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Zooplankton and Hydrology of Hauraki Gulf New Zealand

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New Zealand Oceanographic Institute
Memoir No. 53

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FOREWORD

One of the major deficiencies in our knowledge of the marine environment has been the scarcity of definitive studies of the planktonic fauna.

In this memoir the author presents an account of near-shore plankton populations in northern waters, and of their variability with respect to changes in environment and season. The studies reported here and others currently in press that deal with the plankton fauna from central New Zealand make a substantial contribution to our knowledge of the New Zealand plankton.

J. W. BRODIE
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Zooplankton and Hydrology of Hauraki Gulf New Zealand

JOHN B. JILLETT

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Abstract

Records of temperature, salinity, turbidity, and zooplankton abundance and composition were gathered at regular intervals from two Hauraki Gulf stations. These two stations were chosen to represent conditions in the outer and inner gulf respectively.

Hydrological processes at both stations were those expected from the effect of climatic factors on shallow inshore waters. Surface water temperatures were closely related to air temperatures, and surface salinities were closely related to rainfall. Temperature and salinity gradients were established at the outer gulf station in spring, and these persisted until autumn. In late summer and autumn 1965 a subsurface intrusion of offshore water into the outer gulf resulted from persistent offshore winds.

Variations of abundance of the various zooplankton components were followed in successive samples at both stations. Inshore the zooplankton was typically neritic and lacked variety except amongst larvae of benthic and littoral organisms. Copepods and larvae together accounted for more than 90% of the average catch, but appendicularians, cladocerans, medusae, and ctenophores were sometimes moderately abundant. The essential features of seasonal succession were similar in both years of sampling.

In the outer gulf the zooplankton was more varied, and, although it was essentially neritic in character, an offshore element was nearly always present. Copepods (93%) were again the most abundant group, but larvae (7%) were much less abundant than inshore. Other groups included cladocerans, appendicularians, salps, euphausids, medusae, ctenophores, chaetognaths, pteropods, and heteropods. Variations in the strength of the offshore element have been interpreted in relation to the sequence of hydrological events.

The affinities of Hauraki Gulf zooplankton are clearly subtropical and warm temperate.

INTRODUCTION

This bulletin considers seasonal zooplankton and hydrology in the Hauraki Gulf, northern New Zealand. It is based on fortnightly samples taken between May 1963 and January 1965 from a station in Waitemata Harbour (Sta. A), and monthly samples taken between March 1964 and April 1965 from a station in Jellicoe Channel (Sta. B). Each station is representative of conditions in the inner and outer gulf respectively.

HISTORICAL BACKGROUND

Study of plankton communities of New Zealand waters has been neglected in the past. The various expeditions that have collected in the area have mostly concentrated on dredging, shore collecting, and bathypelagic programmes. The first serious observations were the descriptions by Dana (1852, 1855) of pelagic crustaceans from the collections of the U.S. Exploring

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Expedition in 1838-42. Then in the winter of 1874 HMS *Challenger* made a number of tow-nettings in the Tasman Sea, and the reports of the expedition are the first comprehensive accounts of the plankton of the area.

Foremost of the expedition reports on plankton are those of the British Antarctic *Terra Nova* Expedition, 1910-13. The *Terra Nova* made 75 plankton hauls in northern New Zealand waters, between 30^0 and 40^0S, in the winter of 1911. A further eight hauls were taken in more southerly waters between 30^0 and 50^0S between 1910 and 1913. These are the most extensive and thoroughly worked plankton collections made in these waters by an expedition, and the *Terra Nova* reports must remain the basic literature for many zooplankton groups in the area. Material from most of the expeditions since the *Terra Nova* remains largely unworked.

Apart from expedition reports, individual workers have added to the knowledge of planktonic groups. Even so, few groups are little more than superficially documented. In spite of this lack of local information concerning permanent plankton the world literature is adequate for the identification of the commoner species, and it is apparent that there is little endemism amongst open-water species. Endemism is greater amongst inshore and estuarine plankton communities, where earlier workers have concentrated their efforts. At some seasons larvae and temporary plankton are important and even dominant in inshore plankton, yet at present it is necessary to put them together into major systematic groupings from which only the more distinctive and ubiquitous larvae are distinguished. Such groupings include decapod, barnacle, polychaete, molluscan, ectoproct, echinoderm, and ascidian larvae and eggs, and larval and post-larval stages of fish.

New Zealand plankton communities have been the subject of relatively few publications and the following is a nearly comprehensive list: Bary (1951, 1956, 1959a, 1959b, 1960); Brewin (1951); R. M. Cassie (1958, 1959a, 1959b, 1959c, 1960a, 1963); U. V. Cassie (1960, 1961); Fuller (1950, 1953); Stuckey (1948); and Wear (1965c). The only seasonal studies of zooplankton have been those of Fuller (1953) and Wear (1965c).

This study considers seasonal zooplankton together with the hydrology in the Hauraki Gulf, northern New Zealand.

Kramer (1894) gave an account of the most abundant copepods and cladocerans of the Hauraki Gulf summer plankton. He recorded 12 copepods and four cladocerans.

Fuller (1950) recorded the abundance of the cladoceran *Penilia avirostris* during summer and autumn and commented on the probable temperature requirements of the species. Fuller (1953) also recorded the seasonal occurrence and composition of the Hauraki Gulf plankton and found that the inner gulf had a resident population of relatively constant composition, while that of the outer gulf varied.

Fuller also recorded surface salinities at each of his stations and attempted to explain the seasonal occurrence of plankton populations in the outer gulf according to alternating influences of oceanic water from two different sources. He gave no sampling dates or station details, but it is apparent that the work was not based on regular sampling from the same stations.

The physical environment for plankton in the Hauraki Gulf has been described in general terms by R. M. Cassie (1960b), who outlined the sequence of hydrological events in the annual cycle.

THE HAURAKI GULF

The Hauraki Gulf lies between 36^0 and 37^0 10'S and between 174^0 40' and 175^0 30'E and is situated on the north-eastern coast of the North Island, New Zealand (Fig. 2). The gulf is landlocked excepted in the north and north-east where its seaward boundaries are marked by two islands, Little Barrier and Great Barrier. The gulf is a broad trough of about 40-45m average depth, deepening towards the open sea and becoming shallow towards the western and southern shores.

The waters of the inner gulf (Waitemata Harbour, Tamaki Strait, and Firth of Thames) are shallow and enclosed and receive a number of sizable rivers, so salinity and temperature of the inner gulf might be expected to reflect weather variations (Skerman, 1958). In the outer gulf the catchment area of inflowing rivers is small, and this, coupled with greater depth of water, tends to make temperature and salinity less variable than closer inshore (R. M. Cassie, 1960b; Garner, 1961). Most of the important geographic, climatic, and geologic features of the area have been presented by Dellow (1955).

Climatically the gulf is relatively homogenous. Maximum air temperatures and sunshine hours occur in midsummer (January) and minimum values in winter (June or July). The average rainfall has a winter maximum and a summer minimum but there is a good deal of variation about the average. Winds are variable and though westerlies area the most common, gulf waters are protected from them by land. High winds are sometimes experienced from the exposed north-east quarter.

Offshore water masses have a variable effect in outer areas of the Hauraki Gulf (R. M. Cassie, 1960b; Fuller, 1953). The major currents to the north are the Tasman Current and the Trade Wind Drift (Fig. 1). Off the North Auckland Peninsula the current sets in a southerly direction down the east coast as the East Auckland Current which originates in the subtropical Tasman Current (Wyrtki, 1962; Garner and Ridgway, 1965; Barker and Kibblewhite, 1965). The East Auckland Current is the only offshore current likely to affect the region of the Hauraki Gulf. This current retains its subtropical character and is warmer and more saline than the mean for this latitude.

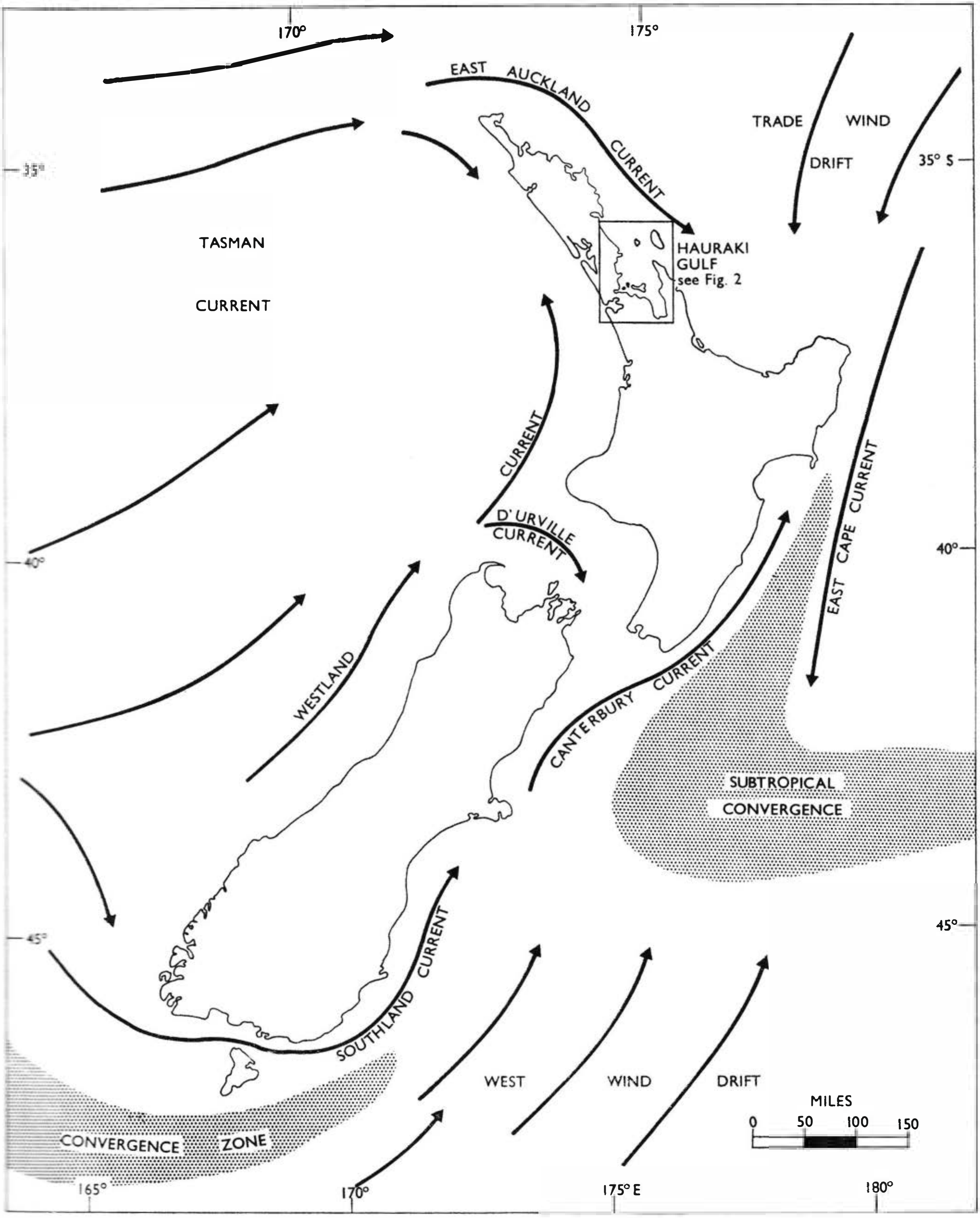

FIG. 1 Surface currents of the waters about New Zealand (After Brodie, 1960; Garner 1961; Wyrtki, 1962; Barker and Kibblewhite, 1965; Garner and Ridgway, 1965)

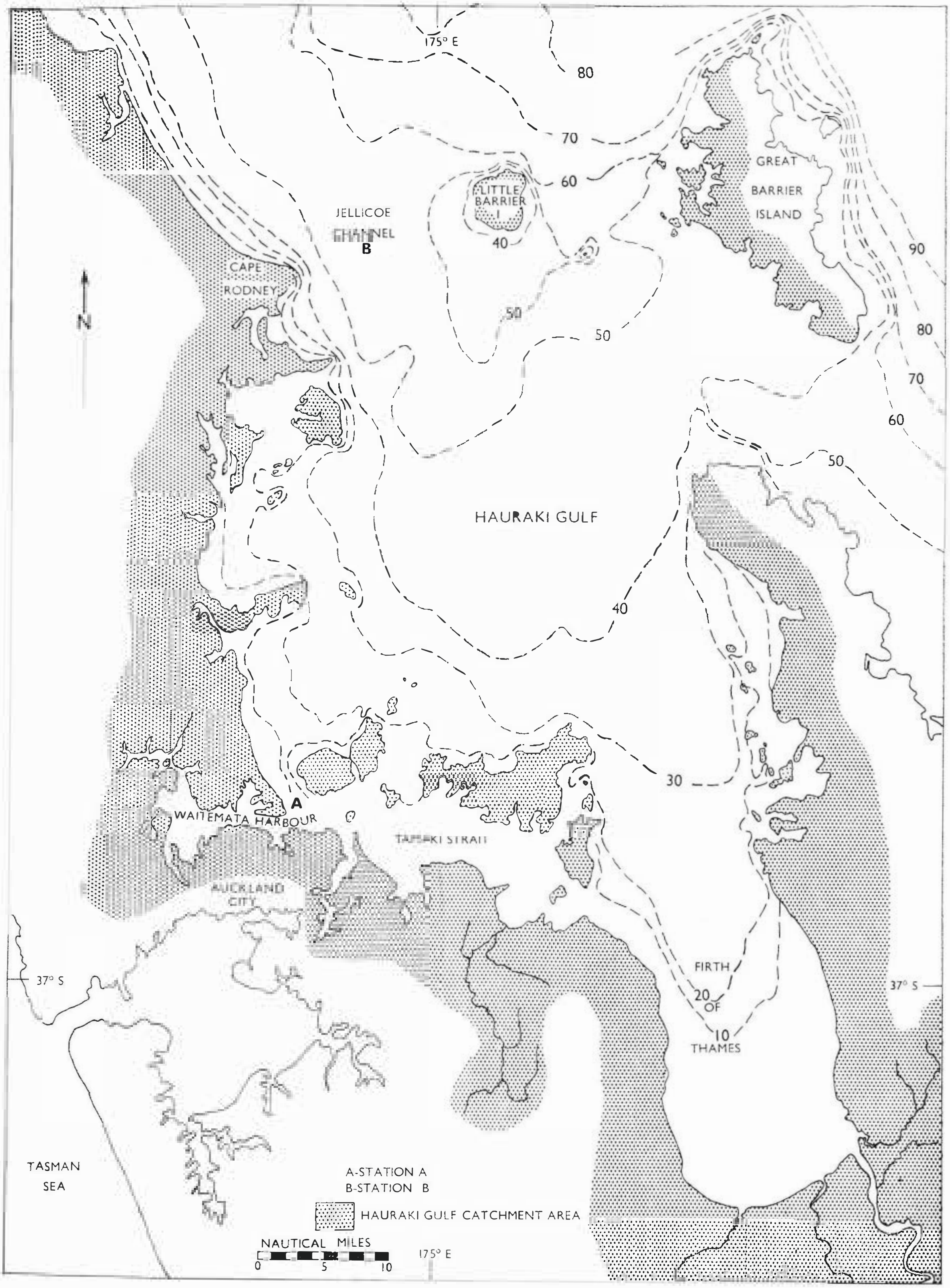

FIG. 2. Hauraki Gulf; bathymetry, land catchment, and the locations of Sta. A and Sta. B. (Depth in metres)

STATIONS

Two stations were selected in the Hauraki Gulf for regular hydrological and planktological sampling (Fig. 2). They were placed so that each represented one of the two regions recognised by Fuller (1953) and by R. M. Cassie (1960b). As emphasis was to be placed on regular, standardised sampling, the stations were chosen close to shore so that the work could be carried out from the available boats in all but the most adverse weather. One (Sta. A) was in the Waitemata Harbour and the other (Sta. B) in the Jellicoe Channel (Fig. 2).

STA. A — WAITEMATA HARBOUR

Sta. A was in the main shipping channel at about 20m depth. The channel at this point is 750m wide, shoaling to 5m on each side. The bottom sediment at Sta. A is coarse, tide-swept shell gravel, but on each side of the shipping channel are extensive areas of fine mud and silt with their associated fauna (Powell, 1937). The tidal stream in the channel attains a speed of 2 knots during spring tides. Estuarine influences and the proximity of Auckland city could introduce special conditions of increased dilution and pollution. Pollution through the discharge of sewage at Orakei had ceased in 1963-5, but sewage was still discharged at North Head and at Birkenhead on a small scale. Formerly pollution was serious on the beaches to the south-east of Sta. A (Wallace and Newman, 1953a, 1953b). Possible effects of dilution and pollution were minimised by sampling near to the harbour entrance at high tide. Conditions here resemble those for the inner gulf in general.

STA. B — JELLICOE CHANNEL

Sta. B was in the Jellicoe Channel at about 50m depth, 8.5km (5 nautical miles) east of Cape Rodney. The channel is wide, with a level bottom from Cape Rodney to Little Barrier Island, a distance of 23.4km (13.5 nautical miles). Tidal streams in the channel attain speeds of 1 knot, but, because of the greater depth, open situation, and distance from any major source of freshwater inflow, it was not considered necessary to limit the tidal conditions under which samples were taken. This station is close to meridian 175°E, chosen by R. M. Cassie (1960b) as a transect line in describing Hauraki Gulf hydrology. Conditions here resemble those of the outer gulf.

FIELD AND LABORATORY METHODS

SAMPLING PROCEDURE AT SEA

As there was considerable difference between the techniques used at each station the sampling procedures for each are listed separately.

STA. A — WAITEMATA HARBOUR

Sta. A was sampled once a fortnight for 21 months from May 1963 to January 1965.

The effects of diurnal variations in the behaviour of plankton were minimised by taking vertical hauls from near the bottom to the surface, so that all levels of the water column were sampled equally, and by limiting sampling to approximately the same time of day on each occasion. Methods were standardised by sampling plankton at slack water within half an hour of high tide on days when high tide was between 1000 and 1200 hours. Tides at this time of day in Auckland recur fortnightly and are amongst the highest in each tidal cycle.

On all but four occasions this station was sampled from a 12ft dinghy.

Hydrology

Temperature. Until the end of March 1964 surface temperatures only were taken using a thermometer graduated in 0.1°C. After this both surface and subsurface temperatures were taken using protected reversing thermometers (Negretti and Zambra).

Salinity. Until the end of March 1964 surface water samples were taken. After this subsurface samples were taken as well, with a Nansen reversing water bottle. Water samples were stored in 250 ml bottles with wax-impregnated cork stoppers until salinity determinations were made.

Turbidity was estimated on each sampling occasion by Secchi Disc readings.

Zooplankton

A simple conical net of monofilament nylon bolting cloth (250 micron mesh) was used. The mouth diameter of the net was 0.5m and the length 1.8m. The cod-end was weighted so that it fished only on the way to the surface in a vertical haul. On each occasion three vertical hauls were made by hand-hauling the net from near the bottom (18m) to the surface. Zooplankton samples were preserved immediately after collection to minimise the effects of predation. When live plankton was required for examination separate samples were taken.

Phytoplankton

Special attention was not given to phytoplankton in this survey, but the numbers of phytoplankton species were estimated in samples taken concurrently with the zooplankton and hydrological samples (U. V. Cassie, 1966).

STA. B — JELLICOE CHANNEL

Sta. B was sampled at monthly intervals for 14 months from March 1964 to April 1965.

Except for two occasions this station was sampled from an 18ft motor boat.

Hydrology

Temperature and Salinity. Temperature observations and water samples were taken using the Nansen reversing water bottle with attached reversing thermometers as at Sta. A. Observations were made at 9m intervals from the surface to 45m. Only one bottle was available, so each observation was made by a separate cast, and during sampling the boat usually drifted.

Turbidity. Water transparency was estimated on each sampling occasion by means of a Secchi Disc.

Zooplankton

Although it is theoretically desirable to use the same methods at both stations, vertical hauls with the gear already in use at Sta. A were not suitable for the conditions at Sta. B. Usually there was a considerable swell at Sta. B, and it proved impossible to vary the hauling rate to compensate for the motion of the boat. Furthermore, varying rates of drift and tidal flow made the 0.5m net stream out rather than sink vertically when it was being lowered. These difficulties were overcome by using a Clarke-Bumpus sampler in oblique hauls. While the boat was drifting the closed sampler was lowered to 45m (near the bottom). The net was then opened by messenger before being hauled slowly to the surface while the boat was moving at about 2-3 knots. Three hauls were made on each occasion. As at Sta. A, zooplankton samples were preserved immediately after collection.

The net used with the Clarke-Bumpus sampler was made of bolting silk (mesh 132 microns) and was finer than the net used at Sta. A.

Phytoplankton

Jar samples (2.5 l) were taken from the surface for qualitative and quantitative estimates (U. V. Cassie, 1966).

LABORATORY PROCEDURE

SALINITY DETERMINATION

The salinities of stored water samples were determined using a transistorised conductivity bridge (Hamon, 1956; Houtman, 1961). The temperature reading was discarded (following the suggestions of Houtman 1961) in favour of built-in temperature compensation over the normal laboratory range. The instrument was used solely in the laboratory as a transfer instrument between samples of unknown salinity and sea water that had been standardised from Copenhagen "normal water". Undoubtedly some accuracy was lost through not using Copenhagen water as a direct standard, and the absolute accuracy is about $\pm 0.02^0/_{00}$S. However, the bridge proved to be extremely sensitive and discriminated between samples differing by as little as $0.01^0/_{00}$S (as determined by Knudsen-Mohr titrations), so the precision is considered to be $\pm 0.01^0/_{00}$S. Each salinity value was derived from the mean of four potentiometer readings taken after the instrument had stabilised.

COUNTING AND RECORDING OF ZOOPLANKTON

Representative data sheets for samples from each station indicate the methods and degree of detail for the recording of zooplankton components (Appendices A, B and C). The full data are appended to the original thesis, copies of which are deposited in the University of Auckland library.

It was usually necessary to subsample the plankton catches after removing and counting the larger and less numerous organisms. In the earlier samples, subsamples were drawn by repeatedly dividing the catch, after vigorous shaking, until eight equal portions of the original catch were obtained. One of each pair in the final division to eighths was counted from nearly every haul. Data presented in Appendix A have been obtained by this method for each of the three catches of a typical sample. After October 1963 subsampling was carried out with a whirling subsampler (Kott, 1953), which produces tenth subsamples. Initially four one-tenth subsamples were counted from each catch, but this number was reduced as results encouraged greater confidence. At least two subsamples were counted from all but the catches in the last few samples. Data in Appendices B and C have been obtained by this method for samples from Sta. A and Sta. B respectively. Both the relative and absolute abundance of the various components are similar, not only for subsamples of the same catch but also for subsamples from replicate catches. This agreement is better for the commoner components than for the less common ones. Results have been expressed in numbers per standard haul rather than in numbers per unit volume. It is essential to note that hauls at each station were made with different gear so they are not directly comparable. At Sta. A approximately 2.5m^3, assuming completely efficient filtration, would be filtered in each standard haul (mouth area of net 1,964cm^2; distance hauled 18m). By comparison, about 4.15m^3 would be filtered in each Clarke-Bumpus haul at Sta. B. The numbers caught have been adjusted to the number expected per 1,000 revolutions of the net cyclometer. The total numbers and volumes of zooplankton in each of the three hauls in each sample were also estimated. For Sta. A a standard haul is a vertical haul through 18m, from near the bottom to the surface, made with a net of 0.5m diameter and 250 micron mesh. At Sta. B oblique hauls were made from near the bottom to near the surface (45m) using a Clarke-Bumpus sampler fitted with a No. 10 silk net (mesh 132 microns). For both stations values have been transformed to values per cubic metre. but these figures are not meaningful in absolute terms and are presented to allow comparison with the results of other workers. Except where otherwise stated, the figures quoted are means per standard haul. For Sta. A (0.5m net) a filtration coefficient of 1:1 has been assumed in deriving absolute values, and for Sta. B these values have been calculated from calibration data supplied with the Clarke-Bumpus sampler.

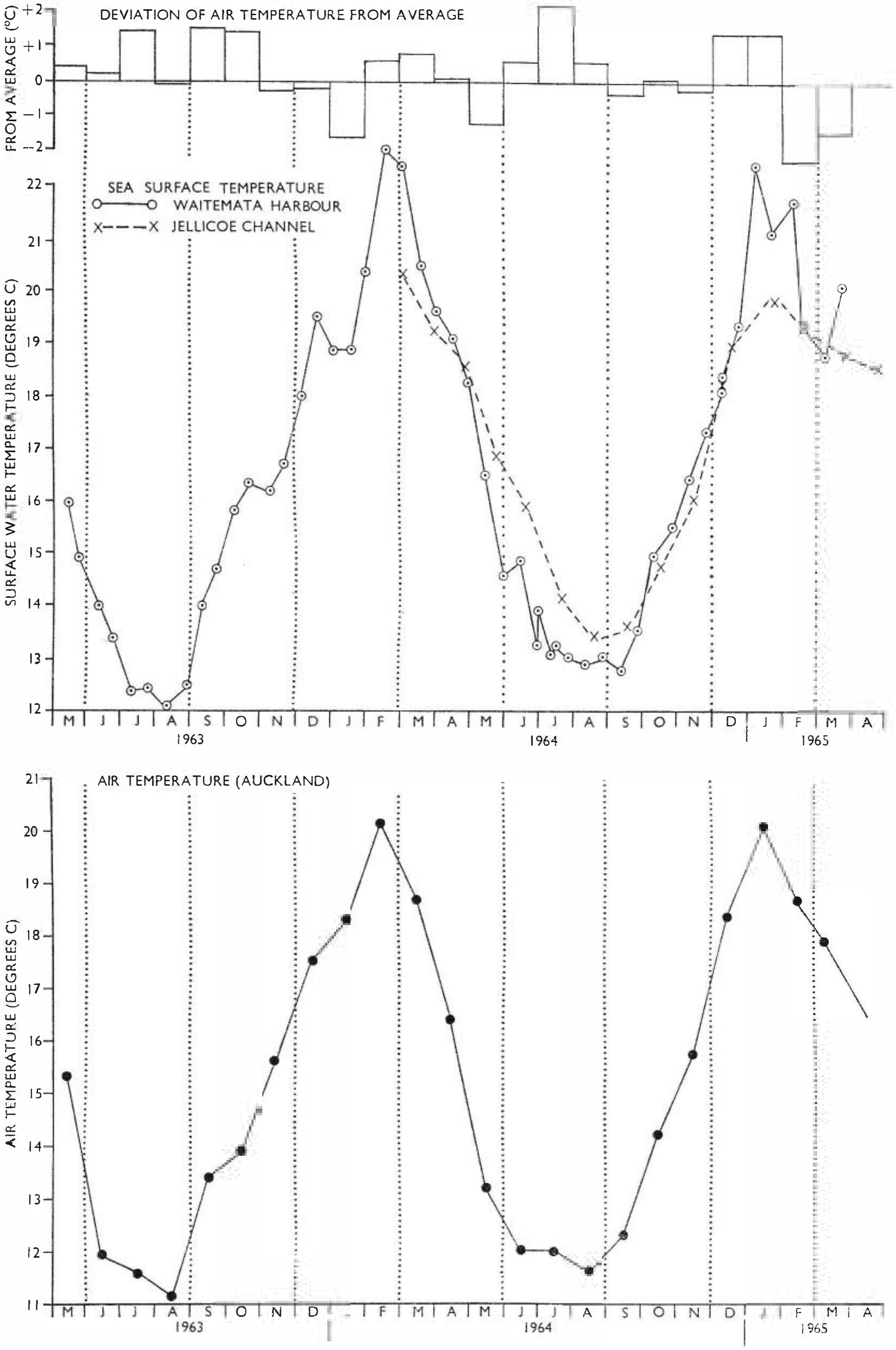

FIG. 3. Sea surface temperatures at Sta. A and B and air temperature with its deviations from average (for Auckland). (Air temperature data from the Department of Civil Aviation, Auckland)

RESULTS

THE PHYSICAL ENVIRONMENT

Sta. A Temperature (Fig. 3; Table 1)

Surface temperatures followed the trend of air temperatures. The lowest readings were 12.1°C in early August 1963 and 12.8°C in early September 1964. Highest temperatures were 22.7°C in mid February 1964 and 22.4°C in early January 1965; thus ranges of 10.6°C and 9.6°C were recorded in each annual cycle. The dates of minimum temperatures differed by 4 weeks and those for maximum values by nearly 6 weeks. Between mid March and mid July in both years temperatures declined at a uniform rate of 1.9°C per month. However, rising temperatures in each cycle followed quite different patterns. From August to December 1963 temperatures rose at an average rate of 1.75°C per month with a marked check in early November. There was a further check in late December and in January before a maximum was reached in mid February. In the following year temperatures rose steadily, without check, reaching a maximum in early January some 6 weeks earlier than in the previous year.

Subsurface temperatures, at a depth of 18m (near the bottom), were recorded for 1 year from April 1964 to March 1965. They closely approximated those at the surface. The average difference was 0.09°C and ranged from —0.55 to +0.02°C. Subsurface temperatures exceeded those at the surface only during periods of rapid decline from early May to mid July. At all other times subsurface temperatures were identical with, or less than, those at the surface.

Sta. A Salinity (Fig. 4, Table 1)

Surface salinities were recorded at Sta. A for two annual cycles (May 1963 to May 1965). Lowest values were in early August 1963 (33.10‰) and in mid July 1964 (33.23‰). Highest values were in early April 1964 (35.58‰) and in mid March 1965 (35.15‰). Ranges for each of these cycles were 2.48‰ and 1.92‰ respectively. While the seasonal trends are similar in both years there are considerable differences in detail and in absolute values. During 1963 and until July 1964 surface salinities varied regularly, but after July 1964 values were consistently lower than in the previous year and fluctuated a good deal about the upward trend line.

Subsurface salinities (April 1964 to March 1965) approximated the surface values but were generally slightly greater. Sample-to-sample variations were less at depth than at the surface.

Sta. A Turbidity (Fig. 5; Table 2)

The Secchi Depth varied from 1.1 to 4.8m. There was no pattern in these values except that they were generally low in winter.

Although approximate extinction coefficients can be obtained from Secchi Disc readings in open water, using the simple formula of Poole and Atkins (1929), extinction coefficients have not been presented for Waitemata Harbour readings because of the anomalous results obtained using this method. Values varied from 0.36 to 1.55, the latter being an improbable figure. It appears that such estimations have no value in extremely turbid. harbour waters. However, the depth of the euphotic zone extends to three to four times the Secchi Depth (Strickland, 1965).

Sta. B Temperature (Fig. 3, 6; Table 3)

Temperature at the surface was highest (20.4°C) in early March 1964 and afterwards declined steadily at a rate of 1.9°C per month, reaching a minimum value (13.4°C) in late August. From mid September until mid December the surface temperature rose steadily reaching a maximum of 20.0°C in late January. The recorded range was thus 7.0°C, some 3.6° less than in the Waitemata Harbour.

Subsurface temperatures departed appreciably from those at the surface. In March 1964 the upper 20m were nearly isothermal at approximately 19.2°C. Below 20m the temperature decreased regularly with depth reaching 17.6°C at 45m (near the bottom). By early April the whole water column was more or less isothermal at 18.5°C. After this it remained isothermal as temperature decreased throughout winter and reached a minimal value in late August. Thermal gradation was initiated in the water column in early spring (September) when a difference of 0.3°C was recorded between the surface and 25m. Below 25m temperature was uniform at 13.3°C, the minimal winter value. As temperatures rose near the surface, the thermal gradient intensified until by December surface waters were 4°C warmer than those at 45m. During this period there was little tendency for a thermocline to develop except in November, when the upper 25m was nearly isothermal and temperatures below this decreased regularly with depth. As surface waters cooled in late summer (February) the upper portion of the water column became isothermal, and with further surface cooling in March and April this isothermal layer deepened down to 35m.

TABLE 1. Temperature, Salinity, and Density at Sta. A - Waitemata Harbour

Date	TEMPERATURE (^0C)		SALINITY ($^0/_{00}$)		DENSITY σ_t	
	Surface	Bottom (18m)	Surface	Bottom (18m)	Surface	Bottom (18m)
15. 5.63	16.2	—	34.90	—	25.7	—
26. 5.63	14.9	—	34.55	—	25.65	—
12. 6.63	14.8	—	34.00	—	25.22	—
25. 6.63	13.4	13.4	34.30	34.4	25.86	25.93
11. 7.63	12.4	—	33.20	—	25.12	—
24. 7.63	12.45	—	33.17	—	25.10	—
9. 8.63	12.1	—	33.10	—	25.14	—
23. 8.63	12.5	—	33.60	—	25.45	—
10. 9.63	14.0	—	33.46	—	25.01	—
23. 9.63	14.7	—	33.30	—	24.71	—
7.10.63	15.8	—	33.80	—	24.86	—
22.10.63	16.4	—	34.20	—	25.15	—
8.11.63	16.2	—	34.72	—	25.55	—
21.11.63	16.7	—	35.15	—	25.64	—
5.12.63	18.0	—	34.99	—	25.30	—
19.12.63	19.5	—	—	—	—	—
3. 1.64	18.9	—	35.37	—	25.32	—
18. 1.64	18.9	—	35.32	—	25.29	—
31. 1.64	20.4	—	35.34	—	25.04	—
17. 2.64	22.7	—	35.47	—	24.34	—
2. 3.64	22.4	—	35.40	—	24.54	—
17. 3.64	20.5	—	35.40	—	24.99	—
1. 4.64	19.7	19.6	35.58	—	25.26	—
16. 4.64	19.1	19.0	35.53	35.60	25.43	25.49
30. 4.64	18.25	18.2	35.48	35.48	25.63	25.63
15. 5.64	16.5	16.7	34.87	35.01	25.67	25.79
31. 5.64	14.6	14.75	34.41	34.87	25.51	25.89
14. 6.64	14.85	14.85	34.46	34.74	25.56	25.79
29. 6.64	13.25	13.5	33.79	34.05	25.48	25.69
1. 7.64	13.9	14.0	33.41	33.79	24.98	25.48
13. 7.64	13.0	13.2	33.23	33.88	25.03	25.55
14. 7.64	13.25	13.2	33.43	33.87	25.19	25.55
28. 7.64	13.0	13.1	34.05	34.14	25.69	25.77
11. 8.64	12.9	12.9	33.89	34.05	25.56	25.69
28. 8.64	13.0	12.9	33.50	33.55	25.24	25.29
11. 9.64	12.8	12.7	33.60	33.69	25.33	25.40
26. 9.64	13.55	13.55	34.16	34.09	25.58	25.52
9.10.64	14.95	14.75	33.77	33.85	25.05	25.11
27.10.64	15.5	15.1	33.99	34.00	25.11	25.24
10.11.64	16.45	16.05	33.69	34.19	24.76	25.16
25.11.64	17.35	17.2	34.35	34.51	25.02	25.15
8.12.64	18.1	18.0	34.82	34.84	25.16	25.17
9.12.64	—	—	34.79	34.83	—	—
23.12.64	19.65	19.1	34.40	34.51	24.44	24.65
7. 1.65	22.4	22.0	34.65	34.68	23.96	23.98
21. 1.65	21.15	21.15	34.26	34.35	23.96	24.04
5. 2.65	21.8	21.6	34.48	34.56	24.00	24.07
19. 2.65	19.4	19.25	34.74	34.78	24.72	24.80
5. 3.65	—	—	34.28	—	—	—
9. 3.65	18.8	18.4	35.15	35.17	25.16	25.37
23. 3.65	20.1	—	34.26	—	24.22	—
6. 4.65	19.8	—	34.74	—	24.59	—
22. 4.65	18.8	—	34.92	—	24.98	—
21. 5.65	15.2	—	34.28	—	25.43	—

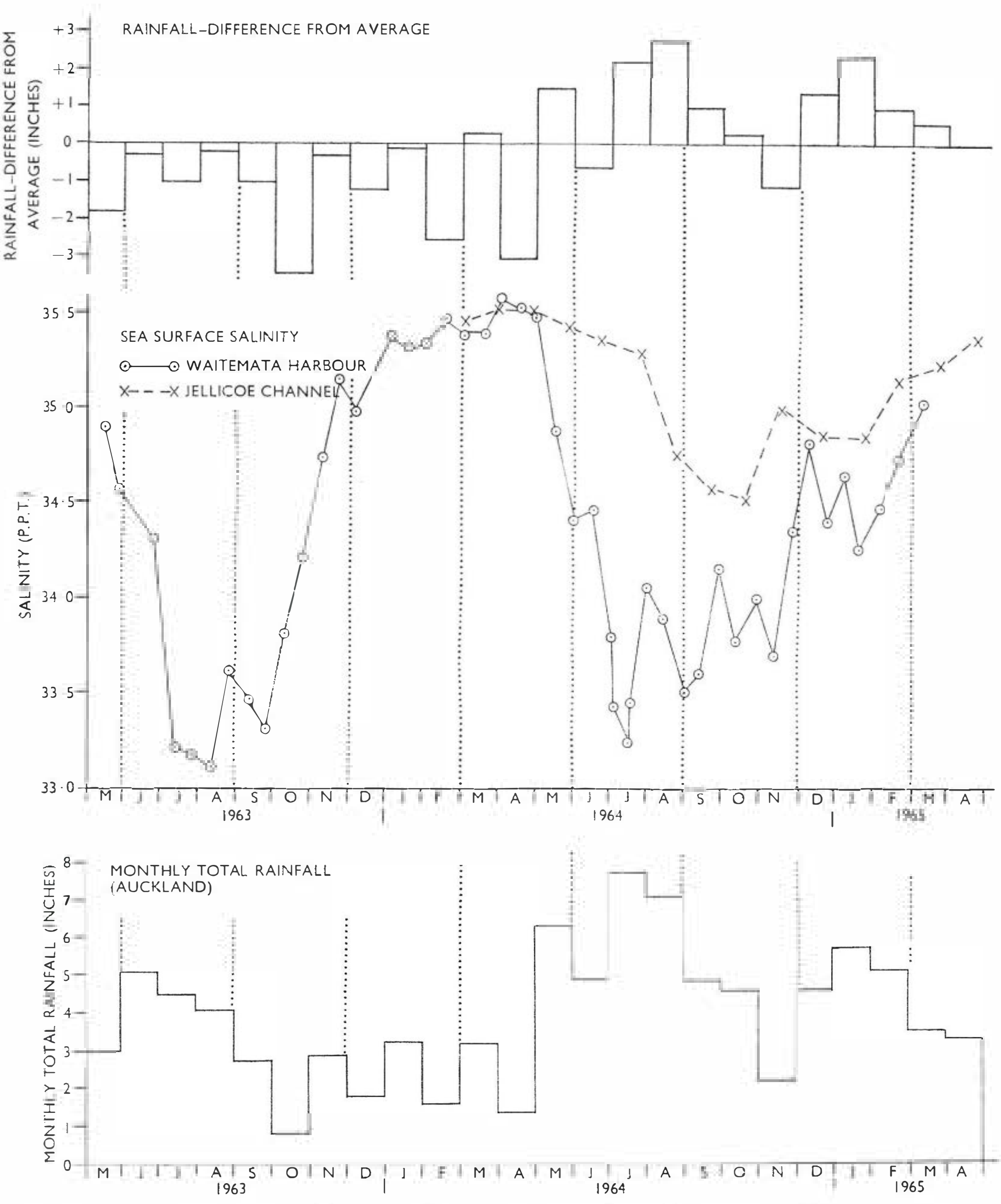

FIG. 4. Sea surface salinities at Sta. A and B and rainfall with its deviations from average (for Auckland). (Rainfall data from the Department of Civil Aviation, Auckland)

TABLE 2. Weather Conditions and Secchi Disc Readings for Sta. A - Waitemata Harbour

Date	Wind Speed (Knots)	Wind Direction	Cloud	Sun	Secchi Disc (m)
15. 5.63	light airs	—	2/10	clear	3.0
26. 5.63	15-20	SW	4/10	clear	2.5
12. 6.63	2-5	S	1/10	clear	2.7
25. 6.63	5-10	SW	3/10	o'cast/clear	2.2
11. 7.63	15	NE	1/10	clear	3.2
24. 7.63	10	SW	8/10	hazy	2.3
9. 8.63	3-5	SW	3/10	clear	1.5
23. 8.63	2	SSW	1/10	slight haze	3.5
9. 9.63	0-3	W	4/10	hazy	2.5
23. 9.63	7	NE	7/10	hazy	3.3
7.10.63	2-3	NE	3/10	slight haze	2.0
22.10.63	5-7	N	10/10	slight haze	3.3
20.11.63	15	SW	9/10	hazy	3.0
5.12.63	3-4	NE	2/10	clear	2.0
19.12.63	3-5	N	10/10	overcast	3.2
3. 1.64	3	W	5/10	clear	3.0
18. 1.64	20-25	SW	6/10	clear	2.3
31. 1.64	8-10	SW	6/10	o'cast/clear	2.3
17. 2.64	light airs	N	3/10	clear	2.3
2. 3.64	calm	—	3/10	clear	—
17. 3.64	calm	—	3/10	clear	—
1. 4.64	4-5	W	7/10	clear	—
16. 4.64	light airs	W	6/10	clear	—
30. 4.64	5-10	SW	7/10	hazy bright	1.8
15. 5.64	light airs	—	nil	slight haze	2.2
31. 5.64	calm	—	nil	clear	2.5
14. 6.64	10	NE	10/10	overcast	1.1
29. 6.64	10	S	9/10	overcast	2.6
13. 7.64	8-10	N	10/10	hazy	1.7
28. 7.64	5-8	SW	2/10	hazy bright	2.4
11. 8.64	3	N	3/10	bright	2.4
28. 8.64	8	SW	3/10	bright	2.8
11. 9.64	15	SW	6/10	intermittent	4.8
26. 9.64	15	W	7/10	intermittent	3.8
9.10.64	2	E	8/10	intermittent	3.5
27.10.64	5-6	S	3/10	intermittent	3.0
10.11.64	10	SW	6/10	intermittent	2.8
25.11.64	light airs	—	9/10	hazy	2.8
9.12.64	2-10	SE	1/10	clear	4.5
23.12.64	15-20	SW	8/10	hazy	2.5
7. 1.65	8-10	NE	5/10	clear	2.4
21. 1.65	0-5	NE	8/10	hazy	1.5
5. 2.65	1-3	SW	10/10	overcast	1.8
19. 2.65	15	SW	7/10	intermittent	1.5
9. 3.65	0-5	NE	5/10	hazy	2.5

Temperatures near the bottom reached their maximum in April, 3 months later than at the surface.

STA. B SALINITY (FIG. 4, 7; TABLE 3)

At the surface maximum salinities were recorded in autumn (April 1964; $35.50^{0}/_{00}$), coinciding with maximum values inshore. However, minimum surface values were recorded some 3 months later than in the Waitemata Harbour (October; $34.5^{0}/_{00}$). The total range was thus $0.9^{0}/_{00}$, about half that recorded inshore in the same period. Surface salinity decreased from April to July at a steady rate of $0.07^{0}/_{00}$ per month; then, after an abrupt drop in early August, continued to decline until October. Salinities rose sharply to $35.03^{0}/_{00}$ in November, but this rise was checked; the November value was not exceeded again until February. The general depression of salinity noted for the Waitemata Harbour during the latter half of 1964 and early 1965 was also apparent in the Jellicoe Channel. Surface salinity rose during autumn 1965, reaching a maximum of $35.4^{0}/_{00}$, some $0.10^{0}/_{00}$ lower than in the previous year in April.

Subsurface salinities differed considerably from those at the surface. The annual range of salinity variation decreased with depth. The variation was $0.50^{0}/_{00}$ below 20m, half the range in surface values (Table 2). During late autumn and early winter salinity gradually decreased while the water column was more or less isohaline. In late winter (August) there was an abrupt salinity decrease in all but the deepest water. In spring there was a progressive decrease of salinity towards the surface. Then in November salinities of the upper waters increased, so that by early summer the column was again nearly isohaline though the deeper waters were still slightly more saline. Salinities increased at all depths during summer, but in autumn the increase was more rapid at depth than nearer the surface. In April salinity values approximated those recorded at the same time in the previous year.

STA. B TURBIDITY (FIG. 5; TABLE 4)

The Secchi Depth in the Jellicoe Channel varied between 6.4 and 18.3m, and thus was always greater than any value obtained in the Waitemata Harbour. There was a pattern to the variations of Secchi Depth. It was relatively high in autumn, decreased through winter, and reached a minimum value in spring. After this it rose again until in autumn 1965 values were comparable with those recorded at the same time in the previous year.

Extinction coefficients have been estimated from the formula of Poole and Atkins (1929):

$$K = \frac{1.7}{D}$$

where K is the extinction coefficient and D is the Secchi depth in metres.

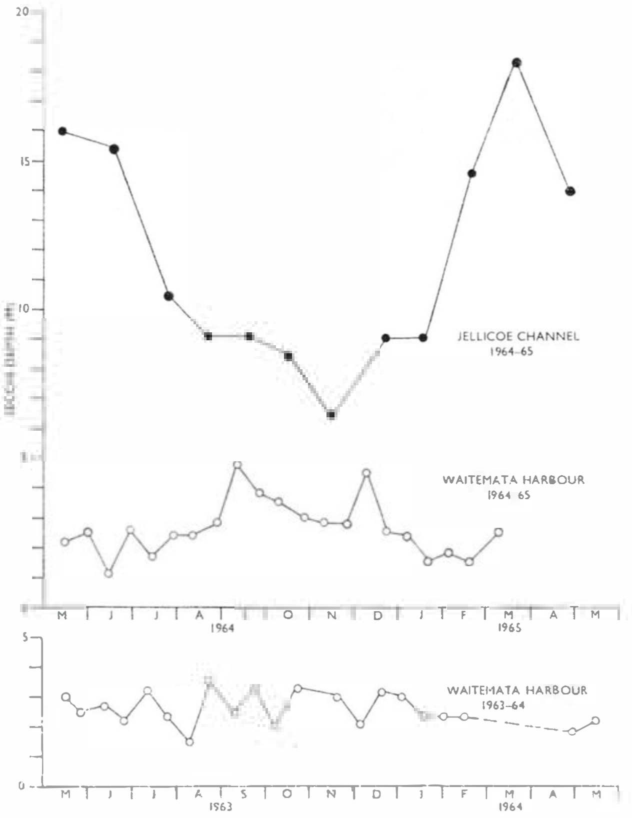

FIG. 5. Seasonal variations of Secchi Depth at Sta. A - Waitemata Harbour and Sta. B - Jellicoe Channel

PREVIOUS WORK

Knowledge of the hydrology of the Hauraki Gulf is far from comprehensive. Most of the published data concern surface temperature (Hounsell, 1935; Dellow 1955; R. M. Cassie, 1956; Skerman, 1958; Garner 1961). These temperature records have been collected mainly as supplementary information in the course of other research projects, and as a result they reflect the original purpose for which they were taken. As nearly all were taken at single fixed points from the shore without reference to tidal conditions, they refer to waters of differing tidal history, and the timing of the seasonal maxima and minima applies to waters flowing past the fixed points. Equivalent values for data recorded under standard tidal conditions will differ from these.

R. M. Cassie (1957, 1960b) discussed subsurface temperatures of the gulf, and Fuller (1953) surface salinity, but neither author was able to draw on regular observations.

Turbidity observations in Hauraki Gulf waters are confined to the few Secchi Disc readings of Dellow (1955), and the visual observations of R. M. Cassie (1957, 1960b). R. M. Cassie (1960b), in his discussion of Hauraki Gulf hydrology, used temperature and salinity to differentiate "Gulf" from "Oceanic" waters and

TABLE 3. Temperature, Salinity, and Density at Sta. B - Jellicoe Channel

Depth (m)	Temperature (⁰C)	Salinity (⁰/₀₀)	Density σ_t	Depth (m)	Temperature (⁰C)	Salinity (⁰/₀₀)	Density σ_t
1.3.64				29.3.64			
0	20.4	35.46	—	0	19.3	—	—
				9	19.2	—	—
				18	19.2	—	—
				27	18.95	—	—
				36	18.45	—	—
				45	17.65	—	—
26.4.64				23.5.64			
0	18.65	35.50	—	0	16.95	35.44	25.88
9	—	—	—	9	17.05	35.43	25.87
18	—	—	—	18	16.95	35.43	25.87
27	—	—	—	27	16.9	35.44	25.88
36	—	—	—	36	16.9	35.46	25.90
45	18.35	—	—	45	16.7	35.44	25.88
20.6.64				24.7.64			
0	15.95	35.37	26.06	0	14.15	35.29	26.43
9	15.9	35.46	26.13	9	14.1	35.33	26.46
18	15.85	35.46	26.13	18	14.05	35.23	26.38
27	15.9	35.44	26.11	27	14.05	35.15	26.31
36	15.85	35.45	26.12	36	14.0	35.24	26.38
45	15.9	35.43	26.10	45	14.0	35.01	26.21
22.8.64				19.9.64			
0	13.4	34.76	26.14	0	13.6	34.58	25.96
9	13.15	34.78	26.21	9	13.5	34.67	26.05
18	13.15	34.78	26.21	18	13.5	34.74	26.11
27	13.3	34.88	26.26	27	13.3	34.90	26.28
36	13.35	34.92	26.28	36	13.3	34.95	26.31
45	13.3	35.10	26.43	45	13.3	35.00	26.36
17.10.64				15.11.64			
0	14.8	34.51	25.64	0	16.0	35.03	25.80
9	14.7	34.51	25.63	9	16.0	34.98	25.76
18	14.25	34.68	25.89	18	15.95	34.88	25.69
27	14.1	34.88	26.10	27	15.9	34.91	25.72
36	13.95	35.03	26.25	36	15.35	35.03	25.95
45	13.55	35.01	26.32	45	13.85	35.10	26.33
19.12.64				23.1.65			
0	19.0	34.86	24.93	0	20.0	34.86	24.68
9	18.1	34.94	25.24	9	19.85	34.86	24.71
18	17.4	34.92	25.36	18	19.3	34.95	24.91
27	16.7	34.98	25.62	27	18.3	34.99	25.22
36	16.15	34.98	25.73	36	17.95	35.02	25.33
45	15.05	35.08	26.05	45	17.2	35.08	25.56
20.2.65				26.3.65			
0	19.0	35.17	25.19	0	18.8	35.23	25.29
9	19.0	35.12	25.14	9	18.8	35.24	25.29
18	19.0	35.14	25.16	18	18.7	35.23	25.40
27	18.7	35.14	25.24	27	18.1	35.34	25.54
36	17.25	35.13	25.60	36	17.2	35.42	25.83
45	16.45	35.11	25.67	45	17.15	35.40	25.84
24.4.65							
0	18.6	35.40	25.49				
9	18.6	35.36	25.46				
18	18.6	35.35	25.45				
27	18.6	35.40	25.49				
36	18.45	35.40	25.52				
45	17.8	35.42	25.64				

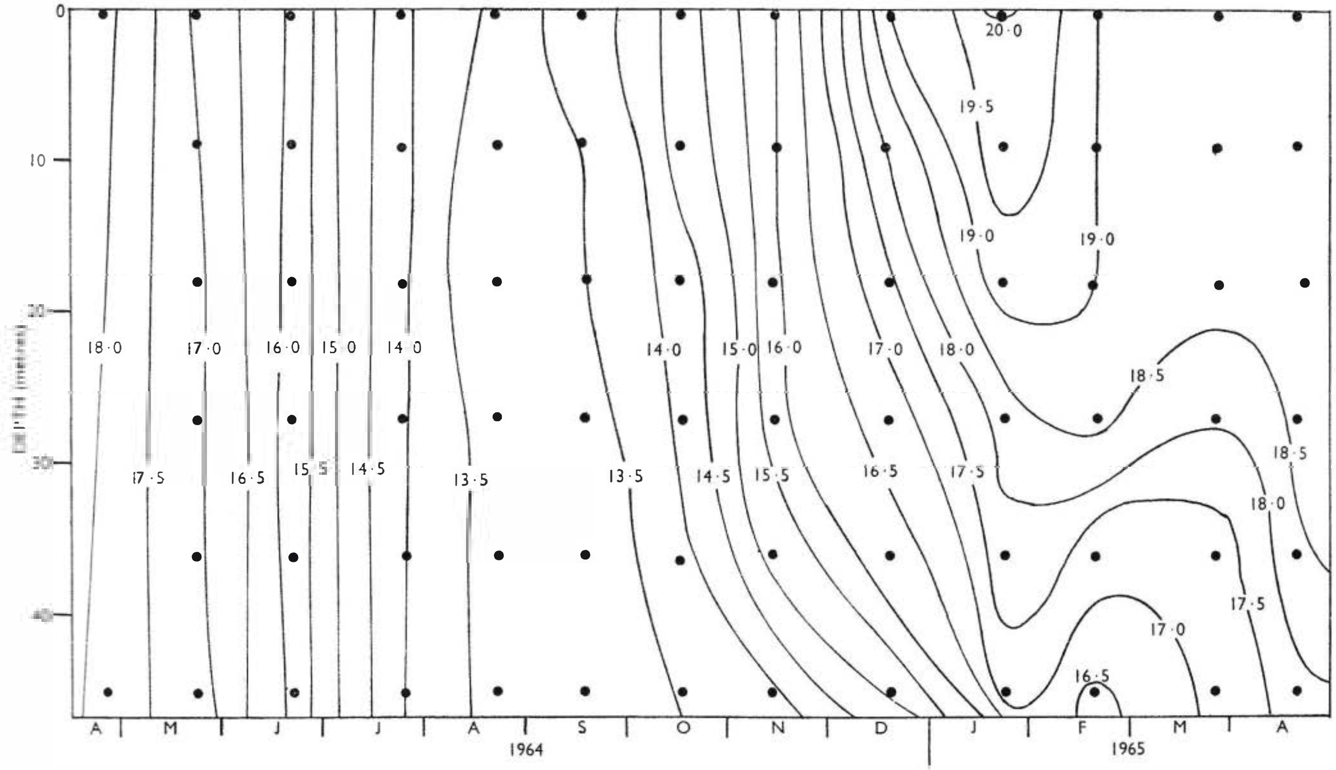

FIG. 6. Isopleth diagram of seasonal variation of subsurface temperature at Sta. B - Jellicoe Channel. (Black circles indicate points from which samples were taken)

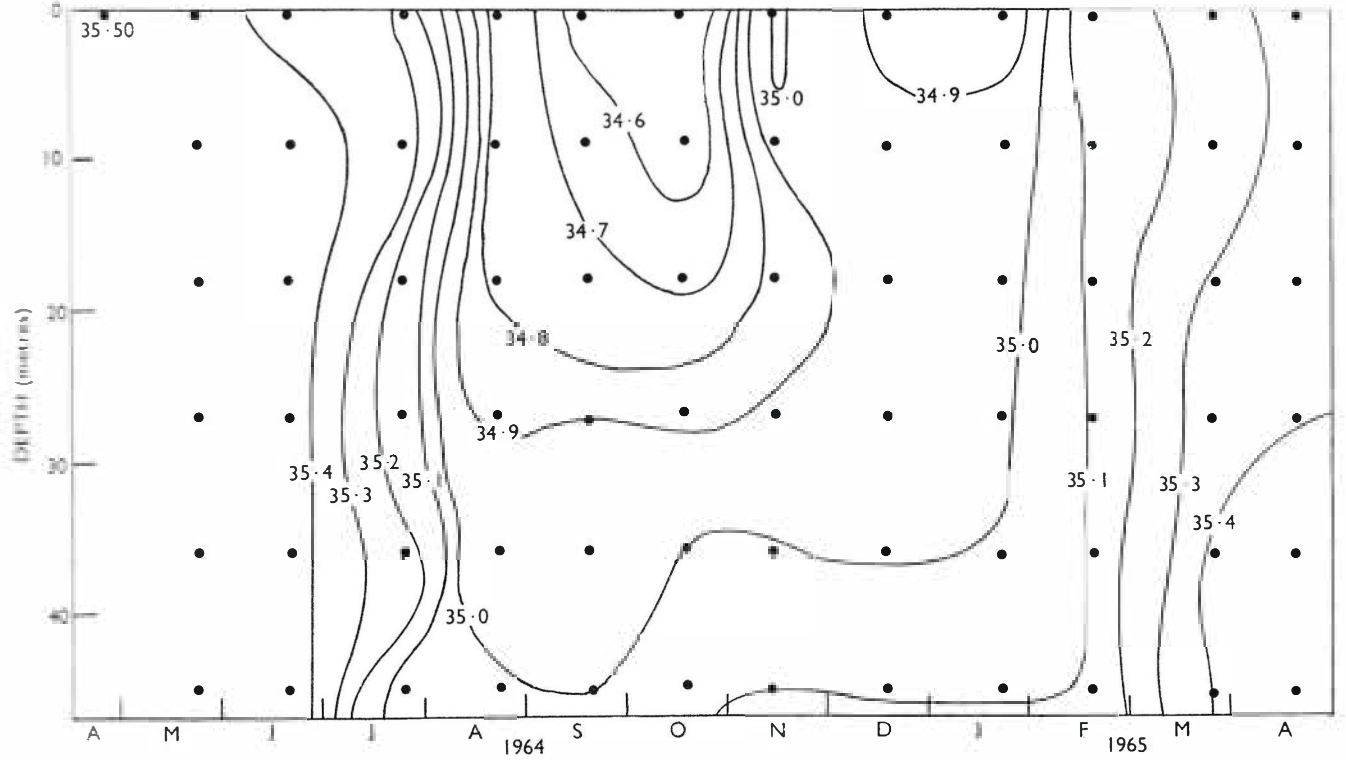

FIG. 7. Isopleth diagram of seasonal variation of subsurface salinity at Sta. B - Jellicoe Channel. (Black circles indicate points from which samples were taken)

TABLE 4. Weather Conditions and Secchi Disc Readings for Sta. B - Jellicoe Channel

Date	Wind Speed (Knots)	Wind Direction	Swell	Sea	Cloud	Sun	Secchi Disc (m)	Extinction Coefficient
1. 3.64	8-10	N	N	mod.	5/10	clear	9.1	0.19
29. 3.64	5	SW	NE	mod. swell	1/10	clear	—	—
26. 4.64	15	NE	nil	mod.	2/10	clear	—	—
23. 5.64	calm	—	nil	calm	9/10	hazy	16.0	0.10
20. 6.64	light airs	SE	SE	slight	1/10	bright	15.5	0.10
25. 7.64	5-8	W	N	slight	5/10	hazy	10.5	0.16
22. 8.64	light airs	—	nil	glassy	2/10	clear	9.1	0.19
19. 9.64	20-25	W	N	heavy chop	8/10	overcast	9.1	0.19
17.10.64	15	W	N	mod. chop	7/10	clear/o'cast	8.5	0.20
15.11.64	15	W	nil	mod. chop	10/10	overcast	6.4	0.27
19.12.64	10	E	N	slight	5/10	clear	9.1	0.19
23. 1.65	10	NE	N	mod.	5/10	clear	9.1	0.19
20. 2.65	15	SW	nil	mod.	4/10	clear	14.6	0.12
27. 3.65	15-20	W	N	mod. chop	4/10	bright	18.3	0.09
24. 4.65	15	NW	nil	mod.	10/10	overcast	14.1	0.12

related this division to that made earlier on planktological evidence by Fuller. The two bodies of water so recognised occupy different regions of Hauraki Gulf and their characteristics are summarised below.

Inner Hauraki Gulf

The outer boundary of this region corresponds quite closely with the 30m contour, and waters in this region are too shallow for a summer thermocline to develop. Shallow depth and proximity to land make temperature and salinity more variable here than further offshore. High turbidity of these waters (R. M. Cassie, 1957) is maintained by the introduction of material in suspension in freshwater run-off from the land and also by wave action on the extensive mud-flat shores and soft bottom. Fuller (1953) found the plankton in this region to be relatively constant in species composition and characteristically neritic.

Outer Hauraki Gulf

Waters seaward of the 30m contour are deep enough for a temperature gradient to develop in summer. The catchment area discharging directly into the outer gulf is small, and this, together with the greater depth of water, reduces the effects of proximity to the land. Therefore, temperature and salinity follow the broad seasonal trends rather than short-term weather variations. Water in this region is usually very clear. Plankton composition is variable and is related to the varying influence of offshore water (Fuller, 1953).

For the outer gulf R. M. Cassie (1960b) also described a summer (January) thermocline separating an upper layer (18-27m) of "Gulf" water of inshore origin from a deeper layer of "Oceanic" water originating from and continuous with offshore water. This is contrasted with the winter situation in which the separate identity of water masses is not as marked, but "Oceanic" water of high salinity fills the outer gulf and cushions inshore water of lower salinity against the shore.

DISCUSSION

The present results are consistent with Garner's (1961) and R. M. Cassie's (1960b) contention that seasonal variations of surface temperature and salinity in the Hauraki Gulf are simple, climatically controlled processes.

In the inner gulf the effect of climate is particularly evident because of the shallow depth and the proximity to land.

Sea-water temperature variations in Waitemata Harbour followed the contemporary trend of air temperatures* (Fig. 3). Although winter water temperatures stabilised within half a degree of the minimum value for 8 to 10 weeks during July and August, summer temperatures were unstable and remained within 0.5°C of the maximum for only 2 to 3 weeks. Both winters in the sampling period were appreciably warmer than average, and this was reflected in the surface water temperatures.

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* Department of Civil Aviation, N.Z. Miscellaneous Meteorological Publication 107 for 1963, 1964, and 1965.

In November 1963 and in January 1964 checks in the rise of water temperature occurred. These both coincided with spells of overcast weather accompanied by cool southerly winds. The monthly mean air temperatures for these months were lower than average while those for months before and after this period were higher than average. This illustrates the effect that air temperatures can have on inshore water temperatures. Similarly, the 6-week difference in the timing of annual maximum sea temperatures between 1964 and 1965 reflects the trend in air temperatures for both years. In the late winter and early summer of 1963-64 air temperatures were below average, particularly in January. After this both air and water temperatures rose to attain their maximum values for the cycle in February. However, in the following summer (1964-65) air temperatures were higher than average in December and early January but then became lower than usual. These differences were reflected in water temperatures, which reached a maximum in early January, some 6 weeks earlier than in the previous year.

Salinity variations followed the trend of rainfall (Fig. 4). Salinity variations in the Waitemata Harbour were generally similar in both years. Salinities were lowest in mid and late winter and highest in summer and autumn, reflecting the inverse relationship of salinity and rainfall distribution. During spring 1963 salinity increased and remained high until late autumn. However, in the following spring (1964) and summer the salinity varied greatly, and, although it tended to increase, absolute values were considerably lower than in the previous year. These differences can be related to differences in rainfall in the two years. The year May 1963 to April 1964 was drier than average; only March had more than average rain. Dryness was particularly marked in October, which had less than a third of the average rain, and in this month salinity rose more rapidly than in any other. The following year, May 1964 to April 1965, was generally wet, two months (June and November) having less than average rain. Salinity in the harbour was continually depressed, particularly in the summer 1964-65, but the general trend was upward.

Air temperature and rainfall acted jointly so that surface waters were generally less dense (Table 1). This stable situation resulted from the higher salinities at depth during periods of cooling and dilution of surface layers and from a combination of higher salinity and lower temperature at depth when both values are increasing at the surface. As any change in temperature or salinity in surface waters is rapidly expressed in subsurface values, rapid mixing by tide and wave action

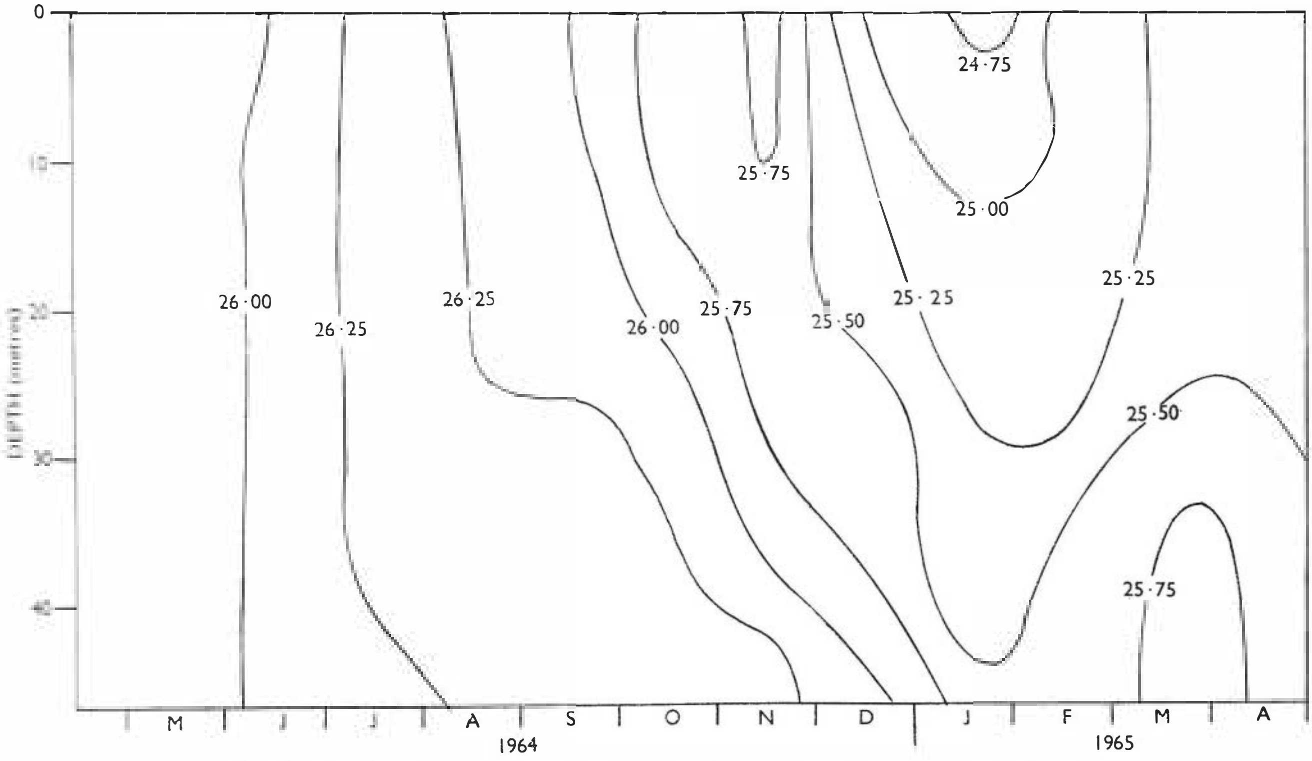
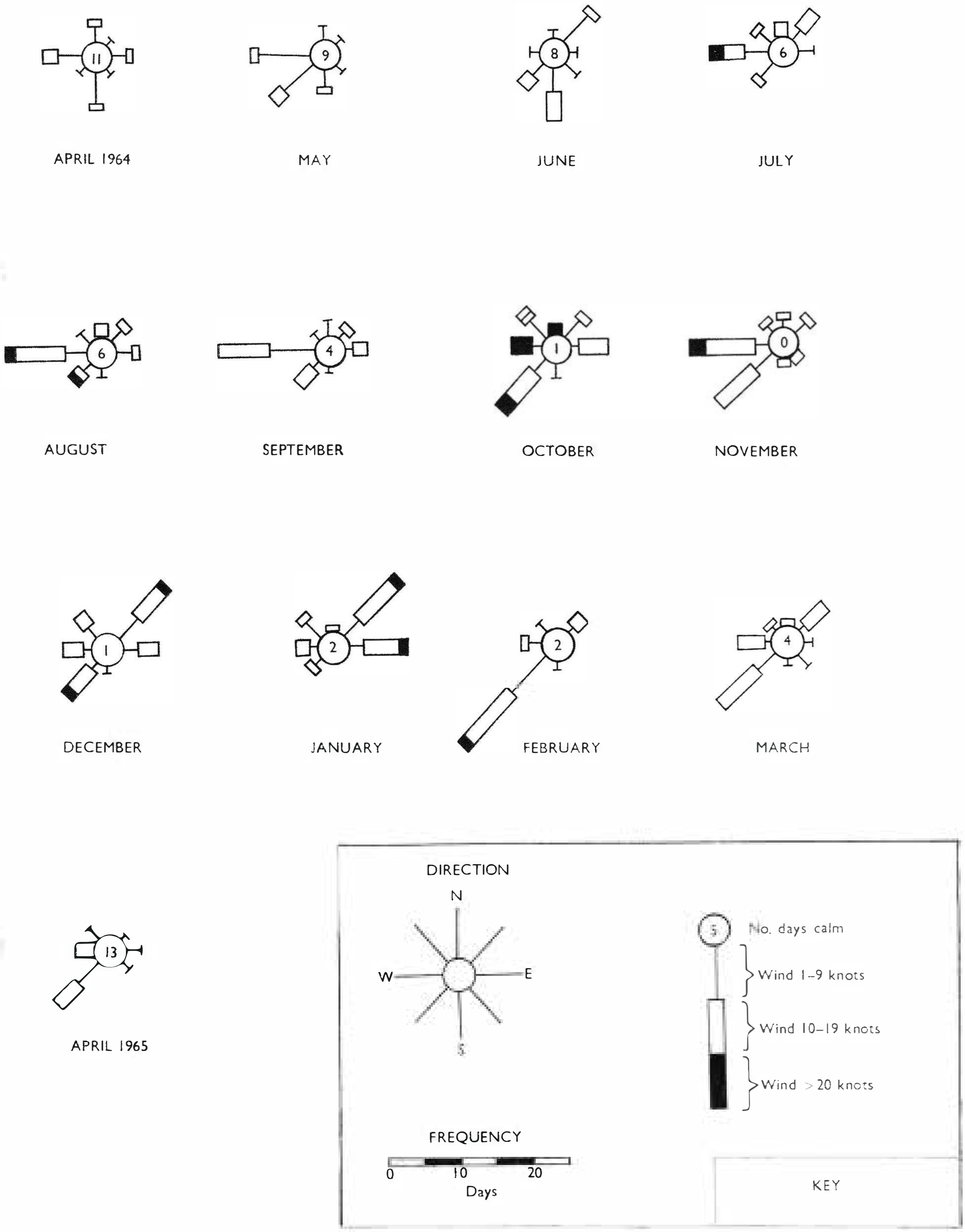


FIG. 8. Isopleth diagram of seasonal variations of density at Sta. B - Jellicoe Channel



APRIL 1964
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
MARCH
APRIL 1965

FIG. 9. Monthly frequency of wind direction and speed at Auckland, April 1964 - April 1965. (Based on 9 a.m. readings)

must occur. Waitemata Harbour is therefore slightly mixed by reciprocal tidal movements that affect all depths (Stommel, 1953).

Secchi depths for harbour waters were always very much smaller (Fig. 5, Table 2) than in the outer gulf. Results were recorded at high water and are undoubtedly representative of the inner gulf and not peculiar to the enclosed harbour waters. If the general rule that the euphotic zone extends down to three to four Secchi depths (Strickland, 1965) is accepted, it is likely that, despite their shallowness, inner gulf waters are frequently too turbid for the euphotic zone to extend to the bottom. This would tend to reduce the productivity of the inner gulf.

In the outer gulf (Jellicoe Channel) the trends of surface salinity and temperature were similar to those inshore, except that they were not as pronounced and there was a slight timing lag between the two areas (Figs 3, 4). Here, in deeper waters away from pronounced shore influence, the sequence of hydrological events was more complex, particularly with respect to the subsurface hydrology (Figs 6-8). Throughout late autumn and winter (April to August) the water column was isothermal and isohaline. Temperature and salinity decreased during this time as a result of heat loss and dilution at the surface. Falling temperature was the factor that increased the density of the surface waters and caused vertical instability. In later winter the fall in temperature ceased and the surface layers began to warm. Surface salinities continued to decline, minimum values being recorded in late October. During this spring period (until late October) warming and dilution at the surface both worked to lower the density of the surface waters, reinstating stability to the water column. As stability increased the deeper layers became effectively isolated from those nearer the surface and consequently showed little change in either temperature or salinity. Depression of salinity during spring affected progressively shallower layers. Since the deeper layers are diluted directly only during the late autumn and winter period of complete vertical mixing in the water column, the amount of rain falling during this period will probably determine the minimum salinity reached by the deepest water in any one year. In 1964 late-autumn and winter rainfall was higher than average, and it is reasonable to suppose that the salinity of the deeper waters was depressed.

Late spring (November) was drier than average and falling surface salinities were first checked and then rose rapidly, the rise recorded in 4 weeks exceeding half the annual range ($0.52^{0}/_{00}$). This rapid rise of salinity caused temporary instability in the upper 30m of the water column, which became isothermal and isohaline. By December a density gradient was again present at all levels, and this situation persisted into January.

After attaining maximum temperatures in mid summer, the surface layers cooled and became more saline. These changes gradually extended into deeper water as an upper layer of isothermal and isohaline water developed. At the same time other significant changes were occurring in the water below 30m. In February a drop of 0.7^{0}C from the previous month's value was recorded near the bottom. This drop, associated with increasing salinities, could hardly have resulted from processes operating at the surface but most probably resulted from a subsurface intrusion of oceanic water. The characteristics of offshore water at this season are consistent with this hypothesis (Garner, 1961). A subsurface intrusion could have been the result of the prevailing offshore winds during February (Fig. 9). In the previous two months (December and January) winds were mostly onshore northerlies and north-easterlies, and these would tend to hold the lighter neritic water within the gulf. In February moderate to fresh offshore southerlies and south-westerlies prevailed. The lighter surface waters would tend to be blown from the gulf by these winds to be replaced at depth by denser offshore waters of lower temperature and higher salinity.

In autumn the cooler water in the lower 20m of the water column gradually lost its thermal identity though salinity continued to increase. This salinity increase possibly resulted from further mixing of offshore waters. By April the column had become nearly isothermal and isohaline, with increasing salinity and falling temperatures at the surface.

Larger Secchi depths in early winter and again in late summer and autumn could well indicate the presence of clearer oceanic water, and the progressively shallower ones in late winter and spring are consistent with the development of neritic characteristics indicated both by hydrology and by plankton composition. So, to some extent, the Secchi Disc depths reflect the hydrological conditions in Jellicoe Channel during late summer and autumn, which are probably controlled by the prevailing winds.

It is difficult to gauge the extent to which the conditions encountered during this survey are typical of the Hauraki Gulf. Data recorded for inshore waters during this survey are similar to those recorded by previous authors, but those for the outer gulf are appreciably different. The January situation described by R. M. Cassie (1960b) had a thermocline lying between 18 and 27m, which separated a distinct upper mass of "Gulf" water and a lower mass of "Oceanic" water. Each of these water masses was described as being relatively homogeneous. No comparable situation was found in the summer 1964-65, and the "Oceanic" element in the plankton was less pronounced than at any other season. The nearest approximation to Cassie's mid-summer situation occurred in March (1965), when "Oceanic" water had undoubtedly been intruded beneath "Gulf" water. At this time a broad thermocline, between 18 and 36m, separated water masses of distinct origins and physical characteristics. The upper mass had a temperature of 18.8^{0}C and a salinity of $35.3^{0}/_{00}$, and the respective values for the lower mass were 17.2^{0} and $35.4^{0}/_{00}$.

It has been postulated that a thermocline develops as a result of the subsurface intrusions of offshore water during periods of strong or prevailing offshore winds. There is no reason to expect such intrusions to take place at a particular time of year, as they are a result of weather patterns that vary considerably from year to year. Intrusions of offshore water would be expected to introduce offshore plankton into the gulf, and it is notable that swarms of *Thalia democratica* such as were noted in the outer gulf in late spring and summer by Fuller (1953) and R. M. Cassie (1956) were not observed in this survey. That such swarms are typical is borne out by local fishermen and by personal observation in three previous summers. On this evidence it may well be that the conditions during this survey were to some extent atypical.

THE COMPONENTS AND OCCURRENCE OF ZOOPLANKTON

The zooplankton has been identified as far as possible in this general survey, and, of the holoplanktonic groups, only the appendicularians and minor crustaceans have not been classified into species. Most larvae are unknown, and identification is difficult and beyond the demands of a general survey. Except where they are unmistakable, no attempt has been made to separate species within larval groups such as polychaetes, cirripedes, decapods, and molluscs.

In general, larvae were not separately recognised, but the following were sufficiently distinctive to be noted:

Cephalochordata
Heteropleuron hectori Benham

Decapoda - Anomura
Petrolisthes elongatus (Milne-Edwards)
Petrolisthes novaezelandiae Filhol

Decapoda
Jaxea sp.

Apart from these species the following larval groups have been recognised separately: teleost eggs and larvae, ascidian tadpoles, echinoderm plutei, auriculariae, gastropod veligers, bivalve veligers, actinotrochs, cyphonautes, polychaete larvae, barnacle nauplii and cyprids, brachyuran zoeae, and miscellaneous decapod larvae.

Each of the zooplankton components is discussed with respect to the variations in abundance (Sta. A, Table 5; Sta. B, Table 6) and dominance at each station over the period sampled. Distributional notes are also given.

The distribution and abundance in time of each of the more important zooplankton components are shown in Figs. 10-41. Abundance has been plotted as (n + 5) on a logarithmic scale, n being the average number of individuals per haul. The addition of a small constant reduces the visual effect of variations that have little significance between small numbers. In most cases a fifth of each haul was counted and the occurrence of a single individual would give an estimate of five in the total haul. The addition of five as a constant raises a single occurrence to 10, a convenient level on a logarithmic scale. Values smaller than 10 indicate that there was less than one individual counted from each of the three hauls in each sample. A series of code words has been used to aid the discussion of abundance, and the scale corresponding to this series is as follows:

Range (No. per Haul)	
< 1	rare
1.1 - 10.0	occasional
10.1 - 100.0	frequent
100.1 - 1,000.0	common
1,000.1 - 10,000.0	abundant
> 10,000.0	very abundant

Vertical broken lines in the figures indicate intervals terminated by a zero observation.

Dominance (% abundance) has also been represented in Figs 10-41. The symbols and code words are as follows:

Symbol	Range (% of total)	Code Words
○	< 1	minor constituent
⌽	1·0 - 6·7	sub-associate
◔	6·8 - 23·3	associate
◐	23·4 - 50	sub-dominant
◕	50·1 - 76·7	dominant
●	76·8 - 93·3 93·4 - 99	ultra-dominant

The scale of dominance has been derived from the percentage of items expected to fall in each class interval of an eight-class-interval binomial distribution. The practical value of this is to reduce the perecntage intervals at the upper and lower ends of the scale where small changes are most likely to have significance. In any sample, using this scale, it is only possible to have one dominant (over 50%) or, where there are no dominants, there may be as many as four sub-dominants if they are very nearly equally represented.

Since copepods dominated most samples and usually comprised more than 50% of the total numbers, the zooplankton has been divided into two fractions for the estimation of dominance, i.e. copepods and non-copepods. Therefore dominance for any copepod is related to the numbers of other copepods in the particular sample, and non-copepods are related only to non-copepods. Copepods and non-copepods are discussed separately, and there are dominants or sub-dominants of each group in each sample.

HOLOPLANKTON

COPEPODA

Calanoida

Calanidae

Calanus australis Brodsky

Occurrence: Tables 5, 6; Fig. 10.

Sta. A: Rare in Waitemata Harbour, single specimens being taken in two samples (26 September 1964 and 9 December 1964). These occurrences coincided with high levels of abundance for the species at Sta. B.

Sta. B: Frequent in Jellicoe Channel and absent only in winter (May to August). In summer it was twice a sub-associate, but its maximum numerical abundance was in late spring. When present it was usually frequent and was once common.

Distribution: New Zealand (Farran, 1929; Brodsky, 1959, 1961; Bary, 1951); south-eastern Australian waters (Dakin and Colefax, 1933, 1940; Vervoort, 1957); Chile (Brodsky, 1959, 1961).

Brodsky (1959, 1961) described *Calanus australis* as one of a group of closely related Pacific and South Atlantic species formerly recognised as *Calanus finmarchicus* (Gunner) and *Calanus helgolandicus* (Claus). Brodsky (1961) noted that from figures and descriptions accompanying New Zealand and Australian records of *C. finmarchicus* (Farran, 1929; Dakin and Colefax, 1940; Vervoort, 1957), it is obvious that they deal with *C. australis.* It is likely that Kott (1957) was also dealing with *C. australis* as *C. finmarchicus.*

Bary (1951) recorded specimens of *Calanus* from southern New Zealand and placed them in *C. helgolandicus.* Again it is apparent that he too was dealing with *C. australis.*

C. australis is not a normal component of inshore Hauraki Gulf plankton. It is unrecorded from subtropical waters, and northern New Zealand appears to be near the northern limit of its range. From Farran (1929) and Bary (1951), who found it sparingly in the open ocean but quite plentifully within the 100m depth contour, *C. australis* appears to be characteristic of "shelf" plankton. Vervoort (1957) found it more common near the surface than at depth.

Calanus tenuicornis Dana

Occurrence: Table 6; Fig. 10.

Sta. A: Nil.

Sta. B: Taken in small numbers during winter and spring, maximum numbers in late winter. Never more than a frequent minor constituent of the copepod catch.

Distribution: Northern New Zealand (Farran, 1929); Foveaux Strait (Bary, 1951); south-eastern Australian waters (Dakin and Colefax, 1933, 1940); East Indies and from 40°N to 52°S in the Indo-west Pacific, but only sparingly and from few localities towards the limits of this range (Vervoort, 1946); and widespread in the warmer Pacific (Grice, 1961).

In this area *C. tenuicornis* is probably characteristic of oceanic waters. It is recorded as common in the North Island, New Zealand, but taken only once further south by Farran (1929). Bary (1951) took it from Foveaux Strait but regarded it, with *Labidocera cervi,* as indicating a warm-water influence. Probably this species is characteristic of warmer oceanic waters and is seldom numerous south of the Subtropical Convergence.

Nannocalanus minor (Claus)

Occurrence: Table 6; Fig. 10.

Sta. A: Nil.

Sta. B: An occasional to frequent minor constituent in autumn and early winter 1964, and, excepting one minor occurrence, then absent until late summer 1965 when it was again a frequent minor constituent.

Distribution: Northern New Zealand (Farran, 1929); off eastern Australia (Dakin and Colefax, 1940) where it is characteristically oceanic (Kott, 1957); East Indies (Vervoort, 1946); and widespread in warmer Pacific waters (Wilson, 1942, 1950; Grice, 1961).

Like *Calanus tenuicornis, Nannocalanus minor* is not characteristic of inshore waters in this area. Farran (1929) found *N. minor* common off the North Island, New Zealand. but not south of 40° 12'S, the southernmost record for the species. This species is characteristically found in warmer oceanic waters.

TABLE 5. Abundance and Occurrence of Zooplankton Components at Sta. A - Waitemata Harbour (1 = 1.0 or less per haul; 2 = 1.1 to 10.0; 3 = 10.1 to 100.0; 4 = 100.1 to 1000.0; 5 = 1000.1 to 10,000.0; 6 = more than 10,000)

Year	1963															1964		
Month	M		J		J		A		S		O		N	D		J		
Day	15	26	12	25	11	24	9	23	9	23	7	22	20	5	19	3	18	31
Calanus australis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Paracalanus parvus	5	4	4	4	4	4	4	4	4	4	4	3	4	3	3	4	5	4
Clausocalanus arcuicornis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ctenocalanus vanus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Centropages aucklandicus	3	3	3	3	3	3	4	3	3	3	3	2	3	2	3	4	4	3
Gladioferens pectinatus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Temora turbinata	5	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4	3	4
Pontella novaezelandiae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Labidocera cervi	3	3	3	3	2	3	3	3	3	2	2	2	2	2	2	1	2	2
Acartia clausi	3	3	4	4	4	4	5	4	4	4	4	3	4	4	4	4	5	4
Clytemnestra rostrata	2	—	1	1	1	3	2	2	1	—	2	3	2	2	2	2	—	—
Euterpina acutifrons	2	2	3	3	4	3	4	4	4	4	4	3	3	3	2	3	3	2
Oithona similis	—	—	—	—	—	1	2	2	2	1	2	2	2	—	—	2	3	—
O. plumifera	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—
O. nana	—	2	2	2	2	2	—	2	—	—	—	—	—	—	—	—	2	3
Oncaea media	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
O. venusta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oncaea sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Corycella rostrata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Corycaeus aucklandicus	4	3	3	3	3	4	3	4	5	5	5	5	4	4	4	4	5	5
Caligoid	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—	—
Penilia avirostris	3	2	—	—	—	1	—	—	1	—	—	2	3	—	—	2	3	3
Podon polyphemoides	—	2	1	2	—	—	—	—	—	—	—	—	—	—	—	—	2	1
Evadne nordmanni	2	2	1	—	—	—	—	—	—	—	—	—	2	—	—	—	3	3
Mysids	—	—	—	—	—	—	2	1	1	2	2	—	—	—	3	—	—	—
Cumaceans	—	—	—	—	—	—	1	—	2	—	2	—	—	2	—	—	—	—
Ostracods	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—
Amphipods	—	—	—	—	—	—	1	—	2	—	—	—	—	2	—	—	—	—
Thalia democratica	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—
Oikopleura spp.	3	3	3	3	3	4	3	3	4	4	4	3	4	3	3	4	4	3
Amphioxus juveniles	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sagitta serratodentata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—
Pleurobrachia pileus	3	3	2	2	3	3	4	4	4	4	4	3	3	3	3	2	—	2
Turritopsis nutricula	2	2	2	2	2	2	2	1	1	1	1	—	—	—	—	—	—	—
Obelia medusae	2	—	—	—	—	3	2	2	2	2	2	3	3	2	3	3	3	3
Miscellaneous medusae	2	3	2	1	2	3	3	3	3	3	4	4	3	3	3	3	3	3
Ephyra larvae	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
Sundry decapod larvae	3	3	2	2	2	3	3	3	3	4	4	3	4	3	3	4	4	3
Brachyuran zoeae	4	4	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4
Petrolisthes elongatus	1	2	1	—	1	2	2	1	1	2	2	2	2	2	2	2	3	3
P. novaezelandiae	2	2	1	2	2	2	2	2	2	3	3	3	3	2	3	3	3	2
Jaxea sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—
Heterosquilla spinosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Barnacle nauplii	2	4	3	3	3	4	4	4	4	3	3	3	5	3	4	6	5	5
Barnacle cyprids	1	—	2	2	2	3	3	3	3	2	3	2	4	2	—	—	3	3
Echinoderm plutei	—	—	—	—	—	—	—	—	—	—	—	2	3	2	2	3	3	2
Other echinoderm larvae	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—
Bivalve veligers	3	2	2	2	2	3	3	3	3	3	3	3	3	3	2	3	3	2
Gastropod veligers	2	3	2	2	2	3	2	3	3	3	3	3	3	2	2	2	3	3
Polychaete larvae	3	3	3	3	3	4	4	3	3	3	3	3	3	3	3	3	3	3
Cyphonautes	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	2	—	2
Actinotrochs	—	—	—	—	—	2	1	2	2	2	2	3	—	—	—	—	—	—
Muller's larvae	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Polyclad	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tornaria	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ascidian tadpoles	—	2	—	—	1	—	2	1	2	—	—	—	—	2	2	3	3	1
Teleost eggs	—	1	—	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Teleost larvae	—	—	—	—	1	2	2	1	2	1	1	2	2	2	2	2	2	2

Year	1964																						1965	
Month	F	M		A			M		J		J		A		S		O		N		D		J	
Day	17	2	17	1	16	30	15	31	14	29	13	28	11	28	11	26	9	27	10	25	9	23	7	21
Calanus australis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	2	—	—	—
Paracalanus parvus	4	4	3	5	5	4	6	4	5	5	5	5	4	5	4	4	4	5	5	5	4	4	4	3
Clausocalanus arcuicornis	—	—	—	—	—	—	—	—	—	—	—	—	—	3	2	2	—	2	—	—	—	—	—	—
Ctenocalanus vanus	—	—	—	—	—	—	—	—	—	—	—	—	—	3	2	2	2	2	—	—	—	—	—	—
Centropages aucklandicus	3	3	3	4	4	4	3	4	4	4	4	3	4	3	3	3	4	4	3	4	4	4	3	4
Gladioferens pectinatus	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Temora turbinata	5	5	5	5	5	5	5	4	3	4	4	3	4	4	4	4	4	4	4	4	3	4	5	3
Pontella novaezelandiae	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Labidocera cervi	3	2	—	2	2	2	3	3	3	2	3	2	3	3	3	2	3	1	3	2	—	3	2	3
Acartia clausi	5	3	3	3	3	4	4	4	4	3	5	4	5	4	2	4	3	3	3	4	3	3	4	3
Clytemnestra rostrata	—	—	3	2	3	2	—	2	2	—	—	—	2	3	3	3	2	—	—	—	—	—	—	2
Euterpina acutifrons	3	3	3	3	3	3	3	3	4	3	4	4	4	4	4	4	4	4	4	4	4	3	4	4
Oithona similis	—	—	2	2	—	2	2	—	—	—	2	3	3	3	3	3	3	3	3	3	3	3	—	2
O. plumifera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2	—	—	—	—	—
O. nana	3	2	3	3	3	3	2	2	2	2	2	2	2	—	—	2	—	—	2	—	—	2	—	3
Oncaea media	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—
O. venusta	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Oncaea sp.	—	—	—	—	—	—	—	—	—	—	—	—	2	3	2	2	—	2	—	—	—	—	—	—
Corycella rostrata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Corycaeus aucklandicus	3	3	4	5	4	3	4	4	4	3	3	3	4	4	3	5	5	4	4	3	3	3	3	3
Caligoid	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Penilia avirostris	2	2	2	2	—	—	—	—	—	—	3	—	—	2	—	—	—	—	—	—	—	—	2	3
Podon polyphemoides	4	3	4	3	4	3	3	—	3	2	2	3	4	5	—	—	—	—	4	2	—	—	2	3
Evadne nordmanni	4	3	4	3	3	4	2	—	—	—	—	2	2	4	3	3	3	2	3	4	3	3	3	4
Mysids	—	2	—	—	—	—	2	—	1	2	2	—	—	—	—	—	—	—	—	—	—	—	—	1
Cumaceans	—	—	—	—	—	2	2	—	2	—	2	—	2	—	—	—	—	2	—	—	—	—	—	—
Ostracods	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	2	2	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—	2	—	2	—	—	—	2
Amphipods	—	—	—	—	—	—	2	—	2	—	2	—	—	—	—	—	—	2	—	—	—	—	—	—
Thalia democratica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oikopleura spp.	4	3	4	4	4	4	4	3	4	3	3	4	4	4	2	—	4	4	3	4	4	4	4	4
Amphioxus juveniles	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Sagitta serratodentata	—	—	—	—	—	—	—	—	—	—	—	2	—	2	—	2	—	—	—	—	—	—	—	—
Pleurobrachia pileus	2	—	—	—	—	—	—	—	2	2	2	3	3	4	4	3	3	4	4	3	3	3	2	2
Turritopsis nutricula	—	—	—	—	—	2	3	3	3	3	3	3	3	2	1	—	1	—	—	—	—	—	—	—
Obelia medusae	3	2	—	—	—	—	—	—	—	2	2	3	2	3	3	3	2	3	3	3	2	2	3	3
Miscellaneous medusae	4	3	2	3	2	3	2	3	3	3	3	2	3	4	3	3	3	3	3	3	3	3	4	4
Ephyra larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Sundry decapod larvae	3	3	2	3	2	3	3	3	2	3	3	3	3	4	4	4	4	4	3	4	4	4	3	3
Brachyuran zoeae	4	3	3	3	3	3	3	4	4	4	4	4	4	4	5	4	4	4	3	4	4	4	3	4
Petrolisthes elongatus	—	1	—	2	—	—	2	2	2	2	2	2	3	2	—	2	3	3	—	2	—	3	1	3
P. novaezelandiae	2	—	2	—	2	2	2	2	2	2	2	2	2	4	4	3	3	3	3	3	2	2	—	—
Jaxea sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	2	—	—	—	—	—	—	—
Heterosquilla spinosa	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Barnacle nauplii	5	4	4	4	4	3	3	4	4	4	4	4	4	4	2	3	3	4	5	5	5	5	5	5
Barnacle cyprids	2	—	—	3	3	2	—	—	2	2	3	2	3	3	3	—	2	3	2	2	3	4	4	4
Echinoderm plutei	3	3	3	2	3	2	—	—	—	—	—	—	—	—	—	—	2	3	2	4	4	3	4	3
Other echinoderm larvae	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	3	2	2
Bivalve veligers	2	2	2	3	3	3	3	2	2	2	3	2	3	4	3	2	3	3	3	4	4	4	3	3
Gastropod veligers	3	3	3	3	3	3	3	—	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	4
Polychaete larvae	3	3	3	4	3	3	3	3	3	4	4	4	4	3	3	3	3	4	4	4	4	4	3	4
Cyphonautes	3	2	2	—	2	2	—	2	—	—	—	2	—	2	—	3	3	3	3	2	—	—	3	3
Actinotrochs	—	—	—	—	—	—	—	—	—	—	2	2	—	3	2	2	2	3	—	—	—	—	2	2
Muller's larvae	2	3	2	—	—	—	2	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	2	2
Polyclad	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Tornaria	2	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Ascidian tadpoles	2	3	3	1	3	2	2	2	3	—	2	1	2	2	—	—	2	2	2	4	1	4	3	4
Teleost eggs	2	2	2	2	—	—	—	—	2	2	2	2	2	2	2	2	2	3	2	3	4	1	—	2
Teleost larvae	2	—	2	2	2	—	2	—	2	2	1	2	2	2	—	—	—	2	2	3	3	2	3	—

TABLE 6. Abundance and Occurrence of Zooplankton Components of Sta. B - Jellicoe Channel. 1 = 1.0 or fewer per haul; 2 = 1.1 to 10.0; 3 = 0.1 to 100.0; 4 = 100.1 to 1,000.0; 5 = 1,000.1 to 10,000.0; 6 = 10,000.1 to 100,000; 7 = more than 100,000.1.

Year	1964										1965			
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Day	29	26	23	20	25	22	19	17	15	19	23	20	27	24
Calanus australis	2	3	—	—	—	—	3	3	4	3	3	3	3	2
Calanus tenuicornis	—	—	2	—	2	3	3	—	1	—	—	—	—	—
Nannocalanus minor	1	2	2	2	—	—	—	—	—	—	—	3	3	—
Eucalanus sp. (immature)	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Rhincalanus cornutus	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Mecynocera clausi	2	2	2	3	—	—	2	3	—	3	—	2	3	3
Paracalanus parvus	4	4	4	5	4	6	6	6	5	5	5	4	5	4
P. aculeatus	—	—	2	2	—	—	—	—	—	—	—	—	—	—
Clausocalanus arcuicornis	1	3	3	3	3	3	4	4	4	—	—	2	3	3
Ctenocalanus vanus	1	2	3	3	3	4	4	—	—	3	—	3	3	3
Centropages aucklandicus	2	3	—	2	—	3	4	4	4	4	4	—	—	—
C. bradyi	—	—	—	2	—	—	2	—	—	—	—	—	—	—
Temora turbinata	5	5	2	4	3	5	5	5	5	3	5	3	5	4
Pleuromamma gracilis	—	—	—	2	2	2	—	—	—	—	—	—	—	—
P. abdominalis	—	—	—	—	2	2	—	—	—	—	—	—	—	—
Lucicutia flavicornis	—	—	—	2	2	—	—	—	—	—	—	—	—	—
Heterorhabdus papilliger	—	—	—	—	—	2	—	—	—	—	—	—	—	—
Candacia bipinnata	—	—	2	2	—	—	—	—	—	—	—	—	—	—
Labidocera cervi	1	—	—	—	—	—	2	3	—	—	—	—	—	—
Acartia clausi	5	5	3	4	4	5	5	5	5	5	4	4	5	5
A. danae	3	—	3	3	—	3	1	—	—	—	—	4	4	3
Microsetella rosea	—	—	2	3	—	3	3	—	—	—	—	—	—	—
Clytemnestra rostrata	3	3	4	3	—	—	2	—	—	—	4	—	—	4
Euterpina acutifrons	3	4	4	4	2	5	4	4	4	4	5	—	4	4
Oithona similis	3	4	5	5	4	4	5	4	5	5	3	5	4	5
O. plumifera	2	—	3	3	3	3	3	3	4	4	—	3	—	—
O. nana	—	4	—	—	—	—	—	—	3	4	5	—	3	4
Oncaea media	1	2	2	3	3	3	3	3	3	1	—	—	1	—
O. mediterranea	—	—	—	2	2	—	2	—	—	—	—	—	—	—
O. venusta	—	2	2	3	3	3	2	—	—	1	—	—	—	—
O. conifera	—	—	—	3	2	—	—	—	—	—	—	—	—	—
Oncaea sp.	—	—	2	3	3	4	3	3	3	3	—	1	—	—
Corycella rostrata	—	—	—	3	—	—	2	3	—	—	—	—	—	—
Corycaeus aucklandicus	5	5	4	5	3	5	4	5	5	4	5	4	5	5
C. crassiculus	—	—	—	2	2	—	—	—	—	—	—	—	—	—
Penilia avirostris	4	4	—	—	2	—	—	—	—	3	7	3	4	5
Podon polyphemoides	—	2	—	—	—	—	—	—	—	—	—	—	—	—
Evadne nordmanni	4	3	2	—	—	5	3	3	4	—	—	3	—	2
Nyctiphanes australis	—	—	3	4	3	3	4	5	5	3	4	5	4	4
Mysids	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	1	—	—	—	2	—	3	—	—	3	3	—	—	—
Ostracods	—	—	—	1	3	—	—	—	—	—	—	—	—	—
Oikopleura spp.	4	5	3	4	5	5	4	4	5	5	5	5	5	5
Fritillaria sp.	—	—	2	—	3	—	—	—	—	—	—	—	—	—
Salpa fusiformis	—	—	—	—	—	—	—	—	—	—	—	2	—	—
Thalia democratica	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Doliolum nationalis	—	—	—	—	—	—	—	—	—	—	—	—	5	6
Creseis virgula	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Limacina inflata	—	—	—	—	—	—	—	—	—	—	—	3	—	—
Firoloida desmaresti	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Sagitta serratodentata	1	2	3	3	3	3	3	2	3	3	4	3	3	3
Pterosagitta draco	—	—	—	2	—	—	—	—	—	—	—	—	—	—
Pleurobrachia pileus	—	3	3	3	3	3	2	4	3	3	5	—	2	3

TABLE 6 — *continued*

Year	1964										1965			
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Day	29	26	23	20	25	22	19	17	15	19	23	20	27	24
Obelia medusae	—	—	—	4	—	3	4	—	—	3	3	—	—	2
Miscellaneous medusae	—	3	2	3	3	4	3	4	—	—	4	3	3	2
Nectophores	—	2	3	2	3	2	—	—	—	—	—	2	—	—
Sundry decapod larvae	2	3	3	4	3	4	4	3	3	3	3	—	3	3
Brachyuran zoeae	—	3	2	3	2	4	3	3	—	3	4	—	3	3
Petrolisthes elongatus	—	—	—	—	—	—	—	—	—	—	3	—	—	—
P. novaezelandiae	—	—	—	2	—	3	2	2	—	—	3	—	—	2
Jaxea sp.	—	—	—	—	—	2	3	—	—	—	—	—	—	—
Jasus (phyllosoma)	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Callianassa larvae	—	3	2	—	—	2	—	—	3	—	—	—	—	3
Stomatopod larvae	2	—	—	—	—	2	2	—	—	—	—	—	—	—
Barnacle nauplii	1	2	2	3	3	3	3	3	—	3	5	3	4	3
Barnacle cyprids	3	3	—	2	—	3	3	3	—	—	4	—	3	3
Amphioxus juveniles	—	—	—	—	—	4	3	2	—	—	—	—	1	—
Ascidian tadpoles	—	—	—	—	—	—	—	—	—	3	—	—	—	—
Echinoderm plutei	5	4	2	2	—	—	—	—	—	4	5	4	—	3
Auriculariae	2	3	—	—	—	—	—	—	—	—	3	—	4	3
Other echino larvae	—	—	—	—	—	—	—	—	—	—	3	—	—	—
Cyphonautes	—	2	2	3	—	2	3	4	4	—	—	—	—	—
Actinotrochs	—	—	—	—	—	2	—	3	—	—	—	—	—	—
Gastropod veligers	3	3	3	4	2	3	3	4	4	4	4	3	4	3
Bivalve veligers	3	3	3	3	3	3	—	4	5	5	5	3	4	3
Polychaete larvae	1	3	3	3	3	4	4	5	—	4	4	3	3	4
Pilidium larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	3
Teleost eggs	2	—	—	—	3	3	3	—	3	—	3	—	3	3
Teleost larvae	3	2	2	2	2	3	2	3	3	4	3	—	—	—

Eucalanidae

Eucalanus sp.

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: The only specimen collected was immature, and the species could not be identified. A number of species of *Eucalanus* are recorded from oceanic waters of the region (Farran, 1929; Bary, 1951).

The single occurrence in coastal waters is consistent with the oceanic distribution of the genus in these waters.

Rhincalanus cornutus (Dana)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: A single immature specimen was taken in August 1964 and identified from the distinctive anchor-shaped rostrum.
Distribution: Off northern New Zealand (Farran, 1929); Great Barrier Reef (Farran, 1936); south-eastern Australian waters (Dakin and Colefax, 1933, 1940); East Indies (Vervoort, 1946); and widespread in the tropical and subtropical Pacific (Grice, 1961).

Rareness of this species is surprising since Fuller (1953) cited it as being found occasionally in the outer gulf in association with salps and indicating the presence of oceanic water. It is also recorded from off northern New Zealand but not from the south (Farran, 1929). The species is characteristically oceanic (Vervoort, 1946).

Mecynocera clausi I. C. Thompson

Occurrence: Table 6; Fig. 10.
Sta. A: Nil.
Sta. B: Occasional to frequent through most of the year, but never more than a minor constituent. Only once absent from two consecutive monthly samples (July and August 1964). Absent from two other samples (November 1964 and January 1965).
Distribution: Common off New Zealand but not south of 40^{0}S (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); East Indies (Vervoort, 1946); off southern New Zealand (Bary, 1951).

Although never very abundant in the outer gulf this species is very distinctive in appearance and will probably prove to be a useful oceanic indicator in the area. Farran (1929) found it especially plentiful off northern New Zealand but not south of 46^{0} 60'S. Although normally regarded as a warm-water, oceanic species (Vervoort, 1946), Bary (1951) captured it well to the south of New Zealand.

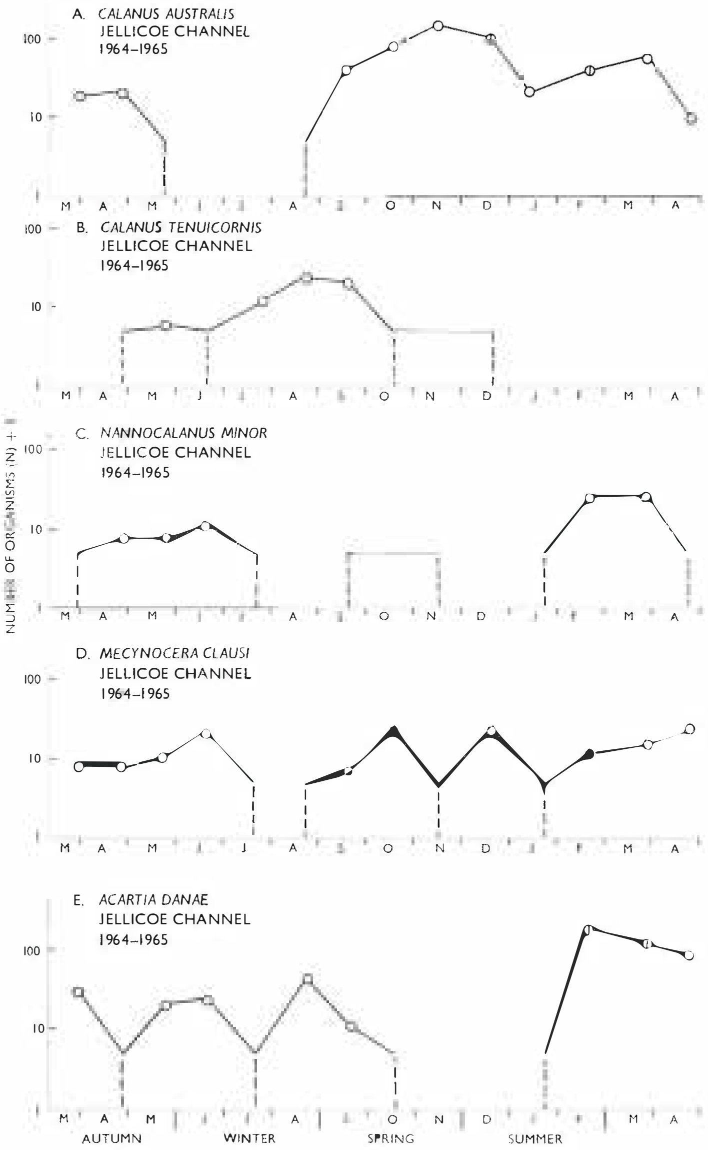


Fig. 10

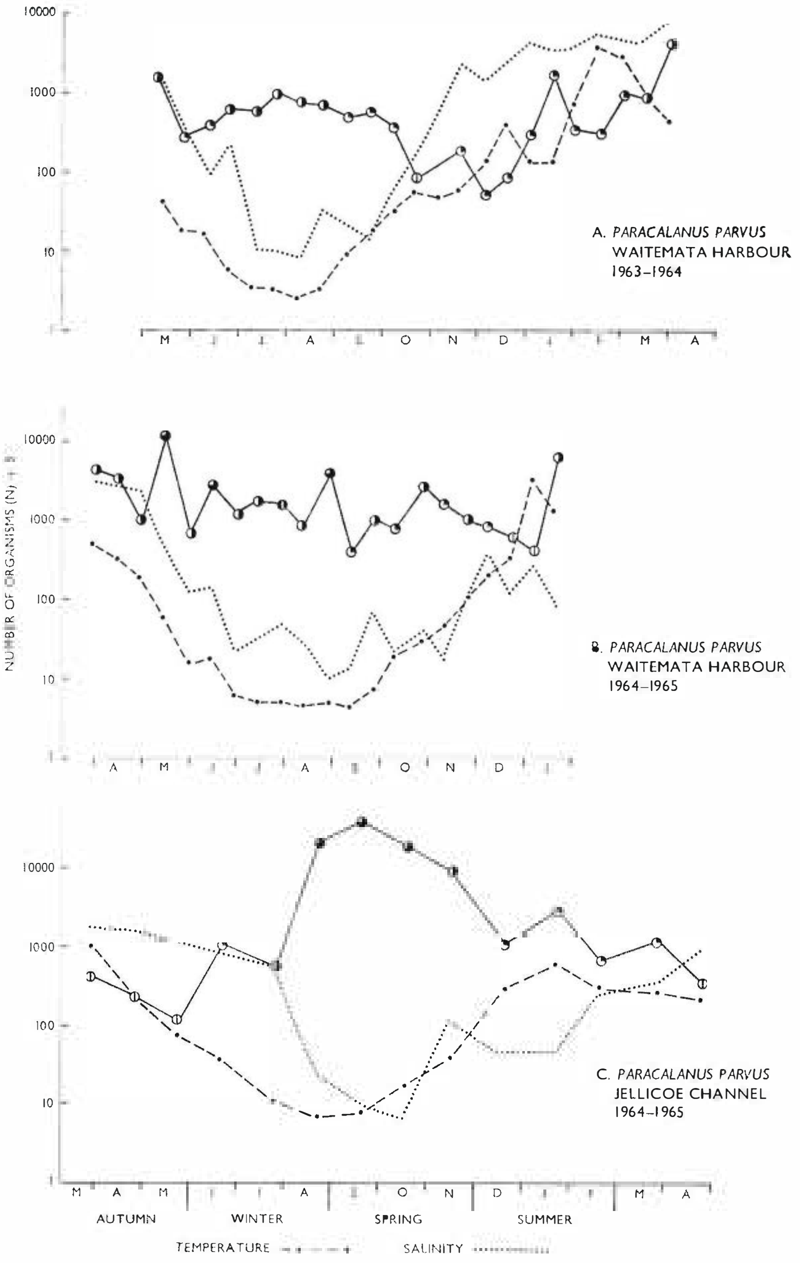
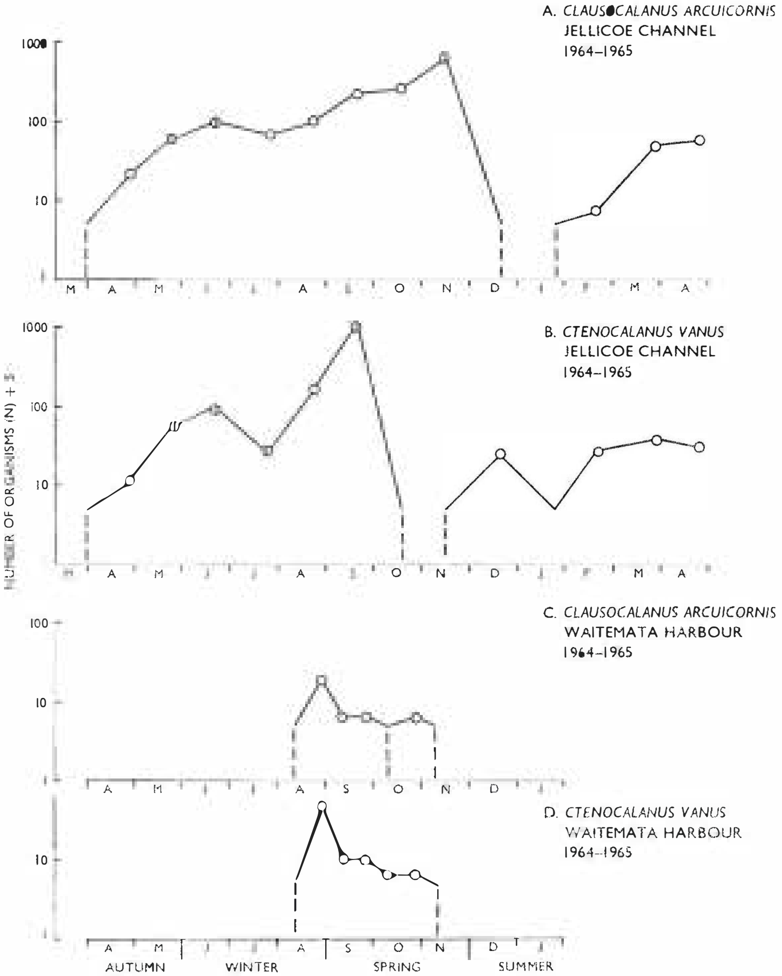


Fig. 11

FIGS 10–11. Seasonal variations of abundance and dominance of zooplankton components (see p.28 for key to symbols)



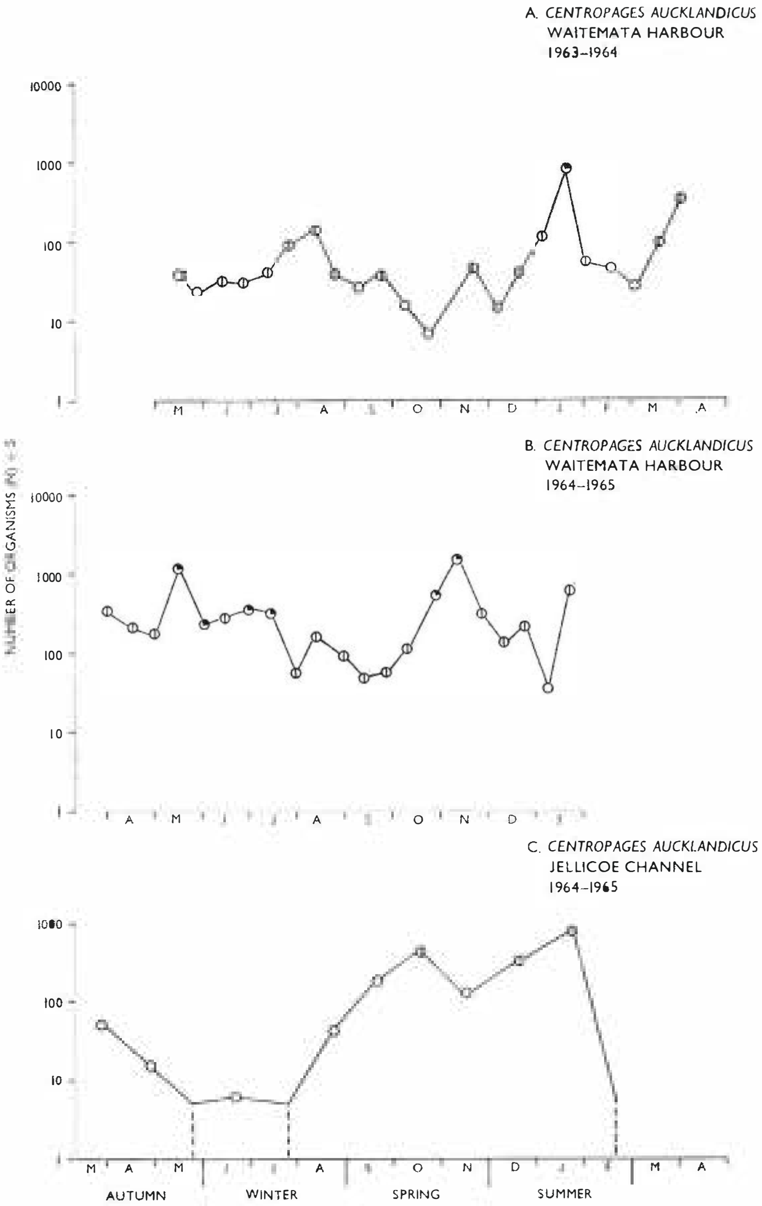
A. *CLAUSOCALANUS ARCUICORNIS*
JELLICOE CHANNEL
1964–1965

B. *CTENOCALANUS VANUS*
JELLICOE CHANNEL
1964–1965

C. *CLAUSOCALANUS ARCUICORNIS*
WAITEMATA HARBOUR
1964–1965

D. *CTENOCALANUS VANUS*
WAITEMATA HARBOUR
1964–1965

Fig. 12



A. *CENTROPAGES AUCKLANDICUS*
WAITEMATA HARBOUR
1963–1964

B. *CENTROPAGES AUCKLANDICUS*
WAITEMATA HARBOUR
1964–1965

C. *CENTROPAGES AUCKLANDICUS*
JELLICOE CHANNEL
1964–1965

Fig. 13

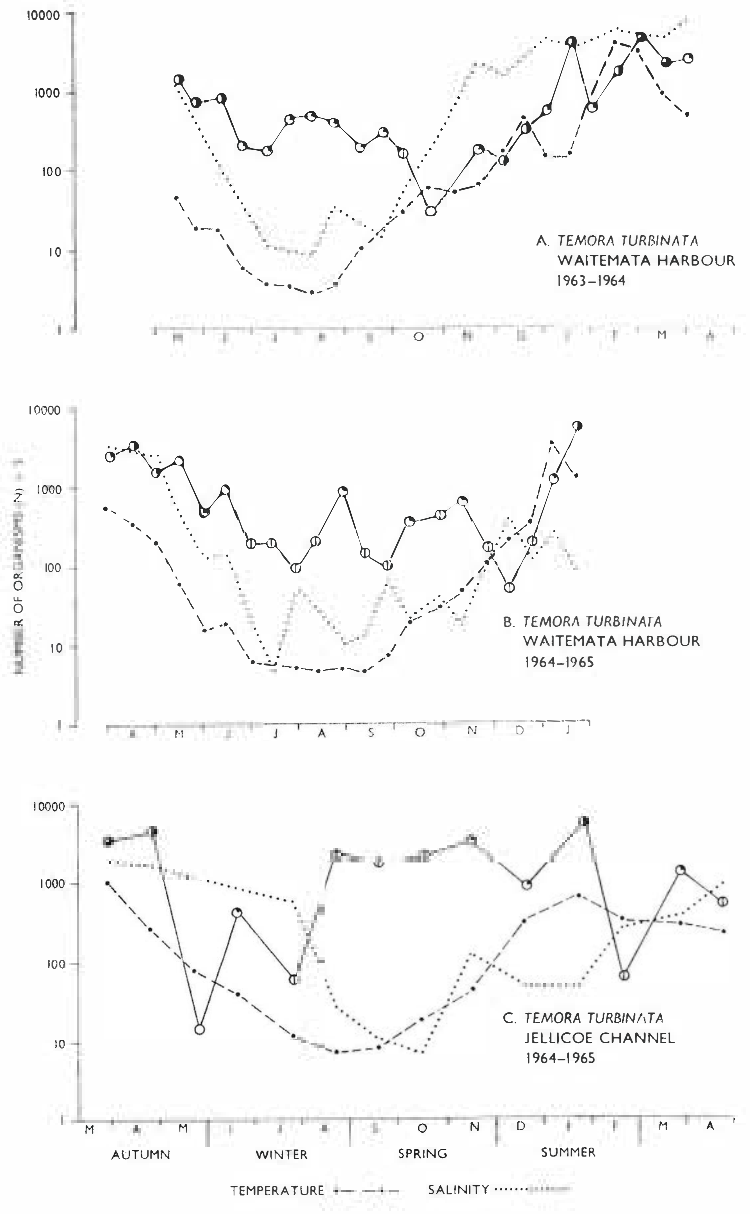

10000
1000
100
10
1
A. TEMORA TURBINATA
WAITEMATA HARBOUR
1963–1964
M J J A S O N D J F M A
NUMBER OF ORGANISMS (N) + 5
B. TEMORA TURBINATA
WAITEMATA HARBOUR
1964–1965
A M J J A S O N D J
C. TEMORA TURBINATA
JELLICOE CHANNEL
1964–1965
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER
TEMPERATURE
SALINITY

Fig. 14

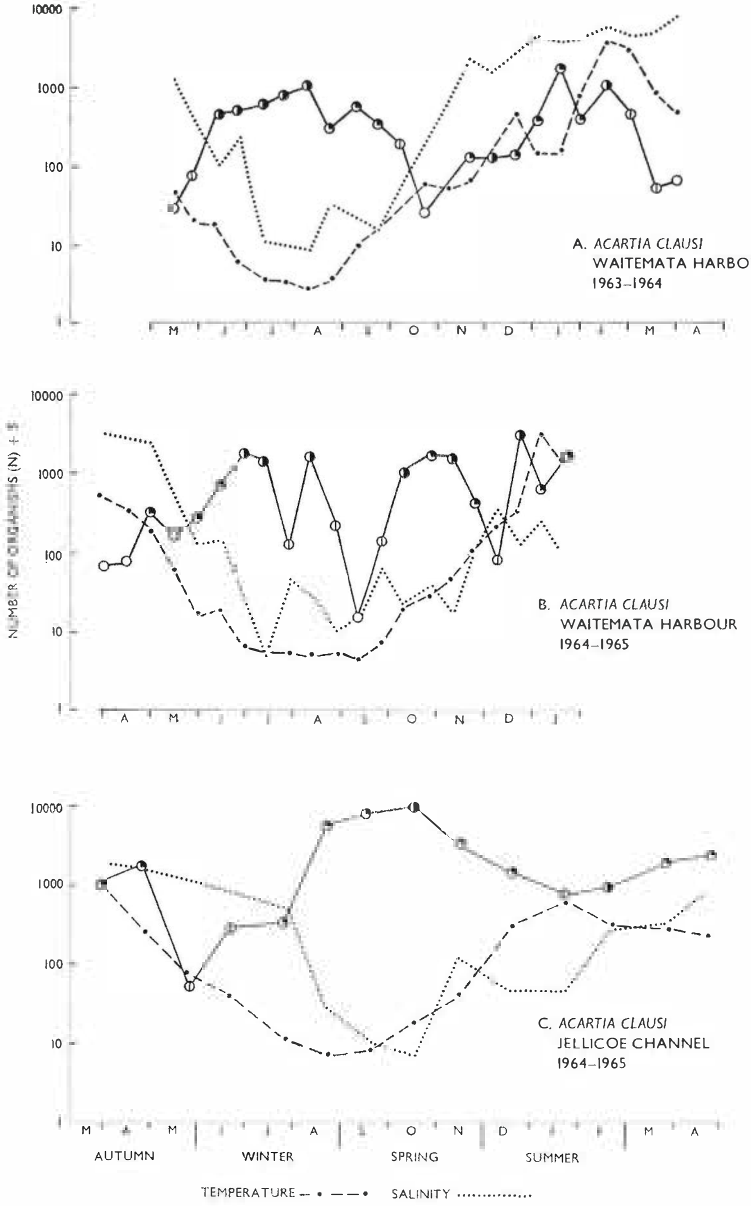

10000
1000
100
10
1
A. ACARTIA CLAUSI
WAITEMATA HARBOUR
1963–1964
M J J A S O N D J F M A
NUMBER OF ORGANISMS (N) + 5
B. ACARTIA CLAUSI
WAITEMATA HARBOUR
1964–1965
A M J J A S O N D J
C. ACARTIA CLAUSI
JELLICOE CHANNEL
1964–1965
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER
TEMPERATURE
SALINITY

Fig. 15

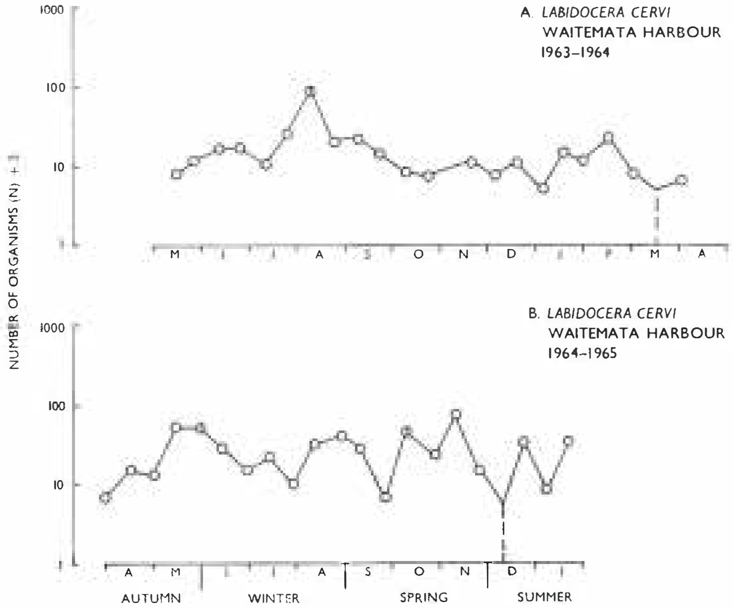

A. LABIDOCERA CERVI
WAITEMATA HARBOUR
1963–1964
B. LABIDOCERA CERVI
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
AUTUMN
WINTER
SPRING
SUMMER

Fig. 16

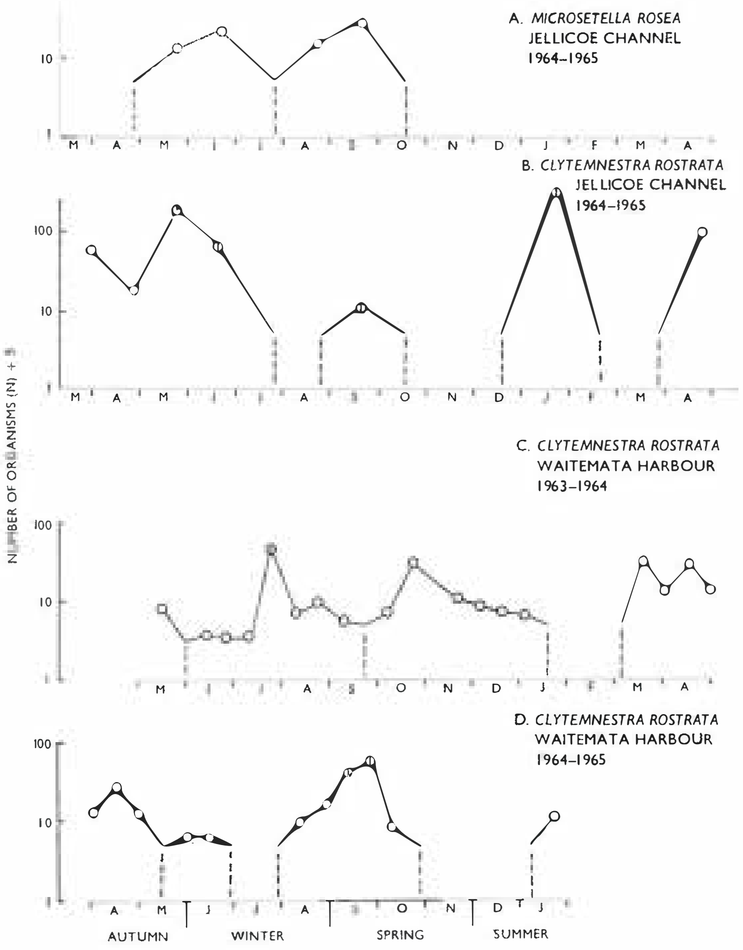

A. MICROSETELLA ROSEA
JELLICOE CHANNEL
1964–1965
B. CLYTEMNESTRA ROSTRATA
JELLICOE CHANNEL
1964–1965
C. CLYTEMNESTRA ROSTRATA
WAITEMATA HARBOUR
1963–1964
D. CLYTEMNESTRA ROSTRATA
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) + 1
100
10
1
M A M J J A S O N D J F M A
M J J A S O N D J F M A
A M J J A S O N D J
AUTUMN
WINTER
SPRING
SUMMER

Fig. 17

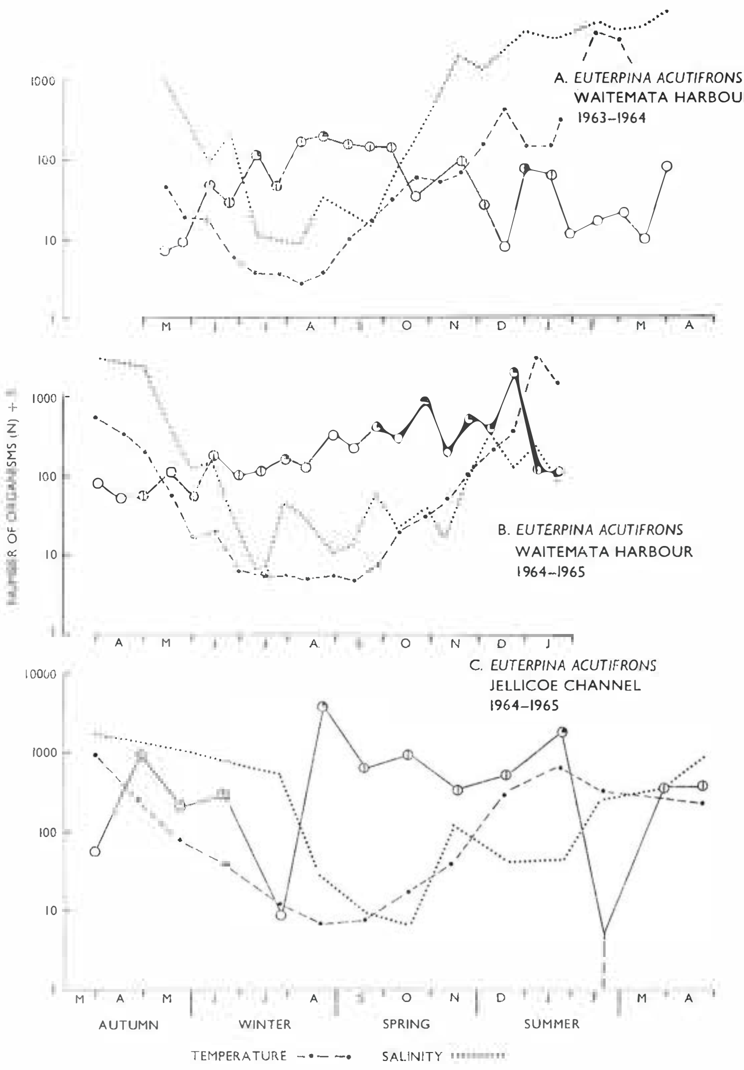

A. *EUTERPINA ACUTIFRONS*
WAITEMATA HARBOUR
1963–1964
1000
100
10
1
M J J A S O N D J F M A
B. *EUTERPINA ACUTIFRONS*
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
A M J J A S O N D J
C. *EUTERPINA ACUTIFRONS*
JELLICOE CHANNEL
1964–1965
10000
1000
100
10
1
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER
TEMPERATURE
SALINITY

Fig. 18

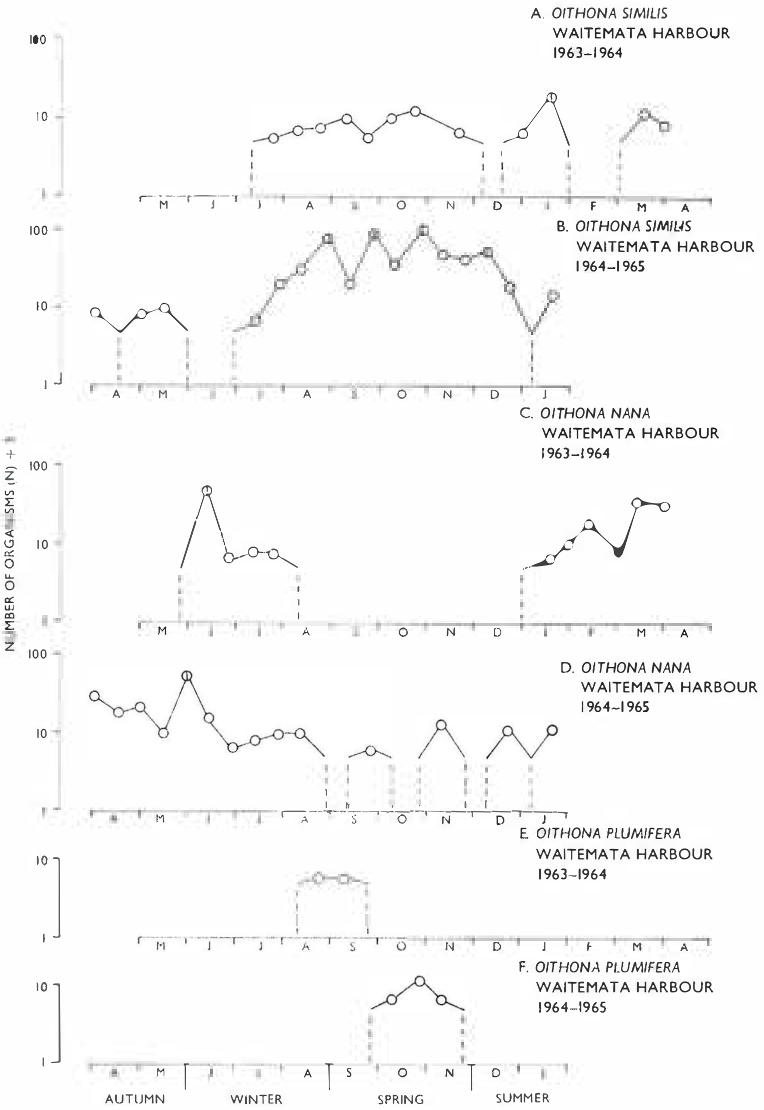

A. *OITHONA SIMILIS*
WAITEMATA HARBOUR
1963–1964
100
10
1
M J J A S O N D J F M A
B. *OITHONA SIMILIS*
WAITEMATA HARBOUR
1964–1965
100
10
1
A M J J A S O N D J
C. *OITHONA NANA*
WAITEMATA HARBOUR
1963–1964
NUMBER OF ORGANISMS (N) + 1
100
10
1
M J J A S O N D J F M A
D. *OITHONA NANA*
WAITEMATA HARBOUR
1964–1965
100
10
1
A M J J A S O N D J
E. *OITHONA PLUMIFERA*
WAITEMATA HARBOUR
1963–1964
10
1
M J J A S O N D J F M A
F. *OITHONA PLUMIFERA*
WAITEMATA HARBOUR
1964–1965
10
1
A M J J A S O N D J
AUTUMN
WINTER
SPRING
SUMMER

Fig. 19

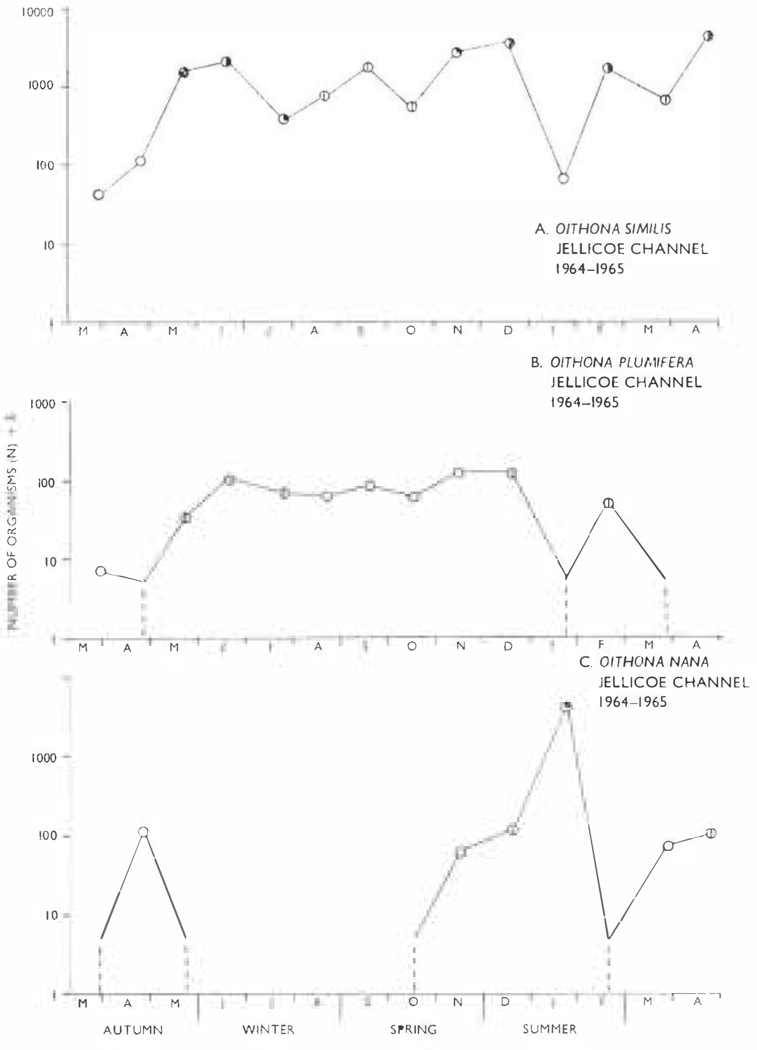

10000
1000
100
10
1
A. OITHONA SIMILIS
JELLICOE CHANNEL
1964–1965
B. OITHONA PLUMIFERA
JELLICOE CHANNEL
1964–1965
C. OITHONA NANA
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 5
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 20

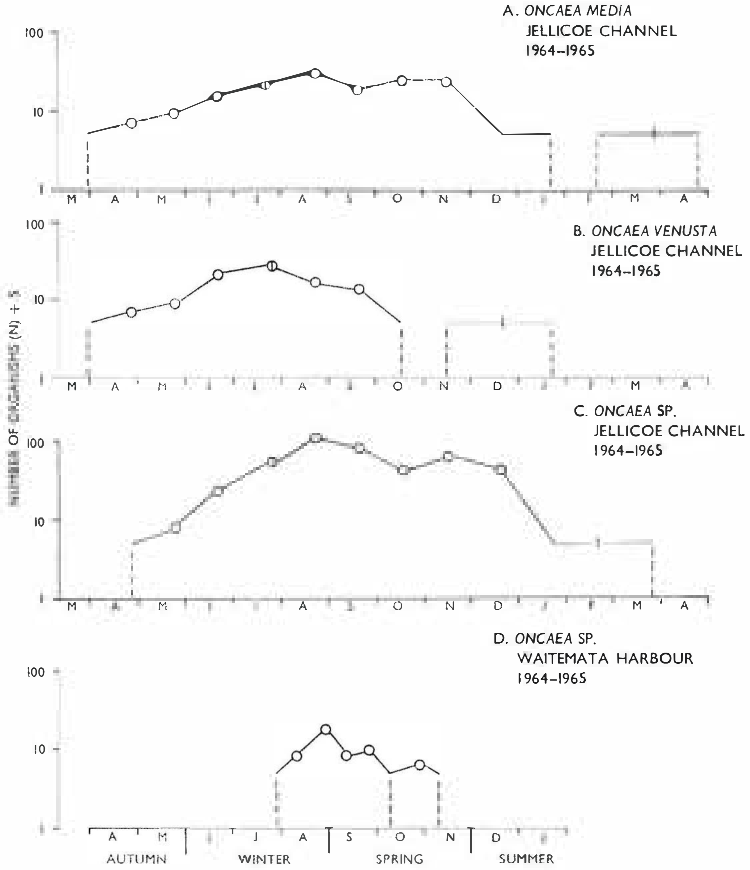

A. ONCAEA MEDIA
JELLICOE CHANNEL
1964–1965
B. ONCAEA VENUSTA
JELLICOE CHANNEL
1964–1965
C. ONCAEA SP.
JELLICOE CHANNEL
1964–1965
D. ONCAEA SP.
WAITEMATA HARBOUR
1964–1965
100
10
1
NUMBER OF ORGANISMS (N) + 5
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 21

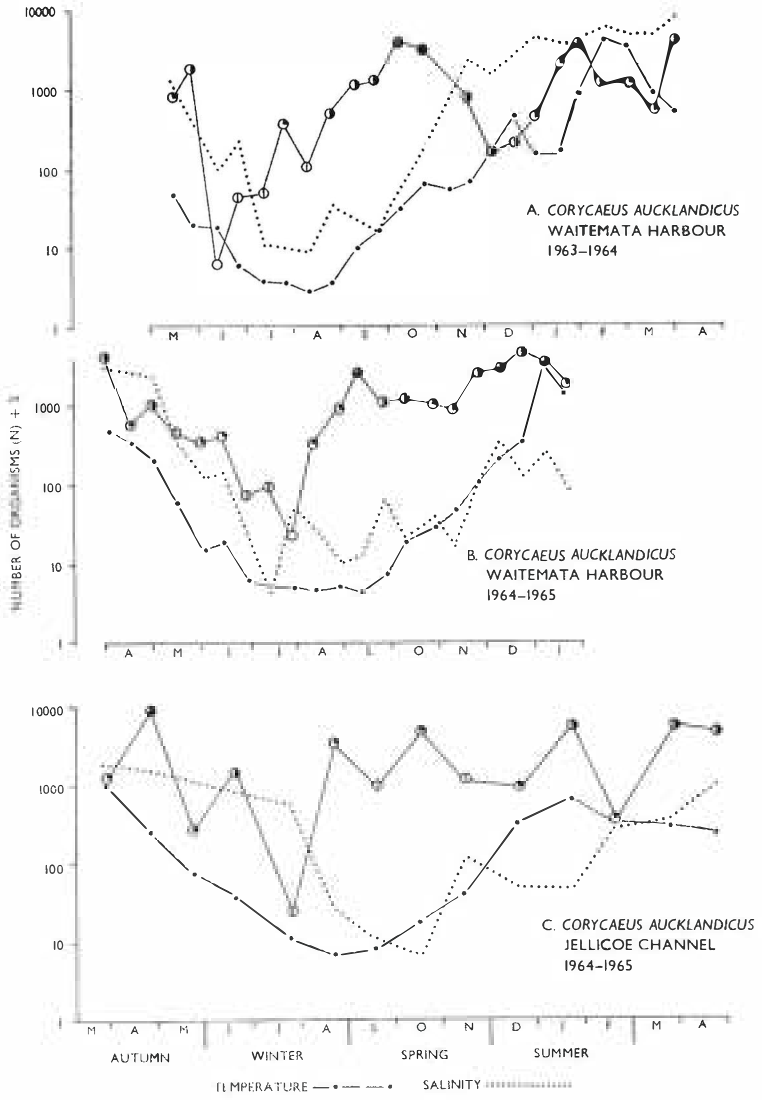

10000
1000
100
10
A. CORYCAEUS AUCKLANDICUS
WAITEMATA HARBOUR
1963–1964
M
A
O
N
D
M
A
NUMBER OF ORGANISMS (N) + 1
1000
100
10
B. CORYCAEUS AUCKLANDICUS
WAITEMATA HARBOUR
1964–1965
A
M
A
O
N
D
10000
1000
100
10
C. CORYCAEUS AUCKLANDICUS
JELLICOE CHANNEL
1964–1965
M
A
M
A
O
N
D
M
A
AUTUMN
WINTER
SPRING
SUMMER
TEMPERATURE
SALINITY

Fig. 22

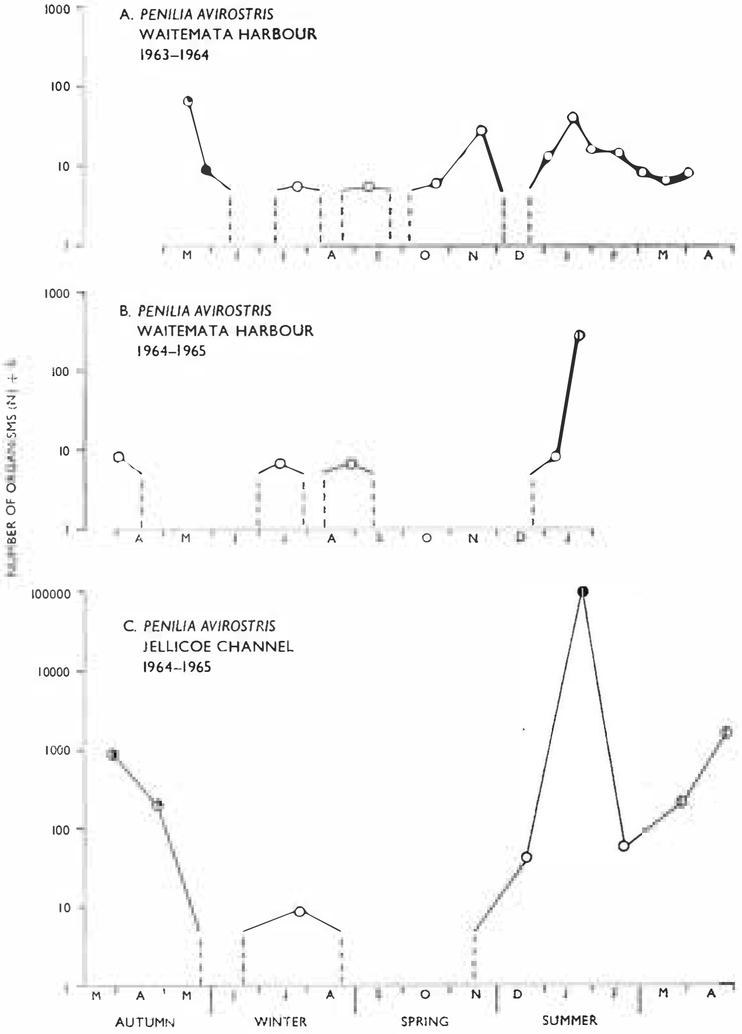

1000
100
10
A. PENILIA AVIROSTRIS
WAITEMATA HARBOUR
1963–1964
M
A
O
N
D
M
A
NUMBER OF ORGANISMS (N) + 1
1000
100
10
B. PENILIA AVIROSTRIS
WAITEMATA HARBOUR
1964–1965
A
M
A
O
N
D
100000
10000
1000
100
10
C. PENILIA AVIROSTRIS
JELLICOE CHANNEL
1964–1965
M
A
M
A
O
N
D
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 23

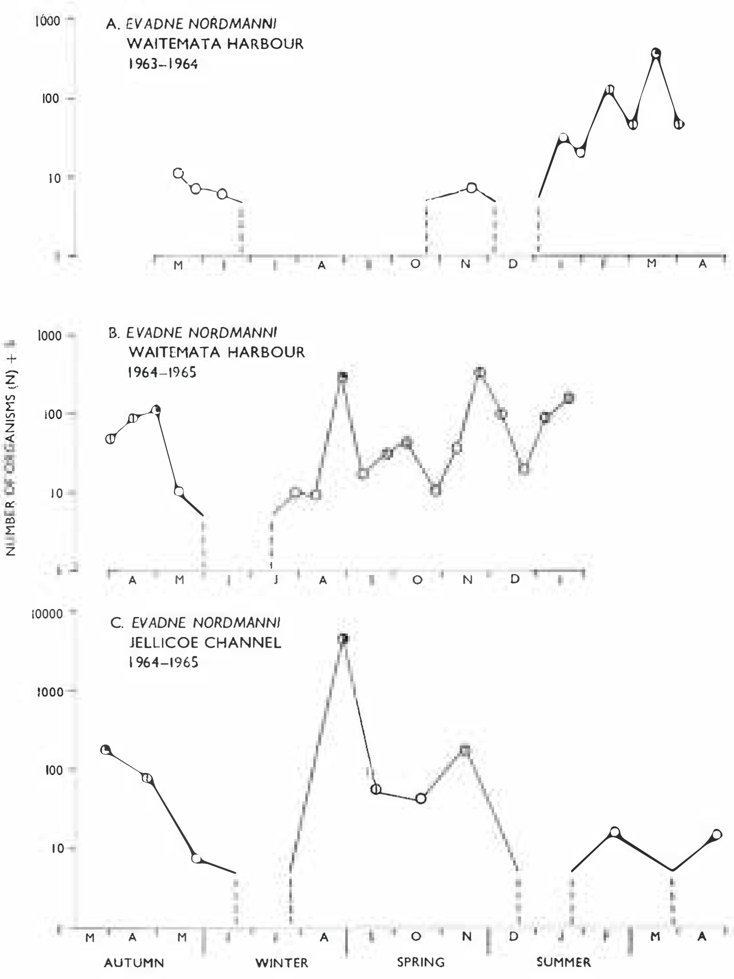

A. EVADNE NORDMANNI
WAITEMATA HARBOUR
1963–1964
B. EVADNE NORDMANNI
WAITEMATA HARBOUR
1964–1965
C. EVADNE NORDMANNI
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
10000
1000
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 24

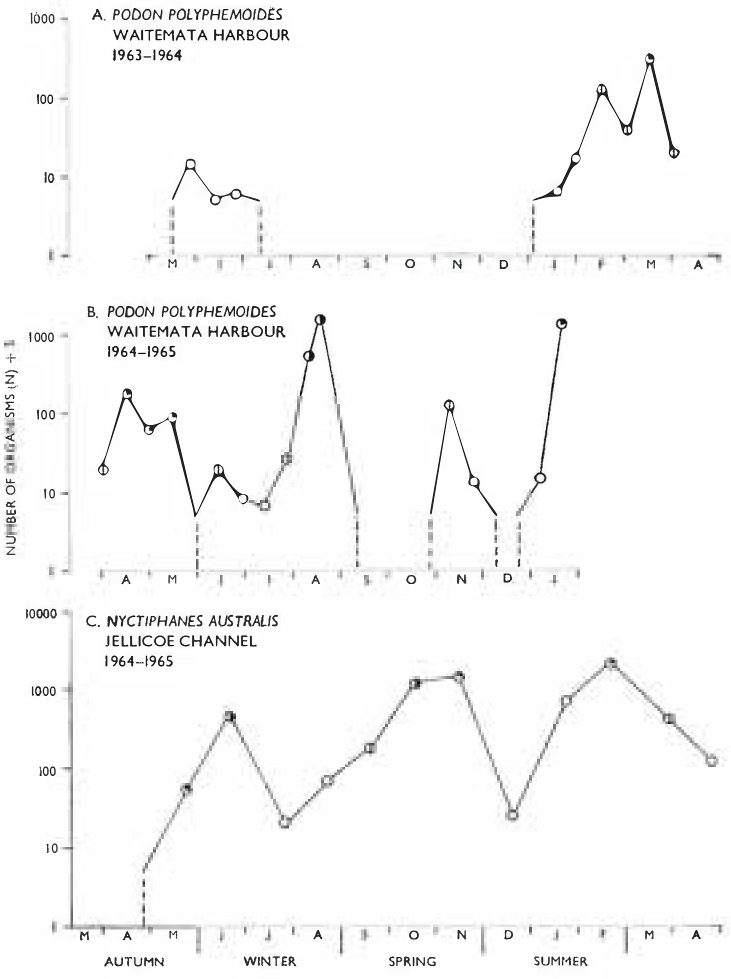

A. PODON POLYPHEMOIDES
WAITEMATA HARBOUR
1963–1964
B. PODON POLYPHEMOIDES
WAITEMATA HARBOUR
1964–1965
C. NYCTIPHANES AUSTRALIS
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
10000
1000
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 25

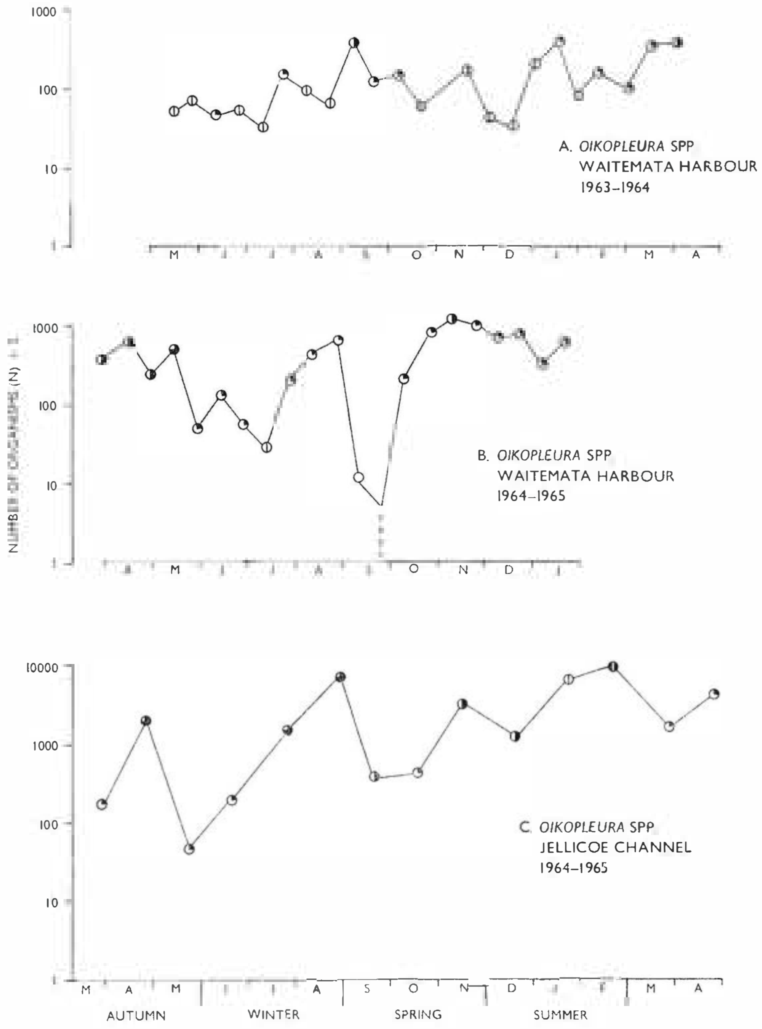

A. OIKOPLEURA SPP
WAITEMATA HARBOUR
1963–1964
B. OIKOPLEURA SPP
WAITEMATA HARBOUR
1964–1965
C. OIKOPLEURA SPP
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
1
10
100
1000
10000
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 26

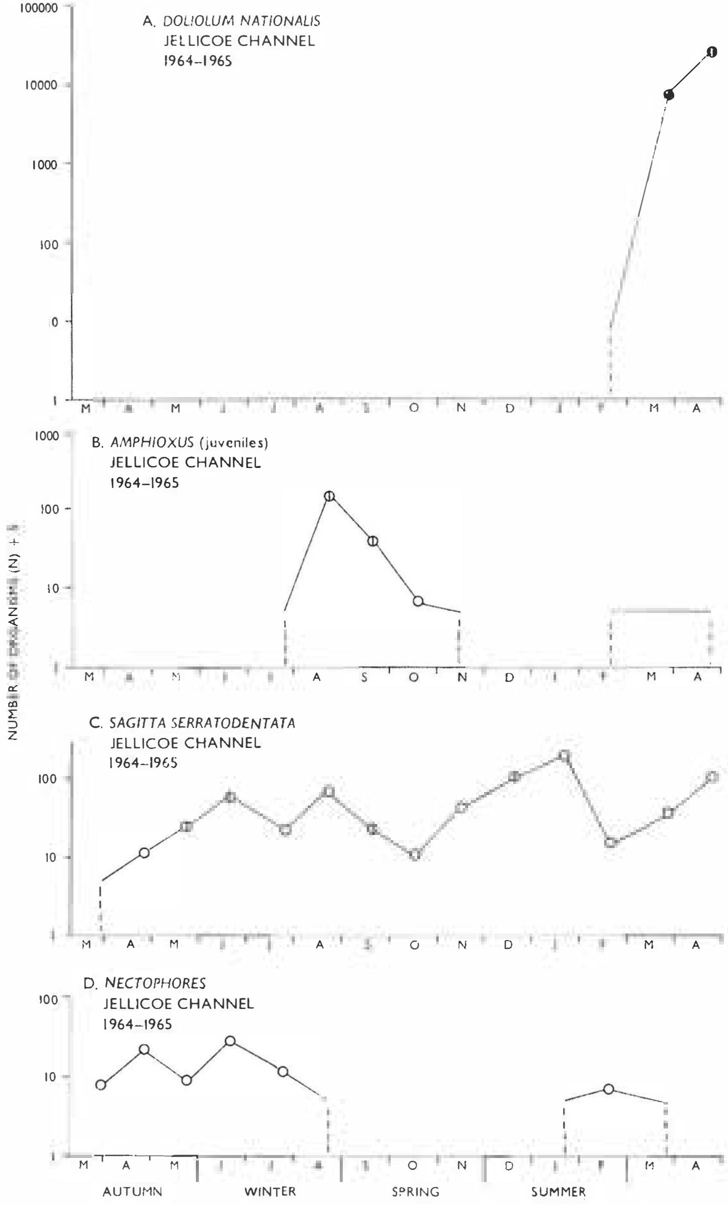

A. DOLIOLUM NATIONALIS
JELLICOE CHANNEL
1964–1965
B. AMPHIOXUS (juveniles)
JELLICOE CHANNEL
1964–1965
C. SAGITTA SERRATODENTATA
JELLICOE CHANNEL
1964–1965
D. NECTOPHORES
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
1
10
100
1000
10000
100000
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 27

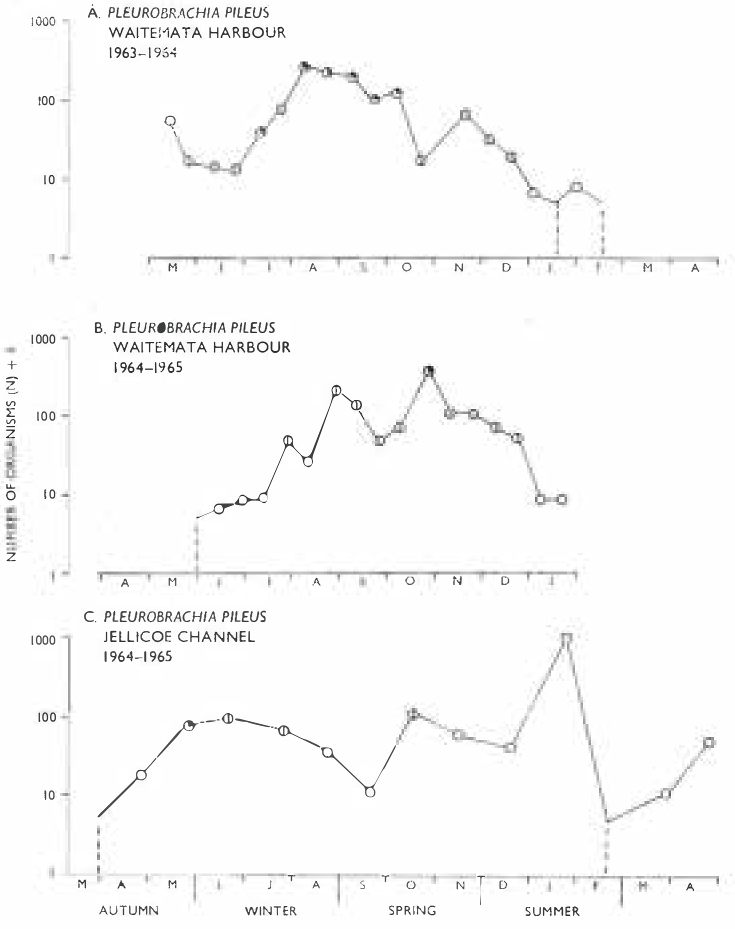

A. PLEUROBRACHIA PILEUS
WAITEMATA HARBOUR
1963–1964
B. PLEUROBRACHIA PILEUS
WAITEMATA HARBOUR
1964–1965
C. PLEUROBRACHIA PILEUS
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 5
1000
100
10
M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 28

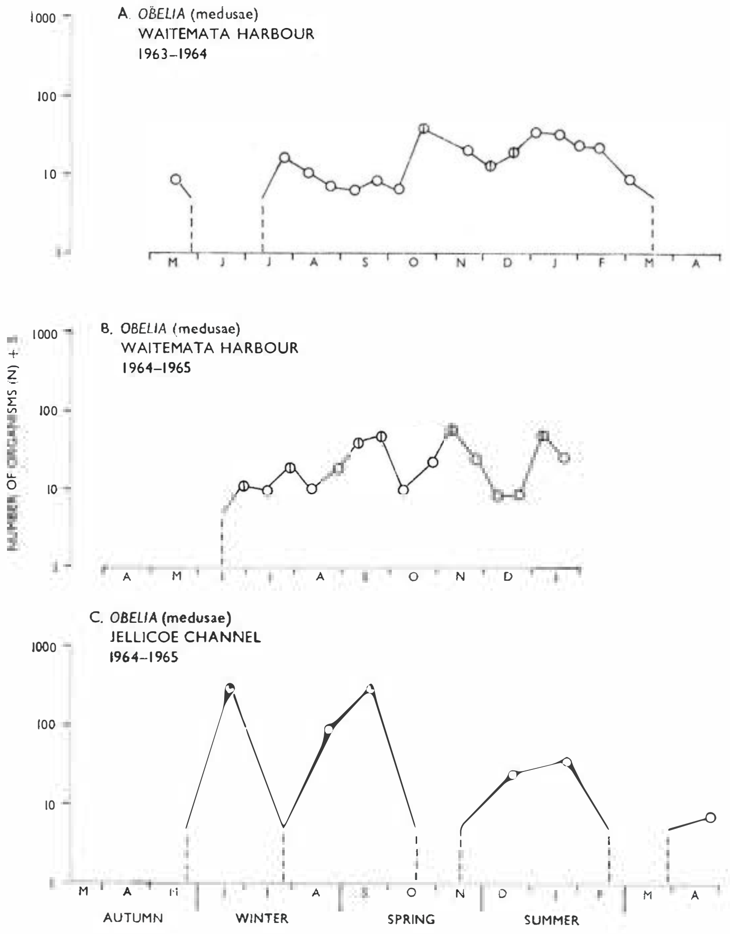

A. OBELIA (medusae)
WAITEMATA HARBOUR
1963–1964
B. OBELIA (medusae)
WAITEMATA HARBOUR
1964–1965
C. OBELIA (medusae)
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 5
1000
100
10
M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 29

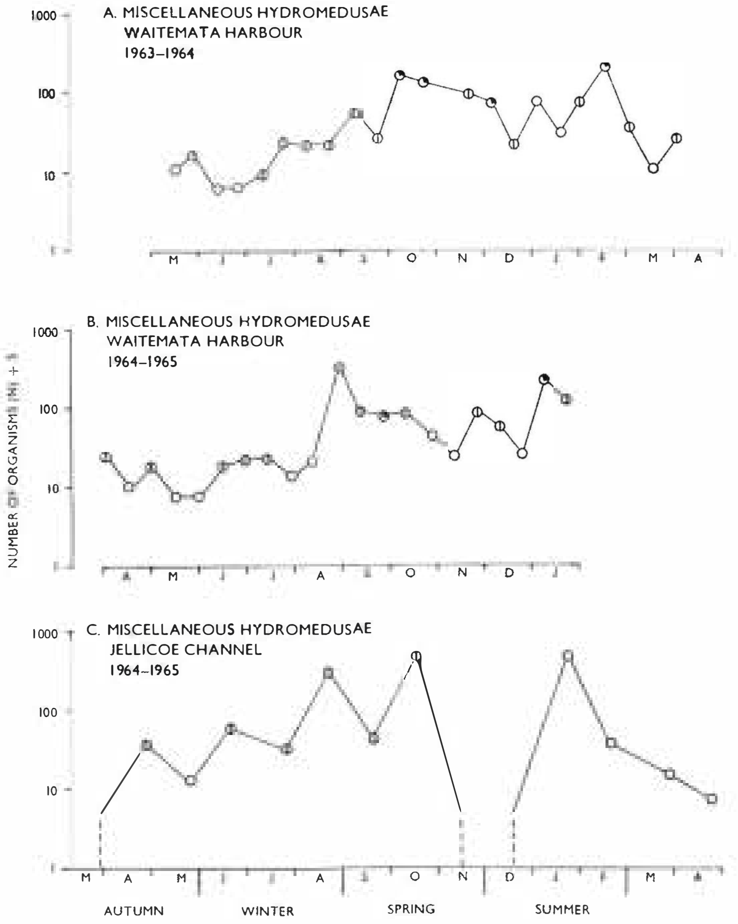

A. MISCELLANEOUS HYDROMEDUSAE
WAITEMATA HARBOUR
1963–1964
B. MISCELLANEOUS HYDROMEDUSAE
WAITEMATA HARBOUR
1964–1965
C. MISCELLANEOUS HYDROMEDUSAE
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
M
A
M
J
J
A
S
O
N
D
J
F
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 30

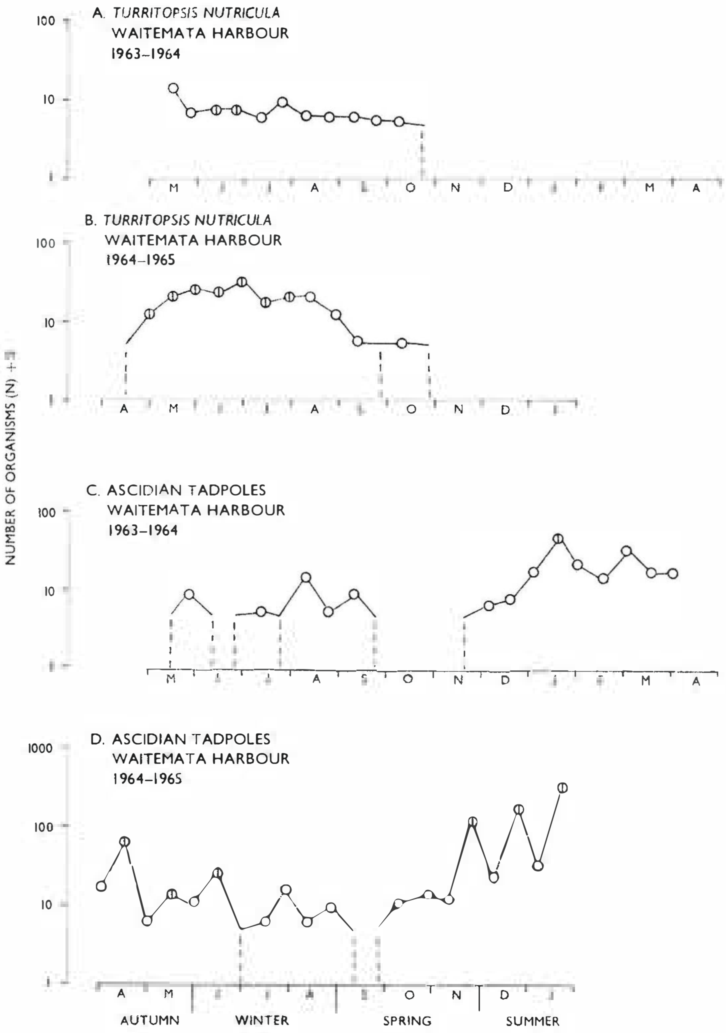

A. TURRITOPSIS NUTRICULA
WAITEMATA HARBOUR
1963–1964
B. TURRITOPSIS NUTRICULA
WAITEMATA HARBOUR
1964–1965
C. ASCIDIAN TADPOLES
WAITEMATA HARBOUR
1963–1964
D. ASCIDIAN TADPOLES
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
M
J
J
A
S
O
N
D
J
F
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 31

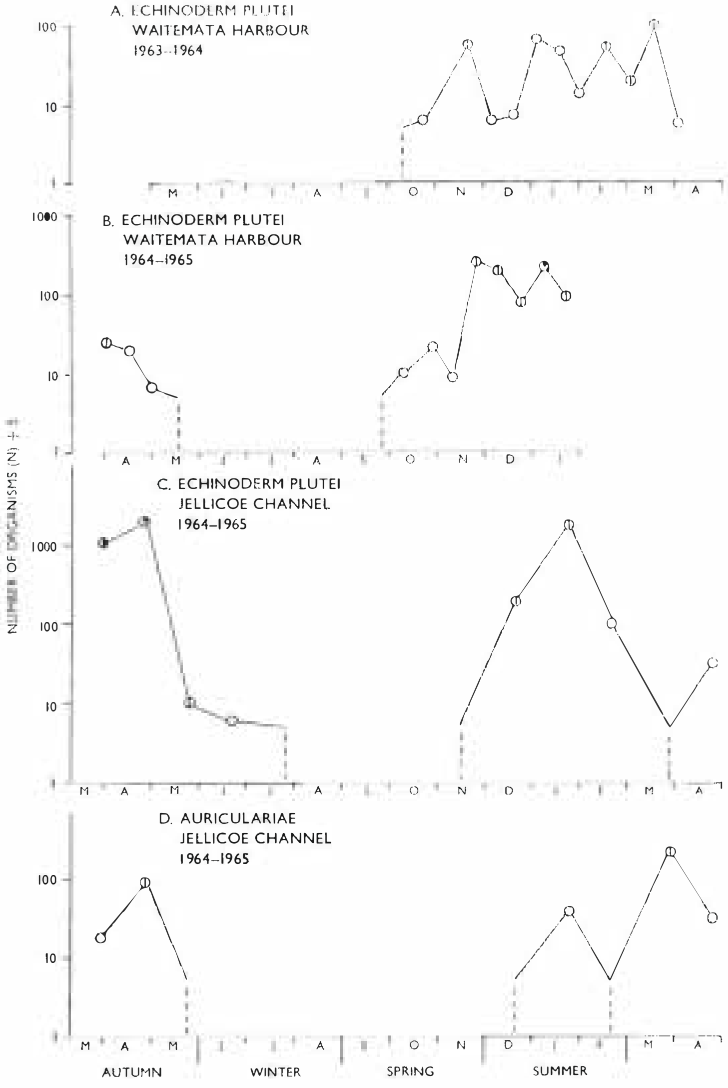

A. ECHINODERM PLUTEI
WAITEMATA HARBOUR
1963–1964
B. ECHINODERM PLUTEI
WAITEMATA HARBOUR
1964–1965
C. ECHINODERM PLUTEI
JELLICOE CHANNEL
1964–1965
D. AURICULARIAE
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 32

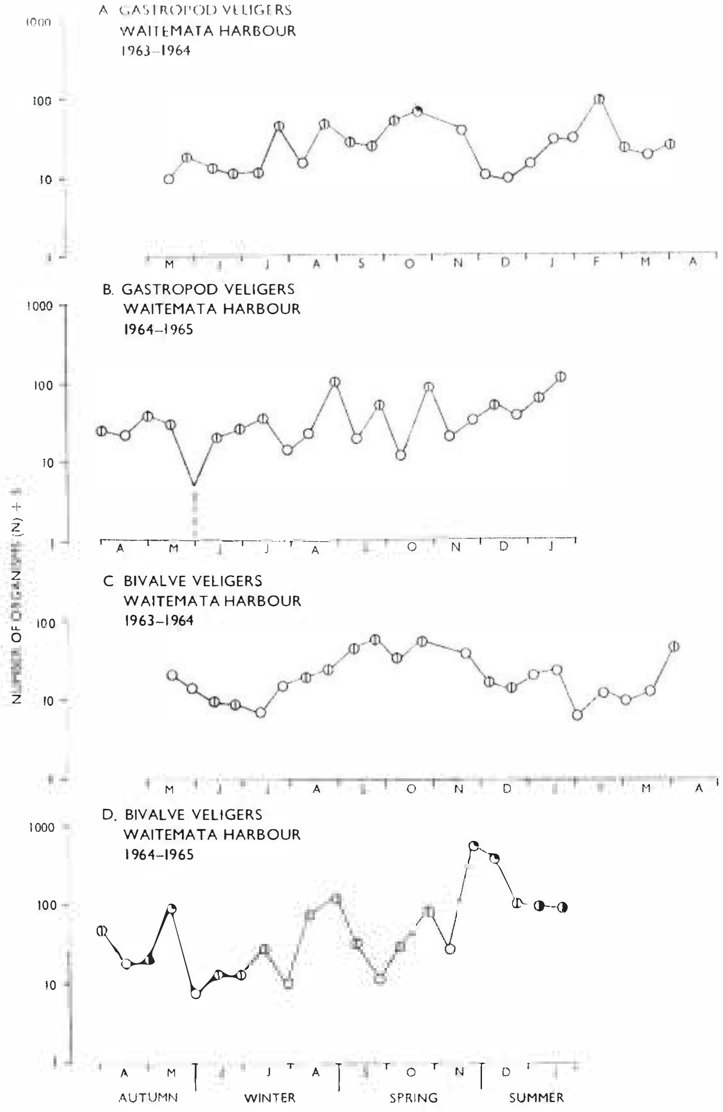

A. GASTROPOD VELIGERS
WAITEMATA HARBOUR
1963–1964
B. GASTROPOD VELIGERS
WAITEMATA HARBOUR
1964–1965
C. BIVALVE VELIGERS
WAITEMATA HARBOUR
1963–1964
D. BIVALVE VELIGERS
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 33

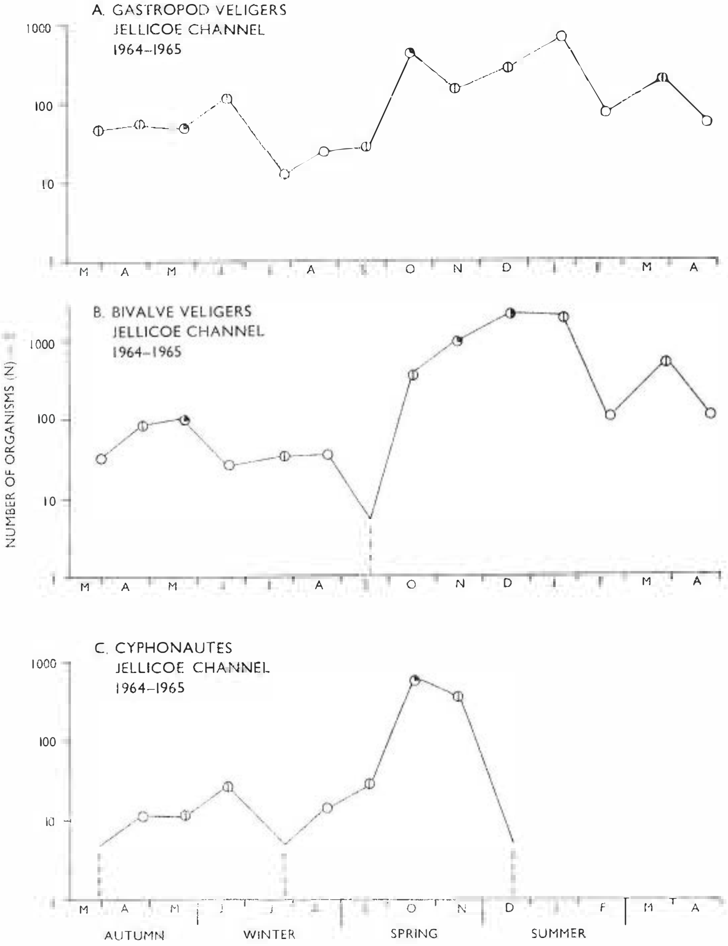

A. GASTROPOD VELIGERS
JELLICOE CHANNEL
1964–1965
B. BIVALVE VELIGERS
JELLICOE CHANNEL
1964–1965
C. CYPHONAUTES
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N)
1000
100
10
1
M
A
M
J
J
A
S
O
N
D
J
F
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 34

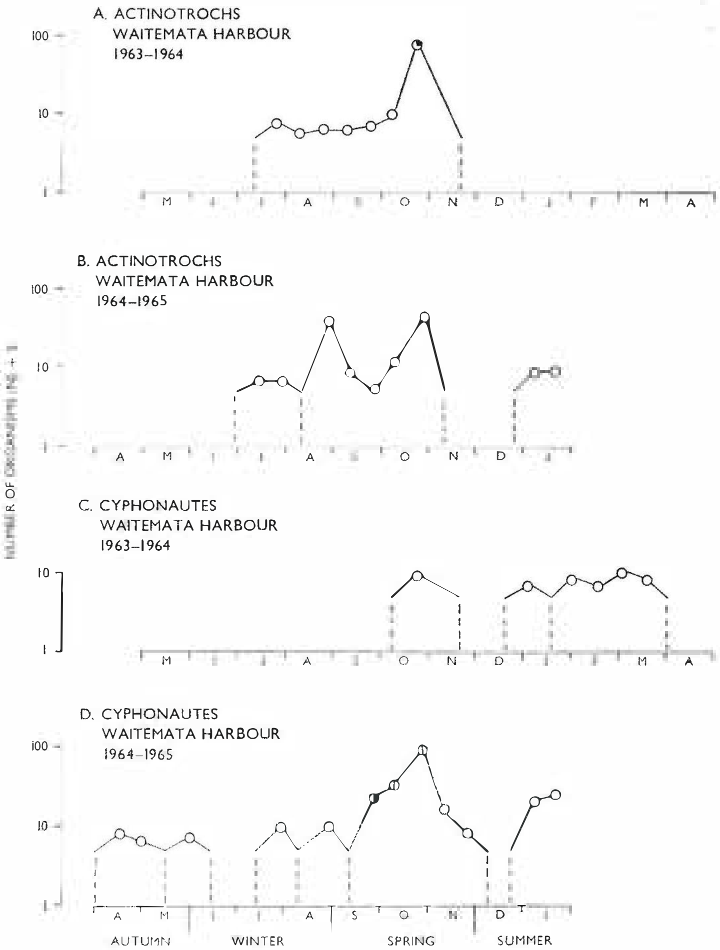

A. ACTINOTROCHS
WAITEMATA HARBOUR
1963–1964
B. ACTINOTROCHS
WAITEMATA HARBOUR
1964–1965
C. CYPHONAUTES
WAITEMATA HARBOUR
1963–1964
D. CYPHONAUTES
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) + 1
100
10
1
M
J
J
A
S
O
N
D
J
F
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 35

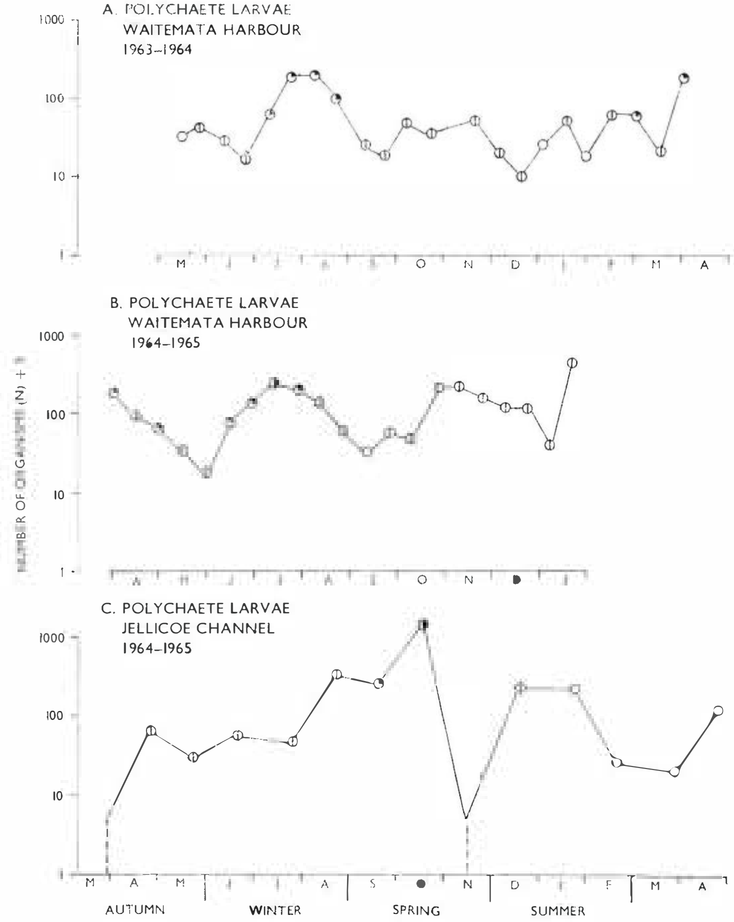

A. POLYCHAETE LARVAE
WAITEMATA HARBOUR
1963–1964
B. POLYCHAETE LARVAE
WAITEMATA HARBOUR
1964–1965
C. POLYCHAETE LARVAE
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
1000
100
10
1
M
J
J
A
S
O
N
D
J
F
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 36

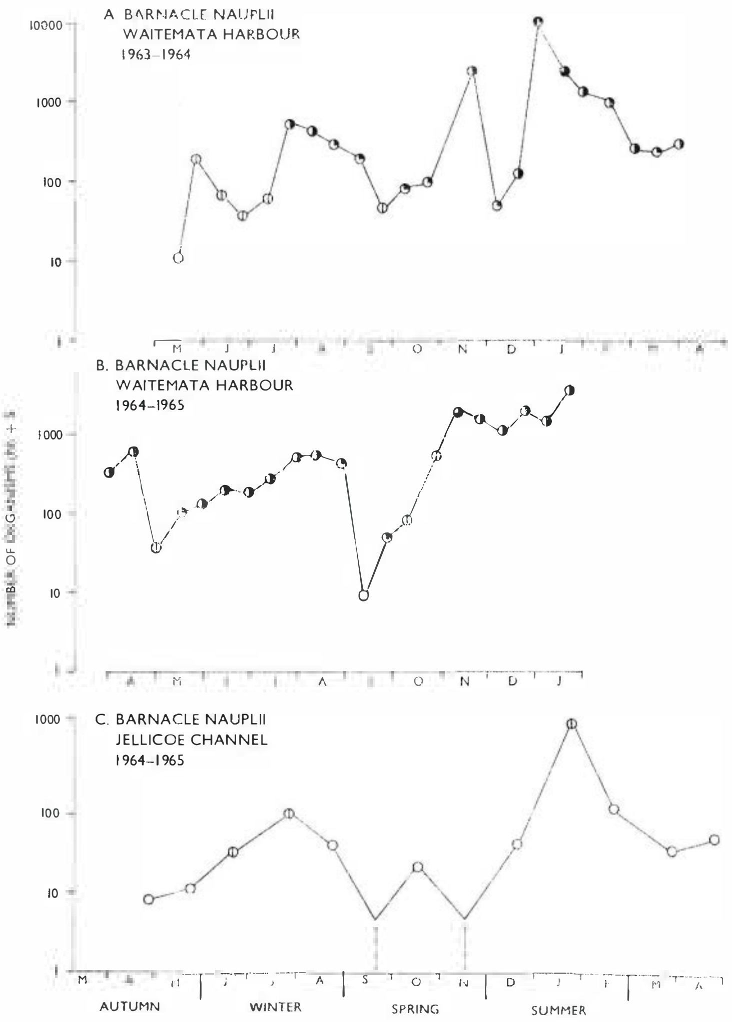

A. BARNACLE NAUPLII
WAITEMATA HARBOUR
1963–1964
B. BARNACLE NAUPLII
WAITEMATA HARBOUR
1964–1965
C. BARNACLE NAUPLII
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + 1
10000
1000
100
10
1
M
J
J
A
S
O
N
D
J
F
M
A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 37

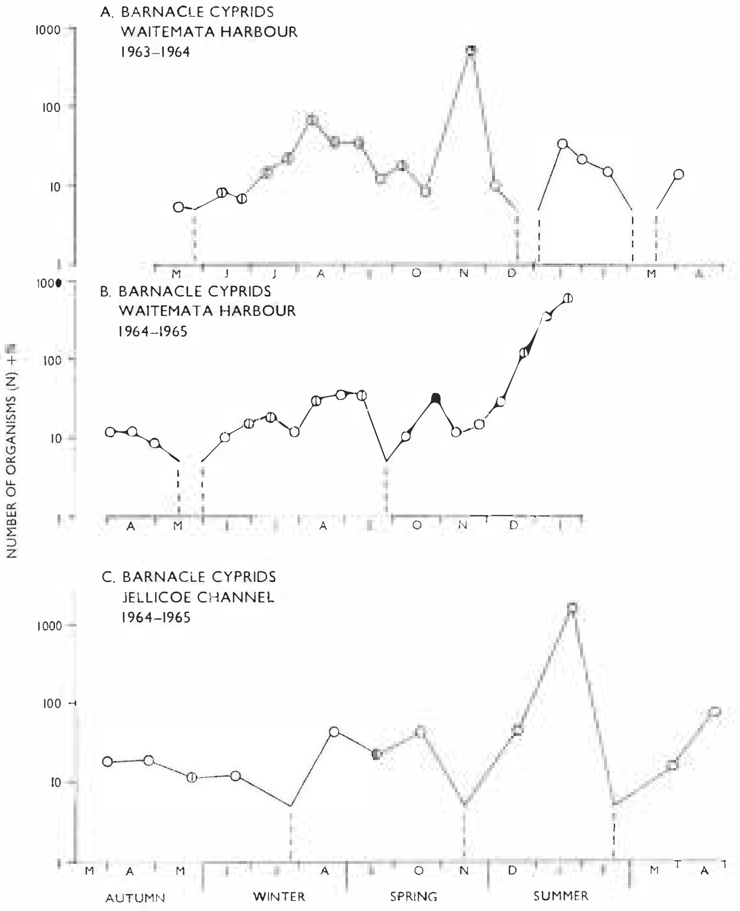

A. BARNACLE CYPRIDS
WAITEMATA HARBOUR
1963–1964
B. BARNACLE CYPRIDS
WAITEMATA HARBOUR
1964–1965
C. BARNACLE CYPRIDS
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) +
1000
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 38

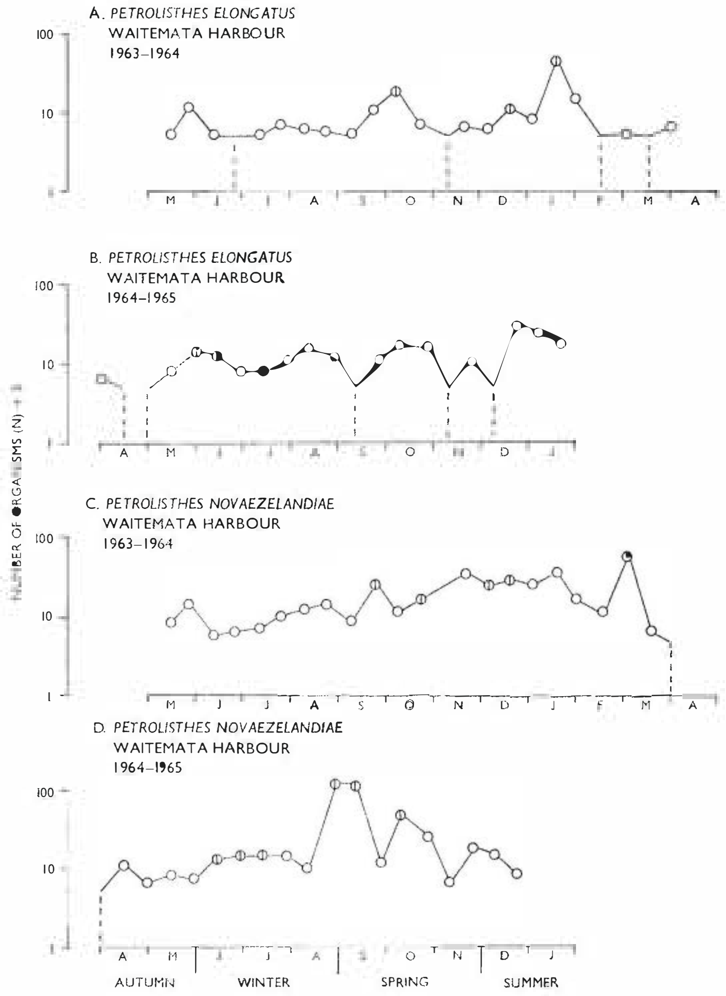

A. PETROLISTHES ELONGATUS
WAITEMATA HARBOUR
1963–1964
B. PETROLISTHES ELONGATUS
WAITEMATA HARBOUR
1964–1965
C. PETROLISTHES NOVAEZELANDIAE
WAITEMATA HARBOUR
1963–1964
D. PETROLISTHES NOVAEZELANDIAE
WAITEMATA HARBOUR
1964–1965
NUMBER OF ORGANISMS (N) +
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
M J J A S O N D J F M A
A M J J A S O N D J
AUTUMN
WINTER
SPRING
SUMMER

Fig. 39

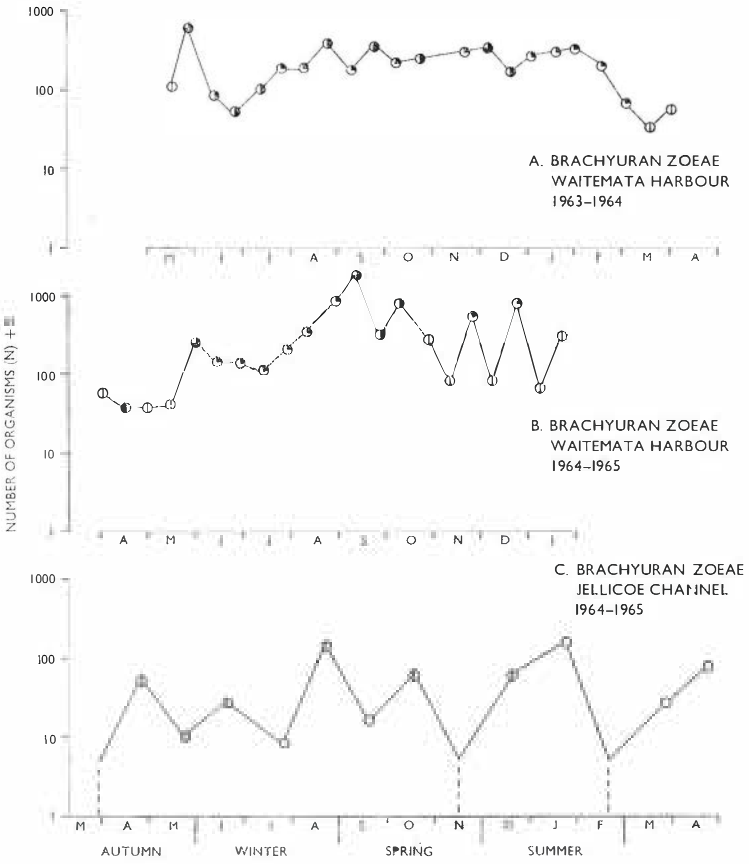

A. BRACHYURAN ZOEAE
WAITEMATA HARBOUR
1963–1964
B. BRACHYURAN ZOEAE
WAITEMATA HARBOUR
1964–1965
C. BRACHYURAN ZOEAE
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + I
1000
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 40

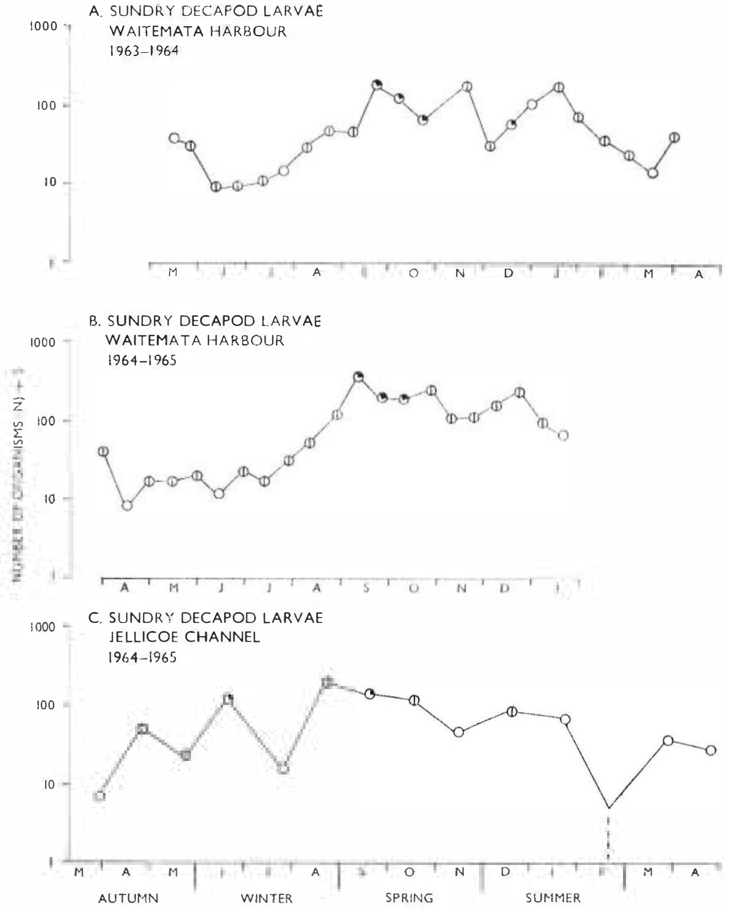
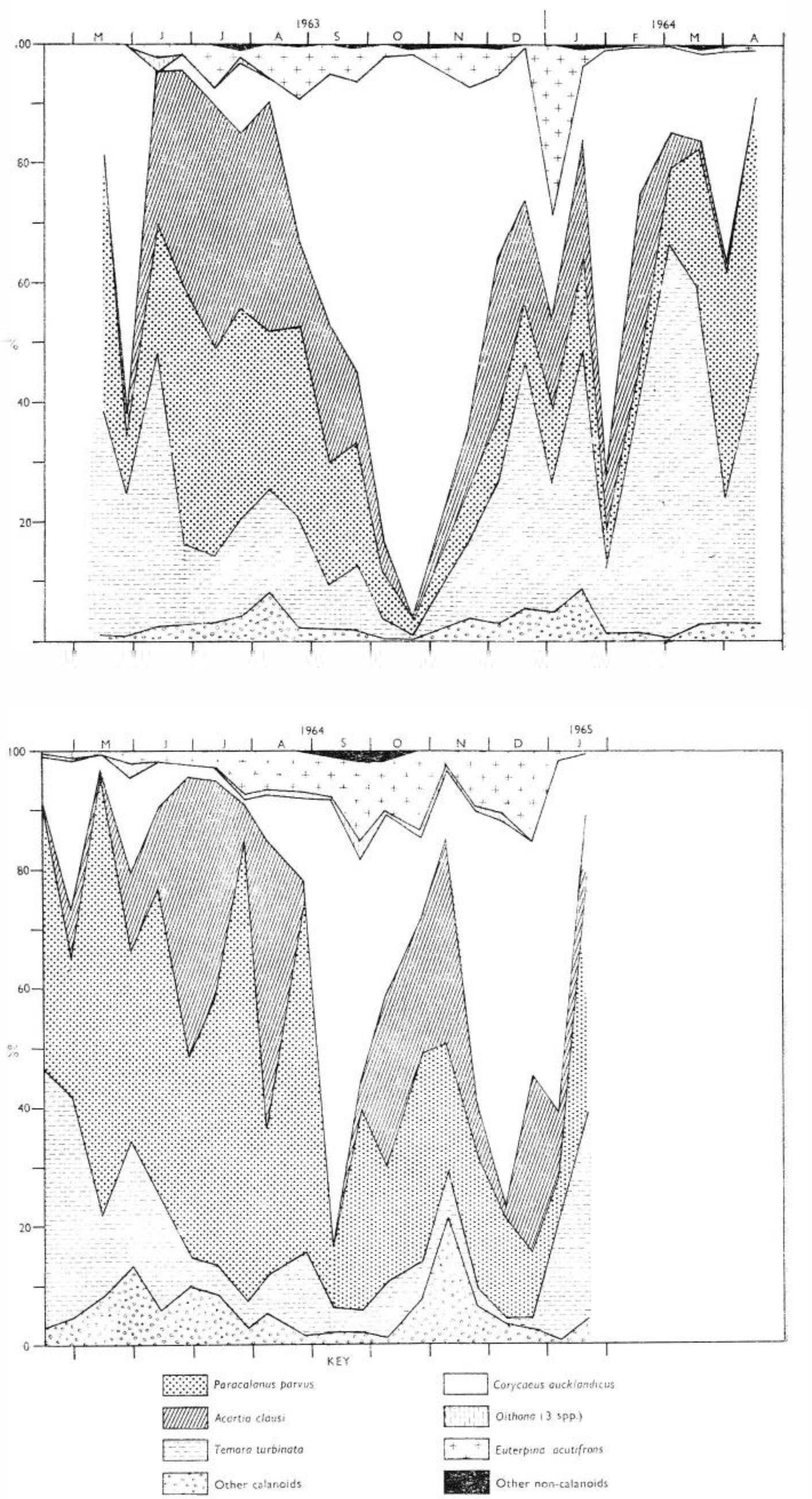

A. SUNDRY DECAPOD LARVAE
WAITEMATA HARBOUR
1963–1964
B. SUNDRY DECAPOD LARVAE
WAITEMATA HARBOUR
1964–1965
C. SUNDRY DECAPOD LARVAE
JELLICOE CHANNEL
1964–1965
NUMBER OF ORGANISMS (N) + I
1000
100
10
1
M J J A S O N D J F M A
A M J J A S O N D J
M A M J J A S O N D J F M A
AUTUMN
WINTER
SPRING
SUMMER

Fig. 41



FIGS 42, 43. Variations in the relative frequencies of major copepod species at Sta. A - Waitemata Harbour, 1963-64 (upper) and 1964-65 (lower)

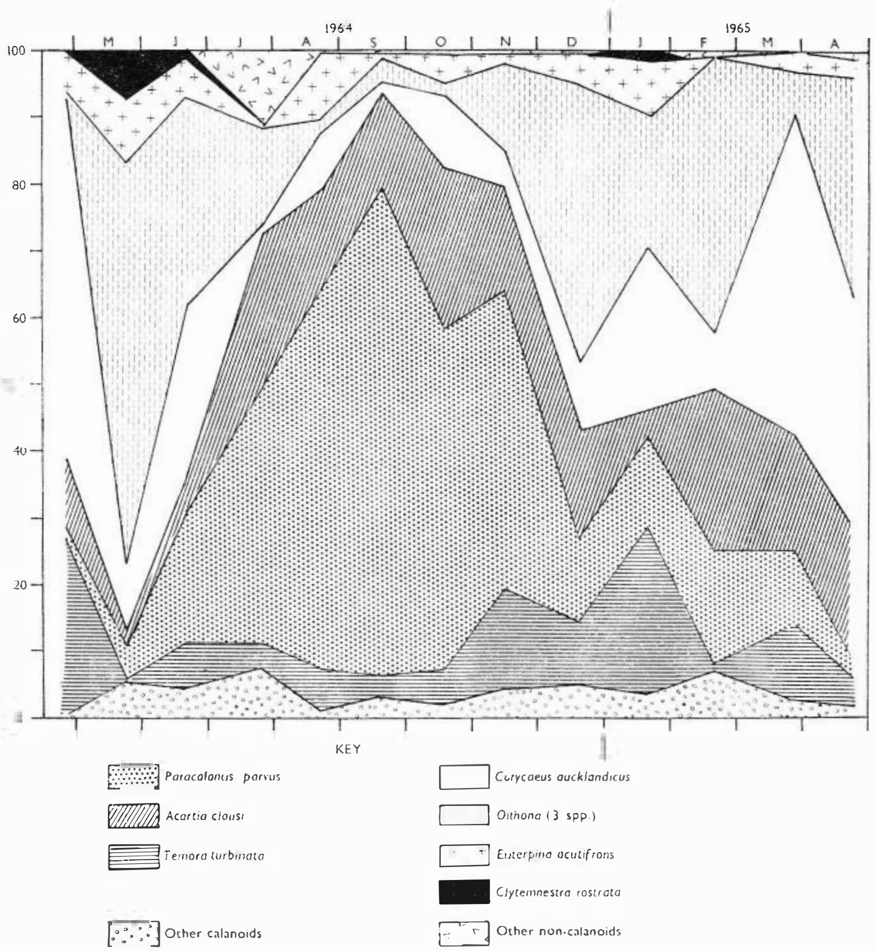


FIG. 44 Variations in the relative abundance of major copepod species at Sta. B - Jellicoe Channel, 1964-65

Paracalanidae

Paracalanus parvus (Claus)

Occurrence: Tables 5, 6; Figs. 11, 42, 43, 44.

Sta. A: The most abundant copepod in the Waitemata Harbour, and abundant or common in nearly all samples. In both years of sampling it was abundant in autumn, when the species was generally sub-dominant. In winter other species were most poorly represented, so that it was frequently dominant and at times ultra-dominant. In spring other copepods became more numerous. Early summer was the time of lowest numbers and the species was only a sub-associate or associate copepod. It was more abundant in 1964-65 and was also more important and abundant in that spring than in the spring of the previous year.

Sta. B: By far the most numerous copepod taken in the Jellicoe Channel as well as in inshore waters. Numerous during autumn 1964, but only a sub-associate within the large copepod population. In June it became an abundant associate and in the following month (July), although less frequent, rose to sub-dominant rank. A huge rise in numbers occurred in late winter, and from August to October *P. parvus* was very abundant and dominant. After this, the species declined in both abundance and relative importance until by autumn it was a common associate, as it had been in the previous year.

Distribution: Hauraki Gulf (Kramer, 1894; Fuller, 1953); off northern New Zealand, Bay of Islands, and to the south (Farran, 1929); southern New Zealand (Bary, 1951); Wellington Harbour (R. M. Cassie, 1959c, 1960a); Otago Harbour (Brady, 1899); and very widespread in all oceans (Vervoort, 1946).

Paracalanus parvus was the most abundant copepod at both inshore and outer gulf stations. The species belongs to a group of very similar species, and, although a great many were dissected, no other member of the group except the rather distinctive *Paracalanus aculeatus* Giesbrecht was found. While it is possible that small numbers of other paracalanid species have been included here, the vast majority of individuals belong to *P. parvus*.

Variations of abundance and dominance occurred at different times at each of the two stations. Inshore in the Waitemata Harbour greatest abundance was in autumn and greatest dominance in winter, which, in the Jellicoe Channel, were seasons of low abundance. In the Jellicoe Channel the species was most abundant and dominated late winter and spring samples, a time of declining values inshore. At both stations maximum dominance occurred at the time of minimum salinities, indicating perhaps greater tolerance to salinity depression than many other copepods.

However, greater tolerance of salinity depression is not consistent with the evidence of R. M. Cassie (1959a, 1960a), who demonstrated a negative relationship with temperature and a positive relationship with salinity for the micro-distribution of *P. parvus* in Wellington Harbour winter and spring plankton. R. M. Cassie (pers. comm.) has subsequently taken *P. parvus* in a transect of Pelorus Sound where it was most abundant at about $34.6^0/_{00}$S, about 6 miles in from the sound entrance. The relationship of *P. parvus* to salinity was conditioned by temperature, which was about 11.9^{0}C at the salinity optimum.

Kramer's (1894) statement that *P. parvus* is only an occasional visitor to the Waitemata Harbour does not agree with the present findings.

Paracalanus aculeatus Giesbrecht

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: One specimen taken in May and two in June.

Distribution: One specimen off northern New Zealand (Farran, 1929); Great Barrier Reef (Farran, 1936); south-east Australian waters (Dakin and Colefax, 1933, 1940; Kott, 1957); south of Tasmania (Vervoort, 1957); East Indies (Vervoort, 1946); and widely distributed in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961).

A subtropical species commonly distributed in the Indo-west Pacific between 22^{0}N and 40^{0}S (Farran, 1936).

Pseudocalanidae

Clausocalanus arcuicornis (Dana)

Occurrence: Tables 5, 6; Fig. 12.

Sta. A: A minor constituent in a few samples in spring 1964. Present in greatest numbers at its first appearance but then became less frequent. Its frequency distribution was almost identical to that of *Ctenocalanus vanus* in samples from this station.

Sta. B: Taken in all but the December and January samples. Normally a minor constituent, but a sub-associate in May, June, and November, after which it was not taken for 2 months but reappeared in February and was frequent in autumn 1965.

Distribution: Hauraki Gulf (Kramer, 1894); off northern New Zealand and south to the Antarctic Circle (Farran, 1929); Otago Harbour (Brady, 1899); off southern New Zealand (Bary, 1959a); south of Australia to the Antarctic Circle (Vervoort, 1957); south-east Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); Great Barrier Reef (Farran, 1936); and widespread in the Pacific (Grice, 1961).

C. arcuicornis is probably more characteristic of shelf or oceanic than neritic waters. It has been taken in the outer Hauraki Gulf by Kramer (1894) and commonly from off northern New Zealand (Farran, 1929). It appears to be a cosmopolitan species found in all oceans and ranging from 74^{0}N (Atlantic) to 84^{0}S (Pacific) (Vervoort, 1946).

Ctenocalanus vanus Giesbrecht

Occurrence: Tables 5, 6; Fig. 12.

Sta. A: Occurrence almost identical to that of *Clausocalanus arcuicornis* in spring 1964. Taken in five consecutive samples — initially frequent but subsequently only occasional.

Sta. B: Taken in most samples except in October, November, and January. Increased in abundance from autumn 1964 to the following spring, when it became common, and achieved maximum abundance in September. Frequent in December and again in autumn 1965.

Distribution: From northern New Zealand to the Antarctic (Farran, 1929); Australia to the Antarctic (Vervoort, 1957); off south-eastern Australia (Dakin and Colefax, 1933, 1940).

C. vanus was recorded from northern New Zealand and commonly south to the Antarctic (Farran, 1929) and south of Australia (Vervoort, 1957). It is primarily an oceanic species of temperate and high latitudes.

Centropagidae

Centropages aucklandicus Kramer

Occurrence: Tables 5, 6; Fig. 13.

Sta. A: Taken in every sample; though often common, it never exceeded associate rank.
More abundant and dominant in the second year of sampling, but throughout the sampling period it was one of the more ubiquitous and important calanoids. Rather less important in the winter of 1963 and less numerous than in the following winter. Maximum numbers occurred in late spring or summer, with a secondary peak in late autumn or winter.

Sta. B: Not as important or abundant in the Jellicoe Channel as inshore. Poorly represented in winter as an occasional minor constituent; but in August it increased in number, and in spring and early summer it further increased and was generally a common sub-associate copepod. Absent in February and not subsequently taken.

Distribution: Endemic to New Zealand waters. Otago Harbour (Brady, 1899); Hauraki Gulf (Kramer 1894); off northern New Zealand and Bay of Islands (Farran, 1929); Cook Strait (Bary, 1951).

C. aucklandicus appears to be characteristic of neritic rather than oceanic waters. Farran (1929) took specimens from the Bay of Islands and also in open water off northern New Zealand and once to the east of Cook Strait. Bary (1951) took two specimens from Cook Strait. He regarded the species as an oceanic one. This is almost certainly incorrect, for *C. aucklandicus* has never been taken in abundance in open waters and is probably abundant only inshore.

Centropages bradyi Wheeler

Occurrence: Table 6.
Sta. A: Nil.

Sta. B: One specimen taken in June and two in September. Only a rare minor constituent.

Distribution: Several stations off New Zealand (Farran, 1929); off southern New Zealand (Bary, 1951); south-eastern Australian waters (Dakin and Colefax, 1933, 1940; Kott, 1957; Vervoort, 1957).

C. bradyi is almost certainly oceanic, as in other localities, being rarely taken in the outer gulf and never inshore. It has been previously recorded from New Zealand oceanic waters, but never in any number (Farran, 1929; Bary, 1951).

Gladioferens pectinatus (Brady)

Occurrence: Table 5.

Sta. A: Taken in only one sample in March 1964, when it was frequent.

Sta. B: Nil.

G. pectinatus was also taken in supplementary hauls from the upper Waitemata Harbour in June and December 1963. In many hauls it was common and frequently sub-dominant.

Distribution: Otago Harbour; off Napier (Brady, 1899); Queen Charlotte Sound; Lake Ellesmere; Otago Harbour; and many estuaries and coastal lagoons of eastern Australia, from Queensland in the north to Tasmania in the south (Bayly, 1963).

Undoubtedly this species is an estuarine indicator. It is common in estuarine localities from southern New Zealand and eastern Australia (Bayly, 1963, 1964) but has not been previously recorded from northern New Zealand.

Temoridae

Temora turbinata (Dana)

Occurrence: Tables 5, 6; Figs. 14, 42, 43, 44.

Sta. A: Present in every sample, and the third most abundant copepod (after *Paracalanus parvus* and *Corycaeus aucklandicus*) taken in Waitemata Harbour. Maximum abundance and dominance in both years was in summer and autumn, and these were the only seasons when the species was an abundant dominant or sub-dominant copepod. Numbers declined through winter, and were generally low in spring. Higher levels of dominance were maintained in winter and spring in 1963 than in the following year. This reflects the lower numbers of other species present in the first sampling year. A notable point is that the spring rise in numbers began much earlier in 1963 than in 1964, though similar levels of abundance and dominance were attained by mid summer. This is probably related to salinity variations, for, while temperatures rose in a similar way in the two years, salinity rose much more rapidly in 1963, October of that year being one of the driest on record. *Temora turbinata* followed the trends of salinity variation, though with some lag. The species was abundant, except in summer 1965, only when salinities in the previous sample exceeded 34.9$^0/_{00}$. Even in the summer of 1965 salinities were higher than they had been in the previous winter and spring. Minimum abundance coincided with the minimal salinities for the year.

Sta. B: Taken in every sample. Although seldom very numerous it was abundant and dominant in March 1964. Numbers declined rapidly in early winter, but it then once more became abundant and maintained this rank until mid summer, after which it was less numerous.

Distribution: Hauraki Gulf (Kramer, 1894; Brady, 1899; Fuller, 1953; off North Island, New Zealand, and to the south (Farran, 1929); Wellington Harbour (R. M. Cassie, 1959c); Otago Harbour and Bay of Islands (Brady, 1899); south-eastern Australian waters (Dakin and Colefax, 1933, 1940; Kott, 1957); and from the western tropical Pacific (Wilson, 1950).

T. turbinata was present in every catch at both Hauraki Gulf stations. It is one of the more abundant and ubiquitous copepods of the area. Greatest abundance was in summer and autumn at both stations, but the species was relatively much more important in outer gulf spring plankton than inshore. The sharp drop in numbers in the outer gulf in February 1965 is thought to be related to hydrological changes (discussed in detail on page 85).

T. turbinata was less abundant inshore in winter and spring when salinities were lower than in the outer gulf, where it was still abundant. Probably *T. turbinata* is nearing the lower limit of salinity tolerance in winter neritic waters and is more characteristic of shelf waters. This contention is supported by Farran (1929), who found *T. turbinata* in great abundance, sometimes constituting almost the entire sample, off the northern coast of the North Island, New Zealand. Farran's samples were taken in winter, a season of minimum abundance inshore in the Waitemata Harbour. Farran found the species rare off the South Island, New Zealand.

T. turbinata is characteristic of northern inshore and shelf waters and occurs rarely off southern New Zealand.

Metridiidae

Pleuromamma abdominalis (Lubbock)

Occurrence: Table 6.

Sta. A: Nil.

Sta. B: An occasional minor constituent in two consecutive winter samples (July and August); absent from all other samples.

Distribution: From New Zealand to the Antarctic (Farran, 1929) and to the south of Australia (Vervoort, 1957); off south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961).

This species has oceanic affinities. It is widely distributed in the south-west Pacific except south of 60°S (Farran, 1929; Vervoort, 1957). Farran found it in much larger numbers off northern New Zealand than elsewhere. It is possibly a useful indicator of oceanic waters.

Pleuromamma gracilis (Claus)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: An occasional to frequent minor constituent in the three winter months (June to August), but otherwise absent.
Distribution: Off northern New Zealand and to the Antarctic (Farran, 1929); off Kaikoura, South Island, New Zealand (Bary, 1951); off south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); to the south of Tasmania (Vervoort, 1957); Great Barrier Reef (Farran, 1936); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961).

Two of the recognised forms of this species were taken. In June a single female of forma *piseki* (Farran, 1929) was taken. In July only forma *maxima* (Steuer, 1932) was taken and in August both were taken.

P. gracilis is primarily an inhabitant of warmer, oceanic waters. Farran (1929) found it commonly off the North Island, New Zealand, and took a few specimens as far south as 60°S. Bary (1951) took a few specimens from off Kaikoura. He also regarded the species as a warmer, oceanic one. Kott (1957) suggested that this species was a valuable indicator of deeper offshore New South Wales waters.

Lucicutidae

Lucicutia flavicornis (Claus)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: An occasional minor constituent in two consecutive winter samples (June and July).
Distribution: Off northern New Zealand (Farran, 1929); off eastern Australia (Dakin and Colefax, 1940); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961).

Another primarily oceanic species taken commonly from off northern New Zealand but not from further south. The species is probably found in warmer oceanic waters. Kott (1957) regarded it as a useful indicator of deeper offshore New South Wales waters.

Heterorhabdidae

Heterorhabdus papilliger (Claus)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: One specimen taken August 1964.
Distribution: Off northern New Zealand (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961).

Primarily an inhabitant of warmer oceanic waters. Farran (1929) took *H. papilliger* from off northern New Zealand but not to the south.

Candacidae

Candacia bipinnata (Giesbrecht)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: A few specimens taken in May and in June 1964.
Distribution: Off northern New Zealand (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961, 1963).

This is primarily an oceanic species of subtropical waters found in all three major oceans but not south of 35°S (Grice, 1963). The Hauraki Gulf is just beyond the recorded southern limit of this range, and these were probably stray specimens brought south in the East Auckland current. Farran (1929) found *C. bipinnata* the most common member of the genus off northern New Zealand.

Pontellidae

Pontella novaezelandiae Farran

Occurrence: Table 5.
Sta. A: One specimen taken in February 1964.
Sta. B: Not taken in the normal diagonal Clarke-Bumpus hauls but in small numbers in supplementary horizontal surface tows in July, August and December.
Distribution: Off northern New Zealand (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and off Albany, Western Australia (Vervoort, 1957).

This species is deep blue with bright orange markings, and almost undoubtedly it is epiplanktonic in the first few centimetres below the surface. This habitat would explain its absence from diagonal and vertical hauls. The species is probably widely distributed in northern New Zealand waters.

Labidocera cervi Kramer

Occurrence: Tables 5, 6; Fig. 16.
Sta. A: Least abundant of the commoner copepods taken in the Waitemata Harbour, but absent from only two samples. Usually a frequent minor constituent, but several times it was more abundant. Few well defined peaks of abundance and little recognisable seasonality in its occurrence.
Sta. B: Taken in small numbers in three samples (March, September, and October 1964).
Distribution: Hauraki Gulf (Kramer, 1894); off northern New Zealand (Farran, 1929); and Cook Strait and Foveaux Strait (Bary, 1951).

By far the largest member of the inshore copepods, and, by analogy with other members of the genus, it is probably carnivorous (Lebour, 1922; Wickstead, 1962). For this reason its importance in the plankton may exceed its relative numerical importance. Taken in nearly every sample inshore, but only infrequently in the outer gulf, this species is probably neritic. This is consistent with the findings of Farran (1929), who records the species in several inshore hauls from northern New Zealand but only once from open water. Bary (1951) took a few specimens from Cook Strait and from Foveaux Strait.

Farran (1929) recorded a variety of *L. cervi* from Melbourne Harbour, and Dakin and Colefax (1933, 1940) recorded it from south-eastern Australia. However, the differences between the New Zealand and Australian populations are probably specific (A. Fleminger, pers. comm.), and the species in the strict sense is probably endemic to New Zealand.

Acartiidae

Acartia clausi Giesbrecht

Occurrence: Tables 5, 6; Figs. 15, 42, 43, 44.

Sta. A: Taken in every haul and the fourth most abundant copepod. Never dominant but often subdominant. In both years two periods of high abundance occurred, one in winter and one in late spring or summer, separated by one of low abundance in spring. Maximum dominance was in winter, a period when other copepod species were not abundant. Except in early summer 1963-4, the abundance of *A. clausi* seemed inversely proportional to salinity. Abundance was attained only when salinities were less than $34.5^{0}/_{00}$, except in summer 1963-4.

Sta. B: The third most abundant copepod taken in Jellicoe Channel and well represented in all samples. Important in mid autumn, but then numbers were low until spring, when they increased rapidly. The species remained at maximum numbers throughout spring and was sub-dominant in the October sample, but then declined, though remaining common until the end of the sampling period. In February *A. clausi* was subdominant as a result of the scarcity of other copepods in the sample. Seasonal variations in the Jellicoe Channel, at least in winter and spring, seem inversely related to salinity values, as they were inshore. Maximum abundance occurred later than in Waitemata Harbour, as did minimum salinities. The three consecutive months of greatest abundance were also the months of minimum salinities.

Distribution: Hauraki Gulf (Kramer, 1894; Fuller, 1953); Wellington Harbour (R. M. Cassie, 1959c); Otago Harbour and Napier (Brady, 1899); off New Zealand (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950).

Other species of *Acartia* closely resemble *A. clausi* and are often sympatric with it (Conover, 1956). Of these, only *Acartia negligens* is recorded from these waters and is readily distinguished from *A. clausi* by the form of the fifth swimming legs. Although a great many specimens were dissected, only *A. clausi* and *A. danae* were present. However, it would not be surprising if other species of *Acartia* were found in these waters.

The species is eurythermal and euryhaline, i.e., characteristic of neritic and shelf waters. Farran (1929) found it common off New Zealand especially in the Bay of Islands.

Acartia danae Giesbrecht

Occurrence: Table 6; Fig. 10.

Sta. A: Nil.

Sta. B: Only a minor constituent in the period March to September and absent from two samples. From October until January it was absent, but in February and March it was a common sub-associate. In April it was again a frequent minor constituent, as in the previous autumn.

Distribution: Off northern New Zealand and once found in the south (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950; Grice, 1961).

A. danae is characteristic of subtropical oceanic-waters. Farran (1929) found it very common off northern New Zealand and took one specimen from the south. That Bary (1951) did not record it from southern New Zealand is consistent with its warm water affinities.

COPEPODA

Harpacticoida

Ectinosomidae

Microsetella rosea (Dana)

Occurrence: Table 6; Fig. 17.

Sta. A: Nil.

Sta. B: Taken in four samples between May and September (absent in July); usually a frequent minor constituent.

Distribution: Off northern New Zealand and to the south (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); south of Tasmania (Vervoort, 1957); and widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950).

M. rosea is probably an oceanic species in this area. Taken a few times off northern New Zealand by Farran (1929) and once further south (40°S). It is probably more characteristic of warmer waters, although Vervoort (1957) records a single specimen from 48°S. south of Tasmania.

Tachidiidae

Clytemnestra rostrata (Brady)

Occurrence: Tables 5, 6; Figs. 17, 44.

Sta. A: Although taken often, never more than common and only occasionally more than a minor constituent. During the year abundance rose to a maximum three times. Between each peak there was at least one sample in which the species was absent. Each peak was of about the same duration but occurred at different times in the two years.

Sta. B: Frequent or common in late autumn and early winter; absent in late winter and spring except for a single occurrence in September. Common in January, thereafter absent until April.

Distribution: Previously unrecorded from New Zealand but widespread in the tropical and subtropical Pacific (Wilson, 1942, 1950).

C. rostrata was more frequent inshore, is probably neritic, and usually an inhabitant of warmer waters.

Euterpina acutifrons (Dana)

Occurrence: Tables 5, 6; Figs. 18, 42, 43, 44.

Sta. A: Taken in every sample but only once abundant. In 1963 maximum abundance occurred in late winter and early spring, but in the following year numbers continued to increase until early summer. Autumn was the season of minimum abundance. In 1963-64 numbers showed an inverse relationship to temperature and also, in most instances, to salinity. Abundance was greatest in late winter and spring, the time of minimum salinities. In 1964-65 this inverse relationship was apparent in autumn and winter but broke down in spring. However, salinities were very much lower in spring and summer 1964 than in the previous year, and the abundance of *E. acutifrons* continued to rise only until shortly after salinities increased quite sharply in early summer.

Sta. B: Taken in all but one sample. Relationships between abundance and temperature/salinity were not as apparent as inshore, though maximum abundance from August to January did coincide with salinities below 35‰, that is, in the lower half of the annual range.

Distribution: Hauraki Gulf (Kramer, 1894; Fuller, 1953); Pelorus Sound (R. M. Cassie, pers. comm.); Otago Harbour, Auckland Harbour, off Gisborne and off Napier (Brady, 1899); off New Zealand and to the South (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and in the south-east Pacific (Wilson, 1942).

E. acutifrons was better represented inshore, and this, coupled with the tendency to abundance during times of low temperatures and salinities, indicates that it is almost undoubtedly neritic. Farran (1929) found it "scarce off New Zealand except in the littoral waters of the Bay of Islands where it was frequent".

COPEPODA

Cyclopoida

Oithonidae

Oithona similis Claus

Occurrence: Tables 5, 6; Figs. 19, 20.

Sta. A: Taken in many samples, usually as an occasional to frequent minor constituent. Most consistently present in late winter and spring when temperatures and salinities were low; less consistently present at other seasons. Poorly represented when temperatures were high.

Sta. B: Present in every sample and at times sub-dominant or even dominant. Little correlation between abundance and physical factors. When relatively important other species were usually scarce.

Distribution: Hauraki Gulf (Kramer, 1894); Wellington Harbour (R. M. Cassie, 1959c); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and widespread in all oceans (Wilson, 1932, 1942, 1950).

The greater importance of *O. similis* in the Jellicoe Channel samples probably is the result of using a finer net there than was used inshore. The species is eurythermal and euryhaline (Vervoort, 1957) but was least abundant at the highest temperatures. Farran (1929) found it common off New Zealand and south to the ice barrier.

Oithona plumifera Baird

Occurrence: Tables 5, 6; Figs. 19, 20.

Sta. A: Taken only in two consecutive samples in late winter/early spring 1963 and in three consecutive spring samples in 1964.

Sta. B: Taken in all months except January, March, and April. Never very numerous and only ever a minor constituent or sub-associate.

Distribution: Off New Zealand and to the south (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and in the tropical and subtropical Pacific (Wilson 1942, 1950).

This is the largest of the three *Oithona* species taken (0.90-1.35mm), and if present it would have been retained in the coarser net used inshore. Probably normally an inhabitant of shelf or oceanic waters. It is typically an offshore species in the Gulf of Mexico (Grice, 1960). Farran (1929) records it as being common throughout the New Zealand region and to the south except within the Antarctic circle.

Oithona nana Giesbrecht

Occurrence: Tables 5, 6; Figs. 19, 20.

Sta. A: Taken in many samples, usually as a minor constituent, but once as a sub-associate. It occurred regularly in winter samples in 1963 and in autumn and winter samples in 1964. Maximum abundance in both years was in early winter. In spring 1964 *O. nana* was consistently present, though it had been absent at this time in the previous year and this is probably related to the lower salinities recorded in spring 1964.

Sta. B: A common constituent in April 1964 but not taken after this until the following November, when it was frequent. In December *O. nana* became more numerous and was abundant in January. In February it was absent, but it reappeared in autumn.

Distribution: Not previously recorded in New Zealand. Off south-eastern Australia (Dakin and Colefax, 1933, 1940); Fiji Islands (Wilson, 1950); and scattered in the Pacific (Wilson, 1942).

Oithona nana is about equally represented at both stations but since this species is very small most would not be retained in the coarser net so it may be more abundant in the inner gulf.

Oncaeidae

Oncaea media Giesbrecht

Occurrence: Tables 5, 6; Fig. 21.
Sta. A: One specimen taken on 17 October 1964.
Sta. B: Present in all samples from March to December 1964, usually as an occasional to frequent minor constituent but once (July) as a sub-associate. Also a rare minor constituent in March 1965.
Distribution: Off northern New Zealand and to the south (Farran, 1929); off south-eastern Australia (Dakin and Colefax, 1933, 1940); and in the tropical and subtropical Pacific (Wilson, 1942).

It is probably an oceanic species in this region. Farran (1929) found it common off northern New Zealand and rare to the south but extending to within the Antarctic Circle. It has not been recorded from southern New Zealand.

Oncaea mediterranea Claus

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: Single specimens were taken in each of three monthly samples in winter and early spring.
Distribution: Off New Zealand and to the south (Farran, 1929); off eastern Australia (Dakin and Colefax, 1933, 1940); south of Tasmania (Vervoort, 1957); and in the central south Pacific between 30°S and 40°S (Wilson, 1942).

O. mediterranea is almost undoubtedly oceanic, and recorded widely from tropical and temperate seas (Vervoort, 1957). Although Farran (1929) recorded a rare colourless form to the south this is typically a warmer water species.

Oncaea venusta Philippi

Occurrence: Tables 5, 6; Fig. 21.
Sta. A: Taken in one sample, 28 August 1964.
Sta. B: In consecutive monthly samples from April to September; occasional to frequent minor constituent, and in one sample a sub-associate.
Distribution: Off northern New Zealand (Farran, 1929); off eastern Australia (Dakin and Colefax, 1933, 1940); and widespread in the Pacific (Wilson, 1942, 1950).

This is probably a warm-water, oceanic species. It was taken by Farran (1929) off northern New Zealand and not south of 36°S.

Oncaea conifera Giesbrecht

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: Taken in two winter samples as an occasional to frequent minor constituent.
Distribution: Off New Zealand and south to beneath the ice (Farran, 1929); off eastern Australia (Dakin and Colefax, 1933, 1940); south of Australia to the Antarctic (Vervoort, 1957); and widespread in all oceans (Wilson, 1942, 1950).

O. conifera is undoubtedly oceanic and is recorded from all oceans from Arctic to Antarctic (Vervoort, 1957).

Oncaea sp.

Occurrence: Tables 5, 6; Fig. 21.
Sta. A: Taken from August to October in all but one sample; only a minor constituent.
Sta. B: Frequent in samples from May to December. Usually a minor constituent but once a sub-associate (July). Also taken in February.

This is the smallest and most abundant *Oncaea* collected. Ovigerous females were often taken. Infrequent occurrence inshore and the small numbers from the Jellicoe Channel indicate that this species also is probably oceanic.

Corycella rostrata (Claus)

Occurrence: Tables 5, 6.
Sta. A: One specimen, on 28 August 1964.
Sta. B: An occasional to frequent minor constituent in June, September, and October.

Probably oceanic. Farran (1929) found it common off northern New Zealand but scarce further south. Also taken from south-eastern Australia (Dakin and Colefax, 1940).

Corycaeus aucklandicus Kramer

Occurrence: Tables 5, 6; Figs. 22, 42, 43, 44.
Sta. A: The second most abundant copepod taken inshore and dominant in more samples than any other species. The variations of abundance followed a distinctive pattern. After being abundant and sub-dominant in autumn, numbers reached a minimum level, usually as a frequent minor constituent in winter, then rose rapidly in late winter, becoming abundant and dominant or even ultra-dominant in spring. After this peak, numbers declined, but in the second year a high level of abundance was maintained, and, although dominance dropped in late spring, it rose again in early summer. This difference can be related to the salinities in spring 1964, which were low compared with those in the previous year.
Sta. B: Variations appear to follow a similar pattern here to those inshore. After being abundant and dominant in mid autumn it declined to a minimum as a frequent sub-associate in mid winter. In late winter numbers rose to abundant, and a level varying from abundant to common persisted until the following autumn when, although numbers at this time were only slightly greater than in spring, other copepod species were less abundant. As inshore, minimum abundance was in the winter months.
Distribution: Common and ubiquitous in the gulf but recorded from northern New Zealand only. Probably typical of neritic and shelf waters. Hauraki Gulf (Kramer, 1894; Fuller, 1953; R. M. Cassie, 1959b).

Farran (1929) did not record *C. aucklandicus*, which is one of the most abundant copepods in the area in which his samples were taken. He described *C. inuncus* as a new species common off northern New Zealand and especially plentiful in the Bay of Islands. This is almost certainly the same species as that described by Kramer (1894).

Corycaeus crassiculus Dana

Occurrence: Table 6.

Sta. A: Nil.

Sta. B: A minor constituent in two winter samples (June and July). This species was common off northern New Zealand (Farran, 1929) but not to the south. It is probably oceanic and restricted to warmer waters.

Distribution: Northern New Zealand (Farran, 1929); off Great Barrier Reef (Farran, 1936); off south-eastern Australia (Dakin and Colefax, 1940); and widespread in the southern Pacific but not south of 36^{0}S (Wilson, 1942).

CLADOCERA

Three species of cladocerans, *Evadne nordmanni* Loven, *Podon polyphemoides* (Leuckart), and *Penilia avirostris* Dana, were seasonally abundant at one or other station. Most *Podon* spp. are *P. polyphemoides*. Other species may may been present but were not identified.

Sididae

Penilia avirostris Dana

Occurrence: Tables 5, 6; Fig. 23.

Sta. A: Seldom well represented, it was initially (May) a frequent associate. In winter and spring only occasional single specimens taken in separate samples. In late spring frequent for a brief period but absent in early summer before reappearing in January. A similar pattern was recorded in both years except that it was not taken in spring 1964.

Sta. B: Seasonally very abundant. More numerous in January 1965 than any other species in a single sample. In autumn 1964 at first common and sub-dominant, then absent, excepting a minor occurrence in mid-winter, until the following summer. In December a frequent minor constituent then in January numbers increased to exceed 100,000 per standard haul as the ultra-dominant non-copepod before dropping to frequent in late summer.

Distribution: Hauraki Gulf (Kramer, 1894; Fuller, 1950, 1953); Bay of Islands (Calman, 1917); south-eastern coastal Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); coastal Japan (Kitou, 1957).

At both stations maximum abundance of *P. avirostris* coincided with maximum temperatures, and it was not taken, except as an occasional minor constituent, at temperatures lower than 18.5^{0}C. Similar seasonal occurrence was recorded for *P. avirostris* in the Hauraki Gulf by Fuller (1950), and it seems to be characteristic of coastal waters of south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); off Zanzibar (Wickstead, 1963); off Japan (Kitou, 1957); and on the Atlantic seaboard of the United States (Deevey, 1952, 1956). There is little doubt that the species is temperature limited in its seasonal and geographic distribution. It is surprising that Calman (1917) recorded it as common in the Bay of Islands in late winter, a time when it is usually scarce.

In spite of its greater importance in the outer gulf, *P. avirostris* is a neritic species and its range hardly extends beyond the shelf. It is not known from southern New Zealand.

Polyphemidae

Podon polyphemoides Leuckart

Occurrence: Tables 5, 6; Fig. 25.

Sta. A: Occasionally abundant and sub-dominant. Distribution was quite different in the two years; it was absent in winter 1963, but attained maximum abundance in winter 1964. A similar difference was recorded for *Evadne nordmanni*, and these two species had very similar patterns of abundance throughout the sampling period. The reasons for this anomaly are not clear. It is of interest that the period of maximum abundance in winter 1964 coincides with the only period when *Clausocalanus arcuicornis*, *Ctenocalanus vanus*, and *Oncaea* sp. were taken inshore.

Fuller (1953) found *Podon polyphemoides* and *Evadne nordmanni* in summer only, and this is probably their usual season of maximum abundance.

Sta. B: Taken in small numbers in April 1964.

Distribution: Hauraki Gulf (Kramer, 1894; Fuller, 1953); south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957).

Podon polyphemoides has a strong preference for neritic waters and was the only cladoceran never taken in abundance in the Jellicoe Channel. It is not recorded from southern New Zealand and is absent from *Terra Nova* samples from the Bay of Islands in early spring.

Evadne nordmanni Loven

Occurrence: Tables 5, 6; Fig. 24.

Sta. A: A pattern of abundance similar to *Podon polyphemoides;* absent in winter 1963 but achieved high abundance then in 1964. Large numbers were also found in summer.

Sta. B: Absent in early winter after being common in autumn. In late winter *E. nordmanni* became abundant and sub-dominant and was frequent in spring but then absent until February and April, when there were two further minor occurrences.

Distribution: Hauraki Gulf (Kramer, 1894; Fuller, 1953); south-eastern Australia (Dakin and Colefax, 1933, 1940); coastal Japan (Kitou, 1957); and in coastal waters of the United States Atlantic seaboard (Deevey, 1952, 1956).

E. nordmanni attained maximum abundance at the two stations in August 1964, the period of minimum salinities. This is consistent with the neritic affinities of the species. Fuller (1953) took *E. nordmanni* only in inner gulf waters.

EUPHAUSIACEA

Nyctiphanes australis G. O. Sars

Occurrence: Table 6; Fig. 25.

Sta. A: Nil.

Sta. B: Present in all but the first two samples in March and April 1964. Three main peaks of abundance occurred in June (sub-dominant), in November (sub-dominant), and in February (sub-associate). No adults were taken, only calyptopis and furcilia larvae identified from Dakin and Colefax (1940), Sheard (1953), and Bary (1956). Each peak of abundance (Fig. 25) corresponds to a period of high relative abundance of the smaller and less active calyptopis larvae. Probably the late larvae and adults are too swift to be caught in a Clarke-Bumpus sampler towed at normal sampling speed. The absence of larger euphausids from samples from small mouthed nets is well known (Tattersall, 1924). For this reason it is probable that *N. australis* is much more abundant in the Jellicoe Channel than these numbers indicate.

Distribution: Otago Harbour (Thomson, 1913); off northern New Zealand (Tattersall, 1924); off southern New Zealand (Bary, 1956); off south-eastern Australia (Dakin and Colefax, 1933, 1940; Sheard, 1953). This species is confined to New Zealand and south-eastern Australia.

It has been shown that *N. australis* makes extensive diurnal vertical migrations and is usually taken in much larger numbers in surface hauls at night than those during daylight hours (Tattersall, 1924; Bary, 1956). Therefore, it might be thought that the absence of post-larvae and adults is a reflection of this behaviour. This, however, is unlikely because these hauls were diagonal ones from very near the bottom to the surface.

The developmental stages of the specimens taken were analysed, although separate instars have not been recognised. Differentiation is based on the stage of development of the eyes and uropods in calyptopis larvae and of abdominal appendages and telsal spines of furcilia larvae. Following Sheard (1953) the following larval groups have been recognised: metanauplius, a group of three calyptopsis larvae, and three (I, II, III) groups of furcilia larvae (Tables 7-9).

A Furcilia I larva lacking pleopods was not described by either Sheard or Bary. This stage is best placed in this group rather than with the calyptopis larvae because of their well developed eyes, which are not covered by the carapace, and because the uropods are well developed. Amongst Furcilia II larvae the following numbers of setose and non-setose pleopods were not encountered by Bary (1956): 1S 2N, 2S 1N, 2S 2N, 2S 3N, 3S, and 3S 1N.

Furcilia III larvae with six or four telsal spines, as described by Bary, were not taken in the Hauraki Gulf.

When larger total numbers were taken there was a higher proportion of smaller larvae, especially calyptopis and Furcilia I groups (Table 10). The occurence of three separate periods in which calyptopis larvae were taken suggests that there are three broods hatched in each year. One brood hatches in early winter, another in late spring, and a third in late summer. Little is known of the population dynamics, and older larvae were not taken in sufficient numbers to indicate the age structure of post-larval and adult populations.

In this area *N. australis* is characteristic of more open waters. The *Terra Nova* took it in large numbers to the north of the North Island but not inshore in the Bay of Islands (Tattersall, 1924). Bary (1956) found it common to the south but only in "coastal" waters with a marked preference for warmer waters (above 13.5^{0}C). Probably it is characteristic of shelf plankton.

Holoplanktonic Crustacean Groups of Minor Importance

No holoplanktonic crustacean group (mysids, cumaceans, amphipods, isopods, and ostracods) was ever more than an occasional minor constituent, and their occurrence appears to have no significant seasonal pattern (Tables 5, 6).

Mysids and cumaceans were never taken in the Jellicoe Channel but were often taken together in the Waitemata Harbour. Their joint occurrence may be related to common behaviour or possibly the net disturbed the bottom.

APPENDICULARIA

Oikopleura spp.

Occurrence: Tables 5, 6; Fig. 26.

Sta. A: In all but one sample and sometimes abundant. Patterns of abundance not evident in the two years. More numerous and dominant, but also more variable, in the second year. Maximum dominance appears to be attained in autumn and in spring. The spectacular drop in September 1964 was concurrent with the occurrence of the normally open water copepods *Clausocalanus arcuicornis, Ctenocalanus vanus,* and *Oncaea* sp.

Sta. B: Nearly always common or abundant and often sub-dominant or dominant. In February sample, mainly because of the scarcity of other species, they were ultra-dominant.

Inshore in the Waitemata Harbour *Oikopleura dioica* Fol was the only abundant species, though others were noted from time to time but not identified. Samples from the Jellicoe Channel contained a variety of species but *O. dioica* was of only minor importance.

This is a widespread genus and, without making specific identifications, affinities cannot be assessed. As in southern New Zealand (Bary, 1960) and eastern Australian waters (Thompson, 1948), *O. dioica* is probably ubiquitous in northern New Zealand coastal waters but rare in the open ocean.

Fritillaria sp.

Occurrence: Table 6.

Sta. A: Nil.

Sta. B: Present in small numbers in the May and July samples.

TABLE 7. Characters Used to Differentiate Stages of Development of Calyptopis Larvae of *Nyctiphanes australis*

Stage	No. Examined	Eyes	Uropods	Telson	Length (mm)
Calyptosis I	24	rudimentary	lacking	little longer than wide	0.94 - 1.08
Calyptosis II	134	rudimentary	lacking	longer than wide	1.07 - 1.22
Calyptosis III	86	well developed	rudimentary	longer than wide	1.40 - 1.78

TABLE 8. Characters Used to Differentiate Stages of Development of Furcilia I Larvae of *Nyctiphanes australis*

No. of Pleopods (non-setose)	No. of Telsal Spines	No. Examined	Length (mm)
0	7	17	2.08 - 2.32
1	7	11	2.18 - 2.20
2	7	10	2.25 - 2.50
3	7	11	2.38 - 2.72
4	7	8	2.64 - 2.94

TABLE 9. Characters Used to Differentiate Stages of Development of Furcilia II and III Larvae of *Nyctiphanes australis*

No. of Setose (S) and Non-setose (N) Pleopods	No. of Telsal Spines	No. Examined	Length
Furcilia II			
1S 2N	7	3	2.8 - 3.2
1S 3N	7	13	3.0 - 3.3
2S 1N	7	5	3.0 - 3.3
2S 2N	7	14	3.1 - 3.8
2S 3N	7	1	3.6
3S	7	2	3.5 - 3.5
3S 1N	7	9	3.7 - 3.9
3S 2N	7	12	3.7 - 4.0
4S	7	2	3.8 - 4.0
4S 1N	7	25	3.6 - 4.5
Furcilia III			
5S	7	45	4.7 - 5.0
5S	5	16	4.7 - 5.3
5S	3	4	4.9 - 5.4
5S	2	2	4.8 - 5.8
5S	1	23	5.7 - 6.4

TABLE 10. The Monthly Occurrence of Larvae of *Nyctiphanes australis* in Each Larval Group.

Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A
Metanauplius	—	—	—	—	—	—	—	—	4	—	—	—	—	—
Calyptosis	—	—	—	9	3	—	4	29	34	—	9	152	3	1
Furcilia I	—	—	1	19	—	—	12	8	17	—	3	2	—	3
Furcilia II	—	—	2	20	—	2	10	32	10	2	—	1	5	1
Furcilia III	—	—	9	35	2	4	6	1	1	2	—	—	30	—
Total	—	—	12	83	5	6	32	70	66	4	12	155	38	5

Fritillaria sp. are not usually taken in neritic waters. They are hitherto unrecorded from New Zealand but several species are recorded from Australia (Thompson, 1948).

THALIACEA

Salpidae

Salpa fusiformis Cuvier

Occurrence: Table 6.

Sta. A: Nil.

Sta. B: A single aggregate form taken in February 1965.

Distribution: Hauraki Gulf (Fuller, 1953); and eastern Australia (Thompson, 1948).

Though scarce in samples in this survey, *S. fusiformis* was common in Hauraki Gulf summer plankton in 1950 and 1951 (Fuller, 1953). The species is undoubtedly oceanic and appears to be limited to warmer seas (Foxton, 1961). Specimens taken by Bary (1960) from Cook Strait and south to the subantarctic were almost certainly *S. thompsoni.*

Thalia democratica Forskal

Occurrence: Tables 5, 6.

Sta. A: A few specimens taken in one sample in November 1963.

Sta. B: A single specimen taken in April 1965.

Distribution: Hauraki Gulf (Fuller, 1953); off the south-east of the South Island and in Cook Strait (Bary, 1960); Wellington Harbour (Wear, 1965c); Kaipara Harbour, New Zealand, and widespread in warmer Australian seas (Thompson, 1948, Russell and Coleman, 1935).

The poor representation of this species, at least in the outer gulf, contrasts with Fuller's (1953) observations that it dominated outer gulf summer plankton together with *Salpa fusiformis* Cuvier and *Salpa cylindrica* Cuvier. Dense swarms of *Thalia democratica* were also noted in the Jellicoe Channel in February 1962 and in November 1962 and 1963 (personal observation).

Thalia democratica is undoubtedly oceanic and must be only an occasional minor component of inshore plankton. Together with other salps, it probably occurs mainly in warmer waters in the New Zealand region although it has been taken from the south-eastern coast of the South Island (Bary, 1960), and it is also seasonally common in Wellington Harbour summer plankton (Wear, 1965c).

Doliolidae

Doliolum (s. str.) *nationalis* Bogart

Occurrence: Table 6; Fig. 27.

Sta. A: Nil.

Sta. B: Taken in two samples in autumn 1965 in which it was dominant and ultra-dominant.

Distribution: To the north of New Zealand (Garstang, 1933); and probably grouped with *D. denticulatus*, which is widespread in warmer Australian seas, Thompson, 1948).

There is some doubt of the validity of this species, since Garstang (1933) stated that the differences between *D. nationalis* and *D. denticulatum* Quoy and Gaimard are probably no more than environmental modifications. Nevertheless, the specimens taken in these samples agree in every respect with those described for *D. nationalis* rather than for *D. denticulatum,* and the former name has been retained (Van Zyl, 1960). Moreover, Fraser (1947) has recognised the two as separate species. Even if they are genetically identical they may have distinctly different affinities, which is more likely if the morphological differences are environmentally induced (Fraser, 1947).

Although several thousand specimens have been examined this was the only doliolid found in the Hauraki Gulf autumn (1965) swarms. With the exception of one larval stage all were gonozoids. This is the first record of an inshore occurrence of a doliolid in the area since T. H. Huxley based his re-description of *D. denticulatum* on specimens taken in the Bay of Islands from HMS *Rattlesnake* (Huxley, 1851).

D. nationalis, like *D. denticulatum,* is limited to temperatures of above 14 or 15°C. In the Pacific it inhabits the subtropical anticyclonic gyres and the area between them (Berner and Reid, 1961). This would include the eastward moving Tasman Current in the Tasman Sea and also the East Auckland Current. It is an oceanic species and must be carried inshore by horizontal mixing processes. It is unrecorded from southern New Zealand and probably never occurs to the south of the Subtropical Convergence.

PTEROPODA

Thecosomata

Cavolinidae

Creseis virgula Rang

Occurrence: Table 6.

Sta. A: Nil.

Sta. B: A minor constituent in one sample, April 1965.

Distribution: Off northern New Zealand (Massey, 1920), off south-eastern Australia (Dakin and Colefax, 1933, 1940; Kott, 1957); off the Great Barrier Reef (Russell and Coleman, 1935); and in the North Pacific (Hida, 1957).

This oceanic species was taken in small numbers off northern New Zealand by the *Terra Nova* (Massey, 1920) and is common in subtropical waters of the northern Pacific (Hida, 1957).

Spiratellidae

Limacina inflata (d'Orbigny)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: A minor constituent in one sample, February 1965.
Distribution: Off northern New Zealand in dredgings (Mestayer, 1916); from northern New Zealand to the Antarctic (Massey, 1920); and in the North Pacific (Hida, 1957).

This is a widespread oceanic species, previously taken from off northern New Zealand to the Antarctic by the *Terra Nova* (Massey, 1920).

HETEROPODA

Pterotracheidae

Firoloida desmaresti Lesueur

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: Taken in June as an occasional minor constituent.
Distribution: Off Auckland and in Cook Strait (Ralph, 1957); to the north of New Zealand (Purchas, 1963); and in the Tasman Sea and all warmer oceans (Tesch, 1949).

Normally an oceanic species often encountered in swarms in the Tasman Sea and in the Pacific to the north of New Zealand (Purchas, 1963) but not south of the South Island, New Zealand (Tesch, 1949).

CHAETOGNATHA

? *Sagitta serratodentata* Krohn

Occurrence: Tables 5, 6; Fig. 27.
Sta. A: Taken infrequently, one or two mature specimens occurring in January and in three winter and spring samples 1964.
Sta. B: Frequent or common in all but one sample, but never more than sub-associate. Higher levels of abundance occurred in winter and again in summer, but there was no pronounced seasonal variation.
Distribution: Off northern New Zealand (and south to the Antarctic?) (Burfield, 1930); Hauraki Gulf (Fuller, 1953); off eastern Australia (Tokioka, 1940; Thomson, 1947); and in the Atlantic (Alvarino, 1965).

Most specimens were immature but their serrate jaws leave no doubt that they belong to the "serratodentata" group. Considering their size, the shape and position of the seminal vesicles, and the well developed collarette, all mature specimens are best referred to *S. serratodentata* rather than to any other species within the group as defined by Alvarino (1961).

In her review of chaetognaths, Alvarino (1965) recognises *S. serratodenta* as occurring only in the Atlantic, and she refers all Pacific records to *S. pacifica* and *S. tasmanica,* both of which were formerly regarded as varieties of *S. serratodentata.* Certainly my specimens do not belong to *S. pacifica, S. tasmanica,* or *S. pseudoserratodentata.*

Bary (1951) took *S. serratodentata* often throughout southern New Zealand waters, but he referred all his specimens to *S. serratodentata* var. *tasmanica,* which is now regarded as being a distinct species (Alvarino, 1961).

Pterosagitta draco (Krohn)

Occurrence: Table 6.
Sta. A: Nil.
Sta. B: One immature specimen, June 1964.
Distribution: Off northern New Zealand (Burfield, 1930); off south-eastern Australia (Dakin and Colefax, 1940; Tokioka, 1940, Thomson, 1947); widespread in the tropical and subtropcal Pacific (Hida, 1957). An oceanic, epiplanktonic, cosmopolitan species of warm temperate seas (Alvarino, 1965).

This is an oceanic species taken commonly off northern New Zealand by the *Terra Nova* (Burfield, 1930), but not recorded far south of the Subtropical Convergence (David, 1958).

CTENOPHORA

Tentaculata

Pleurobrachia pileus (O. F. Muller)

Occurrence: Tables 5, 6; Fig. 28.
Sta. A: Most distinctive and most characteristic of the winter and spring plankton. Not consistently present and never numerous in late autumn. Numbers increased throughout winter, and it was common and an associate in rank by early spring, usually disappearing in mid-summer. By volume, *P. pileus* is dominant in late winter and spring plankton, and because of its predatory habits (Lebour, 1923; Fraser, 1962) it must be more important than numbers indicate. Wear (1965c) found a similar pattern of seasonal abundance in the Wellington Harbour.
Sta. B: Present in all but the February sample, but it did not show similar seasonality here to that inshore. Although the greatest numbers occurred in the January sample, nearly all specimens at this time were very small larvae. Winter was the only season when large, mature specimens were taken and the species was significant by volume.
Distribution: Wellington Harbour (Ralph, 1950; Wear, 1965c).

At times when *P. pileus* was numerous other plankton was relatively scarce, but how far this can be related to the presence of ctenophores has not been assessed.

P. pileus is a neritic form. It is common on both sides of the North Atlantic but is rarely taken in the open ocean (Fraser, 1962).

HYDROZOA

Siphonophora

Nectophores

Occurrence: Table 6; Fig. 27.
Sta. A: Nil.

Sta. B: One or two specimens taken in most autumn and winter samples but not taken from August until February, when a single specimen occurred.

Siphonophores are oceanic in affinity.

Anthomedusae

Turritopsis nutricula McCrady

Occurrence: Table 5; Fig. 31.

Sta. A: Taken inshore from late autumn until early spring in both years. Present when sampling commenced in 1963 and also in April 1964. In both years the last appearance was in October and it was continuously present up until this date. Although never more than frequent, it is relatively large (4-5 mm) and likely to prove a useful macroscopic indicator. The pattern of distribution is almost identical with that in British waters, where it is used as an indicator of the influx of Channel water into the North Sea (Russell, 1953).

Sta. B: Nil.

Distribution: Bare Island, Hawke Bay (Kramp, 1928); Wellington Harbour (Ralph, 1957); Hauraki Gulf (Kramp, 1965); widespread in warmer seas (Kramp, 1961.

Undoubtedly neritic in affinity.

Leptomedusae

Obelia spp.

Occurrence: Tables 5, 6; Fig. 29.

Sta. A: The most abundant medusa taken. Frequent through most of the year though never more than sub-associate in rank. Poorly repreesnted or absent in autumn.

Sta. B: Common only in winter and early spring, sometimes as an associate. Small numbers sometimes present in summer and in one autumn sample.

Wear (1965c) records a similar pattern of abundance for the Wellington Harbour. These medusae are neritic, since they are released by littoral or sub-littoral hydroids.

Miscellaneous medusae

Occurrence: Tables 5, 6; Fig. 30.

Sta. A: Taken in every sample. In both years lowest numbers occurred in autumn and winter and increased in late winter and spring. The group was often common and sometimes associate in rank in spring and summer plankton.

Sta. B: Numbers tended to increase from autumn 1964, reaching a maximum in mid-spring. Absent in November but common in January, after which numbers declined to an autumn minimum.

Medusae are normally neritic in affinity, being released by littoral and sub-littoral hydroids.

MEROPLANKTON

Larvae of Littoral and Benthic Animals

Teleostei

Teleost eggs and larvae.

Occurrence: Tables 5, 6.

Sta. A: Taken in many samples throughout the year but seldom more than occasional minor constituents. In one sample (December 1964) fish eggs were common and sub-associate.

Sta. B: Either eggs or larvae were taken in all but the February sample. Eggs were usually frequent minor constituents but were absent in late autumn and early winter 1964. Larvae were most abundant in spring and early summer as frequent sub-associates but were absent in late summer and autumn 1965.

Cephalochordata

Heteropleuron hectori Benham (amphioxus larvae)

Occurrence: Tables 5, 6; Fig. 27.

Sta. A: One specimen, taken 19 December 1964.

Sta. B: Taken in three consecutive monthly samples from August to October. They were common in August, frequent in September, and occasional in October. In the first two months they were sub-associates.

Adult amphioxus are often taken in dredge samples from the region of the Jellicoe Channel (personal observation). They are apparently rare in or near harbours and estuaries. Larvae were only taken in a limited period so their breeding season must be quite brief. At their first appearance (August) all specimens were much the same size and their length frequency was unimodal (2.70-3.30 mm). In the following month two size groups were present. The larvae in one group were of comparable length to those taken in the previous month (2.85-3.86 mm) and in the other they were considerably larger (4.82-6.00 mm). These two groups could represent two distinct spawnings, the larger September group probably being the only one present in the previous month.

Probably these larvae are typical of spring samples from open coastal localities in the region.

Urochordata

Ascidian tadpoles

Occurrence: Tables 5, 6; Fig. 31.

Sta. A: Occasional minor constituents in winter samples and less abundant than in the spring months. Taken in every sample in summer and autumn and often sub-associates.

Sta. B: Taken only in the December sample as minor constituents.

This group is mainly neritic.

Echinodermata

Echino- and Ophio-plutei.

Occurrence: Tables 5, 6; Fig. 32.
Sta. A: Taken from late spring until late autumn and absent in the 5 month period from May to September. Absent in 1963 until October and after reaching a peak in November they were only occasional in December, then frequent in late summer and autumn. Plutei disappeared in April and were absent until October, the same month as their first appearance in the previous year. Numbers were low in spring but common in summer
Sta. B: Seasonal distribution similar to that inshore, though appearance and disappearance was two months later. Abundant in autumn 1964 but not taken again until the following summer and autumn, when they were again abundant.

Nearly all of the plutei taken belonged to one of three types, of which one was exclusive to Waitemata Harbour samples. This inshore type was a small spatangoid pluteus that was only taken in the early stages of development. It is probably the pluteus of *Echinocardium australe,* the only abundant spatangoid in the Hauraki Gulf. In the Jellicoe Channel two types of pluteus were abundant; one was a spatangoid type at a late stage of development and the other an ophiopluteus. All these plutei had similar seasonal distributions and were not differentiated in counts.

Echinoderm plutei are more abundant and more striking in samples from the open gulf waters, of which they are more typical.

Auriculariae

Occurrence: Table 6; Fig. 32.
Sta. A: Nil.
Sta. B: Frequent in March and April in both 1964 and 1965, and common associates in one sample (March 1965). Also taken in January.

Auriculariae, though larvae, were absent inshore and are probably more common in open coastal situations.

Mollusca

Gastropod and bivalve veligers

Molluscan larvae have been differentiated only into gastropod and bivalve veligers. Both categories, especially the gastropods, contain a great variety of species.

Occurrence: Tables 5, 6; Figs 33, 34.
Sta. A: Both groups taken in nearly every sample as frequent sub-associates. Neither group showed pronounced seasonal variations.
Bivalve larvae were least abundant in late summer, autumn, and winter. Maximum abundance was in early to mid spring in 1963 but not until early summer in 1964.
Gastropod veligers had two periods of greater abundance, one in mid spring and the other in late summer. Numbers were generally low in winter and early summer.
Sta. B: Both groups showed a more definite pattern of abundance than inshore. A sharp increase occurred in mid spring (October), and numbers reached greatest abundance in late spring and early summer. A sharp drop occurred in February, and autumn values fluctuated between frequent and common.

Generally more numerous in neritic plankton.

Phoronidea

Actinotrochs

Occurrence: Tables 5, 6; Fig. 35.
Sta. A: Very seasonal in occurrence. In 1963 they were taken in every sample from late July to late October but at no other time. In 1964 they were taken in the same period and also in small numbers in January 1965. Never very numerous though taken in this restricted period in both years. They are very distinctive and could prove useful in determining the extent of neritic waters in the gulf in late winter and early spring.
Sta. B: Taken in two samples in August and October, the time of their occurrence inshore.

The number of species of phoronid in the area is unknown, but the group is very limited and it is unlikely that there are more than one or two. They have been recorded only from Howick Beach (Wood, 1962), but considering the relatively large numbers of larvae in the plankton they must be quite common.

Bryozoa

Cyphonautes

Occurrence: Tables 5, 6; Figs 34, 35.
Sta. A: In many samples, usually as occasional minor constituents. In one or other year of sampling they were taken at every season. Their longest period of absence was from May to October 1963. Sub-associates only in spring.
Sta. B: Taken in small numbers in autumn and winter, but, as inshore, they were numerous only in spring as common associates or sub-associates. Absent in summer and autumn.

Annelida

Polychaete larvae

Occurrence: Table 5, 6; Fig. 36.
Sta. A: Present in every sample and usually frequent sub-associates. More numerous in winter in both years and relatively numerous in spring. A minor peak occurred in autumn 1964, but the most constant feature was the winter peak.
Although species were not counted separately, larval spionids (probably mostly *Polydora*) and polynoids formed the bulk of the winter population, together with fewer of the distinctive larvae of *Pectinaria* and *Magelona*. *Magelona* larvae were also present in spring when the mitrariae of *Owenia* were quite numerous. Occasional alciopids occurred in autumn and, although adult, they have been included with these larvae.

Sta. B: Frequent sub-associates in autumn and early winter but most numerous in late winter and early spring. Also frequent in autumn.

Cirripedia

Barnacle nauplii and cyprids

Occurrence: Tables 5, 6; Figs 37, 38.

Sta. A: The most abundant and numerous non-copepod group taken inshore (though of relatively little importance in the Jellicoe Channel). Commonly sub-dominant or dominant and at times more numerous than calanoid and cyclopoid copepods. Relatively few nauplii were taken in the late autumn plankton but their numbers increased, reaching a peak in mid winter. In early spring numbers fell to a low level, but in late spring (November) they suddenly became abundant and dominant. In December (1963) nauplii fell in abundance but in the following month rose to very abundant and ultra-dominant, after which, in autumn, values declined. This December drop in numbers did not occur in 1964, and nauplii remained common throughout summer until the end of the sampling period.

In both years greatest abundance and dominance were attained after spectacular rises in late spring and early summer, a secondary peak occurring in the late winter months.

Barnacle cyprids were much less numerous than nauplii but, predictably, had a similar seasonal distribution. They were most numerous in spring and early summer, the only time when they were common associates. A secondary period of abundance occurred in late winter and early spring, which corresponded with a slightly earlier peak for nauplii. The only major anomaly between the numbers of nauplii and cyprids was in January 1964 when maximum numbers of nauplii were taken but cyprids were relatively scarce.

Sta. B: Both nauplii and cyprids were minor, though occasionally abundant, components. As inshore, greatest numbers were taken in January while a secondary period of importance was in winter. Minimum abundance was in spring.

Species of nauplii have not been separately recognised although those of *Elminius modestus* have been identified (Knight-Jones and Waugh, 1949). Two groups of barnacle nauplii were readily differentiated by their size. One, a group of relatively small nauplii (Stage VI, 0.47-0.50mm), was present throughout the year but was rather more numerous in late winter and again in summer. These are most probably the larvae of *E. modestus* and *Chamaesipho columna*, the two abundant small barnacles of the area. Of these, *Elminius modestus* nauplii would be expected to be more numerous since the adult has a wide range of habitats extending into the sub-littoral. The winter and spring maxima for numbers of nauplii correspond approximately to the settlement peaks of *E. modestus* at North Head (Skerman, 1959). The second type of nauplius was much larger (Stage VI, 0.61-0.71mm) and was a balanoid type. They were restricted in occurrence to the period November to February with peak abundance in January. These are undoubtedly the nauplii of *Balanus amphitrite* and *B. trigonis*, the two most abundant balanoids, which settle from November to March. *B. amphitrite* had a peak settlement in January and February (Skerman, 1959).

Wear (1965c) found no distinctive peak in barnacle larvae numbers in Wellington Harbour and on this evidence stated that "this group does not form the striking planktonic landmark in the spring in the South Pacific as it does in Europe" (Pyefinch, 1948; 1949; Barnes, 1950, 1957). Dakin and Colefax (1933) recorded little fluctuation in the numbers of barnacle nauplii off Sydney, but their station was too far offshore for the larvae of predominantly littoral animals to be very important. The fact that Wear took few nauplii in Wellington Harbour could be explained as he used a coarse net (36 gauge grit gauze, mesh 525 microns). In Waitemata Harbour the spring outburst of barnacle larvae is very distinct.

Decapoda

Petrolisthes elongatus (Milne-Edwards)

Occurrence: Tables 5, 6; Fig. 39.

Sta. A: Zoeae were taken throughout the year, and, though not always present, they were only once absent from two consecutive samples (in April 1964). They were never common, and the only evidence of periodicity is that they were more numerous in early summer. The continual presence of zoeae in the plankton and an early summer maximum are consistent with the occurrence of ovigerous females on the shore throughout the year but which are more numerous in late winter and spring (Greenwood, 1965). In Wellington Harbour (Wear 1964b, 1965b) zoeae were absent from the plankton from April to August, and it is likely that lower winter temperatures at that locality inhibit autumn and winter breeding.

Sta. B: A single specimen was taken in January 1965.

Petrolisthes novaezelandiae Filhol

Occurrence: Tables 5, 6; Fig. 39.

Sta. A: In all but one sample, but only once an associate, and only twice common (August and September 1964). Little seasonal periodicity was shown, numbers gradually rising from early winter to late summer in 1963-64 and rising abruptly in early spring 1964. Wear (1964a) also took zoeae throughout the year from Wellington Harbour.

Sta. B: Taken from August to October, and in January and April, generally as frequent minor constituents.

That *P. novaezelandiae* zoeae were more abundant than *P. elongatus* at both stations is not surprising. The latter species has the more extensive habitat, being widely distributed in the sub-littoral.

Jaxea sp.

Occurrence: Tables 5, 6.

Sta. A: An occasional minor constituent in one sample, December 1963, and in three consecutive samples in spring 1964.

Sta. B: Occasional in September and frequent in October, but not taken at any other time.

Brachyuran zoeae

Occurrence: Tables 5, 6; Fig. 40.

Sta. A: Taken in every sample, usually as associates and frequently as sub-dominants. In 1963-64 there was little marked seasonal variation in numbers, but they were rather less numerous in the early winter and in autumn. In 1964 there was greater variation. From low autumn values numbers rose, reaching a minor peak in early winter, but reaching maximum abundance and dominance in early spring. After this, numbers varied considerably, showing no trend in abundance but decreasing towards summer.
In both years numbers increased throughout winter to reach peak abundance in early spring, but this peak was less pronounced in 1963 than in 1964.

Sta. B: Less abundant than inshore. Common only twice and frequent in all other samples except in March and November 1964 and February 1965, when none were taken.

Sundry decapod larvae

This group includes all decapods except those listed separately.

Occurrence: Tables 5, 6; Fig. 41.

Sta. A: Similar patterns of abundance were recorded in both years. Minimum abundance was in autumn and winter. From mid winter on numbers rose so that the larvae became common in September, and they fluctuated about this level until mid summer. After this numbers declined.

Sta. B: As inshore, decapods were most numerous in spring when they were common in three consecutive samples. Also common in June but otherwise frequent, except in February when they were absent.

AFFINITIES OF HAURAKI GULF ZOOPLANKTON

The affinities of Hauraki Gulf plankton have been assessed by the number of species that are common to both this and other South-west Pacific localities and to South African waters. In Table 11 copepods have been listed first as they are the most numerous, varied, and frequently the best documented organisms and are likely to yield the most useful and reliable information. The localities are arranged in order of decreasing numbers of copepod species held in common with the Hauraki Gulf.

Only two other New Zealand localities are available for comparison: northern New Zealand (based on the *Terra Nova* collections) and southern New Zealand (based on the 1951 (unpublished) thesis of Bary). It is immediately apparent that of these, and all other localities listed, Hauraki Gulf copepods have more in common with those from northern New Zealand and less in common with those from southern New Zealand. This difference might be expected as the Subtropical Convergence separates southern New Zealand from the north and is undoubtedly the most important physical boundary of plankton dispersal in the area. It is notable that of the 11 species common to both southern New Zealand and the Hauraki Gulf, Bary regarded six (*Calanus tenuicornis, Centropages bradyi, C. aucklandicus, Pleuromamma abdominalis, P. gracilis,* and *Labidocera cervi*), none of which were numerous, as strays of warm-water species from the north. This indicates an even greater difference between the copepod faunas north and south of the Subtropical Convergence.

South-eastern Australian and South African waters also have a large number of copepod species in common with the Hauraki Gulf, and, in spite of their geographical separation, they have many hydrological features in common. These localities are comparable in latitude and all lie to the north of the Subtropical Convergence. so that the main ocean currents are derivatives of the

TABLE 11. Affinities of Hauraki Gulk Plankton as Indicated by the Number of Species Held in Common with Other Southern Hemisphere Waters. Arranged in Decreasing Order of Abundance for Copepods

Plankton	Hauraki Gulf	Northern N.Z.	South-eastern Australian	South African	Great Barrier Reef	Equatorial Pacific	Southern N.Z.	Authorities (see below)
Copepoda	37	32	28	21	13	13	11	1, 2, 3, 4, 5, 6
Cladocera	3	1	3	—	—	—	0	7, 2, 6
Thaliacea	3	1	2-3	2	1-2	—	2	6, 8, 9, 10
Euphausidacea	1	1	1	0	0	—	1	6, 11, 12, 13, 14
Chaetognatha	2	2	2	2	2	2	1?	6, 15, 16, 17, 18, 23
Pteropoda	2	2	1	—	1	2	0	2, 6, 18, 21, 22
Heteropoda	1	1	1	—	1	—	—	19, 20, 22

Authorities: 1 Farran (1929); 2 Dakan and Colefax (1940); 3 De Decker (1964); 4 Farran (1936); 5 Grice (1961); 6 Bary (1951); 7 Calman (1917); 8 Garstang (1933); 9 Thompson (1948); 10 Van Zyl (1960); 11 Tattersall (1924); 12 Sheard (1953); 13 Nepgen (1957); 14 Tattersall (1936); 15 Burfield (1930); 16 Thomson (1947); 17 Heydorn (1959); 18 Hida (1957); 19 Teach (1949); 20 Kott (1957); 21 Massey (1920); 22 Russell and Coleman (1935); 23 Burfield (1950).

southern anticyclonic gyres. The major current of south-eastern Australia is the south-flowing East Australian Current, and this has a common origin with the Tasman Current (Fig. 1), the chief water mass affecting northern New Zealand waters, so biological similarities between northern New Zealand and south-eastern Australian localities might be expected. The main water mass of South African waters is the south-flowing Agulhas Current, which, like the waters of the Tasman Sea, has a subtropical origin and is modified in its passage south in much the same way as the Tasman Current as it approaches New Zealand.

The copepods of the tropical and subtropical waters of the Great Barrier Reef and the Equatorial Pacific are not very similar to those of the Hauraki Gulf. Thirteen species are common to both localities. Even so, these species are characteristically tropical and subtropical in distribution and comprise a distinctive subtropical element in the Hauraki Gulf fauna. It is also significant that Hauraki Gulf copepods have more similarities with the subtropical Pacific species than with those of southern New Zealand.

Apart from the copepods other holoplankton groups indicate the same affinities. Of the cladocerans, Bary (1951) records none from southern New Zealand while all three species are common off the south-eastern Australian coast. Amongst salps, only the doliolids of the *Terra Nova* expeditions have been studied. The doubt about the number of species in Australian waters that also occur off northern New Zealand arises through the recorded occurrence of *Doliolum nationalis*, which some workers recognise only as a variety of *D. denticulatum*. Though Bary took *Salpa fusiformis* in southern New Zealand, this was forma *aspersa*, now recognised as a distinct subantarctic species, *S. thompsoni* (Foxton, 1961). Bary (1951) also took *Thalia democratica*, but regarded it as a stray from warmer waters.

The euphausid *Nyctiphanes australis* is a shelf species and is common to south-eastern Australian waters and northern and southern New Zealand. Both chaetognaths *Sagitta serratodentata* and *Pterosagitta draco* are recorded from all localities north of the Subtropical Convergence. The one species common to northern and southern New Zealand, ? *Sagitta serratodentata*, was represented by different varieties at the two localities. The pteropods and heteropods also show a similar pattern to other groups, the same species being recorded for all localities for which information is available except southern New Zealand.

This evidence indicates the strong subtropical character of Hauraki Gulf and northern New Zealand planktonic fauna. However, in numbers of individuals, both inner and outer gulf plankton have a dominant neritic element. For example, although 35 species of copepods were taken in the Hauraki Gulf, few of these were abundant, and four species together comprised over 90% of the copepods taken at Sta. A and over 80% of the copepods taken at Sta. B. All four of these species, *Paracalanus parvus*, *Corycaeus aucklandicus*, *Temora turbinata*, and *Acartia clausi*. are characteristically coastal species. Of these only *Corycaeus aucklandicus* appears to be restricted to northern New Zealand waters, while the other three species have similar status in inshore waters elsewhere, *Acartia clausi* and *Paracalanus parvus* being particularly widely distributed. Species of *Corycaeus* are not recorded as major elements of copepod fauna elsewhere though they are often minor components and are sometimes represented by a variety of species (Dakin and Colefax, 1940; Farran, 1936; Grice, 1960; Digby, 1950). By number, neritic species dominated the copepod catch throughout the year, but in autumn 1965 the non-copepod zooplankton of the outer gulf was predominantly oceanic (see page 89).

Further information concerning the affinities of Hauraki Gulf copepods can be gained by comparing them with those of the *Terra Nova* collections. Besides sampling in the open ocean, the *Terra Nova* sampled in the Bay of Islands, an inshore locality about 80 miles north of the Hauraki Gulf which in many ways is comparable to the outer gulf. The comparison of the two collections shows that they are strikingly similar (Table 12). Farran (1929) recorded 23 species from the Bay of Islands, and all but two of these have now been taken in the Hauraki Gulf. In addition, 11 species that Farran (1929) recorded only from the open ocean have now also been taken from the outer gulf. Nearly all of the open ocean species have subtropical centres of abundance and few have been recorded south of 43°S except as strays. Three species, *Clausocalanus arcuicornis*, *Ctenocalanus vanus*, and *Oithona similis*, are exceptions, being eurythermal and having wide ranges.

In Table 12 species are arranged in order of abundance in inshore waters (Waitemata Harbour) and in the outer gulf. All of the common copepods at both stations are neritic species which are more abundant inshore in both this and the *Terra Nova* collections. Although 35 species were taken in the gulf, only a few were abundant. The variety of species was considerably less in the inner gulf, as 21 and 35 species occurred at Sta. A and Sta. B respectively. Even though 21 species were taken from inshore, at various times it was unusual for more than eight to be present in the same sample. There were usually twice this number present in the outer gulf.

The neritic and oceanic species within the non-copepod holoplankton yield information that is consistent with that derived from the copepod fauna. The appendicularians were not all identified to species but the greatest number were *Oikopleura dioica*, a species that may be derived from offshore but achieves maximum abundance in neritic or mixed shelf and oceanic water (Fraser, 1961). All of the cladocerans are characteristically neritic, and none are recorded in quantity from oceanic areas. The same is true of the ctenophore *Pleurobrachia pileus*, and the euphausid *Nyctiphanes australis* is regarded as a shelf rather than an oceanic species.

Salps form the only group in the Hauraki Gulf plankton that is undoubtedly wholly oceanic. They were abundant for a restricted period of the year (see p. 61 for full discussion).

COMPOSITION OF ZOOPLANKTON

MEAN ANNUAL ABUNDANCE OF MAJOR GROUPS

The mean annual abundance of the major zooplankton groups is summarised in Table 13. The variety of zooplankton was rather less inshore in the Waitemata Harbour than in the Jellicoe Channel. Groups entirely absent inshore, or represented in only one or two samples, are generally oceanic or characteristic of shelf but not of neritic waters. These include salps, euphausids, chaetognaths, pteropods, and heteropods. Although only a few groups were absent from inshore samples, many were represented only by euryhaline and eurythermal species either characteristic of inshore waters or widespread and nearly cosmopolitan. Thus, within holoplanktonic groups, there were fewer species inshore.

Sta. A - Waitemata Harbour

Copepods dominated most inshore samples and were by far the most abundant organisms, averaging over 70% of the catch. As a group the larvae of benthic and littoral animals ranked next, their average abundance being 22%. Together these two groups, copepods and larvae, accounted for over 92% of the average numbers. Appendicularians, cladocerans, medusae, and ctenophores were also moderately abundant. Appendicularians and medusae were taken throughout the year but had no particular pattern of abundance, whereas cladocerans and ctenophores were absent for considerable periods.

TABLE 12. Affinities of Hauraki Gulf Copepods as Indicated by their Centres of Main Abundance in This Collection and in the *Terra Nova* Collections from Northern New Zealand (Farran, 1929)

Species	Inner Hauraki Gulf (Order of Abundance)	Outer Hauraki Gulf (Order of Abundance)	*Terra Nova*	
			Bay of Islands	Open Sea
Paracalanus parvus	1	1	abundant	common
Corycaeus aucklandicus	2	2	very abundant	common
Temora turbinata	3	4	common	abundant
Acartia clausi	4	3	common	common
Centropages aucklandicus	5	8	scarce	scarce
Euterpina acutifrons	6	6	frequent	scarce
Labidocera cervi	7	=26	frequent	scarce
Oithona similis	8	5	common	abundant
Clytemnestra rostrata	9	11	—	—
Oithona nana	10	7	—	—
Ctenocalanus vanus	11	10	scarce	common
Oncaea sp.	12	15	—	—
Clausocalanus arcuicornis	13	9	frequent	abundant
Oithona plumifera	14	12	scarce	frequent
Calanus australis	15	14	—	frequent
Oncaea media	=16	17	scarce	common
O. venusta	=16	18	scarce	common
Corycaeus crassiculus	=18	25	—	frequent
Corycella rostrata	=18	22	frequent	frequent
Pontella novaezelandiae	20	—	—	scarce
Gladioferens pectinatus	21	—	—	—
Acartia danae	—	13	rare	abundant
Mecynocera clausi	—	16	rare	frequent
Microsetella rosea	—	19	frequent	frequent
Nannocalanus minor	—	20	scarce	common
Calanus tenuicornis	—	21	scarce	common
Pleuromamma gracilis	—	23	—	common
Oncaea conifera	—	24	frequent	common
Pleuromamma abdominalis	—	=26	—	frequent
Oncaea mediterranea	—	=26	rare	frequent
Lucicutia flavicornis	—	29	—	common
Paracalanus aculeatus	—	=30	—	rare
Centropages bradyi	—	=30	—	scarce
Rhincalanus cornutus	—	32	—	scarce
Candacia bipinnata	—	33	—	common
Heterorhabdus papilliger	—	=34	—	frequent
Eucalanus sp.	—	=34	?	?

TABLE 13. Mean Annual Abundance of the Major Zooplankton Groups.

Group	Total Number Std. Hall/Sample	Mean (%) Annual Abundance
Sta. A - Waitemata Harbour		
1 Calanoids	137,814	48.01
2 Larvae	66,814	22.01
3 Cyclopoids	54,061	19.48
4 Appendicularians	11,456	3.63
5 Harpacticoids	7,791	2.76
6 Cladocerans	6,850	1.72
7 Medusae	2,799	1.18
8 Ctenophores	2,422	1.16
9 Other holoplankton	122	0.04
Sta. B - Jellicoe Channel		
1 Calanoids	173,077	36.80
2 Cyclopoids	65,134	23.40
3 Appendicularians	37,575	12.20
4 Cladocerans	111,609	7.26
5 Larvae	22,559	6.77
6 Salps	33,487	6.46
7 Harpacticoids	12,615	3.22
8 Euphausids	7,259	2.35
9 Medusae	1,980	0.63
10 Ctenophores	1,660	0.50
11 Chaetognaths	678	0.24
12 Other holoplankton	59	0.03

All of these moderately abundant groups showed some fluctuation in numbers and in a few samples cladocerans constituted more than 15%, appendicularians more than 10%, and ctenophores or medusae more than 5% of the sample. Other holoplanktonic groups (mysids, cumaceans, isopods, amphipods, chaetognaths, and salps) together averaged only 0.04% of the catches.

Sta. B - Jellicoe Channel

Copepods were also the most abundant group in the outer gulf, averaging 63% of the catch. The larvae of benthic and littoral animals were much less abundant here, averaging less than 7% of the average catch. Once they constituted 22%, a value comparable with the average for inshore samples. The non-copepod holoplankton was both more varied and more abundant in the Jellicoe Channel and not only were more groups represented, but there was also generally more variety within those groups that were common at both stations. Holoplanktonic groups were taken in the following order of abundance: appendicularians, cladocerans, salps, euphausids, hydromedusae, ctenophores, chaetognaths, pteropods, siphonophores, and heteropods (Table 13). Of these groups, cladocerans, salps, and appendicularians each numbered more than 50%, outnumbering copepods in some samples. Of the other groups, euphausids numbered more than 13%, medusae nearly 5%, and ctenophores more than 2% of the catch in different samples.

SEASONAL VARIATIONS IN ZOOPLANKTON COMPOSITION

Sta. A - Waitemata Harbour

The seasonal abundance of the most numerous zooplankton groups (calanoid copepods, cyclopoid and harpacticoid copepods, larvae, and non-copepod holoplankton) in 1963-64 and 1964-65 is contrasted in Fig. 45. The percentage composition of calanoids, cyclopoids, harpacticoids, larvae, appendicularians, and ctenophores which together comprise nearly 99% of the average catch is shown in Figs 46, 47. The percentage composition of the copepod fraction is in Figs 42, 43.

Information concerning separate groups or species, not considered in the above figures but mentioned in the following text, is in Table 5.

Dominance of the major groups throughout the period sampled is shown in Table 14.

Autumn 1963 (March, April, May)

Calanoid copepods were the most abundant group. At first *Temora turbinata* was dominant, but it later dropped to sub-dominant and then to associate rank. *Paracalanus parvus* was sub-dominant throughout and in May became the most abundant calanoid copepod. Of the other calanoids, *Centropages aucklandicus* was usually a sub-associate, as was *Acartia clausi*, except in April when it was only a minor constituent. *A. clausi* was least important in autumn. A few *Labidocera cervi* were present in every sample. The only important cyclopoid copepod, *Corycaeus aucklandicus*, was at first sub-dominant but became less abundant with the approach of winter. Harpacticoids were never important though *Euterpina acutifrons* was usually present in small numbers.

Among the non-copepods, larvae were collectively the most important group, barnacle nauplii declined from sub-dominant to associate, and polychaete larvae from associate to sub-associate. Other sub-associate larvae were miscellaneous decapods, brachyuran zoeae, bivalve veligers, gastropod veligers, and, in early autumn, pluteus larvae and *Petrolisthes novaezelandiae* zoeae.

Oikopleura spp. were the most abundant holoplanktonic non-copepods as sub-dominants or associates, and the cladoceran *Podon polyphemoides* attained associate rank in April and May. Apart from these more abundant organisms, *Penilia avirostris, Evadne nordmanni*, and hydromedusae were always present, and in May *Pleurobrachia pileus* and *Turritopsis nutricula* became established as conspicuous but never numerous components.

In autumn the summer and early autumn dominants, *Temora turbinata* and *Corycaeus aucklandicus*, declined to a level that was exceeded by *Paracalanus parvus*, the dominant winter copepod. With the approach of winter, plutei and cladocerans gradually disappeared, and *Pleurobrachia pileus* together with *Turritopsis nutricula* became established. Cladocerans are probably usually more numerous in autumn than in the one sampling year, 1964, because there is reason to believe that they failed to become well established in this year (see p. 85).

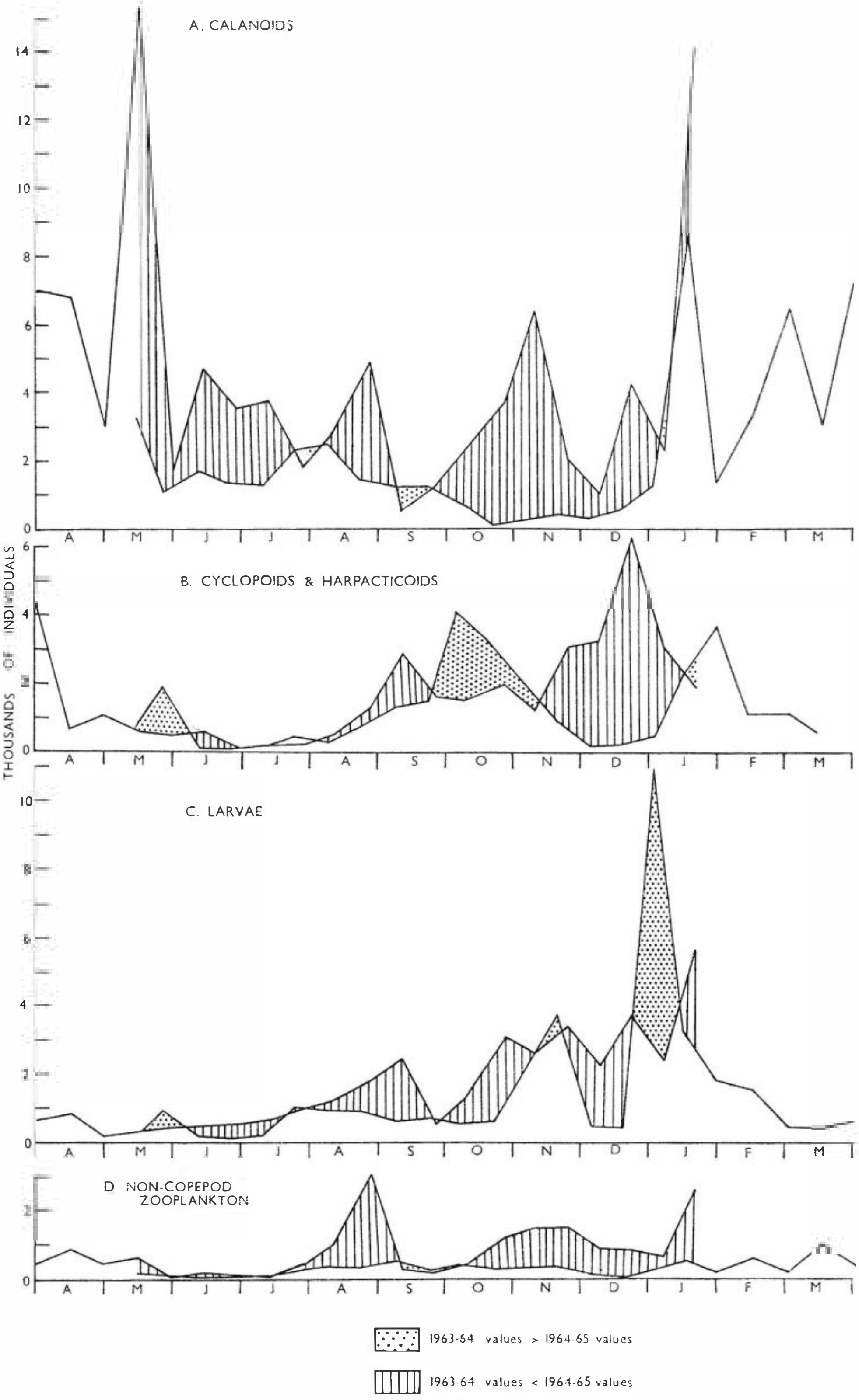


FIG. 45. Anomaly diagram of differences in the abundance of major zooplankton groups between 1963-64 and 1964-65 for Sta. A - Waitemata Harbour

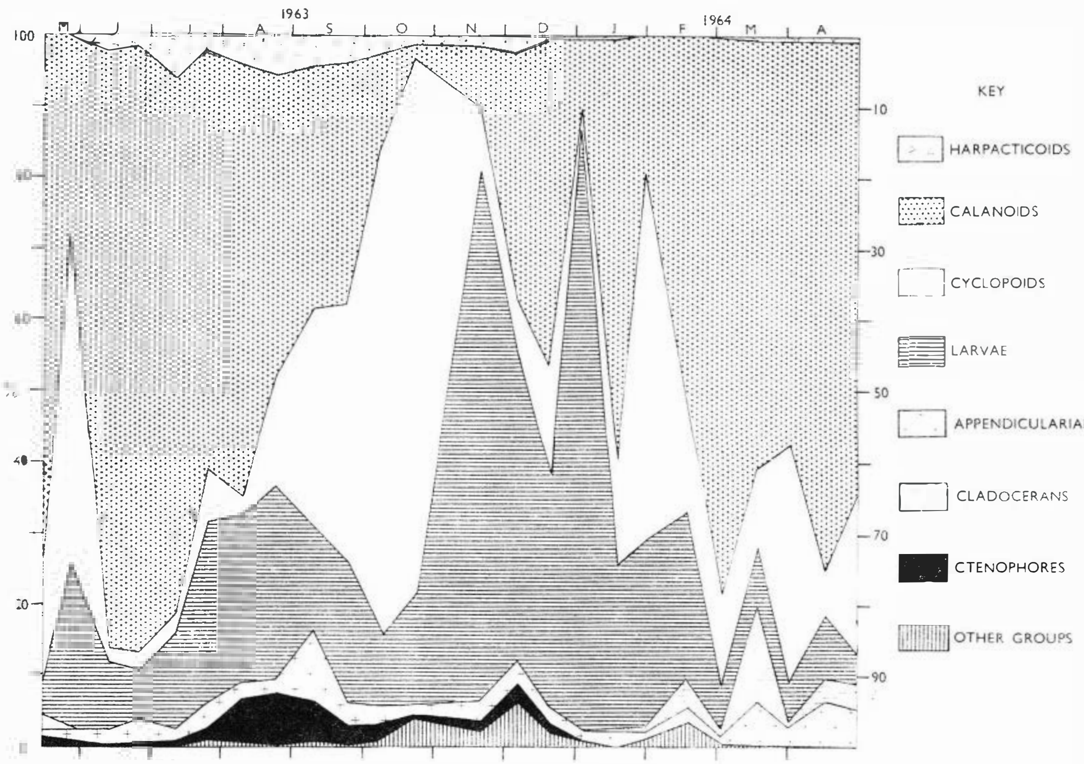


FIG. 46. Variations in the relative abundance of major zooplankton groups at Sta. A - Waitemata Harbour, 1963-64

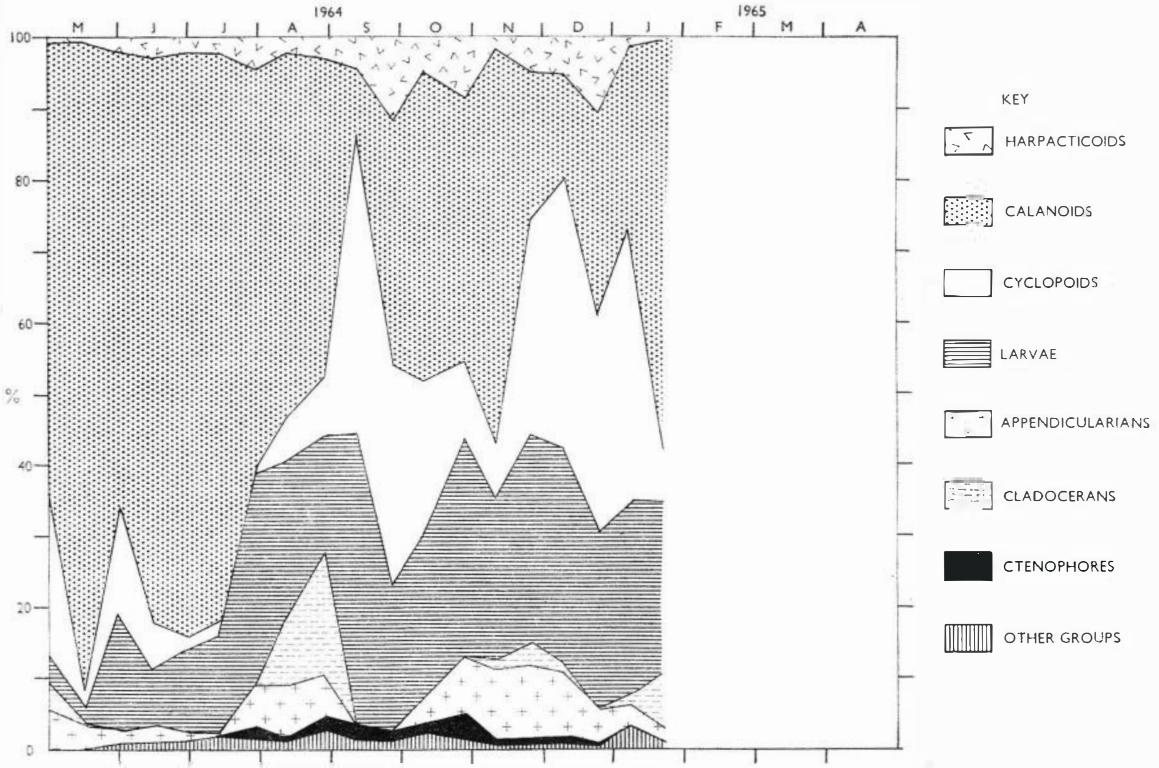


FIG. 47. Variations in the relative abundance of major zooplankton groups at Sta. A - Waitemata Harbour, 1964-65

TABLE 14. Succession of Dominance at Sta. A - Waitemata Harbour
COPEPODS

Level of dominance (%)	March	April	May	June	July	August
50-76.6 Dominant	*Temora*				*Paracalanus*	
23.3-49.9 Sub-dominant	*Corycaeus* *Paracalanus*	*Temora* *Corycaeus* *Paracalanus*	*Paracalanus*	*Acartia* *Paracalanus*	*Acartia*	*Paracalanus* *Acartia*
6.7-23.2 Associate			*Temora* *Corycaeus*	*Temora*	*Temora* *Euterpina*	*Temora* *Corycaeus*
1.0-6.6 Sub-associate	*Centropages* *Acartia*	*Centropages*	*Centropages* *Acartia*	*Corycaeus* *Centropages* *Oithona nana* *Euterpina*	*Corycaeus* *Centropages*	*Euterpina* *Centropages*

Level of dominance (%)	September	October	November	December	January	February
50-76.6 Dominant		*Corycaeus*				
23.3-49.9 Sub-dominant	*Corycaeus*		*Corycaeus*	*Corycaeus* *Temora*	*Corycaeus* *Temora*	*Corycaeus* *Temora*
6.7-23.2 Associate	*Paracalanus* *Acartia* *Temora*	*Paracalanus* *Acartia*	*Paracalanus* *Acartia* *Temora*	*Paracalanus* *Acartia* *Euterpina*	*Paracalanus* *Acartia*	*Paracalanus* *Acartia*
1.0-6.6 Sub-associate	*Euterpina* *Centropages* *Clytemnestra*	*Temora* *Centropages*	*Centropages* *Euterpina*	*Centropages*	*Euterpina* *Centropages*	

NON-COPEPODS

Level of dominance (%)	March	April	May	June	July	August
50-76.6 Dominant			Brachyuran zoeae			
23.3-49.9 Sub-dominant	Barnacle nauplii	Barnacle nauplii *Oikopleura*	*Oikopleura*	Brachyuran zoeae Barnacle nauplii	Barnacle nauplii	*Podon*
6.7-23.2 Associate	*Oikopleura* Polychaete larvae	*Podon*	Barnacle nauplii *Podon*	*Oikopleura* Polychaete larvae	Brachyuran zoeae *Oikopleura* Polychaete larvae	Brachyuran zoeae *Oikopleura* Polychaete larvae Barnacle nauplii *Pleurobrachia*
1.0-6.6 Sub-associate	*Podon* *Evadne* Pluteus larvae *Petrolisthes novaezelandiae*	*Evadne*	*Penilia* *Pleurobrachia* *Turritopsis*	*Pleurobrachia* *Turritopsis* *Petrolisthes novaezelandiae*	*Pleurobrachia* *Turritopsis*	*Evadne*

Level of dominance (%)	September	October	November	December	January	February
50-76.6 Dominant			Barnacle nauplii		Barnacle nauplii	
23.3-49.9 Sub-dominant	Brachyuran zoeae	Brachyuran zoeae		Barnacle nauplii		Barnacle nauplii
6.7-23.2 Associate	*Oikopleura* *Pleurobrachia* Decapod larvae	*Oikopleura* *Pleurobrachia* Decapod larvae Medusae	Brachyuran zoeae *Oikopleura*	Brachyuran zoeae *Oikopleura*	Brachyuran zoeae *Oikopleura*	Brachyuran zoeae *Oikopleura*
1.0-6.6 Sub-associate	*Obelia* *Petrolisthes novaezelandiae*	Cyphonautes Actinotrochs *Petrolisthes novaezelandiae*	*Pleurobrachia* Pluteus larvae	*Pleurobrachia* Pluteus larvae *Obelia* *Petrolisthes novaezelandiae*	*Podon* *Evadne* Pluteus larvae	*Podon* *Evadne* Pluteus larvae

Late Autumn 1963 (May)

Calanoid copepods, the most abundant organisms, were rather more abundant in May 1964 than in the previous year when their numbers were rivalled by those of cyclopoids. Larvae ranked third in abundance and were less numerous at this than at almost any other time. Other groups of less importance were cladocerans, the numbers of which were declining; harpacticoids, which were increasing in number; and appendicularians. In 1963 ctenophores were also present from the first sampling day onwards.

Winter 1963 (June, July, August)

Calanoids were again the most numerous organisms and they were relatively a larger component of the zooplankton at this than at any other season. This was partly due to the scarcity of other organisms, particularly larvae (as found by Wear (1965c) in the Wellington Harbour), but even so calanoids were at least as abundant as at any other time of the year. *Paracalanus parvus* and *Acartia clausi* were the most abundant species, *Paracalanus parvus* always being the more numerous. *Centropages aucklandicus* was always present as a sub-associate and *Labidocera cervi* was invariably taken as a minor constituent. Cyclopoids were less abundant than at any other time, *Corycaeus aucklandicus* reaching minimal numbers in June and July as a sub-associate. After this *C. aucklandicus* began to increase, becoming an associate in August. *Euterpina acutifrons* was taken in significant numbers in winter as sub-associate and in July as a full associate. Winter was the only season when harpacticoids rivalled cyclopoids in number.

As a group larvae ranked second after calanoids, barnacle nauplii being the most numerous group as sub-dominants until August. Brachyuran zoeae were also sub-dominant in early winter, but later they were only associates. Polychaete larvae as associates were more important than at other seasons.

Appendicularians, mostly *Oikopleura dioica*, were again the most abundant non-copepod holoplanktonic animals as associates. *Pleurobrachia pileus* increased in number throughout winter and *Turritopsis nutricula*, though never numerous, was taken in every sample. *Pleurobrachia pileus* and *Turritopsis nutricula* are large and have predatory habits which make them conspicuous and biologically important.

In August 1964 there was a burst of *Podon polyphemoides* and *Evadne nordmanni*, both of which were absent in the previous year. This anomalous occurrence is discussed on p. 88. Contemporarily with this burst, and in a few subsequent samples, several copepods were taken that were not otherwise present in Waitemata Harbour samples. These species were *Clausocalanus arcuicornis*, *Ctenocalanus vanus*, *Calanus australis*, *Oncaea media*, *O. venusta*, *O.* sp., and *Corycella rostrata*, together with the chaetognath *Sagitta* ? *serratodentata* and *Jaxea* larvae.

In winter *Paracalanus parvus* and *Acartia clausi* dominated the copepod population and neither *Temora turbinata* nor *Corycaeus aucklandicus* were abundant when compared with other seasons. Amongst non-copepods, *Pleurobrachia pileus* and *Turritopsis nutricula* were conspicuous and characteristic components of winter plankton. Small barnacle nauplii were the most conspicuous larvae and, together with brachyuran zoeae, they were often sub-dominant. Polychaete larvae were relatively more important in winter than at other times.

Spring 1963 and 1964 (September, October, November)

At first calanoids were the most abundant animals, but they then declined in numbers and in relative abundance, reaching minimum numbers in October 1963 and in September 1964. The numbers of both *Paracalanus parvus* and *Acartia clausi* declined to a level comparable with *Temora turbinata*. At this time no other calanoid increased in number, so the decline is not likely to result from competition within the group. However, the cyclopoid *Corycaeus aucklandicus* continued the increase which had begun in later winter until it became the most abundant copepod. In 1963 *C. aucklandicus* was dominant throughout spring and was ultra-dominant in October. However, in 1964 it dominated only one sample because both *Paracalanus parvus* and *Acartia clausi* regained considerable importance in October and November. These differences between the two years are discussed in detail on p. 85.

The harpacticoids *Euterpina acutifrons* and *Clytemnestra rostrata* were well represented in September in both years.

Amongst non-copepods, larvae were again the most abundant. In early spring various decapods were the most frequent, brachyuran zoeae being sub-dominant, ungrouped decapod larvae associates, and *Petrolisthes novaezelandiae* zoeae sub-associates. Barnacle nauplii were less abundant in September and October than at any other time but in November they increased spectacularly. Balanoid nauplii became dominant, exceeding copepods in number. Sub-associate larvae included polychaetes, bivalve and gastropod veligers, cyphonautes, actinotrochs, and, in November, pluteus larvae.

The appendicularian *Oikopleura dioica* was the most abundant and constant member of the non-copepod holoplankton as an associate. In early spring *Pleurobrachia pileus* was also an associate but its numbers decreased with the approach of summer.

Spring plankton was characterised by the domination of the copepod population by *Corycaeus aucklandicus* while *Paracalanus parvus*, *Acartia clausi*, and *Temora turbinata* were of secondary importance. Amongst non-copepods decapoda were initially abundant, as was *Pleurobrachia pileus*, but these components became less plentiful with the approach of summer. In November large numbers of balanoid nauplii were present and were the dominant non-copepods. Also in late spring some typical summer organisms, including cladocerans and pluteus larvae, appeared in small numbers. Spring was the only season when actinotrochs and cyphonautes were regularly present.

Summer 1963-64 (December, January, February)

The calanoid population was characterised in summer by a high proportion of *Temora turbinata,* which was usually sub-dominant and more abundant than either *Paracalanus parvus* or *Acartia clausi. Centropages aucklandicus* was a sub-associate and *Labidocera cervi* was regularly taken. *Corycaeus aucklandicus* was abundant and sub-dominant but was seldom as important as in spring plankton.

Balanoid nauplii were the most abundant non-copepods and were often sub-dominant or even ultra-dominant until February, when they became less numerous though still sub-dominant. Brachyuran zoeae, together with *Oikopleura dioica,* were numerous and associates. Summer sub-associates included larval polychaetes, bivalves, gastropods, ungrouped decapods, and plutei. *Pleurobrachia pileus* was still taken in significant numbers in December but disappeared in January and February. In summer the cladocerans *Podon polyphemoides* and *Evadne nordmanni* became well established and, together with pluteus larvae, were characteristic of summer and autumn plankton. *Penilia avirostris* was never very numerous in this survey, but was almost limited in its occurrence to summer and autumn. On the evidence of Fuller (1950), *P. avirostris* must be considered as usually more numerous than indicated here.

Corycaeus aucklandicus and *Temora turbinata* are characteristically the most abundant summer copepods, and this is the only season when barnacle nauplii are consistently very abundant. Pluteus larvae and the three cladocerans are better represented in summer than at other times and *Pleurobrachia pileus* is generally poorly represented or absent.

Sta. B - Jellicoe Channel

Changes in the percentage composition of the zooplankton and of the copepod population are shown in Figs 48 and 44 respectively. The succession of dominance of the more important copepod and non-copepod elements is shown in Table 15 and abundance of all groups and species in Table 6.

Autumn 1964 (March, April, May)

A different copepod dominated each sample, *Temora turbinata* being dominant in March, *Corycaeus aucklandicus* in April, and *Oithona similis* in May. *Temora turbinata* was the only abundant calanoid and, after dominating the March sample, it declined rapidly becoming a minor constituent by May. Other calanoids were relatively scarce and the next most abundant species, *Paracalanus parvus* and *Acartia clausi,* were sub-associates or associates. In May, *Clausocalanus*

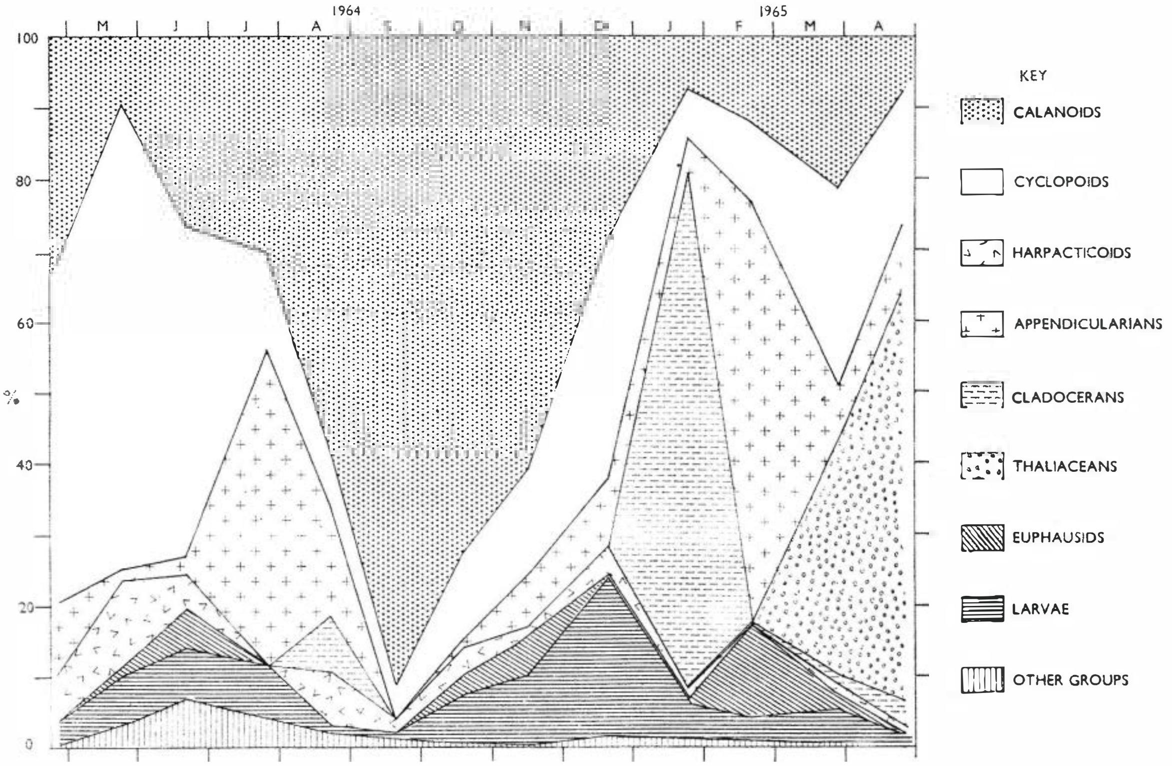


FIG. 48. Variations in the relative abundance of major zooplankton groups at Sta. B - Jellicoe Channel, 1964-65

TABLE 15. Succession of Dominance at Sta. B - Jellicoe Channel

COPEPODS

Level of dominance (%)	March	April	May	June	July	August	September
50-76.6 Dominant	*Temora*	*Corycaeus*	*Oithona similis*			*Paracalanus*	*Paracalanus*
23.3-49.9 Sub-dominant		*Temora*		*Oithona similis* *Corycaeus*	*Paracalanus*		
6.7-23.2 Associate	*Corycaeus* *Acartia*	*Acartia*	*Corycaeus* *Euterpina* *Clytemnestra*	*Paracalanus* *Temora*	*Oithona similis* *Acartia*	*Acartia* *Corycaeus* *Euterpina*	*Acartia*
1.0-6.6 Sub-associate	*Paracalanus*	*Paracalanus*	*Acartia* *Paracalanus* *Clausocalanus* *Ctenocalanus*	*Clytemnestra* *Euterpina* *Acartia* *Clausocalanus* *Ctenocalanus*	*Corycaeus* *Temora* *Ctenocalanus* *Oithona plumifera* *Oncaea* sp. *O. venusta* *O. media*	*Oithona similis* *Temora*	*Corycaeus* *Euterpina* *Oithona similis* *Temora* *Ctenocalanus*

Level of dominance (%)	October	November	December	January	February	March	April
50-76.6 Dominant	*Paracalanus*						
23.3-49.9 Sub-dominant	*Acartia*	*Paracalanus*	*Oithona similis*	*Temora* *Corycaeus*	*Acartia* *Oithona similis*	*Corycaeus*	*Corycaeus* *Oithona similis*
6.7-23.2 Associate	*Corycaeus*	*Acartia* *Temora* *Oithona similis*	*Paracalanus* *Temora* *Acartia* *Corycaeus*	*Paracalanus* *Euterpina* *Oithona nana*	*Corycaeus* *Paracalanus*	*Paracalanus* *Acartia* *Temora*	*Acartia*
1.0-6.6 Sub-associate	*Oithona similis* *Euterpina* *Temora* *Centropages*	*Corycaeus* *Euterpina* *Clausocalanus*	*Euterpina* *Calanus* *Centropages* *Oithona plumifera* *O. nana*	*Acartia* *Centropages* *Clytemnestra*	*Temora* *Calanus* *Acartia danae* *Oithona plumifera*	*Oithona similis* *Acartia danae* *Euterpina*	*Paracalanus* *Temora* *Euterpina* *Oithona nana*

NON-COPEPODS

Level of dominance (%)	March	April	May	June	July	August	September
76.6 Ultra-dominant							
50-76.6 Dominant		*Oikopleura*			*Oikopleura*	*Oikopleura*	
23.3-49.9 Sub-dominant	Pluteus larvae *Penilia*			*Nyctiphanes*		*Evadne*	*Oikopleura*
6.7-23.2 Associate	*Oikopleura* *Evadne*	Pluteus larvae *Penilia*	*Oikopleura* *Pleurobrachia* *Nyctiphanes* Gastropod larvae	*Oikopleura* Decapod larvae *Obelia*			Decapod larvae *Obelia* Polychaete larvae
1.0-6.6 Sub-associate		*Evadne* Auriculariae	Pluteus larvae Cyphonautes *Sagitta*	*Pleurobrachia* Cyphonautes *Sagitta*	*Pleurobrachia*	Amphioxus larvae	Amphioxus larvae *Nyctiphanes* Cyphonautes *Evadne* *Sagitta*

Level of dominance (%)	October	November	December	January	February	March	April
76.6 Ultra-dominant				*Penilia*	*Oikopleura*		*Doliolum*
50-76.6 Dominant						*Doliolum*	
23.3-49.9 Sub-dominant	*Nyctiphanes* Polychaete larvae	*Oikopleura*	*Oikopleura*				
6.7-23.2 Associate	*Oikopleura* Cyphonautes Gastropod larvae	*Nyctiphanes*			*Nyctiphanes*	*Oikopleura*	*Oikopleura*
1.0-6.6 Sub-associate	*Pleurobrachia*	Cyphonautes *Evadne*	*Sagitta* Pluteus larvae	*Oikopleura* Pluteus larvae		*Nyctiphanes* *Penilia* Auriculariae	*Penilia*

arcuicornis and *Ctenocalanus vanus* were relatively important as sub-associates. At first *Corycaeus aucklandicus* was the only important cyclopoid and the second most abundant copepod, but after becoming dominant in April it took second place in May to *Oithona similis.* Harpacticoids were numerous in May when both *Euterpina acutifrons* and *Clytemnestra rostrata* were more abundant than any calanoid.

Early in autumn *Penilia avirostris* and pluteus larvae were sub-dominant and the most numerous non-copepods, but both declined in abundance, first to associate rank, and then in May *P. avirostris* was absent and pluteus larvae were only sub-associates. *Oikopleura* spp. and *Evadne nordmanni* were associates in March, but *Oikopleura* spp. became dominant while *Evadne nordmanni* progressively declined. In May there were no dominant non-copepods, and *Oikopleura* spp., *Pleurobrachia pileus,* and *Nyctiphanes australis* were about equally represented as associates.

Sub-associates in autumn plankton included *Sagitta serratodentata,* gastropod veligers, polychaete larvae, auricularians, cyphonautes, brachyuran zoeae, and ungrouped decapod larvae.

In autumn 1964 the zooplankton was very similar to that taken inshore. *Temora turbinata* and *Corycaeus aucklandicus* were the dominant copepods, and the less abundant species were mostly also taken inshore. *Oithona similis* was the only major copepod not taken in abundance inshore (it may have been abundant there but not caught in the rather coarser net). *Oikopleura* spp. were important at both stations and pluteus larvae and *Penilia avirostris* both declined with the approach of winter. Compared with inshore samples a major difference was the lesser importance of barnacle nauplii.

Winter 1964 (June, July, August)

At first *Oithona similis* and *Corycaeus aucklandicus* were still the most numerous copepods, though they were not as plentiful as in previous samples. *Temora turbinata* and *Paracalanus parvus* rose to associate rank, and the harpacticoids *Euterpina acutifrons* and *Corycella rostrata* dropped to become sub-associates. In late winter *Paracalanus parvus* and *Acartia clausi* rose in abundance becoming dominant and associate respectively. The copepods *Clausocalanus arcuicornis, Ctenocalanus vanus, Oithona plumifera, Oncaea media, O. venusta,* and *Oncaea* sp. were also taken as sub-associates in at least one winter sample.

In June *Nyctiphanes australis* was briefly sub-dominant while *Oikopleura* spp., ungrouped decapod larvae, and *Obelia* medusae were associates. After this *Oikopleura* spp. became dominant, and in August *Evadne nordmanni* was sub-dominant. Sub-associate non-copepods in winter plankton included *Pleurobrachia pileus,* medusae, *Sagitta serratodentata,* polychaete larvae, brachyuran zoeae, barnacle nauplii, decapod larvae, cyphonautes, and, in August, amphioxus juveniles.

In August nearly every group was more numerous, and calanoids rose spectacularly to exceed the numbers of other zooplankton. This rise was the result of a further increase of *Paracalanus parvus* and, to a lesser extent, of *Acartia clausi.* Although *A. clausi* increased fifteen-fold in number between samples it was not sufficient to change its relative rank. It was nevertheless much more abundant than any of its co-associates.

Again the major features of winter plankton in the Jellicoe Channel were similar to those inshore. *Paracalanus parvus* and *Acartia clausi* were by far the most numerous copepods and neither *Temora turbinata* nor *Corycaeus aucklandicus* were of more than secondary importance. *Oikopleura* spp. were the most numerous non-copepods at both stations, and *Pleurobrachia pileus,* though never very numerous, was well represented compared with other seasons. Differences result from the poor representation of larvae in outer gulf samples and from the presence in the outer gulf of significant numbers of the oceanic species *Ctenocalanus vanus, Clausocalanus arcuicornis, Oithona plumifera,* and three *Oncaea* spp.

Spring 1964 (September, October, November)

Copepods were still by far the most abundant group, *Paracalanus parvus* and *Acartia clausi* being the most abundant species. Copepods reached maximum abundance in September and then declined rapidly. *Temora turbinata* was only a sub-associate at first, but with the approach of summer it increased in number and became an associate as the numbers of *Paracalanus parvus* and *Acartia clausi* declined. *Corycaeus aucklandicus* was an associate in October, but was at other times only a sub-associate. *Oithona similis* was a sub-associate except in November when it was a full associate. Other species that were sub-associates in spring were *Ctenocalanus vanus, Clausocalanus arcuicornis, Centropages aucklandicus,* and *Euterpina acutifrons.*

Oikopleura spp. were generally the most numerous non-copepods as sub-dominants, but in October *Nyctiphanes australis* and polychaete larvae were more numerous and replaced them as sub-dominants. Associates in September were decapod larvae, *Obelia* medusae, and polychaetes; in October *Oikopleura* spp., gastropod veligers, and cyphonautes; and in November *Nyctiphanes australis.* Other components which were only sub-associates were amphioxus juveniles, hydromedusae, *Evadne nordmanni, Sagitta serratodentata, Pleurobrachia pileus,* and brachyuran zoeae.

The composition of spring plankton in the Jellicoe Channel was rather different from that inshore. *Paracalanus parvus* and *Acartia clausi* maintained their rank as the most important copepods, and their numbers were never rivalled by those of *Corycaeus aucklandicus.* Larvae were much less numerous than in the inner gulf, but *Nyctiphanes australis,* which was never taken inshore, was well represented. Similarities between the two stations were that the numbers of *Temora turbinata* were low until November, the ranks held by many of the less abundant copepods were similar, and *Oikopleura* spp. were the most abundant non-copepods.

Summer 1964-65 (December, January, February)

Copepods were not abundant in summer and no species was consistently more abundant than others. *Paracalanus parvus* and *Acartia clausi* were superseded in December by *Oithona similis,* which became sub-dominant. *O. similis* in turn was outnumbered in January, when *Temora turbinata* and *Corycaeus aucklandicus* became sub-dominant. In February, *Acartia clausi* and *Oithona similis* were sub-dominant and the most numerous species. Minor ranking copepods also showed considerable change, but there were no recognisable trends. *Oithona nana* and *Centropages aucklandicus,* two neritic species, were present in significant numbers in December and January, but were absent in February, when the oceanic *Acartia danae* appeared in significant numbers for the first time.

Changes also occurred amongst non-copepods. *Oikopleura* spp., sub-dominant in December and ultra-dominant in February, were only sub-associates in January, *Penilia avirostris* becoming super-abundant and ultra-dominant. The high numbers of *P. avirostris* in the January sample are puzzling because. although it was present in the adjacent samples, it was not numerous enough to rank even as a sub-associate. It is unlikely that such an increase could be the result of natural increase, and most probably all January hauls were drawn from the same swarm of *P. avirostris.* Apart from *Oikopleura* spp. and *Penilia avirostris,* the only non-copepod to exceed sub-associate rank was *Nyctiphanes australis,* which was an associate in February.

Summer zooplankton in the Jellicoe Channel also differed from that inshore. *Temora turbinata* and *Corycaeus aucklandicus* had similar status to inshore samples in January when they were co-dominants, but they were otherwise equalled or exceeded by a number of other species. *Oikopleura* spp. and *Penilia avirostris* were far more abundant than inshore. A further major difference was the low number of larvae, though at both stations pluteus larvae and barnacle nauplii were more abundant than at any other season.

Autumn 1965 (March, April, May)

Cyclopoids dominated the reduced copepod population, *Corycaeus aucklandicus* being sub-dominant in March and again in April when *Oithona similis* had similar status. The most abundant calanoids, *Paracalanus parvus, Acartia clausi,* and *Temora turbinata* were not numerous and were either associates or sub-associates. In March *Acartia danae* was still a sub-associate, as it had been in February.

Tunicates dominated the whole zooplankton population, and although *Doliolum nationalis* was not even represented at other times of the year, it was dominant in March and ultra-dominant in April. Such an increase from non-occurrence to super-abundance must have resulted from an invasion from offshore. Associates ranking next in number were *Oikopleura* spp., and sub-associate non-copepods included *Nyctiphanes australis, Penilia avirostris,* gastropod veligers, and auricularian larvae.

Autumn samples from the Waitemata in 1965 were not counted, but a superficial examination showed that their composition was not substantially different from that in the previous year. Only *Corycaeus aucklandicus* maintained similar rank at both stations while *Temora turbinata* was relatively unimportant offshore. The dominant non-copepod, *Doliolum nationalis,* dominated the outer gulf yet was never taken inshore. *Oikopleura* spp. had similar status at both stations, but *O. dioica,* the only common species inshore, was scarce in the Jellicoe Channel. As at other seasons, larvae, especially barnacle nauplii, were comparatively scarce offshore.

VARIATIONS IN DIVERSITY AND INTER-SAMPLE CHANGE

An index of diversity was used by Margalef (1958) to relate the numbers of species to the total numbers of individuals in each of a series of samples.

$$d = \frac{S - 1}{\log_e N}$$

where d = diversity
S = the number of species in the sample
N = the number of individuals in the sample

Margalef applied this diversity index to estuarine phytoplankton and showed that diversity was greater for populations in mixed water than for those in either brackish or truly marine waters. These are differences in space, but the index is equally applicable to differences in time. Disadvantages of the index are that it is not independent of sample size and that it requires the separation of species. Within each series in this survey, sample sizes are comparable, so the first disadvantage is of little importance. The second is not serious either, because, although the species in many groups have not been separately recognised, the same components have been grouped together in an identical way in each sample. Each component, whether a species or not, has been given specific status for the purposes of calculation of the index.

A high diversity indicates that a sample contained a high number of components in relation to the numbers of individuals. A low diversity indicates a small number of components in relation to the numbers of individuals. Lowest diversity is zero, when only one component is present.

Inshore. diversity varied little in comparison with that in the Jellicoe Channel. No particular pattern was shown, except for a tendency for higher values to occur in spring when a greater variety of larvae was taken (Fig. 49). In the Jellicoe Channel diversity had a much greater range, and a peak was attained in early winter,

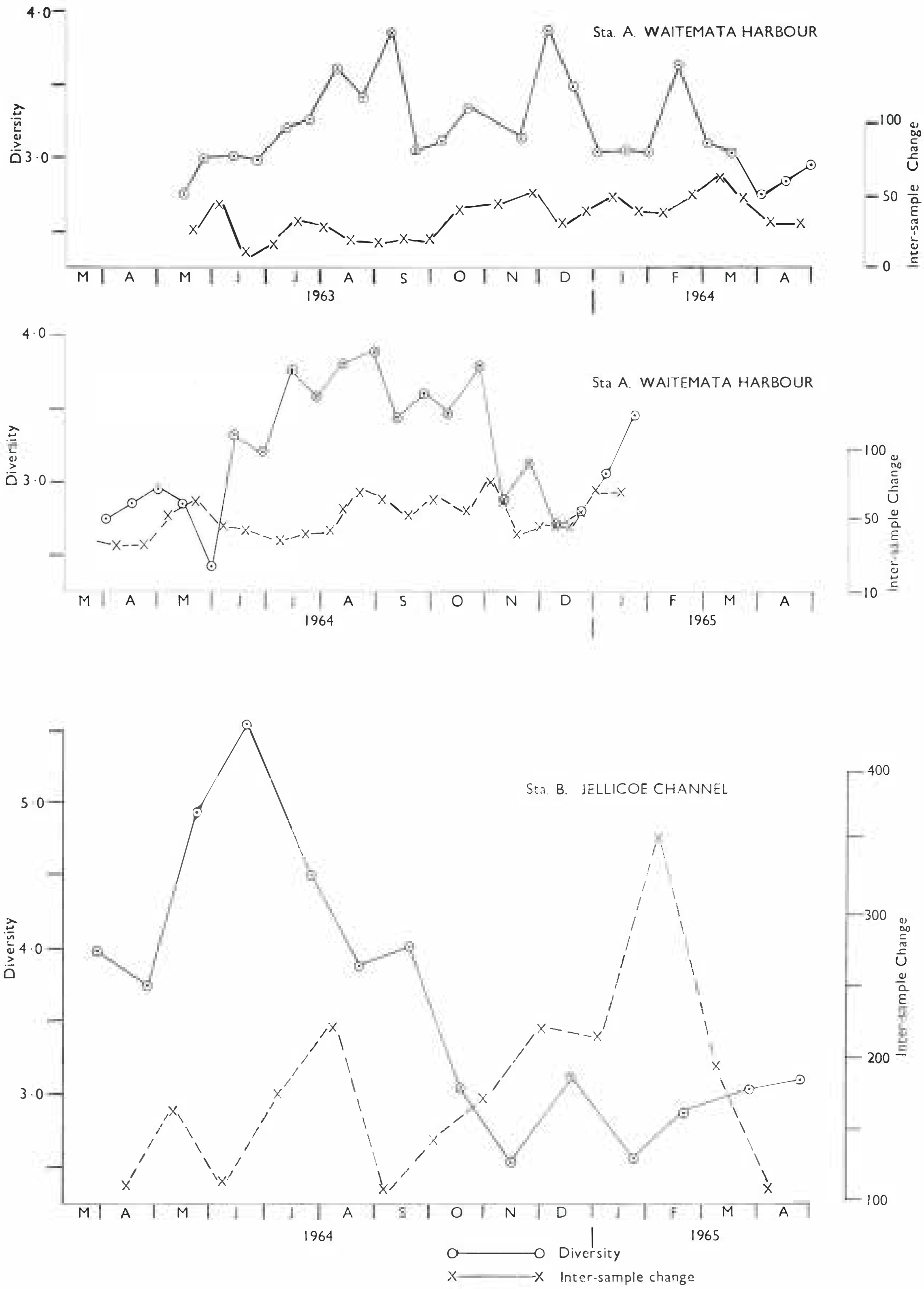


FIG. 49. Variations of diversity and inter-sample change at Sta. A - Waitemata Harbour 1963-64, 1964-65, and at Sta. B - Jellicoe Channel 1964-65

after which diversity fluctuated at about the same level as inshore. The early winter peak indicates either greater variety of components or low total numbers or both. In fact there were no very numerous components in early winter, there being no dominant copepods in June or July and no dominant non-copepods in May or June (Table 15). Variety was greater in winter plankton as a number of components were taken only at this time. This was particularly true in June at peak diversity.

Diversity dropped in late winter as the resident calanoids, especially *Paracalanus parvus* and *Acartia clausi*, increased greatly in numbers and became dominant. Variety declined in late winter and spring for, while the number of neritic components remained nearly constant, the numbers of oceanic components declined. Diversity remained low in late spring, summer, and autumn.

While this index of diversity yields useful information, it does not recognise differences in the abundance of particular components in successive samples. Therefore it is possible for successive samples, having no components in common, to have similar diversity provided that the numbers of individuals and the numbers of components in each are comparable. In January 1965 a large number of neritic components were present and oceanic components were scarce. In the following month many neritic components had disappeared or declined in abundance and many oceanic components had appeared. This changeover in species composition is not reflected by any marked change in the diversity index.

The amount of change between samples has been estimated by the use of a second index which recognises changes in the abundance of each component in successive samples. The index of inter-sample change (2) is calculated as follows:

$$X =_{i} (N_{ij} - N_{i(j+1)})^2$$

N_{ij}=exponent of the common logarithm of the i th species in the j th sample

$(N_{ij} - N_{i(j+1)})^2$ was chosen instead of $(N_{ij} - N_{i(j+1)})$ to emphasise the larger, more significant changes.

As with diversity index the inter-sample change index was relatively stable for the Waitemata Harbour samples and showed little seasonal variation (Fig. 49). Although values inshore were much lower than for the Jellicoe Channel, this would have resulted partly from the closer sampling interval, less change occurring between closer sampling dates. Inter-sample change for the Jellicoe Channel varied almost inversely to diversity. This would be the result of the small effect of appearances and disappearances of the less numerous oceanic species, and the greater importance of the large change in the abundance of the commoner neritic components. There was a minor peak in July-August which was partly the result of a rise in the numbers of the copepods *Paracalanus parvus*, *Acartia clausi*, *Temora turbinata*, and *Corycaeus aucklandicus*, and partly the result of the disappearance of many oceanic components. Then, after a decline in August-September, inter-sample change rose throughout spring, when many oceanic components disappeared and the neritic components varied in abundance from sample to sample. The greatest change was between the January and February samples when a peak resulted from the following changes in plankton composition:

1. Sixteen neritic components (Table 16A) were present and well represented in January, yet they were absent in February. For *Oithona nana*, *Euterpina acutifrons*, and *Pleurobrachia pileus* abundance dropped from over 1,000 per haul.
2. Many neritic components (Table 16B) dropped in abundance, and the only species in this group to register a significant increase was *Nyctiphanes australis*, which is a coastal rather than a neritic species. The most notable decline was that of *Penilia avirostris*, which dropped from over 100,000 per haul to less than a 100.
3. Most of the oceanic components (Table 17B) of Group IB (see p. 88) reappeared in February after being absent in at least the January sample. The most abundant of the reappearing species was *Acartia danae*.
4. Two of the five oceanic components (Table 17C) of Group IC (see p. 88) appeared for the first and only time in February.

This evidence shows that the high value of inter-sample change for January-February arose from the substitution of oceanic for neritic components and from the decline in abundance of many neritic components. This change took place between samples with low diversity indices.

CAUSES OF CHANGE IN ZOOPLANKTON COMPOSITION

SEASONALITY IN THE ZOOPLANKTON

Changes in zooplankton composition are mostly changes in relative abundance within the neritic community which characterises Hauraki Gulf waters. Changes within this community appear to follow a cyclic seasonal sequence. This is consistent with the hydrological evidence that these waters develop their own characteristics and that variations of temperature and salinity are for the most part climatically controlled. At Sta. A, Waitemata Harbour, where data cover nearly two annual cycles, changes in the relative abundance of major groups (Figs 46, 47; Table 14) and copepods (Figs 42, 43) followed similar patterns in both years. Two major differences in the composition of zooplankton in the two years can be related to weather differences. It is notable that there were no sudden appearances or disappearances except amongst poorly represented components. Neither diversity nor inter-sample change indices varied greatly or with any pronounced pattern throughout the year.

The relative composition of the spring copepod population was substantially different in 1963 from that in 1964 (Figs 42, 43). In both years *Paracalanus parvus* and *Acartia clausi* reached minimum relative abundance in spring as their numbers declined and the abundance of *Corycaeus aucklandicus* increased. In 1963 *C. aucklandicus* was the dominant copepod throughout spring, and in October it was ultra-dominant, other species being scarce. In 1964 *C. aucklandicus* reached maximum abundance in early September, some 6 weeks earlier than in the previous year, and then, because its numbers hardly altered, *C. aucklandicus* declined in relative abundance as *Paracalanus parvus* and *Acartia clausi* regained importance in October and November.

There is evidence to suggest that these differences are related to the hydrological situation in the two years. September and especially October 1963 were much warmer and drier than average, and in response both water temperature and salinity rose rapidly (Figs 3, 4). During this time both *Paracalanus parvus* and *Acartia clausi* declined in number and correlation plots for the period show that *Paracalanus parvus* and *Acartia clausi* had similar and generally negative relationships with both temperature and salinity (Figs 50A, B). How-

TABLE 16A. Components from the Jellicoe Channel, Group 2A, Taken in January, but not in February. (1 = 1.0 or fewer per haul; 2 = 1.1 to 10.0; 3 = 10.1 to 100.0; 4 = 100.1 to 1,000.0; 5 = 1,000.1 to 10,000.0; 6 = 10,000.1 to 100,000; 7 = more than 100,000.1)

	1964										1965				
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	Affinity
Centropages aucklandicus	2	3	—	2	—	3	4	4	4	4	4	—	—	—	neritic
Teleost larvae	3	2	2	2	2	3	2	3	3	4	3	—	—	—	neritic
Petrolisthes novaezelandiae	—	—	—	2	—	3	2	2	—	—	3	—	—	2	neritic?
Bipinnaria	—	—	—	—	—	—	—	—	—	—	3	—	—	—	neritic?
Isopods	1	—	—	—	2	—	3	—	—	3	3	—	—	—	?
Clytemnestra rostrata	3	3	4	3	—	—	2	—	—	—	4	—	—	3	widespread
Petrolisthes elongatus	—	—	—	—	—	—	—	—	—	—	3	—	—	—	neritic
Obelia medusae	—	—	—	4	—	3	4	—	—	3	3	—	—	2	neritic?
Oithona nana	—	4	—	—	—	—	—	—	3	4	5	—	3	4	neritic
Pleurobrachia pileus	—	3	3	3	3	3	2	4	3	3	5	—	2	3	neritic
Euterpina acutifrons	3	4	4	4	2	5	4	4	4	4	5	—	4	4	neritic
Teleost eggs	2	—	—	—	3	3	3	—	3	—	3	—	3	3	neritic?
Brachyuran zoeae	—	3	2	3	2	4	3	3	—	3	4	—	3	3	neritic?
Ungrouped decapods	2	3	3	4	3	4	4	3	3	3	3	—	3	3	neritic?
Barnacle cyprids	3	3	—	2	—	3	3	3	—	—	4	—	3	3	neritic?
Auriculariae	2	3	—	—	—	—	—	—	—	—	3	—	4	3	neritic?

TABLE 16B. Components from the Jellicoe Channel, Group 2B, that do not fit into any of the groups in Tables 16A, 17A, B, C (Scale of Abundance as for Table 16A)

	1964										1965				
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	Affinity
Paracalanus parvus	4	4	4	5	4	6	6	6	5	5	5	4	5	4	coastal
Acartia clausi	5	5	3	4	4	5	5	5	5	5	4	4	5	5	coastal
Temora turbinata	5	5	2	4	3	5	5	5	5	3	5	3	5	4	coastal
Corycaeus aucklandicus	5	5	4	5	3	5	4	5	5	4	5	4	5	5	neritic
Oithona similis	3	4	5	5	4	4	5	4	5	5	3	5	4	5	coastal
Oikopleura spp.	4	5	3	4	5	5	4	4	5	5	5	5	5	5	coastal?
Gastropod veligers	3	3	3	4	2	3	3	4	4	4	4	3	4	3	neritic?
Sagitta serratodentata	1	2	3	3	3	3	3	2	3	3	4	3	3	3	open waters
Bivalve veligers	3	3	3	3	3	3	—	4	5	5	5	3	4	3	neritic?
Barnacle nauplii	1	2	2	3	3	3	3	3	—	3	5	3	4	3	neritic?
Polychaete larvae	1	3	3	3	3	4	4	5	—	4	4	3	—	4	neritic?
Medusae	—	3	2	3	3	4	3	4	—	—	4	3	3	2	neritic?
Penilia avirostris	4	4	—	—	2	—	—	—	—	3	7	3	4	5	neritic
Echinoderm plutei	5	4	2	2	—	—	—	—	—	4	5	4	—	—	neritic?
Muller's larvae	1	2	—	—	—	—	—	—	3	—	—	—	—	—	neritic?
Cyphonautes	—	2	2	3	—	2	3	4	4	—	—	—	—	—	neritic?
Mysids	1	—	—	—	—	—	—	—	—	—	—	—	—	—	?
Callianassa larvae	—	3	2	—	—	2	—	—	3	—	—	—	—	3	neritic
Ascidian tadpoles	—	—	—	—	—	—	—	—	—	3	—	—	—	—	neritic?
Calanus australis	2	3	—	—	—	—	3	3	4	3	3	3	3	2	coastal
Nyctiphanes australis	—	—	3	4	3	3	4	5	5	3	4	5	4	4	coastal

ever, the numbers of *Corycaeus aucklandicus* increased in this time and plots show that it had a positive relationship with both temperature and salinity. It is seen that, of the three species, only *C. aucklandicus* increased in number during this period of rapidly rising temperatures and salinities. The relationships of the various species to salinity is not simple, for while *C. aucklandicus* was least abundant at low salinities it was less abundant at high values than at intermediate ones. Conversely, although both *Paracalanus parvus* and *Acartia clausi* were more numerous at low salinities, they were at least as numerous at high as at intermediate values. Even so, it is apparent that *Corycaeus aucklandicus* had different relationships with temperature

TABLE 17A. Zooplankton Components from Jellicoe Channel, Group 1A, that Occurred Chiefly in Winter and that were Absent in Late Spring and in Summer and Autumn 1965. (Scale of Abundance as for Table 16A)

	1964										1965				
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	Affinity
Calanus tenuicornis	—	—	2	—	2	3	3	—	1	—	—	—	—	—	oceanic
Oncaea venusta	—	2	2	3	3	3	2	—	—	1	—	—	—	—	oceanic
Corycella rostrata	—	—	—	3	—	—	2	3	—	—	—	—	—	—	oceanic
Microsetella rosea	—	—	2	3	—	3	3	—	—	—	—	—	—	—	oceanic
Paracalanus aculeatus	—	—	2	2	—	—	—	—	—	—	—	—	—	—	oceanic
Candacia bipinnata	—	—	2	2	—	—	—	—	—	—	—	—	—	—	oceanic
Frittelaria sp.	—	—	2	—	3	—	—	—	—	—	—	—	—	—	oceanic
Pleuromamma gracilis	—	—	—	2	2	—	—	—	—	—	—	—	—	—	oceanic
Lucicutis flavicornis	—	—	—	2	2	—	—	—	—	—	—	—	—	—	oceanic
Oncaea conifera	—	—	—	3	2	—	—	—	—	—	—	—	—	—	oceanic
O. mediterranea	—	—	—	2	2	—	2	—	—	—	—	—	—	—	oceanic
Corycaeus crassiculus	—	—	—	2	2	—	—	—	—	—	—	—	—	—	oceanic
Ostracods	—	—	—	1	3	—	—	—	—	—	—	—	—	—	?
Centropages bradyi	—	—	—	2	—	—	2	—	—	—	—	—	—	—	oceanic
Eucalanus sp. (immature)	—	—	—	2	—	—	—	—	—	—	—	—	—	—	oceanic
Firoloida desmaresti	—	—	—	2	—	—	—	—	—	—	—	—	—	—	oceanic
*Pleuromamma **abdominalis***	—	—	—	—	2	—	—	—	—	—	—	—	—	—	oceanic
Rhincalanus cornutus	—	—	—	—	—	2	—	—	—	—	—	—	—	—	oceanic
Heterorhabdus papilliger	—	—	—	—	—	2	—	—	—	—	—	—	—	—	oceanic
Phyllosomas	—	—	—	—	—	—	2	—	—	—	—	—	—	—	open coast
Jaxea	—	—	—	—	—	2	—	3	—	—	—	—	—	—	open coast

TABLE 17B. Zooplankton Components from the Jellicoe Channel, Group 1B, Taken at Some Time before or after, but not in, the January Sample. (Scale of Abundance as for Table 16A)

	1964										1965				
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	Affinity
Nectophores	2	3	2	3	2	—	—	—	—	—	—	2	—	—	oceanic
Nannacalanus minor	1	2	2	2	—	—	—	—	—	—	—	3	3	—	oceanic
Acartia danae	3	—	3	3	—	3	1	—	—	—	—	4	4	3	oceanic
Clausocalanus arcuicornis	1	3	3	3	3	3	4	4	4	—	—	2	3	3	oceanic
Ctenocalanus vanus	1	2	3	3	3	4	4	—	—	3	—	3	3	3	oceanic
Mecynocera clausi	2	2	2	3	—	—	2	3	—	3	—	2	3	3	oceanic
Oithona plumifera	2	—	3	3	3	3	3	3	4	4	—	3	—	—	open coast
Oncaea sp.	—	—	2	3	3	4	3	3	3	3	—	1	—	—	oceanic
O. media	1	2	2	3	3	3	3	3	3	1	—	—	1	—	oceanic
Amphioxus juveniles	—	—	—	—	—	4	3	2	—	—	—	—	1	—	open coast
Trochophores	—	—	—	—	—	—	—	4	—	—	—	—	3	—	neritic?
Evadne nordmanni	4	3	2	—	—	5	3	3	4	—	—	3	—	2	neritic

TABLE 17C. Zooplankton Components from the Jellicoe Channel, Group 1C, Taken in or after, but not before, the February Sample. (Scale of Abundance as for Table 16A)

	1964										1965				
Month	M	A	M	J	J	A	S	O	N	D	J	F	M	A	Affinity
Limacina inflata	—	—	—	—	—	—	—	—	—	—	—	3	—	—	oceanic
Salpa fusiformis	—	—	—	—	—	—	—	—	—	—	—	2	—	—	oceanic
Doliolum nationalis	—	—	—	—	—	—	—	—	—	—	—	—	5	6	oceanic
Thalia democratica	—	—	—	—	—	—	—	—	—	—	—	—	—	2	oceanic
Creseis virgula	—	—	—	—	—	—	—	—	—	—	—	—	—	2	oceanic

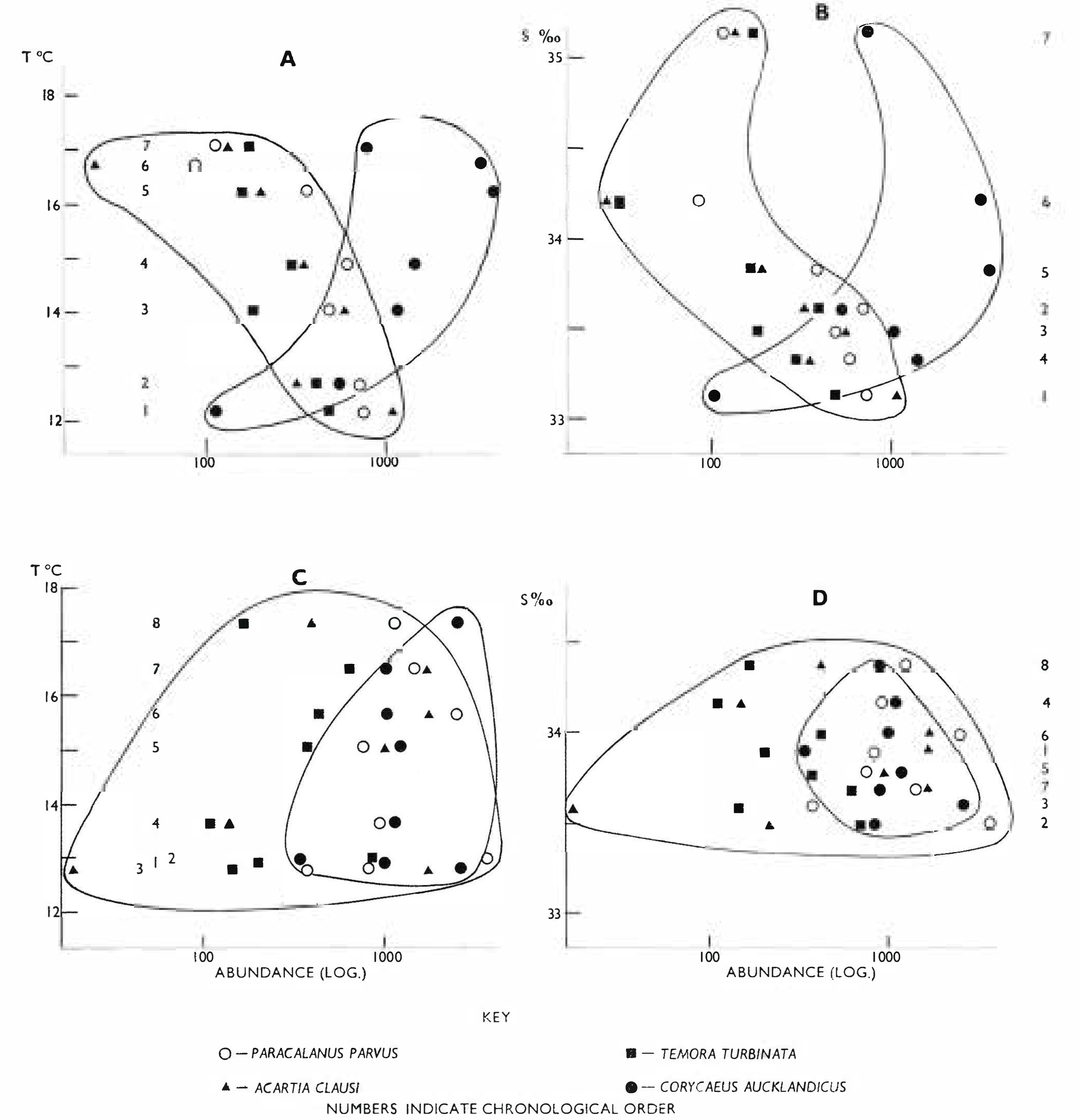


FIG. 50. Relationships of the four major copepod species to temperature and salinity in spring (August to November). Sta A - Waitemata Harbour: A and B Spring 1963; C and D Spring 1964

and salinity and was the only species to become well established in spring 1963 during rapidly rising temperatures and salinities.

In spring 1964 temperatures rose steadily and through much the same range as in the previous year, but salinities fluctuated about a slight upward trend and neither their range nor sequence resembled those of the previous year (Figs 3, 4). During this time all three copepods *Paracalanus parvus, Acartia clausi,* and *Corycaeus aucklandicus* showed wide variations in relative abundance, but correlation plots show little evidence of the relationships that were shown in the previous year (Figs 50C, D). In 1964 nearly all salinities were close to $34^{0}/_{00}$, about the optimum for *C. aucklandicus,* and this species was present at about the same level of abundance at this time in both years. However in 1964 its numbers were rivalled by those of *Paracalanus parvus* and *Acartia clausi.* The major hydrological difference between the two years was the restricted range of salinity in 1964, which appears to be insufficient to show the correlations of the previous year.

Further evidence of the connection between salinity variations and the spring succession of dominant copepods relates to the relative abundance of *Temora turbinata* (Figs 42, 43, 50). This species reaches maximum relative abundance in summer and autumn, at high temperatures and salinities. After this it gradually declines, reaching minimum numbers in spring. The initial increase of *T. turbinata* after this spring minimum coincides with the first appearance of several summer plankton components and could well be used to indicate the beginning of the planktonic summer. In 1963 the initial increase of *T. turbinata* was in late October, some two months earlier than in 1964. However, in spite of the difference in timing, this increase began in the sample after a salinity of $34.50^{0}/_{00}$ had been recorded. The temperature at this sample was some 2°C higher in 1964 than in the previous year. This suggests that there is perhaps a salinity threshold for the species at about this value.

In late spring and early summer 1963 nearly every component declined in abundance, resulting in lower total numbers being taken in December than at any other time. The variations of surface salinity, temperature, and the more significant zooplankton components in the period are shown in Fig. 51.

In the period preceding the fall in total numbers temperatures and salinities rose rapidly, and by October several characteristic winter and spring features had lost their identity. *Paracalanus parvus* and *Acartia clausi* had become relatively scarce and, by October, *Pleurobrachia pileus* had declined from over 100 per haul to little more than 10. *Turritopsis nutricula* disappeared in October, having been taken regularly since late autumn. In late October several characteristic components of summer plankton appeared or began to increase in number. *Temora turbinata* began to increase and *Penilia avirostris* appeared, some 2 months earlier than in the following year. In late November large balanoid nauplii became dominant, comprising 56% of the total numbers. Such a high incidence of barnacle nauplii is a summer feature.

These changes resulted in the establishment of incipient summer features much earlier in 1963 than in the following year. Immediately after this, in November and December, spells of bad weather resulted in various reversals of the seasonal trends of water temperature and salinity, reversals that were concurrent with changes in plankton composition. The winter animals *Paracalanus parvus, Acartia clausi* and *Pleurobrachia pileus* showed a secondary rise in abundance, and the summer components *Temora turbinata* and pluteus larvae were checked, while *Penilia avirostris* disappeared altogether. The numbers of barnacle nauplii dropped from 2,500 per haul to 50 per haul between consecutive samples. This spectacular drop in the numbers of barnacle nauplii, coupled with the low abundance of other plankton at the time, was responsible for the low total numbers of zooplankton taken in December 1963. Low abundance of zooplankton other than barnacle nauplii could be related to the premature summer conditions that had developed in October. At that time the populations of previously well represented species were reduced to levels from which they could not easily recover, and a subsequent reversal of rising temperatures and salinities coincided with checks in the rising numbers of other species that were just becoming established.

In January temperature and salinity reached high levels and were rather more stable than in previous months. At this time typical summer zooplankton was captured after the following changes: *Temora turbinata* increased and became the most numerous copepod; pluteus larvae increased; *Penilia avirostris* reappeared though never regained great abundance; barnacle nauplii showed a further spectacular increase, rising from 120 to over 10,500 per haul between adjacent samples; and the winter and spring indicator, *Pleurobrachia pileus,* disappeared in January.

At Sta. B, Jellicoe Channel, data cover only one annual cycle, and unusual features within the sampling period cannot be recognised. However, the changes within the resident gulf species are likely to follow a seasonal sequence.

INFLUENCE FROM OFFSHORE WATERS

Sta. A - Waitemata Harbour

Oceanic species were never very numerous and were not taken in more than a few samples (Fig. 52). It is notable that the occurrence of offshore species was mostly restricted to the period late August to late October 1964. Their occurrence in this restricted period suggests that they were introduced into the inner gulf together with offshore water and then gradually disappeared from the inshore plankton, being unable to

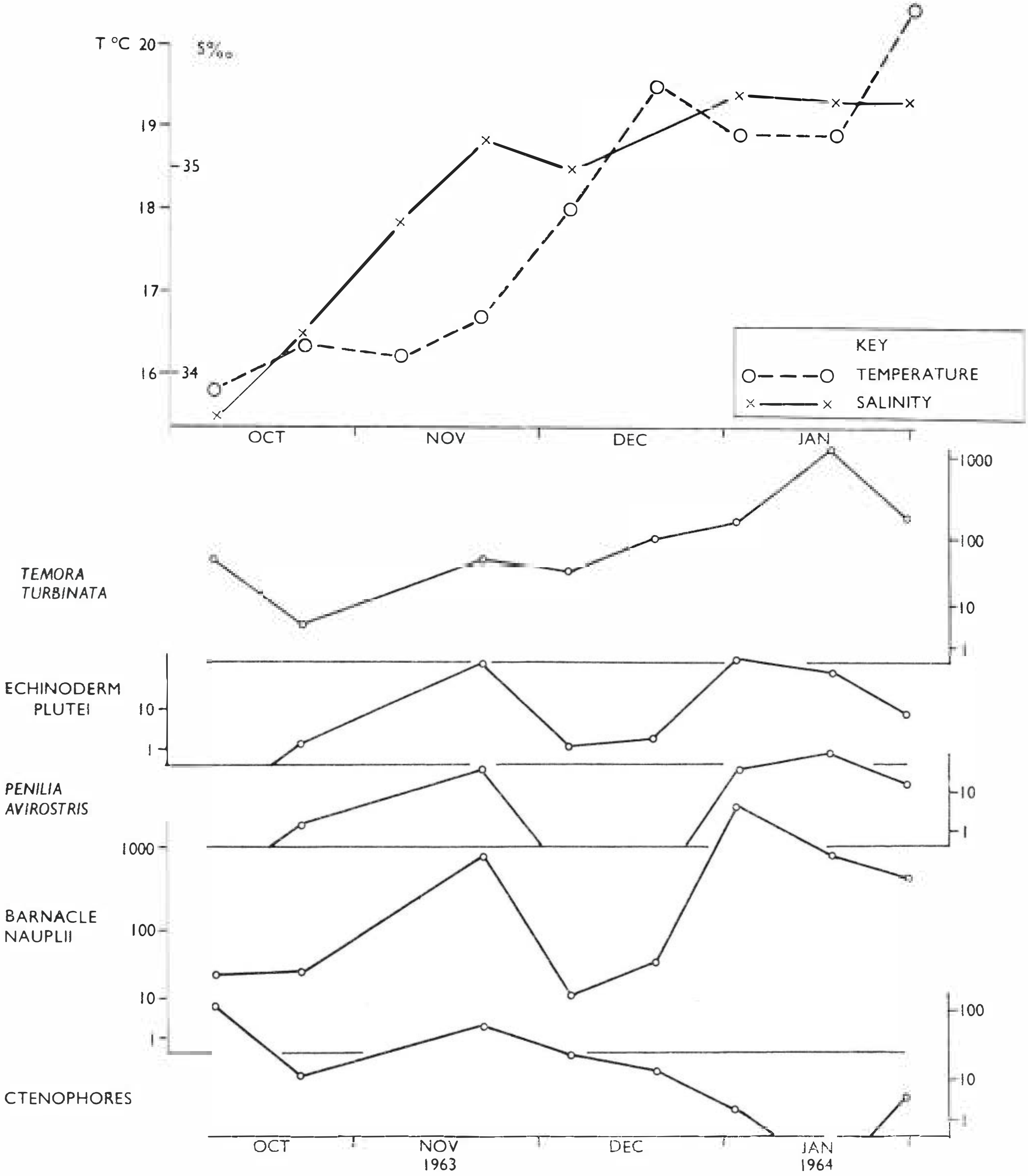


FIG. 51. Variations of temperature, salinity, and selected zooplankton components from October 1963 to January 1964. Sta. A - Waitemata Harbour

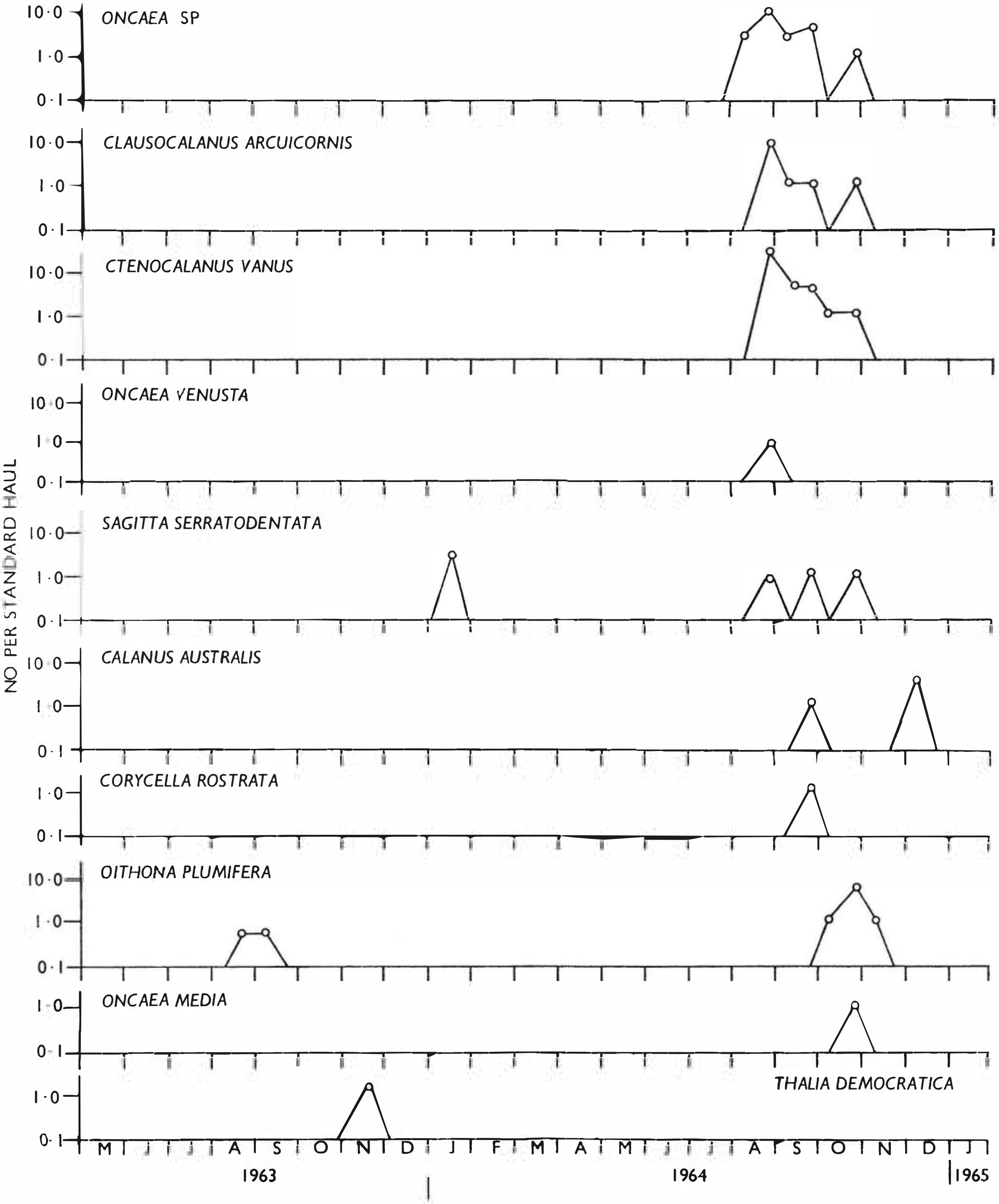


FIG. 52. The occurrence at Sta. A - Waitemata Harbour of species that are more typical of open waters

maintain themselves in the neritic habitat. There is some hydrological evidence to support this hypothesis. Salinities rose by about 0.50⁰/₀₀ in early August at a time when rainfall was greater than average and at a season when salinities were otherwise depressed. Further support is found in the frequency distribution of the three species *Clausocalanus arcuicornis, Ctenocalanus vanus,* and *Oncaea* sp., which were all numerous at first and became less frequent in successive samples until their disappearance in late October. These three were the most abundant of the offshore species, and only small numbers of others were taken. The few minor occurrences of offshore species at other times of the year have no recognisable pattern and probably represent stray individuals.

Two cladocerans, *Evadne nordmanni* and *Podon polyphemoides* were more numerous in two consecutive samples at minimum temperatures in August 1964 than at any other time (Figs 24, 25, 47). Neither of these species was taken at all in winter in 1963 and they were then most abundant in summer and autumn. Fuller (1953) found both these species abundant and considered them characteristic of summer inner gulf plankton in 1949 and 1950. Elsewhere, at a wide range of localities, maximum abundance has also been attained in late spring and summer (Marshall, 1925; Jorgensen, 1933; Dakin and Colefax, 1933; Deevey, 1956 and Bainbridge, 1958).

For marine cladocerans, including *Podon polyphemoides* and *Evadne nordmanni,* it has been suggested that reproductive capacity is greater in waters of higher temperature, leading to greatest abundance in summer plankton. However, the evidence of Bainbridge (1958) suggests that for *E. nordmanni* the matter is more complex and that other factors, especially food, play an important role. Bainbridge analysed the phytoplankton held in the appendages of preserved *E. nordmanni* in relation to the available phytoplankton and showed that it was a very selective feeder, especially on *Ceratium furca* and *Peridinium* spp. It is notable that *Ceratium furca* became the dominant phytoplankton species contemporarily with this late winter burst of *Evadne nordmanni* in the Waitemata Harbour (U. V. Cassie, 1966). It may be significant that *E. nordmanni* also appeared inshore at the same time as several copepod species that were otherwise taken only in the outer gulf. At this time *E. nordmanni* was more abundant in the Jellicoe Channel than at any other time, though *Podon polyphemoides* was not taken then.

Sta. B - Jellicoe Channel

Zooplankton composition was more variable in the Jellicoe Channel than inshore. A number of oceanic components were taken in every sample, and a few of these were abundant at times. It is mainly the variations in the abundance of these oceanic components that result in the wide range and patterns of variability of diversity and inter-sample change indices (Fig. 49). The zooplankton components have been arranged in groups according to their patterns of occurrence:

Group 1A: (Table 17A) Components that occurred chiefly in winter and that were absent in late spring and summer and autumn 1965. Of the 21 components in this group all but two are oceanic. The exceptions are unidentified ostracods, whose affinities cannot be determined, and phyllosoma larvae that are more typical of open coastal than neritic water. This group contains a quarter of the total number of components from Sta. B, and there is no apparent reason why they should be more or less limited in their occurrence to the winter months as only phyllosomas have strongly seasonal life cycles.

Group 1B: (Table 17B) Components taken at some time before or after, but not in, the January sample.

Eight of the 12 components in this group are oceanic and, of the others, two are typical of coastal waters and two are neritic. This group is also predominantly oceanic, and only trochophores, *Evadne nordmanni,* and amphioxus juveniles are likely to be strongly seasonal. The group was well represented in winter together with Group 1A and again in autumn together with Group 1C, but was poorly represented in November and December before its absence in January.

Group 1C: (Table 17C) Components taken in or after, but not before, February 1965.

The five species in this group are all oceanic, and, apart from *Doliolum nationalis,* were not numerous. *D. nationalis* was more abundant in the two samples in which it was taken than any other species and was first dominant and then ultra-dominant.

Group 2A: (Table 16A) Components taken in January but not in February.

This group contains a large number of larval components, the affinities of which could be a matter for conjecture. However, neritic plankton is characterised by a high proportion of larvae, and where affinity can be assessed with some certainty it is neritic. There is little doubt that this is the affinity of the group as a whole. The group was best represented in January in the absence of oceanic components and when most components were at least as abundant as in any other sample. In February these components were absent.

Group 2B: (Table 16B) Components that do not fit into any of the preceding groups.

This large group contains nearly all of the more abundant components, which were responsible for most of the major variations of composition, total numbers, and volume of zooplankton.

The 21 components in this group are typical of neritic or coastal waters. They were nearly all taken throughout the year both here and inshore, and together they comprise the bulk of zooplankton at both stations.

Only one of these components, *Nyctiphanes australis*, was never taken inshore, but this has been regarded as an open coastal species elsewhere in New Zealand (Tattersall, 1924; Bary, 1956).

Two species, *Calanus australis* and *Sagitta serratodentata*, were not normally taken inshore, but both are generally regarded as being widespread in coastal waters. It is immediately apparent that each of the groups contains components of similar affinities. Groups 1A, 1B, and 1C are almost exclusively oceanic, and Groups 2A and 2B are almost exclusively neritic. It is essential to note that no component has been excluded in this arrangement.

Thus the oceanic element was stronger at two seasons of the year; the first in winter at peak diversity and the second in late summer after peak inter-sample change. In winter the water column was isothermal and isohaline, and probably a certain amount of horizontal mixing accompanied vertical mixing. This could result in the introduction of the variety of offshore elements that were present in winter plankton (Tables 17A, B). High diversity in winter is also a reflection of the lack of strongly dominant species. Diversity declined towards spring as fewer oceanic species were taken and the neritic calanoid copepods *Paracalanus parvus* and *Acartia clausi* became dominant. In spring oceanic species became fewer until by mid summer the plankton was almost entirely neritic with a few dominant species.

The second influx of oceanic species in late summer and autumn 1965 was spectacular as the plankton composition changed almost completely from predominantly neritic to predominantly oceanic. This change coincided with the subsurface intrusion of cooler, more saline "oceanic" water into the outer gulf.

The strongly neritic character of the outer Hauraki Gulf zooplankton in 1964 and early 1965 contrasts with Fuller's (1950, 1953) observations that oceanic plankton dominated the outer gulf at all seasons. In this survey oceanic components were always present in the outer gulf and occasionally in Waitemata Harbour samples. However, this element was never dominant except in the outer gulf in autumn 1965. In numbers of holoplankton components the oceanic element in the outer gulf was frequently greater than the neritic one, but only on rare occasions were any of the oceanic species numerous.

Fuller (1953) found the outer gulf summer plankton dominated by the salp *Thalia democratica*, together with *Salpa fusiformis*, *S. cylindrica*, and the copepods *Rhincalanus cornutus* and *Sapphirina* spp. The winter plankton was dominated by *Sagitta serratodentata*, *S. planctonis*, and *S. hexaptera*, together with the copepod *Oncaea venusta*. In this survey a very few *Thalia democratica* were taken, once inshore and one in the Jellicoe Channel. Only single specimens of *Salpa fusiformis* and *Rhincalanus cornutus* were taken. *Sagitta serratodentata* and *Oncaea venusta* were frequently taken in moderate numbers but while *O. venusta* was more frequent in winter than at other seasons, *Sagitta serratodentata* was not. *Sagitta planctonis*, *S. hexaptera*, *Sapphirina* spp., and *Salpa cylindrica* were not taken in this survey. The thaliacean *Doliolum nationalis*, which was seasonally abundant in this survey, was not recorded by Fuller (1953), and there are no records of doliolids from coastal northern New Zealand waters since that of Huxley (1851). These differences do not arise from the location of the outer gulf station, which was well beyond Fuller's outer limit for purely neritic plankton, but probably arise from differences in the extent of influence and composition of oceanic plankton.

VARIATIONS IN TOTAL NUMBERS AND VOLUME

NUMBERS

Sta. A - Waitemata Harbour

The numbers of zooplankton per standard haul, from May 1963 to January 1965, fluctuated greatly (Fig. 53). The trend was for numbers to be low in early winter, increasing in late winter and spring, and reaching a peak in mid summer. After this, in 1964 autumn, numbers were generally high. The differences between consecutive samples were often great. For instance, between 19 December 1963 and 3 January 1964 there is an increase by a factor of 10. The highest numbers were recorded in January 1965 (24,410) and mid May 1964 (16,870), and the lowest number in December 1963 (1,150). Thus the maximum range of zooplankton numbers was 1,150 to 24,410.

Numbers dropped in late autumn (May) and remained low at about 1,800 for three consecutive samples in mid winter. In late July and August there was a rise to about 4,000, and this trend continued into late spring, when about 5,000 were present. In early summer (December) there were fewer individuals present than at any other time; about 1,200 per haul in consecutive samples. After this numbers increased abruptly to 14,000 in January, the highest value in the first year of sampling. Early in January swarms of barnacle nauplii comprising 78% of the numbers were responsible for these high values. Later, in the middle of the month, this proportion dropped to 20%, the decrease being balanced by an equivalent increase in the numbers of other organisms, particularly copepods. In late summer (February) numbers dropped to about 6,500, but during autumn they tended to increase, reaching values around 10,000 in May. Though mean monthly numbers showed a steady increase in these autumn months there was much variation between samples. The sample for mid May 1964 was numerically the second largest taken, containing 16,880 individuals, of which the copepod *Paracalanus parvus* comprised 70%.

In late May numbers dropped, as they had done in the previous year, and they remained low at about 4,500 during June and July. In August numbers increased to 11,000, but they dropped again in the follow-

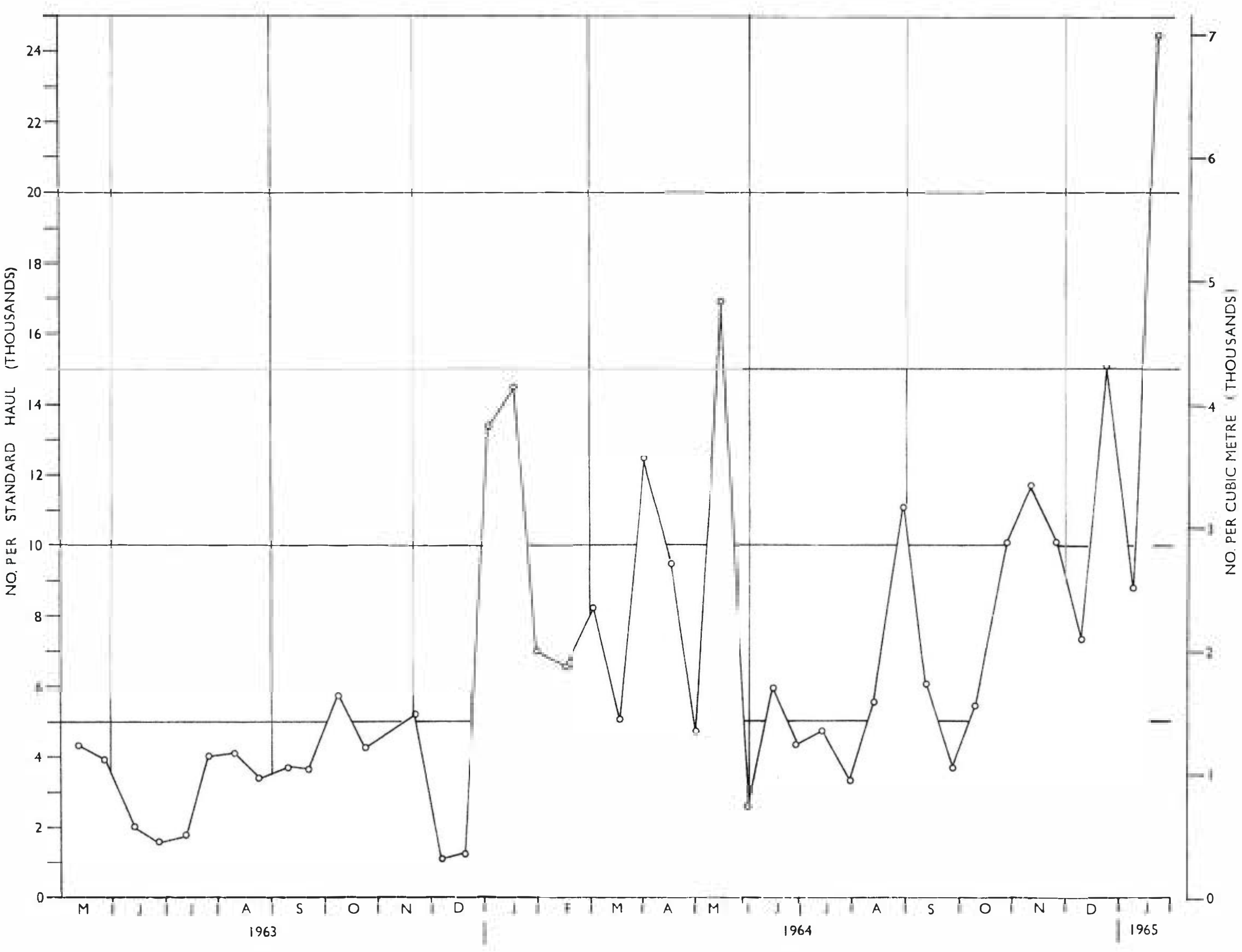


FIG. 53. Variations of zooplankton numbers at Sta. A - Waitemata Harbour

ing month. October numbers showed a further increase, and this trend continued with some variation until the end of the sampling period in late January, when 24,500, the greatest number recorded, were present.

Although samples were taken over a period of nearly two years, seasonality in the variations of numbers is not immediately apparent. This results partly from the wide variations between consecutive samples but mostly from the tendency for values in 1964 to exceed those in the previous year. Because of the higher values recorded in 1964 values showed an upward trend over the entire period. Even so, the trends are similar in the two years, lower values being recorded in winter than at other seasons, and numbers tending to increase to a mid-summer peak. In 1964 the mid-summer peak was succeeded by another peak in late autumn (May). One anomalous feature is the exceptionally low numbers recorded in consecutive samples in December 1963. A period of low numbers at this time was not recorded in the following year. The possible reasons for this drop have been discussed on p. 85. It originated mainly from the temporary disappearance of barnacle nauplii at a time when other zooplankton was scarce.

Sta. B - Jellicoe Channel

Numbers varied in a recognisable pattern, ranging from 3,211 in May to 131,858 in January (Fig. 54). The greatest difference between consecutive monthly counts was a rise from 13,639 in December to 131,858 in January.

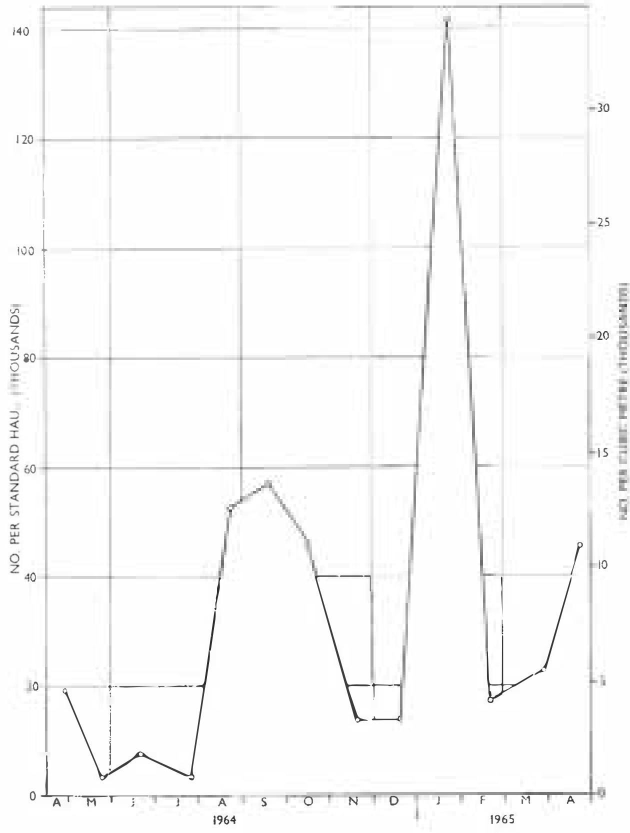


FIG. 54 Variations of zooplankton numbers at Sta. B - Jellicoe Channel

In autumn 1964 numbers decreased from about 19,000 in March to about 3,200 in May. Numbers remained low at around 5,000 in June and July, after which there was a rapid rise to 51,000 in August and 57,000 in September. This early spring peak was followed by a steady decline in counts during the later spring months until in early summer (December) about 13,600 were present. Numbers then rose sharply to the highest recorded count, 132,000 in January, and it is notable that of these 78% were of one species, the cladoceran *Penilia avirostris*. In February numbers dropped sharply to 20,000, a level that hardly changed in March, but an increase to 49,800 occurred in April. The March, and especially the April samples, were characterised by the abundance of the salp *Doliolum nationalis,* which accounted for 50% of the April numbers. But for the presence of this salp zooplankton numbers would have approximated those for the same time in the previous year.

Some features of the variations of total numbers are common to both the inner and outer gulf stations. Lowest values were generally in winter (June and July) and highest in January. The most striking difference is the relative importance of the spring increase. At Sta. A in 1964 the August increase was not sustained into September, and this peak was greatly exceeded in late spring and early summer. At Sta. B the August increase was relatively more pronounced and continued into September. Numbers then declined steadily for 3 months, a time of rising numbers inshore. Although contemporary data is not available for both stations, inshore autumn numbers were greater than spring numbers, and offshore spring values are greater than those for autumn.

As has been stated, absolute comparisons of counts between stations lack meaning, different gear being used at each station. However, in March 1964 trials were conducted at Sta. B using the 0.5 m net already in use at Sta. A. In each of two trials three vertical hauls from near the bottom to the surface were made, and making the same assumptions as at Sta. A, approximately 8.7 m^3 would be filtered in each haul. Estimates from these trials average 2,540 animals/m^3 for March, which is some 25% higher than the March average for Sta. A (1,917/m^3). Thus it seems likely that zooplankton was more abundant in the outer gulf at this time.

During the second trial with the 0.5 m net at Sta. B a haul was made with the Clarke-Bumpus sampler. The numbers estimated from this one Clarke-Bumpus haul (2,130/m^3) are only slightly less than those estimated from hauls with the larger net (2,430/m^3). Though this difference is too small to be significant, it is consistent with the results of Fleminger and Clutter (1965), who found that larger diameter nets gave higher estimates in relation to their mouth area.

VOLUME

Sta. A - Waitemata Harbour

As with mean numbers, it is apparent that there is considerable variation in mean zooplankton volumes (Fig. 55). The lowest values were recorded in June 1963 (0.45 and 0.60ml) and in late May 1964 (0.65ml). The largest volumes occurred in late August and early September 1964 (4.20 and 3.93ml). The range was therefore 3.75ml.

Initially volumes fell, and then remained low in June and July. From late July volumes rose, reaching a maximum in mid January. During this time a major drop in volumes occurred in December, coinciding with the similar fall in numbers. In late January volumes fell sharply then fluctuated with a tendency to increase until mid May. Autumn values were generally lower than those for the previous spring.

In late May 1964 volumes fell to the lowest value in the year, but they subsequently rose to a relatively stable level in June and July. They then rose further, reaching the highest recorded values in late August. After this volumes declined and varied considerably during the remaining spring and summer months but showed no apparent trend.

Patterns are even less obvious in the variations of catch volumes than in mean total numbers. Minimum values for both measures were in early winter, and in the first 12 months of sampling maximum values for both coincided in January 1964. Catch volumes were relatively high in spring and low in autumn when compared with mean numbers; in fact the largest catch volumes were in early spring 1964, well before the largest numbers. The disparity between the patterns of numbers and volumes results from the larger numbers of larger organisms such as decapod larvae, *Pleurobrachia pileus, Turritopsis nutricula,* and a variety of smaller hydromedusae in spring. Autumn volumes are low in relation to numbers, this being a reflection of the poor representation of larger individuals. Autumn

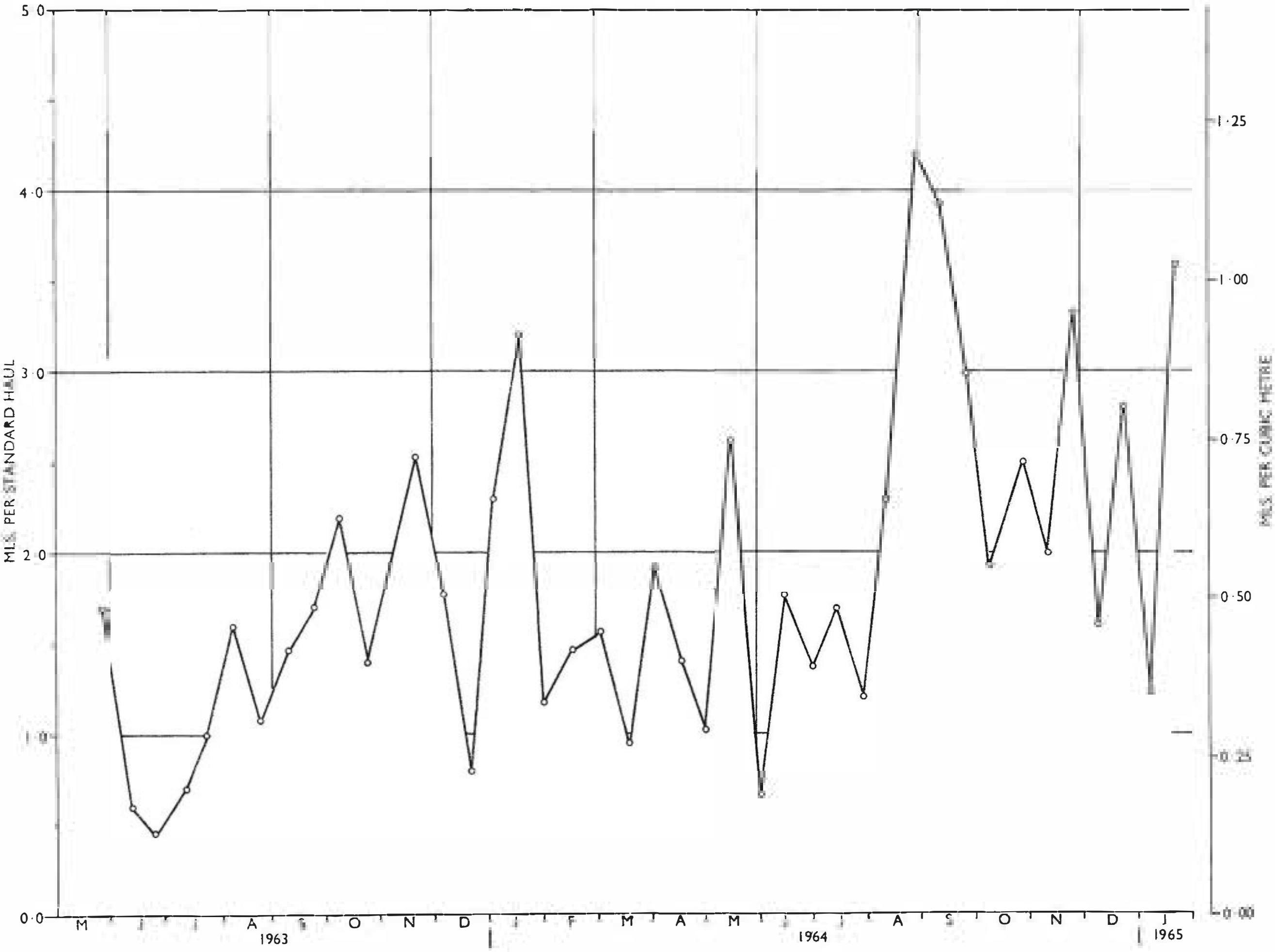


FIG. 55. Variations of zooplankton volume at Sta. A - Waitemata Harbour

samples were dominated by large numbers of small copepods, barnacle nauplii, and appendicularians.

Detritus and phytoplankton accounted for a negligible proportion of volume, and the only phytoplankton species noted in appreciable numbers were the centric diatoms *Coscinodiscus wailesii* and *Biddulphia sinensis* in the winter months of 1964.

Sta. B - Jellicoe Channel

Again, as with numbers, mean volumes followed a more recognisable pattern than at Sta. A (Fig. 56). Minimum volumes occurred in May and July 1964 (0.65 and 3.04ml), and maximum volumes occurred in October and November 1964 (178.90 and 117.98ml). Thus, the range was 178ml.

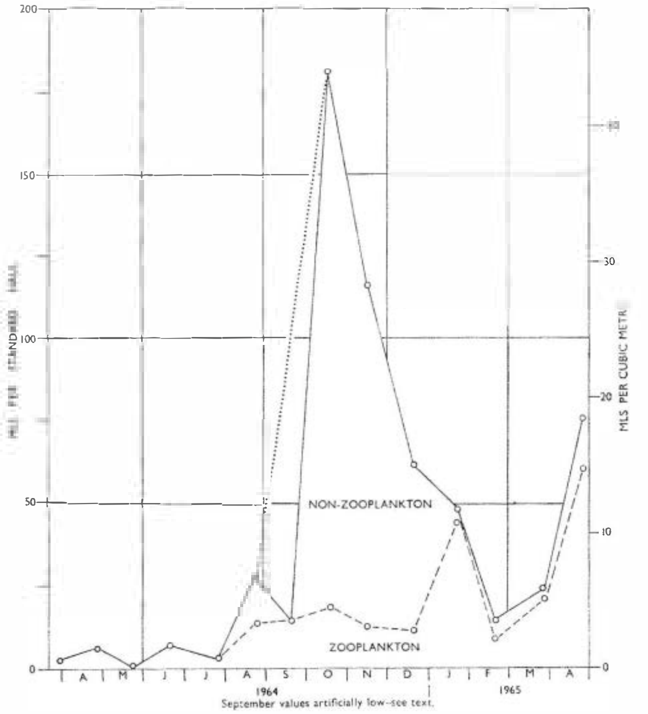


FIG. 56. Variations of catch volume at Sta. B - Jellicoe Channel

Catch volumes were low throughout late autumn and early winter 1964 then rose abruptly in August until October, when the maximum value was recorded. After this, volumes decreased through late spring and summer until autumn, when they again increased.

Values for the total catch do not give a true indication of zooplankton variations at Sta. B. The net used was much finer than at Sta. A, and from late winter until early summer clogging by phytoplankton was a serious problem. This phytoplankton was dominated by the dinoflagellate *Ceratium fusus,* which comprised at least 60% and, more often, nearly 90% of the cells collected from October to January (U. V. Cassie, 1966). Individual cells of *C. fusus* ranged between 250 and 500 microns in length, and must have been responsible for effectively reducing the mesh aperture of the net so smaller cells of other species were also retained. The numbers of revolutions of the net cyclometer were much lower when large amounts of phytoplankton were retained. In September samples the phytoplankton was removed by flotation before the zooplankton was subsampled and the volumes were measured. This has led to an artificially low mean catch volume for September.

Zooplankton volumes have been separately assessed for samples in which phytoplankton comprised an appreciable proportion of the total catch, that is for late winter, spring, and summer samples. This has been done by measuring the settled volume of the zooplankton sorted from sub-samples in addition to measuring the settled volume of the total catch. Zooplankton volume varied between 0.65ml (May) and 60.80ml (April), a range of 60.15ml. Zooplankton volumes were small in autumn and early winter, and in these samples phytoplankton and detritus were present in such negligible quantities that the entire catch could be regarded as zooplankton. From August until October zooplankton volume increased, then it decreased until December. In January zooplankton volume was much greater than in adjacent samples, and this peak resulted from the huge numbers of a single species, the cladoceran *Penilia avirostris,* which made up 79% of the zooplankton volume. This species was present in only relatively small numbers in December and February. During autumn zooplankton volume rose steeply, the year's maximum value being recorded in April. In these autumn months the thaliacean *Doliolum nationalis* was very numerous and comprised over 70% of zooplankton volume. This species was not present in autumn 1964. Large numbers of the relatively large euphausid *Nyctiphanes australis* also helped to boost zooplankton volume in autumn months.

DISCUSSION

Valid comparisons can be made only between data gathered with similar gear. The 0.5 m net used in the Waitemata Harbour is comparable, except for its slightly finer mesh (250 microns), with the International Coarse Silk Net which was used in the Great Barrier Reef Lagoon (Russell and Coleman, 1931; Russell, 1934). Nets of this pattern have also been used in the Singapore Strait and Zanzibar Channel (Wickstead. 1961, 1963). The general principle that standing crop and seasonal variation increases away from the Equator is demonstrated in Fig. 57. Amongst the localities shown lowest numbers and least variation is indicated for the Singapore Strait, and highest numbers and greatest seasonal difference is indicated for Waitemata Harbour and inshore Zanzibar waters. Great Barrier Reef and offshore Zanibar waters appear to be intermediate with respect to both numbers and seasonality. Where seasonal trends are marked at these stations they are similar. Maximum numbers occur in January in the Waitemata Harbour, inshore Zanzibar, and Great Barrier Reef waters, and, at all these localities, numbers are generally low from June to September. The ratio of smallest to largest average monthly numbers is also of the same order of magnitude at these different localities.

The Waitemata Harbour does not appear to differ in any pronounced way from other neritic, tropical, and subtropical localities where data has been gathered in a similar way.

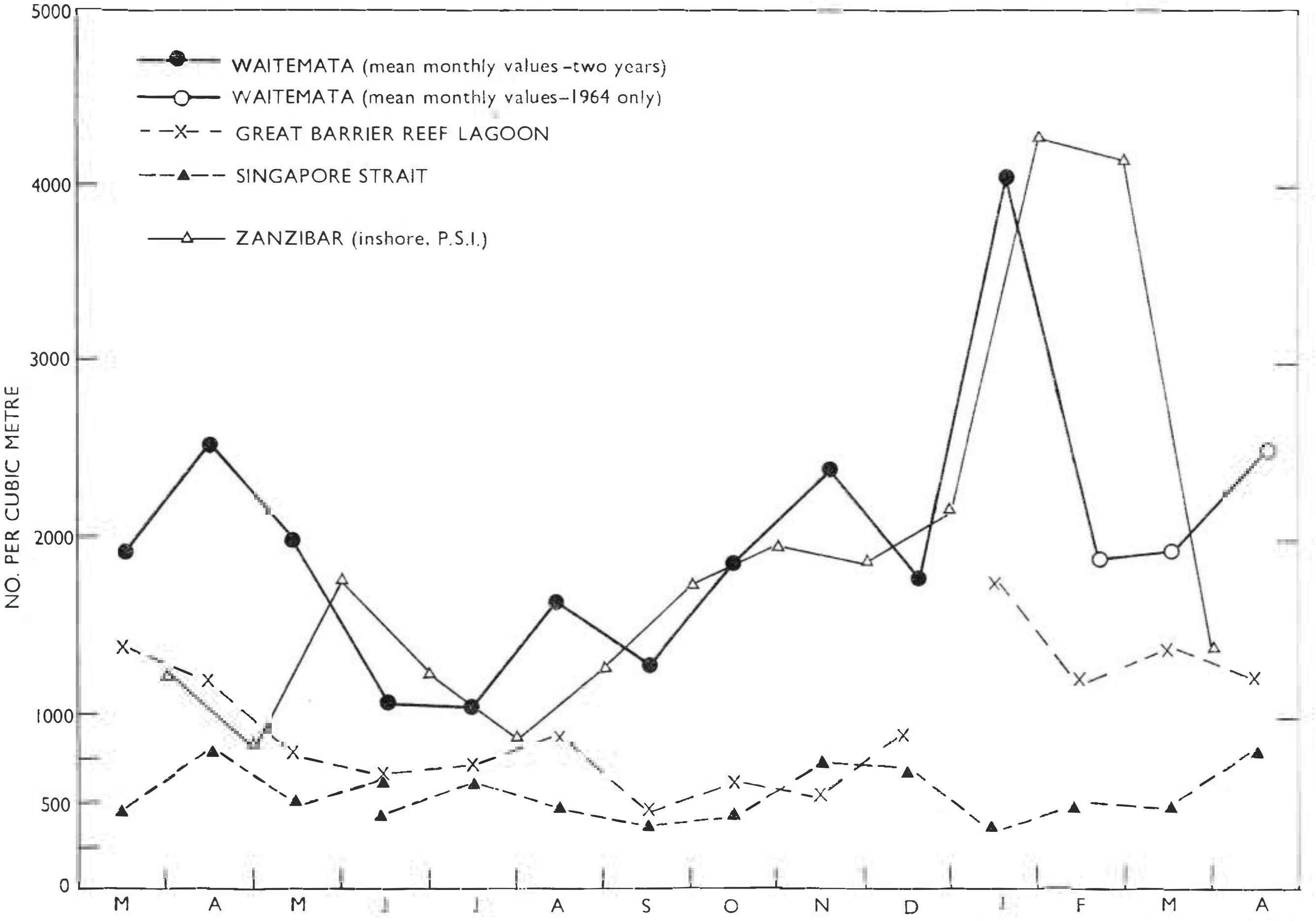


FIG. 57. Comparison of variations of zooplankton numbers in the Waitemata Harbour with those at other localities where similar gear has been used

SUMMARY

Records of temperature, salinity, turbidity, and plankton in the Hauraki Gulf have been based on regular sampling at two stations, one in the Waitemata Harbour and the other in the Jellicoe Channel. These stations were chosen to represent inner and outer gulf conditions respectively, the distinction having been made by earlier workers (Fuller, 1953; R. M. Cassie, 1960b). The Waitemata Harbour station was sampled at fortnightly intervals for 21 months and the Jellicoe Channel station at monthly intervals for 14 months.

Sea surface temperature and salinity showed the same overall trends at both stations, but inshore values had greater range and variability. Most variations at both stations can be directly related to long- and short-term variations in air temperature and rainfall, and their departure from average. Differences between years can also be related to these climatic factors. Subsurface temperature and salinity inshore were always very close, though seldom identical, to those at the surface, and it is apparent that Waitemata Harbour waters are only slightly stratified. In the outer gulf the water column was isothermal and isohaline during winter, but temperature and salinity gradients were established in spring and persisted until late autumn. Waitemata Harbour waters were always rather turbid and gave a small Secchi Depth in comparison with the Jellicoe Channel.

Hydrological processes at the two stations were generally those expected from the effect of climate on a self-contained body of water, except at the Jellicoe Channel station in late summer and autumn 1965, when cooler, more saline, and less turbid offshore water appeared. This water was almost undoubtedly introduced as counterflow, balancing the seawards removal of surface water by the strong and persistent offshore winds that prevailed at the time.

Zooplankton in the Waitemata Harbour was typically neritic, generally lacking variety except amongst larvae of benthic and littoral organisms. Only once were a few specimens of the characteristic estuarine copepod *Gladioferens pectinatus* taken, and estuarine influence must have been slight, at least at high water. Copepods were the most abundant organisms, comprising more than 70% by number of the average catch, followed by larvae of benthic and littoral organisms. These two groups, copepods and larvae, together comprised more than 90% of the average catch. In addition, appendicularians, cladocerans, hydromedusae, and ctenophores were sometimes moderately abundant.

A variety of copepods was taken, but only four species (*Paracalanus parvus, Corycaeus aucklandicus, Temora turbinata,* and *Acartia clausi*) were ever very abundant, together comprising 90% of the copepods in the average catch. In addition, smaller numbers of *Centropages aucklandicus, Euterpina acutifrons,* and *Labidocera cervi* were nearly always present and sometimes common.

The essential features of seasonal succession of zooplankton in the Waitemata Harbour were similar in both years of sampling. The major differences between the two years appear to be related to hydrological and climatic differences. Amongst copepods *Paracalanus parvus* and *Acartia clausi* were more abundant in winter and spring, *Corycaeus aucklandicus* in spring and summer, and *Temora turbinata* in summer and autumn. Cladocerans *Penilia avirostris, Evadne nordmanni,* and *Podon polyphemoides* were best represented in summer and autumn, and the only ctenophore, *Pleurobrachia pileus,* was common and characteristic in later winter and spring. Larvae as a group were least abundant in autumn and winter and reached greatest abundance in late spring and summer. Barnacle nauplii in particular achieved great abundance and completely dominated a number of mid-summer samples. The only common appendicularian, *Oikopleura dioica*, showed little seasonality. One of the less abundant, though larger and more distinctive components, the anthomedusan *Turritopsis nutricula,* was taken in every sample from late autumn to early spring, but at no other time, in both years. In spring 1964 a number of components were taken in a few consecutive samples that were otherwise more typical of the outer gulf. None of these were common, and they were best represented at their first appearance, after which they soon disappeared. They were probably introduced as a minor invasion from the outer gulf.

Jellicoe Channel zooplankton was more varied than that inshore and an "oceanic" element was nearly always present. Copepods (63%) were again the most abundant group but larvae (7%) were much less abundant. Non-copepod groups were present in the following order of abundance: cladocerans, appendicularians, salps, euphausids, hydromedusae, ctenophores, chaetognaths, pteropods, and heteropods. Many of these groups are predominantly oceanic and were scarce or absent inshore. Oceanic elements were usually varied but, except in autumn 1965, none were numerous, and the plankton was characteristically neritic. Generally the same neritic components had similar status as inshore. The only additional abundant copepod was *Oithona similis*.

The strength of the oceanic zooplankton varied seasonally in the Jellicoe Channel. It was strong in

early winter and then diminished until mid summer, after which it suddenly increased. These variations have been interpreted in relation to the sequence of hydrological events. After mid summer the salp *Doliolum nationalis* became so numerous that it completely dominated the autumn plankton. A number of oceanic copepods became moderately abundant and pteropods and salps were taken only in this period. This plankton changeover coincides with the influx of cooler, more saline, and less turbid offshore water that was introduced into the gulf during persistent and strong offshore winds.

Variations of zooplankton numbers and catch volume showed similar general trends. In the Waitemata Harbour there was a general upward trend throughout, but lower numbers were recorded in winter than at other seasons, and numbers increased to a mid-summer peak and remained high through autumn. Jellicoe Channel numbers showed the same trends, but there was also an initial, well sustained rise in early spring. Variations of zooplankton number are consistent with other subtropical and warm temperate localities.

Hauraki Gulf zooplankton holds nearly every species in common with northern New Zealand (Burfield, 1930; Calman 1917; Farran, 1929; Garstang, 1933; Massey, 1920; Tattersall, 1924) and has decreasing numbers of species in common with south-eastern Australia, South Africa, Great Barrier Reef, equatorial Pacific, and lastly, southern New Zealand. The lack of affinity between northern and southern New Zealand is undoubtedly a reflection of the separation of the localities by the Subtropical Convergence.

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REFERENCES

ALVARINO, A. 1961: Two new chaetognaths from the Pacific. *Pacif. Sci. 15(1)*: 67-77.

—— 1965: Chaetognaths. *In* "Oceanography and Marine Biology" Vol. 3. Ed. H. Barnes. Allen and Unwin, London.

BAINBRIDGE, V. 1958: Some observations on *Evadne nordmanni* Loven. *J. mar. biol. Ass. U.K.* 37: 349-70.

BARKER, P. H.; KIBBLEWHITE, A. C. 1965: Physical data from the *Tui* Cruise, 1962. *N.Z. Jl Sci. 8*: 604-34.

BARNES, H. 1950: A note on the barnacle larvae of the Clyde Sea area as sampled by the Hardy Continuous Plankton Recorder. *J. mar. biol. Ass. U.K. 29*: 73-80.

—— 1957: Processes of restoration and synchronisation in marine ecology. The spring diatom increase and the "spawning" of the common barnacle, *Balanus balanoides* (L.). *Arnee biol. 33*: 67-85.

BARY, B. McK. 1951: "A Systematic and Ecological Study of the Summer Macroplankton, Southern New Zealand". Unpublished Ph.D. Thesis, Victoria University of Wellington.

—— 1956: Notes on ecology, systematics and development of some Mysidacea and Euphausiacea (Crustacea), from New Zealand. *Pacif. Sci. 10(4)*: 431-67.

—— 1959a: Species of zooplankton as a means of identifying different surface waters and demonstrating their movements and mixing. *Ibid. 13(1)*: 14-54.

—— 1959b: Ecology and distribution of some pelagic Hyperiidea (Crustacea: Amphipoda) from New Zealand waters. *Ibid. 13(4)*: 317-34.

—— 1960: Notes of ecology, distribution and systematics of pelagic Tunicata from New Zealand. *Ibid 14(2)*: 101-21.

BAYLY, I. A. E. 1963: A revision of the coastal water genus *Gladioferens* (Copepoda: Calanoida). *Aust. J. mar. Freshwat. Res. 14(2)*: 194-217.

—— 1964: Ecological studies on the planktonic Copepoda of the Brisbane River Estuary with special reference to *Gladioferens pectinatus* (Brady) (Calanoida). *Ibid. 16*: 315-50.

BENHAM, W. B. 1907: New Zealand Ctenophores. *Trans. N.Z. Inst. 39*: 138-43.

BERNER, L. D.; REID, J. L., 1961: On the response to changing temperature of the temperature-limited plankter *Doliolum denticulatum* Quoy and Gaimard, 1845. *Limnol. Oceanogr. 6(2)*: 205-15.

BRADY, C. S. 1899: On the marine Copepods of New Zealand. *Trans. zool. Soc. Lond. 15(2) no. 1.*

—— 1918: Copepoda. *Scient. Rep. Australas. Antarct. Exped. Ser. C. 5(3)*: 1-48.

BREWIN, B. I. 1951: Seasonal changes in microplankton in the Otago Harbour during the years 1944 and 1945. *Trans. R. Soc. N.Z. 79(3-4)*: 614-27.

BRODIE, J. W. 1960: Coastal surface currents around New Zealand. *N.Z. Jl. Geol. Geophys. 3(2)*: 235-52.

BRODSKY, K. 1959: On phylogenetic relations of some *Calanus* (Copepoda) species of the northern and southern hemisphere. *Zool. Zh. 33*: 1537-53.

—— 1961: Comparison of *Calanus* species (Copepoda) from the southern and northern hemispheres. *Inf. Ser. N.Z. Dep. scient. ind. Res. 33*: 22pp.

BURFIELD, S. T. 1930: Chaetognatha. *Nat. Hist. Rep. Br. Antarct. Terra Nova Exped. Zool. 7(4)*: 203-28.

—— 1950: Chaetognatha. *Scient. Rep. Gt Barrier Reef Exped. 5(8)*: 459-73.

CALMAN, W. T. 1917: Crustacea. Part IV. Stomatopoda, Cumacea, Phyllocarida and Cladocera. *Nat. Hist. Rep. Br. Antarct. Terra Nova Exped. Zool. 3(5)*: 137-61.

CASSIE, R. M. 1956: Spawning of the snapper, *Chrysophrys auratus* Forster, in the Hauraki Gulf. *Trans. R. Soc. N.Z. 84(2)*: 309-28.

—— 1957: Shallow water diving in marine ecology. *Proc. N.Z. ecol. Soc. 5*: 4-5.

—— 1958: Apparatus for investigating spatial distribution of plankton. *N.Z. Jl Sci. 1(3)*: 436-48.

—— 1959a: An experimental study of factors inducing aggregation in marine plankton. *Ibid. 2*: 339-65.

—— 1959b: Microdistribution of plankton. *Ibid. 2(3)*: 398-409.

—— 1959c: Some correlations in replicate plankton samples. *Ibid. 2(4)*: 473-84.

—— 1960a: Factors influencing the distribution of plankton in the mixing zone between oceanic and harbour waters. *Ibid. 3(1)*: 26-50.

—— 1960b: Hydrology of the Hauraki Gulf. *Proc. N.Z. ecol. Soc. 7*: 40-3.

—— 1963: Multivariate analysis in the interpretation of numerical plankton data. *N.Z. Jl Sci. 6(1)*: 36-59.

CASSIE, U. VIVIENNE 1960: Seasonal changes in diatoms and dinoflagellates off the east coast of New Zealand. *Ibid. 3(1)*: 137-72.

—— 1961: Marine phytoplankton in New Zealand waters. *Botanica mar.* 2(suppl.): 54pp.

—— 1966: Diatoms, dinoflagellates and hydrology in the Hauraki Gulf, 1964-1965. *N.Z. Jl Sci. 9(3)*: 569-86.

CONOVER, R. J. 1956: Oceanography of Long Island Sound 1952-1954. VI. Biology of *Acartia clausi* and *A. tonsa*. *Bull. Bingham oceanogr. Coll. 15*: 156-233.

DAKIN, W. J. 1934: The plankton calendar of the continental shelf of the Pacific coast of Australia at Sydney compared with that of the Irish Sea. *In* "James Johnstone Memorial": 164-74. Univ. Press. Liverpool.

DAKIN, W. J.; COLEFAX, A. N. 1933. The marine plankton of the coastal waters of New South Wales. I. The chief planktonic forms and their seasonal distribution. *Proc. Linn. Soc. N.S.W. 58(3-4)*: 186-222.

—— 1940: The plankton of the Australian coastal waters of New South Wales. *Monogr. Dep. Zool. Univ. Sydney, 1*: 215pp.

DANA, J. D. 1852, 1855: Crustacea. *In* U.S. Exploring Expedition during the years 1838-42, under the command of Charles Wilkes. 13(2): 1019-262 (1852); Atlas (1855), pl. 70-88.

DAVID, P. M. 1958: The distribution of the Chaetognatha of the Southern Ocean. *"Discovery" Rep. 29*: 199-228.

——— 1959: Chaetognatha. *Rep. B.A.N.Z. Antarct. Res. Exped. 1929-31, Ser. B, 8*: 73-9.

DE DECKER, A. 1964. Observations on the ecology and the distribution of Copepoda in the marine plankton of South Africa. *S. African Dep. Comm. Indust. Div. Fish., Invest. Rep. 49*.

DEEVEY, G. B. 1952. A survey of the zooplankton of Block Island Sound 1943-46. *Bull. Bingham oceanogr. Coll. 13*: 65-119.

——— 1956: Oceanography of Long Island Sound 1952-54. V. Zooplankton. *Ibid. 15*: 113-55.

DELLOW, VIVIENNE 1955: Marine algal ecology of the Hauraki Gulf, New Zealand. *Trans. R. Soc. N.Z. 83(1)*: 1-91.

DIGBY, P. S. B. 1950: The biology of the small planktonic copepods of Plymouth. *J. mar. Biol. Ass. U.K. 29*: 393-438.

FARRAN, G. P. 1929: Copepoda. *Nat. Hist. Rep. Br. Antarct. Terra Nova Exped., Zool. 8(3)*: 203-306.

——— 1936: Copepoda. *Scient. Rep. Gt Barrier Reef Exped. 5(3)*: 73-142.

FLEMINGER, A.; CLUTTER, R. 1965: Avoidance of towed nets by zooplankton. *Limnol. Oceanogr. 10*: 96-104.

FOXTON, P. 1961: *Salpa fusiformis* Cuvier and related species. *"Discovery" Rep. 32*: 1-32.

FRASER, J. H. 1947: Thaliacea II. Family: Doliolidae. *Fich. Ident. Zooplankton 10*. 4pp.

——— 1961: The oceanic and bathypelagic plankton of the north-east Atlantic and its possible significance to fisheries. *Mar. Res. 1961(4)*. 48pp.

——— 1962: The role of ctenophores and salps in zooplankton production and standing crop. *Rapp. P.-v. Réun. Cons. perm. int. Explor. Mer 153(19)*: 121-3.

FULLER, A. S. 1950: Temperature requirements of *Penilia avirostris* Dana in the Hauraki Gulf, New Zealand. *Nature, Lond. 165*: 734pp.

——— 1953: Seasonal variation in the plankton and salinity of the Hauraki Gulf, New Zealand. *Ibid. 171*: 525-6.

GARNER, D. M. 1959: The sub-tropical convergence in New Zealand waters. *N.Z.Jl Geol. Geophys. 2(2)*: 315-37.

——— 1961: Hydrology of New Zealand coastal waters, 1955. *Bull. N.Z. Dep. scient. ind. Res. 138*.

GARNER, D. M.; RIDGWAY, N. M. 1965: Hydrology of New Zealand offshore waters. *Bull. N.Z. Dep. scient. ind. Res. 162*.

GARSTANG, W. 1933: Tunicata. Part I. Doliolida. *Nat. Hist. Rep. Br. Antarct. Terra Nova Exped. Zool. 4*: 195-251.

GREENWOOD, J. G. 1965: The larval development of *Petrolisthes elongatus* (H. Milne-Edwards) and *Petrolisthes novaezelandiae* Filhol (Aomura, Porcellanidae) with notes on breeding. *Crustaceana 8(3)*: 285-307.

GRICE, G. D. 1960: Copepods of the genus *Oithona* from the Gulf of Mexico. *Bull. mar. Sci. Gulf Carribb. 10(4)*: 485-90.

——— 1961: Calanoid copepods from equatorial waters of the Pacific Ocean. *Fishery Bull. Fish Wildl. Serv. U.S. 61 (186)*: 171-246.

——— 1963: A revision of the genus *Candacia* (Copepoda, Calanoida) with an annotated list of the species and a key for their identification. *Zoöl. Meded., Leiden 38(10)*: 171-94.

HAMON, B. V. 1956: A portable temperature-chlorinity bridge for estuarine investigations and sea-water analysis. *J. scient. Instrum. 33*: 329-33.

HEYDORN, A. E. F. 1959. The Chaetognaths off the west coast of the Union of South Africa. July 1954 - June 1955. *S. African Dep. Comm. Indust. Div. Fish. Invest. Rep. 36*. 56pp. Pretoria.

HIDA, T. S. 1957: Chaetognaths and pteropods as biological indicators in the north Pacific. *Spec. scient. Rep. U.S. Fish Wildl. Serv. 215*. 13pp.

HOUNSELL, W. K. 1935: Hydrographical observations in Auckland Harbour. *Trans. R. Soc. N.Z. 64*: 257-71.

HOUTMAN, TH. J. 1961: An improved portable conductivity salinometer for sea-water samples. *N.Z. Jl Geol. Geophys. 4*: 407-14.

HURLEY, D. E. 1955: Pelagic amphipods of the sub-order Hyperiidea in New Zealand waters. I. Systematics. *Trans. R. Soc. N.Z. 83(1)*: 119-94.

HUXLEY, T. H. 1851: Remarks upon *Appendicularia* and *Doliolum*, two genera of tunicates. *Phil. Trans. R. Soc. 1851, 2*: 599-602.

JONES, N. S. 1963: The marine fauna of New Zealand. Crustaceans of the order of Cumacea. *Bull. N.Z. Dep. scient. ind. Res. 152*.

JORGENSEN, O. M. 1933: On the marine Cladocera from the Northumbrian plankton. *J. mar. Biol. Ass. U.K. 19*: 177-266.

KITOU, M. 1957: Offshore distribution of plankton produced in coastal water. *Inf. Bull. Planktol. Japan 5*: 5-7.

KNIGHT-JONES, E. W.; WAUGH, G. D. 1949: On the larval development of *Elminium modestus* Darwin. *J. mar. Biol. Ass. U.K. 28*: 413-27.

KOTT, PATRICIA 1953: Modified whirling apparatus for the sub-sampling of plankton. *Aust. J. mar. Freshwat. Res. 4(2)*: 387-93.

——— 1955: The zooplankton of Lake Macquarie, 1953-54. *Ibid. 6(3)*: 429-42.

——— 1957: Zooplankton of East Australian waters, 1945-54. *Rep. Div. Fish. Oceanogr. C.S.I.R.O. Aust. 14*: 33pp.

KRAMER, A. 1894: On the most frequent pelagic copepods and cladoceres of the Hauraki Gulf. *Trans. N.Z. Inst. 27*: 214-23.

KRAMP, P. B. 1928: Papers from Dr Th. Mortensen's Pacific Expedition 1914-16. XLIII. Hydromedusae. I. Anthomedusae. *Vidensk. Meddr dansk naturh. Foren. Bd 85*: 27-64.

——— 1961: Synopsis of the medusae of the world. *J. mar. Biol. Ass. U.K. 40*: 1-469.

KRAMP, P. B. 1965: The hydromedusae of the Pacific and Indian Oceans. *Dana Rep.* 63: 1-161.

LEBOUR, M. V. 1922: Food of plankton organisms. *J. mar. Biol. Ass. U.K. 12(4)*: 644-77.

——— 1923: Food of plankton organisms II. *Ibid. 13(1)*: 70-92.

LOWNDES, A. G. 1935: The swimming and feeding of certain calanoid copepods. *Proc. zool. Soc. Lond. 1935*: 687-715.

MARGALEF, R. 1958: Temporal succession and spatial heterogeneity in phytoplankton. *In* "Perspectives in Marine Biology", Ed. A. A. Buzzati-Traverso. University of California Press.

MARSHALL, S. M. 1925: A survey of the Clyde plankton. *Proc. R. Soc. Edinb. 45*: 117-41.

MASSEY, A. L. 1920: Mollusca. Pt. 3. Pteropoda. *Nat. Hist. Rep. Br. Antarct. Terra Nova Exped., Zool.* 2*(9)*: 203-32.

MESTAYER, M. K. 1916: Preliminary list of Mollusca from dredgings taken off the northern coast of New Zealand. *Trans. N.Z. Inst. 48*: 122-8.

NEPGEN, C. S. DeV. 1957: The euphausids of the west coast of South Africa. *S. African Dep. Comm. Indust. Div. Fish. Invest. Rep. 28*: 1-30.

POOLE, H. H.; ATKINS, W. R. C. 1929: Photo-electric measurements of submarine illumination throughout the year. *J. mar. Biol. Ass. U.K. 16*: 297-324.

POWELL, A. W. B. 1937: Animal communities of the sea-bottom in Auckland and Manukau Harbours. *Trans. R. Soc. N.Z. 66*: 354-401.

PURCHAS, P. 1963: Some Heteropods and Pteropods of the oceanic water north of New Zealand. Unpublished B.Sc. dissertation. University of Auckland.

PYEFINCH, K. A. 1948: Notes on the biology of cirripedes. *J. mar. Biol. Ass. U.K. 27*: 464-503.

——— 1949: Short-period fluctuations in the numbers of barnacle larvae, with notes on comparisons between pump and net plankton hauls. *Ibid. 28*: 353-70.

RALPH, P. M. 1950: Ctenophores from the waters of Cook Strait and Wellington Harbour. *Trans. R. Soc. N.Z. 78 (1)*: 70-82.

——— 1953: A guide to the athecate hydroids and medusae of New Zealand. *Tuatara* 5*(2)*: 59-75.

——— 1957: A guide to the New Zealand heteropod molluscs. *Ibid.* 6*(3)*: 116-20.

RUSSELL, F. S. 1934: A comparison of the abundance of zooplankton in the Great Barrier Reef Lagoon with that of some regions in northern European waters. *Scient. Rep. Gt Barrier Reef Exped. 2*: 176-201.

——— 1953: "The medusae of the British Isles". C.U.P.

RUSSELL, F. S.; COLEMAN, J. S. 1931: The zooplankton. I. Gear, methods and station lists. *Scient. Rep. Gt Barrier Reef Exped.* 2*(2)*: 5-35.

——— 1935: The zooplankton. IV. The occurrence and seasonal distribution of the Tunicata, Mollusca and Coelenterata (Siphonophora). *Ibid.* 2*(7)*: 203-76.

SHEARD, K. 1949: Plankton characteristics at Cronulla, N.S.W. 1943-46. *Bull. Commonw. scient. ind. Res. Org. 245*: 1-23.

——— 1953: Taxonomy, distribution and development of the Euphausiacea (Crustacea). *Rep. B.A.N.Z. Antarct. Res. Exped., Ser. B 8(1)*: 1-72.

SKERMAN, T. M. 1958: Seasonal variations in surface temperature within New Zealand harbours. *N.Z. Jl Geol. Geophys. 1(1)*: 197-218.

——— 1959: Marine fouling at the Port of Auckland. *N.Z.Jl Sci. 1*: 57-94.

STEUER, A. 1932: Copepoda 6: *Pleuromamma* Giesbrecht, 1898, der Deutschen Tiefsee-Expedition. *Wiss. Ergebn. dt. Tiefsee-Exped. "Valdivia 21(1)*: 1-119.

STOMMEL, H. 1953: The role of density currents in estuaries. *Proc. Minnesota Int. Hydraul. Conv. 1953*: 305-12.

STRICKLAND, J. D. H. 1965: Production of organic matter in the primary stages of the marine food chain. *In* "Chemical Oceanography" Vol. 1. Ed. J. P. Riley and G. Skirrow. Academic Press, London.

STUCKEY, R. G. 1948: Studies on the free-living copepods of Wellington Harbour. Unpublished M.Sc. Thesis, Victoria University of Wellington.

TANAKA, O. 1956: The pelagic copepods of the Izu region, middle Japan. Systematic account. II. Families Paracalanidae and Pseudocalanidae. *Publs Seto Mar. biol. Lab. 5(3)*: 367-406.

TATTERSALL, W. M. 1924: Crustacea. Part VIII, Euphausiacea. *Nat. Hist. Rep. Terra Nova Br. Antarct. Exped., Zool. 8(1)*: 1-36.

——— 1936: Mysidacea and Euphausiacea. *Scient. Rep. Gt. Barrier Reef Exped.* 5*(4)*: 143-76.

TESCH, J. J. 1949: Heteropoda. *"Dana" Rep. 34.* 53pp.

THOMPSON, H. 1942: Pelagic tunicates in the plankton of south-eastern Australian waters, and their place in oceanographic studies. *Bull. Coun. scient. ind. Res., Melb. 153.* 47pp.

——— 1948: Pelagic tunicates of Australia. Handbook. *Coun. scient. ind. Res. Melb.*

THOMSON, G. M. 1883: On the New Zealand Copepoda. *Trans. N.Z. Inst. 15*: 93-116.

——— 1913: The natural history of Otago Harbour and the adjacent sea, together with a record of the work carried on at the Portobello Marine Fish Hatchery. *Ibid. 45*: 225-51.

THOMSON, J. M. 1947: The Chaetognatha of south-eastern Australia. *Bull. Coun. scient. ind. Res, Melb. 222*: 1-43.

TOKIOKA, T. 1939: Chaetognatha collected chiefly from the Bays of Sagami and Suruga, with some notes on the shape and structure of the seminal vesicle. *Rec. oceanogr. Wks Japan* 10*(2)*: 122-50.

——— 1940: A small collection of Chaetognatha from the coast of New South Wales. *Rec. Aust. Mus.* 20*(6)*: 367-79.

VAN ZYL, R. P. 1960: A preliminary study of the salps and doliolids off the west and south coasts of South Africa. *S. African Dep. Comm. Indust. Div. Fish. Invest. Rep. 40.* 1-31, Pretoria.

VERVOORT, W. 1946: Biological results of the *Snellius* Expedition. XV. The bathypelagic Copepoda Calanoids of the *Snellius* Expedition. I. Families Calanidae, Eucalanidae, Paracalanidae and Pseudocalanidae. *Temminckia 8*: 1-181.

——— 1957: Copepods from Antarctic and Subantarctic plankton samples. *Rep. B.A.N.Z. Antarct. Res. Exped., Ser. B, 3.* 160pp.

WALLACE, G. M.; NEWMAN, L. E. 1953a: Bacteriological survey of Auckland Harbours. I. Extent of sewage fields in Waitemata Harbour. *N.Z.Jl Sci. Technol. B 34*: 15-522.

——— 1953b: Bacteriological survey of Auckland Harbours. II. Condition of beaches to the east of Orakei sewer outfall, Waitemata Harbour. *Ibid. B 35*: 225-38.

WEAR, R. G. 1964a: Larvae of *Petrolisthes novaezelandiae* Filhol. 1885. (Crustacea, Decapoda, Anomura). *Trans. R. Soc. N.Z., Zool. 4(18)*: 229-44.

——— 1964b: Larvae of *Petrolisthes elongatus* (Milne-Edwards, 1937). (Crustacea, Decapoda, Anomura). *Ibid., Zool. 5*(*2*): 39-53.

——— 1965a: Larvae of *Petrocheles spinosus* Miers, 1876 (Crustacea, Decapoda, Anomura) with keys to New Zealand porcellanid larvae. *Ibid., Zool. 5*(*12*): 147-68.

——— 1965b: Breeding cycles and pre-zoea larva of *Petrolisthes elongatus* (Milne-Edwards 1837). (Crustacea, Decapoda). *Ibid., Zool. 5*(*13*): 169-75.

——— 1965c: Zooplankton of Wellington Harbour, New Zealand. *Zoology Publs Vict. Univ. Wellington, N.Z. 38*: 1-31.

WICKSTEAD, J. H. 1961: A quantitative and qualitative survey of some Indo-West-Pacific plankton. *Fishery Publs colon. Off. 16*: 1-200.

——— 1962: Food and feeding in pelagic copepods. *Proc. zool. Soc. Lond.* 139: 545-55.

——— 1963: Estimates of total zooplankton in the Zanibar area of the Indian Ocean with a comparison of the results with two different nets. *Ibid. 141*: 577-608.

WILSON, C. B. 1932: The copepods of the Woods Hole Region, Massachusetts. *Bull. U.S. natn. Mus. 158.* 635pp.

——— 1942: The copepods of the plankton collected during the last cruise of the "Carnegie". *Publs Carnegie Instn 536.* 237pp.

——— 1950: Copepods gathered by the U.S. Fisheries steamer "Albatross" from 1887 to 1909, chiefly in the Pacific Ocean. *Bull. U.S. natn. Mus. 100, 14*(*4*): 141-441.

WOOD, D. H. 1962: An Ecological Study of a Sandy Beach (Howick). Unpublished M.Sc. Thesis, University of Auckland, New Zealand.

WOOD, E. J. F. 1954: Dinoflagellates in the Australian Region. *Aust. J. mar. Freshwat. Res. 5*(*2*): 171-351.

WYRTKI, K. 1962: Geopotential topographics and associated circulation in the western South Pacific Ocean. *Ibid. 13*: 89-105.

APPENDIX A

Analysis of Hauls at Sta. A - Waitemata Harbour on 23 August 1963 Indicating Methods and Degrees of Detail for the Recording of Zooplankton Components (see p. 15)

Haul	1				2				3				
Total sample													
Labidocera cervi	12				17				12				
Pleurobrachia pileus	130				125				137				
Turritopsis nutricula	—				3				—				
Other medusae	—				2				1				
Petrolisthes elongatus	1				1				1				
P. novaezelandiae	14				7				9				
Subsample size	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	No./Haul
Paracalanus parvus	77	84	68	101	79	77	85	90	102	85	97	99	696.0
Centropages aucklandicus	5	2	4	1	—	6	6	3	8	4	9	3	34.0
Temora turbinata	44	44	46	38	53	48	42	44	72	48	60	62	400.7
Labidocera cervi	1	—	—	—	—	—	1	1	—	—	—	—	15.7
Acartia clausi	22	31	36	31	39	34	17	31	24	30	31	26	234.7
Corycaeus aucklandicus	72	39	55	71	49	81	57	75	64	60	79	61	508.7
Oithona similis	1	1	—	—	—	—	—	—	1	—	1	—	2.7
O. plumifera	—	—	—	—	—	1	—	—	—	—	—	—	0.7
Euterpina acutifrons	27	26	18	31	20	19	26	26	24	18	31	22	192.0
Clytemnestra rostrata	—	—	3	1	—	—	—	3	—	—	—	—	4.7
Mysids	—	—	—	—	—	—	—	—	1	—	—	—	0.7
Oikopleura spp.	8	9	7	7	5	5	8	5	5	11	4	17	60.7
Pleurobrachia pileus	16	10	8	18	22	12	15	19	17	12	16	10	246.0
Turritopsis nutricula	—	—	—	—	—	—	—	—	—	—	—	—	1.0
Obelia medusae	—	—	—	—	1	—	—	—	—	—	1	1	2.0
Other medusae	4	3	2	2	2	3	5	1	1	1	2	2	16.7
Sundry decapod larvae	7	5	5	5	5	5	3	2	6	6	6	9	42.7
Petrolisthes elongatus	—	—	—	—	—	—	—	—	—	—	—	—	1.0
P. novaezelandiae	—	—	—	1	—	—	—	—	—	1	—	—	10.0
Brachyuran zoeae	50	33	46	72	48	54	40	39	55	58	57	32	389.3
Barnacle nauplii	32	41	31	45	30	37	26	55	40	32	39	32	293.3
Barnacle cyprids	5	2	2	6	4	1	2	7	3	4	4	4	29.3
Polychaete larvae	13	6	9	15	14	17	18	10	7	11	9	15	96.0
Bivalve veligers	3	1	2	—	4	2	—	3	11	—	2	2	20.0
Gastropod veligers	12	5	4	4	6	4	7	4	7	3	3	4	42.0
Actinotrochs	—	—	—	2	—	—	—	—	—	—	—	—	1.3
Ascidian tadpoles	—	—	—	—	1	—	—	—	—	—	—	—	0.6
Fish eggs	1	1	—	1	2	1	2	1	2	—	1	—	8.0
Fish larvae	—	1	—	—	—	—	—	—	—	—	—	—	0.7
Subsample total	1,532				1,570				1,687				
Correction	× 2 + 157				× 2 + 155				× 2 + 160				
Total	3,221				3,295				3,534				3,350

APPENDIX B

Analysis of Hauls at Sta. A - Waitemata Harbour on 31 January 1964 Indicating Methods and Degrees of Detail for the Recording of Zooplankton Components (see p. 15)

Haul	1		2		3		No./Haul
Subsample size	1/10	1/10	1/10	1/10	1/10	1/10	
Paracalanus parvus	36	30	31	30	43	42	353.3
Centropages aucklandicus	8	5	3	3	4	7	50.0
Temora turbinata	51	50	43	50	62	71	545.0
Labidocera cervi	—	1	1	1	—	1	6.7
Acartia clausi	34	34	39	40	53	45	408.3
Corycaeus aucklandicus	386	290	308	246	485	428	3,571.7
Oithona nana	1	—	—	1	1	—	5.0
Euterpina acutifrons	—	1	2	—	—	1	6.7
Penilia avirostris	1	1	—	1	3	1	11.7
Evadne nordmanni	2	11	1	1	4	2	35.0
Podon polyphemoides	1	1	3	—	2	—	11.7
Oikopleura spp.	7	8	6	3	11	11	76.7
Pleurobrachia pileus	—	1	—	—	1	—	3.3
Obelia medusae	4	2	4	—	—	1	18.3
Other medusae	14	8	6	6	4	4	70.0
Sundry decapod larvae	5	9	2	5	11	9	68.3

APPENDIX C

Analysis of Hauls at Sta. B - Jellicoe Channel on 22 August 1964 Indicating Methods and Degrees of Detail for the Recording of Zooplankton Components (see p. 15)

Haul	1		2		3		Total No. (all hauls	Estimated No. per 1000 revs.)
No. of revolutions	181		162		177			
Subsample size	1/10	1/10	1/10	1/10	1/10	1/10		
Calanus tenuicornis	2	—	—	—	—	—	10	19.2
Rhincalanus cornutus	—	—	—	—	1	—	5	9.6
Paracalanus parvus	433	312	337	348	324	357	10,555	20,298.0
Clausocalanus arcuicornis	2	1	—	4	2	1	50	96.2
Ctenocalanus vanus	2	4	3	5	2	—	80	153.8
Centropages aucklandicus	2	—	—	—	1	1	20	38.5
Temora turbinata	65	36	36	40	40	37	1,270	2,442.3
Pleuromamma abdominalis	1	—	—	—	—	—	5	9.6
P. gracilis	1	—	—	—	—	—	5	9.6
Heterorhabdus papilliger	—	— (1)	—	—	—	—	1	1.9
Acartia clausi	84	73	81	126	117	134	3,075	5,913.5
Acartia danae	—	1	2	1	—	—	20	38.5
Microsetella rosea	1	—	—	—	—	—	5	9.6
Euterpina acutifrons	90	64	48	74	74	67	2,085	4,009.6
Oithona similis	8	10	9	5	21	21	320	615.4
O. plumifera	2	—	1	—	2	2	35	67.3
Oncaea media	—	1	1	—	—	—	10	19.2
O. venusta	—	—	—	—	—	1	5	9.6
Oncaea sp.	4	2	1	1	1	3	60	115.4
Corycaeus aucklandicus	68	46	71	54	59	47	1,725	3,317.3
Evadne nordmanni	78	58	97	105	91	73	2,510	4,826.9
Nyctiphanes australis	—	—	1	4	2	—	35	67.3
Amphioxus juveniles	8	2	2	2	—	1	75	144.2
Oikopleura spp.	143	113	120	104	114	145	3,695	7,105.8
Sagitta serratodentata	2	1	1	1	—	2	36	69.2
Pleurobrachia pileus	—	—	2	1	—	—	17	32.7
Obelia medusae	2	1	1	2	—	3	45	86.5
Other medusae	7	3	7	1	6	9	165	317.3
Sundry decapod larvae	1	1	2	4	2	1	55	105.8
Brachyuran zoeae	2	1	6	2	2	2	75	144.2
Petrolisthes novaezelandiae	—	1	—	—	1	—	10	19.2
Callianassa larvae	—	—	1	—	—	—	5	9.6
Jaxea larvae	—	—	—	— (1)	—	—	1	1.9
Stomatopod larvae	—	—	1	—	—	—	5	9.6
Barnacle nauplii	2	1	—	1	—	—	20	38.5
Barnacle cyprids	2	2	—	—	—	—	20	38.5
Cyphonautes	1	—	—	—	—	—	5	9.6
Actinotrochs	—	—	—	1	—	—	5	9.6
Polychaete larvae	11	—	5	4	15	—	175	336.5
Gastropod veligers	—	—	—	—	1	1	10	19.2
Bivalve veligers	—	—	—	1	2	—	15	28.2
Teleost eggs	1	1	—	2	—	—	20	38.5
Teleost larvae	—	1	1	—	1	1	20	38.5
Subsample total	1,760		1,731		1,790			
Correction	× 10/2 + 1		× 10/2 + 1		× 10/2 + 3			
Total	8,801		8,656		8,953		26,410	50,788

(Numbers in brackets refer to animals sorted from catch before subsamples were taken)