# SOME FACTORS INFLUENCING THE DISTRIBUTION OF PELAGIC COPEPODS IN THE QUEEN CHARLOTTE ISLANDS AREA

by

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## Abstract

The distribution of certain copepod species of the north coast of British Columbia suggests that breeding is restricted to limited regions of well-defined temperature and salinity characteristics. Currents are responsible for the spread of juveniles and adults from these areas. A description of the probable circulation pattern in the vicinity of the Queen Charlotte Islands as inferred from plankton collections is submitted.

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## INTRODUCTION

During the summer of 1953, the waters adjacent to the Queen Charlotte Islands were surveyed in the C.G.M.V. Cancolim II under the sponsorship of the Defence Research Board and the scientific direction of Dr. R.F. Scagel and Mr. F.G. Barber. Plankton samples were taken at each station (Fig. 1) with physical data, in order to permit a study of the relationship of plankton to oceanographic conditions in the area.

One of the most striking factors became evident, when the deeper hauls were seen to contain different copepod species than were caught in hauls from shallow water. This situation suggested that the species had certain vertical ranges some of which were in deeper water. Further study determined the vertical distributions of many copepod species. With this information, it was possible to study the factors effecting horizontal distribution.

The occurrence as well as the abundance of various species appeared to be associated with great differences in salinity and temperature. The regions where species were abundant and present in all stages were assumed to be breeding areas. Where the copepods were rare and represented by a few stages only, they were considered in many cases to be individuals scattered from an adjacent breeding population.

This scattering in turn was the result of another physical factor. The currents although not known at the time of study were suggested as responsible for the dispersal of individuals from breeding areas. As scattering seemed to be prevalent in several localities, it became possible to suggest the currents in these areas.

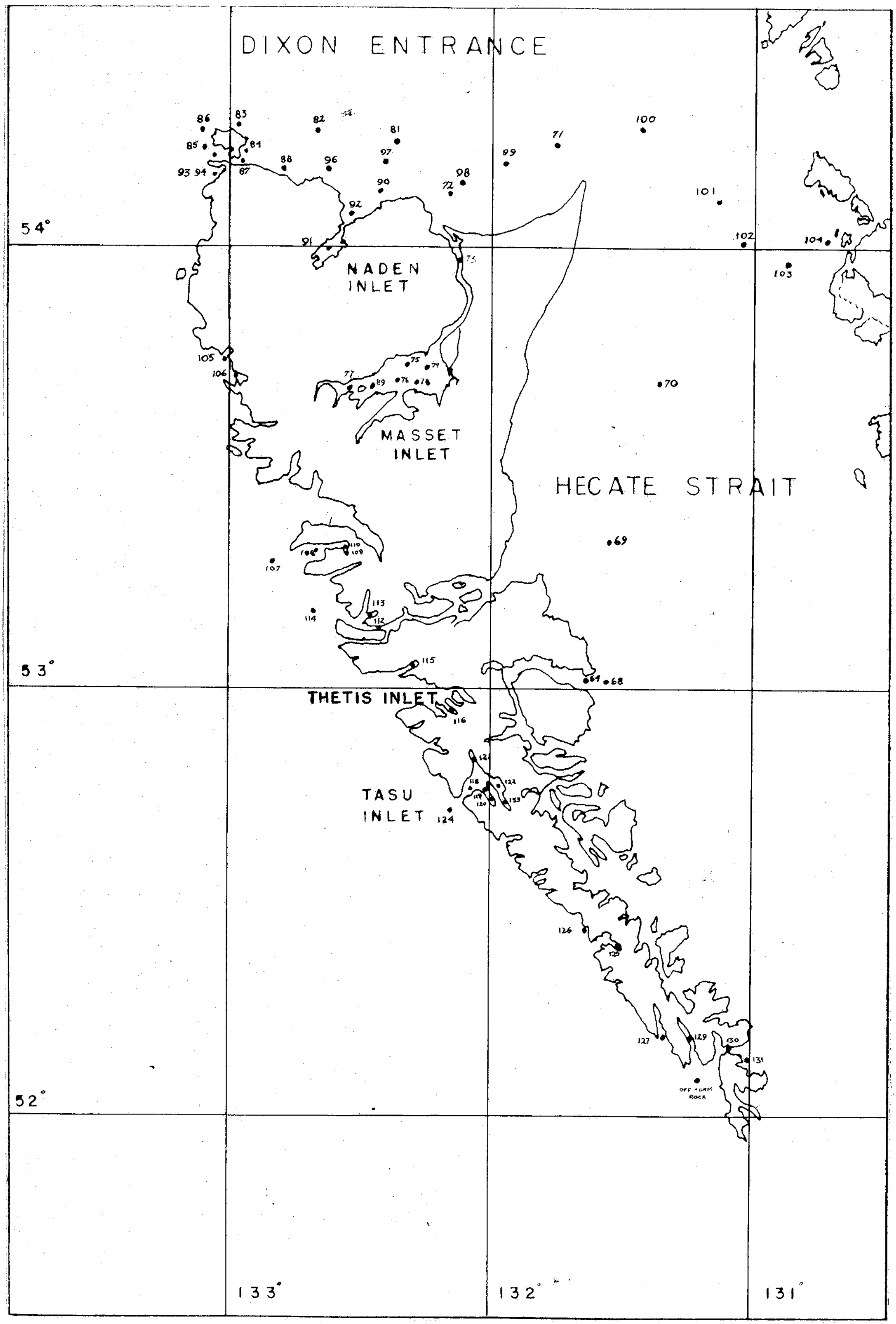


Figure 1. Plankton stations taken adjacent to the Queen Charlotte Islands by the Cancolim II during the summer of 1953.

# METHODS AND MATERIALS

Plankton samples were taken between July 18th and August 8th in 1953, in the Queen Charlotte Islands area including Dixon Entrance and Hecate Strait. The station positions are shown in Figure 1. At all stations indicated, vertical hauls were taken from near the bottom to the surface with a thirty inch diameter net having a number ten mesh. At about one half of the stations, additional hauls were made from one, three or fourteen meters to the surface. A ten inch diameter net was used for these hauls. At station 89 in Masset Inlet, samples were obtained from water pumped through a hose from a discrete depth. The samples were preserved in formalin.

The samples were considered only qualitatively as no direct accurate measurements were made of the volumes of water filtered. An indication of faulty filtration was noted at some stations (69, 72, 73, 86, 87, 112, 114, 115, 116, 128) where Microstella norvegica and Acartia clausi were captured in the supplementary haul but not in the deep haul. This suggests that the large net used for the deep haul was clogged by the time it reached the surface and failed to capture species living near the surface.

Also, no attempt was made to take duplicate samples. Many workers (Barnes and Marshall, 1951, and Hardy and Gunther, 1935) have found that variability between duplicate plankton hauls can be large, due to the patchy distribution of the plankton. Hence, in considering numbers of plankton animals in the samples studied, only gross differences are considered significant.

The copepods were determined to species except for a few genera found in the deep water. Most were identified by referring to Davis (1949) although Giesbrecht (1892), Sars (1903) and Esterly (1905, 1911, 1924) were also consulted. Difficulties arose in the determination of a few species which were neither common or widespread. In a few cases, it seemed evident that further systematic work is necessary in this region. For example, a species of Gaetanus was found. According to Jesperson and Russel *(1952) very few males of this genus have been described. Therefore, these specimens are in need of investigation.

As the method of sampling did not justify exact quantitative calculations only approximate numbers of each species were determined. The numbers at each station were denoted by four terms. "Rare" refers to approximately one animal in a thousand cubic centimeters, "few" to ten, "common" to twenty-five and "abundant" to fifty. As no definite numbers divided one category from another, it was difficult in some cases to decide which term to use, but wherever the results were crucial the samples were rechecked.

Vertical Distribution:

It was immediately apparent that the deep hauls contained more species. This strongly suggested that different species were living at different depths. Evidence indicating that species occur within certain vertical ranges can be seen in

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* Directors of Publication. Section referred to is written by W. Verwoort.

many systematic and ecological publications on the copepods. Depth distributions are given in general, by Davis (1949), Giesbrecht (1892) and Wilson (1950), while Furuhasi (1953) has studied in considerable detail the vertical distributions of copepods in Japanese waters. In an attempt to deduce this distribution from the occurrence of species in the hauls, the samples were arranged in order of increasing depth. The appearance of species in the deeper samples gave an indication of the approximate depth at which they occurred. In order to present this data graphically the samples were considered in groups of twenty-five. For example the first group included samples taken from the surface to a depth of 10 meters while the second group included samples taken from slightly greater depths to the surface. For each species the percentage of samples in which it occurred in each group was considered. In Figure 2. where a species occurred in a group, in more than fifty percent of the samples it was represented by a heavy line, if less by a fine line. It can be seen in Figure 2 that Clausocalanus acuicornis occurred in only the deepest group of samples and in less than fifty percent of them. It is then represented by a thin line in the last group. Psuedocalanus minutus, on the other hand, occurred in more than fifty percent of the samples in all groups. Hence, it is represented by a heavy line through all groups.

The upper limits to the vertical distributions of the species living near the surface could be fairly well determined by comparing the results of the supplementary haul with those of the deep haul. The analyses of the species and their approximate numbers in the two hauls yielded important information as to how restricted a species was to the upper layer, if and when it moved down and how the age groups were arranged vertically. If a species were common in the surface haul and in the deeper haul, it was assumed to be living almost entirely at the surface, while a species absent from the surface haul but present in the deep haul presumably occurred somewhere below the depth of the surface haul.

Some species, however, lived well below the depths of the supplementary hauls. In some localities where deeper stations were close together, it was possible to estimate the approximate depth where the uppermost individuals occurred by comparing adjacent stations, one with and one without the species. The depth of the station where the species was not found was less than that of an adjacent station where it occurred, and this depth was taken as the uppermost limit to the vertical distribution of the species at the second station. For example, if Metridia lucens was common at station "a," with a depth of 100 meters and absent at an adjacent station "b" at 50 meters, then it was assumed to be living at station "a" below 50 meters. Although the results appear adequate, it is realized that error may be present because of the dependency of a particular upper limit on the depth of the adjacent haul. However, they seem workable and have yielded some valuable information.

Horizontal Distribution:

In the discussion, horizontal distributions have been depicted on small maps on which the occurrence of the species and its relative abundance are indicated by circles. The distributions are considered in the light of temperature and salinity data as well as geographical location and in a few cases, bottom topography. The occurrence of a species at a particular point was taken to mean one of several things: if the individuals were abundant, present in all stages and producing eggs, the conditions in this locality have been in the recent past and are favourable for the reproduction of that species, if the individuals were rare and represented by only a few stages then they were considered in some instances to be scattered from a larger population. In the latter case it is difficult to distinguish between a population which is increasing and a group of individuals merely surviving. However, each case is considered separately and no overall interpretation is used.

With a clearer idea of conditions which are optimum and suboptimum for each species, it becomes possible to visualize centers of reproduction and the movements of individuals away from these localities, by the currents prevalent in the area.

Dispersal was best studied in species which were neither widespread nor rare. *Pseudocalanus minutus* and *Oithona helgolandica* were too common everywhere. The limits for survival of these two are probably well outside the conditions in this area. *Epilabidocera amphitrites* and *Aetideus armatus* on the other hand were so few and scattered as to be almost useless for a study of dispersal.

Variation in the size of copepods became a very useful criterion for distinguishing populations. The absolute size of adult copepods have been found to vary with locality (Ussing 1938) and season (Digby 1950). In the literature there is no indication that the size of the adult depends on the length of time it has been an adult. Considering the sizes of the different developmental stages of several copepods (Johnson 1934 a b and Lebour 1916) it is evident that size increases occur during the moult between stages.

In an attempt to explain the variation of the sizes of adults, Ussing considers Krogh's observation that an increase in temperature will produce an increase in the rate of development. He remarks that if a copepod developed in cold water, it would eat more than a copepod developing in warm water under the same food conditions. As the size of any one stage depends on the size of the previous stage as well as on food conditions in the recent past, Ussing suggests that temperature, influencing the length of feeding time, and food concentration, affecting the amount consumed could cause the size variations that he observed near Greenland.

In one area at one time, these factors would affect the growth of all copepods the same. Whether or not this effect varied, the net result would be apparent in the size variation of the adults of that area. Hence a very narrow size range would be expected. This was found to be the case, first in Metridia lucens. Even if neither the past conditions are known nor their exact effect on the size of the copepod, the narrow size range in one locality is in itself useful, as copepods dispersed from one area may be recognized by their size.

In Dixon Entrance the size ranges of several species were determined in order to find the extent and direction of dispersal. These species were measured from the tip of the head to the end of the caudal furcae, using an ocular micrometer marked off in .05 mm. intervals. Significant differences in the size ranges were apparent. These could be used to detect direction of scattering.

Marked differences in the proportions of the age classes of a few species was considered in one or two cases to indicate population distinctiveness, but only when the water mass in that locality was shown to be distinct by size differences in other species or the presence of different species. This method was more effective in considering the dispersal of the sub-surface species in which the age groups have a definite vertical distribution, the young being nearer the surface. The presence of young only, at a station indicated that they had drifted away from above the adults which lived in deeper water. As this technique was quantitative only in Masset Inlet and was not used throughout the study the results are presented in the discussion.

The term population refers in this study to a group of animals of one species which has developed in one area at one time. It is also used in this sense by Barnes and Marshall (1951).

## RESULTS

The water flowing past the Queen Charlotte Islands comes from the northern portion of the North Pacific Drift (Sverdrup et al 1952). This broad diffuse current divides just south of the island. The northern arm moving up the coast has a fairly uniform temperature which fluctuates seasonally to about 200 meters but rarely warms to above 15 degrees centigrade. With these temperature characteristics this area can be considered in one of Giesbrecht's faunistic zones (Giesbrecht 1892). He has divided the plankton fauna into three geographical zones: the southern cold water, the central warm water and the northern cold water. The last is limited to the south by the 15 degree centigrade isotherm. Hence, the waters being studied belong in this zone. Consequently, the copepods are mostly northern cold water species. The almost complete absence of warm water species eases the classification difficulties considerably. Thirty-two species of copepods were determined. These are listed below.

<u>SUB-ORDER CALANOIDEA</u>:

Acartia clausi Giesbrecht
A. longiremis (Lilljeborg)
Aetideus armatus (Boeck)
Bradyidius similis ° (Sars)
Calanus cristatus Krøyer
C. finmarchicus (Gunnerus)
C. tonsus Brady

*Candacia columbiae Campbell

Centropages mcmurrichi Willey

Chiridius gracilis° Farran

Clausocalanus acuicornis (Dana)

*Epilabidocera amphitrites (Mcmurrich)

Eucalanus bungii Giesbrecht

Euchaeta japonica Marukawa

Eurytemora hirundoides (Nordqvist)

Gaetanus sp.

Heterorhabdus proximus° Davis

Metridia longa (Lubbock)

M. lucens Boeck

Paracalanus parvus (Claus)

Pleuromamma sp.

Pseudocalanus minutus (Krøyer)

Rhincalanus nasutus° Giesbrecht - one specimen seen

Scolecithricella minor (Brady)

S. subdentata (Esterly)

Tortanus discaudatus (Thompson and Scott)

SUB-ORDER CYCLOPOIDEA

*Corycaeus affinis McMurrich

Oithona helgolandica Claus

O. plumifera Baird

Oncaea conifera Giesbrecht

SUB-ORDER HARPACTICOIDEA

Microstella norvegica (Boeck)

M. rosea Dana

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A few other harpactacoids were present in the samples but as these were not common or widespread, they were not determined. As mentioned before all these species are northern cold water forms, although a few are also found in warm water. Several are peculiar to the North Pacific. These are marked with an asterisk. The distribution of all the species at the stations can be seen in Table I (Appendix).

The vertical distribution of these species is shown in Figure 2. A line in the figure indicates the occurrence of a species at the stations having depths as indicated. As was mentioned before the stations were grouped according to depth. The dark line indicates that a species was found in more than fifty percent of the stations of the group indicated. Although Calanus finmarchicus was caught in a few cases near the surface, because it was more common in deeper water it was considered as a subsurface form. Of the species which were caught in hauls of 22 meters or more, one, Bradyidius similis, is benthic and will not be considered as part of the plankton. Aetidius armatus and Epilabidocera amphitrites are too sparce for further consideration.

The upper limits to the vertical distributions of the subsurface species could be roughly determined by comparisons of adjacent stations, in one of which the species is either absent or rare. The compared stations are shown in Table II. The depth of the shallow stations are the depths of the upper limits to the species' distribution. These are seen to be quite variable. This variability prevents the detailed use of

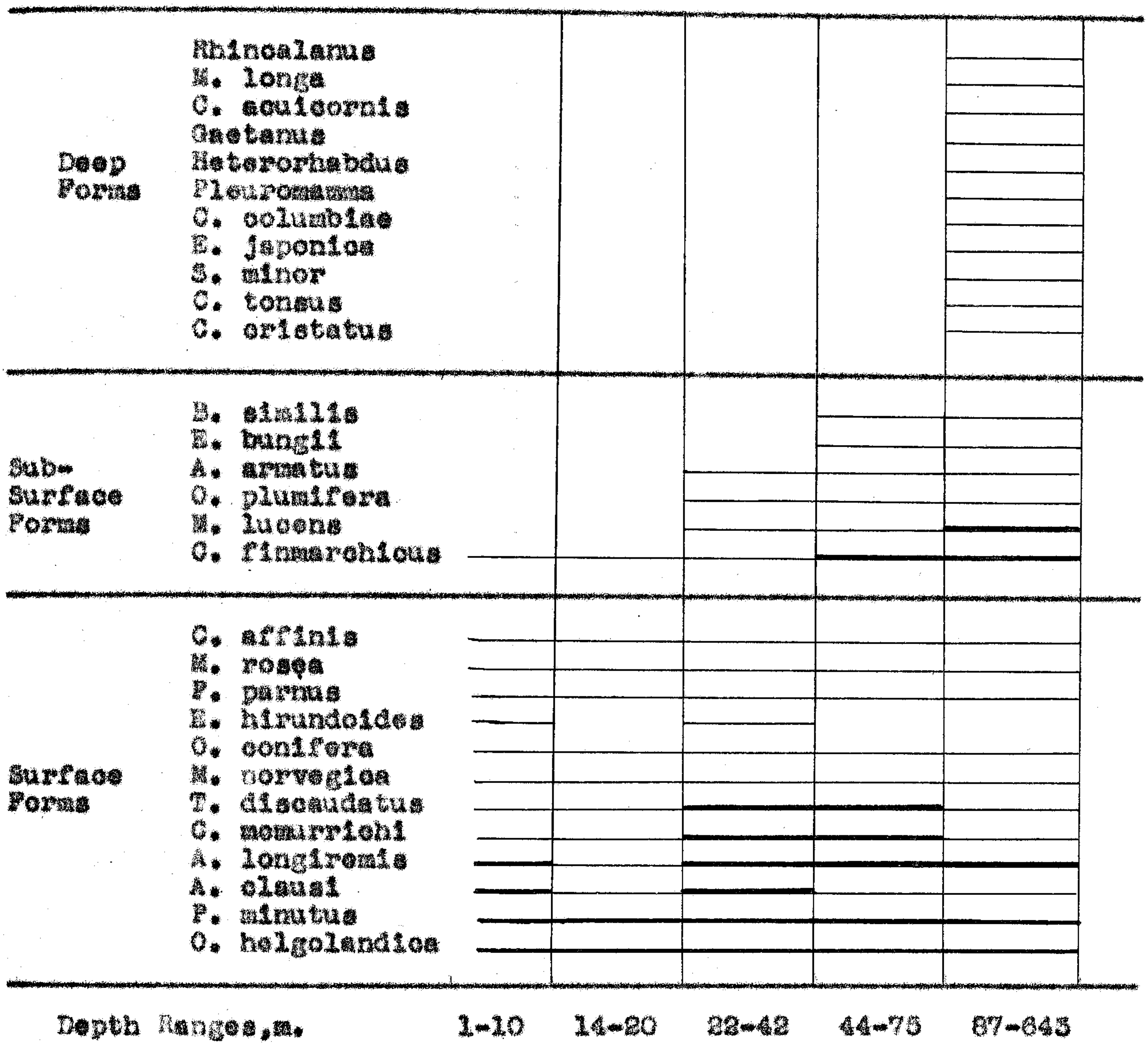



Figure 2. The occurrence of copepod species in samples taken from different depths to the surface.

TABLE II

STATIONS COMPARED IN DETERMINING THE UPPER VERTICAL LIMITS OF THREE SPECIES

| Calanus finmarchicus | | | | Metridia lucens | | | | Eucalanus bungii | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Present | | Absent | | Present | | Absent | | Present | | Absent | |
| Sta. | Dep. M | Sta. | Dep. M | Sta. | Dep. M | Sta. | Dep. M | Sta. | Dep. M | Sta. | Dep. M |
| 64 | 44 | 68 | 23 | 97 | 65 | 90 | 36 | 81 | 135 | 90 | 36 |
| 104 | 75 | 103 | 36 | 83 | 366 | 86 | 91 | 83 | 366 | 86 | 91 |
| 99 | 91 | 72 | 53 | | | | | 114 | 164 | 108 | 100 |
| 97 | 65 | 90 | 36 | 119 | 175 | 122 | 104 | 82 | 206 | 96 | 46 |
| 86 | 91 | 85 | 55 | 110 | 33 | 109 | 24 | | | | |
| 111 | 119 | 108 | 100 | | | | | | | | |
| 112 | 91 | 113 | 45 | | | | | | | | |

average depth distributions for any one area. Instead local upper limits have been used, except for one case (page 47) for particular areas.

Finally, eleven species were caught only in the very deep water, 87 meters or more. These stations are mostly off the shelf on the west coast and in the deeper regions of Dixon Entrance. The species found were not represented by great numbers and were not widespread, half of them were caught only in two or three of the very deep hauls. These species are presumably characteristic of the deep oceanic water which occurs close to the west coast and in Dixon Entrance. In the literature (Jespersen and Russel 1952) these species are termed oceanic, while the others mentioned above are mostly neritic.

The results of measurements of several species in Dixon Entrance are recorded in the following Table III.

TABLE III

SIZE RANGES IN MILLIMETERS OF SEVERAL SPECIES OF COPEPODS FOUND IN DIXON ENTRANCE

Adult Males

| Sta. | A. clausi | A. longiremis | T. discaudatus | C. mcmurrichi |
|---|---|---|---|---|
| 99 | | 0.95-1.01 | 1.53-1.80 | 1.43[2] |
| 98 | 0.70-1.00 | | | |
| 97 | | | 1.73* | 1.41* |
| 71 | | 1.00-1.06 | | |
| 73 | | | 1.86-2.10[2] | 1.27-1.60 |
| 75 | | | | 1.30-1.44 |
| 96 | 0.72-0.75 | 0.96-1.01 | 1.52-1.77 | 1.44-1.78 |
| 88 | | 0.90* | | |
| 90 | 0.72-0.78 | 0.90* | | 1.25-1.33 |
| 91 | 0.91-1.00 | 0.92-1.00 | 1.36-1.50 | 1.24-1.55 |

Adult Females

| Sta. | A. clausi | A. longiremis | T. discaudatus | C. mcmurrichi |
|---|---|---|---|---|
| 99 | | 1.17-1.31 | 1.87-1.94[2] | |
| 98 | 0.85-1.04 | | 1.62* | |
| 97 | | | | |
| 71 | | 1.20-1.40 | | |
| 73 | 0.92-0.97 | | | 1.48-1.52 |
| 75 | | | 1.70* | |
| 96 | 0.90-0.93 | 1.14-1.35 | 1.63-2.40 | 1.52-1.83 |
| 88 | | 1.20-1.25 | | |
| 90 | 0.88-1.00 | 1.15-1.25 | | 1.45-1.69[2] |
| 91 | 0.95-1.12 | 1.09-1.27 | 1.35-1.57 | 1.40-1.72 |

*-1 specimen measured

2-2 specimens measured

## DISCUSSION

The horizontal distributions of the more common species can be considered in detail. Each is considered separately, because as a species, each has its own physiological limits, seasonal fluctuation and vertical distribution.

### Species living near the surface:

#### Paracalanus parvus:

P. parvus was found in the upper 14 meters of water in seven out of nine stations where supplementary hauls were taken (Table I Appendix). At five of these stations the numbers caught in the deep haul approximated those in the shallow haul, so it was assumed that here P. parvus was living almost entirely at the surface. At two stations it occurred slightly below 14 meters as well as at the surface, while at the remaining two stations it was rare and was caught entirely below the surface layer. This species therefore can be considered as a surface form rarely occurring below 14 meters.

P. parvus was found in large numbers at only three localities (Figure 3.). In Thetis and Tasu Inlets it seems likely that P. parvus has increased locally as these are isolated populations, the absence of this species at the stations being indicated by the arrows.

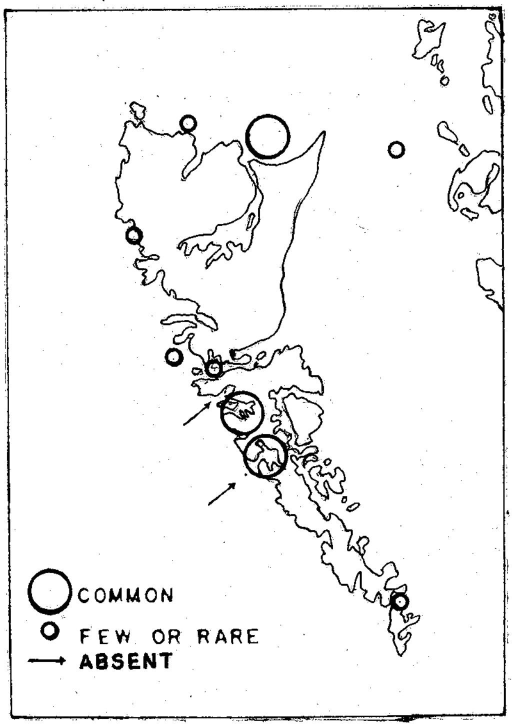



Fig. 3. The distribution of Paracalanus parvus

In Dixon Entrance, however, the population may have come from elsewhere. As there were no P. parvus in Naden or Masset Inlets, it is possible that it could have drifted into Dixon Entrance from the north or the east.

Thetis and Tasu Inlets have the highest surface temperatures of the area sampled (Table I). As P. parvus is living mostly at the surface here, these temperatures may be correlated with its abundance.

Giesbrecht (1892) classes this species as characteristic of all three faunistic zones. However, he has stated that its northern limit is at the 10°C. isotherm. Although this limitation is an approximation, with a consideration of winter temperatures, stated by Barber and Tabata (1954) to be about 7.7°C. in Dixon Entrance, it is realized that the water temperatures in this area indicate that P. parvus is living here close to its northern limit. If this is the case, then temperature as a limiting factor would be expected to influence the abundance of P. parvus.

It is not suggested that P. parvus cannot survive during the winter but it probably does not breed then, as the temperatures are below Giesbrecht's limit. However, in the spring as the water warms, breeding could commence. If waters in different localities warm sooner than in others, then these will after a time be populated with more P. parvus.

Acartia clausi:

A. clausi lives immediately below the surface in most areas and does not appear to extend much deeper than about 15 or 20 meters. Only at two stations was it found completely below 14 meters.

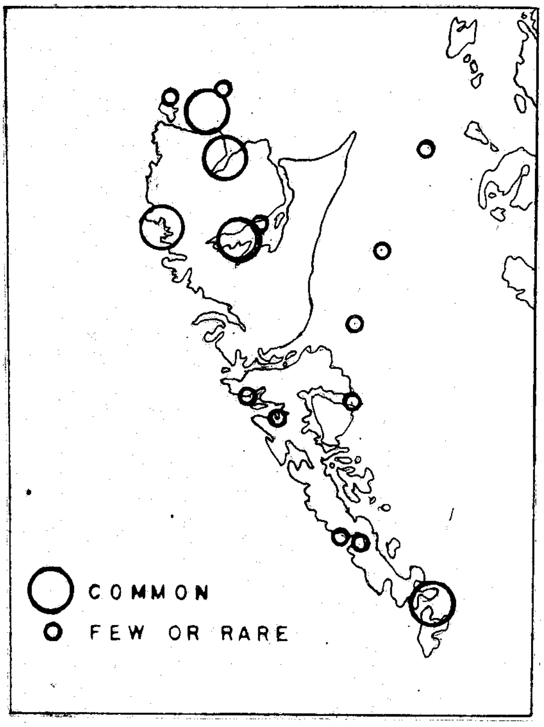


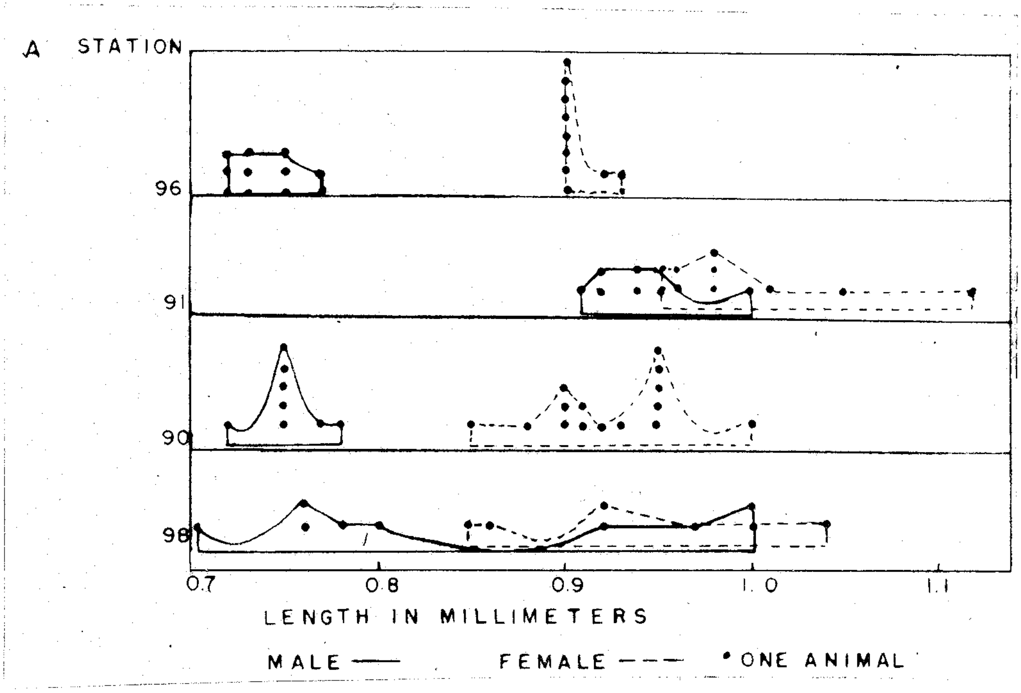

Figure 4. The distribution of *Acartia clausi*

The species is most common in three localities (Fig. 4.). The greatest numbers were found in Dixon Entrance and Naden Inlet. For some unknown reason it is absent or rare from the surface waters of deep stations. As this species is euryhaline, it may prefer low salinity water found at the surface near land where runoff supplies fresh water.

Temperature, however, may also have an important influence on the seasonal fluctuations of this copepod, similar to *P. parvus*. Giesbrecht (1892) has noted that *A. clausi* is characteristic of warm and northern cold water but is limited to the north by the 11°C. isotherm. Its profusion, then, may be due at the time of sampling to the previous as well as present existence of low salinity warm (11°C.) water.

In addition to the above factors, the effect of a scattering from population centers is evident in Dixon Entrance. *A. clausi* was studied here in more detail. By determining the size ranges of the animals at different stations it was possible to distinguish two separate populations and their distributions. The results may be seen in the following illustration (Figure 5).

The distinct separation between the size ranges of the



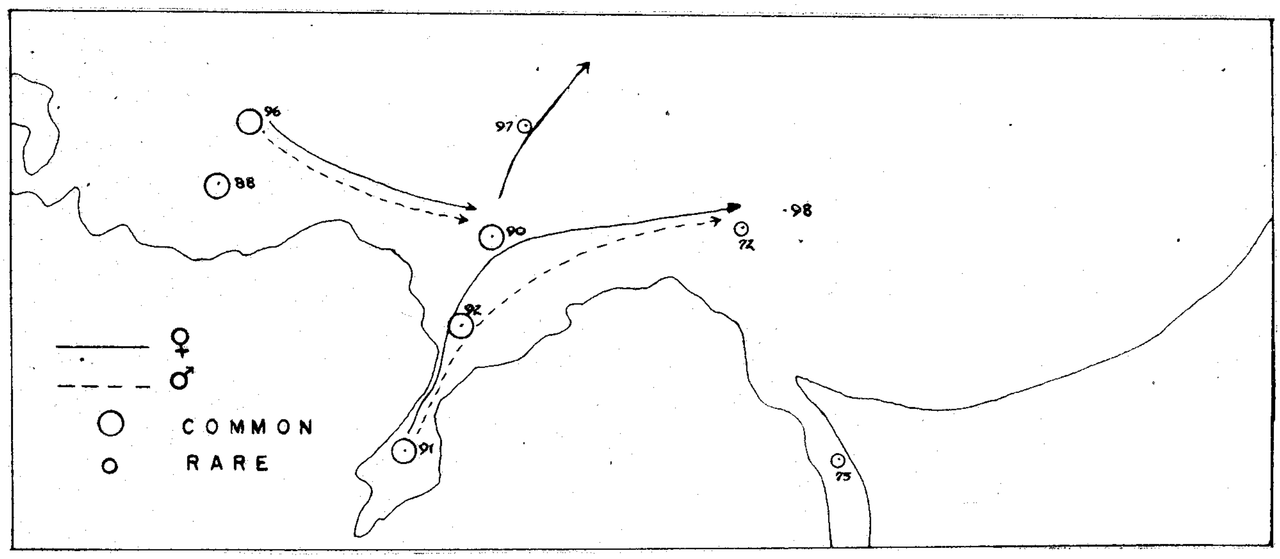




Figure 5. a. Size Variation of Acartia clausi in Dixon Entrance
b. Currents suggested by this variation

copepods at stations 96 and 91 is striking. This is taken to mean that A. clausi at both these stations have grown up in different environments probably in slightly different food and temperature conditions (see page 9 ) and thus are considered as separate populations. At station 90, the males belong with the population at station 96 while the females are a mixture of copepods from stations 96 and 91. Station 98 contains a mixture of animals of both sexes from stations 96 and 91. The mixing and spreading of these populations suggests the currents (Fig. 5) which may be responsible. These will be discussed later in the account of Dixon Entrance as a whole.

Centropages mcmurrichi:

C. mcmurrichi was found at 26 stations mostly in Dixon Entrance and Hecate Strait. (Figure 6). Twenty of these have supplementary hauls, the results of which give a fairly good indication of its vertical distribution. The following chart (Table IV) summarizes the results.

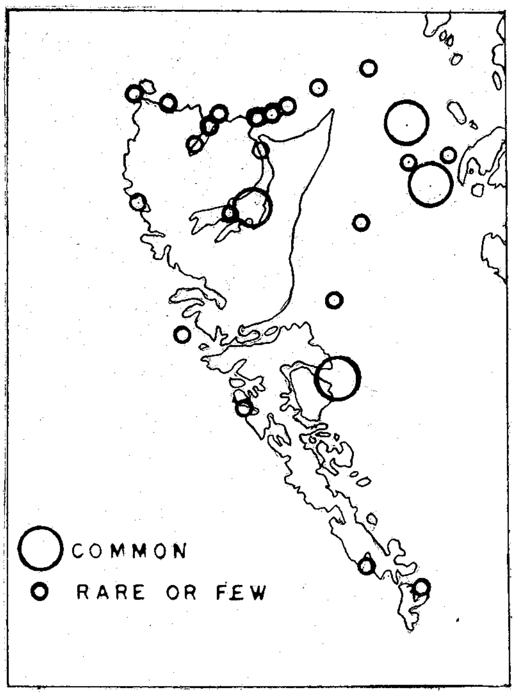



Figure 6. The distribution of Centropages mcmurrichi

Although there are too few stations at night, at these, C. mcmurrichi especially the young stages is found up to the surface. During the day, there

## TABLE IV

THE VERTICAL DISTRIBUTION OF CENTROPAGES MCMURRICHI AS INDICATED BY ITS OCCURRENCE IN SUPPLEMENTARY AND DEEP HAULS

| | Above | | | Below | | | |
|---|---|---|---|---|---|---|---|
| Station | Depth Meters | Nos. | immature only | Depth Meters | Nos. | immature only | Time |
| 131 | 14 | r | ✓ | | | | 1930 |
| 68 | 1 | r | | | c | | 2015 |
| 70 | 1 | r | ✓ | | | | 0145 |
| 72 | | | | 3 | r | | 0642 |
| 73 | 3 | r | | | c | | 0800 |
| 126 | | | | 14 | r | | 0800 |
| 64 | 1 | r | ✓ | | c | | 0810 |
| 71 | | | | 1 | f | | 0900 |
| 39 | 1 | r | | | | | 1055 |
| 127 | | | | 14 | r | | 1130 |
| 85 | | | | 3 | r | | 1315 |
| 119 | | | | 14 | r | | 1330 |
| 86 | | | | 3 | r | | 1350 |
| 114 | | | | 14 | r | | 1400 |
| 128 | 16 | f | ✓ | | | | 1415 |
| 87 | | | | 3 | r | | 1500 |
| 121 | | | | 16 | f | ✓ | 1630 |
| Off Adam Rk. | | | | 16 | f | | 1630 |
| 88 | 3 | r | | | | | 1715 |
| 130 | | | | 16 | r | | 1730 |

c - Common
f - Few
r - Rare

is some tendency for it to remain below. At this time, when it is at the surface, it is represented by the whole of a small population or by the upward extension of a large population. It would seem, then, that C. mcmurrichi lives just below the surface with the younger stages uppermost. Although at times it occurs above 14 meters, it shows a tendency to move down during the daytime. Most of the population, however, lives slightly below 14 meters.

C. mcmurrichi is most common in Hecate Strait. In Dixon Entrance it is common only at one station while on the west coast it is rare and scattered, represented by only a few immature specimens. This situation suggests that seasonal fluctuations are responsible for the difference in numbers. The small separate populations on the west coast and in Naden Inlet would appear to be populations increasing under present conditions, which may have been present in Hecatė Strait previously. However, the data does not indicate anything definite.

Scattering by currents does seem responsible for some of the rare occurrences in Dixon Entrance. Copepods from several stations were measured. The results can be seen in the following diagram (Figure 7).

It has been suggested that C. mcmurrichi is living slightly below the surface, extending into deeper water than does A. clausi, thus being subject to different water movements.

In the western part of Dixon Entrance, relatively large specimens of C. mcmurrichi are common. These, however do not move past station 90, as the copepods at this locality are well below the size range of those at station 96. Although it was very sparse at station 97 the one specimen was closer in size to those farther west. The few copepods at station 90 have likely come out of Naden Inlet. These are small and can be traced westward into Masset Sound (station 73).

The eastern part of Dixon Entrance contained very few C. mcmurrichi, too few for measurements. Because of the predominance of young stages here, it does not seem likely that they have come from the west.

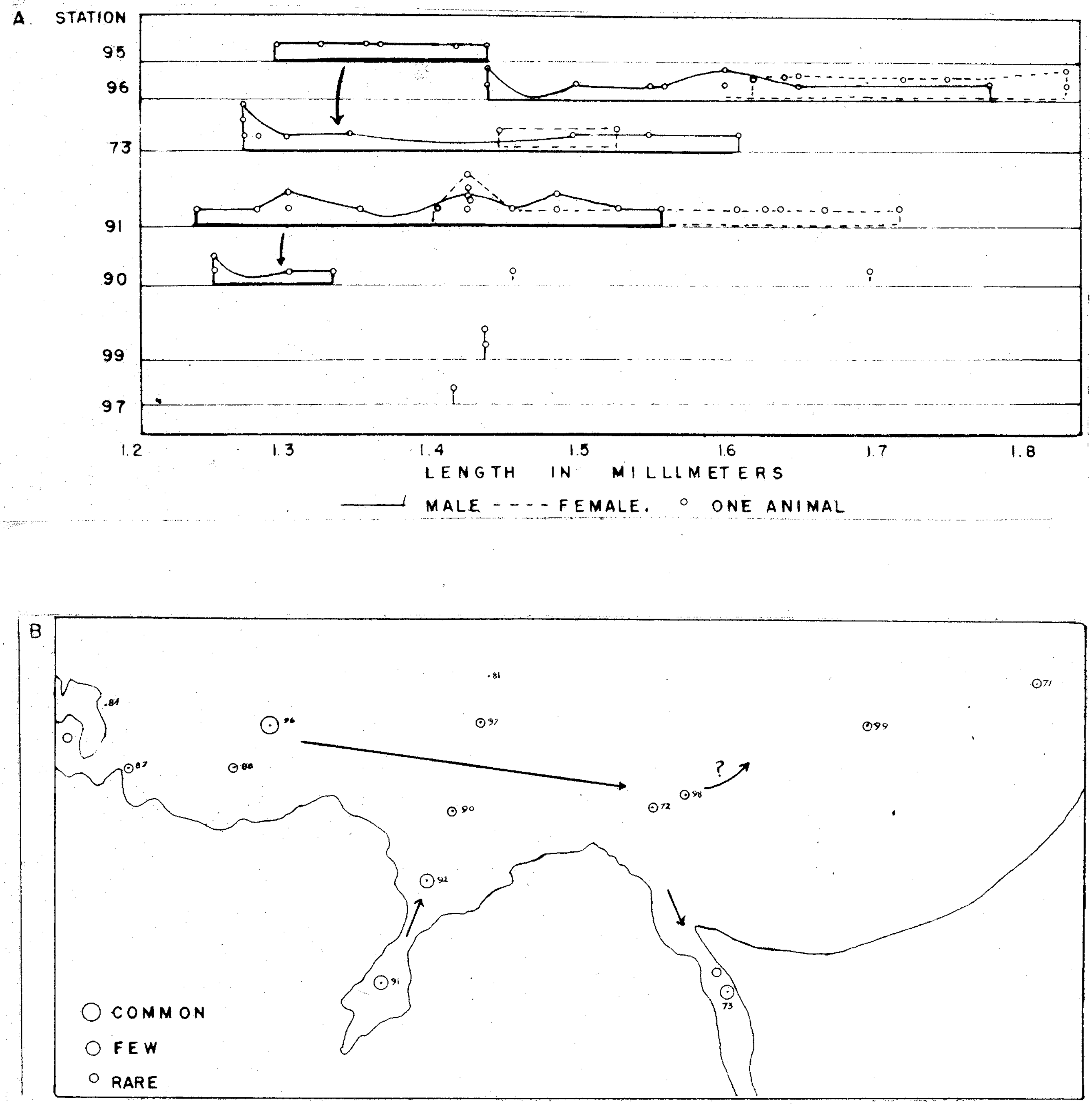



Figure 7. a) The size variation of <u>Centropages</u> <u>mcmurrichi</u> in Dixon Entrance
b) Currents suggested by this variation

The size range of the males in Masset Sound is fairly wide including sizes comparable to those in Masset and Naden Inlets and at station 96. It is evident that the small copepods at station 73 could have come from station 90, directly west, while the medium sized individuals may have come from inside Masset Inlet. The larger copepods here are only comparable in size to those at station 96. Because this species is so common at station 73, it is not conceivable that it has spread from station 96, through regions where it is scarce, unless perhaps, the intervening area has in the recent past contained more _C. mcmurrichi_.

Although the problem of seasonal fluctuations is present also in this species, some indication of scattering by water movements is suggested by the size range variation and population structures of this species in Dixon Entrance. The currents illustrated will be discussed in relation to others in the account of Dixon Entrance.

_Tortanus discaudatus:_

The vertical distribution of this species can be reasonably well deduced from the twenty-five stations which have supplementary hauls. In Table V on page 27 the stations are arranged in a time sequence. The depth of the supplementary haul is given with the approximate numbers of copepods. Below the depth of the shallow haul, the numbers are based on the results of the deep hauls.

The species tends to remain below 14 meters although it can survive in the surface water. The eggs are laid both

TABLE V

THE VERTICAL DISTRIBUTION OF <u>TORTANUS DISCAUDATUS</u> AS INDICATED BY ITS OCCURRENCE IN SUPPLEMENTARY AND DEEP HAULS

| Station | Time | Above Depth | Above Nos. | Below Depth | Below Nos. |
|---|---|---|---|---|---|
| 72 | 0642 | 3 | e | 3 | r + e |
| 126 | 0800 | | | 14 | r |
| 73 | 0800 | | | 3 | r |
| 64 | 0810 | | | 1 | r |
| 94 | 0845 | | | 14 | f |
| 71 | 0900 | | | 1 | e |
| 69 | 1055 | 1 | r (imm) | 1 | c |
| 127 | 1130 | | | 14 | c all stages |
| 101 | 1215 | | | 14 | f |
| 85 | 1315 | | | 3 | f |
| 114 | 1400 | | | 14 | r |
| 128 | 1415 | 14 | f | 14 | f |
| 87 | 1500 | | | 3 | r |
| 129 | 1515 | 14 | c | 14 | A |
| Off Adam Rk. | 1630 | | | 14 | f |
| 121 | 1630 | | | 14 | r |
| 82 | 1645 | | | 10 | f + e |
| 115 | 1710 | | | 14 | r, imm. |
| 88 | 1715 | | | 3 | r + e |
| 130 | 1730 | | | 14 | f |
| 111 | 1800 | | | 14 | r |
| 83 | 1900 | | | 10 | e |
| 131 | 1930 | 14 | r, imm. | 14 | r, imm. |
| 116 | 1945 | 14 | imm. | 14 | f |
| 68 | 2015 | | | 1 | c |
| 70 | 0145 | | | 1 | c |
| 110 | 0225 | | | 14 | r |

e - eggs  c - common  f - few  r - rare

above and below 14 meters but the young seem to occur just above the adults.

Johnson (1934a) has indicated that this species is very widespread although rarely becoming abundant. Its profusion in the area.sampled could not be related to the physical characteristics of water at twenty meters. As this species is a primary carnivore, the presence of suitable animal food may be responsible for its abundance, especially when the survival of the very young nauplii depends on the presence of small protozoans in the surrounding water. As the food conditions could not be estimated, the reason for its abundance in certain areas is still questionable.

The species, however, is very widespread (Figure 8), a result perhaps of its vertical distribution. Occurrence mostly below 14 meters enables the adults to remain inside inlets with shallow sills for example, Naden Inlet as well as in the slower moving subsurface waters outside the inlets. On the other hand its occasional presence in the surface layer brings it under the influence of faster currents. The water below 14 meters however, must be responsible for most of the dispersal of this species.

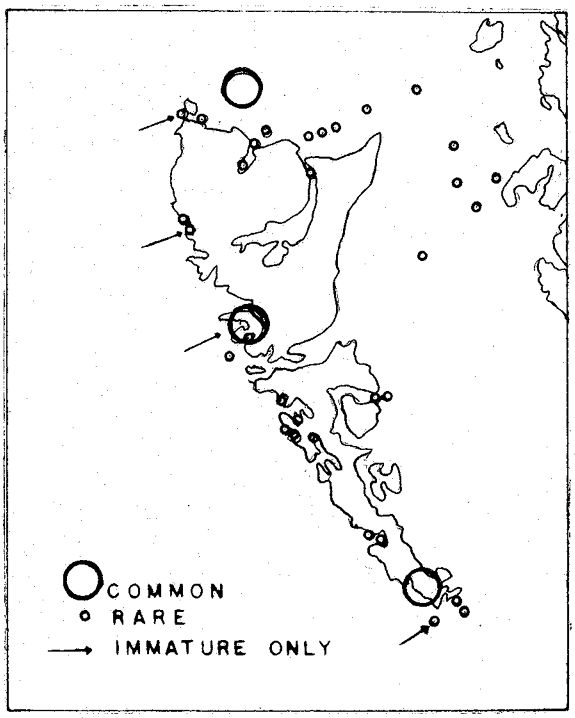



Figure 8. The distribution of Tortanus discaudatus

This dispersal was evident in Dixon Entrance where T. discaudatus was measured. The results of this are seen in Figure 9 a. Although scarce in Dixon Entrance it is distinctly larger here than in Naden Inlet. Because of their similar size ranges, the copepods in Dixon Entrance are considered to be one

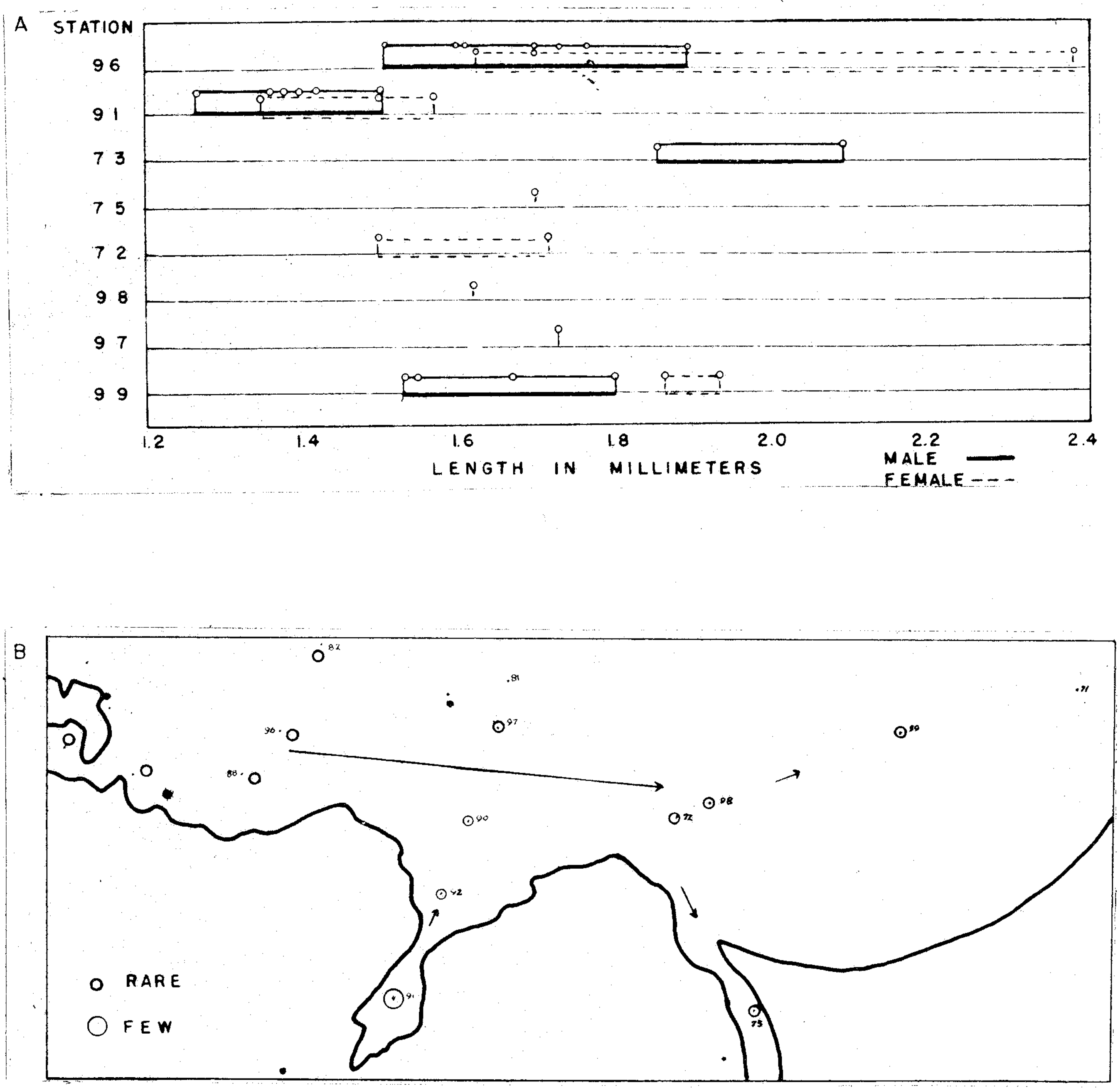



Figure 9 a) The size variation of Tortanus discaudatus in Dixon Entrance
b) The currents suggested by this variation

continuous population in which the adults have been subject to the same past conditions. There is only a slight suggestion in the size of the female at station 72 that a few Naden Inlet copepods are spreading out into the open water. One of the two copepods measured in Masset Sound was, however, unusually large. It could not have originated from inside the inlet because here T. discaudatus is extremely rare. Besides, the one specimen that was measured from here was much smaller than that in the sound. The other copepod fell within the size range of the Dixon Entrance copepods. It could have originated from station 96 or less likely from station 99. As the size variation of C. mcmurrichi also indicated a subsurface inflow of Dixon Entrance water into Masset Sound it is quite possible that this is also suggested by the distribution of T. discaudatus.

Oncaea conifera:

O. conifera lives in a fairly wide range of depths. From an analysis of the results from station 89 in Masset Inlet (Table VI appendix) it is evident that this species inhabits water from 75 meters to the surface. The presence of eggs at 50 or 60 meters is strongly indicative that conditions only here are favourable for breeding. In Tasu Inlet it also occurs in the subsurface as well as the surface water. The eggs here are present in hauls taken from 14 meters. From the temperature data of both localities exemplified in Figure 11, it is evident that the eggs are being laid at a temperature of about 11°C.

All the stations where O. conifera occurs have temperatures allowing breeding. In the following Figure 10 are arranged the temperature curves for stations where O. conifera was A) common or few; B) rare and C) absent. The last group is made up of stations taken in west coast inlets. These were chosen on the grounds that O. conifera seems to typify inshore waters (Figure 11). The stations where O. conifera is present are all characterized by a high surface temperature, above 13.5°C.. Of the stations where O. conifera is absent but having temperatures at which it can breed (127, 128, 129, 105, 108, 109, 110, 117) only three have high surface temperatures and these (117, 110, 109) are shallow, having very little bottom water below 11°C.. It would seem, then, that O. conifera becomes common in localities where there is a fairly deep layer

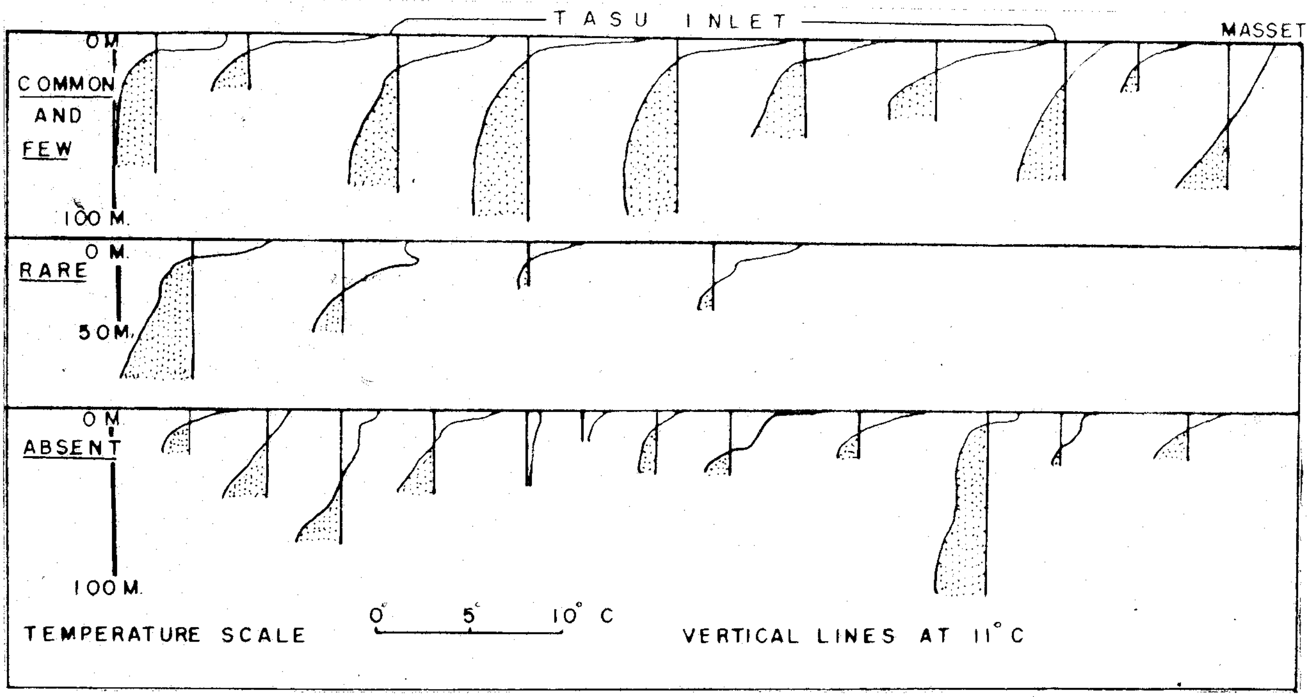



Figure 10. The relation of temperature to the distribution of O. conifera

of water below 11°C. as well as warm surface water. Perhaps the development of the young requires a high temperature. This apparent dependency on warm surface water is sufficient to limit O. conifera to inlets in this area. Nowhere in the outside water does the temperature rise above 13.5°C..

O. conifera is represented also by a few nonbreeding individuals at other stations (Figure 11). On the west coast four of these stations where eggs or both eggs and adults were absent are seen to be slightly north of the main population centers of Tasu and Thetis Inlets. The distribution suggests scattering by a northward moving current in this area. From Tasu Inlet, O. conifera is presumably swept out in the surface water and carried northward. Only a nonbreeding part of the population moves out here as no egg sacs were found at station 124. Its rarity farther north may indicate that it is dying or being widely dispersed. In three inlets to the north, however, O. conifera is represented by a few individuals in the deeper water below 14 meters. If the circulation of water in these inlets is typical, then the surface water is moving out and being replaced by an inwardly flowing

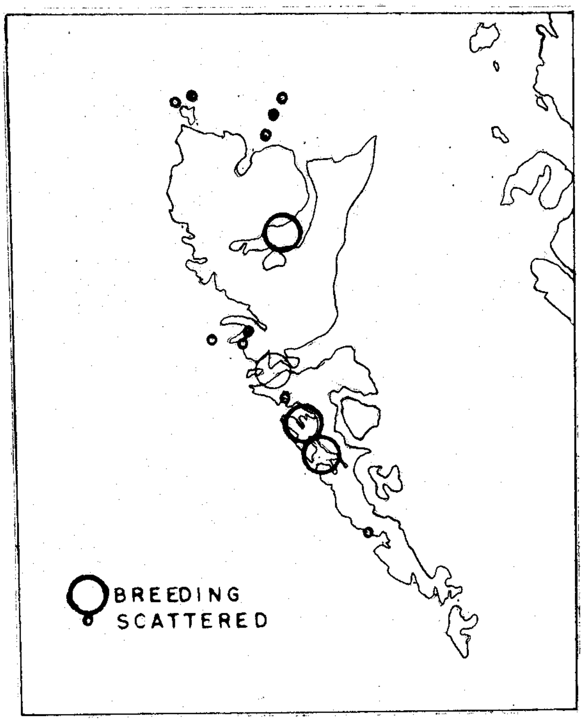



Figure 11. Distribution of Oncaea conifera

bottom water. The unusual occurrence of O. conifera in the deep water here perhaps suggests that at the time of sampling it was being carried in the deeper water into these inlets from outside.

Scattered individuals also occur in Dixon Entrance. As these have not drifted out of Masset or Naden Inlets, it would seem likely that they come from north of the sampled area.

Coryceaeus affinis:

C. affinis is distributed much like O. conifera. Breeding population are present in Tasu and Thetis Inlet (Figure 12) although they are not as obviously breeding as O. conifera. However, the relatively large number of this species in Thetis Inlet is assumed to have arisen there. In Tasu Inlet a female carrying an egg sac was seen. The rarity of egg sacs may merely mean that the copepods are just beginning to mate and that the breeding cycle is attuned to seasonal fluctuations. C. affinis is more common in Puget Sound where populations with many females carrying egg sacs have been noted.

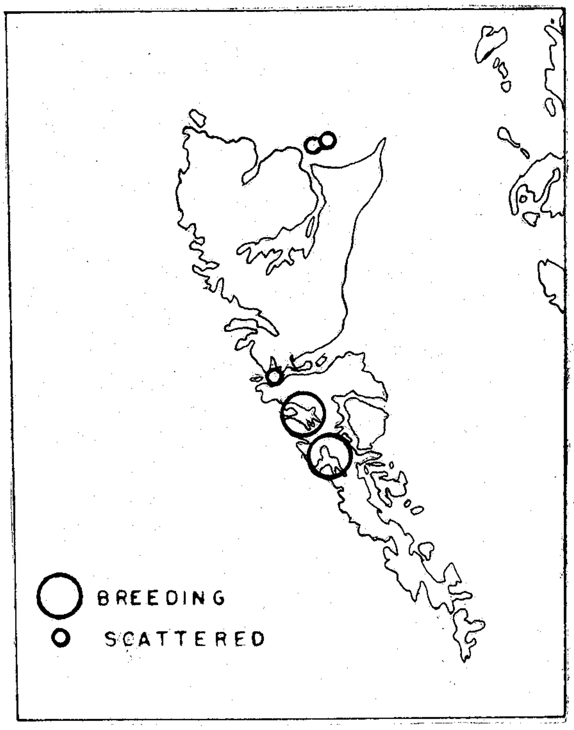



Figure 12. The distribution of Corycaeus affinis

Whether or not *C. affinis* breeds in the same condition as *O. conifera*, it is difficult to say. It is however, common where the warmest surface waters of the area are found. This may be significant to the development of the young stages, although this species is not always found in the surface layer.

Another factor influencing its distribution becomes evident with a consideration of Tasu Inlet. *C. affinis* seems to be flourishing in the long arms but does not spread into the main part of the inlet. *O. conifera* on the other hand, moved right out of the inlet. A reason for this lack of dispersal may be seen in the vertical distribution of *C. affinis*. It is absent or at times rare, in the surface water, while *O. conifera* is always present there (Figure 13).

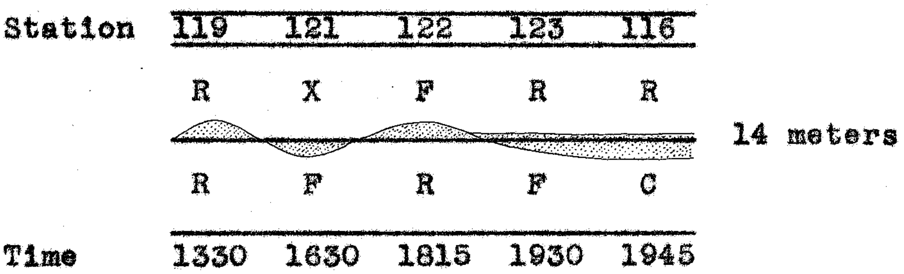



Figure 13. The vertical distribution of *Corycaeus affinis*

It might be suggested that *C. affinis* in occurring in the deep layer only for a time is kept in the arms by an inwardly flowing bottom current. Its mere lack of dispersal at any rate would suggest that this species might be able to increase in other localities but has failed to reach them.

There are some apparently scattered *C. affinis* at five other stations. The locations of these, however, give no clues to the origin of the individuals. They may have come from outside the sampled area.

Subsurface species:

The following three species, C. finmarchicus, M. lucens and E. bungii, are limited to the deeper water as seen in Figure 2 and in Table I (Appendix). The vertical distribution of the age groups of the first two species was determined from the data of station 89 in Masset Inlet, (Figure 26, page 57, Table VI, Appendix). In both, the young live closer to the surface than the adults. Both sexes of M. lucens live at approximately the same depth. The male C. finmarchicus, however, appears to occur in deeper water than the female. The absolute depths are not considered typical, as M. lucens adults are certainly limited to water deeper than 30 meters in Dixon Entrance. Because of the scarcity of E. bungii, it was not possible to determine the distribution of the age groups.

Station 89 data also indicates that M. lucens and C. finmarchicus perform a diurnal vertical migration, the latter moving up from deeper water, close to the surface at night. Other authors (Clark, 1933 and Nicholls, 1933) have found this same behavior in these two species. According to Esterly (1911b), however, Eucalanus elongatus, a close relative of E. bungii, does not migrate vertically in San Diego Bay. Whether or not this is typical also of E. bungii in the Queen Charlotte area is not known. This species, however, is not found in the shallower hauls which capture C. finmarchicus and M. lucens.

<u>Calanus finmarchicus</u>:

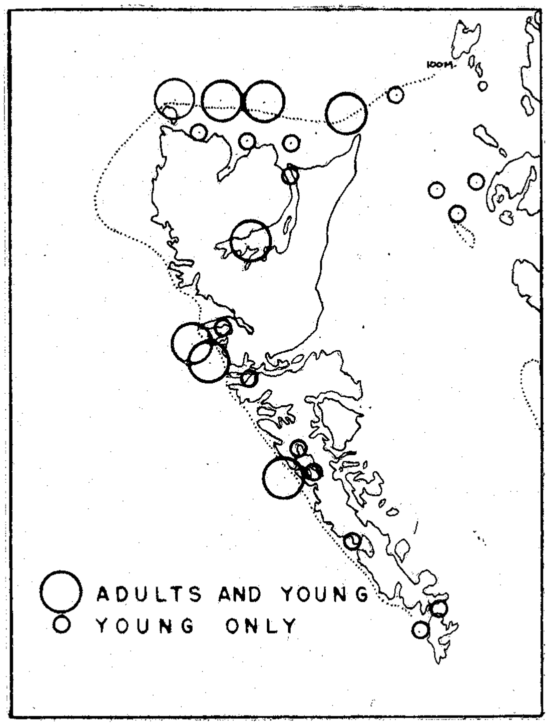



Figure 14. The Distribution of <u>Calanus finmarchicus</u>

The horizontal distribution of this species can be seen in Figure 14. The restriction of the adults to the deeper water is very noticeable, as well as the wider distribution of the younger stages. Although it can not be shown that the young live in the shallower water in Dixon Entrance, it is quite possible that during their vertical migration they come up into the surface waters long enough to be transported onto shallow areas. This process may be visualized in the following diagram (Figure 15) illustrating the vertical distribution of <u>C. finmarchicus</u> at the locality indicated by the line in Figure 14.

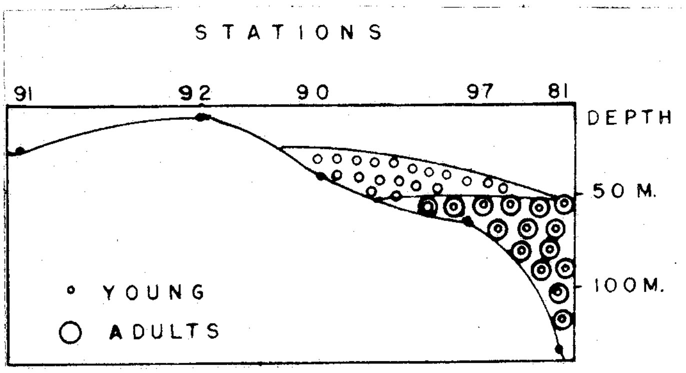



Figure 15. The vertical distribution of <u>Calanus finmarchicus</u> off Naden Inlet in Dixon Entrance

This effect is also noticeable in Tasu Inlet, where the young move into the shallow arms away from the main population in the deep part of the inlet. In both these places, scattering is probably the result of currents just above 50 meters.

Metridia lucens:

The distribution of M. lucens (Figure 16) suggests that it is limited to deeper water than is C. finmarchicus. The upper limits to its vertical range in different areas (Table II) also indicates this. Its restriction to the deeper water is very likely responsible for the lack of dispersal of the young stages. In only two localities, off Naden Inlet and in Tasu Inlet, is this effect evident.

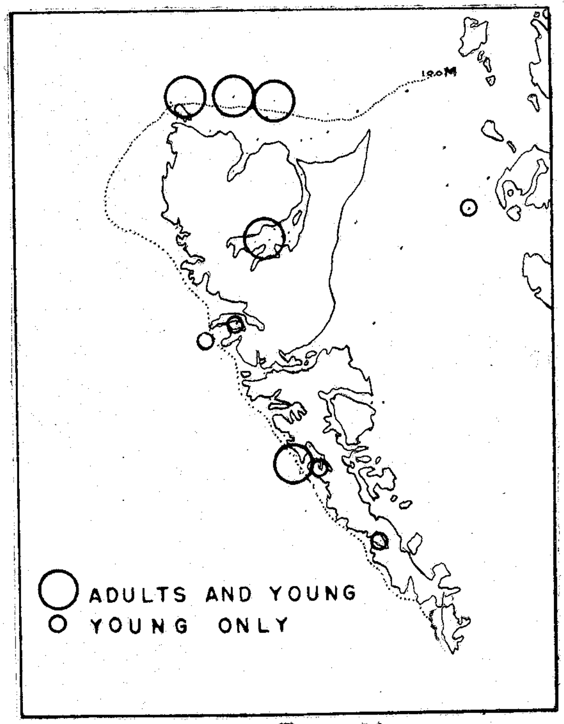



Figure 16. The distribution of Metridia lucens

Eucalanus bungii:

As this species was so rare, no conclusions could be drawn from the age distributions. Stage V copepodids and adult females were present in nearly all samples in which it was found. There is the suspicion, however, that this species is more common than the plankton samples indicate. Johnson (1948) has found that it is quite capable of evading plankton nets.

The upper limits to its vertical distribution (Table II) is very similar to that of M. lucens. In spite of this, this species does not spread onto shallow areas (Figure 17). When the vertical distributions of the three species are considered together (Figure 18) off Naden Inlet, this effect is noticeable. The fact that it probably does not migrate upward into an on-shore current, evident in the distribution of the other two species, very likely accounts for its limited distribution.

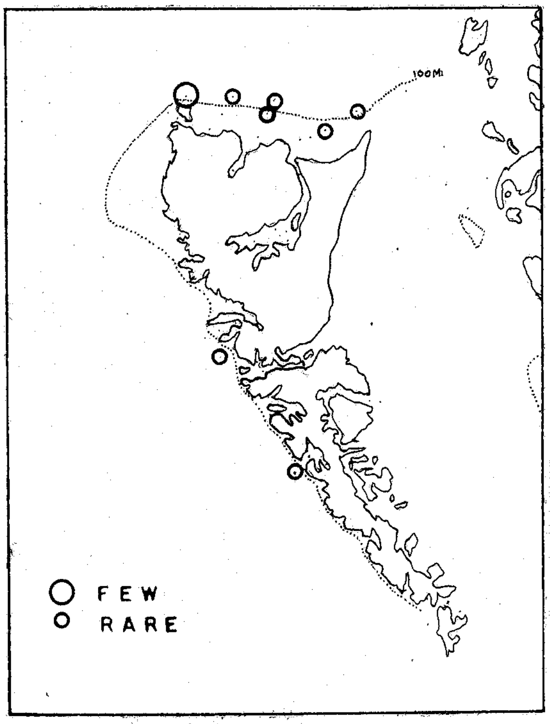



Figure 17. The distribution of Eucalanus bungii

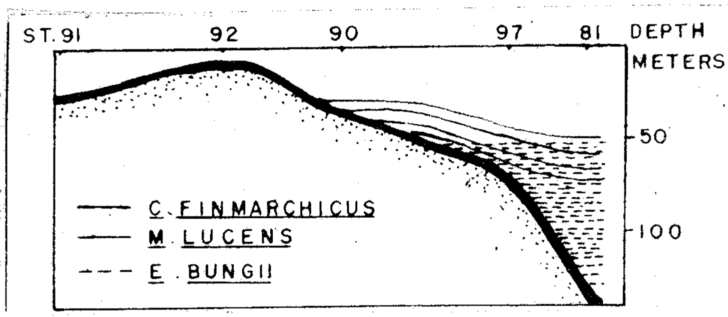



Figure 18. The vertical distribution of three species off Naden Inlet in Dixon Entrance

## Part 2: Currents suggested by the dispersal of Copepods

The distributions of all the species including those which are rare are considered now in several areas, with suggestions of possible current patterns. These areas are in order: Tasu Inlet, Dixon Entrance, Masset Inlet.

### Tasu Inlet:

Tasu Inlet is fairly large and highly productive body of water on the west coast of Moresby Island(Figure 1.). At the time of sampling its plankton consisted largely of copepods. The composition of its fuana, however, reflects the influence of open ocean water, by the presence of salps and siphonophores, as well as water from shallow areas characterized by pelycepod larvae. In addition to this the presence of three long bays make this inlet a complex body of water. The results of seven deep plankton hauls as well as five supplementary hauls along with considerations of the physical data and topography do, however, give some idea of its circulation.

The main part of Tasu Inlet is large and relatively deep (Figure 21). It is separated from the open ocean by a narrow sill, with a depth of 30 meters. Towards the heads of the three bays, the depth decreases to about 30 or 40 meters. Wright Inlet, however, has a deeper pocket (maximum depth - 175 meters) behind a sill of 50 meters depth.

Surface temperatures are high, up to 19°C. in Botany Bay. This warm water is also present in the main part of the inlet but not outside the mouth. The temperature, however, decreases sharply with depth, water at 20 meters being around

10°C.. The deeper water at station 118 is near 7°C.. The salinity also increases sharply with depth from about 28‰ to 32‰ at 20 meters becoming as high as 33 in the deeper water at station 118. The conditions at the surface suggest that there has been an unmixed slowly moving layer of fresher water there for some time, during which it has warmed considerably.

The distribution of surface plankton, although scarce, does suggest some outward flow of surface water. Two rather restricted species common in Tasu Inlet, O. conifera and P. parvus, are found in all surface samples although the majority occur below 14 meters. Only two other species, O. helgolandica and P. minutus were also consistently found at the surface, but as these were so widespread it was not possible to determine the centers of population increase. O. conifera and P. parvus seem to breed in the three arms (Figure 19). They occur in lesser numbers, O. conifera without its eggs sacs at station 118. O. conifera only reaches station 124 presumably via a surface current. As the temperature is low and the salinity high here, considerable mixing must have occurred between stations 118 and 124. The presence of O. conifera suggests that some of the mixed water has originated from the surface at stations 118. A surface outflow from Wright Inlet and Botany Bay is also suggested by the distribution of C. affinis, represented here by a few individuals (Figure 20).

Species living below 14 meters as well as in shallow water are apparently limited to the bays (Figure 20). Although these copepods are represented by few individuals, their lack of dispersal suggests that water between 14 and 30 meters is not moving out of the bays. Also, the abundance of O. conifera and P. parvus, which live mostly below 14 meters implies that very little water at these depths is moving out.

The bottom water of the arms may be typified by the presence of C. finmarchicus. In Figure 21, the distribution of the adults and late copepodid stages is seen to be in deeper water only. The young, however, living above the adults appear to have spread into the shallow bays indicating an inward flow of water just above 50 meters and possibly up the 25 meters. M. lucens seems to be restricted to the deeper water at station 118. The presence of a few young individuals in the deep pocket at station in Wright Inlet, however, suggests that strays are being carried to a slight extent over the sill at about 50 meters.

The remaining species in the deep part do not seem to scatter. This suggests very little vertical movement of the deep water.

The relationship of the deep water inside the sill to that outside is illustrated by a comparison of stations 118 and 124 (Figure 22). Five species live inside below 100 meters, M. lucens and S. minor being uppermost. Except for M. lucens all are represented by fewer individuals here than outside. At station 124, an additional five species occur presumably belonging to the deeper water. The presence of stage V copepodids and female adults of E. bungii is of considerable importance. By a comparison of adjacent stations in other parts, the upper limits to its vertical distribution is near 36 to 100 meters. This species then characterizes the water about 6 to 70 meters below

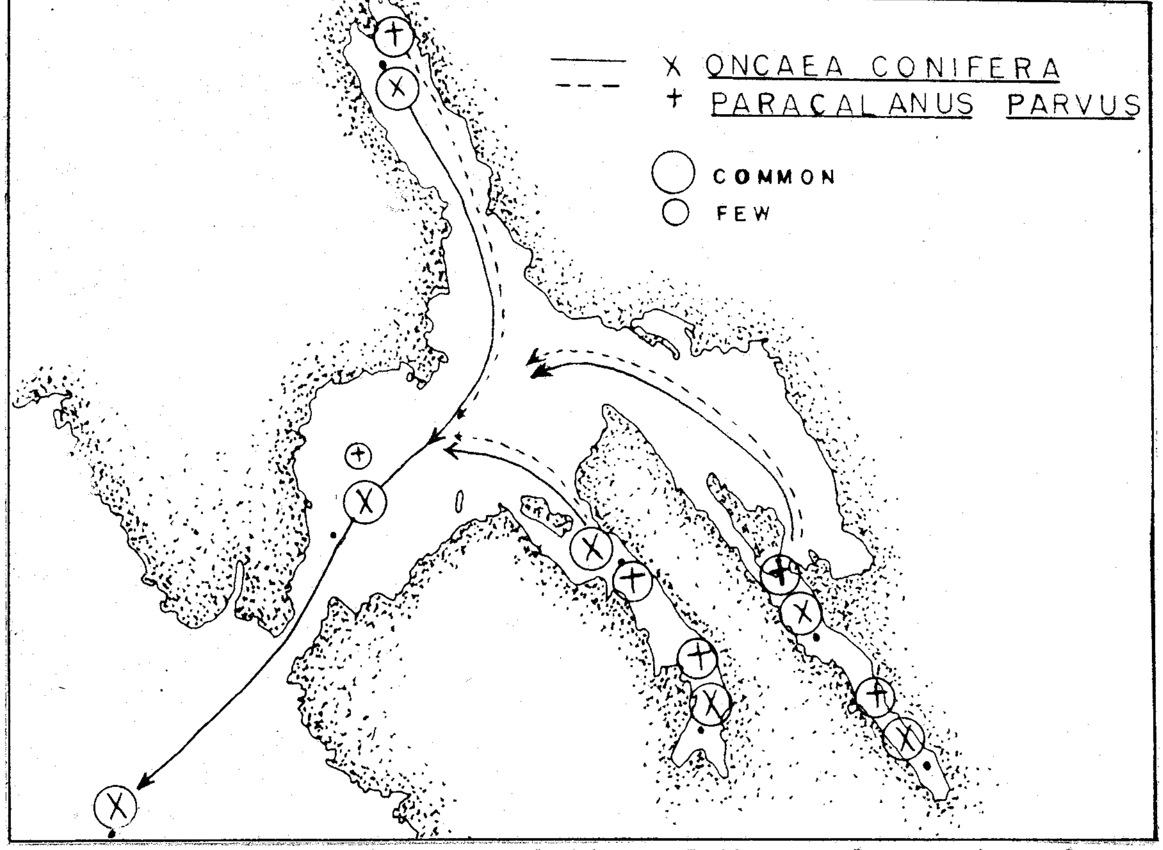



Figure 19. A proposed circulation of the surface water above 14 meters in Tasu Inlet

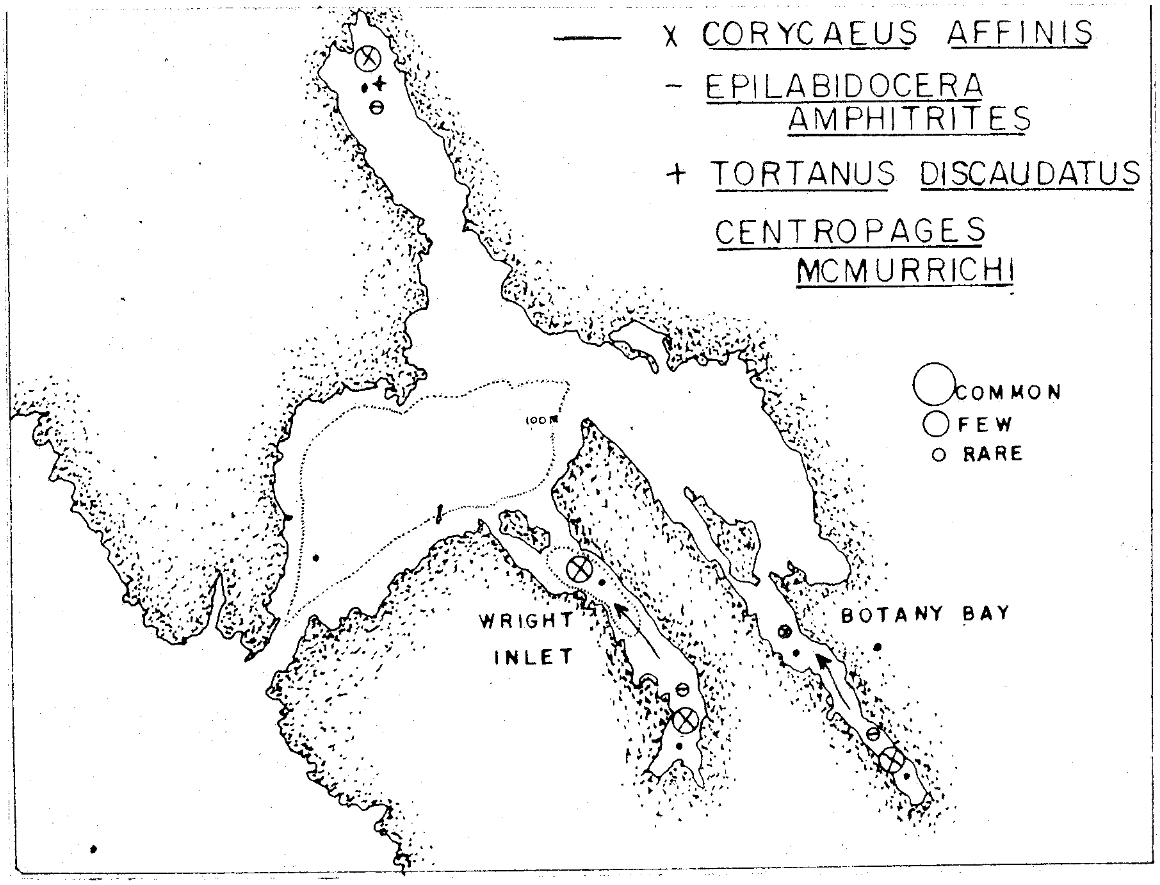



Figure 20. A proposed circulation of water between 14 and about 30 meters in Tasu Inlet

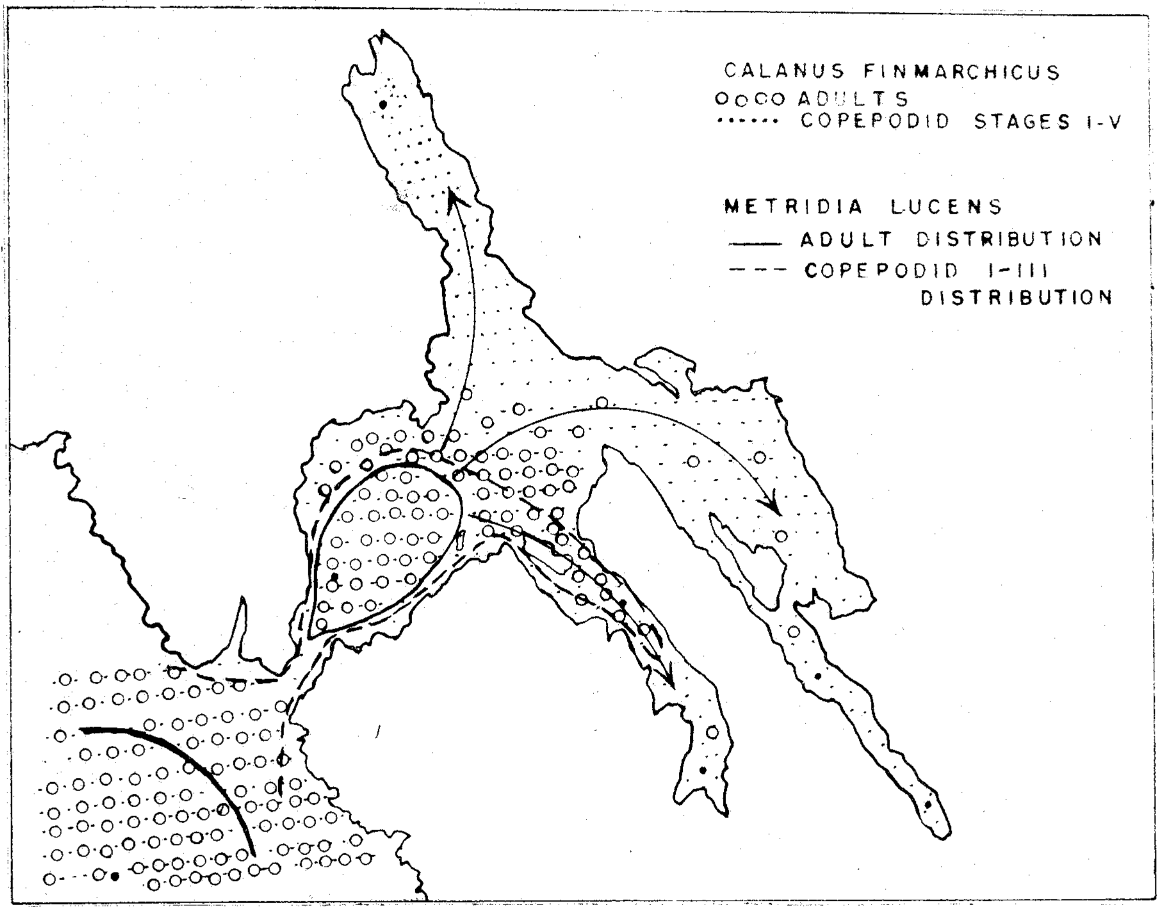



**Figure 21.** A proposed circulation of the deep water of Tasu Inlet

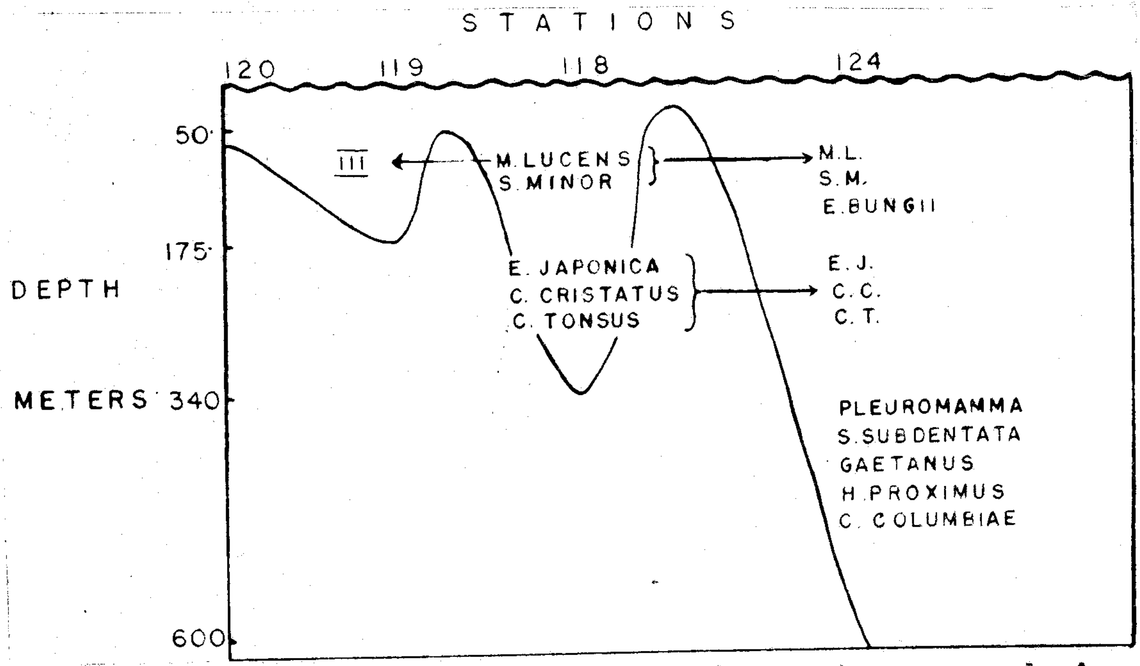



**Figure 22.** The distribution of the deep water copepods in Tasu Inlet and immediately outside

sill depth. As *E. bungii* does not occur inside the inlet, it may be said the water just below sill depth is not entering the inlet at the present time nor has likely done so in the recent past.

Further evidence for this isolating effect of the sill may be seen in the population structure of *E. japonica*. The rare individuals at station 118 were all copepodids at stage V. Outside stages IV, V as well as female adults and eggs were found. The existence of rare individuals of only one stage inside the inlet suggests that these have perhaps been carried into the inlet at some time but at present are separated from those outside. According to Campbell (1934) *E. japonica* breeds in the deep water at 200 to 400 meters. Here also, the young develop. It cannot be assumed then, the copepodids inside the inlet arrived there at a previous time via an inwardly flowing current which carried a few young off the top of the *E. japonica* population outside. Although it seems likely that water below the sill depth has at some time in the past moved up and over the sill, it is not doing so at the time of sampling. Any water moving into the inlet must be from a depth of above 20 to 36 meters.

In this analysis, it is suggested that a slow surface current moves out of the arms into the main part of the inlet some of it flowing over the sill. There is some movement of subsurface water into the arms at 20 to 50 meters. The deep water in the center of the inlet is not mixing vertical and at the time of sampling is distinct from the deep water outside the inlet.

Dixon Entrance:

The water immediately offshore, north of Graham Island is sufficiently well sampled to be investigated in detail. The presence of large areas of unsampled water to the north and west make this analysis very difficult. The currents proposed are, thus, only suggestions but they do illustrate the possibilities for the use of plankton animal distribution.

Dixon Entrance has a narrow, shallow shelf (Figure 25). About 20 miles from the shore off Naden Inlet the depth increases to 300 meters. Only one sample was taken in water this deep about 5 miles north of Langara Island.

The water is cold, about 11° to 13°C. at the surface dropping to about 6°C. near the bottom at the deeper stations. The salinity ranges from about 30‰ to 33‰ at the surface. The deep water has a fairly uniform salinity of about 33‰.

The currents as estimated from the distribution of copepods will be considered in three groups: surface to 10 or 15 meters (Figure 23), between 15 and 30 meters (Figure 24) and below 30 meters (Figure 25).

The surface movements are suggested by the distribution of *A. clausi*, *P. parvus* and *M. norvegica* (Figure 23). The size variation of *A. clausi* is the best indicator here of an eastward movement. Its scarcity in the east suggests that it is also being carried northward. The occupation of the eastern water indicates that this is a somewhat separate water mass and receives a few individuals of *A. clausi* from the west and possibly from Masset Inlet. The flow of surface water from Naden Inlet as indicated by *A. clausi*, is also suggested by the distribution of *M. norvegica*. This species also occurring offshore from Naden Inlet may possibly indicate an onshore surface current here.

An eastward movement of water at 15 to 30 meters is also evident in the size variations of C. memurrichi and T. discaudatus (Figure 24), the lengths of these copepods being comparable right across the coast. Some flow of water out of Naden Inlet is also indicated but this seems to be much less than the outward flow of surface water. Because these species are so scarce it is impossible to judge whether or not they move north. However, a separate water mass in the east is also implied by the presence of large A. longiremis, above the size range of those found in the western part. Also the population of C. memurrichi, composed almost entirely of young animals may be different to that in the west.

The scarcity of adults in this area indicates that individuals from the large population in Masset Inlet are not moving out and eastward, since it is made up of all stages including many adults. On the contrary, the large size variation of C. memurrichi in Masset Sound implies that some at least, have come from farther west (station 96), and the entrance to Naden Inlet, and a few possibly from inside Masset Inlet. The inflow of slightly subsurface water into Masset Sound is also indicated by T. discaudatus, a species extremely rare in Masset Inlet.

Movements of the deeper water (Figure 25) can be visualized as responsible for the spreading of the copepodid stages of C. finmarchicus and M. lucens onto the shallow areas.

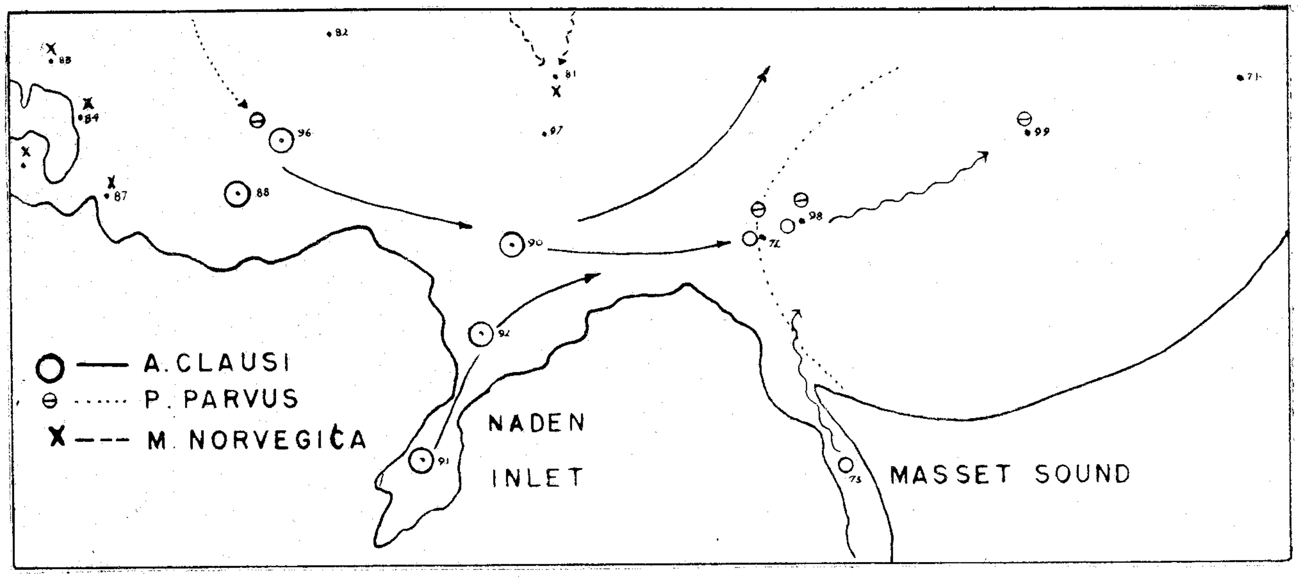



Figure 23. A proposed circulation of surface water in Dixon Entrance

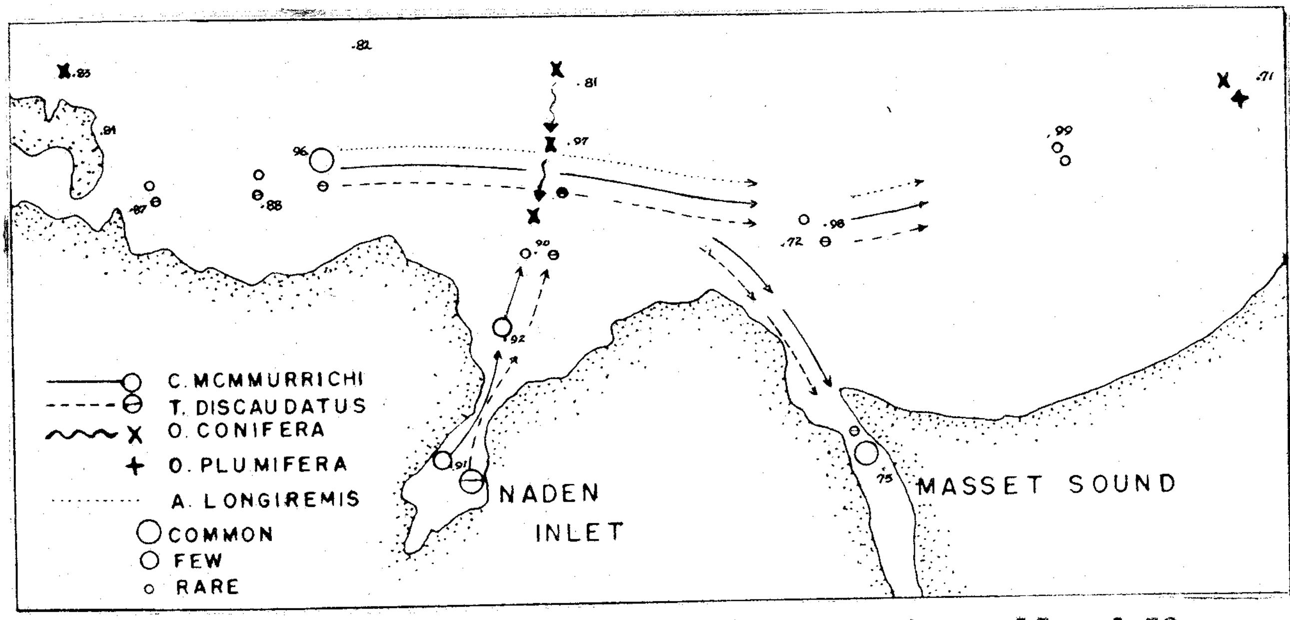



Figure 24. A proposed circulation of water between 15 and 30 meters in Dixon Entrance

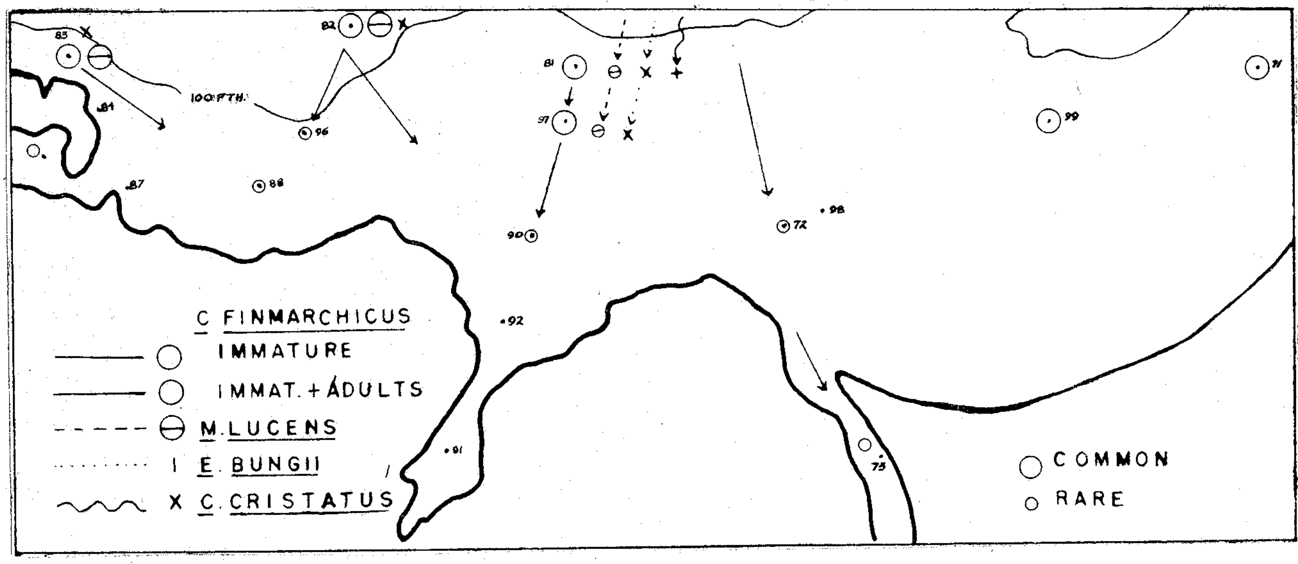



Figure 25. A proposed circulation of water between about 40 and 100 meters in Dixon Entrance

C. finmarchicus seem to be living slightly above M. lucens as its young are spread onto most of the shallow areas. An example of this was seen in Figure 15. This scattering presumably indicates an onshore movement of water at about 40 or even 20 meters. The spread of M. lucens' young onto the shelf in only one place, opposite Naden Inlet indicates an exceptional onshore current here at about 50 meters. Upwelling in this region is also suggested by the appearance at station 81 of C. cristatus, a species otherwise occurring in much deeper water (station 83) from 364 meters. This species does not occur at station 82 at a depth of 206 meters.

Of special note is the spread of very young C. finmarchicus into Masset Sound (copepodid stages 11 and 111). The origin of these could only be the open water, as only stage V being found inside Masset Inlet. The presence of these young stages here along with specimens of C. mcmurrichi and T. discaudatus confirms the idea that water slightly below the surface was moving into Masset Sound from the outside at the time of sampling.

Masset Inlet:

Masset is the largest of the inlets studied (Figure 1). It is about twenty miles long and five miles wide. The western part situated close to high mountains is the deepest, about 80 meters as sounded from station 78 (Figure 27). Towards the eastern region the water shallows to twenty meters. The narrow sound opening into the eastern part, extends for about twenty miles with a depth of twenty meters before opening into Dixon Entrance.

At the time of examination, the surface water was warmer in Masset Inlet than in Dixon Entrance. It decreased from about 14°C. at the surface to 8°C. in the deeper water. The salinity in the deep water was unusually low. At the surface, it was 22‰, increasing slightly at mid depth but decreasing again towards the bottom. Although there are many rivers entering the inlet from all directions, the Yakun River entering the southeastern corner from a large drainage area to the south is thought to be the main contributor of fresh water. The low salinity near the bottom as well as the length of the shallow sound make this inlet very interesting.

The inlet was surveyed on the 20th of July. Both a deep haul and a supplementary haul were taken at each station. Station 89, however, was occupied for 24 hours on July 24th.

A supplementary haul, pumped hose samples and a deep haul were taken four times during that period.

Ten species of copepods were found in Masset Inlet:

| | | |
|---|---|---|
| C. mcmurrichi | P. minutus | A. longiremis |
| T. discaudatus | A. clausi | C. finmarchicus |
| E. amphitrites | O. conifera | O. helgolandica |
| M. lucens | | |

O. helgolandica and P. minutus are common and widespread in the inlet. Only rare specimens of E. amphitrites and T. discaudatus were captured. The six remaining species are sufficiently numerous and varied in concentration to indicate the physical factors influencing their distribution.

The vertical distribution of the six species at station 89 can be seen in Figure 26 (Table VI Appendix). This diagram shows the relative abundance of species at different depths over a 24 hour period. Three species C. mcmurrichi, A. longiremis, and A. clausi are living near the surface. A. longiremis seems to occur near three meters here. At other stations it occurs below this but it is assumed to be living just below three meters. C. mcmurrichi occurs from the surface to about 10 meters.

C. mcmurrichi is common and probably breeding in the upper 14 meters as young were also found here. Its horizontal distribution and relative abundance is illustrated in the following diagram (Figure 27).

The low salinity surface water, if Masset Inlet is typical of most inlets with a fresh water inflow, would tend to move out and over the sound. C. mcmurrichi is, however, living and

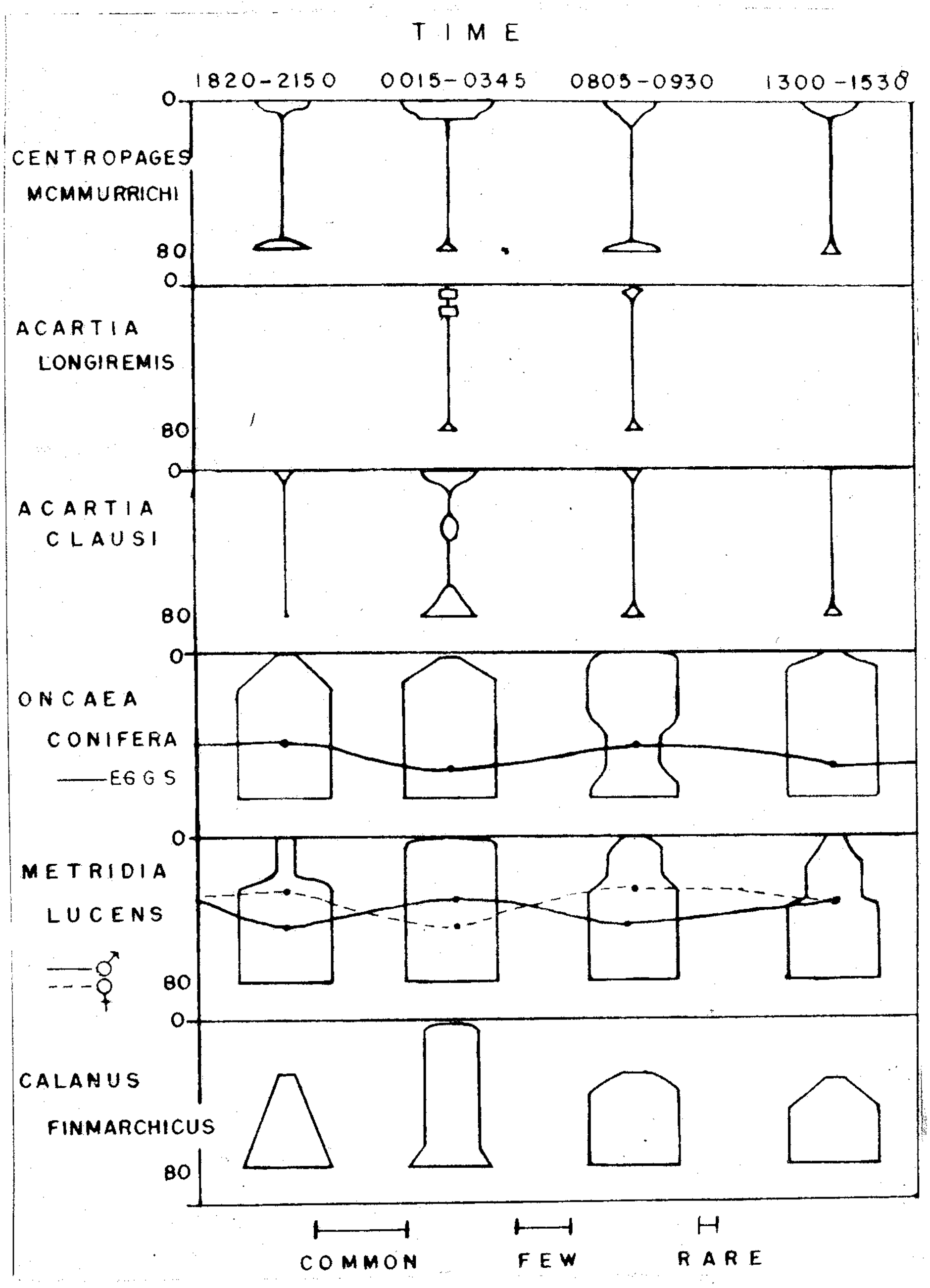



Figure 26. The relative abundance and Vertical distribution of copepods at Station 89 in Masset Inlet over a 24 hour period.

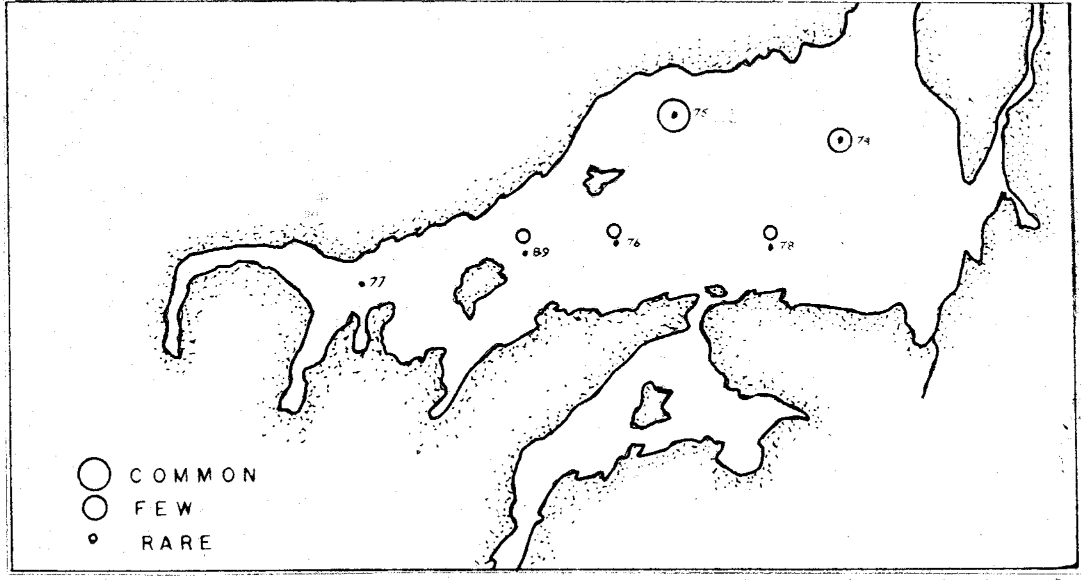



Figure 27. The relative abundance and horizontal distribution of <u>Centropages mcmurrichi</u> in Masset Inlet

and reproducing in this layer. It could not become abundant where the surface water was being rapidly replaced. <u>C.mcmurrichi</u> would more likely become common in slowly moving water. Its abundance suggests a slow movement of surface water and the possible existence of an eddy in the inlet.

<u>A. clausi</u>, unlike the aforementioned species lives entirely in the surface three meters. It can be seen from Figure 28, that it occurs most commonly opposite the mouths of large bays. As seen in previous results, <u>A. clausi</u> is often common in bays, typified by Naden Inlet. Also the vertical distribution makes it subject to the outward flowing surface water. It is quite possible then, that <u>A. clausi</u> is more abundant in the bays opening into Masset Inlet. If so, these copepods would move out into the main part and account for the large numbers at Stations 77 and 78.

The other three species are most abundant in the deeper water although they do occur near the surface. <u>O. conifera</u> and <u>M. lucens</u> occur in fewer numbers near the surface but

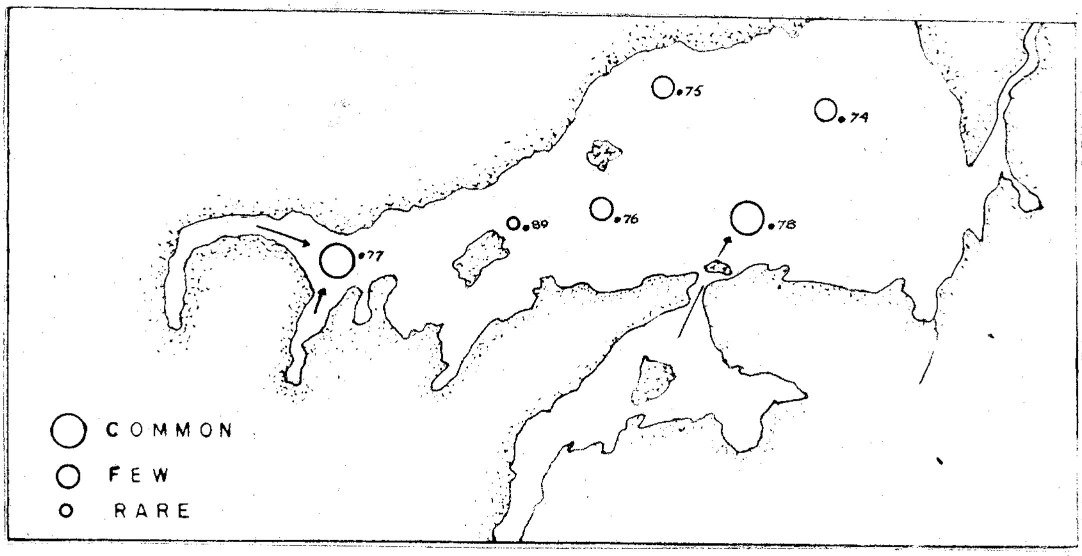



Figure 28. The distribution of Acartia clausi in Masset Inlet.

C. finmarchicus approaches the surface only at night. These species may indicate the movements of the deeper water.

Although O. conifera lives in the whole water column, females carrying egg sacs were seen only in pumped samples taken near 50 meters and in the deep vertical haul. Free egg sacs were also noted in these samples. As this species, characteristic of the superfamily the Cyclopoidea, carries its eggs until they hatch, it can be assumed that the free egg sacs had fallen off females after the sample was collected. This evidence suggests that O. conifera is reproducing in the deeper water at about 50 or 60 meters and if so could only be producing young in the western part of the inlet where these depths are found. O. conifera, however, is found in lesser numbers and without egg sacs farther east (Figure 29). Considering that production occurs only in the west, the individuals living near the surface must drift westward away from their origin.

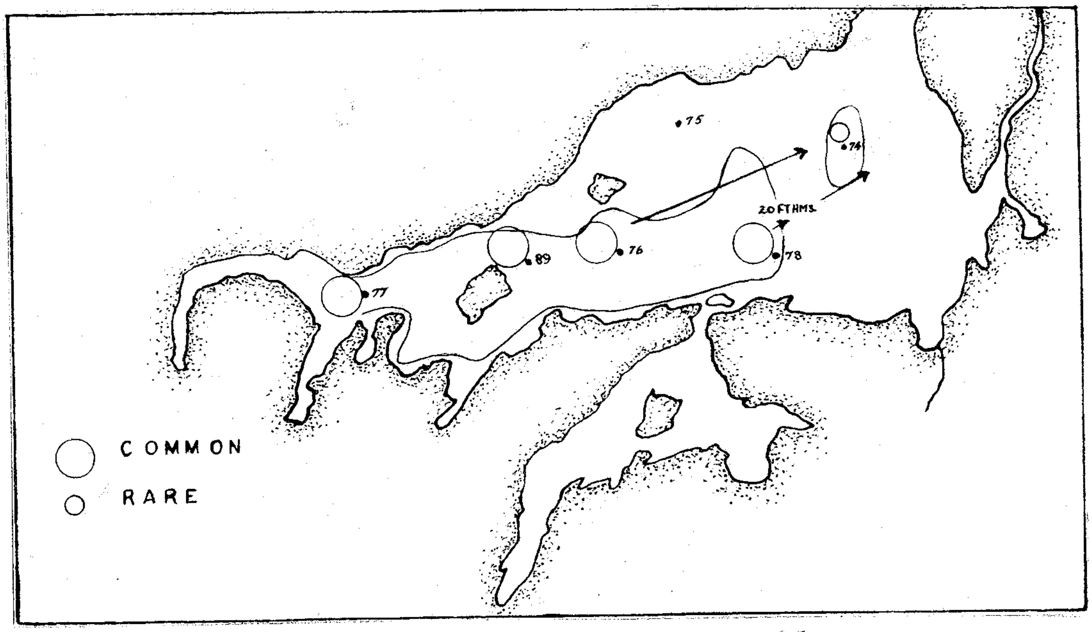



Figure 29. The distribution of Oncaea conifera

The vertical distribution of M. lucens is similar to that of O. conifera. The adults live at 30 to 50 meters, while the young live above this and are continually present even if scarce in the surface layer. Figure 30 (Table VII Appendix) indicates the population structures of this species at different stations.

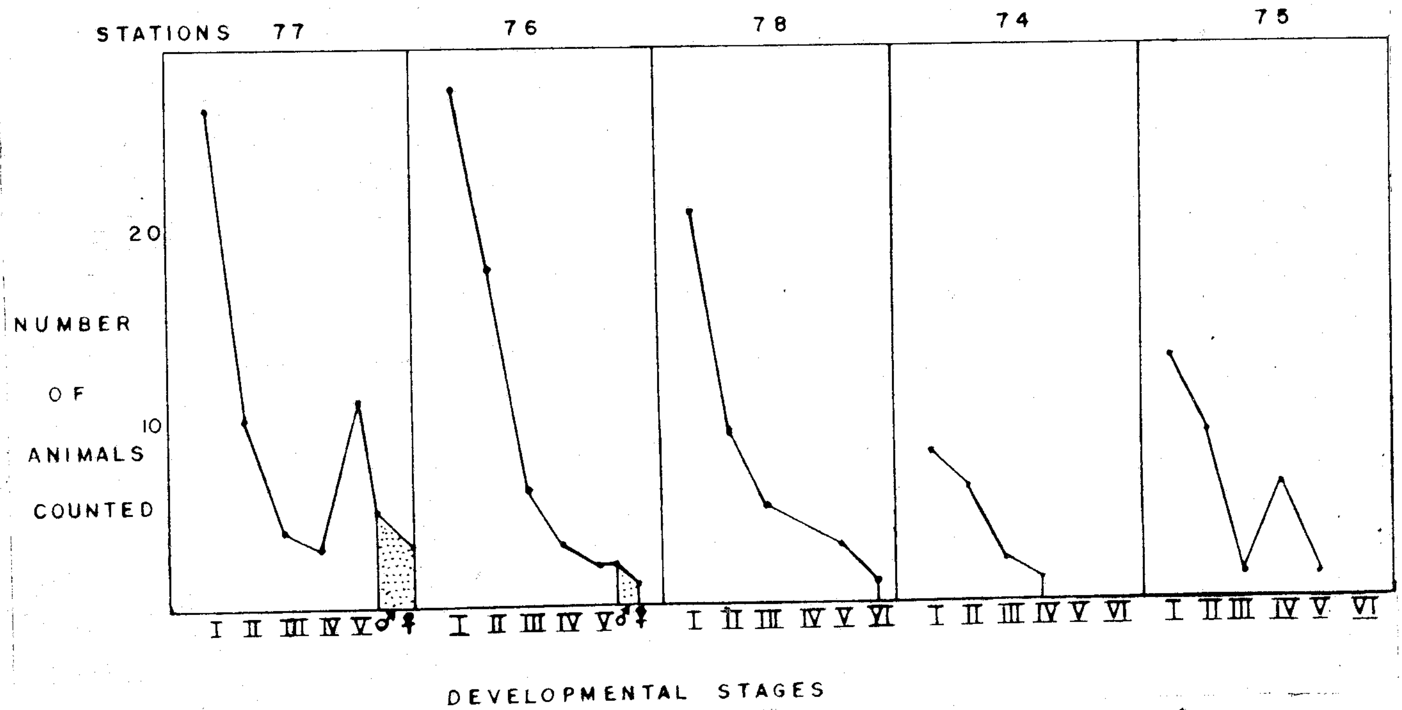



Figure 30. The population structures of Metridia lucens in Masset Inlet

This data is presented also in Figure 31. The extents of the distribution of adults and copepodids is indicated. It can be seen that the adults are present only in the western area while copepodids in stage V range farther east and copepodids stage I cover the whole sampled area. As only the young are dispersed, the currents responsible for this must be present above 30 meters.

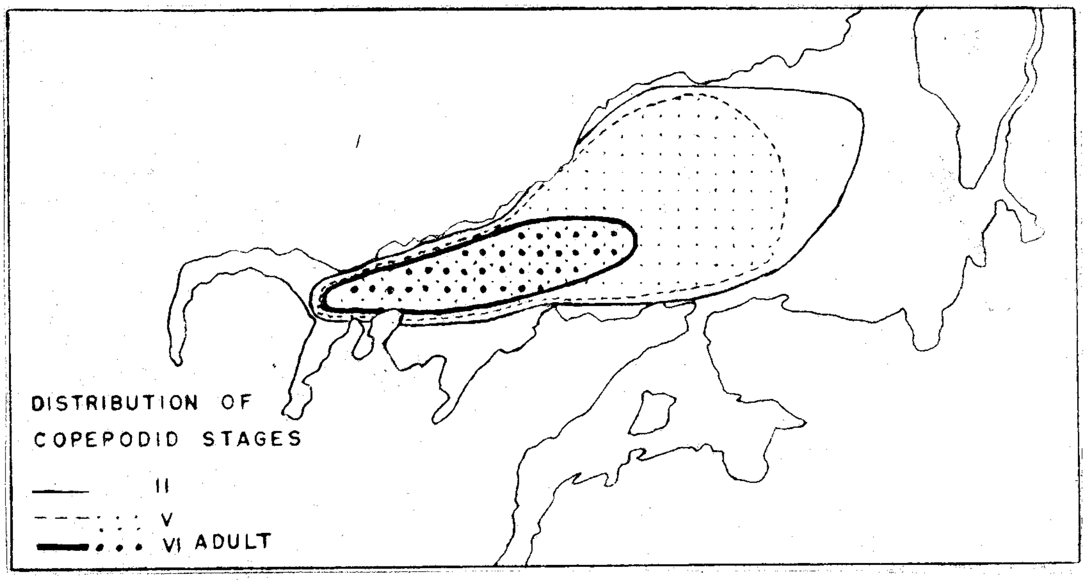



Figure 31. The horizontal distribution of several copepodid stages of Metridia lucens in Masset Inlet

Calanus finmarchicus is represented in Masset Inlet by copepodids in stage V although a few adult females were seen as well as an occasional copepodid stage IV. It occurs entirely at stations 77, 76, 75, 89 (Table VII Appendix). Although it does move up to the surface at night, it is not dispersed, as is M. lucens, over the rest of the inlet. Hence the current which spreads the young of M. lucens must not be very fast or steady as it does not cause C. finmarchicus to spread while the species is near the surface.

The three species living in the deeper water appear to be isolated in Masset Inlet by the long shallow sound. Two of them, *M. lucens* and *O. conifera* are reproducing at the time of sampling but it is doubtful that *C. finmarchicus* is doing so. This species is mostly represented by stage V copepodids, a few adults and an occasional stage IV copepodid. It is very difficult to say whether these were washed into Masset recently or whether they have been there for some time. It seems possible that the very young stages of *C. finmarchicus* may have been carried into the inlet. At the time of sampling it is present in its very young copepodid stages in Masset sound. It is not impossible that a strong inflow into the sound could bring a fair number of this species into the inlet.

In summary, it seems that there are no definite rapid moving currents in Masset Inlet. As species living near the surface are able to reach large numbers by reproducing, it is reasonable to suggest that very little surface water is moving out over the sound at the time of sampling. There is some indication, however, that surface water is moving out of the bays. Also there seems to be a slight eastward movement of water above 30 meters. Apparently very little water is moving into the inlet over the sound, judging from the absence of young *C. finmarchicus* inside the inlet.

## SUMMARY AND CONCLUSIONS

Thirty-two species of copepods were identified. All were characteristic of northern cold water. These species were found to have certain vertical ranges, some occurring only in the deep water. Hence, fewer species were encountered from hauls at shallow stations.

With a consideration of vertical distributions, the relation of copepod distribution and abundance to physical conditions was studied. Temperature was found to influence the abundance of several species living near the surface. As these species were limited to the north by temperatures present in the area during the winter, it was suggested that they became abundant only in the summer and first in localities which warmed early. It was also evident that several species living in deeper water could breed only in the low temperatures there, thus not occurring in large numbers in the shallower water. In addition to temperature, low salinity seemed to correlate with the presence of one species, known to prefer water of low salinity. It is apparent, then, from this study that physical conditions have some influence on the presence and abundance of copepods in the Queen Charlotte area.

Dispersal was also seen to influence distribution. The scattering of a species from its breeding area could be traced and currents responsible for this are suggested. In Tasu Inlet, the extent of surface outflow and subsurface inflow are indicated as well as the isolation of the deep water inside the shallow sill from that outside. In Masset Inlet, the surface outflow was not outstanding, instead, the existence of slowly moving eddies seemed evident. Species living in the deep water here also appeared to be isolated by the long shallow sill. Although no inflow from Dixon Entrance is evident at the time of sampling, it is suggested that periodically a fairly large amount of water moves into Masset Inlet from Dixon Entrance.

A study of Dixon Entrance indicated an eastward flow of surface water as well as a movement of deeper water onto the shelf particularly off Naden Inlet.

This study although exploratory has indicated some of the factors which need to be considered in future plankton studies. It has illustrated the biologist's need for knowledge of physical conditions, especially the movements of water which have been shown to have a considerable effect on the distribution of copepods.

Also many problems concerning the plankton animals themselves are evident. A more basic knowledge of their seasonal fluctuations, vertical migrations and physiology is required for this area. It is felt that in order to solve these problems, the plankton should be studied as such and not as supplements to physical studies. As this study has shown, copepods have possibilities in current determinations but these will not be realized fully until more is known about the animals themselves.

## ACKNOWLEDGMENTS

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# APPENDIX

Symbols Used

R - rare

F - few

C - common

A - abundant

e - eggs

i - immature only

→ - all stages to

TABLE I

THE OCCURRENCE AND RELATIVE ABUNDANCE OF THE COPEPOD SPECIES IN ALL THE PLANKTON SAMPLES

| Locality | Hecate Strait | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 68 | | 69 | | 64 | | 65 | 70 | | 103 | 104 | 102 | 101 | 100 |
| Haul Depth | 23 | 1 | 22 | 1 | 44 | 1 | 6 | 18 | 1 | 36 | 75 | 69 | 27 | 91 |
| Surface Temp. °c | 14.8 | | | | 14.5 | | | | | 11.8 | | | | 12.6 |
| Copepods: | | | | | | | | | | | | | | |
| O. helgolandica | C | F | C | F | F | F | F | C | F | F | R | C | C | C |
| P. minutus | C | F | C | F | A | F | A | C | F | C | C | C | C | C |
| A. clausi | | R | R | F? | F | F | R | R | R | | | | F | |
| A. longerimis | F | ? | C | F | F | R | F | C | F | C | C | C | C | C |
| C. mcmurrichi | C | R | R | R | C | R | F | R | R | C | F | R | C | F |
| T. discaudatus | C | | C | R | R | | | C | | F | R | R | | R |
| M. norvegica | | | | R | | | | | | | | R | | |
| O. conifera | | | | | | | | | | | | | | |
| E. hirundoides | | | | | | | | | | | | | | |
| P. parvus | R | | | | | | | | | | | | F | |
| M. rosea | | | | | | | | | | | | | | |
| C. affinis | | | | | | | | | | | | R | | |
| C. finmarchicus | R | | | | R | | | | | Ri | C | Ci | | F |
| M. lucens | | | | | | | | | | Ri | | | | |
| E. amphitrites | | | | | | | | | | Ri | | | | |
| O. plumifera | | | | | | | | | | | | | | |
| A. armatus | | | | | | | | | | | | | | |
| E. bungii | | | | | | | | | | | | | | |
| B. similis ? | | | | | | | | | | | | | | |
| C. cristatus | | | | | | | | | | | | | | |
| C. tonsus | | | | | | | | | | | | | | |
| S. minor | | | | | | | | | | | | | F | R |
| E. japonica | | | | | | | | | | | | | | |
| C. columbiae | | | | | | | | | | | | | | |
| Pleuromamma | | | | | | | | | | | | | | |
| Heterorhabdus | | | | | | | | | | | | | | |
| Gaetanus | | | | | | | | | | | | | | |
| C. acuicornis | | | | | | | | | | | | | | |
| M. longa | | | | | | | | | | | | | | |
| Rhincalanus | | | | | | | | | | | | | | |
| Chiridius | | | | | | | | | | | | | | |
| S. subdentata | | | | | | | | | | | | | | |

R - rare F - few C - common A - abundant
e - eggs i - immature only → - all stages to

TABLE I (continued)

| Locality | Dixon Entrance | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 71 | | 99 | 98 | 72 | | 73 | | 91 | 92 | 90 | 97 | 81 | | 88 | | 96 |
| Haul Depth | 127 | 1 | 91 | 47 | 54 | 3 | 15 | 3 | 27 | 8 | 35 | 65 | 13.5 | 10 | 42 | 3 | 45 |
| Surface Temp. | | | 12.7 | | 12.0 | | | | 13.4 | 11.9 | 11.9 | | | | | | 12.1 |
| Copepods: | | | | | | | | | | | | | | | | | |
| O. helgolandica | F | Fi | R | C | C | C | C | F | F | F | C | C | C | C | C | C | A |
| P. minutus | C | | C | F | C | C | C | C | C | R | F | F | C | C | C | F | C |
| A. clausi | | | R | F | R | C | C | C | A | C | C | R | | | C | C | C |
| A. longerimis | C | Fi | C | C | A | C | C | R | C | F | R | R | C | A | C | | A |
| C. mcmurrichi | F | | R | Fi | R | | C | | F | F | R | R | | | R | R | C |
| T. discaudatus | e | | R | R | R | e | R | | C | Fi | R | | | | Re | | Re |
| M. norvegica | | | | | | R | | R | R | F | | | R | R | | F | |
| O. conifera | R | | | | | | | | | | R | R | R | | | | |
| E. hirundoides | | | | | | | | R | R | F | | | | | | | |
| P. parvus | | | F | R | R | | | | | | | | | | | | R |
| M. rosea | | | R | | | | | | | | | | | | | | |
| C. affinis | | | | R | | | | | | | | | | | | | R |
| C. finmarchicus | C | | C | | R | | | | | | R | C | C | | Ri | | Ri |
| M. lucens | | | | | | | | | | | R | Ri | Ri | | | | |
| E. amphitrites | | | | | R | | | | | | R | R | | | | | R |
| O. plumifera | R | | R | | R | | | | R | | | | | | | | |
| A. armatus | | | | | | | | | | | | | | | | | |
| E. bungii | R | | R | | | | | | | | | R | R | | | | |
| B. similis? | | | | | | | | | | | | | | | | | |
| C. cristatus | | | | | | | | | | | | | R | | | | |
| C. tonsus | | | | | | | | | | | | | | | | | |
| S. minor | | | R | | | | | | | | | | | | | | |
| E. japonica | | | | | | | | | | | | | | | | | |
| C. columbiae | | | | | | | | | | | | | | | | | |
| Pleuromamma | | | | | | | | | | | | | | | | | |
| Heterorhabdus | | | | | | | | | | | | | | | | | |
| Gaetanus | | | | | | | | | | | | | | | | | |
| C. acuicornis | | | | | | | | | | | | | | | | | |
| M. longa | | | | | | | | | | | | | | | | | |
| Rhincalanus | | | | | | | | | | | | | | | | | |
| Chiridius | | | | | | | | | | | | | | | | | |
| S. subdentata | | | | | | | | | | | | | | | | | |

TABLE I (continued)

| Locality | Dixon Entrance | | | | | | | | | | | | | | | | | West Coast Inlets | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 82 | | 83 | | 88 | 87 | | 84 | | 86 | | 85 | | L.I. | 94 | 93 | 99 | O.B | 106 | 110 | | 108 | 109 | 107 | 111 | |
| Haul Depth, meters | 206 | 10 | 364 | 10 | 42 | 42 | 3 | 10 | 3 | 91 | 3 | 55 | 3 | 1 | 55 | 25 | 22 | 14 | | 33 | 14 | 100 | 24 | 219 | 119 | |
| Surface Temp. °C | 11.8 | | | | | 11.8 | | | | | | 12.9 | | | | | | | | | | 12.7 | | 13.7 | | |
| Copepods: | | | | | | | | | | | | | | | | | | | | | | | | | | |
| O.helgolandica | C | C | C | C | C | C | C | C | A | C | C | C | C | A | C | C | C | C | C | C | C | F | R | F | C | C |
| P.minutus | C | C | C | | | C | | F | | C | C | C | | R | C | C | C | | C | C | C | C | Ri | C | C | |
| A.clausi | R | C | F | | C | | F | C | F | | | | | R | F | | R | R | C | | | | | | | |
| A.longerimis | C | C | F | R | C | C | F | C | F | C | C | C | C | | C | C | R | | | | | F | | R | F | F |
| C.mcmurrichi | | | | | F | R | | | | R | | R | | | R | Ri | R | | | | | | | | | |
| T.discaudatus | Fe | | e | | Fe | R | | | | | | R | | | R | R | R | Ri | Ri | Ri | | | Ri | | R | |
| M.norvegica | R | | F | A | | | F | F | F | | F | | F | | | | | | | | | | | | R | |
| O.conifera | | | F | | | | | | | R | | | | | | | | | | | | | | R | R | |
| E.hirundoides | | | | | | | | | | | | | | | | | | | | | | | | | | |
| P.parvus | | | | | | | | | | | | | | | | | | | R | | | | | | | |
| M.rosea | R | | F | | | | | | | | | | | | R | | | | | | | | | | | |
| C.affinis | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.finmarchicus | C | | C | | | | | | | Ri | | Ri | Ri | | | R | R | | | | | R | | | C | |
| M.lucens | C | | | | | | | | | | | | | | | | | | | Ri | | | | Fi | | |
| E.amphitrites | | | | | | | | | | | | | | | | | | | | | | | | | | |
| O.plumifera | | | | | | | | | | | | | | | | | R | | | | | | | | R | |
| A.armatus | | | | | | | | | | | | | | | | | | | | | | | | R | R | |
| E.bungii | R | | F | | | | | | | | | | | | | | | | | | | | | | | |
| B.similis | | | | | | | | | | | | | | | | | | | | | | | | | | |
| C.cristatus | | | R | | | | | | | R | | | | | | | | | | | | | | | | |
| C.tonsus | | | R | | | | | | | | | | | | | | | | | | | | | F | | |
| S.minor | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| E.japonica | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| C.columbiae | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| Pleuromamma | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| Heterorhabdus | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| Gaetanus | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| C.acuicornis | | | | | | | | | | | | | | | | | | | | | | | | | | |
| M.longa | | | C | | | | | | | | | | | | | | | | | | | | | | | |
| Rhincalanus | | | | | | | | | | | | | | | | | | | | | | | | | R | |
| Chiridius | | | R | | | | | | | | | | | | | | | | | | | | | | | |
| S.subdentata | | | | | | | | | | | | | | | | | | | | | | | | | | |

R - rare  F- few  C - common  A - abundant  e - eggs  i - immature only  → - all stages to

TABLE I (continued)

| Locality | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 114 | | 113 | | 112 | | 115 | | 116 | | 128 | | 117 | |
| Depth | 164 | 14 | 45 | 14 | 91 | 14 | 23 | 14 | 24 | 14 | 73 | 14 | 48 | 14 |
| Surface Temp. | 14.8 | | 15.1 | | 15.0 | | 16.2 | | 17.6 | | 13.6 | | 15.0 | |
| Copepods: | | | | | | | | | | | | | | |
| O.helgolandica | C | C | C | | C | R | C | A | C | C | C | C | F | F |
| P.minutus | C | R | C | R | C | | | | | | A | F | A | Ri |
| A.clausi | | | | | | | F | | F | | | F | | |
| A.longerimis | R | F | | | F | | | | | | F | | R | |
| C.mcmurrichi | R | | | | | ?i | | | | | Ri | F | | |
| T.discaudatus | R | | F | | R | | R | | F | R | F | F | F | |
| M.norvegica | | F | | | | R | | F | | R | | F | | |
| O.conifera | | | R | | C | F | R | | F | F | | | | |
| E.hirundoides | | | | | | | | | | | | | | |
| P.parvus | | R | | | F | F | F | | C | Fi | | | | |
| M.rosea | | | | | | | | | | | | | | |
| C.affinis | | | | | R | | | | C | R | | | | |
| C.finmarchicus | R | | | | F | | | | | | | | | |
| M.lucens | | | | | | | | | | | | | | |
| E.amphitrites | | | | | | | | | F | | | | | |
| O.plumifera | F | | | | | | | | | | | | | |
| A.armatus | | | | | | | | | | | | | | |
| E.bungii | R | | | | | | | | | | | | | |
| B.similis | | | | | | | | | | | | | | |
| C.cristatus | | | | | | | | | | | | | | |
| C.tonsus | R | | | | | | | | | | | | | |
| S.minor | | | | | | | | | | | | | | |
| E.japonica | | | | | | | | | | | | | | |
| C.columbiae | | | | | | | | | | | | | | |
| Pleuromamma | | | | | | | | | | | | | | |
| Heterorhabdus | | | | | | | | | | | | | | |
| Gaetanus | | | | | | | | | | | | | | |
| C.aculcornis | R | | | | | | | | | | | | | |
| M.longa | | | | | | | | | | | | | | |
| Rhincalanus | | | | | | | | | | | | | | |
| Chiridius | | | | | | | | | | | | | | |
| S.subdentata | | | | | | | | | | | | | | |

R - rare F - few C - common A - abundant e - eggs i - immature only → - all stages to

TABLE I (continued)

| Locality | Tasu Inlet | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 121 | | 123 | | 122 | | 119 | | 118 | | 120 | 124 |
| Depth | 36 | 14 | 30 | 14 | 95 | 14 | 175 | 14 | 347 | 54 | 14 | 643 |
| Surface Temp. | | | 18.3 | | | | 18.7 | | | | | |
| Copepods | | | | | | | | | | | | |
| O.helgolandica | C | R | R | R | R | F | F | R | | F | F | R |
| P.minutus | F | | R | F | F | | F | | F | A | C | C |
| A.clausi | | | | | | | | | | | | |
| A.longerimis | R | | | | | R | R | R | | F | | R |
| C.mcmurrichi | R | | | | | | R | | | | | |
| T.discaudatus | R | | | | | | | | | | | |
| M.norvegica | | | | | R | R | | | R | | | R |
| Olconifera | C | C | C | C | C | C | C | C | F | C | C | C |
| E.hirundoides | | | | | | | | | | | | |
| P.parvus | A | C | C | C | C | C | C | A | F | C | C | |
| M.rosea | | | | | R | | | | | | | |
| C.affinis | F | | F | R | R | R | R | R | F | | F | |
| C.finmarchicus | Fi | | F | | C | | C | | A | Fi | F | C |
| M.lucens | | | | | | | R | | C | | | C |
| E.amphitrites | R | | R | | | | | | | R | | |
| O.plumifera | | | | | | | | | | F | | |
| A.armatus | R | | R | | C | | F | | F | R | | R |
| E.bungii | | | | | | | | | | | | F |
| B.similis | | | | | | | | | | | | |
| C.cristatus | | | | | | | | | R | | | R |
| C.tonsus | | | | | | | | | R | | | |
| S.minor | | | | | | | R | | R | | | F |
| E.japonica | | | | | | | | | R | | | R |
| C.columbiae | | | | | | | | | | | | R |
| Pleuromamma | | | | | | | | | | | | R |
| Heterorhabdus | | | | | | | | | | | | R |
| Gaetanus | | | | | | | | | | | | R |
| C.acuicornis | | | | | | | | | | | | |
| M.longa | | | | | | | | | | | | |
| Rhincalanus | | | | | | | | | | | | |
| Chiridius | | | | | | | | | C | | | F |
| S.subdentata | | | | | | | | | | | | R |

R - rare

F - few

C - common

A - abundant

e - eggs

i - immature only

→ - all stages to

TABLE I (continued)

| Locality | | | | | | | | | | | | | | | | | | Masset Inlet | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 126 | | 125 | 127 | | Adam Rk. | | 129 | | 130 | | 131 | | 74 | | 75 | | 76 | | 77 | | 78 | |
| Depth, meters | 20 | 14 | 36 | 50 | 14 | 120 | 14 | 45 | 14 | 41 | 14 | 20 | 14 | 48 | 3 | 30 | 3 | 87 | 3 | 55 | 3 | 38 | 3 |
| Surface Temp °C | | | 15.8 | | | | | | | | | 13.4 | | | | | | | | | | | |
| Copepods | | | | | | | | | | | | | | | | | | | | | | | |
| O.helgolandica | C | C | C | C | C | C | C | F | F | C | C | C | C | F | C | F | C | C | C | C | C | F | |
| P.minutus | C | | | C | | C | R | C | F | C | F | | | A | C | C | C | A | C | C | C | A | A |
| A.clausi | R | F | R | | | | | | | | | C | | F | F | F | F | R | F | R | C | R | C |
| A.longerimis | C | | C | F | | F | | R | F | F | R | C | Ri | F | | C | | R | | | | F | |
| C.mcmurrichi | R | | | R | | F | | | | R | | Ri | Ri | F | F | C | F | R | | R | | C | F |
| T.discaudatus | R | | Ri | C | | F | | A | C | F | | Ri | | ? | | | | | | | | e | |
| M.norvegica | F | R | | | | | F | R | R | | F | | F | | | | | | | | | | |
| O.conifera | | R | R | | | | | | | | | | | R | | | | C | | C | F | F | |
| E.hirundoides | | | | | | | | | | | | | | | | | | | | | | | |
| P.parvus | F | | | | | | | | | | | F | | | | | | | | | | | |
| M.rosea | | | | | C | | | | | | | | | | | | | | | | | | |
| C.affinis | | R | | | | | | | | | | R | | | | | | | | | | | |
| C.finmarchicus | Ri | | | | | | R | | Ri | | | | | | | | R | F | | F | | | |
| M.lucens | | | Ri | | | | | | | | | | | R | R | | | C | | C | | F | |
| E.amphitrites | | | Ri | | | | | | | R | | | | R | | F | | R | | | | Ri | |
| O.plumifera | | | R | | | F | | | | R | | | | | | | | | | | | | |
| A.armatus | | | | | | | | | | | | | | | | | | | | | | | |
| E.bungii | | | | | | | | | | | | | | | | | | | | | | | |
| B.similis | | | | F | | R | | | | | | | | | | | | | | | | | |
| C.cristatus | | | | | | | | | | | | | | | | | | | | | | | |
| C.tonsus | | | | | | R | | | | | | | | | | | | | | | | | |
| S.minor | | | | | | | | | | | | | | | | | | | | | | | |
| E.japonica | | | | | | | | | | | | | | | | | | | | | | | |
| C.columbiae | | | | | | | | | | | | | | | | | | | | | | | |
| Pleuromamma | | | | | | | | | | | | | | | | | | | | | | | |
| Heterorhabdus | | | | | | | | | | | | | | | | | | | | | | | |
| Gaetanus | | | | | | | | | | | | | | | | | | | | | | | |
| C.aculcornis | | | | | | | | | | | | | | | | | | | | | | | |
| M.longa | | | | | | | | | | | | | | | | | | | | | | | |
| Rhincalanus | | | | | | | | | | | | | | | | | | | | | | | |
| Chiridius | | | | | | | | | | | | | | | | | | | | | | | |
| S.subdentata | | | | | | | | | | | | | | | | | | | | | | | |

R - rare F - few C - common A - abundant e - eggs i - immature only → - all stages to

# TABLE VI

## MASSET INLET STATION 89, JULY 24, 1953

| Depth | Time | P.minutus | O.helgolandica | C.mcmurrichi | A.clausi | M.lucens | C.finmarchicus | O.conifera |
|---|---|---|---|---|---|---|---|---|
| 1 | 0015 | Ci→♀ | Ci→A | Fi→♀♂ | F→♂ | R III | | |
| 3 | 0045 | Ci→♀♂ | C | C ♀♂ | F→♀ | C I→V A | F V A | Ri ○○ |
| 10 | 0130 | Ci | C | F V ♂ | R→♂ | C III→V | F V | Fi |
| 14 | 0200 | C " | C | | | C II→A | F V | C |
| 25 | 0230 | C " | C | | R ♀ | C II→A | F V | C |
| 36 | 0245 | R ♀ | C | | R ♀ | Ci→♂ | F V | C |
| 50 | 0300 | F I V | F | | | C II→♀♂ | R V | C |
| 64 | 0310 | F I V | R | | R ♀ | C II→♂ | F V | eggs Ci |
| 82 | 0345 | C | | | F | R | C V | C? |
| 74 | 0030 | C | R | R | | C | C V | C? |
| 74 | 0630 | C | F | R | | C | C V | C eggs |
| | | | | | | | | |
| 1 | 0805 | C→♀♂ | F A | F ♀ | Ri ♂ | R III | | F ○○ |
| 3 | 0815 | C " | F→♀♂ | R ♂ | Ri ♀ | R III | | C |
| 10 | 0840 | C " | C " | R ♀ | | F III→V | | C |
| 19 | 0900 | C " | C " | | | F III→V | | C |
| 30 | 0915 | F " | C " | | | C II→♀ | R V | C |
| 50 | 0930 | R " | F " | | | C →♀♂ | C V→♀ | eggs F |
| 74 | 0930 | C " | F " | F→♀♂ | R ♀ | C →♀♂ | C V→♀ | eggs C |

C - common   F - few   R - rare   i - immature   → - from younger stages to   A - adults

TABLE VI (continued)

| Depth | Time | P.minutus | O.helgolandica | C.mumurrichi | A.clausi | M.lucens | C.finmarchicus | O.conifera |
|---|---|---|---|---|---|---|---|---|
| 1 | 1300 | C→♀ | C → ♀♂ | F→♀ | R ♀♂ | R I | | R ♀♂ |
| 3 | 1310 | C→♀ ♂ | Ci | F→♀ ♂ | | R IV | | R |
| 10 | 1345 | C→♀ ♂ | C → ♀♂ | R imm | | R II→V | | C |
| 14 | 1410 | F→♀ ♂ | C → ♀♂ | | | F II→III | | C |
| 25 | 1413 | R→♀ | C → ♀♂ | | | F II→III | | C |
| 36 | 1445 | R→♀ | C → ♀ | | | C II→♀♂ | R V | C |
| 50 | 1455 | R→♀ | R - ? | | | C → ♀♂ | C V | C |
| 64 | 1505 | F→♀ | R | | | C →♂ | C V | eggs C |
| 75 | 1530 | A | F | R ♀ | R ♀ | C →♂ | A | eggs C |
| 1 | 1820 | C→♀ ♂ | F→♀♂ | F→♀♂ | R ♂ | R III | | R ♂ |
| 3 | 1840 | C→♀ ♂ | F→♀♂ | F→♀ | R ♀ | R III | | R ♀ |
| 10 | 1845 | C→♀ ♂ | C→♀♂ | | | R III→IV | | F ♀ ♂ |
| 20 | 1900 | F→♀ ♂ | C→♀♂ | | | R III→IV | | C |
| 30 | 1915 | R→♀ | C→♀♂ | | | C I→♀ | R IV | C |
| 50 | 1925 | R | F | | | C→♀♂ | F V | eggs C |
| 75 | 1830 | C | C | F | | C | C | eggs C |

C - common F - few R - rare i - immature → - from younger stages to A - adults

TABLE VII

THE AGE PROPORTIONS OF COPEPODITE STAGES OF *M. lucens* AND *C. finmarchicus*

| Station | I | II | III | IV | V | ♀ | ♂ |
|---|---|---|---|---|---|---|---|
| *Metridia lucens* | | | | | | | |
| 74 | 8 | 6 | 2 | 1 | | | |
| 75 | 13 | 9 | 1 | 6 | 1 | | |
| 76 | 28 | 18 | 6 | 3 | 2 | 1 | |
| 77 | 27 | 10 | 4 | 3 | 11 | 3 | 5 |
| 78 | 21 | 9 | 5 | 0 | 3 | | 1 |
| *Calanus finmarchicus* | | | | | | | |
| 75 | | | | | 1 | | |
| 76 | | | | | 4 | 1 | |
| 77 | | | | | 10 | | |