Zooplankton of Wellington Harbour, New Zealand

by

R. G. Wear

Zoology Publications from Victoria University of Wellington

No. 38

Issued 31 May 1965

Distributed on an exchange basis from the Department of Zoology
VICTORIA UNIVERSITY OF WELLINGTON, NEW ZEALAND

Zooplankton of Wellington Harbour, New Zealand

By Robert G. Wear,

Zoology Publications from Victoria University of Wellington.
No. 38, issued 31 May 1965.

Abstract

During 1961 to 1963 regular plankton tows were taken from Wellington Harbour. These plankton samples were analysed, the macroplankton fauna identified, and the abundance of each species recorded. Class Crustacea was made the subject of special study and identified larva illustrated. A plankton calendar of the dominant macroplankton species was prepared and the characteristics of the plankton in each month described. Irregular variations are discussed. Surface water temperature variation was found to influence the abundance of numerically dominant species. Ecological factors determining the nature of the harbour population are discussed. The zooplankton of Wellington Harbour is compared with that of coastal New South Wales, Australia.

Introduction

The present Wellington Harbour plankton collecting programme commenced on 2 January 1961, under the direction of Professor L. R. Richardson, assisted by members of the staff and research students from the Department of Zoology, Victoria University of Wellington. Subsequent routine samples were taken at weekly intervals, and these samples revealed a rich plankton fauna in Wellington Harbour. By January, 1964, the present collection consisted of about 250 plankton samples. Several small breaks in the continuity of the record occurred, the longest of these being in March, 1962, when no samples were taken. However, the greater part of the three-year period is covered by four to six samples every month. This plankton programme is continuing.

The fauna discussed in this paper is macroplanktonic. It includes the Coelenterata represented by Hydrozoa and Ctenophora; Chaetognatha of the genus *Sagitta;* Crustacea including both permanent and temporary planktonic forms; Chordata represented in the Urochordata by the family Salpidae, and in the Vertebrata by the eggs and larvae of various fish. Particular attention has been given to both decapod and stomatopod larvae which form a major component of the plankton. Other groups not mentioned above formed only a small fraction of the total volume of plankton samples, and these have been disregarded.

It was not possible to identify all the taxa to the specific level, as the systematic status of many New Zealand marine organisms has not yet been determined. Many crustacean larvae reared in the laboratory to juveniles still eluded final identification, as juvenile stages frequently lacked the adult characters used in classification.

In the plankton, short period fluctuations of considerable magnitude were observed. In some cases these resulted in the absence of species normally abundant. However, the broad seasonal trends in the Wellington Harbour plankton have emerged with quite startling clarity, and some quantitative work has been done to assist in the description of these trends. In addition a number of relatively common and distinctive species were identified and selected as seasonal indicator species. An annual plankton calendar has been prepared from monthly and seasonal changes in the abundance of these species.

The decapod larval terms "zoea" and "megalopa" are here employed in the sense suggested by D. I. Williamson (1957) and where possible the ambiguous term "post-larva" has been avoided. Non-larval stages following the megalopa have been termed "juvenile stages".

MATERIALS AND METHODS

PLANKTON SAMPLING

Plankton samples for analysis were obtained with a 36 gauge extra heavy grit gauze two foot diameter cone net, with a 2lb "Agee" preserving jar tied into the collar. The sampling gear was towed behind a launch using from 50 fathoms to 60 fathoms of 8lb three-quarter inch hemp. While taking a sample, the towing speed which varied between $\frac{3}{4}$ knot and $1\frac{1}{2}$ knot was adjusted to correct for current, wave, and wind resistance to both the gear and the launch. This allowed the net to filter at depths between one fathom and three fathoms for the greater part of the ten to twenty minute towing period. By turning the launch in a tight circle once during each tow, the speed of the net in relation to the water was reduced allowing the net to sink and filter at depths of five or six fathoms for about five minutes.

On completion of every tow the plankton adhering to the mesh on the inside of the net was washed into the jar with rinses of sea water. The bulk of the sample was preserved in 5% formalin solution in the field, while a selected sub-sample was kept for the study of living material. The date, time of day, cloud and wind conditions, state of tide, and surface water temperature, were all recorded for each plankton tow.

ANALYSIS OF SAMPLES

The volume of plankton in each sample was recorded in a graduated measuring cylinder after settling for ten minutes. Where the duration of a tow was greater or less than the standard of 20 minutes the total volume of plankton was adjusted by simple proportion. From the number of samples in each month the mean monthly volume was estimated.

For comparison of samples with wide variations in volume the following sub-sampling technique was employed to obtain a constant representative volume (10cc) of each sample.

Samples were diluted to approximately two litres with fresh water and well stirred. Sub-samples of 50cc were then removed and allowed to settle in a 50cc measuring cylinder. The excess water was siphoned off and successive sub-samples were added to the measuring cylinder to give exactly 10cc of settled plankton. This 10cc sub-sample was diluted to approximately 100cc with water and poured into a very large, shallow Petri dish which was placed on top of a circular piece of black paper divided into ten equal sectors with white ink. Three randomly selected sectors were counted for each of the species considered in the analysis. If the results of these three counts were erratic, further sectors were counted. When the total volume of a sample greatly exceeded 10cc, a further 10cc sub-sample was taken and treated in the above manner.

The number of individuals of each species in a 10cc sub-sample was thus obtained by simple proportion from the number counted in three or more of the sectors, and the result was adjusted to the total volume of the sample by simple proportion.

The counted and estimated animals were then divided into the following five major elements: *Pleurobrachia pileus* (O. F. Müller); *Obelia geniculata* (L.); *Octophialucium funerarium* (Quoy and Gaimard) together with *Phialella quadrata* (Forbes); Salpidae; and Crustacea. These five elements representing either individual species or groups of species were found to have considerable seasonal variation in numbers. This is reflected in their respective contributions to the total volume of the plankton samples (Text-fig. 8).

The species constituting the bulk of the volume together with the species selected as seasonal indicators were used to compile the annual plankton calendar (Text-fig. 7).

LABORATORY REARING OF CRUSTACEAN LARVAE

Unidentified larval Crustacea were reared further in the laboratory. Two or three larvae were placed in a covered finger bowl filled with approximately 200cc of fresh sea water. The larvae were fed every second day with teased particles from the mantle and gonads of the marine mussel *Perna canaliculus* (Gmelin). To reduce invasions of protozoans, fungi, and bacteria to a minimum, the amount of mussel supplied at each feeding was no more than required by the species, the amount being learned by experience. The early juvenile stages of several brachyuran species consumed their own weight of mussel in only three feedings over a six day period. Anomuran larvae were found to be considerably less voracious, taking up to seven or eight feedings to consume a similar quantity. The sea water was drained and renewed on non-feeding days. These frequent water changes eliminated the need for aeration and ensured the regular removal of faecal pellets and any unconsumed food material.

Throughout 1961 and 1962 the experiments were without temperature control and temperatures fluctuated between 16°C. and 23°C. Under these conditions the mortality rate was extremely high, but limited results were obtained. In April, 1963 an insulated refrigerator trough 30 inches in length, 18 inches in width, and eight inches deep was made available for rearing experiments. Finger bowls containing larvae were placed in the trough and the temperature was held between 11°C. and 13°C. Within this temperature range the rate of larval and juvenile ecdyses was comparatively rapid, and harmful infections of fungi, protozoans, and bacteria were kept at a low level. Lower temperatures greatly increased the intermoult period of the larvae and temperatures in excess of 15°C. increased the mortality rate to a level similar to that of experiments without temperature control.

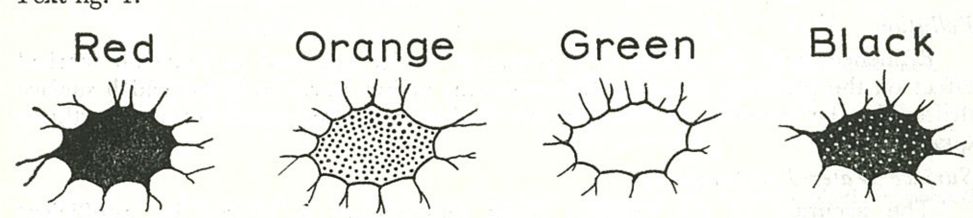
Very encouraging results were obtained with this refrigerating apparatus, and the use of mussel as food was found to be generally successful in the rearing of larval and juvenile Brachyura, larval Stomatopoda, and many later stage anomuran larvae. This feeding method gave little success with early stage anomuran zoeae.

REARING LARVAE FROM ADULT CRUSTACEA

Decapod crustacean larvae found in the plankton were in some cases identified by comparison with larvae hatched from eggs of ovigerous females obtained from beach collections. Females carrying eggs about to hatch showing larval eye spots were kept in a small sea-water aquarium until the eggs hatched. The hatched larvae were kept alive for as long as possible by the described laboratory rearing method.

ILLUSTRATIONS

Drawings of entire specimens were made on squared paper with the aid of a wide field "Spencer" binocular microscope fitted with a squared micrometer in one eyepiece. Coloured chromatophores are indicated by the code shown in Text-fig. 1.



TEXT-FIG. 1.—Key to chromatophores.

THE STATIONS

LOCATION

Two adjacent bays in Wellington Harbour were selected as research stations. Station One extends from Point Halswell south-east across Kau Bay to Kau Point in a zone approximately 300 yards wide (Text-fig. 2). Station Two extends Station One from Kau Point south across Mahanga Bay to Point Gordon and is approximately 200 yards wide (Text-fig. 2).

SURROUNDING SHORES AND SEA FLOOR

The littoral zone of both stations (Kau Bay and Mahanga Bay) consists mainly of rough shingle interspersed with rocks, but large rock outcrops extend to well below the low water mark at Point Halswell, Kau Point, and Point Gordon. From the low water mark to a depth of approximately one fathom there are extensive colonies of *Macrocystis pyrifera* (L.) and other algae clinging to a rocky substrate. *Macrocystis pyrifera* is concentrated mainly at Point Gordon, Kau Point and in Kau Bay. From one fathom to approximately five fathoms the sea floor shelves steeply, and is covered with coarse sand and gravel on which thick patches of red-green algae and large sponges grow. The sand and gravel merges into soft grey mud below five fathoms. Both plankton stations lie for the most part over the muddy substrate at depths between seven and nine fathoms.

HYDROGRAPHY

Wind Influence

Station One is directly exposed to the prevailing northerly winds. Tows were not usually attempted in winds from this quarter above force four on the Beaufort Scale. Station One is however sheltered by steep hills from the less frequent southerly winds. Station Two is also exposed to the north, but its northern end is sheltered by the rocks of Kau Point.

Tidal Currents

The tidal flow pattern for Wellington Harbour has been outlined by Brodie (1958, p. 701, fig. 2). He shows that the tide floods in through the restricted harbour entrance channel at a speed of approximately $\frac{1}{2}$ knot, but slows to $\frac{1}{4}$ knot in the inner harbour. The main current passes close to Seatoun, Mahanga Bay, and Point Halswell, and continues in a clockwise direction parallel to the inner harbour coastline to follow a southerly course along the eastern harbour bays to Eastbourne. This pattern of flow is reversed during the ebb tide. Both plankton stations are therefore influenced by oceanic waters during the flood tide only, and during the ebb tide a flow from the northern inner harbour mixed with water from Evans Bay covers the area.

Fresh Water Influence

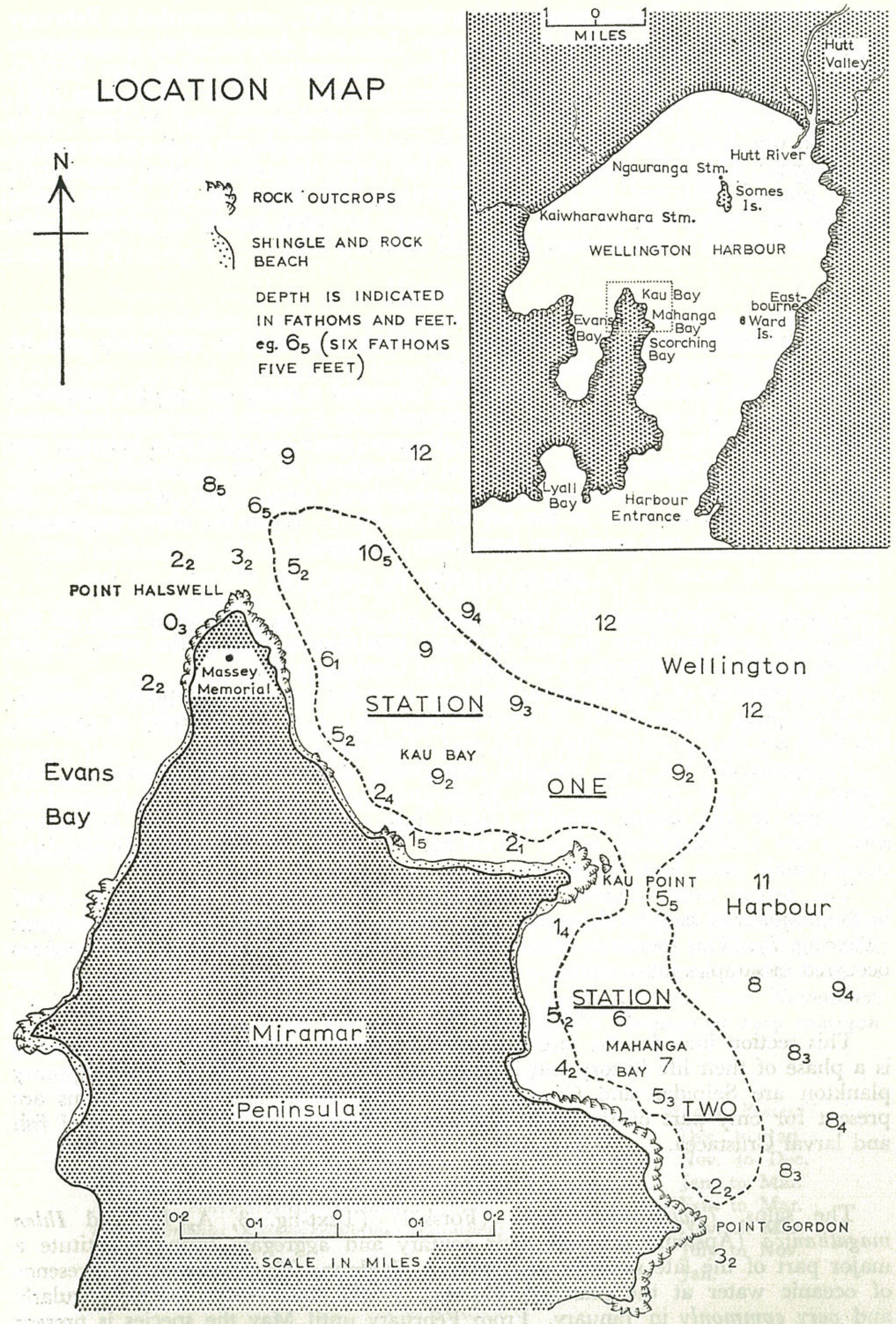
With heavy flooding in the Hutt River and the Kaiwharawhara and Ngauranga streams the plankton stations were discoloured by muddy water. Under such conditions no significant change was seen in the plankton samples.

Pollution

Effluence from the Ngauranga Freezing Works appeared to have no marked effect on the plankton samples. Effluence was mainly particles of fat which surface drifted in the direction of the stations during prolonged wind from a northerly quarter.

Surface Water Temperatures

The accuracy of the monthly mean temperature is limited by insufficient recordings, but from the information available broad seasonal patterns can be



TEXT-FIG. 2.—Location map of Wellington Harbour. Showing the harbour plankton research stations.

seen (Text-fig. 8). Highest temperatures, above 18.0°C., were recorded in February of each year, and the coolest months were July and August when temperatures below 10.0°C. were recorded. The highest temperature recorded was 20.0°C. on 1 February 1962, and the lowest temperature was 8.8°C. on 11 August 1961.

Mean monthly surface water temperatures varied from year to year. This variation was due to the difference in air temperatures as shown by the meteorological records. Thus the milder winter of 1962 kept the mean water temperature above that of 1961 and 1963 by approximately 2°C. (Text-fig. 8). Short period temperature fluctuations of 3°C. or 4°C. were recorded mainly in winter during calm weather and in midsummer after cold southerly rain.

The Fauna

The plankton fauna of Wellington Harbour discussed in this study can be divided into two sections as described below.

The numerical abundance of the species discussed is based on the data presented in Text-fig. 7. All quantities may be equated with a single 20 minute horizontal plankton tow with a 36 gauge two foot diameter cone net at depths between one fathom and six fathoms. The numerical equivalents of the expressions "rare", "few", "common", "very common", abundant" and "very abundant", lie within the ranges set down in the key to Text-fig. 7. When the above expressions have been used in this sense they have been italicised.

1.—PERMANENT PLANKTON

The species comprising this first section are present in their adult form all the year round and numbers do not fluctuate significantly during the year. These include Isopoda, Amphipoda, Copepoda, and Chaetognatha.

Small numbers of Isopoda occur but these have not received any special attention.

Amphipoda (Hyperiidae) of several species occur in the majority of samples, but these are *rare* in all months of the year (Text-fig. 7).

Copepoda are the most plentiful component of the permanent plankton, and many species are present in the Wellington area. Copepoda are particularly significant in the winter months (June, July, August) when other crustacean species are comparatively scarce (Text-fig. 7). Parasitic Copepoda (Caligidae) mainly male have been taken only *rarely*.

The arrow worm *Sagitta serratodentata* var. *tasmanica* Thomson, is found in the majority of samples throughout the year, but it is never numerically significant (Text-fig. 7). This species is considered to be of oceanic origin, as greater numbers occurred in samples taken during a flooding tide.

2.—TEMPORARY PLANKTON

This section includes the larger number of species. Their planktonic existence is a phase of their life history and is therefore seasonal. Included in the temporary plankton are Salpidae and Ctenophora of which adult and juvenile forms are present for only part of the year, medusae of Hydrozoa, eggs and larvae of fish and larval Crustacea.

Salpidae

The salps, *Thalia democratica* (Forskäl) (Text-fig. 3, A, B) and *Ihlea magalhanica* (Apstein) in both their solitary and aggregate forms, constitute a major part of the late summer and autumn plankton. They indicate the presence of oceanic water at the plankton stations. *Thalia democratica* occurs regularly and *very commonly* in January. From February until May the species is present in most samples but in greatly reduced numbers (Text-fig. 7). *Ihlea magalhanica* is the rarer species and occurs only in January and February (Text-fig. 7).

Ctenophora

Pleurobrachia pileus (O. F. Müller) (Text-fig. 3, C) is dominant in the winter plankton. However, this is one of the most variable planktonic species. In 1961, exceptionally large numbers were recorded, with peak abundance occurring two months earlier than in 1962 and 1963 (Text-fig. 8). *Pleurobrachia pileus* first appears *rarely* in April, and *few* are sampled in May. The species is *common* in June and *abundant* in July and in August when it may dominate many samples. In September, October and November, *P. pileus* is *common* in all samples, but occurs only *rarely* in December and January. In February and March the species is absent (Text-fig. 7).

Hydrozoa

The most abundant medusa throughout the year is that of *Obelia geniculata* (L.) (Text-fig. 3, D). The hydroids are found in great numbers on the *Macrocystis pyrifera* colonies at Point Gordon, Kau Point and in Kau Bay. The hydroids start to liberate medusae in April, when small medusae measuring between 1.6mm and 2.5mm in diameter occur *abundantly* in the plankton. From May through to December both large and small medusae are *very abundant*. These are *very common* in January. *Few* medusae are recorded in February and March, when the majority of these are large and measure over 5mm in diameter (Text-fig. 7).

The medusae of *Octophialucium funerarium* (Quoy and Gaimard) (Text-fig. 3, E) and of *Phialella quadrata* (Forbes) (Text-fig 3, F) occur in significant numbers in the plankton. These are readily separated by the presence of eight radial canals in *Octophialucium funerarium*, and four radial canals in *Phialella quadrata*. The medusae of *Octophialucium funerarium* occur *rarely* in occasional August samples, and this infrequent occurrence continues from September into December. *Few* medusae are recorded in January, and they are *rare* in February and March. During the next four months occasional very large medusae were caught below six fathoms, but were absent from the surface samples. *Phialella quadrata* is both smaller in size and more common, and occurs throughout the year. This medusa is *few* in number in September, *common* in October through to December, *very common* in January, and *rare* for the remainder of the year (Text-fig. 7).

Pisces

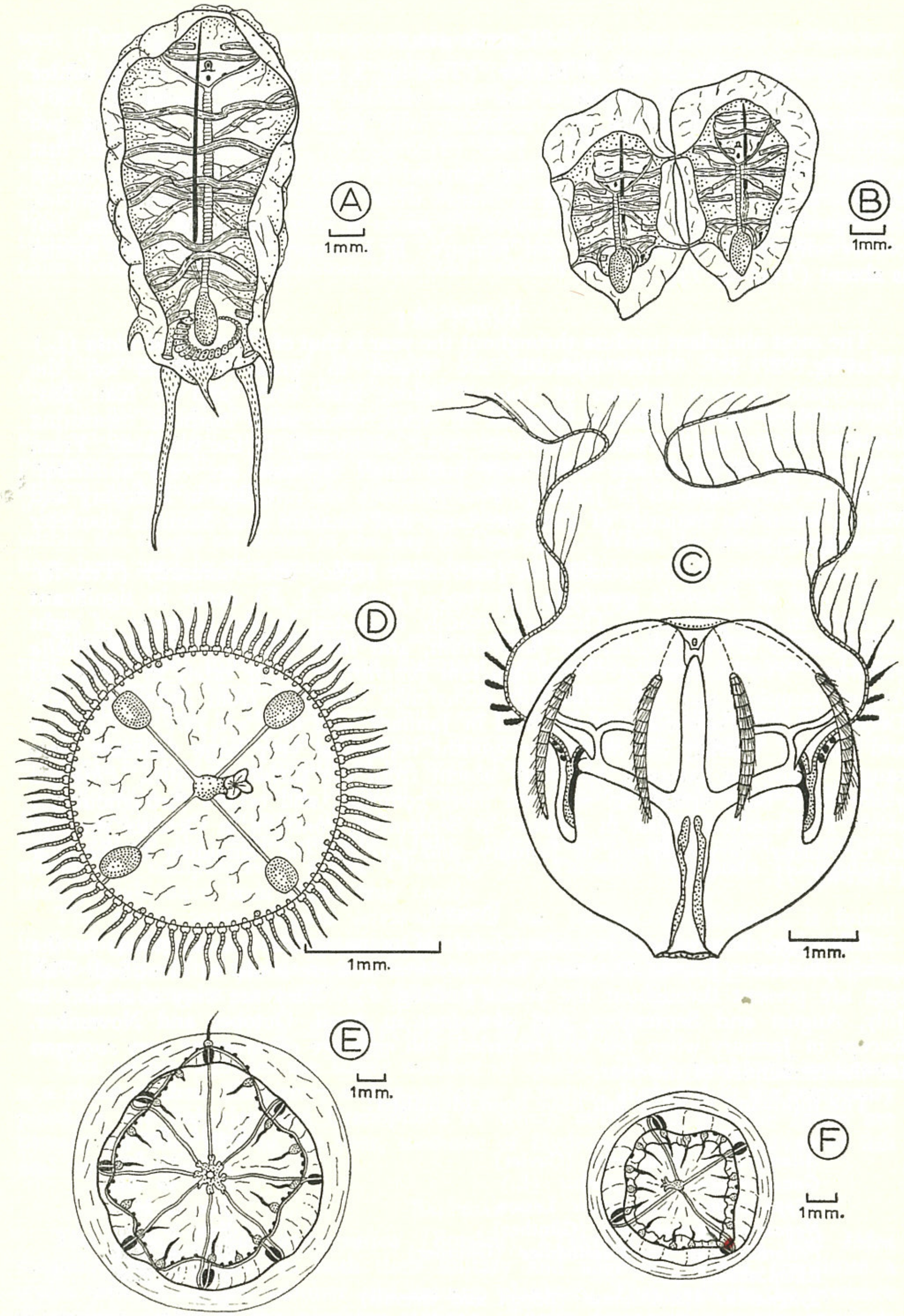
The eggs, larvae, and juveniles of fish of many species are abundant in the spring plankton (July to October), but very few of these could be identified. Fish eggs are present throughout the year (Text-fig. 7). They are *very abundant* in July, August and September, and *abundant* in April, October and November. Except in January when *few* are recorded, fish eggs are *common* or *very common* for the remainder of the year.

The following juvenile fish have been identified:

Species	*Months Present*
Allomycterus jaculiferus (Cuvier)	Dec. to Jan.
Gonorhynchus gonorynchus (L.)	Nov. to Dec.
Hippocampus abdominalis Lesson	Jan. to Mar.
Novodon convexirostris (Günther)	Feb. to Mar.
Peltorhamphus novae-zeelandiae (Günther)	Nov. to Mar.
Rhombosolea spp.	July to Nov.
Syngnathus blainvillianus (Edoux and Gervais)	Jan.

Crustacea

Larval Crustacea belonging to many genera and species are conspicuous in the plankton. This Class has been made the subject of a special study.



TEXT-FIG. 3.—Fig. A, *Thalia democratica* (Forskäl): solitary form. Fig. B, *Thalia democratica* (Forskäl): aggregate form. Fig. C, *Pleurobrachia pileus* (O. F. Müller). Fig. D, *Obelia geniculata* (L.) Medusa. Fig. E, *Octophialucium funerarium* (Quoy and Gaimard) Medusa. Fig. F, *Phialella quadrata* (Forbes) Medusa.

EUPHAUSIACEA

It was not possible to identify euphausid larvae without dissection, and the significance of this group in the harbour plankton did not warrant this detailed study. Several species first occur in September and are present through to December, but in these months they are *few* in number. They are *common* in January and February, but *rare* in March and April. Euphausid larvae are absent for the remainder of the year (Text-fig. 7). An euphausid larva, probably of the fifth "Furcilia" stage is illustrated in Text-fig. 4, A.

CIRRIPEDIA

Two different cirripede nauplii were recorded from the harbour, but neither could be identified. A large sized species (Text-fig. 4, B) occurred for three months in the spring (August to October), but it was never *abundant* except in September (Text-fig. 7). Other much smaller nauplii and metanauplii, probably of two species, occurred both in spring and autumn, but never in quantity.

In Europe cirripede larvae occur with explosive outburst in the spring at the time of diatom increase (Pyefinch, 1948, 1949; Barnes, H., 1950, 1957). Dakin and Colefax (1933) recorded little seasonal fluctuation for Australia, and no great spring abundance has been noted for Wellington Harbour. It would appear therefore, that this group does not form the striking planktonic landmark in the spring in the South Pacific as it does in Europe.

STOMATOPODA

Two species of Stomatopoda are recorded for Wellington Harbour. These are *Squilla armata* Milne Edwards, and *Heterosquilla spinosa* (Wood-Mason). Two larval forms were also obtained from the plankton, and these were reared through to a juvenile stage in the laboratory and referred to the above two species.

First and second stage "Alima" larvae of *Squilla armata* are *common* in March and April and *very common* in October of each year. Although later stage larvae are present all the year round (Text-fig. 7), the high proportion of early stage larvae in the above months suggests that in each year, *S. armata* liberates larvae in a spring peak and a less pronounced autumn peak. A stage two "Alima" larva of *S. armata* is illustrated in Text-fig. 4, D.

The larvae of *Heterosquilla spinosa* first appear *rarely* in August, and *few* are recorded from September into January. They are absent for the remainder of the year (Text-fig. 7). A high proportion of early stage larvae occur in spring (August to October) which is probably the only spawning season of the year for *H. spinosa*. A stage five larva of this species is illustrated in Text-fig. 4, C.

DECAPODA

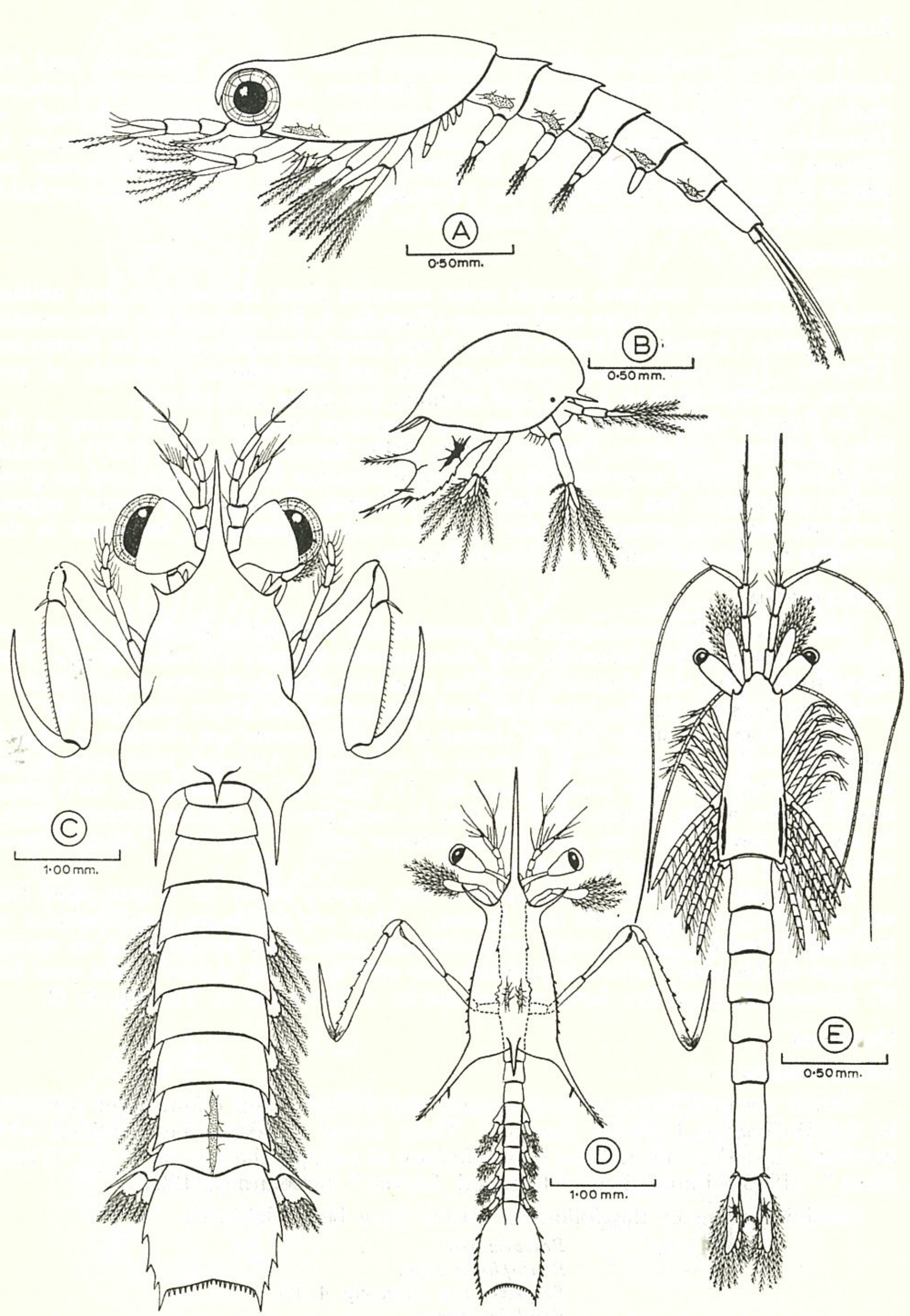
S.O. Natantia

Natant decapod larvae of both oceanic and shallow water origin occur regularly in the Wellington Harbour plankton. These larvae could not be identified with certainty beyond genus and the only reference of value is the reports of the "Terra Nova" (1910) Expedition: "Decapod Larvae" by Gurney, 1924.

Oceanic larvae of the following genera have been obtained:

Processa 1sp.
Pontophilus 2spp.
Sergestes 1sp. (Text-fig. 4, E)
Pandalus 2spp.

The larvae of *Sergestes* sp. occur *rarely* from July to September, but are absent for the remainder of the year (Text-fig. 7). The larvae of two species of the genus *Pandalus* occur *rarely* throughout the year (Text-fig. 7). Early stage *Pandalus* larvae are more common in October and November, and again in April



TEXT-FIG. 4.—Fig. A, Euphasid larva: 5th "Furcilia" stage. Fig. B, Cirripede Nauplius larva. Fig. C, *Heterosquilla spinosa* (Wood-Mason): Stage 5 larva. Fig. D, *Squilla armata* Milne Edwards: Stage 2 "Alima" larva. Fig. E, *Sergestes* sp.: Late larva.

and May. These oceanic larvae were more abundant in samples taken during a flooding tide and during southerly winds which blow directly into the harbour from the Cook Strait area.

Larvae of shallow water decapod Natantia were common within the harbour, and again these larvae could not be placed with certainty in any genus.

S.O. Reptantia

Section Palinura

Adults of *Jasus edwardsi* (Hutton, 1875) (according to Holthius (1963)—syn. *J. lalandei*) are found at Kau Point. Small numbers of first stage Phyllosoma larvae attributed to this species (Text-fig. 5, A) are *rare* in the September plankton but are absent for the remainder of the year. Later stage Phyllosoma larvae were not found. Dr Pike (Mar. Dept. pers. comm.) has found that "berried" females of *J. edwardsi* from Island Bay, Wellington, begin to liberate their larvae early in August, and about half the females are spent by the beginning of October. The appearance of first stage Phyllosoma larvae in Wellington Harbour in September agrees with these observations. *Jasus edwardsi* is the only known representative of the Palinura recorded in Wellington Harbour. *Jasus verreauxi* (Milne Edwards) is not known to breed as far south as Wellington (Pike, pers. comm.).

S.O. Reptantia

Section Anomura

Larvae of about 18 species of Anomura are found in the Wellington Harbour plankton. Many of these have been identified in the following families:

Galatheidae	:	?*Munida* Leach, 2 or 3 spp.
Porcellanidae	:	*Petrocheles spinosus* Miers.
		Petrolisthes novaezelandiae Filhol.
		Petrolisthes elongatus (Milne Edwards)
Axianassidae	:	2 spp.
Laomediidae	:	*Jaxea* Nardo, 1 sp.
Callianassidae	:	*Callianassa filholi* Milne Edwards
Paguridae	:	5 spp.

The larvae of this section (Anomura) are more abundant than those of any other section of the Decapoda, and occur with greater regularity.

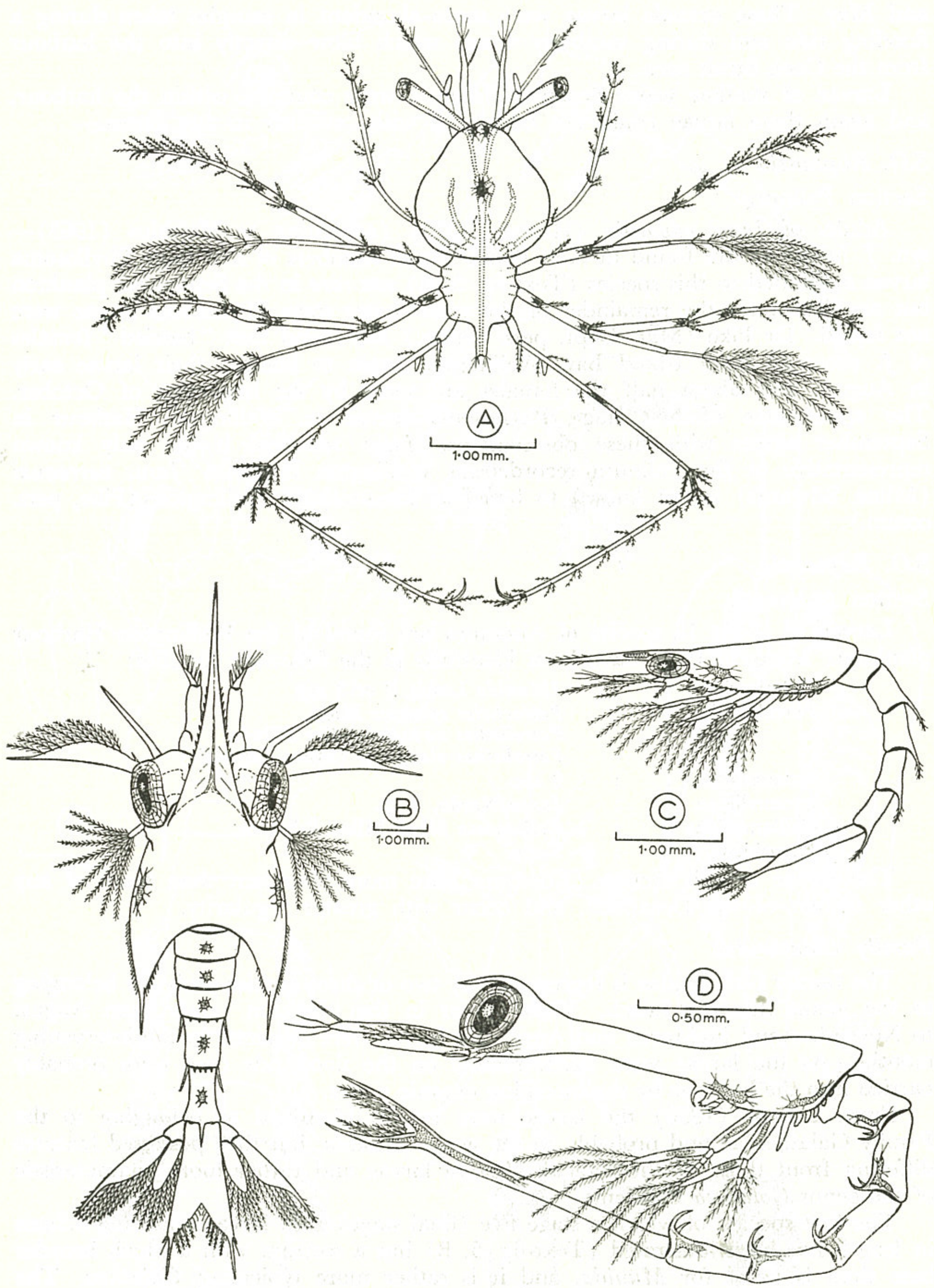
Family Galatheidae

The family Galatheidae is represented by two or three species probably belonging to the genus *Munida* Leach. These occur in the plankton *rarely* from August to November and in March and April. No larvae were obtained in the intervening months. As the larvae were taken mainly on the flood tide they were probably carried into the harbour by the incoming oceanic water.

From Lebour (1930) the larvae were readily identified as belonging to the Family Galatheidae and probably to the genus *Munida,* but they possessed features differing from those of the typical *Munida* larvae and rather more characteristic of the genus *Galathea* Fabricius.

The first species, of which a stage five (final stage) zoea larva measuring 6.5mm in length has been illustrated (Text-fig. 5, B) has a rostrum with a much broader base than is usual for *Munida,* and it is rather more typical of *Galathea.* The antennal scale is also more like that of *Galathea,* and is shorter and broader than in known *Munida* larvae. On the other hand the telson is longer and narrower and has more posterior setae than is usual in either *Munida* or *Galathea* larvae.

A stage four larva obtained from the Wellington plankton is very similar to the illustrated stage five larva. However this larva measured only 3.8mm in length. A length increase of 2.7mm is hardly possible in successive larval stages, so it is



TEXT-FIG. 5.— A, *Jasus edwardsi* (Hutton): Stage 1 "Phyllosoma" larva. Fig B, *?Munida* sp.: Stage 5 zoea larva. Fig. C, Axiid larva: Stage 2 zoea. Fig. D, *Jaxea* sp.: Stage 1 zoea larva.

probable that these two larvae are of different species belonging to the same genus. However they have not been separated for the purposes of this study.

The second species from the Wellington plankton has a rostrum and antennal scale rather more typical of *Galathea* than of *Munida*, but the long slender shape of this larva and the form of its telson identify it with the genus *Munida*.

Hence, when obtained, the adults of these larvae will also have characters that differ appreciably from the typical *Munida gregaria* which is so plentiful in the outside deeper water fauna. The early post larva of this species occurs in dense swarms in the Tory Channel area and around Banks Peninsula in December. Its larvae should therefore be present in abundance some three months earlier (September and October). The breeding season of *M. gregaria* and the two (probably three) species from the Wellington Harbour should therefore coincide. The larvae of *M. gregaria* have been described by Rayner (1935), and the species given here certainly do not compare with these. As *M. gregaria* appears to be the only species of *Munida* recorded for New Zealand, the Wellington larvae must belong to an unrecorded species. However when fully identified these larvae could conceivably belong to a genus other than *Munida*.

During the Victoria University of Wellington deep water biological investigations in Cook Strait (1954-1957) adults of eight or nine galatheid species representing the genera *Munida, Galathea* and *Uroptychus* Henderson, and possibly several unknown genera were collected. None of these have yet been described. From the Bay of Plenty, Pike (pers. comm.) has recorded the genus *Munidopsis* Whiteaves, as well as species of *Munida, Galathea,* and *Uroptychus* which were not obtained during this University's work in Cook Strait. Hence there are four or more genera and twelve or more species of Galatheidae occurring in New Zealand waters which have not been described as adults. Of these the larvae of *Munida gregaria* only are known (Gurney, 1939; *Zoo. Rec.* 1940–).

Family Porcellanidae

The zoea larvae of *Petrocheles spinosus* Miers, *Petrolisthes novaezelandiae* Filhol and *Petrolisthes elongatus* (Milne Edwards), with their enormously long rostrum and posterior carapace spines, are among the most distinctive decapod larvae in the plankton. The larvae of these three species have been described in detail (Wear, 1964a, 1964b, 1965).

Petrocheles spinosus larvae are present from July through to January of each year. However these larvae are *rare* (Text-fig. 7) and occur only in some samples.

The zoea larvae of *Petrolisthes novaezelandiae* are found in the plankton throughout the year. *Few* larvae are recorded in August, but they are *common* in September and October, *very common* in November, December and January, and *common* from February through to April. However these larvae are usually *rare* in May, June and July (Text-fig. 7). Occasional tows may catch *P. novaezelandiae* larvae in great abundance, especially during November and December.

Petrolisthes elongatus zoea larvae first appear in September, but they are *rare* from this month until the end of November. *Few* larvae are recorded in December and January, but they are *common* in February and *rare* in March. From April to August they are not recorded (Text-fig. 7).

Family Axianassidae

Two species of axiid larvae were recognised in the Wellington plankton.

The first species (Text-fig. 5, C) is *rare* in August and October, and is *common* only in September. It is absent for the remainder of the year. This larva compares with a larva described by Gurney (1924, p. 149, fig. 59, c, d, e) which was taken in considerable numbers from Three Kings Islands, and from Spirits Bay, near North Cape. Gurney was unable to place this larva in a genus.

The second species is represented by a *few* larvae in October and November samples from Wellington Harbour, but in December they are *rare*. This larva is not recorded for the remainder of the year. This species is very similar to two species described by Gurney (1924) from Three Kings Islands and the Bay of Islands. Gurney has provisionally identified these larvae as *Iconaxiopsis* sp., and the second species from Wellington Harbour is sufficiently similar to these to warrant its inclusion in the genus *Iconaxiopsis*.

There have been no adult Axianassidae described from New Zealand waters.

Family Laoemediidae

One of the most common and conspicuous larval decapod species in the summer plankton is the striking, long-necked, *Lucifer*-like larva to which the name of "Trachelifer" was given by Brook (1889). "Trachelifer" larvae were taken from the Bay of Islands by the "Terra Nova" Expedition of 1910, and these were assigned by Gurney (1924) to the Family Laoemediidae on the basis of their resemblance to the larvae of *Jaxea nocturna* (Chierghin), and attributed to the genus *Jaxea* Nardo. Larvae caught in Wellington Harbour (Text-fig. 5, D), when reared, moulted to a juvenile of the genus *Jaxea* having adult features of this genus.

The larvae of *Jaxea* sp. first appear *rarely* in September and *few* are recorded in October and November. They are *abundant* in December and January, *common* in February, and *rare* in March. From April to August these larvae are not found in the plankton (Text-fig. 7). A single 20 minute horizontal plankton tow in late December or in January may produce over 5,000 "Trachelifer" larvae. During these two months considerably fewer larvae were found in occasional samples from other areas in the harbour. The abundance of first and second stage larvae caught at Stations One and Two suggests that adults are present in considerable numbers in the substrate of Kau Bay and Mahanga Bay.

No adult species of *Jaxea* have yet been described from New Zealand waters. However, Pike (pers. comm) has obtained an undescribed *Jaxea* in 40 fathoms to 90 fathoms in several North Island localities. I also obtained seven adults from Evans Bay, Wellington Harbour, in July, 1964. Five of these were caught at night in an otter trawl in soft mud at a depth of six fathoms, and the remaining two were taken from the stomach of a male dogfish (*Mustelus antarcticus*). The characters of the juvenile reared from Wellington larvae compare closely with those of the adult species obtained by me and by Dr Pike.

Family Callianassidae

Callianassid larvae from the Wellington Harbour plankton (Text-fig. 6, A) were identified as *Callianassa filholi* Milne Edwards by hatching first stage larvae from an ovigerous female. Later stage larvae were obtained from the plankton and reared through to the juvenile stages. A *few* of these larvae first appear in the July plankton. They are *very common* in August, *abundant* in September, and *very common* from October through to late December. They are still *common* in January but *rare* in February and March, and absent from April to June (Text-fig. 7).

C. Devine (pers. comm.) in his M.Sc. thesis studies on *C. filholi* at New Brighton, Christchurch, in 1962, found adults of this species only between the high and low tide marks. I found no evidence of adults living intertidally on Scorching Bay, or on any of the smaller sandy beaches on the western side of Wellington Harbour. Small populations of *C. filholi* are known to occur on the sandy beaches of the eastern side of the harbour. However in August and September, early stage larvae occur abundantly at Stations One and Two, usually in large swarms, and it is improbable that these are liberated on the eastern side of the harbour. Relatively few larvae were found in plankton samples from other

harbour localities. Hence the possibility of *C. filholi* favouring a sub-littoral habitat in Wellington Harbour must now be considered.

Callianassid Crustacea have been recorded from most of the oceans and from habitats which range from 400 fathoms to between the tide marks (de Man, 1928). Habitat varies considerably from species to species. Hailstone and Stephenson (1961) found that *C. australiensis* was strictly intertidal, and Dahl (1953) found the intertidal habitat to characterise the genus. However, Gustafson (1934) records that *C. subterranea* in the Gullmar fjord, Sweden, is restricted to depths of 30 to 35 metres.

Family Paguridae

Our knowledge of the systematics of the New Zealand Paguridae is still confused, and relies mainly on the work of Filhol (1885). This family is badly in need of revision before the adults can be identified with certainty. Dawson (Oceanographic Inst.) and Pike (Mar. Dept.) have informed me (pers. comm.) that Dr Forest (Paris) is at present revising the New Zealand Paguridae, and much of the material is in his possession pending publication.

Characters of pagurid larvae are given by Gurney (1924, p. 182), MacDonald, Pike and Williamson (1957), and Pike and Williamson (1959). As in all decapod Crustacea, larval forms provide a very valuable indication of the number of distinct species, and preliminary work has resulted in the recognition of five pagurid species in the Wellington Harbour plankton. Three of these species occur *commonly* from September to December and again in April and May, but are *rare* for the remainder of the year. A fourth species is *common* in October and November only, and the fifth species is *rare* and occurs only during the spring (September to November). However the family Paguridae is represented in the plankton all the year round (Text-fig. 7). One of the three more common species is illustrated (Text-fig. 6, B) and is a larva of the "*Pagurus bernhardus*" type (MacDonald, Pike, and Williamson, 1957, pp. 219–226, figs. 2, 3).

Three species of zoea larva were reared in the laboratory to the megalopa stage, which in the Paguridae is known as the "Glaucothoe" larva. One of these survived to the first juvenile hermit stage but this lacked sufficient adult characters for identification.

S.O. Reptantia

Dromiacea

"The systematic position of the Dromiacea has, on the evidence of adult anatomy, been a subject of considerable difference of opinion, and they have been associated on the one hand with the Anomura and on the other hand with the Brachyura" Gurney (1924, p. 188).

Gurney (1924, 1942), Lebour (1934), and Pike and Williamson (1960), consider that the Dromiacea must be removed from the Brachyura with which they are currently classified. However the Dromiacea are difficult to place in the Anomura and cannot be placed in the Thalassinidea. Pike (1947) from detailed anatomical comparisons with Anomura, Dromiacea, and Brachyura, and Gurney (1942) both derive the Dromiacea from "the anomuran section of the Thalassinidea". However larval evidence suggests that the Dromiacea should be separated from the Brachyura and classified as a separate group apart from the line of descent of the Brachyura.

A dromiid larva occurs *rarely* in the Wellington Harbour plankton in spring and autumn. It is considered to be of oceanic origin as it is more plentiful in samples from Palliser Bay and Island Bay. This larva is certainly a dromiid, but there have been no adult dromiids described from New Zealand waters. However Hale (1927) records *Petalomera wilsoni* (Fulton and Grant) from South Australia, and Pike (pers. comm.) has found this species in shallow water down to 40 fathoms in Tasman Bay. The generic characters of *Petalomera* larvae are unknown, but they will undoubtedly follow the general dromiid pattern. These Wellington larvae may well belong to *P. wilsoni*.

The characters of this larva support the separation of the Dromiacea from the Brachyura, and further, on the basis of several " pagurid " characters it supports Pike and Williamson (1960) who consider that the Paguridea, Galatheidea, and Dromiacea may have differentiated from a common pre-thalassinid ancestor.

This larva will be the subject of future work.

S.O. Reptantia

Section Brachyura

With the exception of the Dromiacea, all brachyuran larvae conform to a general morphological pattern which is remarkably uniform throughout the whole group (Gurney, 1924; Lebour, 1928). Basically the larvae have dorsal, rostral and paired lateral carapace spines. Variation in the form of these spines, or the absence of one or more of these spines, are the primary characters used in the separation of families and genera. Specific distinction is based on secondary characters such as the form of the telson, the spines on the abdominal segments, the length of the antennal endopodite, and the chromatophore pattern.

The high degree of endemism among New Zealand Brachyura and the lack of literature concerning the larvae of these endemic groups makes identification impossible without either hatching the eggs of identified ovigerous females, or rearing the larvae to a juvenile stage which can then be referred to an adult species. There is an urgent need for further work in this field.

The zoea and megalopa larvae of about 32 brachyuran species can be distinguished in the Wellington Harbour plankton. This is more than the number of adult species recorded for the Wellington area. The majority of these larvae could not be identified. However, the few genera and species identified belong to the following families:

Cancridae	:	*Cancer novaezealandiae* (Jacquinot and Lucas).
Pinnotheridae	:	*Pinnotheres* sp.
		Pinnotheres novaezealandiae Filhol.
Hymenosomidae	:	*Halicarcinus edwardsi* Filhol.
		Halicarcinus 2 spp.
Grapsidae	:	*Hemigrapsus edwardsi* (Hilgendorf).
		Cyclograpsus lavauxi Milne Edwards.
Xanthidae	:	*Heterozius rotundifrons* Milne Edwards.

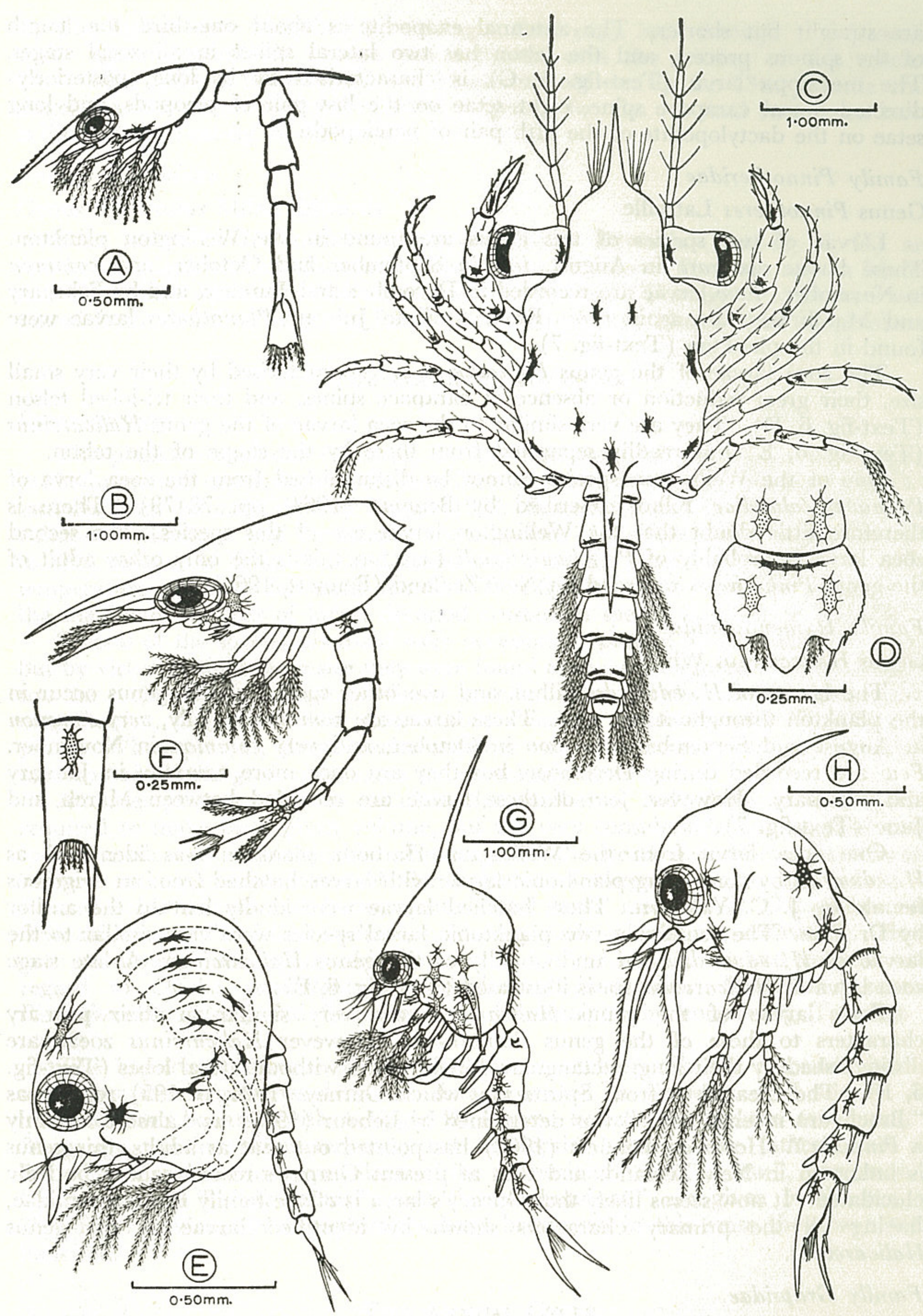
Among the fauna are several families and genera in common with the Plymouth fauna of the United Kingdom, possessing larval stages comparable with those belonging to corresponding Plymouth groups (Lebour, 1928). Several of the above families were identified from Lebour's descriptions, but families such as the Grapsidae and the Hymenosomidae are not represented in the United Kingdom.

Family Cancridae

Genus *Cancer* L.

Larvae in the Wellington Harbour plankton were identified as *Cancer novaezealandiae* (Jacquinot and Lucas) after rearing the megalopa larva to a juvenile crab in the laboratory. These larvae first appear *rarely* in July or in August, but in September and October they are *common*. *Few* larvae are recorded in November, and in December they are again *rare*. From April through to June this species is not recorded (Text-fig. 7).

The zoea larvae are similar to known larvae of the genus *Cancer* in having dorsal, rostral, and paired lateral carapace spines which are all well developed. The smooth dorsal and rostral spines are long and straight; and the lateral pair



TEXT-FIG. 6.—Fig. A, *Callianassa filholi* Milne Edwards: Stage 1 zoea larva. Fig. B, Pagurid Larva: Stage 3 zoea. Fig. C, *Cancer novaezealandiae* (Jacquinot and Lucas): Megalopa larva. Fig. D, *Pinnotheres novaezealandiae* Filhol: Telson of zoea larva. Fig. E, *Halicarcinus* sp.: Final stage zoea larva. Fig. F, *Halicarcinus* sp.: Telson of zoea larva. Fig. G, *Hemigrapsus edwardsi* (Hilgendorf): Final zoea larva. Fig. H, *Heterozius rotundifrons* Milne Edwards: Stage 1 zoea larva.

are straight but shorter. The antennal exopodite is about one-third the length of the spinous process, and the telson has two lateral spines in all zoeal stages. The megalopa larva (Text-fig. 6, C) is characterised by its long, posteriorly-directed dorsal carapace spine, eight setae on the last pair of pleopods, and long setae on the dactylopodite of the fifth pair of pereiopods.

Family Pinnotheridae

Genus *Pinnotheres* Latreille

Larvae of two species of this genus are found in the Wellington plankton. These larvae are *rare* in August, *few* in September and October, and *common* in November. *Few* larvae are recorded in December and January, and by February and March they are again *rare*. From April to July no *Pinnotheres* larvae were found in the plankton (Text-fig. 7).

The zoea larvae of the genus *Pinnotheres* are characterised by their very small size, their great reduction or absence of carapace spines, and their tri-lobed telson (Text-fig. 6, D). They are very similar to the zoea larvae of the genus *Halicarcinus* (Text-fig. 6, E) but readily separated from these by the shape of the telson.

One of the Wellington species cannot be distinguished from the zoea larva of *P. novaezealandiae* Filhol described by Bennett (1964, pp. 78–79). There is therefore little doubt that the Wellington larvae are of this species. The second zoea larva is probably of *P. schauinslandi* Lenz, as this is the only other adult of the genus *Pinnotheres* recorded for New Zealand (Bennett, 1964).

Family Hymenosomidae

Genus *Halicarcinus* White

The larvae of *H. edwardsi* Filhol, and two other species of this genus occur in the plankton throughout the year. These larvae are *common* in July, *very common* in August and September, *common* in October, and *very common* in November. *Few* are recorded during December, but they are once more *common* in January and February. However, *few* of these larvae are recorded between March and June (Text-fig. 7).

One zoea larva from the Wellington Harbour plankton was identified as *H. edwardsi* by comparing planktonic larvae with larvae hatched from an ovigerous female by J. C. Yaldwyn. These hatched larvae were kindly lent to the author by Dr Pike. The remaining two planktonic larval species were very similar to the larvae of *H. edwardsi,* and undoubtedly of the genus *Halicarcinus.* A late stage zoea larva of *Halicarcinus* sp. is illustrated (Text-fig. 6, E).

Zoea larvae of the genus *Halicarcinus* are very similar in their primary characters to those of the genus *Pinnotheres.* However *Halicarcinus* zoeae are distinguished by their long, rectangular, forked telson without lateral lobes (Text-fig. 6, F). The zoea larva from Spirits Bay which Gurney (1924, p. 195) records as "Brachyura incertae sedis" was determined by Lebour (1928) as "almost certainly a *Pinnixia*". However, Bennett (1964) has pointed out that as adults, this genus is unknown in New Zealand, and that at present Gurney's record cannot be fully elucidated. It now seems likely that Gurney's larva is of the family Hymenosomidae, having all the primary characters shown by identified larvae of the genus *Halicarcinus.*

Family Grapsidae

Genus *Hemigrapsus* Dana

The zoea larvae of *Hemigrapsus edwardsi* (Hilgendorf) are *rare* in the September plankton, *few* in October, and *common* from November into January. *Few* larvae are recorded in February and March and the species is again *rare* in April, but absent for the remainder of the year (Text-fig. 7).

The larvae were identified by rearing a final stage zoea through to a juvenile crab. Quite remarkable success was achieved with the rearing of this species. On 1 May 1964, a reared crab was 15 months old and in the 13th juvenile crab stage. Larvae were also hatched from ovigerous females. A final stage zoea larva is illustrated (Text-fig. 6, G).

Family Xanthidae

Genus *Heterozius* Milne Edwards

Zoea larvae of *Heterozius rotundifrons* Milne Edwards (Text-fig. 6, H) are *few* in the plankton from November through to February. They are *rare* in March and April and absent for the remainder of the year (Text-fig. 7). Larvae were reared from identified ovigerous females and subsequently identified in the plankton.

The Plankton Calendar

Introduction

The plankton calendar (Text-fig. 7) has been compiled from seasonal variation in the numerical occurrence of the described species in Wellington Harbour plankton samples from January 1961 to August 1963. Seasonal trends in the monthly mean volume of plankton, and the relative contributions of the five major faunal elements to this volume is illustrated and correlated with the mean of the surface water temperature readings for each month (Text-fig. 8). The monthly variation in the maximum number of larval decapod crustacean species is shown in Text-fig. 9.

Several of the species discussed were occasionally present in quite small numbers, but by virtue of their large size they were found to make an appreciable contribution to the volume of plankton. Such species were *Thalia democratica, Ihlea magalhanica, Octophialucium funerarium, Phialella quadrata,* and *Pleurobrachia pileus.* When present, these species together with the smaller but very abundant medusae of *Obelia geniculata* cause major volumetric increases.

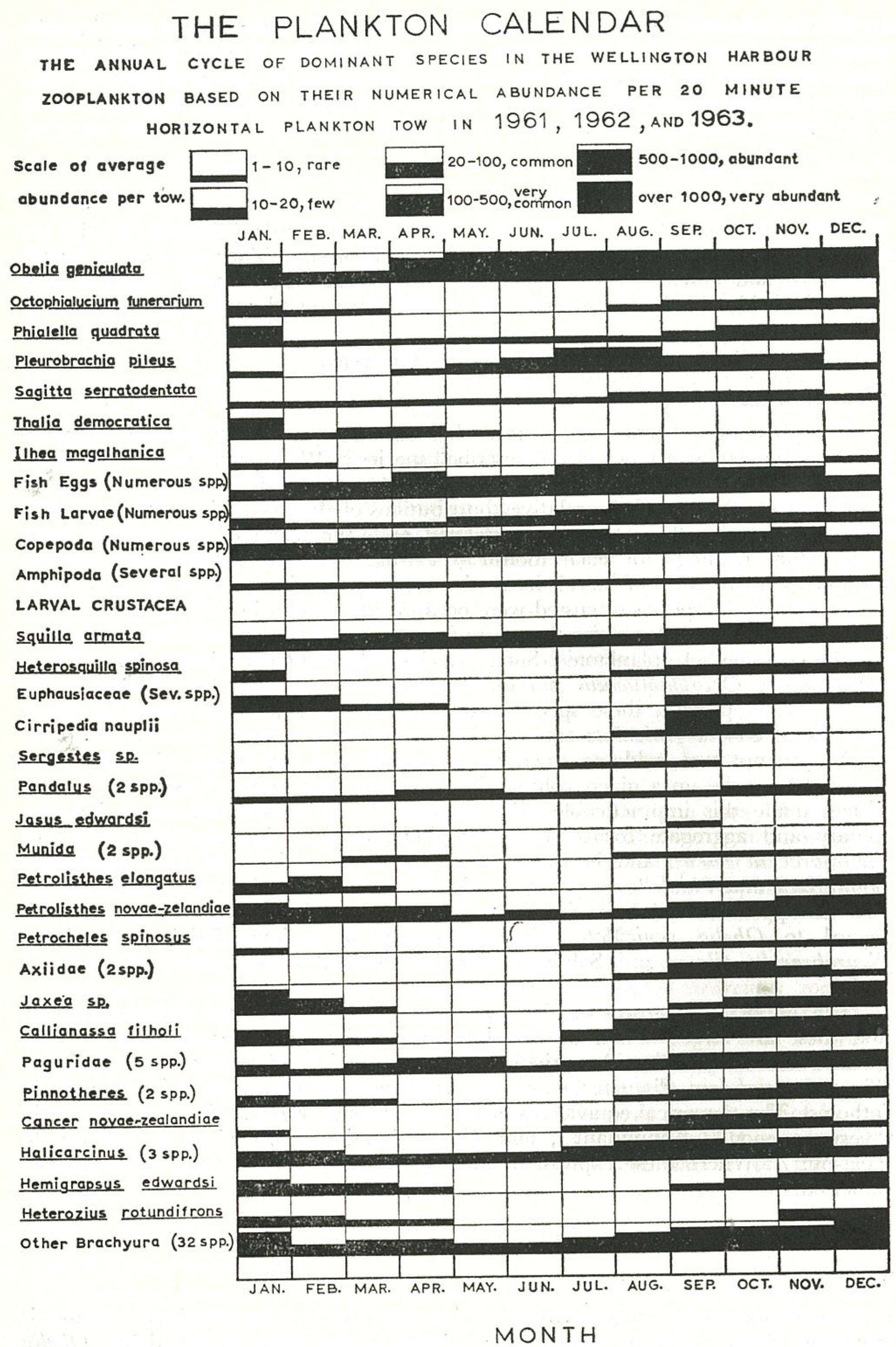
An attempt was made to calculate the number of individuals of each species required to make up a given volume, but the very considerable size range of some species made this impracticable. For example the great size differences between solitary and aggregate forms of the Salpidae, between juveniles and adults of *Pleurobrachia pileus,* and between small and large medusae of *Octophialucium funerarium* and *Phialella quadrata,* made any such calculations misleading. However an approximate relationship between numerical abundance and volume with regard to *Obelia geniculata, Octophialucium funerarium, Phialella quadrata, Pleurobrachia pileus,* and Salpidae, may be obtained by correlating Text-figs. 7 and 8.

The important features of the plankton in each month are described below, and these are largely based on the data presented in Text-figs. 7, 8 and 9. All quantities are equated with a single 20 minute horizontal plankton tow, using a 36 gauge two-foot diameter cone net at depths between one fathom and six fathoms. The numerical equivalents of the expressions "rare", "few", "common", "very common", "abundant", and "very abundant" are given in the key to Text-fig. 7. Where these expressions have been used in this sense they have been italicized.

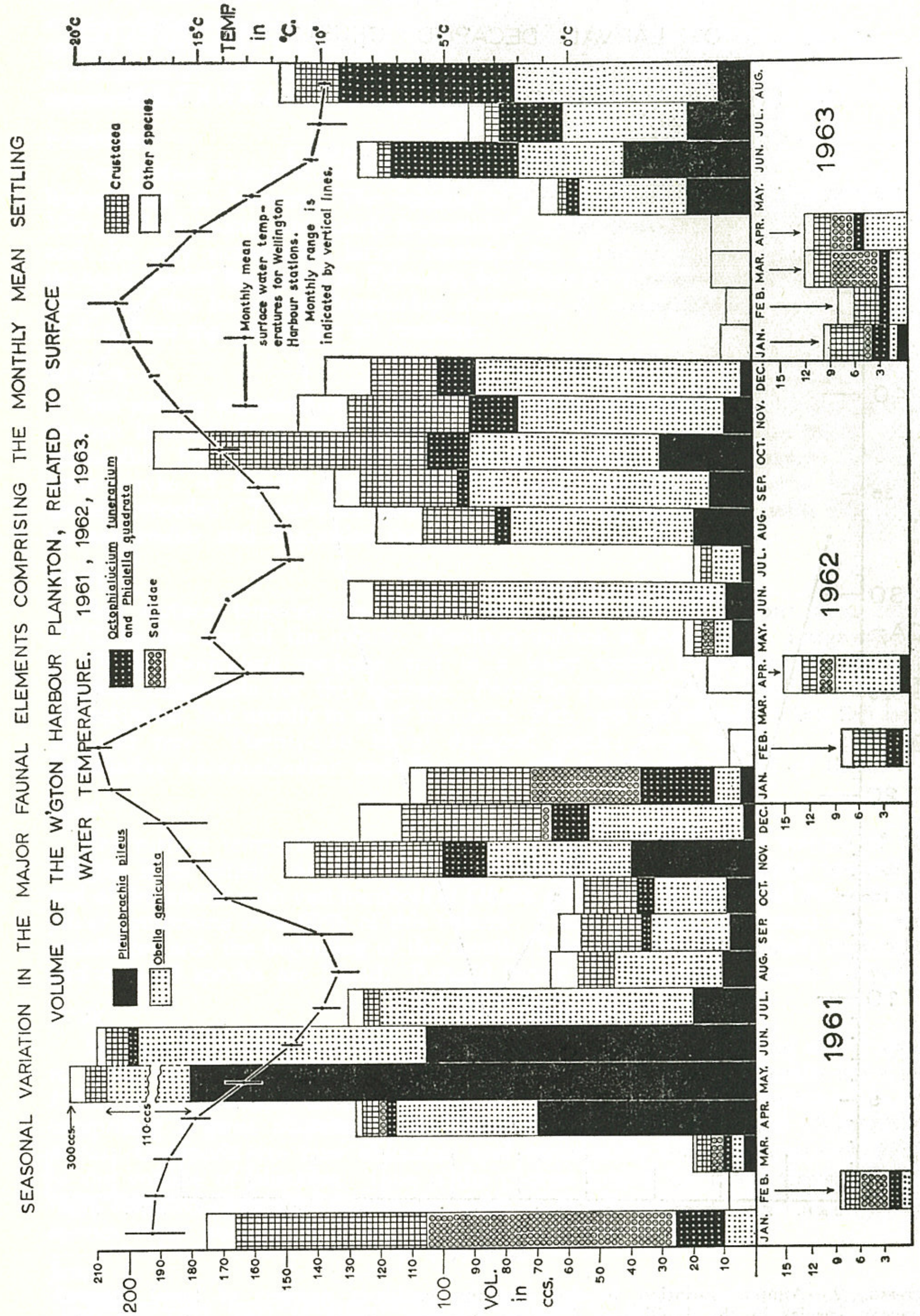
The Annual Cycle

January

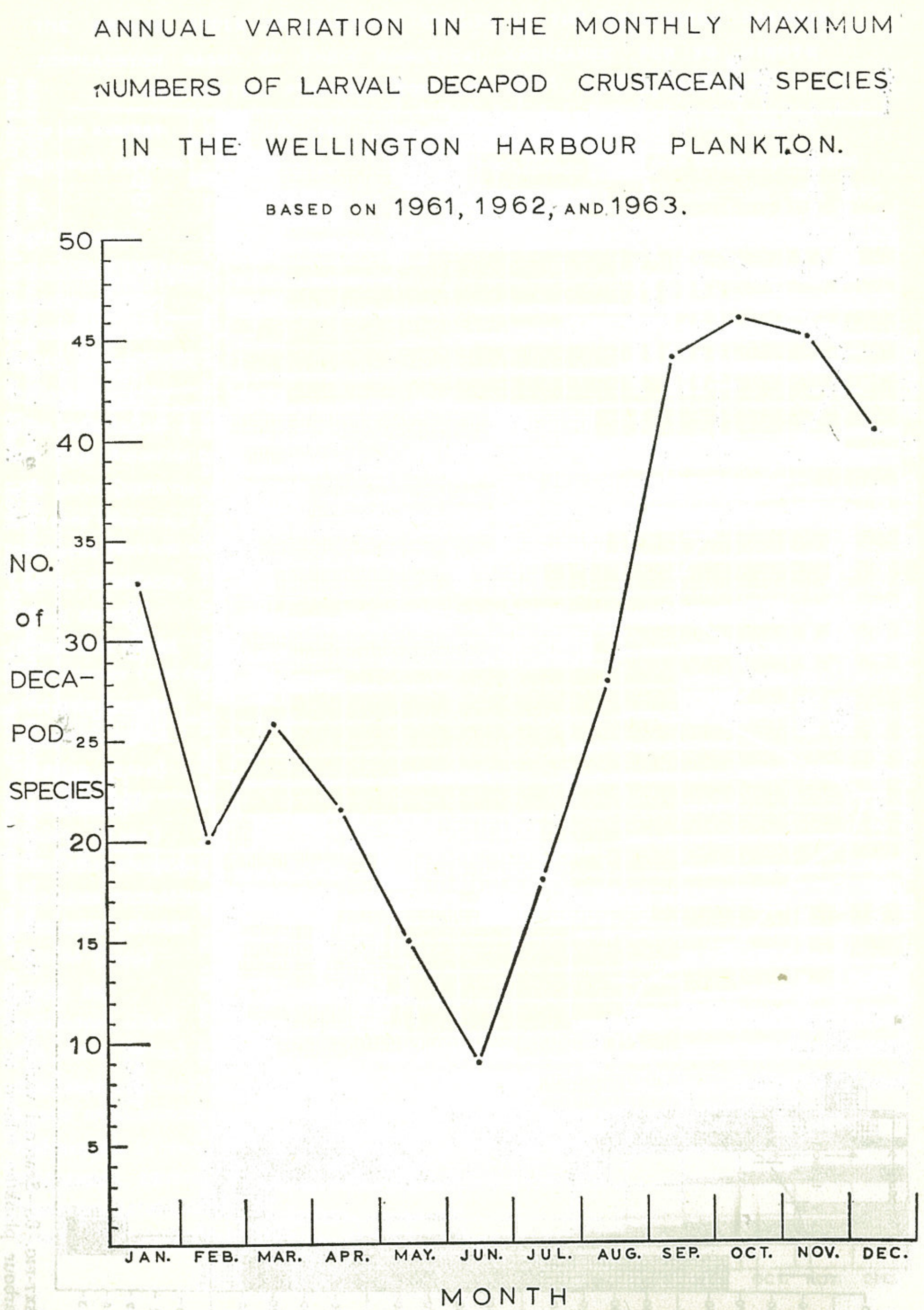
Sea temperatures vary between 17°C. and 19°C. The plankton volume is generally about 100cc, or more when *Thalia democratica* is abundant. *Obelia geniculata* occupies less than 10% of the volume, while Salpidae, especially *Thalia*



TEXT-FIG. 7.—The Plankton Calendar. The Annual Cycle of Dominant Species in the Wellington Harbour Zooplankton based on their numerical abundance per 20-minute Horizontal Plankton Tow in 1961, 1962 and 1963.



TEXT-FIG. 8.—Seasonal variation in the major faunal elements comprising the monthly mean settling volume of the Wellington Harbour plankton related to surface water temperature during 1961, 1962 and 1963. Based on 20-minute horizontal plankton tows.



TEXT-FIG. 9.—Annual variation in the monthly maximum numbers of larval decapod crustacean species in the Wellington Harbour plankton. Based on 1961, 1962 and 1963.

democratica, make up over 40% of the volume of most samples. Hydromedusae make up about 20% of the volume. *Pleurobrachia pileus* is *rare* and may be absent. About one-third of the volume comprises larval Crustacea, with 33 decapod species recorded for this month. Of these the larvae of *Jaxea* sp. and *Petrolisthes novaezelandiae* are usually the most common, but other species are strongly represented.

FEBRUARY

Sea surface temperatures vary between 17.5°C. and 20°C. but are consistently higher than in January. The volume of February samples is rarely more than 10cc, and all species are poorly represented. *Pleurobrachia pileus* is usually absent, and the only stomatopod larvae recorded are those of *Squilla armata*. Twenty decapod species are found in February, but these are represented by *few* individuals excepting the larvae of *Petrolisthes elongatus, P. novaezelandiae, Jaxea* sp. and *Halicarcinus* spp. which are all *common*.

MARCH

Sea surface temperatures in this month are between 16°C. and 17°C. Plankton volume is about 15cc, with greater numbers of *Thalia democratica* being mainly responsible for this small increase. Larval Crustacea have increased with first stage larvae of *Squilla armata, Munida* spp., Paguridae and some brachyuran species recorded. Twenty-six larval decapod species are present with *Petrolisthes novaezelandiae* and Paguridae the most common.

APRIL

Sea surface temperatures are between 14°C. and 16°C. but may fall to 12°C. by the end of the month. Plankton volume is about 50cc. Large numbers of *Obelia geniculata* medusae and to a lesser extent *Pleurobrachia pileus* are together responsible for this increase. *Phialella quadrata* and *Thalia democratica* are recorded, but usually in small numbers. Fish eggs are *abundant*, but fish larvae are still *rare*. Twenty-two larval decapod species were found in April, with *Petrolisthes novaezelandiae* and Paguridae still the most common of these.

MAY

Sea surface temperatures are between 12°C. and 14°C. The volume of May samples is extremely variable. Catches of up to 500cc may be taken towards the end of the month with vast numbers of *Obelia geniculata* medusae and *Pleurobrachia pileus* comprising over 90% of this volume. *Thalia democratica* occurs only *rarely*, usually towards the beginning of the month. Decapod larvae are poorly represented and only 15 species are found. Pagurid larvae are the most common of these.

JUNE

Sea surface temperatures fall from about 12°C. at the beginning of the month to 10°C. at the end of June. The volume of June samples is generally more than 130cc, and occasional tows may produce more than a litre of plankton mainly comprising a great abundance of *Obelia geniculata* medusae and *Pleurobrachia pileus*. Copepoda are now *abundant* and occasionally make a large contribution to the volume of plankton. June is the poorest month for larval Crustacea. The most common crustacean larvae are those of *Squilla armata*. Only nine decapod species occur and all of these are very poorly represented.

JULY

Sea surface temperatures range between 10°C. and 11°C. but slightly lower temperatures are occasionally recorded. Vast numbers of *Obelia geniculata* medusae and *Pleurobrachia pileus* still persist and may comprise over 90% of the volume of one litre or more in some samples. The majority of samples produce a volume of between 50cc and 100cc of plankton. *Phialella quadrata* was *very common* in July samples of 1963, but was absent in July of 1961 and 1962. The first evidence of the spring increase in the zooplankton appears in mid-July. Fish eggs are *very abundant* and fish larvae are now *common*. As in June Copepoda are *abundant*. Of the decapods, 18 species are found in July, but these are represented mainly by a few first stage larvae occurring towards the end of the month.

August

Sea surface temperatures are the lowest for the year in early August and readings below 9.5°C. are relatively common. However towards the end of August there is a rise to approximately 11°C. The volume of plankton is usually greater than 100cc, and is comprised mainly of *Obelia geniculata* medusae and *Pleurobrachia pileus* which occur in *abundance*. *Octophialucium funerarium* and *Phialella quadrata* are present but their abundance is variable. Fish eggs are *very abundant* and fish larvae *very common*. Copepoda are *very common*. The spring increase of larval Crustacea makes up about one-third of the volume of plankton. Twenty-eight species of larval decapod can be recognised in August samples, the most common larva being of *Callianassa filholi*.

September

Sea surface temperatures between 11°C. and 13°C. are recorded in this month. The average volume of plankton is about 100cc, and over one-third of this volume is made up of Copepoda and crustacean larvae. *Obelia geniculata* medusae are still *very abundant* and *Pleurobrachia pileus* is *common*, but these species do not occur in the vast numbers characterising the winter months. Large numbers of fish eggs and larvae are usually present. In September larval Crustacea reach a maximum which is sustained through to late January. Stomatopod larvae are *common* and cirripede nauplii and metanauplii occur in *abundance*. Larval decapod Crustacea are very numerous and 44 species occur. Of these *Callianassa filholi* dominates all samples and may be *very abundant*. Other species are well represented. *Jasus edwardsi* Phyllosoma larvae occur in September only.

October

Sea surface temperatures are between 13°C. and 15°C. Average tows produce between 50cc and 100cc of plankton. *Obelia geniculata* is *very abundant* and *Pleurobrachia pileus* is *common*, but together they comprise only about 50% of the volume. Fish eggs and larvae are still *very common*, but these do not occur in the abundance characterising the previous three months. In comprising about 45% of the volume, larval Crustacea are more abundant than in any other month of the year. *Squilla armata* larvae are *very common* with early stage larvae dominant. Forty-six larval decapod species are recorded with *Callianassa filholi* the most abundant species.

November

Sea surface temperature recordings vary between 15°C. and 16.5°C. Between 100cc and 200cc of plankton is produced by an average tow in this month. The bulk of this volume is made up with *Obelia geniculata, Pleurobrachia pileus, Octophialucium funerarium,* and *Phialella quadrata*. Crustacean larvae are still *very abundant,* but these comprise less than one-third of the volume of plankton. Decapod Crustacea are represented by the larvae of up to 45 species, with *Petrolisthes novaezelandiae, Callianassa filholi* and *Halicarcinus* spp. the most abundant.

December

Sea surface temperatures vary between 15°C. and 17.5°C. but most of the recordings are around 17°C. The volume of plankton in this month is similar to November, and varies between 100cc and 150cc. The abundance of *Obelia geniculata* medusae falls off rapidly towards the end of the month, and by December *Pleurobrachia pileus* is usually *rare*. *Ihlea magalhanica* occurs *rarely,* but *Thalia* is still absent. Larval Crustacea are *abundant* but comprise less than one-third of the volume of plankton. Forty species of decapod larvae have been isolated in December samples. *Petrolisthes novaezelandiae, Callianassa filholi* and *Jaxea* sp. are dominant among the Decapoda. Up to 5,000 larvae of *Jaxea* sp. are recorded in some samples. In December brachyuran zoeas occur in peak abundance for the year.

Irregular Variations

Although usually conforming to the described monthly pattern, the plankton is characterised by short-period fluctuations which are non-seasonal.

In several cases plankton samples were neither quantitatively nor qualitatively representative of the month in which they were taken. The following volumes were recorded for successive samples from Station One in June and July, 1961:

June 1	270cc
June 13	120cc
June 15	190cc
June 22	120cc
July 5	20cc
July 12	180cc
July 20	270cc
July 26	200cc

The sample taken on 5 July produced only a small fraction of the volume normal for these months, and *Obelia geniculata* medusae and *Pleurobrachia pileus* which usually dominate the June and July plankton were very scarce. The larvae of several brachyuran species present in the majority of the above samples were absent on 5 July.

A similar example occurred on 25 January 1962, when a volume of 10cc was recorded compared with 230cc, 180cc and 230cc recorded on 3, 10 and 15 January respectively. Neither the volume nor the faunal composition of the sample taken on 5 January compared with other January samples. Brachyuran larvae representing 15 species dominated this sample, while Copepoda, porcellanid larvae, and *Jaxea* sp. were *rare,* and Salpidae, *Octophialucium funerarium* and *Phialella quadrata* were absent.

The larvae of species occurring seasonally were occasionally identified in samples taken outside the expected seasonal boundaries. A single stage one larva of *Petrocheles spinosus* was recorded on 2 May 1962. This species was absent from all samples between December 1961 and 2 May 1962, and did not reappear in the plankton until July 1962. Several stage one larvae of *Jaxea* sp. were recorded on 24 May 1962. Only late stage larvae were present in February 1962, and stage one larvae of this species were not subsequently recorded until September 1962. In such out of season occurrences as these larvae did not appear in sufficient numbers to suggest a secondary period of liberation.

During the spring and summer months occasional plankton samples were dominated by many hundreds of early stage larvae of any one of several crustacean species. These monospecific swarms were probably produced by large numbers of adults liberating their larvae simultaneously, and the larvae were not dispersed by tidal action. This is supported by the observation that species occurring sparsely in the plankton for several weeks may be suddenly represented by an abundance of first stage larvae in a single plankton sample, with subsequent samples yielding very few.

Identified decapod Crustacea forming such larval swarms are as follows: *Hemigrapsus edwardsi, Petrolisthes novaezelandiae, Callianassa filholi, Jaxea* sp. Of these, *Callianassa filholi* and *Jaxea* sp. swarm quite frequently in the months of their greatest abundance.

DISCUSSION

Surface water temperature probably influences numerically dominant species thereby controlling many of the fluctuations in the volume of plankton. A critical temperature seems to be between 15°C. and 16°C. When the temperature falls consistently below this level *Obelia geniculata* medusae and *Pleurobrachia pileus* occur in great abundance and cause a sharp rise in the volume of plankton. As the temperature rises above 16°C. in early summer these two species become rare or absent. The converse probably applies to the Salpidae, especially *Thalia democratica* which makes a large contribution to the volume of summer and autumn samples. Salpidae do not occur until early December when the surface water temperatures are consistently above 15°C. or 16°C. but in late May when the temperature again falls below 15°C. Salpidae are absent.

Minor variances from the described monthly pattern were noted during the research period. For example in 1963, *Jaxea* sp. and *Callianassa filholi* larvae appeared in the plankton two or three weeks earlier than expected, and *Pleurobrachia pileus* became absent at the end of November, which was over a month earlier than in 1961 and 1962. Also, in 1961 cirripede nauplii were present in September only, but in 1962 and 1963 their occurrence was quite considerably protracted, with fewer larvae occurring over the three months of August, September and October.

It is not possible to interpret the causes of early or delayed larval liberations, shortened or protracted liberation periods, or the many irregular variations characterising the plankton samples without continuous plankton recording over an uninterrupted period of time correlated with meteorological and hydrological data.

Skerman (1958) gives evidence of diurnal temperature variations in the magnitude of 4.5°C. in summer. He writes that thermograph records showed 4.0°C. differences in temperature within the uppermost six feet of water on several occasions. However Maxwell (1956) found that differences between bottom and surface temperatures in Wellington Harbour were at the most 2.0°C.

Skerman's data and the data obtained during this current research programme suggests that marine animals within the harbour environment are influenced by sudden short-period variations in temperature. During laboratory rearing experiments, adult Crustacea collected from the littoral and sub-littoral margins of Wellington Harbour, and juvenile Crustacea reared from planktonic larvae, survived abrupt temperature changes of plus or minus 16°C. without obvious detriment. This showed that many species possess a wide eurythermal capacity.

Skerman contends that the short-period temperature fluctuations in the harbour environment may be outside the eurythermal capacity of the shelf forms beyond the harbour entrance—a factor which may determine the composition of the harbour population. From laboratory experiments involving living plankton, the fact that the larvae of adult Crustacea known to occur only beyond the harbour entrance (*Sergestes* sp., *Pandalus* spp., *Munida* spp., and possibly *Petalomera* sp.) survived abrupt temperature changes over a wide range suggests that short-period temperature variations are not the limiting factor determining the harbour population. A more probable limitation would be an insufficiently long period of sustained optimum temperatures to induce some species to breed, or to complete their larval metamorphosis.

Wilson (Plymouth) showed that the nature of the water itself had a very marked influence on the development of larvae (polychaetes and echinoderms), and it is possible, therefore, that the oceanic larvae which come into the harbour environment are unable to develop in this water mass. Many species living on or in different types of substratum are unable to metamorphose unless the required substratum is found (Wilson, 1951). Larvae of parents living within the harbour environs will therefore be the only species likely to complete their larval metamorphosis and to become established. All others will be transitory.

Dakin and Colefax (1933, 1940) have outlined a calendar for the more frequently occurring organisms in the plankton of the coastal waters of New South Wales, Australia. These are the only published seasonal analyses of a Southern Hemisphere plankton community available for comparison with the plankton of Wellington Harbour.

The annual range of sea surface temperatures for New South Wales is from 23°C. in February to 15°C. in August. The temperatures are therefore generally higher than in the Wellington Harbour where slightly lower summer maxima (20°C.) and much lower winter minima (9°C.) are recorded.

In the New South Wales plankton the abundance of *Thalia* in all months except June, July and August is probably a result of the relatively high sea temperatures. *Thalia* occurs only in late summer and autumn in the cooler Wellington waters.

Obelia geniculata and *Pleurobrachia pileus* which dominate the Wellington Harbour winter plankton are not discussed by Dakin and Colefax (1933, 1940). Ctenophores are recorded in the late summer and autumn samples from New South Wales, but these are at no stage dominant, and it is not known whether or not these ctenophores include *P. pileus*. The winter "bloom" of *Obelia geniculata* and *Pleurobrachia pileus* in the Wellington plankton suggests that these species favour lower temperatures than occur in New South Wales waters. It is probable that the distribution of *Obelia geniculata* follows the southern circumpolar, cold-temperate distribution of *Macrocystis pyrifera* outlined by Knox (1960).

The zooplankton of the Wellington Harbour follows essentially the same seasonal pattern described for that of New South Wales. However, the zooplankton of New South Wales developed in late spring or in early summer (November or December) and tended to sustain itself at a high level during the summer and into late autumn. The peaks are in November-December and in March (Dakin and Colefax, 1933). In the Wellington Harbour the first evidence of the spring increase in the zooplankton is in mid-July, and this continues through August to reach a maximum in September, which is sustained through to late January. There is a sharp fall-off in February, which recovers to reach a very minor autumn maximum in March and early April. This late summer decrease and autumn recovery of the zooplankton is not as marked in New South Wales (Dakin and Colefax, 1940).

From a consideration of the evidence presented in this study, it is clear that the majority of zooplanktonic species occur in a seasonal cycle. This cycle is independent of the seasonal trends in the total volume of the plankton. Total volume is largely dependent on the abundance of *Obelia geniculata* and *Pleurobrachia pileus* which tend to have temperature optima differing from the majority of species in the plankton.

As the major components of the Wellington Harbour plankton are known to occur elsewhere in New Zealand waters, it is possible that the plankton of other coastal or harbour areas of New Zealand shows a similar seasonal pattern to that described for Wellington Harbour. There is a need for further work in this field which is largely still untouched, and studies of this type from other New Zealand localities would prove especially valuable.

SUMMARY

(1) The present series of Wellington Harbour plankton collections commenced on 2 January 1961, under the direction of Professor L. R. Richardson assisted by members of the staff and research students from the Department of Zoology, Victoria University of Wellington. By January, 1964, the collection consisted of 250 plankton samples.

(2) This collection has been used to form the basis of an analysis of the seasonal changes in the abundance of the more important macro-zooplankton organisms over the three years.

(3) It was not possible to identify all the taxa to the specific level as the systematic status of many New Zealand marine organisms has not yet been determined.

(4) Plankton samples were obtained from two stations in Wellington Harbour with a two-foot diameter cone net. These samples were analysed in the laboratory. Unidentified larval Crustacea were reared further in the laboratory. Decapod crustacean larvae found in the plankton were in some cases identified by comparison with larvae hatched from the eggs of ovigerous females obtained from beach collections.

(5) The plankton fauna discussed in this study can be divided into two sections.

(a) *Permanent Plankton*: The species in this section are present in their adult form all the year round and do not fluctuate significantly during the year. These include Isopoda, Amphipoda, Copepoda and Chaetognatha.

(b) *Temporary Plankton*: This section includes the larger number of species. Their planktonic existence is a phase in their life history and is seasonal. Of the species in this section larval Crustacea have been made the subject of special study. Many species have been identified and their seasonal abundance discussed.

(6) The plankton calendar has been compiled from seasonal variation in the numerical occurrence of the described species in Wellington Harbour plankton samples from January 1961 to August 1963. Seasonal trends in the monthly mean volume of plankton, and the relative contributions of five major faunal elements to this volume is illustrated and correlated with the mean of the surface water temperature readings for each month. The monthly variation in the maximum number of larval decapod crustacean species is shown.

(7) Some of the species discussed were occasionally present in quite small numbers, but by virtue of their large size they were found to make an appreciable contribution to the volume of plankton. Such species were *Thalia democratica, Ihlea magalhanica, Octophialucium funerarium, Phialella quadrata,* and *Pleurobrachia pileus.* When present, these species together with the smaller but very abundant medusae of *Obelia geniculata* cause major volumetric increases.

(8) The important features of the plankton in each month are described, and these are based on the data presented in Text-figs. 7, 8 and 9. The first evidence of the spring increase in the zooplankton is in mid-July, and this continues through August to reach a maximum in September, which is sustained through to late January. There is a sharp fall-off in February, which recovers to reach a very minor autumn maximum in March and early April.

(9) The seasonal cycle shown by the majority of species is independent of the seasonal trends in the total volume of plankton. The volume of plankton is greatest in winter, and is largely dependent on the abundance of *Obelia geniculata* medusae and *Pleurobrachia pileus* which tend to have winter temperature optima. These differ from the majority of species which seem to have late spring and summer temperature optima. Few other species are recorded in winter.

(10) Surface water temperature probably influences numerically dominant species, thereby controlling many of the fluctuations in the volume of plankton. A critical temperature seems to be between 15°C. and 16°C.

(11) Although usually conforming to the described monthly pattern, the plankton is characterised by short-period fluctuations which are non-seasonal. In several cases plankton samples were neither quantitatively nor qualitatively representative of the month in which they were taken. Also, the larvae of species occurring seasonally were occasionally identified in samples taken outside the expected seasonal boundaries. During the spring and summer months monospecific swarms of crustacean larvae were produced by large numbers of adults liberating their larvae simultaneously, and the larvae were not dispersed by tidal action. Such irregular variations as these cannot be interpreted without continuous plankton recording over an uninterrupted period of time correlated with meteorological and hydrological data.

(12) Skerman (1958) considers that the short-period temperature fluctuations in the harbour environment may be outside the eurythermal capacity of the shelf forms beyond the harbour entrance—a factor which may determine the composition of the harbour population. Laboratory experiments have shown shelf forms to have a wide eurythermal capacity. A more probable limiting factor would be an insufficient period of sustained optimum temperatures to induce species to breed or to complete their larval metamorphosis. Wilson (1951) showed that the nature of the water itself and substratum specificity are important factors for the completion of larval metamorphosis and the establishment of a species in a given environment.

(13) Dakin and Colefax (1933, 1940) have outlined a calendar for the more frequently occurring organisms in the plankton of the coastal waters of New South Wales, Australia. These are the only published seasonal analyses of a Southern Hemisphere plankton community available for comparison with the zooplankton of Wellington Harbour. The Wellington Harbour zooplankton follows essentially the same seasonal pattern described for New South Wales.

ACKNOWLEDGMENTS

I am grateful to Professor L. R. Richardson for suggesting this study, for placing the Zoology Department's plankton collection at my disposal, and for his guidance throughout this work. I am indebted to the academic staff, technicians and students of the Zoology Department who assisted in collecting plankton from Wellington Harbour. I wish to thank Dr P. M. Ralph for identifying planktonic coelenterates, and Dr R. B. Pike (Marine Department) for assistance with literature on decapod larvae and for encouraging discussions and constructive criticism.

LITERATURE CITED

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, pp. 73–80, tbls. 1–5.

——— 1957. Processes of Restoration and Synchronization in Marine Ecology. The Spring Diatom Increase and the "Spawning" of the Common Barnacle, *Balanus balanoides* (L.) *Année biol.*, 33, pp. 67–85, figs. 1–5, tbls. 1–5.

BENNETT, E. W., 1964. The Marine Fauna of New Zealand: Crustacea Brachyura. *N.Z. Dep. sci. industr. Res. Bull.*, 153, pp. 1–120, 141 figs.

BRODIE, J. W., 1958. A Note on Tidal Circulation in Port Nicholson, New Zealand. *N.Z. J. Geol. Geophys.*, 1, no. 4, pp. 684–702, figs. 1–11.

BROOK, G., 1889. Notes on a *Lucifer*-like Decapod Larva from the West Coast of Scotland. *Proc. roy Soc. Edin.*, 15, pp. 420–423, figs. 1, 2.

DAHL, E., 1953. Some Aspects of the Ecology and Zonation of the Fauna on Sandy Beaches. *Oikos*, 4, no. 1, pp. 1–27, figs. 1–8.

DAKIN, W. J., AND COLEFAX, A. N., 1933. The Marine Plankton of the Coastal Waters of New South Wales. 1. *Proc. Linn. Soc. N.S.W.*, 58 (3–4), pp. 186–222, figs 1–7, tbls. 1, 2.

——— 1940. The Plankton of the Australian Coastal Waters off New South Wales. 1. *Publ. Univ. Sydney Dept. Zool.*, 1940, pp. 1–215, pls. 1–4, figs. 1–936.

FILHOL, H., 1885. Passage de Venus sur le Soleil. Mission de l'Ile Campbell. *Zoologie*. 3 (2), pp. 411–424, pls. 50, 51, 52.

GURNEY, R., 1924. *Nat. Hist. Rept. "Terra Nova" Exped.* Zoology 8, Crustacea, pp. 37–202, figs. 1–78, London, 1924.

——— 1939. Bibliography of the Larvae of Decapod Crustacea. *Ray. Soc. Publ.*, London, 1939, pp. 1–123.

——— 1942. Larvae of Decapod Crustacea. *Ray. Soc. Publ.*, London, 1942, pp. I–VII + 1–306, figs. 1–122.

GUSTAFSON, G., 1934. On the Thalassinidea of the Swedish West Coast. *Ark. Zool.*, 28a, no. 1, pp. 1–19, figs. 1–4.

HAILSTONE, T. S., AND STEPHENSON, W., 1961. The Biology of *Callianassa (Trypaea) australiensis* Dana, 1852. (Crustacea, Thalassinidea). *Univ. Queensland Dept. Zool. Publ.*, 1, no. 12, pp. 259–285, pls. 1–3, figs. 1–15, tbls. 1, 2.

HALE, H. M., 1927. The Crustaceans of South Australia (1). Government Printer, Adelaide. Australia, 1927, pp. 1–201, figs. 1–202 (pp. 113, 114, fig. 111).

HOLTHUIS, L. B., 1963. Preliminary Descriptions of some new species of Palinuridea (Crustacea, Decapoda, Macrura, Reptantia). *Koninkl. Nederl. Akadamie van Wetenschappen, Amsterdam*, ser. C, 66, no. 1, pp. 54–60.

KNOX, G. A., 1960. Littoral Ecology and Biogeography of the Southern Oceans. *Proc. roy. Soc. Lond.*, ser. B, 152, no. 949, pp. 577–624, figs. 54–73.

LEBOUR, M. V., 1928. The Larval Stages of the Plymouth Brachyura. *Proc. zool. Soc. Lond.*, 1928 (2), pp. 473–560, pls. 1–16, figs. 1–5.

——— 1930. The Larvae of the Plymouth Galatheidae 1. *Munida banffica, Galathea strigosa* and *Galathea dispersa*. *J. Mar. biol. Ass. U.K.*, 17, no. 1, pp. 175–187, pls. 1–3, 1 fig.

——— 1934. The Life History of *Dromia vulgaris*. *Proc. zool. Soc. Lond.*, 1934 (2), pp. 241–249, pls. 1–5.

MACDONALD, J. D., PIKE, R. B., AND WILLIAMSON, D. I., 1957. Larvae of the British species of *Diogenes, Pagurus, Anapagurus* and *Lithodes* (Crustacea, Decapoda). *Proc. zool. Soc. Lond.*, 128, pp. 209–257, figs. 1–11.

MAN, J. G. de, 1928. The Decapods of the "Siboga" Expedition, 7. The Thalassinidae and Callianassidae collected by the "Siboga" Expedition with some remarks on the Laomediidae. *"Siboga" Exped.*, 39a (6), pp. 1–187, pls. 1–20.

MAXWELL, B. E., 1956. Hydrobiological Observations for Wellington Harbour. *Trans. roy. Soc. N.Z.*, 83 (3), pp. 493–503, figs. 1, 2, tbls. 1–3.

PIKE, R. B., 1947. *Galathea, L.M.B.C. Mem. 34, L'pool*, 1947, pp. 1–178, pls. 1–20, figs. 1–14.

PIKE, R. B., and WILLIAMSON, D. I., 1959. Crustacea, Decapoda: Larvae. XI. Paguridea, Coenobitidea, Dromiidea, and Homolidea. *Cons. int. Explor. Mer*, Zooplankton Sheet 81, 1959, pp. 1–9, figs 1–68.

——— 1960. Larvae of Decapod Crustacea of the Families Dromiidae and Homolidae from the Bay of Naples. *Pubbl. Staz. zool. Napoli*, 31, pp. 553–563, figs. 1, 2.

PYEFINCH, K. A., 1948. Notes on the Biology of Cirripedes. *J. Mar. biol. Ass. U.K.*, 27, pp. 464–503, figs. 1–18, tbls. 1–9.

——— 1949. Short-period Fluctuations in the Numbers of Barnacle Larvae, with Notes on Comparisons between Pump and Net Plankton Hauls. *J. Mar. biol. Ass. U.K.*, 28, pp. 353–370, figs. 1–7, tbls. 1–8.

RAYNER, G. W., 1935. The Falkland Species of the Crustacean genus *Munida*. *"Discovery" Rept.*, 10, pp. 211–247.

SKERMAN, T. M., 1958. Seasonal Variations in Sea-water Surface Temperatures within New Zealand Harbours. *N.Z. J. Geol. Geophys.*, 1, no. 1, pp. 197–218, figs. 1, 2, tbls. 1–8.

WEAR, R. G., 1964a. Larvae of *Petrolisthes novaezelandiae* Filhol, 1885 (Crustacea, Decapoda, Anomura). *Trans. roy. Soc. N.Z.*, 4, no. 18, pp. 229–244, 5 figs.

——— 1964b. Larvae of *Petrolisthes elongatus* (Milne Edwards, 1837). (Crustacea, Decapoda, Anomura). *Trans. roy. Soc. N.Z.*, 5, no. 2, pp. 39–53, 6 figs.

——— 1965. Larvae of *Petrocheles spinosus* Miers, 1876 (Crustacea, Decapoda, Anomura) with Keys to New Zealand Porcellanid Larvae. *Trans. roy. Soc. N.Z.* 5, no. 12, pp. 147–168, 7 figs.

WILLIAMSON, D. I., 1957. Crustacea, Decapoda, Larvae. 1, General. *Fich. Ident. Zoopl.*, no. 67, 1957, pp. 1–7, figs. 1–32.

WILSON, D. P., 1951. Larval Metamorphosis and the Substratum. *Ann. Biol., Paris*, 27, pp. 259–269, figs. 1–3.

ROBERT G. WEAR, M.Sc.,
Zoology Department,
Victoria University,
P.O. Box 196, Wellington,
New Zealand.