptica and Scolecithrix danae which may also accompany more tropical oceanic waters into the coastal area.

(c) Summary of Local Occurrences of Species

From a careful analysis of the local occurrences discussed in the previous section, species have been sorted into the following ten groups.

(1) Species valuable as indicators from the northern coastal area: Temora turbinata, Undinula vulgaris, Undinula darwinii, Centropages furcatus, Eucalanus crassus.

(2) Species of the transition area extending into the northern

coastal area: Centropages orsinii, Evadne spinifera, Evadne tergestina, Penilia schmackeri, Creseis acicula, Thalia democratica, Oikopleura longicauda, Oikopleura fusiformis, Oikopleura rufescens, Fritillaria pellucida.

(3) Species valuable as indicator organisms from the southern coastal area: Calanus finmarchicus, Centropages kroyeri, Tortanus barbatus, Evadne nordmanni.

(4) Other species in the southern coastal area extending into the transition area: Acartia clausii, Paracalanus spp. Centropages bradyi, Labidocera cervi, Podon polyphemoides, Iasis zonaria, Ihlea magalhanica.

(5) Species valuable as indicators of surface offshore New South Wales waters: Rhincalanus nasutus, Sapphirina spp. Thalia democratica, Doliolum denticulatum, Firoloida desmaresti, Fritillaria borealis, Pterosagitta draco.

(6) Species valuable as indicators of deeper offshore New South Wales waters: Euchaeta marina, Pleuromamma gracilis, Lucicutia flavicornis.

(7) Species valuable as indicators of offshore waters to the north of New South Wales (?): Calanopia elliptica, Scolecithrix danae, Fritillaria megachile, Fritillaria haplostomata, Fritillaria formica, Kowalewskaia tenuis, Krohnita pacifica.

(8) Species valuable as indicators of surface offshore Tasmanian waters: Pleuromamma gracilis, Lucicutia flavicornis, Nannocalanus minor, Pyrosoma atlanticum, Salpa fusiformis, Ihlea magalhanica, Iasis zonaria.

(9) Species valuable as indicators of deeper offshore Tasmanian waters: Aetideus sp., Pleuromamma abdominalis.

(10) Other species: Candacia bipinnata, Candacia pectinata, Pontella securifer, Calanoides carinatus, Doliolum gegenbauri.

Group 2 contains those organisms which were found to be present throughout the year in New South Wales coastal waters. Certain of these species were found to increase to seasonal peaks at certain times. Species listed in groups 1, 3, and 5 were considered to move into an area rather than to occur as endemic species appearing at different seasons. This explanation is considered justified because the species in each of these groups appeared together, and the dominant organism changed suddenly and did not become dominant after

a gradual increase in numbers. These changes in the nature of the zooplankton were noted regularly year after year, at more or less the same time, and any variation in the time of the change affected all the species of the group.

(d) Seasonal Distribution of Zooplankton

The seasonal distribution of zooplankton species for three of the coastal stations of New South Wales is shown in Tables 1 - 3.

Table 1 shows the seasonal distribution of zooplankton at Jibbon in 1945. In the period January to March the northern coastal forms were represented by Undinula vulgaris but the southern coastal species were predominant with the local species, Penilia schmackeri and Evadne tergestina flourishing. Thalia democratica and Doliolum denticulatum representing the summer swarm were also present in fair numbers. Fritillaria formica and Kowalewskaia tenuis were rarely found in coastal collections but occurred in offshore waters and in this period they were found in small numbers with the salps.

In the period April to June there was a change to a fauna dominated by the northern coastal species with offshore species Fritillaria haplostomata and Fritillaria pellucida appearing in June.

From July to September the zooplankton was completely dominated by Thalia democratica and its associated Sapphirina sp. with Ihlea magalhanica appearing at the end of the period. From October to December the swarms of Thalia democratica gradually disappeared and the southern coastal forms appeared and increased in numbers.

There were certain differences in the zooplankton at Jibbon in 1946. In March Centropages orsinii was present. The northern coastal species were present in greater numbers during January to March, dominated by Paracalanus spp. and Acartia clausii which did not decrease but remained in smaller numbers until the appearance of the salp swarm in July. As in 1945, northern coastal species increased and dominated the zooplankton during April to June. The offshore species, with the exception of Thalia democratica and Doliolum denticulatum, were not present in 1946. Salpa fusiformis was present in April when the March salp swarm was disappearing.

TABLE 1

JIBBON 1945

	J - M	A - J	J - S	O - D
Southern Coastal Species				
Paracalanus spp.	xxxxx	x	-	xxx
Acartia clausii	xxxxx	xx	-	xxx
Calanus finmarchicus	xx	-	-	xx
Centropages kroyeri	xx	-	-	x
Centropages bradyi		x	-	x
Evadne nordmanni	x	-	-	-
Northern Coastal Species				
Undinula vulgaris	xx	xxxx	-	-
Temora turbinata	-	xxxxx	-	-
Undinula darwinii	-	xxxx	-	-
Centropages furcatus	-	xx	-	-
Creseis spp.	x	xx	xx	x
Eucalanus crassus	-	xx	x	-
New South Wales Coastal Species				
Centropages orsinii	x	x	-	-
Oikopleura spp.	xxx	xx	-	-
Penilia schmackeri	xx	xxxx	x	-
Evadne tergestina	xxx	xx	-	x
Evadne spinifera	xx	-	-	-
Fritillaria pellucida	-	xx	x	-
Oceanic Species				
Doliolum denticulatum	xxx	xxxx	xx	-
Thalia democratica	xx	x	xxxxxx	x
Sapphirina spp.	x	-	xxx	-
Doliolum gegenbauri	-	x	-	-
Rhincalanus nasutus	-	xx	-	-
Euchaeta spp.	-	x	x	-
Nannocalanus minor	x	xx	-	-
Calanopia elliptica	-	x	-	-
Scolecithrix danae		-	x	-
Calanoides carinatus	-	-	-	xx
Firoloida desmaresti			x	-

TABLE 2

COFF'S HARBOUR (COMPOSITE OF SEVERAL YEARS)

	J - M	A - J	J - S	O - D
Southern Coastal Species				
Paracalanus spp.	xx	x	-	xx
Acartia clausii	-	xx	-	xx
Calanus finmarchicus	-	-	-	x
Centropages kroyeri	-	-	-	-
Centropages bradyi	-	x	-	x
Evadne nordmanni	-	-	-	-
Northern Coastal Species				
Undinula vulgaris	xx	xxx	-	xx
Temora turbinata	xxxx	xxxx	-	xxx
Undinula darwinii	xx	xx	-	xx
Centropages furcatus	xx	xx	-	xx
Creseis spp.	-	x	x	x
Eucalanus crassus	xx	xx	x	-
New South Wales Coastal Species				
Centropages orsinii	-	x	-	-
Oikopleura spp.	x	xx	xx	x
Penilia schmackeri	xx	x	-	xxx
Evadne tergestina	xxx	xx	-	xx
Evadne spinifera	xx	-	-	xxx
Fritillaria pellucida	-	xx	x	x
Oceanic Species				
Doliolum denticulatum	-	xx	xxx	-
Thalia democratica	x	-	xxx	-
Sapphirina spp.	-	-	xx	-
Doliolum gegenbauri	-	xx	-	-
Rhincalanus nasutus	x	x	x	-
Euchaeta spp.	x	x	x	-
Nannocalanus minor	-	-	-	-
Calanopia elliptica	-	x	-	-
Scolecithrix danae	-	x	-	-
Calanoides carinatus	-	-	-	xx
Firoloida desmaresti		present		

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TABLE 3

EDEN (COMPOSITE OF SEVERAL YEARS)

	J - M	A - J	J - S	O - D
Southern Coastal Species				
Paracalanus spp.	xxxx	xxx	xx	xx
Acartia clausii	xxx	xxxx	xx	xx
Calanus finmarchicus	xx	xx	xx	xxx
Centropages kroyeri	-	xx	xx	xx
Centropages bradyi	x	x	x	x
Evadne nordmanni	xxx	x	-	-
Northern Coastal Species				
Undinula vulgaris	-	x	-	-
Temora turbinata	x	x	-	-
Centropages furcatus	-	x	-	-
Creseis spp.	-	-	-	-
Eucalanus crassus	x	x	-	x
New South Wales Coastal Species				
Centropages orsinii	-	-	-	x
Oikopleura spp.	-	xx	-	xx
Penilia schmackeri	xx	x	-	-
Evadne tergestina	xx	x	-	x
Evadne spinifera	-	xx	-	-
Fritillaria pellucida	-	x	x	x
Oceanic Species				
Doliolum denticulatum	-	xx	-	-
Thalia democratica	xx	-	xx	-
Sapphirina sp.	x	-	x	-
Doliolum gegenbauri	-	-	-	x
Rhincalanus nasutus	x	-	-	-
Euchaeta spp.	-	-	-	-
Nannocalanus minor	xx	-	-	-
Calanopia elliptica	-	-	-	-
Scolecithrix danae	-	-	-	-
Calanoides carinatus	-	-	x	xxx

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Calanoides carinatus (with other southern coastal species) was plentiful from October to December 1946, Evadne tergestina, Evadne spinifera, and Temora turbinata were conspicuous in December instead of in January as in 1945.

During the remaining years of the survey the cycle of zooplankton at Jibbon was similar to that for 1945-46. The groups of species varied in magnitude or occurred earlier and persisted later in certain years, but generally the plankton appeared at Jibbon in the order indicated in Table 1.

Table 2 indicates the seasonal distribution of species at Coff's Harbour. Southern coastal plankton species seldom occurred at this station. Evadne spinifera and E. tergestina appeared earlier than they did at Jibbon and persisted later. Northern coastal copepod species were never absent from the plankton.

Table 3 indicates the seasonal distribution of species at Eden coastal station in 1953. The northern coastal species and those usually found at Jibbon did occur at Eden in some years but only in small numbers. However, at the Eden offshore station, northern coastal species were plentiful. In February 1954 F.R.V. "Derwent Hunter" took plankton hauls containing Temora turbinata, Penilia schmackeri, Evadne tergestina, and Undinula vulgaris.

(e) Annual Variations in Zooplankton

An analysis of the data discussed in the Section III(b) indicates annual variations in the distribution of the plankton. In 1945 there was a strong invasion of southern coastal species which persisted late at Jibbon. The northern coastal species did not appear off Jibbon until March, then they were particularly numerous and completely dominated the zooplankton as far south as Jibbon. There was also evidence of a particularly strong offshore invasion from the northern tropical area of species such as Calanopia elliptica, Scolecithrix danae, Stegosoma magnum, and with less numerous occurrences of Tectillaria fertilis, Kowalewskaia tenuis, Fritillaria formica, and Fritillaria haplostomata. This invasion was not evident south of Jibbon. Thompson (1942) records similar incursions of Appendicularia from the northern offshore area in 1938-39. In 1949 the salp swarms usually found in March and July were very much reduced; in that year Temora turbinata and Centropages furcatus characteristic of the northern coastal area

persisted at Jibbon until October. Also in that year the numbers of Doliolum denticulatum were small at all stations, indicating that this species may have an offshore origin with Thalia democratica. Calanoides carinatus was present in August, though in other years it did not appear until October. Evadne tergestina appeared in August instead of in December or January. Penilia schmackeri, although not present in large numbers, persisted until September when usually it had disappeared by June. All of these unusual occurrences associated with the absence of Thalia democratica indicate the absence of the water mass bearing the salp. Its absence enabled both the southern and northern species to persist longer in the area.

In 1950 the zooplankton appeared to be normal except for the occurrence of large numbers of Evadne nordmanni off Jibbon, suggesting a strong invasion from the south. In 1952 and 1953 there were only small numbers of Thalia democratica and Doliolum denticulatum in the summer swarm; Copepod numbers were particularly high, the offshore species were present, both from the northern tropical area and the New South Wales offshore area with Euchaeta marina, Rhincalanus nasutus, Pleuromamma gracilis, Stegosoma magnum, and Krohnita pacifica present in the deeper hauls at Jibbon. These persisted until August when the winter salp swarm appeared. In 1954 the summer salp swarm was not strong but large numbers of Doliolum denticulatum were present.

Fuller (1953) records that in Hauraki Gulf, New Zealand, Temora turbinata and Acartia clausii were constant components of the inner coastal populations, and in the summer months Penilia schmackeri, Podon polyphemoides and Evadne spp. were present in quantities. The outer region of the Gulf oceanic population varied according to the season and Thalia democratica, Salpa fusiformis, Salpa cylindrica, Rhincalanus cornutus, and Sapphirina sp. were dominant in November to April of one year and October to May in the next. This succession of zooplankton, with minor differences in species, is very similar to the conditions in the New South Wales coastal area and the two invasions of salps there could correspond to the March and July swarms off New South Wales.

IV. CONCLUSIONS

This survey shows that for the period under review the dominant zooplankton in New South Wales coastal waters was derived in turn from coastal areas to the north of Port Stephens, to the south of Eden and from offshore areas. At Port Stephens the plankton for most of the year was of the

northern coastal variety and southern species rarely appeared. At Eden coastal station the plankton for most of the year was dominated by southern coastal species and the northern species were rarely present.

The area between Port Stephens and Eden was a transition area where southern and northern coastal species occurred at different times of the year. Offshore species from both surface and deep waters from tropical and subtropical regions were observed to invade coastal waters during April to October from Eden to Jibbon. To the north of Jibbon the offshore species appeared as early as January and were more frequent. At Jibbon southern coastal forms dominated the plankton from October to December; during January to March there was a change over to northern coastal species which dominated the plankton during April to June. During July the surface offshore waters appeared to invade the coastal area bringing huge swarms of Thalia democratica. During January to June certain species flourished from Ulladulla to Evans Head; these were not found offshore and it is assumed that they were autochthonous species for the New South Wales coast.

Jibbon is at the centre of the area surveyed and had the greatest succession of species both from the north and the south. At the extremes of the area, the zooplankton was more constant throughout the year. Northern coastal waters appeared to spread laterally as they moved south so that their associated plankton species were found further offshore in the Eden area than they were in the north.

Thompson (1942), in his consideration of the distribution of Tunicata, found no southern limit to the south-east Australian area. Sheard (Thompson 1942, p.18) suggested that there was only justification for a division of this area "when the problem is considered in the light of marginal reef and sand dwelling animals subject to localized conditions." The present work shows that the area may be very clearly sub-divided for the zooplankton of the continental shelf. Offshore the surface zooplankton was subtropical as far south as the Subtropical Convergence which was found at latitude 41°S in both February and November 1954. The zooplankton of the deeper waters included those species found in surface waters south of 41°S.

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No constant diurnal variation in the vertical distribution of zooplankton was observed at any of the stations. Certain copepods and tunicates at the deeper stations of the Tasman Sea were found to be characteristic of different water layers and to occur in those layers at

all times. Hauls were not taken below 100 m to differentiate the water column in greater detail and thus to confirm or disprove diurnal vertical migrations. At coastal stations the same copepod species were generally found in the same proportions at the surface and in vertical hauls. Differences were observed in the vertical distribution of certain species. Thalia democratica, when it first migrated into a coastal area, was present mainly in the surface hauls; later it gradually invaded all depths and was found in equal density in surface and vertical hauls. Certain of the offshore species characteristic of deeper oceanic waters were most commonly taken in the deeper hauls at coastal stations. These differences appeared to be caused by water circulation rather than by diurnal migrations.

In Secting III(b) several species have been designated as indicator species of southern coastal, northern coastal, and offshore water. Rochford (1957) has named the regional water masses circulating in the Tasman Sea and has given their temperature and chlorinity characteristics. It may now be possible to associate certain of the indicator species designated in this report with those water masses as they affect the coastal waters of New South Wales.

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