DISTRIBUTION, ABUNDANCE AND BIOMASS OF THE MACROZOOPLANKTON OF KANEOHE BAY, OAHU, HAWAII 1966-1971

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ABSTRACT

Many hundreds of zooplankton samples have been collected in Kaneohe Bay during the years 1950 through 1970, but data from the various studies completed during this interval are not generally available. This report makes available enumeration data from about 300 zooplankton samples collected between December 1966 and March 1971.

A general feature of zooplankton distribution and abundance in the bay is that highest total zooplankton abundances are found in the eutrophic southeastern basin, but only a few species have their greatest abundance there. Most species abundances change along an environmental gradient. Spatial abundance patterns for the 19 most important macrozooplankton taxa are discussed.

The data presented in this report are compared to results of studies completed by Hiatt (1951) and Piyakarnchana (1965). During the twenty-year period of 1950-1970, total zooplankton abundance seems to have increased somewhat, presumably as a result of eutrophication, but there have been few changes in zooplankton species composition. The only change is that macrocopepods have become less common in the southern sector of the bay and the pelagic tunicate, *Oikopleura longicauda*, has become more abundant.

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INTRODUCTION

This technical report makes available three separate sets of previously unpublished zooplankton enumeration data and some biomass data collected in Kaneohe Bay between 6 December 1966 and 4 March 1971. The first set of data, collected between 6 December 1966 and 23 February 1968, was the basis of a Master of Science thesis completed by myself (Peterson, 1969). The second set (24 July 1968 - 12 June 1969) was collected by R. Clutter and others as part of a study to evaluate possible effects of domestic sewage on Kaneohe Bay. The third set (13 December 1970 - 4 March 1971) is a small portion of the samples collected by J. Miller (HIMB) as part of a study of the distribution and abundance of fish larvae. With the exception of 32 samples in the Clutter data, I was responsible for the enumeration of all samples presented in this report.

This report is divided into four parts. Part I is a general discussion of some of the results found in each of the three data sets. Each data set (i.e., the Peterson, Clutter and Miller data) is discussed separately. Much of Part I is a summary of Peterson (1969). Part II is a discussion of seasonal cycles of zooplankton abundance and other patterns of abundance of 19 important taxa. In this section, I integrate previously published Kaneohe Bay zooplankton data with data presented in the appendix of this report. Differences in abundance between years are compared where possible. In Part III, the biomass data are given. Dry weights, ash-free dry weights, caloric content and carbon-hydrogen-nitrogen content are given for selected zooplankton. Part IV contains the zooplankton enumeration data in appendix form. Charts showing sampling locations, and methods of sample collection are included with these data.

Almost all of the data discussed in this report are from zooplankton samples collected with relatively coarse mesh nets, having either 0.3 mm or 0.5 mm meshes. I chose to define the term "macrozooplankton" as including those taxa quantitatively retained by nets having the above stated mesh sizes. Some information is available on the "microzooplankton" of Kaneohe Bay. Abundances of taxa in this size class, primarily small copepods, are discussed briefly later in this report.

The data given in this report were collected under NSF grants GB-5698 and GB-7132, and a University of Hawaii Institutional Sea Grant No. 2-35243.

PAST STUDIES AND LIMITATIONS OF INDIVIDUAL DATA SETS

Although a number of field surveys of macrozooplankton abundance have been completed within Kaneohe Bay, individual data sets are not strictly comparable for one reason or another. Data from each study have their own unique problems.

Hiatt (1951) carried out a bimonthly survey of the macrozooplankton of the bay over a 12 month period. His data have limited utility for a number of reasons. No mention is made of sampling station locations, of the type of plankton net used, of net mesh size, or of the method of towing the net. I could not even find out in what year his study was done. Data on abundance of taxa are presented qualitatively (i.e., the data are tabulated as "abundant, common or rare"). Nonetheless, these data have some value for their relative abundances and, as discussed later in this report, they do seem to indicate that there have been some changes in zooplankton community composition, between the years of 1950 and 1970.

Piyakarnchana (1965) carried out a bimonthly survey over the 12 month period August 1963 through July 1964. A regular set of stations in the southern sector of Kaneohe Bay were occupied. The top few meters of the water column were sampled with nets towed horizontally. Net mesh size was 0.285 mm. Enumeration data were not given for all taxa, but abundances of some of the important taxa can be extracted from his figures. He tabulated the abundances of other taxa in the same manner as Hiatt, as abundant, common or rare. There is one limitation on these data of Piyakarnchana: since net tows sampled only the top few meters of the water column, the data are not representative of the zooplankton living deeper in the water column.

Ziemann (1970) studied zooplankton patchiness from serial samples collected within the top 50 cm of the water column by a Longhurst-Hardy Plankton Recorder. The plankton net had a 50 cm mouth diameter and 0.33 mm meshes. Horizontal tows were taken along nine transect lines on three dates: 4 March, 19 June and 29 September 1969. Enumeration data are available for the more important taxa, and are listed in his report.

Peterson's data (this report) were gathered over a 15 month period but more than half of the samples were taken during the months of November through February. Other samples were collected at irregular intervals. A variety of sampling gear were used, including conical nets having 0.5 m and 1 m mouth diameters, and a plankton purse seine. All nets were constructed of 0.33 mm mesh Nitex nylon mesh.

Clutter's data are from nets having a 0.5 m diameter mouth, hauled vertically through the water column. Net meshes were 0.33 mm. Nine stations, representing the entire bay, were sampled regularly between July 1968 and June 1969.

Miller's data are from nets pushed through the surface layer of the water column. The nets were square-mouthed of 0.36 m^2 area. Net mesh apertures were 0.5 mm. Serial samples were gathered on three dates between December 1970 and March 1971.

A DESCRIPTION OF KANEOHE BAY

A comprehensive discussion of the history, geology, hydrology and physical oceanography of the Kaneohe Bay area can be found in the report, "Estuarine Pollution in the State of Hawaii. Vol 2: Kaneohe Bay Study", Technical Report No. 31, Water Resources Research Center, University of Hawaii, Honolulu, Hawaii. Also, see Bathen (1968) for a study of the physical oceanography of the bay. The remarks which follow are taken from Peterson (1969).

Kaneohe Bay is located on the windward side of Oahu, Hawaiian Islands. The total area of the bay is about 45 km^2. One-third of this area is fringing and patch reef covered by about 1 m of water at high tide. The average depth of the remainder of the bay is 12 m. The maximum depth is 19 m.

Tester (1951) divided the bay into three geographical areas. Each of the areas is unique. The northern sector is neritic-oceanic in character. There are no reef barriers shallower than about 3 m, so exchange between the bay and ocean are high. A narrow navigation channel has been dredged through the northern sector reefs which improves the deep circulation in this region. The middle sector is lagoonal in character. It lies behind a large shallow barrier reef of coral and sand. Water flows freely over this barrier only at high tide. The southern sector is a semi-enclosed basin. Flow of oceanic water into this basin is restricted by Mokapu Peninsula and by Mokuoloe Island (Coconut Island, location of the Hawaii Institute of Marine Biology). Fifty percent of the freshwater runoff into the bay comes into this basin. In addition, two sewer outfalls are located in this southern basin.

A fourth sector, a transition zone between the southern sector and middle sector was added by myself. The four sectors were thought to contain distinct faunal assemblages. Clutter (1973) redefined my transition zone and southern sector boundaries. Both his boundaries and mine are shown on the chart of Kaneohe Bay in Figure 1.

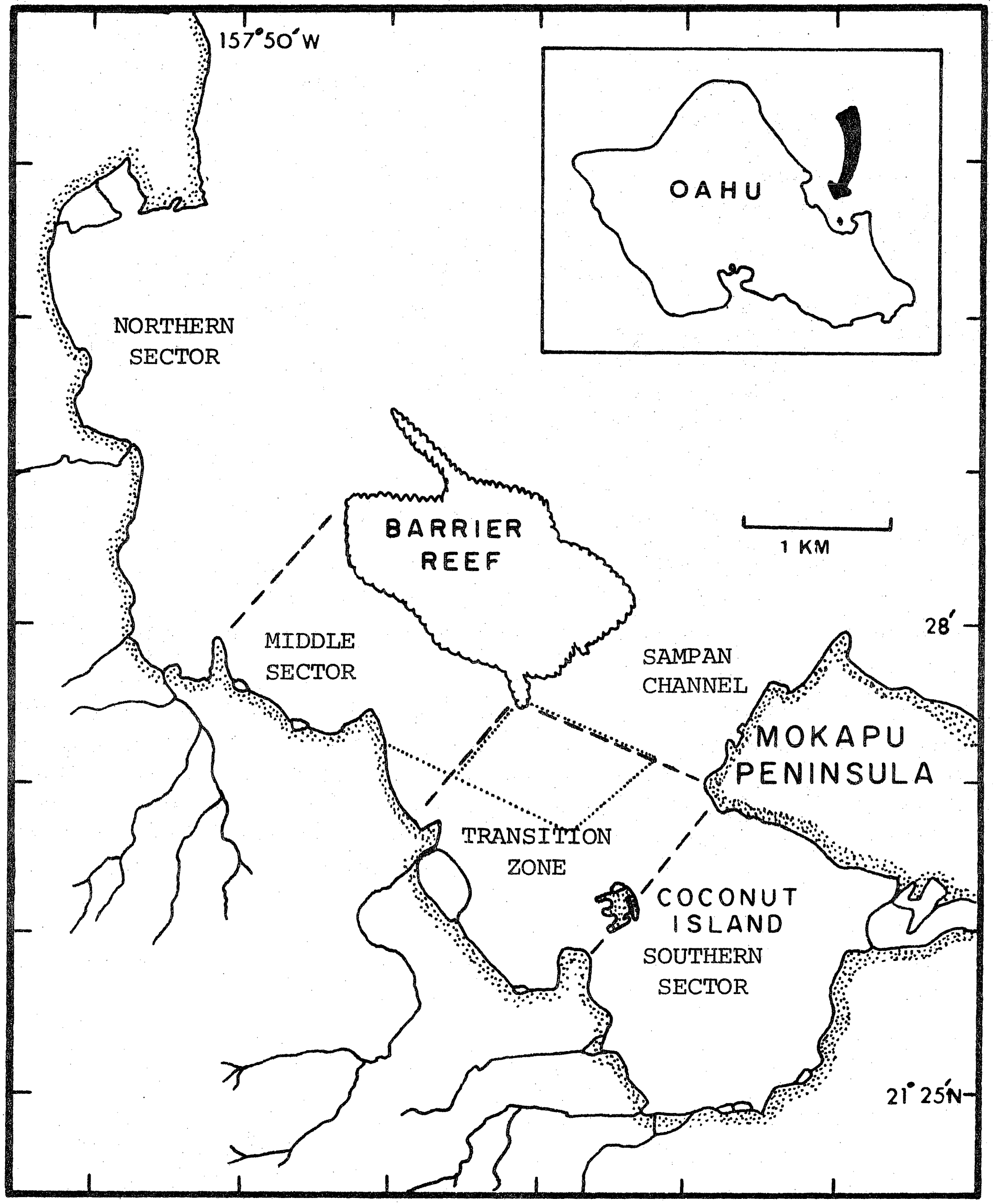

Figure 1. Reference chart of Kaneohe Bay. The boundaries of the various sectors defined by Peterson (1969) are indicated by the dashed lines. Clutter (1973) reduced the area of the transition zone (shown by the dotted lines) to about one-third of Peterson's area and increased the area of the southern sector to include most of Peterson's transition zone.

PART I. GENERAL REMARKS

THE PETERSON DATA

This data set includes samples gathered between 6 December 1966 and 23 February 1968. Collection methods and the data are presented in the appendix. The primary goal of this sampling program was to compare abundance and diversity of macrozooplankton found in the different geographical sectors. To the best of my knowledge, these samples were the first to be collected outside of the southern sector of Kaneohe Bay. Samples were collected at irregular intervals, so conclusions about seasonal cycles of abundances were not possible. More than half of the samples were collected between November 1967 and February 1968.

DISTRIBUTION AND ABUNDANCE OF THE RESIDENT COMPONENTS

Sixty-eight taxa were recognized in this study, but only 43 of them were considered to be permanent residents of Kaneohe Bay. The other 25 were transported into the bay from the offshore neritic community. Of the 43 resident taxa, only 19 had average abundances in excess of $5/m^3$. These 19 animals were:

(1) The Copepods *Acartia hamata*, *Undinula vulgaris*, *Labidocera hawaiiensis*, and *Pseudodiaptomus marinus*

(2) The Holoplanktonic Carnivores *Sagitta enflata*, *Lucifer chacei*, and ctenophores

(3) The Holoplanktonic Herbivores Oikopleura longicauda, Lucifer chacei protozoeas and schizopods, and cladocerans (Evadne sp)

(4) The Meroplanktonic crab zoeas, decapod shrimp mysis, barnacle nauplii, gastropod veligers A and B, hydromedusae A and E, and Nehu (anchovy) eggs

Abundances of all permanent resident components can be found in tables in Peterson (1969). Table 1 of this report lists the average abundances of the 19 important taxa listed above. In Part II of this report, seasonal cycles of distribution and abundance of these 19 taxa are discussed.

Most of the 43 resident species were not equally abundant in all sectors of the bay. Many species populations changed in numbers along an environmental gradient from the southern sector through the transition zone and middle sector to the northern sector. All resident components were placed into one of three distributional categories depending upon how they seemed affected by the environmental gradient.

1. Negative Gradients: Animals that had their maximum abundance in the southern sector

2. Positive Gradients: Animals that had their maximum abundance in the northern sector, middle sector or transition zone, and graded to lower abundances in the southern sector

3. Zero Gradients: Animals that seemed to be cosmopolitan throughout the middle sector, transition zone and southern sector

The important resident taxa are grouped in Table 1 according to their response to the environmental gradient.

Table 1. Abundance (number/m^3) of the important zooplankton taxa, averaged over only those samples in which the taxa occurred, in the southern sector (S), transition zone (T), middle sector (M), northern sector (N) and Sampan channel (C). Animals are grouped by their abundance pattern. Taxa in the first group were most abundant in the southern sector. Taxa in the second group were most abundant outside of the southern sector. Taxa in the third group were equally abundant in the southern sector, transition zone and middle sector, on the average. The abundances listed are from Peterson's data only.

	S	T	M	N	C
GROUP 1					
barnacle nauplii	478.8	82.7	1.0		177.7
Sagitta enflata	318.6	239.6	132.5	14.5	5.0
Hydromedusae-E	246.0	45.1	4.4	0.1	1.6
gastropod veliger-A	62.5	43.3	2.9	5.8	3.7
Hydromedusae-A	25.3	1.6	0.8	0.1	0.6
Anchovy eggs	9.5	4.6	4.2		1.3
gastropod veliger-B	5.5	1.5	0.3		1.4
Pseudodiaptomus	11.6	2.9	3.4		0.4
GROUP 2					
crab zoea	13.2	45.1	14.3	1.5	50.0
Lucifer protozoea	15.4	17.8	5.6	0.2	20.0
Lucifer schizopod	9.4	19.0	4.2	2.5	3.1
Lucifer adults	6.5[a]	12.8	4.6	0.8	5.6
Cladocerans	5.8	8.4	0.2		
decapod shrimp mysis	6.3	21.3	24.6	1.9	16.2
Undinula vulgaris	0.8	4.7	11.9	6.7	13.2
Labidocera hawaiiensis	1.8	8.1	7.1	6.3	19.2
Acartia hamata	2.4	6.3	19.0	17.1	27.4
GROUP 3					
Oikopleura longicauda	121.3	98.0	111.1	28.5	47.9
Ctenophores	21.8	17.2	23.4[b]	0.1	1.1

a = does not include April-June 1967 samples
b = does not include one large catch on 5 October 1967

The following 21 resident taxa were most abundant in the southern sector: The copepods Pseudodiaptomus marinus and Cyclops-type, the chaetognath Sagitta enflata, scyphomedusae B, C, and D, mysids, hydromedusae A and E, polychaete trochophores and post-trochophores, brachiopod larvae, bivalve and gastropod veligers, echinoderm bipinnaria, barnacle nauplii and cypris, crab megalops and Nehu eggs. Three of these taxa were never found outside of the southern sector: bipinnaria larvae, polychaete trochophores, and the copepod Cyclops-type.

Thirteen taxa had their greatest abundance outside of the southern sector. Seven were most abundant in the transition zone. They were: ostracods, cladocerans, the sergestid shrimp Lucifer chacei adults and larvae, crab zoea and Stenopus (cleaner shrimp) larvae. Four taxa were most abundant in the middle sector: decapod shrimp mysis, stomatopod larvae, hyperiid amphipods and the copepod Undinula vulgaris. Two taxa, both copepods, had their greatest abundance in the northern sector: Acartia hamata and Labidocera hawaiiensis. All of the above taxa occur frequently in the southern sector with the single exception of Stenopus larvae. It was never taken in the southern sector.

Nine taxa had equal average abundances in the southern sector, transition zone and middle sector. They were the pelagic tunicate Oikopleura longicauda, a lobate ctenophore species, a gammarid amphipod (Amphipod A) and polychaete late-stage larvae (listed as "frog" in the appendix because the shape of the taxa vaguely resembled a squatting frog). Five taxa in this category were rarely seen: scyphomedusae ephyra and four species of harpacticoid copepod. All harpacticoid counts have been lumped in the appendix data.

FREQUENCY OF OCCURRENCE

Ten taxa occurred in 50% or more of all samples collected in the southern sector, transition zone and middle sector, so were considered ubiquitous. They were Acartia hamata, Sagitta enflata, ctenophores, Lucifer chacei adults and larvae, Oikopleura longicauda, gastropod veliger-A, crab zoeas and decapod mysis.

RELATIVE ABUNDANCE

The abundance of a species relative to the abundance of all other species taken with it in a sample provides some information about community structure. Relative abundance is expressed herein as a percentage of the total catch.

There were gradients of relative abundance but the pattern of the gradient sometimes differed from the pattern seen for average abundance, for some of the important taxa. For example, Sagitta enflata was most abundant in the southern sector but made up only 33% of the catch, on the average. Its relative abundance was greatest in the transition zone where it averaged 40% of the catch. Relative abundance in the middle sector was 29% of the catch. Both Oikopleura and ctenophores were more important on a percentage basis in the middle sector. Table 2 lists averaged relative abundance for the more important taxa.

RANKED ORDER OF ABUNDANCE

Species abundance was ranked in each sample in order of decreasing abundance. Rank-frequency tables were generated (Tables 3,4, and 5).

Table 2. Averaged relative abundances, expressed as a percent of the total catch, for the most important zooplankton occurring in the southern sector, transition zone, and middle sector. Percentages were averaged over only those samples in which the taxa occurred.

	Southern Sector	Transition Zone	Middle Sector
HOLOPLANKTON			
Acartia hamata	0.3	1.2	7.9
Undinula vulgaria	0.1	1.2	2.2
Labidocera	0.4	1.7	2.4
Sagitta enflata	33.5	40.2	28.6
Lucifer chacei	* 1.0	3.0	1.1
Ctenophores	2.7	2.9	15.2
Oikopleura longicauda	16.0	16.1	25.5
Lucifer protozoea	2.5	2.8	2.0
Lucifer schizopod	1.3	3.5	1.3
MEROPLANKTON			
Medusa A	5.4	0.5	0.4
Medusa E	15.2	4.8	1.0
Veliger A	4.7	5.5	6.5
Barnacle nauplii	25.7	10.5	0.2
Crab zoea	2.3	9.0	2.9
Decapod mysis	0.9	2.8	7.4

* Does not include May-June 1967 samples.

Table 3. Rank-frequency distribution, mean rank, and overall rank of the 14 most important zooplankton taken in the southern sector. The rank-frequency distribution is given only for the first 10 ranks. Sum of ranks includes all possible ranks. Rank 1 indicates greatest abundance.

	Ranks										Sum of Ranks	Mean Rank	Overall Rank
	1	2	3	4	5	6	7	8	9	10			
Sagitta enflata	36	29	6	4		1	1				141	1.83	1
Barnacle nauplii	25	7	15	9	1	2	2	1	2	1	268	3.83	2
Oikopleura	7	17	23	15	3		1	1		4	335	4.47	3
Medusa E	2	3	7								93	4.65	4
Veliger A	2	4	11	10	14	8	4	3	6	2	422	6.81	5
Crab Zoea		2	3	9	9	14	7	12	4	11	535	6.95	6
Ctenophores		4	1	14	8	5	9	5	3	6	453	7.08	7
Lucifer protozoea		1	5	2	12	12	15	2	7	4	547	7.49	8
Amphipod A					1		1	3	2	1	362	7.93	9
Decapod mysis			2	1	3	8	7	12	10	10	634	8.93	10
Anchovy eggs				1	3	2	1	2	2	1	260	8.96	11
Lucifer adults	3	1	1	1	6	1	4	4	2	2	431	9.17	12
Lucifer schizopod		2		1	3	5	7	10	7	10	616	9.62	13
Medusa A	2	3	2	5	3	1	4	5	3	2	499	9.98	14

Table 4. Rank-frequency distribution, mean rank, and overall rank of the 14 most important zooplankton taken in the transition zone.

	Ranks 1	2	3	4	5	6	7	8	9	10	Sum of Ranks	Mean Rank	Overall Rank
<u>Sagitta enflata</u>	39	11	4	3							85	1.49	1
<u>Oikopleura</u>	9	12	9	10	4	3	2	1		2	232	4.07	2
Medusa E	1	1	2	6	1		1		2	2	182	4.44	3
Crab zoea	1	11	8	7	7	4	6	7	4	1	289	5.07	4
Veliger A		3	15	6	6	10	7	2	5	2	317	5.56	5
Decapod mysis		4	6		7	6	5	11	7	6	402	7.05	6
<u>Lucifer</u> protozoea		2	1	6	8	8	5	5	6	5	405	7.23	7
Barnacle nauplii	5	5	3	4	1	1	2	1	2	7	359	7.81	8
Ctenophores		3		4	5	8	12	6	3	2	432	8.00	9
<u>Lucifer</u> adults		3	5	2	6	4	3	5	2	5	419	8.21	10
<u>Lucifer</u> schizopod	1	2	2	3	6	7	2	4	4	5	434	8.51	11
Amphipod A						1	2	1	4	1	255	10.20	12
<u>Acartia hamata</u>					5	1	4	3	3	6	480	10.43	13
Medusa A				1		1		1		1	370	10.88	14

Table 5. Rank-frequency distribution, mean rank, and overall rank of the 14 most important zooplankton taken in the middle sector.

	Ranks										Sum of Ranks	Mean Rank	Overall Rank
	1	2	3	4	5	6	7	8	9	10			
<u>Oikopleura</u>	7	8	6		1	1	1				72	2.88	1
<u>Sagitta</u>	8	10	2	1	2	1		1			75	2.88	2
Decapod mysis	2	1	7	5	2	2	2	2	3		124	4.76	3
Veliger A	1	2	6	4	3	2			1	1	128	6.34	4
Crab zoea			4	3	1	5	1	1	3	3	142	6.45	5
Ctenophores	6	1		2	1	2	4	1	1	3	164	6.56	6
<u>Lucifer</u> protozoea			1	3	3	3	3	1	3	2	149	7.09	7
<u>Acartia hamata</u>	2	2		2	2	3			1	2	186	8.08	8
<u>Lucifer</u> schizopod				2	2	3	1	1	3	3	157	8.26	9
<u>Lucifer</u> adults				1	3		5	4	2	1	191	8.68	10
<u>Undinula vulgaris</u>	1			1	2	3	1		1	3	190	9.05	11
Amphipod A					2	2	4		2	1	154	9.62	12
<u>Labidocera</u>		1	1				1	4	1	3	188	9.89	13
Stomatopod larvae								2		4	167	11.13	14

On the basis of the sum of ranks and overall rank in each sector, seven species were found to be common to the first ten ranks in the southern sector, transition zone and middle sector. These were *Sagitta enflata*, *Oikopleura*, ctenophores, *Lucifer chacei* protozoea, decapod mysis, crab zoea. and gastropod veliger-A. In addition, barnacle nauplii and hydromedusae-E had high ranks in the southern sector and transition zone. These nine taxa seem to be the most important macrozooplankton in the bay.

MACROZOOPLANKTON ASSEMBLAGES IN EACH SECTOR

Several distinct macrozooplankton assemblages can be described for Kaneohe Bay. The trophic structure is different in each sector and each sector seems to harbor its own unique assemblage.

THE SOUTHERN SECTOR. Six species of the 55 taxa taken in the southern sector made up more than 90% of the average standing stock, on a numerical basis: barnacle nauplii (454/m^3), *Sagitta enflata* (319/m^3), hydromedusae-E (143/m^3), *Oikopleura longicauda* (118/m^3), gastropod veliger-A (62/m^3) and ctenophores (18/m^3). All other 49 taxa had average abundances less than 18/m^3.

Copepods made up only 0.5% of the macrozooplankton standing stock, carnivorous holoplankton 31%, herbivorous holoplankton 13%, and meroplankton constituted about 56%. The latter group are mostly herbivorous or omnivorous forms.

THE TRANSITION ZONE. Nine of the 57 taxa taken in the transition zone made up 90% of the averaged total catch: *Sagitta enflata* (240/m^3), *Oikopleura longicauda* (98/m^3), barnacle nauplii (68/m^3), crab zoea (45/m^3), gastropod veliger-A (43/m^3), decapod mysis (21/m^3), hydromedusae-E (18/m^3), Lucifer protozoeae (18/m^3) and Lucifer schizopods (17/m^3).

Copepods made up 2.5% of the average standing stock, carnivorous holoplankton 44%, herbivorous holoplankton 22% and meroplankton 35%.

The major contrast between the southern sector and transition zone was in meroplankton composition. Barnacle nauplii and hydromedusae declined sharply in the transition zone.

THE MIDDLE SECTOR. Six species made up greater than 90% of the average catch: Sagitta enflata (132/m^3), Oikopleura longicauda (107/m^3), ctenophores (34/m^3), decapod mysis (25/m^3), gastropod veliger-A (17/m^3), and Acartia hamata (17/m^3). Copepods made up 9% of the standing stock, holoplanktonic carnivores 47%, holoplanktonic herbivores 32% and meroplankton 12%.

General characteristics of the middle sector assemblage were high numbers of macrocopepods near the barrier reef, and high numbers of both ctenophores and decapod shrimp mysis. Few barnacle nauplii were taken in the middle sector. The overall rank of Sagitta enflata was rank 2. Oikopleura longicauda was rank 1.

THE NORTHERN SECTOR. Only four samples were taken in the northern sector, so the following statements must be considered extremely tenuous.

Six species made up 90% of the standing stock: Oikopleura longicauda (28/m^3), Acartia hamata (17/m^3), Sagitta enflata (14/m^3), Labidocera hawaiiensis (7/m^3), Undinula vulgaris (6/m^3) and gastropod veligers (6/m^3).

Copepods made up 37% of the catch, carnivorous holoplankton made up 19%, herbivorous holoplankton 36% and meroplankton 8%.

THE SAMPAN CHANNEL. The zooplankton found in the Sampan Channel varied with the tide. During incoming tide, the copepods Acartia hamata, Undinula vulgaris, and Labidocera hawaiiensis dominated the catch. During outgoing tide, high numbers of meroplankton, particularly barnacle nauplii and crab zoea were taken. Very low numbers of all holoplanktonic carnivores and hydromedusae were found. Relative densities of carnivores were lowest in the channel. Lucifer chacei adults averaged 5.5/m^3, Sagitta enflata 5/m^3, hydromedusae-E 1.6/m^3, ctenophores 1/m^3 and hydromedusae-A 0.6/m^3.

The paucity of holoplanktonic carnivores may be explained by one of three hypotheses. Either water from the bay does not enter the channel during outgoing tide, or else it does go out the channel and the chaetognaths, hydromedusae, and ctenophores suffer mortality. If the latter hypothesis can be shown to be essentially correct, then one would have a mortality source for these carnivores. An alternate hypothesis is that only the top meter or two of the water column is exchanged with the tides. If the carnivores usually avoid the top two meters of the water column, then this would be a mechanism for their avoiding removal from the bay during outgoing tides.

DIVERSITY OF THE MACROZOOPLANKTON ASSEMBLAGES

Four diversity indices were calculated. Calculated values for each sample are listed in Peterson (1969) and are not reproduced here.

The result of each index was that the southern sector was the least diverse area of Kaneohe Bay. The result of the MacIntosh (1967) index was that diversity increased through the transition zone, middle sector, Sampan Channel to the northern sector. The order of increasing diversity by the Shannon-Weiner index (MacArthur and MacArthur, 1961), the Simpson index (1949) and the Gleason (1922) index was southern sector (lowest), middle sector, transition zone, Sampan Channel and northern sector (highest).

These indices simply imply that which has already been said: the southern sector of Kaneohe Bay has the highest standing stock of macrozooplankton with dominance of one or a few species.

THE CLUTTER DATA

Clutter thoroughly surveyed the bay by collecting a series of zooplankton samples at regular intervals at 10 stations over a one-year period (24 July 1968 - 12 June 1969). He sampled both the microzooplankton and macrozooplankton with plankton nets, and chlorophyll-a and phytoplankton cells with water bottles. Most of the zooplankton samples are uncounted.

Clutter (1969, 1973) summarized the chlorophyll and zooplankton settled volume data taken at all stations during the 12 month period. In addition, he discussed macrozooplankton species enumeration data for four dates (24 July, 31 July, 7 August and 14 August 1968) at eight stations. He concluded that mean standing stocks of chlorophyll-a have not changed markedly between 1959 and 1968. Zooplankton volumes were little different in 1968-69 compared to 1963-64 and 1966-67. Some of his conclusions on zooplankton species abundance and distribution differ from Peterson (1969). It must be remembered that over half of Peterson's data was taken during the winter months November through February. Clutter's data were only from July and August. Differences would not be surprising.

I continued counting some of Clutter's samples sometime after he completed his report. Counts were completed for station 9 (the southern sector) through 16 April 1969. In addition, some of the important taxa were counted from the May and June 1969 samples. Counts were made of station 4 (middle sector) through 18 December 1969. All of these data are listed in the appendix of this report, along with a chart showing station locations.

There is little doubt that macrozooplankton were more abundant in the southern sector between 24 July 1968 and 8 January 1969 than during any other previously sampled interval. *Sagitta enflata* and *Oikopleura longicauda* had average and peak abundances never before seen. Chaetognath abundances were greater than $500/m^3$ on nearly all sampling dates between 7 August and 20 November 1968. Peak abundances were greater than $1000/m^3$ on three sampling dates. *Oikopleura* peaked at $2300/m^3$ and $1375/m^3$ in August 1968.

However, even with the dramatic increase in macrozooplankton numbers, we see little change in the herbivore/carnivore ratio. This suggests that the zooplankton trophic structure really hasn't changed very much. There is simply more of everything. Piyakarnchana (1965) found an average of 47% carnivores in the southeastern basin between July 1963 and June 1964. Clutter's samples, taken over the same months but five years later, contained an average of 42% carnivores. Percentages cannot be calculated from the Hiatt data, but examination of his relative abundance table suggests that carnivores made up large percentages of the catch.

Chaetognaths, ctenophores and Lucifer had great abundance or were common in nearly all samples collected by Hiatt. These samples were collected some 20 years before Clutter's samples.

I have calculated average abundance, in number/m^3, of the major taxa at Clutter's station 9 and station 4 over the period 24 July through 18 December 1968 (see table below). Abundance patterns that are different from those found by Peterson are seen. Over this time interval, Lucifer adults and larvae showed no abundance gradient. Crab zoea were slightly more abundant in the southern sector. Ctenophores and Oikopleura were much more abundant in the southern sector. Other taxa had the same patterns that Peterson found. Abundances of chaetognaths, barnacle nauplii and gastropod veligers were greatest in the southern sector. Abundances of copepods and decapod shrimp mysis were highest in the middle sector.

	SOUTHERN SECTOR	*MIDDLE SECTOR*
	Station 9	Station 4
Copepods	14.2	39.5
Sagitta	653.2	209.5
Lucifer	8.1	10.3
ctenophores	53.2	22.2
Oikopleura	426.0	232.0
gastropod veligers	101.1	31.2
Lucifer protozoea	66.0	51.7
Lucifer schizopod	20.5	18.5
crab zoea	24.5	16.4
decapod mysis	25.0	65.8
barnacle nauplii	583.8	11.7

Table 6 is the rank-frequency distribution for macrozooplankton at Clutter's stations 9 and 4. The southern sector data are similar to Peterson's data (Table 3, p. 13 of this report). Highest ranks of abundance are found for Sagitta, Oikopleura, barnacle nauplii, and gastropods in both data sets. The middle sector data compared to Peterson's are exactly the same for the first three ranks (Oikopleura, Sagitta and decapod mysis). Other taxa are in a somewhat different order but the two tables are quite similar.

Clutter also computed indices of community diversity for his July and August data. His conclusion that diversity was highest in the northern sector and lowest in the southern sector was the same as Peterson's. Clutter's diversity index values are listed in the appendix of this report.

THE MILLER DATA

In 1970, John Miller (Hawaii Institute of Marine Biology) began a survey of larval fish distribution and abundance in the surface waters of Kaneohe Bay. He designed and constructed a special plankton sampler (Miller, 1973) which greatly simplified the collection of synoptic samples. The paired nets were pushed by a small boat, and sampled the top 1 m of the water column.

Data from three transect lines, a total of 27 samples, are listed in the appendix. The 13 December 1970 series was taken in the northern and middle sectors of the bay. The 30 January 1971 series was taken in the Sampan Channel and the 4 March 1971 series sampled the middle sector, transition zone and a portion of the southern sector.

Table 6. Rank-frequency distribution of the most important zooplankton occurring in the southern sector and middle sector in the Clutter data. Rank 1 indicates greatest abundance.

SOUTHERN SECTOR , Station 9 : 24 July 1968 - 8 January 1969

	RANK OF ABUNDANCE										
TAXA	1	2	3	4	5	6	7	8	9	10	10
Sagitta	8	6									
Oikopleura	2	3	5	1	1	1					1
barnacle nauplii	4					1	1	1		1	5
ctenophores		1	3	3	2		2			1	2
gastropods		4	1		1	1	1		2		1
protozoea			4	2	2	1		3			2
crab zoea				2	2	3	2	1		1	2
decapod mysis				1	2	2	1	2	1		5
copepods				1	1		2	1	1		8
polychaetes				1	1	1	2	1	2		6
schizopod					1		1	8		1	7
Lucifer									2	1	11

MIDDLE SECTOR, Station 4: 24 July - 18 December 1968

	RANK OF ABUNDANCE										
TAXA	1	2	3	4	5	6	7	8	9	10	10
Oikopleura	6	5	1	1							
Sagitta	2	5	2	1	2		1				
decapod mysis	2	2	1	4		3	1				
copepods	1	1	1	2	4	2		1			1
protozoea	1		4	1	2	1	1	1	1		1
gastropods	1		1		1	1	1	1	1	1	5
ctenophores			2	3			1		1	1	5
crab zoea				1	1	1	2	1	4		3
schizopod					2	3	2	1		2	3
barnacle nauplii				1			2		1	1	8
ostracods					1				2	3	7
Lucifer							1	3	1	1	7

A very different picture of the Kaneohe Bay macrozooplankton appears from Miller's data. Relative numbers of certain taxa are quite different when compared to Peterson's and Clutter's abundance estimates obtained from samples collected by nets hauled horizontally at some depth, or vertically through the entire water column. In both the Peterson (Table 5) and Clutter (p.21) data from the middle sector, Oikopleura, Sagitta and decapod mysis had ranks of abundance of 1,2, and 3 respectively. In the Miller data, highest ranks were occupied by Lucifer, Labidocera, crab zoea, decapod mysis and stomatopod larvae. Very few Oikopleura, Sagitta or ctenophores were taken, suggesting that they live deeper in the water column. Ziemann's (1970) data from surface tows are similar to Miller's: taxa that had highest ranks of abundance were Lucifer, Labidocera, crab zoea and decapod mysis.

Studies of small scale vertical distribution of macrozooplankton are needed in order to determine which zooplankton species live together. Without this knowledge, we cannot fully describe the community structure. With data presented in this report,one can only begin to get a feel for the structure and possible dynamics of the macrozooplankton community.

PART II. ABUNDANCE PATTERNS

Average abundances and seasonal cycles of distribution and abundance of the 19 most important taxa are discussed in this section, drawing from the data of Hiatt (1951), Piyakarnchana (1965), Ziemann (1970) and all data presented in the appendix of this report.

THE COPEPODS

Zooplankton samples collected in the bay with nets having 0.3 mm mesh apertures or larger usually capture few copepods. Copepods however are very abundant throughout the bay, but they are toc small to be retained quantitatively by large mesh nets. Two important genera of "microcopepods" have been identified: *Oithona* and *Paracalanus*. Typical numbers of *Paracalanus* copepodites + adults range from 50,000 to 200,000 individuals/m^3 (50 to 200 per liter). The abundance of microcopepods collected by 0.065mm mesh nets during the 1968-69 pollution study were studied by Bartholomew (1973). Peterson (1969) included some microcopepod data in his thesis. Clutter (1969) discussed the Edmondson (1934) data.

UNDINULA VULGARIS

This copepod occurred most frequently outside of the southern sector. Between December 1966 and February 1968 it was taken in 49% of the southern sector samples, 74% of the transition zone samples, 81% of the middle sector samples, 96% of the Sampan Channel samples and all four northern sector samples. It occurred in 50% of Clutter's samples taken at station 9 (southern sector) between 21 August 1968 and 16 April 1969, and 67% of the station 4 (middle sector) samples taken between August and December 1968.

Typically, <u>Undinula</u> has its greatest abundance outside the southern sector. From the Peterson data, the gradient of average relative density was $0.8/m^3$ in the southern sector, $4.7/m^3$ in the transition zone, $11.9/m^3$ in the middle sector and $13.3/m^3$ in the Sampan Channel.

The middle sector and Sampan Channel averages are influenced by two tows which sampled swarms. On 23 February 1968 at Buoy 19, $169/m^3$ were taken. The second highest observation in the middle sector was $21/m^3$. On 19 November 1967, $178/m^3$ were taken in the Sampan Channel on the incoming tide. The second highest observation in the channel was $31/m^3$. If the highest densities in the middle sector and Sampan Channel are not included in the averaging, then the mean relative densities in the transition zone, middle sector and Sampan Channel are the same: $4.7/m^3$, $6.8/m^3$ and $6.7/m^3$ respectively.

For the Clutter data, averaged densities were $1.9/m^3$ in the southern sector at station 9 and $5.4/m^3$ in the middle sector at station 4.

All of these abundance estimates are comparable to Johnson's (1954) estimates of <u>Undinula</u> abundances in Bikini and Eniwetok lagoon. He also noted that this species tends to swarm. He reported a maximum abundance of $255/m^3$.

Farran (1949) found a seasonal cycle in <u>Undinula</u> abundance. Greatest numbers occurred during the austral spring along the Barrier Reef. Lowest abundances were during the austral winter. In Kaneohe Bay, February 1968 numbers were much lower than November 1967. Highest numbers in Clutter's samples were in April and October.

Copepodites were seen more ofter than adults, and females frequently carried spermatophores.

LABIDOCERA HAWAIIENSIS

This *Labidocera* species was called *Labidocera madurae* by Piyakarnchana, but was described as a new species by E.C.Jones (formerly of the National Marine Fisheries Service, Honolulu) as an independent study project under R. Clutter. A formal description of the species was not published.

Labidocera adults and copepodites were taken in all areas of Kaneohe Bay. Their frequency of occurrence was similar to *Undinula*: occurrence in 21% of the southern sector samples, 70% of the transition zone samples, 72% of the middle sector samples, and 73% of the Sampan Channel samples, during Peterson's study. Relative densities ranged from 1.8/m^3 in the southern sector, to 8.1/m^3 in the transition zone and 19.2/m^3 in the Sampan Channel. Relative density in the middle sector was 7.1/m^3 and in the northern sector, 6.3/m^3.

Like *Undinula*, the averaged densities were influenced by large aggregations. Two large swarms were sampled in the Sampan Channel on 23 February 1968: 115/m^3 and 99/m^3. The third highest abundance here was 26/m^3 on 18 November 1967. In the transition zone, 143/m^3 were taken at Buoy 24 on 3 February 1968. The second highest abundance was 22/m^3. Removal of these patch observations from the density calculation yields the following adjusted density estimates: 8.4/m^3 in the Sampan Channel and 4.7/m^3 in the transition zone.

From Miller's and Ziemann's (1970) data, it is clear that *Labidocera* is found predominantly in the surface layers. If this is generally true, then abundances estimated by nets hauled vertically through the water column will greatly underestimate the abundance of this copepod, on a m^3 basis.

Sex ratios were highly disparate. Of 683 individuals taken during the 2-3 February 1968 tidal series, only one was a male. At this time, 565 of the 683 specimens were adults. In other samples, sex ratios were uneven.

ACARTIA HAMATA

Acartia hamata was described by Mori in 1937. Grice (1964) was of the opinion that *A. hamata* was synonymous with *Acartia fossae* described by Gurney in 1927, from the Suez Canal. If the Kaneohe Bay *Acartia* can be shown to be synonymous to Gurney's descriptions, then *Acartia fossae* must be accepted as the correct species name. I made the identification of *A. hamata* from Mori's description of the female. Jones (undated MS) called the Kaneohe Bay *Acartia*, *A. fossae*.

Of all macrocopepods occurring in Kaneohe Bay, this one occurred the most frequently in the southern sector. It was found in 62% of the southern sector samples, 81% of the transition zone samples, 86% of the middle sector samples and all northern sector and Sampan Channel samples collected during Peterson's study. Relative densities were $2.4/m^3$ in the southern sector, $6.3/m^3$ in the transition zone, $19.0/m^3$ in the middle sector, $17.1/m^3$ in the northern sector and $27.4/m^3$ in the Sampan Channel.

Abundances were considerably higher during Clutter's study. The average relative density at station 9 (southern sector) from 21 August 1968-16 April 1969 was $7.1/m^3$. Over the interval 21 August to 18 December 1968, density at station 9 was $4.6/m^3$ and at station 4, $37.6/m^3$.

Acartia hamata is present in both Bikini and Eniwetok lagoons. Johnson (1954) found 5.1/m^3 and 8.5/m^3 respectively.

Acartia hamata appears to be transported into the bay from a neritic population, and is probably a non-breeding bay resident. Of the many thousands of individuals observed, only one female carried a spermatophore. Copepodites were rarely seen.

PSEUDODIAPTOMUS MARINUS

Pseudodiaptomus marinus has its greatest abundance in the southern sector. Its relative density was 10.7/m^3 and it occurred in one-fourth of the samples. In the transition zone its relative density was 3.0/m^3 and frequency of occurrence was 11%. In the middle sector, relative density was 4.5/m^3 in three samples in which it occurred. It was not taken in the middle sector, and was taken but once in the Sampan Channel.

There is evidence that Pseudodiaptomus marinus prefers the deeper waters of the southeast basin and that it lives very near the sediment-water interface. On 18 April 1967, a deep tow which hit bottom soon after launching contained the highest abundances of Pseudodiaptomus: 80/m^3. At night they migrate up into the water column. Data from the November and February tidal series support this vertical migration hypothesis. Water depth at the stations in the southern sector was about 14 m. Our plankton nets were hauled vertically only through the top 12 m in November 1967 and 11 m in February 1968. The bottom two or three meters were not sampled. Pseudodiaptomus were taken only in the night or early morning samples, indicating migration.

Pseudodiaptomus was taken in only one of Clutter's samples from station 9. This was surprising because his samples were gathered in exactly the same manner as the November and February tidal series data of Peterson. The explanation is that Clutter's samples were all collected during the day. This is further support for the vertical migration hypothesis.

This copepod carries its eggs. Notes were taken on the presence of eggs on females. When present, the number of eggs per female was 18. During the February 1968 tidal series, 20% of the specimens were egg-bearing females. In the April 1967 sample, only 4% were egg-bearing. No females carried eggs in the November samples. It seems possible that breeding occurs between late winter and spring.

Another copepod had the same abundance pattern as *Pseudodiaptomus*. It was not identified but resembled a freshwater *Cyclops*. It was not a *Corycaeus* species. *Pseudodiaptomus* was always present when *Cyclops*-type was taken in the southern sector. The species may be euryhaline, living nearer the Kaneohe Stream mouth.

THE HOLOPLANKTONIC CARNIVORES

SAGITTA ENFLATA

This chaetognath is the dominant macrozooplankter. It was the only species taken in all samples from the bay. It has been abundant and probably dominant in the bay since at least the time of Hiatt's study.

Perhaps the most striking aspect of the distribution and abundance of *Sagitta enflata* is the gradient of its abundance. Numbers are always highest in samples collected in the southeast basin compared to samples collected elsewhere in the bay. The average density in all of Peterson's samples was 318/m^3 in the southern sector, 239/m^3 in the transition zone and 132/m^3 in the middle sector. During the 2-3 February 1968 tidal cycle study, abundances graded from 609/m^3 at the station nearest the southern corner of the southeast basin to 431/m^3 in the middle of the basin and 267/m^3 and 158/m^3 at stations in the transition zone.

Similar gradients were seen in the middle sector along the minor axis of the bay (i.e., onshore-offshore) on 13 July 1967. Chaetognath numbers decreased from 504/m^3 near the Standard Oil dock, to 295/m^3 midway across the bay and 194/m^3 at Buoy 21, near the barrier reef.

There is little evidence for a seasonal cycle of abundance in the Peterson data. For samples collected near the middle of the southeast basin, during May 1967 Sagitta averaged 429/m^3. In June the average density was 429/m^3, in August 406/m^3, in November 414/m^3 and in February 1968, 431/m^3. These averages are based on 3, 6, 6, 9, and 6 samples respectively.

The Piyakarnchana data (1965, p. 147) suggests that chaetognath abundances are cyclic with a regular period. Peaks appear in his data at about 80 day intervals: mid August to mid November, mid November to late January and late April to late June.

The Clutter data is also cyclic. A peak is seen on 14 August 1968 and again on 6 November. Total elapsed time was 85 days. The entire population crashed in December, exactly like the Piyakarnchana data. Numbers remained low until late May 1969 when another peak developed.

Vertical distribution of Sagitta enflata is not clear, but the greatest abundances seem to be in mid-water. On 19 May 1967 at Tester-2, I found $74/m^3$ in the top 25 cm of the water column, and $504/m^3$ at a depth of three meters. On 22 June 1967, a 1 m and 10 m sample had $618/m^3$ and $258/m^3$ respectively. During the 1 August 1967 middle sector transect, chaetognaths were much more abundant at 2 m than at 10 m. Comparative abundances were $408/m^3$ and $27/m^3$, and $447/m^3$ and $1/m^3$ respectively. The same result was found during the 5 October 1967 middle sector transect. The 2 m and 10 m comparison was $178/m^3$ vs. $7/m^3$, $214/m^3$ vs. $12/m^3$ and $175/m^3$ vs. $20/m^3$.

LUCIFER CHACEI

A cursory examination of the Peterson and Clutter data would suggest that this sergestid shrimp is an unimportant species because it is usually not abundant. Its average densities during Peterson's study were $24.5/m^3$ in the southern sector, $12.8/m^3$ in the transition zone, and $4.6/m^3$ in the middle sector. During Clutter's study, Lucifer chacei averaged $8.1/m^3$ at station 9 (southern sector) between 24 July and 18 December 1968, and $6.3/m^3$ between 8 January and 16 July 1969. Lucifer averaged $9.2/m^3$ at station 4 (middle sector) between 24 July and 18 December 1968.

I believe that these average densities grossly underestimate the abundance of Lucifer chacei because it seems to live predominantly in the surface waters of the bay. Abundances of surface living fauna may be underestimated by a factor of 10 by nets hauled vertically through the 14 m thick water column. So little is known about the vertical distribution of this shrimp that one cannot begin to assess its importance. There is a strong suggestion in the data that Lucifer is abundant only at the surface. The 13 December 1970 data of Miller would support such a hypothesis. Lucifer was dominant in all of the samples. Other support comes from some of Peterson's horizontal tows. On 19 May 1967 $167/m^3$ were found in the top 25 cm of the water column. $16/m^3$ were found at 3 m. On 9 October 1967, 41 were taken at the surface and 15 at 2 m depth at Buoy 17. On 2 May 1968, in a one-minute tow, 38 were taken at the surface and 13 at 2 m depth at Tester-10, and on the same date at Tester-2, 456 were taken at the surface and 224 at 2 m. Finally, on 13 May 1968 at Buoy 26, $11/m^3$ were at the surface and $5/m^3$ at 3 m.

Lucifer was very abundant in the Piyakarnchana samples. This may have been because he sampled only that portion of the water column where Lucifer is abundant, the top meter or two.

Lucifer abundances are strongly seasonal in the southern sector. In 1964, maximum abundances were found on 30 June when $460/m^3$ were taken. In 1967 adult abundances peaked on 9 May ($165/m^3$) and 6 June ($537/m^3$). In 1968 a peak was seen on 2 May in the middle of the southern sector. In 1969, adults and larvae were most abundant on 14 May and 16 July.

Lucifer larvae are abundant in the bay at other times of the year, indicating that there are at least two periods of population increase. The highest numbers of protozoea in 1967 were in May ($167/m^3$ on the 8th) and November ($134/m^3$ in the Sampan Channel, $123/m^3$ over the sewer outfall), and $113/m^3$ in the transition zone. Highest numbers of schizopod stage were on 6 December 1966 ($196/m^3$), May 1967 ($203/m^3$) and November 1967 ($111/m^3$).

In the Clutter data, peaks in protozoea numbers are seen on 28 August 1968 (210/m^3), 14 May 1969 (110/m^3) and 16 July 1969 (225/m^3). All of these observations agree with Piyakarnchana, who found peaks in abundance from December-February and June-August.

A good field study of the population dynamics of this animal would be simple to conduct and could be extremely interesting. The timing of the population increases are generally known. Life tables could easily be constructed because adults carry their eggs. Such a study would be completed at minimal cost at the Hawaii Institute of Marine Biology because the field laboratory lies at its doorstep.

CTENOPHORES

The pattern of ctenophore abundance resembles that of the chaetognaths: abundances are generally high in the southern sector, transition zone and middle sector. Few ctenophores were taken in the Sampan Channel or northern sector.

During 1967-68, ctenophore densities were higher in the middle sector (34.2/m^3) than in the southern sector (18.1/m^3). Transition zone numbers were 16.3/m^3. During Clutter's study, between 24 July and 18 December 1968, densities were 22.3/m^3 in the middle sector (station 4) and 54.0/m^3 in the southern sector (station 9).

Maximum abundances in the Peterson data were 304/m^3 on 5 October 1967 and 212/m^3 on 1 August 1967 in the middle sector. On 25 August 1967 140/m^3 and on 20 June 1967 105/m^3 were found in the southern sector. 101/m^3 was the highest in the transition zone, on 22 June 1967. Maxima in the Clutter data were $152/m^3$ on 15 January 1969 and $131/m^3$ on 18 December 1968 at station 9. The maxima in the middle sector was $60/m^3$.

Ctenophores were rare in Piyakarnchana's samples. One might conclude that ctenophore numbers have increased in recent years, since they were common in Peterson's and Clutter's samples. Such a conclusion would be in error because Hiatt (1951) listed them as having great abundance during most months of his study. Natural year-to-year variation in abundance may be a characteristic of this population.

THE HOLOPLANKTONIC HERBIVORES

Oikopleura longicauda

This pelagic tunicate is not restricted to the southern sector but is abundant throughout the entire bay. In the Peterson samples, its average relative densities were $118/m^3$ in the southern sector, $98/m^3$ in the transition zone and $107/m^3$ in the middle sector.

Abundance gradients were sometimes seen. During the November 1967 tidal study, Oikopleura densities were $223/m^3$ in the southern sector (station 2), $178/m^3$ at station 7 and $75/m^3$ at station 6 in the transition zone. No gradient was seen during the February 1968 tidal cycle study. Densities were $120/m^3$ at station 1 and $191/m^3$ at station 2 in the southern sector and $165/m^3$, $111/m^3$, $216/m^3$ and $170/m^3$ in the transition zone and middle sector at stations 3, 4, 5, and 7 respectively. During the 23 February 1968 synoptic survey, high abundances were found at many places in the bay, throughout the middle sector, transition zone and middle sector stations. Abundances were $227/m^3$ and $228/m^3$ at two middle sector stations, 276/m^3 at one transition zone station and 326/m^3 and 211/m^3 at the two southern sector stations.

Abundances at Clutter's stations 9 and 4, between 24 July and 18 December 1968 averaged 170/m^3 and 156/m^3 respectively. Peak abundances on 7 and 14 August 1968 were not included in these average density calculations. At station 9, 2292/m^3 and 1374/m^3 occurred on these two dates. At station 4, abundances were 910/m^3 and 445/m^3. Between 8 January and 16 April 1969, densities averaged 193/m^3 at station 9.

Oikopleura abundances seem to be regularly cyclic. Abundances from the Piyakarnchana, Peterson and Clutter data are plotted in Figure 2. Population peaks are seen at approximately three month intervals, in February, April-May, August-September and November.

During the first population increase (in February), Piyakarnchana found 262/m^3 between 7 February and 7 March 1964. Peterson found an average of 210/m^3 during February. Clutter's data peaked earlier, in the middle of January. By mid-February, his numbers were low.

The second population increase is in the spring. Both Piyakarnchana and Peterson had peaks around the first of May. The Clutter data peaked earlier again, between mid-March and mid-April.

The third population increase occurred during the summer months. Piyakarnchana's data show a peak on 26 June 1964. Peterson's middle sector data and Clutter's southern sector data have peaks around the first of August.

The fourth population increase occurs in November in all three data sets. Piyakarnchana found 207/m^3 in mid-November, Peterson found 230/m^3, and Clutter found 590/m^3.

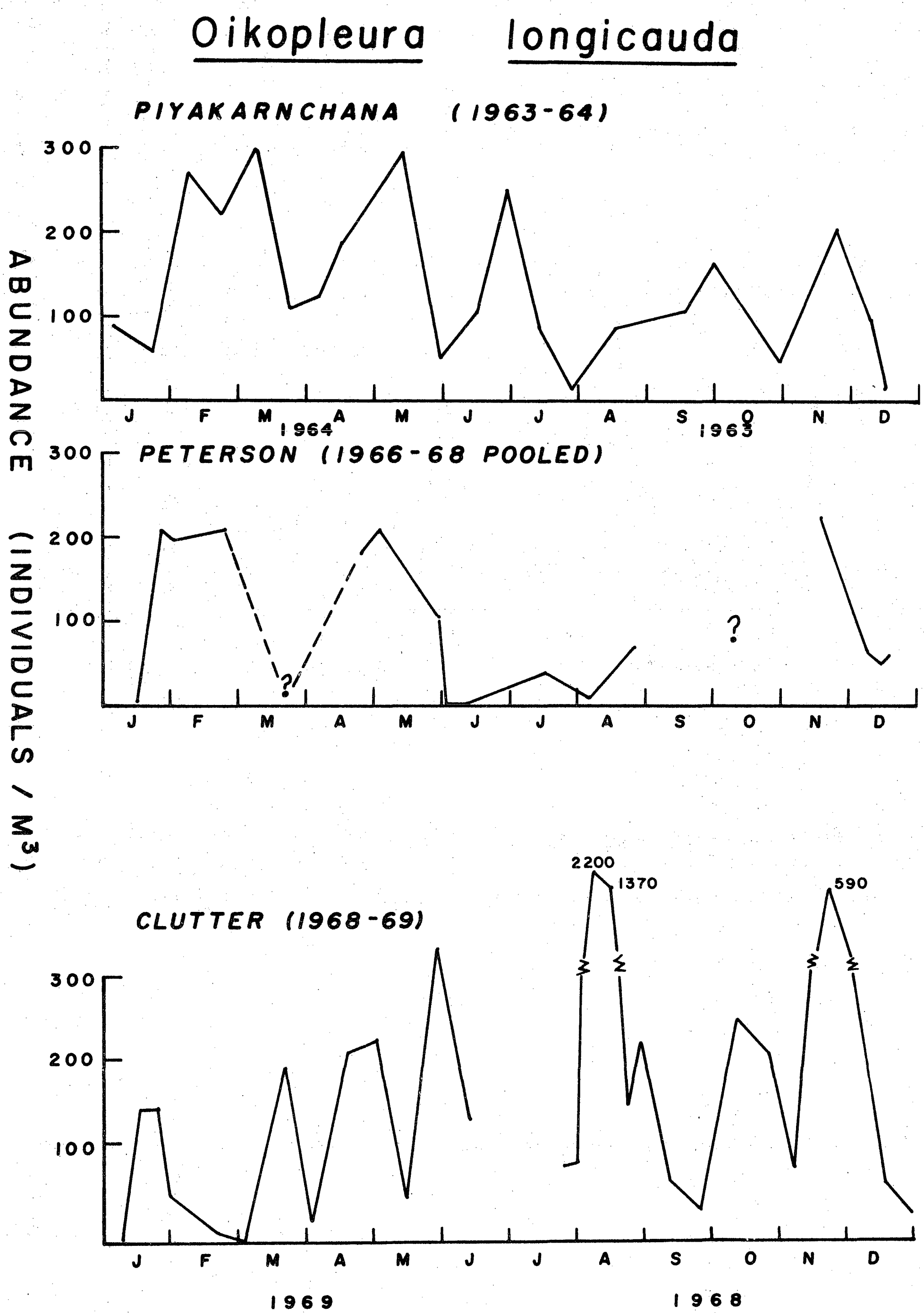

Figure 2. Abundance of Oikopleura longicauda during Piyakarnchana's study (1963-64), Peterson's study (1966-68), and Clutter's study (1968-69). Oikopleura was much more abundant during Clutter's study.

Oikopleura abundances appear to be greater now than during the time of Hiatt's study. He listed them as uncommon in all months except August and October. They were abundant in all months of Piyakarnchana's study, and were abundant and even dominant in many of Peterson's and Clutter's samples.

CLADOCERANS

In temperate coastal waters, cladocerans are typically abundant in the autumn. The Kaneohe Bay population seems to peak on a similar schedule. *Evadne* occurred in Piyakarnchana's samples between September and December. They were common during November. Clutter's samples contained *Evadne* in October and November, averaging $5.2/m^3$. In the Peterson samples, they appeared later, during winter and spring, in December 1966, and January, April and May 1967. Average abundance was $5.8/m^3$. The maximum abundance during this period was $20/m^3$.

MEROPLANKTON

HYDROMEDUSAE

Two types of hydromedusae were abundant in some samples from the southeast basin of Kaneohe Bay. They were labeled medusae-A and medusae-E in Peterson (1969). Medusae-A resembles *Sarsia* sp.. Medusae-E remains unidentified.

Medusae-A appeared in samples collected between the months of November to May. The greatest abundance was during the November tidal cycle study and was at the station located directly over the City of

Kaneohe sewer outfall. The average abundance there was $109/m^3$. The average densities declined at station 2, in the middle of the basin, to $4.8/m^3$. Densities over the Kaneohe Marine Corps Air Station outfall were $3.1/m^3$. The parent hydroid colonies seem to be located in the southern corner of the southeast basin.

Abundance estimates from the southern sector during the winter of 1966-67 were $13/m^3$ on 6 December 1966, $15/m^3$ on 12 January 1967 and $9/m^3$ on 23 January 1967. During the winter of 1967-68, $31/m^3$ and $45/m^3$ were taken on 12 December 1967 and $2.3/m^3$ on 2 February 1968. Abundances were only $1/m^3$ on 23 February 1968.

In Clutter's data, medusae-A first appeared on 23 January 1969. Highest abundances were $22/m^3$ (on 19 February 1969), $67/m^3$ (on a April) and $25/m^3$ (on 16 April 1969).

Piyakarnchana did not report high numbers of any medusae in his study. Since these hydromedusae can be very abundant, one would think that he would have mentioned it. It seems safe to assume that they are new residents of the bay, at least since 1964.

Medusae-E had its greatest abundance in February 1968, in the middle of the southeast basin. At station 2, it averaged $402/m^3$ during the 2-3 February 1968 tidal cycle study. It was taken only during November-February, and did not appear in any of Clutter's samples.

GASTROPOD VELIGERS

Two types of gastropod veligers were distinguished. Veliger-A was a prosobranch, probably a limpet larvae. Veliger-B was an opistho-branch, possibly a sea slug (tectibranch) larvae.

Gastropod veligers had their greatest abundance in the southern sector. In the Peterson data, average density of veliger-A was 63/m^3 in the southern sector, 43/m^3 in the transition zone and 2.4/m^3 in the middle sector. In the Clutter data, the average was 69/m^3 in the southern sector over the period 24 July 1968 to 16 April 1969. Between 24 July and 18 December 1968, the average at station 9 was 87/m^3 and at station 4 was 31/m^3.

Maximum abundances in the southern sector, during Peterson's study, were 131/m^3 on 12 January 1967, 300/m^3 on 8 May 1967, 332/m^3 on 10 August 1967 and 231/m^3 on 23 February 1968. High numbers were also seen on 2 May 1968. During Clutter's study, maximum numbers were 412/m^3 on 31 July 1968, 160/m^3 on 21 August 1968 and 213/m^3 on 6 November 1968.

Abundance peaks appear irregularly. The pattern seems to be that highest abundances occur sometime between May and August, and during the winter months. Low abundances occur in all data sets in September, October, December and the spring months. In Hiatt's samples, gastropod and clam larvae (pooled) were rare during eight months and missing during August, September, October and December. Piyakarnchana lists gastropod veligers as rare during September, November, and February, abundant during June and July, and common during the other months. Peterson found highest abundances in May, August and January in the southern sector, and November through February in the transition zone. Highest abundances in the Clutter samples occurred in July, August, November and March in the southern sector.

Veliger-B were abundant only during brief periods in the summer and winter, indicating either two spawnings per year, or the spawning of two different species. On 22 June 1967, $7/m^3$ were taken and on 13 July 1967, $14/m^3$ were taken. On 2 February 1968 densities at station 2 averaged $10/m^3$ with a maximum of $17/m^3$. On 18 December 1969, $40/m^3$ were taken in the southern sector. Finally, on 12 November 1969, they were abundant in a qualitative sample.

CRAB ZOEA

Crab zoea had their highest average relative density in the Sampan Channel and transition zone during Peterson's study. Densities were $50/m^3$ in the Sampan Channel and $45/m^3$ in the transition zone. Densities in the southern sector were $13.2/m^3$ and in the middle sector, $12.2/m^3$. The maximum abundance was $268/m^3$ and was in the Sampan Channel on 3 February 1968. Other high abundances listed in chronological order were $123/m^3$ on 10 December 1966, $160/m^3$ on 12 January 1967, $157/m^3$ on 13 July 1967 and $174/m^3$ on 23 February 1968.

In Clutter's data, average densities at stations 9 and 4 were $25.8/m^3$ and $16.4/m^3$ between 24 July and 18 December 1968, respectively. The maximum abundance seen during his study was $54/m^3$ on 28 August 1968.

Crab zoea abundances do not seem to be affected by reduced salinity. During the 18-19 November 1967 study, zoea numbers were consistently highest at the stations located directly over the sewer outfalls, as compared to the station in the middle of the basin.

High numbers were found in the Sampan Channel during both incoming and outgoing tides.

There is a seasonal variation in abundances. Hiatt found lowest numbers in July and November. Zoea were common in January, May and August, and very abundant during the other months. Piyakarnchana lists crab zoea as abundant only in May and June, and common during the other months. Peterson found highest numbers in January and February, and lowest in June. Zoea did not have any dramatic peaks in Clutter's data. In summary, there does not appear to be a pattern. This is not surprising because a large number of crab species are represented in this taxa.

Zoea are more abundant at the surface of the bay. They were four times more abundant in the top 25 cm than at 3m, on 19 May 1967, and six times more abundant in the top 1 m as compared to deeper in the column, on 22 June 1967. In both the 1 August 1967 and 5 October 1967 middle sector transects, zoea were much more abundant at 2 m than 10 m. They were the third most abundant taxa in the transition zone during the 12 December 1967 series. In the Miller surface samples, zoea were the third most abundant taxa, ranking behind Lucifer and either chaetognaths or Labidocera.

DECAPOD SHRIMP MYSIS

Decapod shrimp mysis have their lowest abundance in the southern sector. This is no doubt a result of the distribution of living coral reef habitat. The southern sector has none of this habitat.

During Peterson's study, average relative densities were $6.3/m^3$ in the southern sector, $21.3/m^3$ in the transition zone and $24.6/m^3$ in the middle sector. During Clutter's study, average densities were $26.1/m^3$ in the southern sector and $52.4/m^3$ in the middle sector between 24 July and 18 December 1968. In Clutter's samples collected between 24 July and 14 August 1968, abundances were higher in the transition zone than in the middle sector at station 4 or in the southern sector. Highest abundances during this period were in the northern sector at station 6.

Highest abundances during Peterson's study were in April, May and July, and during Clutter's study, July-September. Hiatt lists shrimp mysis as rare during April, May and July. They were also rare in February and October, and common in all other months. Piyakarnchana combined shrimp and stomatopod larvae. The taxa were rare in August and December, and common in all other months, in the southern sector.

Maximum abundances observed were $179/m^3$ on 15 May 1967, $180/m^3$ on 13 July 1967 and $211/m^3$ on 24 July 1968.

BARNACLE NAUPLII

Barnacle nauplii may be the most important meroplankton in the bay. Average abundances in the southern sector are high because incredibly large numbers periodically appear in zooplankton samples. Highest abundances were $37{,}000/m^3$ on 12 January 1967, $11{,}600/m^3$ on 11 September 1968 and $5100/m^3$ on 18 November 1967.

Barnacles seem to spawn at three-month intervals: April-May, August-September, and between November and February. During Peterson's study, peaks were seen on 19 May 1967 (553/m^3), 10 August 1967 (983/m^3), and 3 February 1968 (1580/m^3). The 12 January 1967 and 18 November 1967 peaks were previously noted. During Clutter's study, peaks were seen on 11 September 1968, and 8 January 1969 (542/m^3). A small peak occurred in April 1969. In addition, large numbers of barnacle nauplii were taken in a qualitative tow on 19 December 1969.

Hiatt lists barnacle nauplii as abundant only in November and December. Piyakarnchana found them abundant only during the summer months. Since numerous peaks were seen in recent data sets, one possible conclusion is that barnacles are on the increase in the bay.

ANCHOVY EGGS

Anchovy eggs were never abundant. Their relative densities during Peterson's study were 10.7/m^3 in the southern sector, 4.1/m^3 in the transition zone and 4.2/m^3 in the middle sector. They were taken in only one Sampan Channel sample. They averaged 7.5/m^3 in Clutter's southern sector samples. Maximum abundances were 31/m^3 on 15 June 1967, 32/m^3 and 83/m^3 on 3 February 1968, and 40/m^3 on 9 October 1968.

PART III.

BIOMASS

The preceeding discussion of numerical abundance, frequency of occurrence and relative abundance of taxa can only suggest which animals are important components of the pelagic ecosystem. One cannot really objectively speak of importance without at least some estimate of the standing stock of dry weight biomass and carbon content. To complete an argument on importance, certain dynamic measurements are necessary, such as respiration and grazing rates of individuals, and turnover and production rates of populations. Only standing stock measurements are reported below.

The acquisition of the biomass data which follow was begun in the fall of 1971. Time limitations did not allow completion of the project, so data are incomplete. Standard methods were used to gather the data. Animals were collected with plankton nets and maintained alive in the laboratory in aquaria. Live animals were utilized within six hours of collection. To dry material, animals were dropped into distilled water for a second or two, removed, and placed on pre-weighed aluminum boats, and dried overnight at 60° C. Ash determinations were made in a muffle furnace at 450-500° C overnight. All weighing was done with a Cahn electrobalance. Carbon, hydrogen and nitrogen were analyzed in an F & M Model 185 C-H-N analyzer. Caloric content was estimated with a Phillipson Microbomb Calorimeter. The C-H-N analyzer was calibrated with cyclohexane-2-4dinitrophenyl-hydrazone. The bomb calorimeter was calibrated with benzoic acid.

Table 7. Dry weights of selected zooplankton taxa from Kaneohe Bay. Body lengths are total length except for the copepods which are carapace length only.

	Dry weight, in ug/individual	Mean body length, in mm	No. of observations	% Ash content	No. of observations
COPEPODS					
Undinula vulgaris	50.0	1.4	3		
Labidocera hawaiiensis	115.0	1.6	7	8.4 ± 1.1	5
Acartia hamata	21.0	1.0	1		
Paracalanus sp	2.5	0.5	3		
CARNIVORES					
Sagitta enflata	171.0	9.2	62	55.7 ± 4.9	13
Lucifer chacei adults	232.0	8.5	3	36.0	1
Ctenophores	1890.0	4.4	13	74.5 ± 7.3	5
HERBIVORES					
Ostracods	25.0	0.8	4		
Amphipods	45.0	1.3	1		
MEROPLANKTON					
veliger-A	26.0	0.6	3		
veliger-B	31.0	1.0	1	47.8	1
protozoea	7.6	1.2	4		
schizopod	20.0	2.5	4		
crab zoea	25.8	mixed	7	32.4	2
megalops	256.0	1.5	1		
decapod mysis	89.8	2.2	5		
stomatopod	131.0	3.2	2		
barnacle nauplii	4.8	mixed	4	46.5	1
Nehu eggs	24.6	1.0	1		

Table 8 lists the standing stock of zooplankton dry weight (in mg) for the southern sector and middle sector, calculated from the Peterson abundance data listed in Table 1 (p. 9 of this report) and the Clutter abundance data listed on page 21. The table was constructed by multiplying estimates of dry weight per individual by the numerical estimate of abundance for each taxa. Ctenophores are not listed because of the uncertainties in my estimates of their dry weight.

Chaetognaths dominate the total biomass listed in Table 8. In the southern sector, they make up 85% of the total weight of the listed animals in both Peterson's and Clutter's samples, and 80% in the middle sector samples. Although biomass data are not available for all macrozooplankton taxa, chaetognaths certainly make up more than 50% of the total macrozooplankton weights.

When the macrozooplankton data are compared to Bartholomew's (1973) microcopepod data, chaetognaths still dominate. Bartholomew's estimates of microcopepod standing stocks ranged from 1.1 mg/m^3 to 38.2 mg/m^3, with an average weight of 15.5 mg/m^3 in the southern sector.

It is interesting to note that barnacle nauplii, although numerically very abundant, make up only a very small fraction of the total biomass.

Table 9 lists the caloric content of a few zooplankton taxa and for the phytoplankton species Skeletonema costatum. This diatom was collected during a thick "pea soup" bloom on 12 December 1969. Most of the ash estimates listed in Table 9 are in disagreement with independent estimates obtained with the muffle furnace. Because of this discrepancy, the caloric content data are difficult to evaulate.

Table 8. Annual average standing stock of macrozooplankton from Kaneohe Bay, expressed as mg dry weight/m^3. The units mg/m^2 can be obtained by multiplying the listed data by 12 m which is the average depth of the bay. These data were derived from the numerical abundances listed in Table 1 (p. 9) and p. 21 of this report, and represent the years 1967 and the latter half of 1968.

	SOUTHERN SECTOR		*MIDDLE SECTOR*	
	PETERSON	CLUTTER	PETERSON	CLUTTER
Sagitta enflata	54.5	111.7	22.7	35.8
Oikopleura longicauda	2.4	10.4	2.2	4.7
barnacle nauplii	2.3	2.8	0.001	0.06
gastropod veligers	1.6	2.6	0.08	0.8
Lucifer adults	1.5	1.9	1.1	2.4
Lucifer protozoea	0.12	0.5	0.04	0.4
Lucifer schizopod	0.19	0.35	0.08	0.37
mixed copepods [1]	0.40	---	1.8	---

1 = *Acartia* + *Undinula* + *Labidocera*

Table 9 . Caloric content of selected zooplankton and phytoplankton from Kaneohe Bay.

	Dry weight, in mg	Ash-free dry weight, in mg	% Ash	Corrected Rise	Total calories	Calories per gm ash-free dry weight
<u>Skeletonema costatum</u>	12.996	4.626	64.4	8.01	15.46	3,342
" a	7.100	4.260	60.0	3.59	6.93	1,627
<u>Paracalanus</u> sp	3.076	2.520	18.1	9.12	17.60	6,984
"	4.728	4.160	12.0	14.75	28.47	6,844
	1.040	0.090	13.5	2.23	4.30	4,777
<u>Labidocera hawaiiensis</u>	12.860	11.732	8.8	32.98	63.48	5,411
<u>Sagitta enflata</u>	19.900	14.230	28.5	26.54	51.22	3,599
"	5.646	4.420	21.7	10.56	20.38	4,611
<u>Lucifer chacei</u>	13.842	11.486	14.8	31.32	30.45	5,263
stomatopod	4.820	*	*	10.28	19.84	
"	5.684	4.842	14.8	7.78	15.02	3,102
mixed crustacea b	9.266	7.982	13.8	20.00	38.60	4,836
mixed crustacea c	7.188	6.134	14.7	16.83	32.48	5,295

a = assumed 60% ash
b = predominantly crab zoea
c = predominantly <u>Lucifer</u> protozoea

Table 10 lists carbon, nitrogen and hydrogen content, as percent of dry weight, for a selection of zooplankton and the phytoplankton species *Skeletonema costatum*. The expected result of about 40% carbon and 10% nitrogen for the zooplankton was obtained.

Length - dry weight data are listed in the appendix of this report, on page 120. Chaetognath length-weight scatter diagrams are shown in Appendix Figure 10, page 121, for both dry weights and ash-free dry weights. Qualitative observations on zooplankton species composition taken during the biomass study period of November 1969 - January 1970, are listed on appendix page 122.

Table 10. Carbon, nitrogen and hydrogen in selected phytoplankton and zooplankton taxa, expressed as percent of dry weight.

	% C	% N	% H
Skeletonema costatum	10.85	2.35	3.02
"	8.35	2.24	3.09
"	8.19	2.15	2.33
"	9.11	**	**
"	11.17	**	2.14
Paracalanus sp	36.03	9.64	7.81
Euchaeta sp [1]	41.17	6.80	3.48
Acartia hamata	36.32	8.85	5.60
Lucifer chacei	43.70	9.84	10.96
mixed crustacea [2]	34.35	8.88	4.69
barnacle nauplii	40.16	9.00	5.69
"	41.28	8.40	5.57
decapod mysis	36.70	9.39	9.83
stomatopods	29.59	8.10	5.24
gastropod veligers	43.89	10.44	16.14

1 = collected off Waianae coast of Oahu
2 = predominantly Lucifer protozoea

CHANGES IN THE PLANKTON

It is difficult to evaluate the problem of whether or not the zooplankton assemblage in Kaneohe Bay has changed appreciably over the years because the available data sets are not strictly comparable. The problems are outlined below:

1. We do not know either how, when, or where Hiatt (1951) collected his samples, only that they were taken bimonthly.
2. Piyakarnchana's (1965) samples were collected with nets towed horizontally through the top few meters of the water column only so his data are most representative of the surface living zooplankton.
3. Peterson's (1969) samples were collected at irregular intervals with a variety of samplers and sampling methods. There is neither temporal or spatial consistency in the data.
4. Clutter's (1973) samples are a good set. They were taken during a sampling program that benefitted greatly from an understanding of the shortcomings of the previously collected data sets.

Given these problems, it is risky to compare absolute or relative abundances of zooplankton in the Clutter data to the Piyakarnchana data or even to the Hiatt data. Only the most general patterns should be discussed. I believe that one may safely conclude (as Clutter has) that the abundance of Oikopleura is greater and that the macrocopepods (Labidocera, Undinula, and Acartia) have decreased in abundance in the southern sector, between 1950 and 1970. However, Clutter's conclusion that the Lucifer population was at lower levels in 1968 as compared to the time of Hiatt's study may be in error, because estimates of the abundance of Lucifer are subject to strong sampler bias. Since Lucifer appears to have a neustonic distribution pattern, then surface tows will indicate a much higher abundance than vertical hauls through the entire water column. Another conclusion from the available data sets is that even though total abundance of all macrozooplankton may have increased over the years 1963 to 1968, community composition in terms of percent of numbers of carnivorous macrozooplankton has not changed. Carnivores were very abundant even at the time of Hiatt's study.

Another potential problem in interpreting the data is year to year variation in species abundance and community composition. A somewhat different zooplankton assemblage could be living in the bay during years of very high rainfall as compared to years of very low rainfall. Figure 3 shows rainfall data for the years 1963 - 1973. Piyakarnchana's samples were collected during a dry winter while Peterson's and Clutter's were collected during wet winters.

In considering the problem of changes in the plankton resulting possibly from increased amounts of domestic sewage pumped into the bay, one must thoughtfully consider some observations made by Tester (1951) and cited previously by Peterson (1969) and Clutter (1973):

Tester says,

> "In the southern sector and middle sectors, the waters have a brownish tinge indicating the presence of silt and perhaps plankton.
>
> "During the course of each days operation, there was a steady accumulation of inert organic material on the silk [of the plankton net]. It was impossible to remove this either by use of a pressure hose or by towing the net inside out between stations. It could only be removed by scrubbing the net with a brush at the end of the day.

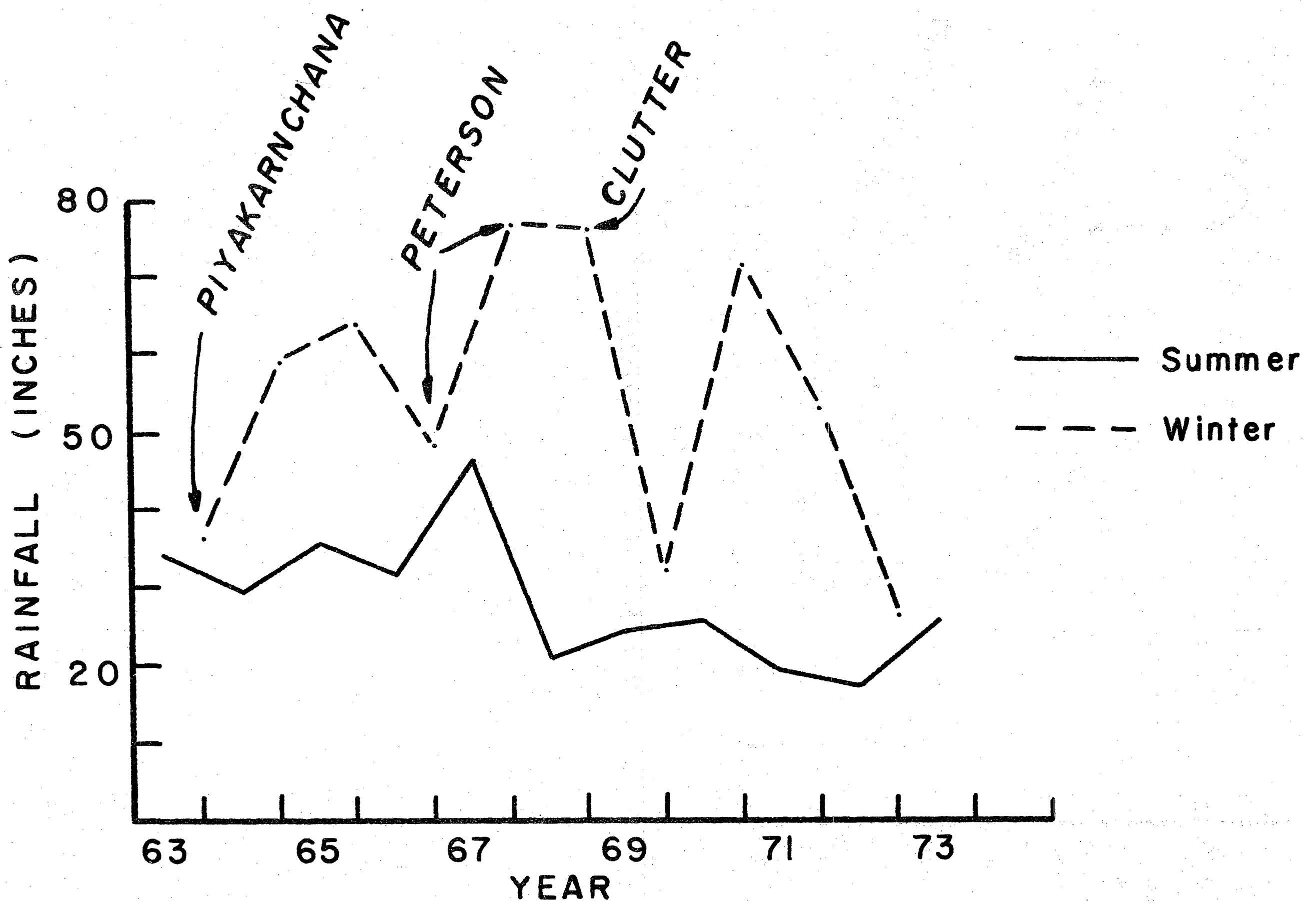

Figure 3. Rainfall measured at the Kaneohe Mauka weather station, summed over the six-month intervals of May-October (summer) and November-April (winter). The time periods when various zooplankton studies were completed in Kaneohe Bay are identified. The Piyakarnchana samples were collected during a much drier winter than the Peterson or Clutter samples.

> "Segregation of the Nehu eggs and larvae [from the plankton samples] was complicated by the presence of large numbers of chaetognaths and ctenophores which had to be teased apart."

Similar observations were made during my study, in 1967, nineteen years after Tester's study of the distribution and abundance of Nehu eggs and larvae.

It is interesting to note that Smith et al. (1973) concluded that increases in dredging activity, sedimentation rates and domestic sewage input have had a drastic effect on the benthic and coral reef communities in the southern sector (southeastern basin) of Kaneohe Bay. Since no such drastic changes have occurred in the macrozooplankton community, one is tempted to conclude that the primary ecological factors affecting change in the benthos are <u>not</u> eutrophication, but reduced salinity (due to increased runoff), turbidity (caused by increased dredging activity) and increased sedimentation rates.

Caperon et al. (1971) concluded that the southern sector was eutrophic and that eutrophication would spread north into transition zone and middle sector waters. This may not be a problem, however, since tidal mixing and flushing are much higher in these areas compared to the sluggish circulation in the southeast basin. Nutrient-rich waters would be diluted rapidly and transported offshore. There are no data on the offshore neritic zooplankton populations that would allow one to determine if changes have occurred there, as a result of offshore transport of nutrient-rich water.

NECESSARY FUTURE RESEARCH

A zooplankton data set needs to be generated which contains samples collected following both the collection methods of Piyakarnchana and Clutter. These samples would allow direct comparison of events in 1963-64 to 1968-69, and to events at the time when such a study might be completed.

Our understanding of the trophic relationships would be greatly benefitted by at least two field projects. The first would be a study of the vertical distribution of zooplankton during day and night, during various states of the tide and under a variety of wind stresses. It could be a useful study if samples were gathered twice weekly over a three month interval. The second study would be a long time series of twice weekly vertical hauls taken with the purpose of understanding population dynamics and intraspecific associations of *Sagitta*, ctenophores, *Lucifer*, *Oikopleura* and the microcopepods (represented by at least four species; Hirota, personal communication). These eight taxa are the only important members of a very simple zooplankton community.

A systems model of the Kaneohe Bay ecosystem will inevitably be attempted someday. The pelagic realm must be treated as a three layer system: surface layer, mid water areas, and deep layer. Although complete vertical distribution studies are lacking, existing data suggest that the surface layer is dominated by *Lucifer chacei*, *Labidocera hawaiiensis*, crab zoea and decapod mysis, that the mid water areas are dominated by *Sagitta* and ctenophores, and that the deep water is affected somewhat by *Pseudodiaptomus* and mysids, at least in the southern sector.

The degree of stratification of the microcopepods in the water column is unknown. In addition, inputs of pelagic larvae of benthic invertebrates must be included into a systems model.

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APPENDIX

All zooplankton enumeration data which are tabulated here are listed in chronological order. In the Peterson data, some of the columns are headed with information listed in the following order:

DATE
SAMPLING GEAR
TIME OF DAY
STATION
SAMPLE NUMBER
DEPTH OF TOW

Other columns of data are headed only with time of day and sample number. Abbreviations for sampling gear are MN = one meter mouth diameter conical plankton net, 1/2 MN = one-half meter mouth diameter conical plankton net, PS = plankton purse seine. All nets were constructed of 0.33 mm mesh Nitex nylon. Station abbreviations are T = Testor's (1951) stations, B = navigational buoy number, Sam B - Sampan channel navigational buoy. "Deep" tows were from undetermined depths of roughly 10 m. Sample number is used only for the Peterson. These numbers are used in Peterson (1969) to identify diversity index values for each station. The Clutter and Miller data are headed only by date and station number.

THE PETERSON DATA. The Peterson data set includes samples gathered between 6 December 1966 and 23 February 1968. These samples were the basis for a Master's thesis (Peterson, 1969). Many of the samples gathered between 6 December 1966 and 5 October 1967 were collected at stations chosen by Drs. Clutter and Murphy as part of a comparative study of catches of fish larvae and zooplankton by a plankton purse seine and one meter plankton net (Murphy and Clutter, 1972)

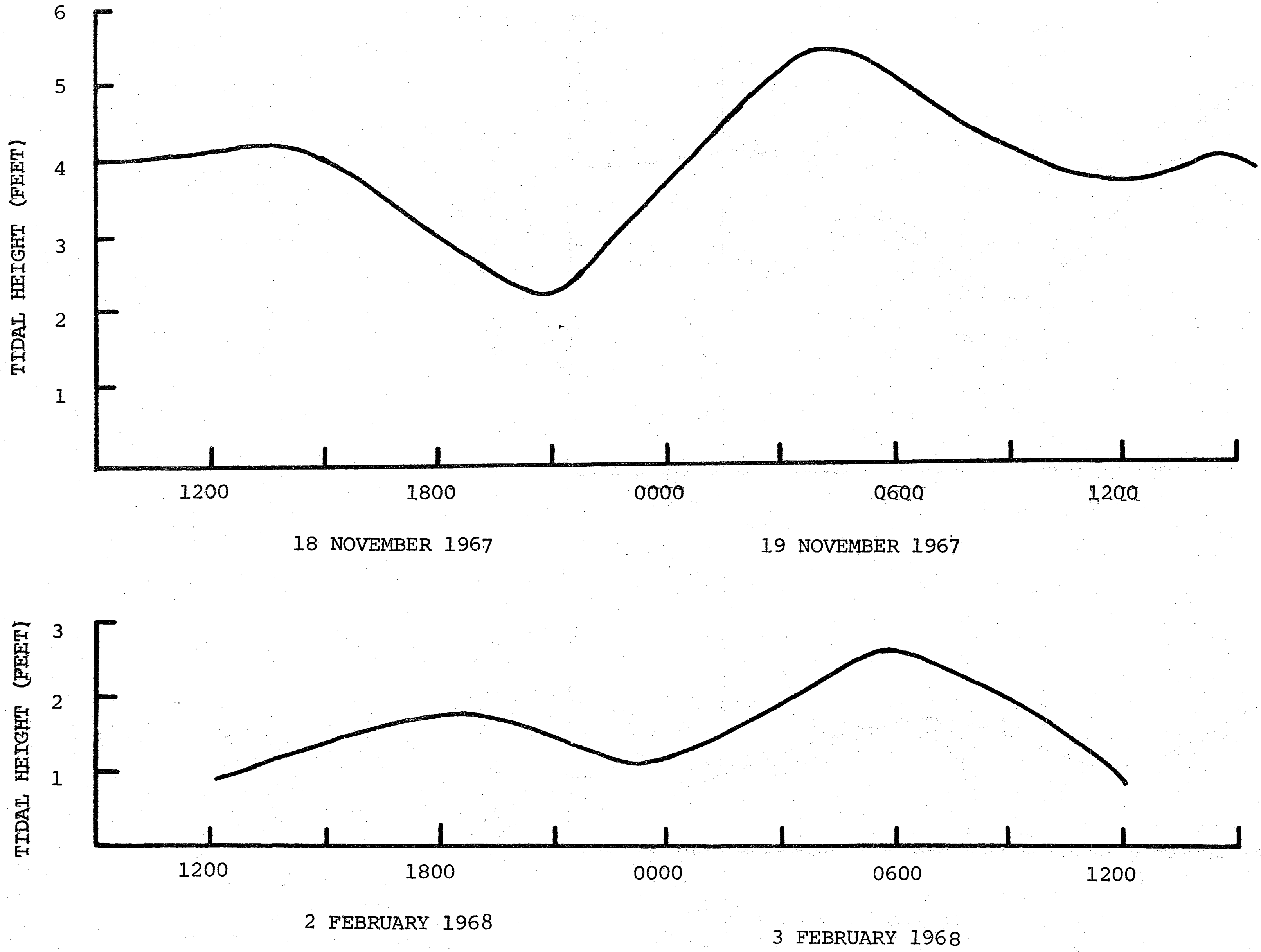
Other samples collected during this period were taken to compare catches of zooplankton at the surface vs. deeper in the water column (18 April, 8 May, 9 May, 19 May and 22 June 1967). Samples were collected in the middle sector to examine onshore-offshore abundance gradients, on 13 July, 1 August and 5 October 1967. All of the samples collected during this period were by nets towed horizontally or by the plankton purse seine. In this block of data, the one meter net tows that do not have a depth of tow indicated in the column headings, were step-oblique tows that sampled the top 7 m of the water column.

During 18-19 November 1967 and 2-3 February 1968, zooplankton were sampled at regular intervals during a tidal cycle over a 24-hour period at seven stations. The samples were from vertical tows taken from a depth of 12 m to the surface (in November) and 11 m (in February). At stations where water depths were less than 12 m, tows were taken from the bottom to the surface. Tidal curves for these two studies are shown in Appendix Figure 1.

On 12 December 1967, the zooplankton in the top 1 m of the water column were sampled at eight stations around Coconut Island and at one station in the southeast basin. Samples were gathered with a one half meter net towed horizontally near the surface.

On 23 February 1968, a synoptic survey was completed between the hours of 1000h and 1335h at 21 stations. Horizontal tows were taken at a depth of 2 m with a one meter plankton net.

In addition to these samples, some other samples were taken which were not included in my Master's thesis. These were: two non-quantitative tows from the middle sector on 9 October 1967, four non-quantitative tows



APPENDIX FIGURE 1. Tidal curves for the two tidal cycle studies, the reference datum being arbitrarily set at zero.

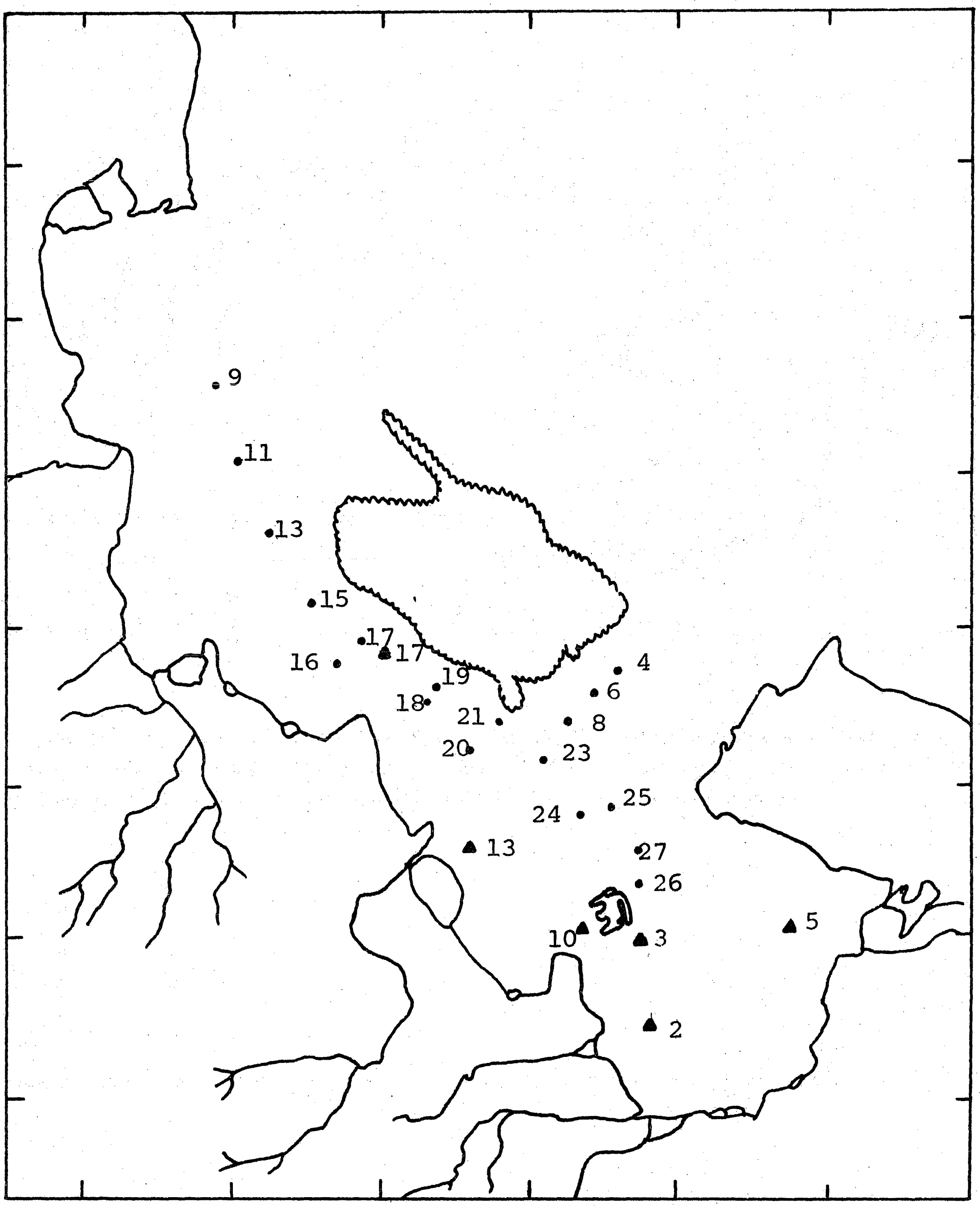
from the southern sector on 2 May 1968, and 17 quantitative surface tows on 13 May 1968. On the latter date, 30 individual gallon buckets of surface water were filtered through a 0.065 mm mesh cone. Both sets of samples collected on 13 May 1968 were taken to look at temporal and small scale variation in zooplankton catches.

For those persons reading this report whose primary interest are samples collected in the southeast basin (= southern sector), data are available from the following dates: 6, 10 December 1966, 12, 23 January 1967, 18 April through 25 August 1967 (many dates), 18-19 November 1967, 12 December 1967, 2-3 February 1968, 23 February 1968 and 2, 13 May 1968.

All of the Peterson data are in numbers of individuals per cubic meter of water filtered, except the 9 October 1967 and 2 May 1968 data which are qualitative.

THE CLUTTER DATA. The Clutter data were gathered by a pair of plankton nets which sampled the macrozooplankton (using 0.33 mm mesh nets) and microzooplankton (using 0.065 mm mesh nets) simultaneously. Only the macrozooplankton data are listed here. See Bartholomew (1973) for some of the microzooplankton data. Clutter's data are from nets hauled vertically through the top 11 m of the water column, depth permitting. *ABUNDANCES LISTED IN THE APPENDIX ARE NUMBERS PER TWO CUBIC METERS.* This is because nets with mouth diameters of one-half meter filter two cubic meters of water over an 11 m distance.

THE MILLER DATA. The Miller samples were taken with paired nets, each having a 0.36 m^2 mouth area and 0.5 mm meshes, that were pushed through the surface layers (see Miller,1973). *DATA ARE NUMBERS OF INDIVIDUALS PER FIVE MINUTE TOW.*



Appendix Figure 2. Location of Tester's stations (▲) and various navigational bouys (•) where zooplankton samples were collected between the dates 6 December 1966 and 25 August 1967.

PETERSON DATA	1966			1967				
	6Dec PS#1 1030h T-10 1	6Dec PS#2 1130h T-3 2	10Dec MN#1 1050h T-3 3	12Jan MN#1 1340h T-24 4	12Jan MN#2 1425h T-5 5	12Jan MN#3 1515h T-10 6	23Jan MN#1 1205h T-5 7	23Jan MN#3 1355h T-10 9
Undinula	6.0	3.6	0.7	0.3	2.0	1.6	1.6	0.9
Calanopia								0.2
Labidocera				0.4		1.8	0.2	
Acartia	2.1		2.0	0.2	2.9	1.4	0.2	1.2
Oithona								
Oncaea venusta	0.2							
Corycaeus								0.2
Setella				0.1				
Harpacticoids	0.2	0.3		0.1		0.4	0.2	0.2
Sagitta	201.3	92.3	173.2	28.8	83.9	198.7	10.0	13.3
Leucifer	0.9	5.1	2.0	11.9	8.2	8.0		3.8
Ctenophores	0.4			0.1		0.2		0.6
Medusae-B				1.6	2.1	0.5	1.6	0.2
Medusae-D	0.8						1.0	1.4
Oikopleura	53.0	45.0	54.2	5.3	4.1	1.4	207.8	395.5
Evadne	5.0	0.8	1.3				20.0	11.6
Mysids		0.3	0.7					
Amphipod-B				1.0		0.2		
Medusae-A	1.7	8.3	13.2	6.3	14.6	1.4	9.2	0.2
Medusae-E	0.4	1.0	0.7			0.5		0.2
polychaete		0.8	1.3	0.2			2.9	
brachiopod		1.0	1.3					
bivalve			101.8					
veliger-A	12.4	35.0	43.6	24.2	131.0	102.9	6.7	58.7
protozoea	54.7	24.7	31.7	0.7	6.1	5.4		1.4
schizopod	165.0	78.1	3.3	0.8	4.1	0.4		2.4
zoea	32.3	39.1	123.0	34.6	159.6	37.9	7.3	5.2
megalops	0.2							
mysis	6.6	5.1	9.9	1.9	13.3	4.3	5.5	7.1
barn. nauplii	3.0	6.2	0.7	119.7	***	495.1	11.4	223.2
cypris				3.0	14.3	4.6		0.2
stomatopod			0.7	0.2			1.6	
Nehu eggs	2.1		2.0	2.8		0.5	3.3	0.5
"frog"								0.2

***barnacle nauplii = 37,453/m^3

1967

	23Jan MN#2 1300h Sam B-6	11Mar MN#1 1225h Ocean	11Mar MN#2 1345h B-9	20Apr MN#1 1020h T-17	20Apr MN#2 1210h B-13	15May MN#1 1535h B-13	15May MN#2 2200h B-13	16May MN#3 0620h B-13	16May ½MN 0545h B-13 Deep
	8	10	11	12	13	14	15	16	17
Undinula	0.8	6.5	1.1	8.0	21.2	0.7	3.5	0.9	0.6
Calanopia					0.2		0.3		
Labidocera	0.7	2.7	10.6	2.7	3.0	5.0	61.3	26.0	0.5
Candacia		0.2							
Acartia	4.6	2.1	34.3	8.3	67.8	7.9	61.9	117.3	8.2
Unid Calanoids		1.7							
Oithona	0.1	6.5	0.03		0.1		0.3		
Oncaea venusta	0.1	0.3	0.03						0.2
Oncaea sp			0.03		0.1		0.1	0.1	
Corycaeus		0.7	0.1		0.3	0.1		0.1	
Copilia			0.03				0.7	0.2	0.4
Harpacticoids	1.6		0.03			0.1	0.3		0.4
Pontellina	0.04								
Sagitta		0.2	0.9	62.3	30.6	8.5	10.9	0.5	0.7
Leucifer	0.1	0.2	1.4	2.9	4.3	5.5	9.6	1.2	0.1
Ctenophores		0.1		3.3	0.8	0.7	0.3		0.1
Medusae-D	0.1			0.2					
Medusae-sp								0.1	
Oikopleura	30.8	0.7	37.4	114.5	31.1	127.8	19.5	11.6	4.6
Evadne				0.2					
Pteropods	0.3	0.4							
Creseis					0.1				
Ostracods							0.3		
Mysids	0.2	0.5			0.1		1.8		
Amphipod-A		0.1	0.1	0.8		0.1			
Amphipod-B		0.1	0.1			0.1	2.8		0.1
Medusae-A	0.1								
veliger-A	4.2		2.7			12.9	0.1	0.3	0.1
veliger-B						0.1			
protozoea		0.1	0.3	2.7	1.0	21.5	2.3	0.4	0.6
schizopod			2.5	0.6	2.5	0.7		0.3	1.0
zoea	17.6	40.9	1.4	4.1	8.8	2.1	27.7	0.8	0.2
megalops						0.3	0.1		0.1
mysis	8.5	12.4	3.0	13.8	178.4	32.5	138.8	9.6	1.8
barn nauplii	2.4	0.1							
stomatopod				0.8	0.9	0.7	7.9	0.2	0.1
Nehu eggs	1.3			1.2					

1967

	18Apr PS 1040h T-25 18 1m	18Apr ½MN 1230h T-25 19 Deep	8May MN#2 2130h T-2 20 1m	8May ½MN 2135h T-2 21 Deep	9May MN#4 0925h T-2 22 1m	9May ½MN 0935h T-2 23 Deep	19May ½MN 1300h T-2 24 12cm	19May ½MN 1310h T-2 25 3m
Undinula			0.6	0.3				
Pseudodiaptomus		80.0	0.6	11.3				
Labidocera	5.3		0.6	2.6			3.1	
Acartia	0.8	0.2	1.9	0.1			0.4	
Oncaea venusta	0.2							
Oncaea spp	0.1							
Corycaeus			0.6					
Copilia							0.6	
Harpacticoids				0.7			1.2	
Sagitta	284.2	459.2	574.2	424.0	291.3	4.1	74.2	504.5
Leucifer	17.2	7.0	52.9	91.0	7.8	161.7	166.9	16.3
Ctenophores	7.4			55.0		0.3		0.3
Medusa-B				1.4	0.6			
Medusa-D				0.4				6.1
Medusae-sp	10.7							
Oikopleura	158.9	0.5	65.6	24.6	185.8	2.1	0.4	93.8
Evadne					1.2			
Mysids				0.1		6.5		
Ostracods				0.1				
Amphipod-A	11.8	2.3	1.9	2.5	3.0	0.5		5.1
Amphipod-B				0.5		0.8		
polychaete					0.6	0.1	0.2	
trochophores								0.3
brachiopod								2.0
bivalves	0.2	0.3	10.7		0.6			
veliger-A	0.3	1.3	300.0	96.6	277.0	0.2	1.2	61.2
veliger-B			1.3					
protozoea	0.6	0.5	47.3	167.0	14.4	0.3	2.1	2.6
schizopod	6.3	0.2	25.8	203.0	12.6		9.4	16.3
zoea	2.7	31.8	65.6	47.4	3.0	5.6	74.2	18.4
megalops	0.1	0.2	2.5	2.0		0.2		1.5
mysis	5.2	0.1	41.0	21.0	6.6	0.6	2.5	5.1
barn. nauplii	16.3	99.4					0.2	553.4
cypris		12.2						
stomatopod			1.3					
medusae-A				0.1				0.3
medusae-E			0.6		1.2			4.1

1967

	6June PS#1 1520h T-2 26	6June PS#2 2110h T-2 27	8June PS 1130h T-10 30	8June ½MN 1200h T-10 31 Deep	15June PS 1145h T-13 32	15June ½MN 1205h T-13 33 Deep	20June MN#1 1500h T-2 28 1m	20June MN#2 2035h T-2 29 1m
Undinula			0.1		0.1	0.5		
Labidocera	0.3		5.9		2.1			
Acartia					0.01		0.2	
Oncaea sp					0.01			
Harpacticoids								0.3
Sagitta	229.4	612.5	615.4	250.8	460.2	574.4	541.9	435.4
Leucifer	537.1	29.9	77.9	2.9	51.2	8.2	1.2	10.2
Ctenophores		9.6		1.1	8.0	10.9	23.9	105.3
Medusae-B							0.2	0.3
Medusae-D						0.9	0.2	1.6
Oikopleura	0.6		7.2	1.7	10.5	14.5	0.3	
Mysids	1.8							
Amphipods		1.9	4.0	1.3	2.2		2.4	0.8
polychaete						0.5		
brachiopod				0.1				
bivalve				0.5			1.5	
veliger-A			6.1	0.4	18.2	13.6	58.6	36.3
veliger-B							3.2	4.8
protozoea			54.6		4.2	53.6	32.4	11.8
schizopod		3.2	8.2	0.3	1.8	48.2	14.4	15.5
zoea	0.5	2.1	51.3	0.8	3.8	0.5	5.3	6.4
megalops		0.3		0.1				
mysis	7.8	10.3	84.3	4.3	31.5	10.9	17.7	17.1
barn nauplii							4.4	43.3
cypris								8.6
stomatopod			8.2		0.5		1.2	0.3
Stenopus				0.4	0.5			
Nehu eggs				2.1		30.9		4.3

1967

	22June	22June	22June	22June	13July	13July	13July	13July
	PS	½MN	½MN	½MN	MN#1	MN#2	MN#3	MN#4
	1300h	1510h	1530h	1545h	1000h	1020h	1040h	1130h
	T-24	T-2	T-10	T-10	Middle Sector Transect			
	34	35	36	37	44	45	46	47
		Deep	Deep	1m	2m	2m	2m	2m
Undinula	0.32	0.2	0.1		1.2	2.1		
Acartia	0.2		0.03	27.8	0.3	1.8		
Labidocera	0.6			0.3				0.02
Oncaea venusta			0.03	0.4				
Oncaea spp.					0.1	0.1	0.4	0.02
Corycaeus					0.1	0.1		
Copilia								0.02
Monstrilla					0.1			
Harpacticoids					0.1			0.2
Sagitta	445.6	491.3	257.5	618.0	197.8	297.8	519.2	504.2
Leucifer	29.4	1.3	5.7	8.3	0.7	1.4	3.1	2.3
Ctenophores	13.0	57.7	77.4	100.9	0.3	5.8	24.1	8.2
Medusae-B				0.1				
Medusae sp		8.8	4.1	1.1	0.9		1.4	
Oikopleura		0.2	2.2	0.3	87.1	77.4	162.4	53.4
Amphipods	4.3	5.0		1.3	3.9	5.3	9.4	
polychaete							0.2	
brachiopod		0.1						
veliger-A	11.7	11.2	6.5	27.5	6.9	2.0	22.8	56.2
veliger-B		7.2			13.6			
protozoea	17.0	0.3	3.4	20.3	0.4	0.5	2.4	14.0
schizopod	25.4	0.1	5.3	7.7			2.0	
zoea	11.5	5.8	4.0	24.2	157.2	96.8	24.3	137.7
mysis	14.7	9.1	18.9	37.4	180.0	109.9	111.4	15.6
barn nauplii	0.5	0.6	0.6					
cypris		0.3	0.1					
stomatopod	2.7	0.7	1.3	0.8	0.4		0.6	
Stenopus	0.6		1.0		0.1		0.2	
megalops	0.2							

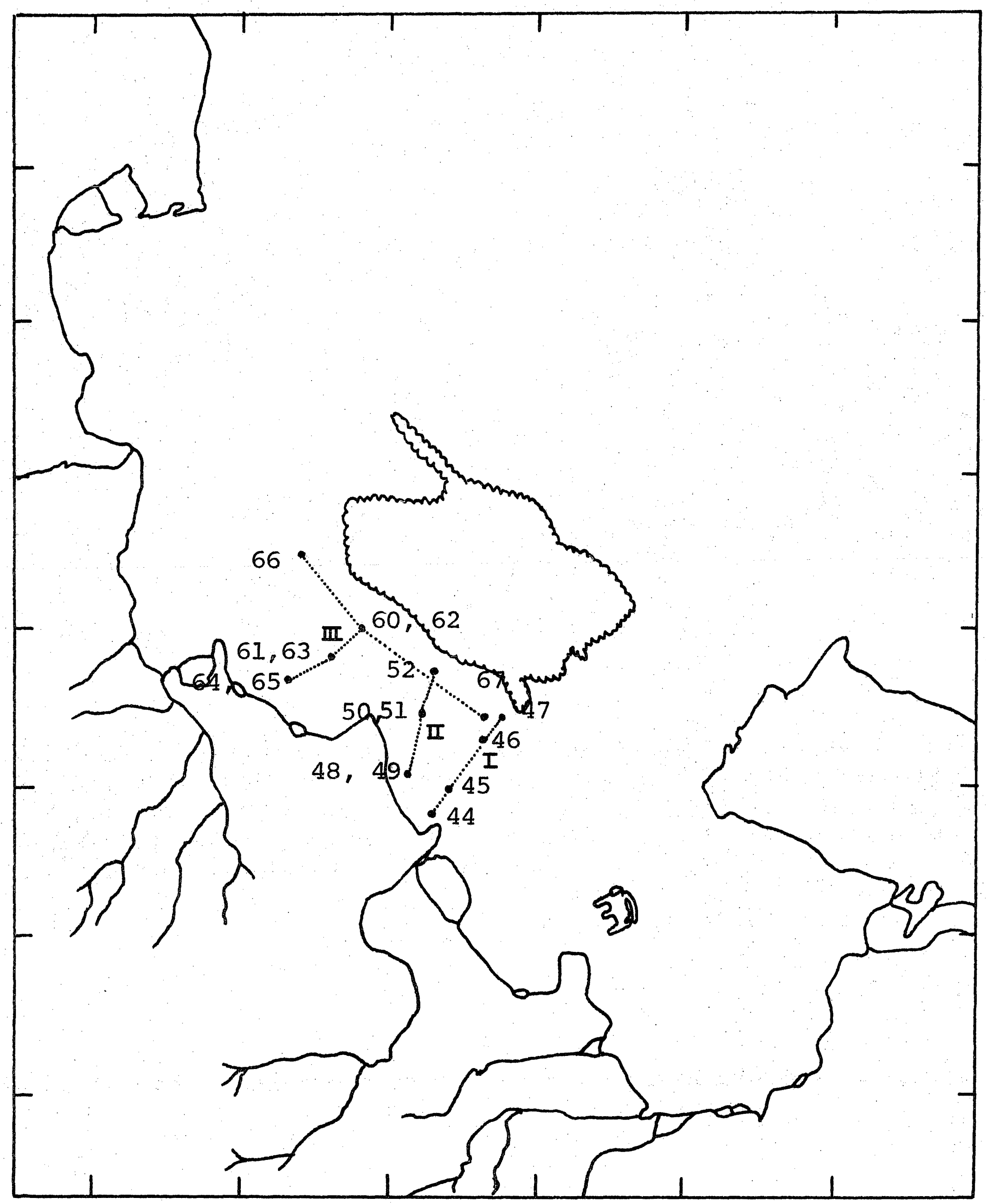
1967

	20July MN#1 1630h T-2 38	20July MN#2 2145h T-2 39	1 Aug MN#1 1300h Middle Sector Transect 48 2m	1 Aug ½MN 1310h 49 Deep	1 Aug MN#2 1330h 50 2m	1 Aug ½MN 1340h 51 Deep	1 Aug MN#3 1350h 52 2m
Undinula	0.3		0.1		0.03		
Acartia	0.3		1.2	0.3	0.2		0.3
Calanopia					0.03		
Pontellina	0.3						
Labidocera					0.03		
Copilia				0.2			
Harpacticoids			0.03				
Sagitta	181.8	442.4	408.2	26.7	446.9	0.5	397.5
Leucifer	5.9	24.8	0.3	0.2	0.6		1.0
Ctenophores	4.6		24.1	70.6	2.8	211.7	1.0
Medusae-B	0.7					0.9	
Medusae-D	0.3						
Medusae spp			1.3		0.6		
Oikopleura	46.9	36.2	263.6	0.2	173.2	10.8	105.2
Amphipods	3.3		4.4	0.8	1.7	1.4	2.3
Ostracods				0.2		3.2	
Pteropods	1.0						
Foraminifera				0.2			
polychaete	0.7	0.4					
brachiopod	0.3			0.8		2.3	
bivalves	3.3	0.8	0.3	0.3	0.3	1.4	0.3
veliger-A	30.6	31.1	17.9	33.4		45.5	4.3
veliger-B	0.3	1.7				2.3	
protozoea	24.8	10.1	1.7	1.1	5.6	5.4	0.8
schizopod	7.2	11.0	0.8	0.6	1.9	1.4	0.5
zoea	13.0	17.7	1.1		12.1		1.3
megalops							0.5
mysis	10.4	16.0	32.3	1.0	0.8	5.0	14.8
barn nauplii	26.1	26.1		0.3	0.6		
cypris		0.8					
stomatopods	2.6	2.1	0.8		0.8		0.5
Stenopus					0.3		0.5
Nehu eggs				1.3			

1967

	10Aug MN#2 1724h T-5 40	10Aug MN#4 2106h T-5 41	25Aug MN#1 1250h T-5 42	25Aug MN#2 1335h T-5 REPLICATED	25Aug MN#3 1413h T-5	25Aug MN#4 1456h T-5 43
			There were no copepods in these tows			
Sagitta	603.7	285.5	207.1	592.2	317.2	431.3
Leucifer	0.3	3.4	0.3		0.02	
Ctenophores	3.7	0.3	83.3	68.2	25.3	140.2
Medusae-D		0.3	0.7			
Medusae-F		2.9	0.9	0.3		
Oikopleura	3.3	1.0	67.7	121.9	40.5	42.0
Amphipods	0.3	1.5	0.2			
Ostracods				0.02	0.02	
Mysids		0.3				
trochophores	18.3	2.0	0.2	0.8	0.4	6.4
polychaete	0.7		0.3			
brachiopods	0.3		0.1	0.07	0.3	1.4
bivalves	0.7		0.9			0.7
veliger-A	332.4	22.1	25.9	***	***	7.8
veliger-B	2.0	0.5	0.9	***	***	5.0
bipinnaria					0.1	5.0
protozoea	10.6	0.5	6.7	***	***	29.9
schizopod	3.3	1.0	5.3	***	***	27.1
zoea	7.3	4.9	2.1	***	***	18.5
megalops	0.7				0.1	
mysis	11.3	3.4	4.8	***	***	10.7
barn nauplii	983.2	108.4	5.5	***	***	53.4
cypris	18.6	5.9	3.3	1.1	0.7	7.8
stomatopod	0.7					0.7
Nehu egg	1.3		0.5			10.7
frog					0.2	

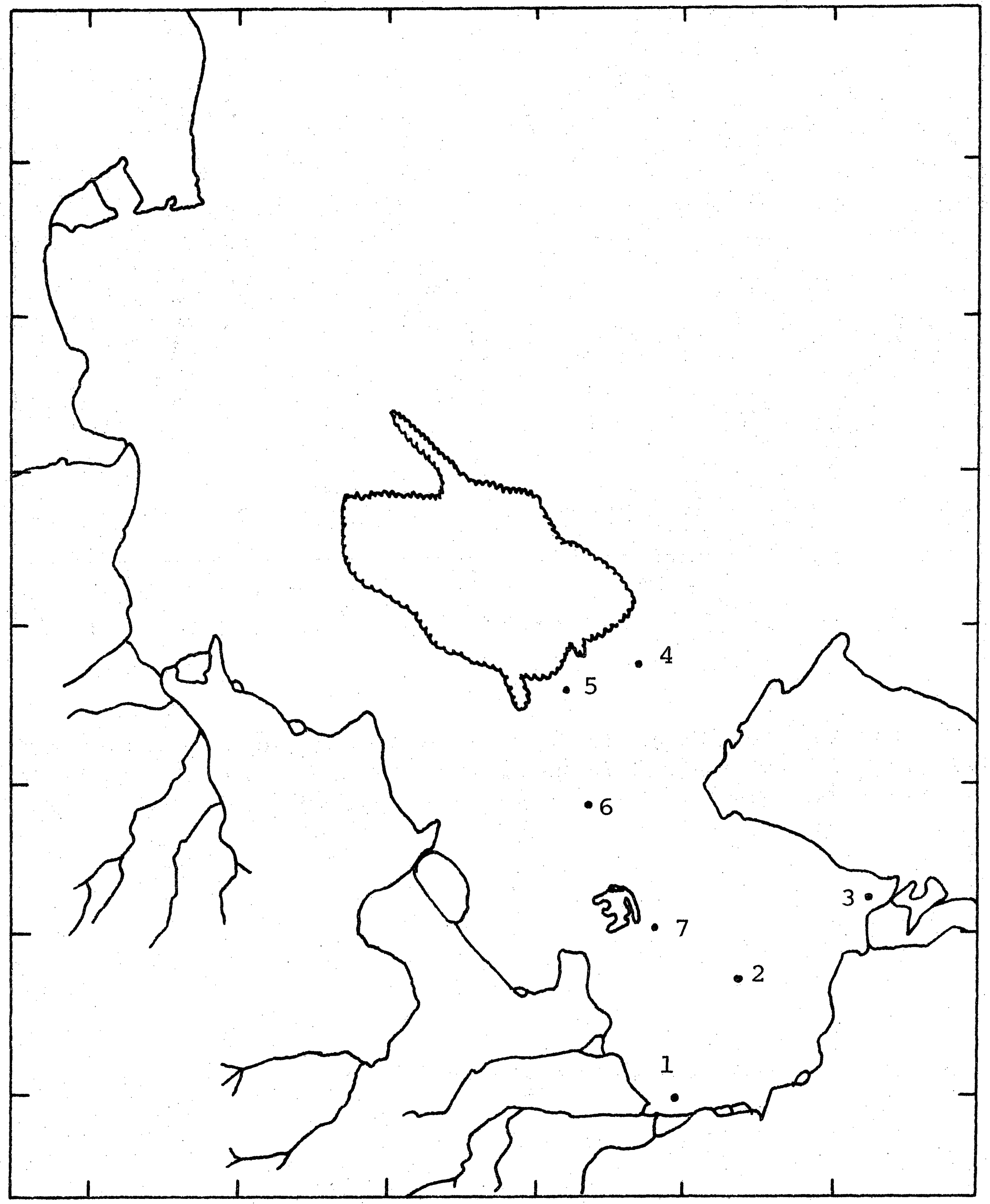
*** = taxa not counted



Appendix Figure 3. Location of the middle sector transect stations. Samples were taken along line I on 13 July 1967, along line II on 1 August 1967 and along line III on 5 October 1967. The numbers sample reference numbers. Samples were collected with a one meter net towed horizontally at a depth of 2 m.

1967

	5 Oct MN 1315h 2m 53	5 Oct MN 1330h 2m 54	5 Oct ½MN 1320h Deep 55	5 Oct ½MN 1335h Deep 56	5 Oct MN 1345h 2m 57	5 Oct ½MN 1350h Deep 58	5 Oct MN 1400h 2m 59	5 Oct MN 1430h 2m 60
	These tows were taken along a middle sector transect							
Undinula	0.8	0.7			0.2		0.3	0.3
Calanopia								0.03
Labidocera	0.3	2.0			0.2		0.4	0.7
Acartia	11.2	0.7			0.03	0.1	13.6	5.2
Oncaea venusta							0.03	
Oncaea spp						0.1	0.1	0.03
Corycaeus					0.03			0.02
Sagitta	177.9	214.1	6.9	11.5	175.3	20.6	57.1	530.0
Leucifer	2.7	1.1			1.9		2.0	13.5
Ctenophores	78.7	304.0	7.9	71.6	5.3	40.1	11.2	37.9
Medusae sp	2.2	5.5	0.4	0.5	1.0	0.2	1.8	0.6
Oikopleura	98.2	53.5		0.2	149.2	0.4	230.1	284.5
Amphipods	1.6	5.0	0.4	0.2	2.9	0.6	0.8	3.2
brachiopod		0.6						
veliger-A	9.8	6.1	0.3	0.5	16.3	1.1	0.5	11.9
protozoea	2.2	8.3	0.4			0.1	38.0	4.9
schizopod		5.5	0.4	0.4		0.3	24.2	0.5
zoea		3.4		0.1	7.7	0.1	3.1	13.5
megalops		0.6						
mysis	23.9	35.8	1.0	1.3	15.8	2.9	53.5	75.8
barn nauplii		1.7	0.1	0.1				
stomatopod					0.2		0.3	
Stenopus							0.3	
cypris		4.4						



Appendix Figure 4. Location of the 18-19 November 1967 tidal series stations. Zooplankton were collected with a net hauled vertically through the water column. The net had a ½ m mouth and 0.33mm mesh.

18-19 November 1967
Tidal Series
Average Abundance of Important Taxa

	STATION					
	1	*3*	*2*	*6*	*7*	*4*
Acartia	2.0	3.1	1.8	16.3	6.2	44.2
Sagitta	130.0	88.8	429.1	173.4	435.6	3.5
Ctenophores	8.9	7.1	30.5	38.2	50.1	2.3
Medusae	7.1	5.0	13.1	13.2	18.2	3.8
Oikopleura	87.0	78.8	223.2	75.5	177.6	91.6
Medusae-A	98.5	4.4	6.4	0.8	0.8	1.1
gastropod veligers	2.6	6.3	26.5	43.6	50.7	11.1
bivalve veligers	2.6					
protozoea	10.9	30.5	11.3	50.5	16.2	31.5
schizopod	1.7	8.7	4.2	60.9	15.1	3.8
zoea	10.9	10.7	5.8	23.9	12.8	23.7
mysis	1.8	5.1	4.2	24.5	11.1	17.4
barn nauplii	25.0	417.8	1500.0	267.1	306.0	328.6
cypris	3.0	2.2	1.4	4.5	4.7	3.9

18-19 November 1967
Tidal Series
Station 1
6m

	1200h 61	1510h 62	1815h 63	2130h 64	0017h 65	0340h 66	0625h 67	0930h 68	1240h 69
Undinula			0.8					0.8	
Pseudodiaptomus	4.0			0.8	1.6	0.8			
Acartia		0.8					0.8	0.8	5.6
Oncaea		0.8	0.8						
Corycaeus						0.8			
Cyclops	0.8	3.2							
Harpacticoids						0.8	0.8		
Sagitta	66.0	30.0	143.2	166.6	333.9	185.9	132.8	61.2	50.7
Leucifer					0.8				
Ctenophores	12.1	2.4	11.3	3.2	14.5	18.5	0.8		8.1
Medusae sp	5.6	4.0	8.9	2.4	12.9	3.2	8.1	2.4	16.1
Oikopleura	19.3	18.5	62.0	70.8	162.5	148.0	107.8	169.0	24.9
Medusae-A	117.5	3.2	111.0	11.3	147.2	73.2	128.7	115.1	179.4
polychaete			3.2		1.6	2.4	2.4	1.6	2.4
brachiopod	3.2	0.8				0.8			0.8
bivalve	2.4		3.2	0.8	1.6	0.8	4.0	1.4	6.4
gastropod	2.4		3.2	0.8	1.6	0.8	4.0	1.6	6.4
protozoea	5.6	16.1	9.7	8.9	15.3	12.1	7.2	16.1	7.2
schizopod				2.4	2.4	1.6	1.6	1.6	0.8
zoea	3.2	8.0	10.5	2.4	6.4	7.2	8.9	8.0	43.5
megalops		1.6							0.8
mysis	0.8		2.4				2.4	0.8	2.4
barn nauplii	31.4	12.9	30.6	23.3	20.1	6.4	28.2	23.3	49.1
cypris	1.6	1.6	9.7	4.0	1.6	0.8			1.6
ascidian	***	***	***	***		9.7	0.8		

18-19 November 1967
Tidal Series
Station 2
12m

	1220h 70	1520h 71	1825h 72	2135h 73	0034h 74	0350h 75	0635h 76	0940h 77	1250h 78
Undinula	0.4	0.8	0.8	0.8	1.2	0.8	0.4	0.8	0.4
Purple Calanoid					0.4				
Pseudodiaptomus				1.2					
Acartia	2.4	4.4	0.8	2.8	1.2	1.2	1.2	0.8	1.6
Oncaea venusta								0.4	
Oncaea spp		0.4							
Cyclopoid Unid									0.4
Corycaeus									
Sagitta	407.5	515.3	614.3	449.4	424.4	217.2	275.2	449.8	508.9
Leucifer		0.4	1.6	0.8	0.4				
Ctenophores	14.1	13.3	17.7	47.9	25.3	37.0	62.0	31.0	26.6
Medusae	7.6	8.5	30.6	17.3	14.1	2.0	4.4	16.1	17.3
Oikopleura	17.7	26.6	381.8	199.9	202.8	298.1	120.7	309.8	451.8
Medusae-A			20.5	1.2	2.4	13.7	0.8	2.8	3.6
trochophores			2.0	2.8	2.8	0.4	1.6	1.6	0.4
polychaete	2.4	4.0	2.4	6.0	2.4	2.8	0.8	2.0	5.6
brachiopod				0.4	2.4	0.4	1.2	2.0	2.4
gastropod	36.6	57.5	28.6	16.9	21.3	6.4	13.3	38.2	19.7
protozoea	2.8	12.1	24.1	10.5	11.3	3.2	5.2	14.5	18.1
schizopod	1.6	6.4	7.2	1.2	3.2	0.4	3.2	5.2	9.7
zoea	1.6	9.3	11.3	8.1	2.8	2.0	1.2	12.1	3.6
megalops		0.8							
mysis	4.0	2.8	4.4	5.6	2.0	2.0	2.4	6.0	8.9
barn nauplii	5054.3	5131.6	***	651.7	442.9	128.7	101.8	126.3	358.0
cypris	0.8	0.4	2.4	2.0	0.8	2.8		1.2	0.4
stomatopod							0.4		
ascidian							0.4	1.2	
Nehu eggs					9.3	2.0	0.8	3.6	2.4
frog				0.8				0.4	0.4

18-19 November 1967
Tidal Series
Station 2
Day-Night comparison of the
top 6m to a 12m water column

	1520h	1525h	0034h	0040h
	71	79	74	80
	12m	6m	12m	6m
Undinula	0.8	2.4	1.2	1.6
Purple Calanoid			0.4	
Acartia	4.4	9.7	1.2	2.4
Oncaea	0.4			
Corycaeus		0.8		
Cyclops			0.4	
Sagitta	515.3	682.3	424.4	230.1
Leucifer	0.4		0.4	
Ctenophores	13.3	27.4	25.3	12.9
Medusae	8.5	33.8	14.1	3.2
Oikopleura	26.6	234.9	202.8	403.9
trochophore		3.2	2.8	
polychaete	4.0	11.3	2.4	0.8
brachiopod		0.8	2.4	
veliger	57.5	93.3	21.3	31.4
protozoea	12.1	29.8	11.3	18.5
schizopod	6.4	4.0	3.2	1.6
zoea	9.3	12.1	2.8	5.6
megalops	0.8			
mysis	2.8	8.0	2.0	3.2
barn nauplii	5135.6	3977.8	442.9	616.3
cypris	0.4	1.6	0.8	2.4
ascidian		1.6		
Nehu eggs			9.3	7.2
frog		0.8		0.8

18-19 November 1967
Tidal Series
Station 3
6m

	1240h 81	1540h 82	1835h 83	2145h 84	0100h 85	0405h 86	0645h 87	0950h 88	1305h 89
Undinula		1.6	0.8					0.8	0.8
Pseudodiaptomus			0.8		0.8	2.4		0.8	
Acartia		2.4		0.8	5.6	4.0	3.2	3.2	2.4
Corycaeus					0.8				
Cyclops	0.8	0.8							
Harpacticoids					0.8				
Sagitta	4.8	165.7	51.5	69.2	19.3	7.2	2.4	440.9	37.8
Leucifer			0.8						
Ctenophores	3.2	9.7	3.2	3.2	4.8		0.8	10.5	21.7
Medusae		11.3	2.4	8.0	0.8			4.8	2.4
Oikopleura	1.6	29.0	26.6	173.0	68.4	206.8	48.3	153.7	1.6
Medusae-A		12.1		1.6	0.8	2.4	0.8	8.9	
polychaete	0.8	2.4			3.2	2.4		4.0	2.4
brachiopod				0.8		0.8			0.8
gastropod	0.8	2.4	3.2	0.8	8.9	0.8	2.4	17.7	19.3
protozoea	1.6	7.2	11.3	2.4	123.1	43.4	9.7	64.3	11.3
schizopod			1.6		16.1	12.1		9.7	4.0
zoea	2.4	6.4	16.9	1.6	16.9	16.1	6.4	18.5	11.3
megalops								0.8	
mysis	0.8		8.0	5.6	9.7	10.5	0.8	4.8	0.8
barn nauplii	12.1	500.4	515.7	88.5	513.3	65.2	26.6	1070.1	968.7
cypris	9.7	0.8	0.8	0.8	0.8	1.6	0.8	2.4	2.4
stomatopod		0.8			0.8				
ascidian						0.8	0.8	3.2	1.6

18-19 November 1967
Tidal Series
Station 4

	1300h 90 4m	1555h 91 4½m	1850h 92 4m	2205h 93 4½m	0110h 94 4½m	0420h 95 4m	0700h 96 5m	1005h 97 4½m
Undinula	1.2	1.1		8.6	178.1	2.4	16.4	9.7
U. darwini					8.6			
Euchaeta					2.1			
Calanopia			1.4					
Lucicutia					2.1			
Candacia					3.2			
Labidocera			3.4		1.1		1.0	
Acartia	1.2	22.5	18.2	26.8	21.5	1.2	164.1	97.8
Unid Calanoids					2.1			
Oithona					9.7	1.2		
Oncaea venusta					1.1	4.8		
Oncaea sp				1.1		1.2		1.2
Corycaeus					3.2	1.2	4.8	
Microsetella						3.6		
Sagitta		2.1	5.7	4.3	5.4		1.0	2.4
Leucifer			1.1					
Ctenophores			2.3				1.0	3.6
Medusae		2.1	2.3	1.1			4.8	8.5
Siphonophores					1.1			
Oikopleura	12.1	12.9	88.6	34.3	1.1	7.2	317.9	258.3
Pteropods				1.1	1.1	1.2		
Ostracods					3.2			
Amphipods			3.4	1.1			1.0	
Mysids			2.3		1.1			
Medusae-A							1.0	1.2
polychaete				2.1		1.2	1.0	1.2
gastropod	1.2	6.4	8.0	9.7			13.5	27.8
protozoea			130.7	11.8	11.2	1.2	14.5	19.3
schizopod			5.7		2.1		3.9	3.6
zoea	3.6	5.4	8.0	21.5	16.1		36.3	74.8
mysis	2.4	8.6	5.7	26.8	18.2		30.9	29.0
barn nauplii	59.1	328.3	186.3	55.8	8.6	2.4	542.6	1445.8
cypris	2.4	1.1	6.8			1.2	1.0	10.9
stomatopod					1.0		1.0	
ascidian	2.4						5.8	

18-19 November 1967
Tidal Series
Station 5

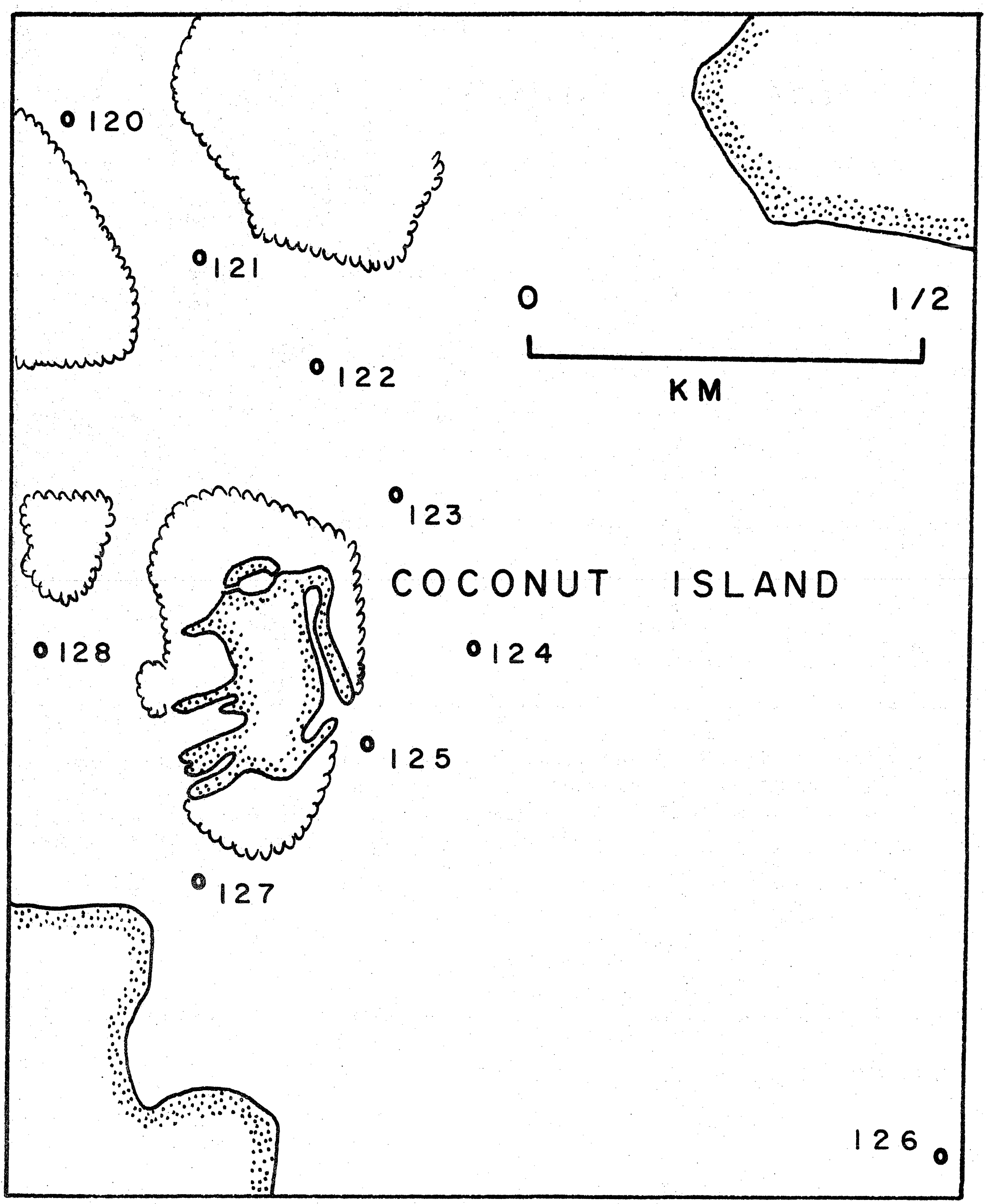
	1320h	1600h	1900h	2220h	0125h	0430h	0710h	1015h
	98	99	100	101	102		103	104
	3½m	3½m	3½m	3m	3m		4m	3½m
Undinula	1.4	1.4	1.5	1.6	30.6		4.8	16.6
Euchaeta					1.6			
Scolecithrix					1.6			
Labidocera			13.4	1.6	22.5		2.4	26.2
Acartia	12.4	29.0	13.4	1.6	14.5		33.8	42.8
Oithona					4.8			
Oncaea					1.6			
Corycaeus							1.2	5.5
Copelia					1.6			
Sagitta	2.8	5.5	3.0		17.7		3.6	
Leucifer			19.3		16.1			
Ctenophores							1.2	
Medusae							2.4	4.1
Siphonophores					1.6			
Oikopleura	1.4	12.4	31.2	1.6	1.6		62.8	209.7
Pteropods					1.6			
Amphipods	1.4		8.9		6.4			
Mysids			4.5		1.6			
polychaete	2.8				1.6		2.4	1.4
gastropod	2.8	1.4						1.4
protozoea		1.4	93.6				4.8	6.9
schizopod		1.4	5.9		1.6		3.6	
zoea	13.8		19.3	8.0	48.3		9.7	48.3
megalops			1.5					
mysis	4.1	1.4	56.4	3.2	56.3		7.2	9.7
barn nauplii	84.1	386.2	135.5	14.5	11.3			589.0
cypris	2.8	1.4	1.5					1.4
stomatopod					4.8		1.2	1.4
ascidian		1.4						4.1

18-19 November 1967
Tidal Series
Station 6

	1335h	1615h	1910h	2230h	0135h	0445h	0720h	1025h
	10m	9½m	10m	10m	10m	10m	10m	10m
	105	106	107	108	109	110	111	112
Undinula	2.4	3.6		1.9	4.8	3.4	8.2	2.4
Calanopia		0.5						
Labidocera	0.5		1.0	0.5	3.4	0.5	0.5	1.4
Acartia	8.2	16.3	4.4	18.8	28.5	11.6	32.4	10.1
Unid Calanoids		0.5						
Oncaea venusta			0.5					
Oncaea spp		1.0	0.5					
Copilia						0.5		
Setella							0.5	
Corycaeus				0.5	0.5		0.5	
Harpacticoids		0.5		1.0	0.5		1.0	0.5
Sagitta	202.3	91.0	384.8	347.1	105.7	43.9	148.7	63.7
Leucifer	0.5	1.5	9.2	5.3	6.3	5.3		
Ctenophores	42.5	21.3	35.7	45.4	33.8	25.1	33.3	68.1
Medusae		1.5	8.7	15.0	14.0	6.8	38.6	7.7
Oikopleura	50.2	42.2	75.8	104.3	107.7	76.8	71.0	76.3
Pteropods					0.5			
Ostracods		0.5	4.4	0.5	1.9	1.0	4.8	0.5
Amphipods		0.5	1.5				0.5	1.0
Mysids			0.5					
polychaete	4.3	3.6	11.6	2.4	6.8	2.4	1.5	10.6
brachiopod				0.5		1.0	1.5	
gastropod	19.8	5.6	103.8	105.7	67.6	28.5	4.3	13.5
protozoea	15.0	40.1	84.0	50.7	113.4	39.1	31.9	29.4
schizopod	22.7	111.3	89.3	41.0	86.4	83.0	36.2	16.9
zoea	4.8	11.2	18.3	29.9	56.0	31.9	28.5	10.6
megalops				0.5				1.0
mysis	2.9	2.0	24.1	68.6	47.3	23.2	21.2	6.8
barn nauplii	98.0	51.8	384.3	289.2	690.3	204.7	380.0	38.6
cypris	1.0	1.0	11.6	11.1	5.8	1.4	1.4	2.9
stomatopod				0.5	1.0	1.9		
ascidian		0.5			0.5	3.9	7.7	21.7
Nehu eggs		0.5						0.5
frog							0.5	
Medusae-A			0.5	1.0		0.5		1.5

18-19 November 1967
Tidal Series
Station 7
12m

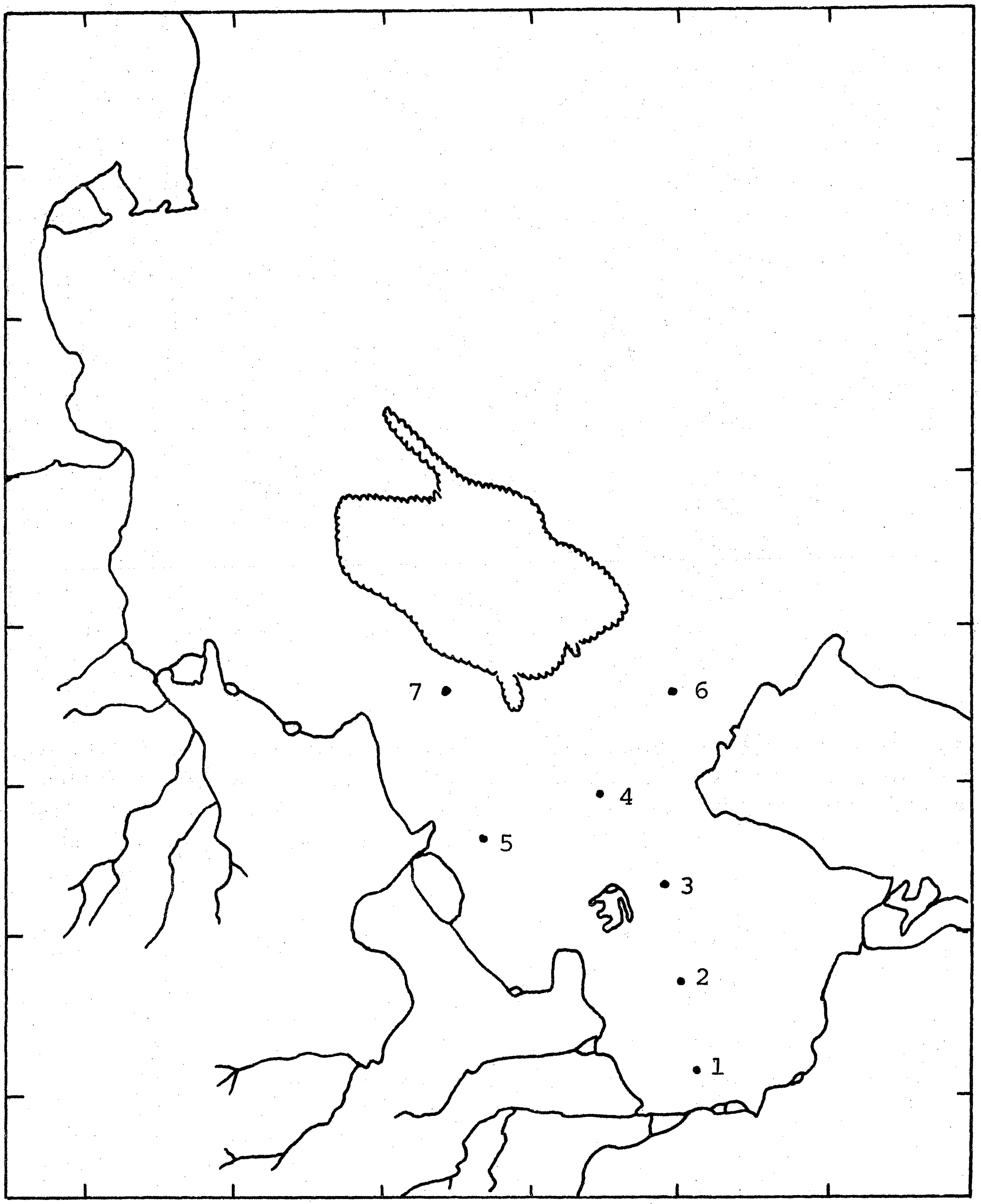
	1350h 113	1625h 114	1920h 115	2245h 116	0145h 117	0500h 118	0730h 119	1030h
Undinula		0.4	0.4		0.4	0.8	0.4	
Pseudodiaptomus			0.4		0.4			
Labidocera				0.4	0.4	0.8		
Acartia	2.0	4.4	18.5	6.4	2.4	4.4	5.6	
Oncaea venusta	0.4							
Oncaea spp		0.4						
Harpacticoids			0.4		0.4		0.4	
Sagitta	448.2	441.7	440.9	588.6	425.6	382.6	321.8	
Leucifer		0.4	3.2		0.4	0.8		
Ctenophores	60.8	27.0	45.9	31.0	37.0	96.2	52.7	
Medusae	16.1	9.3	14.1	18.1	17.3	36.2	16.5	
Oikopleura	162.5	76.8	131.2	189.1	148.5	219.3	315.8	
Pteropods					0.4			
Ostracods		0.4	0.4					
Mysids			0.4					
Amphipods	0.4				0.4	0.4		
Medusae-A		0.8	0.8	1.2	0.4	0.8	0.4	
trochophores	0.4		0.4					
polychaete	2.4	1.2	5.2	3.6	3.2	1.6	2.4	
brachiopod	0.4		0.8	0.4	0.8	0.8		
gastropod	17.7	86.5	43.1	48.3	90.1	42.2	27.0	
protozoea	27.8	21.7	3.6	8.9	18.5	10.1	22.9	
schizopod	17.3	15.3	12.5	3.6	17.7	20.9	18.5	
zoea	6.4	7.2	29.8	14.1	12.5	5.6	13.7	
megalops	0.4		0.4	0.4		0.4	0.8	
mysis	7.6	8.9	16.9	10.5	13.3	8.5	11.7	
barn nauplii	577.3	469.9	415.2	166.6	187.1	160.9	164.9	
cypris	1.2	3.2	8.5	10.1	6.4	3.2	0.4	
stomatopod			0.4	0.8		1.2	0.4	
ascidian				1.6		8.1	7.5	
Nehu egg					2.0	10.9	4.4	
frog				0.4				



Appendix Figure 5. Location of the 12 December 1967 surface series sampling stations. The numbers are sample reference numbers. These samples were taken with a ½ m plankton net of 0.33 mm meshes towed horizontally directly beneath the surface.

12 December 1967
Surface Series
½MN

	1405h 120	1415h 121	1420h 122	1425h 123	1430h 124	1435h 125	1520h 126	1530h 127	1535h 128
Undinula	0.3	0.3	0.8	0.8	0.5	0.2	0.5	0.4	0.5
Calanopia			0.5			0.1			
Euchaeta		0.1		0.1			0.1		
Labidocera	1.6	8.4	9.3	4.3	3.5	2.0	4.4	3.4	5.4
Acartia	0.2	1.6	1.1	0.9	1.4	0.8	1.3	0.4	0.3
Oithona						0.1			
Oncaea venusta				0.1					
Oncaea sp					0.1	0.1			
Corycaeus	0.3	0.2	0.1	0.3	0.2	0.1	0.2	0.2	0.4
Harpacticoids	0.3	0.5	0.4	0.4		0.1	0.3	0.1	0.2
Sagitta	61.2	119.7	78.3	99.9	137.7	78.3	52.8	90.9	168.3
Leucifer	33.8	37.2	42.3	44.5	19.3	6.3	1.1	6.2	11.9
Ctenophores			0.6	1.3	1.9	0.1	0.3	1.2	4.7
Medusae-B	0.1	0.1	0.9	1.3	0.5	0.5	0.5	0.3	0.9
Medusae-C			0.1			0.1		0.1	
Medusae-D				0.4	0.7	0.5	0.2	0.2	0.6
Medusae-sp	0.2	0.7		0.4	0.5	0.2		0.6	0.8
Oikopleura	2.9	0.8	6.4	17.0	85.8	46.4	53.4	22.2	95.2
Pteropods	1.3	3.3	0.5	0.3		0.1			
Amphipod-A			0.1						
Amphipod-B	0.1	0.4	0.1	0.1				0.1	
Caprella		0.1							
Medusae-A	0.4	0.3	1.3	3.5	5.8	30.6	45.4	11.3	15.2
ephyra						0.1			
trochophores						0.1			
polychaete		0.2	0.3	0.3					0.3
brachiopod								0.1	
gastropod	1.3	7.3	19.4	58.4	29.0	217.0	56.2	39.8	33.9
protozoea	1.1	5.7	12.0	4.2	0.8		1.6	1.2	1.1
schizopod	3.4	11.1	13.2	8.6	1.6	0.1	2.4	2.0	1.0
zoea	25.0	47.2	66.4	48.0	11.1	5.0	13.1	5.7	7.9
porcellanid			0.1						
mysis	3.9	9.8	8.4	10.6	3.6	2.0	1.6	1.4	2.6
barn nauplii	6.2	2.3	21.6	19.0	3.3	2.5	9.4	1.9	2.4
cypris				0.1					
stomatopod	0.3	0.2	1.8	1.7	0.3		0.1	0.3	
ascidian	0.1	1.1	0.6	0.3	0.1	0.1	0.4	0.2	



Appendix Figure 6. Location of the 2-3 February 1968 tidal series sampling stations. Samples were taken with a plankton net hauled vertically from a depth of 11m to the surface. The net had a ½ m mouth and 0.33 mm meshes.

2-3 February
Tidal Series
Average Abundance of Important Taxa

	STATION						
	1	2	3	4	5	6	7
Labidocera		0.4	0.4	0.6	36.8	2.8	20.3
Pseudodiaptomus	26.8	6.6	3.5	3.3	0.4	4.5	0.4
Acartia	0.4	0.7	0.7	2.6	4.3	1.4	24.6
Sagitta	609.1	431.2	267.0	232.3	208.3	170.6	6.4
Leucifer	2.3	3.5	4.7	4.3	9.7	7.5	2.9
Ctenophores	1.6	12.8	21.1	7.0	7.0	9.6	0.4
Oikopleura	119.9	191.3	165.2	216.1	111.2	170.2	7.5
Pteropods			0.4	0.4	0.7	0.4	3.5
Medusae-E	335.9	401.9	146.9	19.7	5.5	5.4	
veliger-A	17.6	18.8	34.4	21.1	25.5	15.5	4.0
veliger-B	8.5	10.4	4.0	0.9	0.4	0.4	0.4
protozoea	2.2	3.2	6.6	11.0	34.2	13.4	8.1
schizopod	1.3	1.9	3.2	10.4	14.9	9.8	3.2
zoea	4.5	9.8	55.4	16.9	98.5	32.4	59.6
mysis	1.0	2.5	7.7	4.8	13.3	12.3	11.3
barn nauplii	1174.2	299.9	118.6	2.9	4.2	0.4	7.2
cypris	3.9	3.2	1.1		0.4		
Nehu eggs	14.3	27.7	2.5	6.3	0.4	7.5	

2-3 February 1968
Tidal Series
Station 1

	1230h	1735h	2240h	0205h	0543h	1000h
	129	130	131	132	133	134
Undinula		0.4	0.8			
Pseudodiaptomus			31.2	27.2	21.9	
Acartia				0.4		
Oithona		0.4				
Oncaea			0.4			
Harpacticoids	0.4					
Sagitta	560.8	559.0	537.9	726.7	645.5	624.9
Leucifer		0.9	3.1	4.0	1.3	
Ctenophores	2.6		0.4	1.8	1.3	1.8
Medusae-B			0.4	0.9		
Medusae-C		0.9			0.9	0.9
Medusae-D		1.3	0.4	0.9	0.4	
Medusae-sp	0.9	1.8		2.6		
Oikopleura	158.4	90.4	47.4	131.2	80.3	211.9
Amphipods	0.9	0.9	0.9	0.9	0.9	
Caprella		0.4				
Medusae-A	4.0	1.8	0.9		1.3	
Medusae-E	435.7	236.1	250.1	344.5	299.0	450.2
polychaete	0.9	0.4	0.4	0.4	0.4	
veliger-A	19.7	41.3	4.4	5.7	14.9	19.3
veliger-B				9.2	11.0	5.3
protozoea	1.3	3.1	1.3	1.8	2.2	3.5
schizopod	0.4	1.8	0.4	3.1	1.3	0.9
zoea	4.8	6.1	3.1	9.7	0.8	2.6
megalops		0.4				
mysis	0.4	2.2	0.9	0.4	0.9	1.3
barn nauplii	1382.0	1374.3	863.6	1169.0	1579.7	676.6
cypris	2.2		3.1	5.7	6.1	2.2
stomatopod		0.4		1.3		0.4
Nehu eggs		0.4	4.8	32.9	32.0	1.3
frog			1.3	0.9	2.6	

2-3 February 1968
Tidal Series
Station 2

	1252h 135	1750h 136	2255h 137	0215h 138	0605h 139	1045h 140
Pseudodiaptomus			11.4	4.4	4.0	
Labidocera						0.4
Acartia				0.9		0.4
Oithona				0.4		
Cyclops	0.9					
Sagitta	365.1	363.3	320.3	628.4	498.5	411.6
Leucifer			2.2	3.5	7.5	0.9
Ctenophores	9.7	5.3	16.7	26.3	14.5	4.0
Medusae-B				0.4		
Medusae-C				0.4		
Medusae-D	0.9	1.8	1.3	2.2		2.2
Medusae-sp	1.3			0.4	0.9	
Oikopleura	258.9	95.2	176.4	270.3	181.7	165.4
Amphipods	1.8	3.5	2.6	3.5	1.8	0.4
Medusae-A	8.7	0.4	0.9	1.3		0.4
Medusae-E	309.8	428.3	580.1	300.6	578.3	214.3
polychaete	1.8	0.4	0.9	0.9	0.9	
brachiopod		0.4	0.4			
veliger-A	21.1	13.6	11.4	15.4	26.8	24.6
veliger-B			17.6	16.2	7.0	0.9
protozoea	4.0	2.6	4.8	2.2	1.8	3.5
schizopod	0.9	0.9	1.8	4.0	1.3	2.6
zoea	3.1	4.8	12.7	14.0	19.3	4.8
mysis	1.8	2.2	1.3	2.2	4.4	3.1
megalops		0.4		0.9	0.9	
barn nauplii	24.6	271.2	742.5	466.0	247.5	47.4
cypris	0.9	1.3	1.8	11.0	3.1	0.9
stomatopod		0.4		0.9	0.9	0.9
Nehu eggs	39.1	28.1	83.4	3.5	2.6	9.7
frog		0.4	0.9	3.1		

2-3 February 1968
Tidal Series
Station 3

	1430h 141	1805h 142	2305h 143	0230h 144	0622h 145	1056h 146
Undinula		0.4				
Pseudodiaptomus			4.4	5.7	0.4	
Labidocera	0.4					0.4
Acartia	0.4				0.9	
Sagitta	131.6	267.7	314.2	352.4	259.3	276.9
Leucifer	0.4	0.4	4.0	5.7	13.2	
Ctenophores	18.9	12.7	20.2	38.2	18.4	18.0
Medusae-D	3.5	3.1	0.9	2.6		0.9
Medusae-sp	0.9		1.3	0.4		
Oikopleura	177.7	154.5	173.8	145.7	172.5	167.2
Pteropods	0.4					
Ostracods	1.3	1.3	3.5	0.9	6.1	1.3
Amphipods		1.3	0.9	1.8	1.3	1.8
Caprella			0.9			
Medusae-A			1.3	0.4	0.9	0.4
Medusae-E	9.2	93.0	274.7	391.9	66.7	45.6
ephyra			0.4	0.4		
polychaete		0.9		0.4		
brachiopod		0.9				
veliger-A	43.4	9.2	25.5	31.6	71.1	25.5
veliger-B			7.9	4.8	1.8	1.3
protozoea	11.4	3.1	5.7	9.7	4.8	4.8
schizopod	3.1	1.8	2.2	4.0	5.7	2.6
zoea	112.8	7.5	120.2	46.5	14.9	30.3
megalops				0.8	0.4	
mysis	3.1	4.4	8.3	14.5	8.8	7.0
barn nauplii	6.6	23.3	158.0	315.9	13.2	194.8
cypris		0.4	0.9	2.2	0.9	1.3
stomatopod			2.2	1.8	5.3	1.3
Nehu eggs		1.3	3.5			2.6
frog			0.9	2.2		0.9

2-3 February 1968
Tidal Series
Station 4

	1442h 147	1812h 148	2315h 149	0245h 150	0637h 151	1105h 152
Undinula	0.9	0.9		3.1	2.2	0.4
Pseudodiaptomus			0.4			
Labidocera	3.1		14.9	142.6	22.4	0.9
Acartia	10.5	2.2	4.8	6.6	1.3	0.4
Corycaeus			0.4			
Copilia					0.4	
Sagitta	201.4	96.5	254.5	70.2	129.0	200.1
Leucifer	2.6		8.8	21.5	13.2	2.2
Ctenophores	5.7	3.5	24.6	5.7	1.3	0.9
Medusae-D	0.4					
Oikopleura	72.8	111.5	123.3	27.2	127.3	204.9
Pteropods	0.4		0.9			
Ostracods	2.2	0.9	2.6		6.6	0.4
Amphipods				0.9		0.4
Medusae-A	0.9	0.9	1.8		0.4	
Medusae-E	5.7	2.2	13.2	5.7	1.3	4.8
polychaete	0.4	1.3	1.8			
brachiopod						
bivalve				0.4		
veliger-A	51.8	8.8	36.0	12.3	9.2	34.7
veliger-B			0.4			
protozoea	21.9	33.8	37.3	25.9	79.4	6.6
schizopod	13.2	12.3	17.1	8.3	26.8	11.9
zoea	51.3	99.2	178.6	134.3	94.3	33.4
megalops				0.9		
mysis	8.3	8.8	30.3	14.9	10.5	7.0
barn nauplii	0.9	2.6	4.8	2.2	7.9	7.0
cypris						0.4
stomatopod			3.5	1.8		0.4
Nehu eggs					0.4	
frog			0.4		0.9	

2-3 February 1968
Tidal Series
Station 5

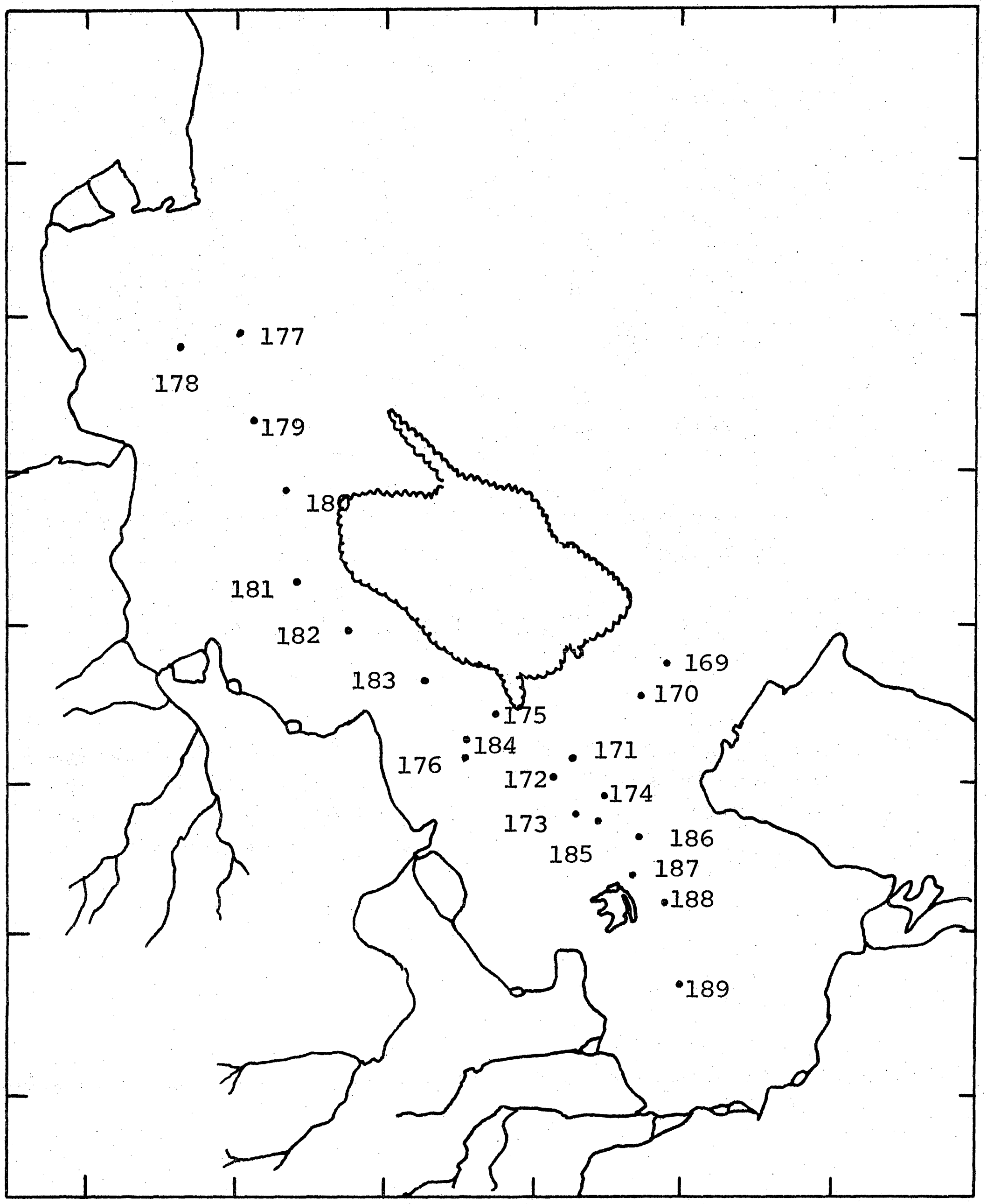
	1510h 153	1835h 154	2340h 155	0310h 156	0645h 157	1116h 158
Undinula				1.3	0.9	0.4
Calanopia					0.4	
Pseudodiaptomus			3.1	3.5		
Labidocera	0.9			0.4	0.4	
Acartia	2.2	1.3		5.7	1.3	
Oncaea venusta					0.4	
Copilia	0.4					
Sagitta	236.1	169.4	254.5	279.1	223.4	231.3
Leucifer	0.4		1.8	9.7	5.3	
Ctenophores	4.4	5.3	7.0	12.7	4.0	8.8
Medusae-B					0.4	
Medusae-D		1.3		0.9	0.4	1.3
Medusae-sp	1.8	2.2		0.4		
Oikopleura	130.8	207.1	231.3	323.0	167.6	236.9
Pteropods		0.4				
Ostracods	0.9			0.4	3.1	
Amphipods		0.4	0.9			
Mysids			0.4	0.4		
Medusae-A		0.4	3.1	0.9	1.3	
Medusae-E	9.0	19.3	23.7	26.3	11.9	28.1
polychaete	1.3	1.8	3.1	0.9	0.9	0.9
brachiopod	0.4					
bivalve		0.4		0.4		
veliger-A	6.1	14.5	25.0	34.2	36.0	11.0
veliger-B			0.9	0.9		
protozoea	4.8	5.7	5.7	22.8	14.0	13.2
schizopod	0.9	5.7	1.8	8.8	7.0	5.7
zoea	7.0	54.9	7.0	10.5	7.0	14.9
megalops				0.9		
mysis	2.6	4.8	1.8	6.6	5.7	7.0
barn nauplii	0.9	1.3	5.3	2.2	3.5	4.4
stomatopod				0.4	0.4	
Nehu eggs			8.8	4.4	11.0	0.9
frog		0.9	0.9	4.0	0.9	1.8

2-3 February 1968
Tidal Series
Station 6

	1530h 159	1855h 160	2359h 161	0330h 162	0707h 163	1145h 164
Undinula	1.3	0.4	0.4	8.3	2.6	1.3
Pseudodiaptomus			0.4			
Labidocera	5.7	6.1	98.7	2.2	5.3	4.0
Acartia	54.4	6.1	2.2	51.8	22.8	10.1
Unid Calanoids				1.3		
Oithona				3.1		
Corycaeus	0.4			0.9		0.4
Copilia	0.4		0.4			
Harpacticoids			0.4			
Sagitta	8.8	3.1	11.9	3.1	5.3	6.1
Leucifer			5.3	0.4		
Ctenophores			0.4			
Medusae-D	0.4					
Medusae-sp	0.4					
Oikopleura	4.8	6.1	10.5	3.5	11.0	8.8
Pteropods			2.6	4.4		
Ostracods				0.4		
Amphipods		0.4	0.4	1.3	0.4	
Mysids				0.9		
Medusae-A	0.4	0.4				0.4
Medusae-E			0.9		1.8	2.2
polychaete	0.4	0.4	1.3		0.9	0.4
veliger-A	5.7	0.4	7.9	0.9	3.1	5.7
veliger-B				0.4	0.4	
protozoea	3.1	0.9	17.1	1.7	19.8	6.1
schizopod	0.9		6.1	0.9	3.5	4.8
zoea	7.9	3.8	21.1	267.7	14.0	38.2
megalops			0.4			
mysis	4.0	0.4	7.5	39.5	7.5	8.8
barn nauplii		0.4	6.6	0.9	22.8	5.3
stomatopod			1.3	4.0		
squid				0.4		

2-3 February 1968
Tidal Series
Station 7

	1550h 165	1909h 166	0015h 167	0345h 168	0725h	1125h
Undinula	1.3	0.4	0.4	1.3		
Euchaeta			0.4			
Calanopia				0.4		
Pseudodiaptomus		0.9	6.6	6.1		
Labidocera	0.4	1.3	5.3	4.0		
Acartia	0.4	1.3	1.3	2.6		
Sagitta	129.0	201.0	180.4	172.0		
Leucifer	0.9	5.7	14.5	8.9		
Ctenophores	2.2	4.4	12.7	18.9		
Medusae-D	0.4		0.9	0.4		
Medusae-sp	1.3			0.4		
Oikopleura	114.5	158.9	236.1	171.1		
Pteropods			0.4	0.4		
Ostracods		0.4	1.8	2.6		
Amphipods		0.4	0.4			
Medusae-A	1.3		0.9			
Medusae-E	9.2	2.6	1.3	8.3		
polychaete	0.4	0.9	2.2			
bivalve	0.4					
veliger-A	17.6	14.0	21.9	8.3		
veliger-B				0.4		
protozoea	16.7	10.1	12.3	14.5		
schizopod	13.2	15.4	4.8	5.7		
zoea	17.6	18.9	20.6	72.4		
mysis	11.0	13.6	7.5	17.1		
barn nauplii			0.4			
stomatopod	1.3	0.4	0.4	3.1		
Nehu eggs		6.6	2.6	13.2		
frog		1.3	2.2	7.9		



Appendix Figure 7. Station locations for the 23 February 1968 synoptic survey. Numbers are sample reference numbers. The samples were collected with a one meter plankton net of 0.33 mm meshes towed horizontally at a depth of 2 m.

23 February 1968
Synoptic Survey

	1000h 169	1015h 170	1030h 171	1040h 172	1050h 173	1055h 174	1120h 175	1125h 176
Undinula	13.6	7.0	2.6	22.4	20.6	3.3	50.3	25.5
Euchaeta	0.3						0.3	
Calanopia								0.4
Candacia	0.3							
Labidocera	114.5	34.1	13.8	45.4	5.7	3.3	11.9	3.8
Acartia	17.9	13.3	5.5	3.4	12.3	3.7	19.2	10.1
Unid Calanoids	12.5	5.0			0.5	1.5	2.6	0.4
Oithona	4.9	3.0	0.3	0.3	0.3	0.7	2.0	0.4
Oncaea venusta	1.4	0.6	0.5	0.8	0.4	0.7	1.2	0.4
Oncaea sp	0.8			0.3	0.1		1.2	
Corycaeus sp	12.5	1.3	0.5	0.3	0.3		0.3	0.4
Monstrilla		0.1						
Harpacticoids		0.1		0.3	0.1			
Sagitta	3.3	2.4	98.1	172.7	60.7	229.0	93.0	174.4
Leucifer		1.7	23.4	61.1	6.6	22.6	2.6	1.1
Ctenophores	0.3	0.1	38.7	19.1	3.4	3.7	2.6	5.9
Medusae-D			0.5					
Oikopleura	42.9	32.3	145.6	71.5	20.3	19.2	12.1	10.1
Foraminifera	0.8							
Creseis		0.1						
Ostracods	0.3							
Amphipods	0.5	0.1		0.5		0.7	0.9	
Caprellid		0.1						
Pycnogonid	0.3							
Medusae-A		0.5			0.3			0.4
Medusae-E			0.5					
polychaete	7.1	5.3			0.5		0.3	
bivalve	0.3	0.1						
veliger-A	0.8	3.0	45.2	93.9	2.2	7.4	9.6	74.7
veliger-B	2.4	2.3	1.0	0.3	0.1	0.4		
protozoea			8.3	0.8	0.4	3.0	0.3	1.0
schizopod	1.6	0.4	3.6	0.8	0.4	1.9		
porcellanid zoea		0.1						
zoea	86.0	34.3	11.4	12.0	31.8	64.0	173.9	110.9
megalops	0.3	0.1						
barn nauplii	1.6	4.5	2.1	3.1	1.5	0.4	0.3	0.4
cypris	0.5	0.3	2.1	1.0	0.1			
mysis	11.9	29.3	4.2	2.9	3.3	4.1	62.2	10.1
stomatopod	0.3	0.1						

23 February 1968
Synoptic Survey

	1155h 177	1200h 178	1220h 179	1230h 180	1240h 181	1250h 182	1300h 183
Undinula	14.0	9.1	2.6	13.1	8.9	18.6	168.7
Calanopia		0.1					
Labidocera	6.6	3.2	4.9	11.0	1.7	2.5	7.4
Acartia	11.2	18.1	4.8	14.1	34.2	17.6	64.8
Unid Calanoids	0.5	0.5	0.5	4.1	0.2		
Oithona	0.4	0.2	0.2	1.6	0.5	2.5	0.4
Oncaea venusta	0.2	0.1		0.2	0.5	0.3	
Oncaea sp						0.3	
Corycaeus	0.1	0.1	0.04	0.6		0.3	0.4
Harpacticoids		0.1					
Sagitta	8.5	23.4	34.2	221.6	184.2	140.9	159.1
Leucifer	0.5	0.7	0.5	17.8	10.8	5.4	4.8
Ctenophores			0.1	0.6	6.0	6.6	7.0
Medusae-B				0.6			
Medusae-D	0.04		0.1				
Oikopleura	35.8	17.8	12.4	228.5	226.8	163.6	90.3
Pteropods						0.3	
Creseis						0.3	
Amphipods				0.2	0.4		
Mysids						0.3	0.4
Medusae-A	0.1	0.1	0.1	0.2			
Medusae-E	0.1		0.04			0.3	
polychaete	0.1						
veliger-A	11.3		3.4	31.8	36.8	83.1	69.6
protozoea			0.04	0.6			
zoea	2.7		0.5	2.0	9.1	13.8	88.8
megalops			0.04				
mysis	1.9		0.7	3.7	5.3	3.2	13.3
barn nauplii				3.3		0.9	
cypris				1.0			
Nehu eggs					0.5		

23 February 1968
Synoptic Survey

	1315h 184	1325h 185	1335h 186	1345h 187	1350h 188	1355h 189
Undinula	5.9	5.0	0.9	1.1	0.5	0.7
Labidocera	5.6	3.9	2.7	0.4	0.7	0.4
Acartia	5.6	6.0	1.3	0.8	0.2	0.4
Oithona	2.0					
Corycaeus	0.3				0.2	0.4
Oncaea		0.4				
Harpacticoids				0.4		
Sagitta	161.8	327.7	496.3	267.1	230.2	239.9
Leucifer	1.3	7.1	9.8	4.2	9.5	5.1
Ctenophores	16.3	3.9	17.0	1.9	2.6	1.1
Medusae-D		0.4				
Oikopleura	17.9	74.3	276.7	98.5	326.6	211.4
Amphipods			6.7	0.8	0.7	
Medusae-A	0.3	0.7		0.4	0.2	1.1
Medusae-E	0.3					0.4
polychaete	0.3	1.8			1.0	0.4
bivalve	0.3				0.2	0.4
veliger-A	15.3	80.0	231.2	16.0	10.9	61.6
veliger-B	0.3	0.7		0.4		
protozoea	4.9	5.3	8.0	6.9	4.3	10.8
schizopod	1.8	1.4	21.4	4.6	3.3	1.5
zoea	62.3	27.6	6.3	22.2	10.9	15.6
mysis	8.7	5.3	4.5	10.7	8.1	4.5
barn nauplii		3.5	8.0	2.3	0.2	0.4
cypris	0.3		1.8	2.3	6.2	5.2
stomatopod				0.8		
Nehu eggs				0.8		0.7

9 October 1967, Bouy 17
Horizontal tows, one meter net, 0.33 mm mesh
Qualitative only, one minute tows
1/8 Aliquot

Acartia hamata	71	161
Labidocera hawaiiensis	155	34
Undinula vulgaris	1	2
Oncaea venusta	1	0
Oncaea spp	3	3
Corycaeus spp	2	2
Sagitta enflata	352	547
Lucifer chacei	41	15
Ctenophores	1	4
Oikopleura longicauda	177	432
Veliger-A	326	796

2 May 1968
Horizontal Tows with ½-MN, 0.33 mm mesh
Qualitative, for 1 minute

	T-10 0m	T-10 2m	T-2 0m	T-2 2m
Labidocera	0	0	1	
Calanopia	0	2	0	
Sagitta	+++	+++		
Lucifer	38	13	456	224
Ctenophores	14	19	84	
Oikopleura	+++	+++		
Amphipods	2	1	0	
Medusae B	16	6	12	
Medusae D	5	0	0	
Medusae sp	12	4	0	
ephyra	0	0	1	
Medusae-A	68	7	4	
Medusae-E	0	1	0	
bivalves	4	15	0	
veliger-A	+++	+++		
veliger-B	0	0	12	
protozoea	1	0	228	
schizopod	11	4	23	
crab zoea	++	30		
mysis	121	140	18	
barn. nauplii	80	++		
cypris	22	26	8	
polychaete	5	0	20	
frog	0	0	16	
Nehu eggs	27	22	0	
Stenopus	4	0		

+++ = abundant
++ = common
0 = not present in sample
blank = not counted

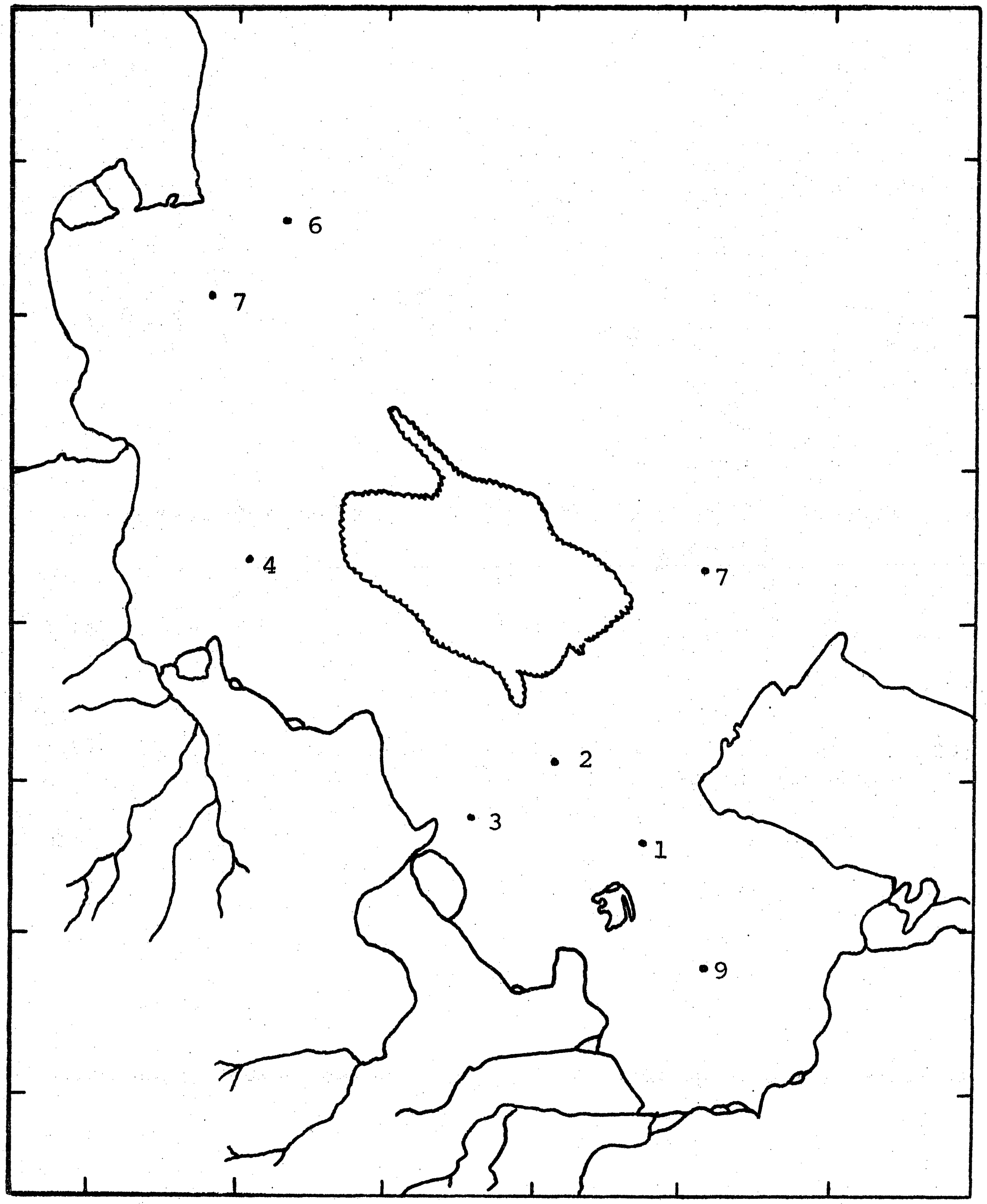
13 May 1968, west of entrance to HIMB, Coconut Island (exceptions noted)
Horizontal tows, $\frac{1}{2}$ m net, 0.33 mm mesh, surface samples (exceptions noted)
Morning tows = slack water
Afternoon tows = incoming tide
Abundances no./m^3 Not all taxa were counted

	0917	0922	0935	0938	0943	0948	0953
Acartia	4.3	4.6	1.1	4.0	8.8	3.0	4.8
Undinula	2.4	0.6	0.5	4.4	1.6	3.2	1.5
Labidocera	0.9	1.3	0.5	1.0	1.9	1.1	8.2
Other copepods		0.1			0.2	0.6	0.2
No. of copepod spp		1			1	3	1
Lucifer	5.7	4.3	5.8	8.7	13.8	9.4	28.2
Ctenophores	13.4	8.2	25.3	26.4	12.6	35.6	9.1
Nehu eggs	0.8	0.6	1.3	0.8	0.3	0.2	
megalopa	0.2	0.1	0.3	1.4			
Stenopus larvae							0.2
Medusae-A	0.2	0.4	0.5				

	1347	1352	1356	1400	1403	1408	1410 southwest of Coconut I.	1420 Bouy 27	1425 entrance to Coconut I. 0.5 m	1430 entrance to Coconut I. 2 m
Acartia	1.7	3.4	3.9	1.4	4.2	4.2	1.1	14.9	0.6	
Undinula	0.7	0.2		0.7	0.2		0.2	9.8	0.4	0.5
Labidocera	0.2	0.9	1.1	0.4	0.5		1.1	0.6	1.8	
Other copepods	0.2	0.4	0.3		0.2			0.8	0.6	
No. of copepod spp	1	2	1		1			3	2	
Lucifer	42.0	27.9	24.2	8.2	11.0	11.1	23.3	39.3	10.5	5.3
Ctenophores	0.4	4.5	1.6	0.5	0.7	0.8	5.5	6.3	3.6	
Nehu eggs		0.2	0.3	0.4	0.5					0.3
megalopa			0.3						0.2	
Stenopus larvae		0.2	0.5		0.2					
Medusae-A		0.2	0.5			0.3	0.2			

13 May 1968, west of entrance to HIMB, Coconut Island
Individual one-gallon plastic buckets from the surface,
filtered through 0.065 mm mesh cones
Morning samples at 1000h
Afternoon samples at 1430h

Paracalanus	8	7	10	10	7	15	8	8	24	8	14	8	7	28	26	MORNING SERIES
Oithona	2	1	4	2	2	0	2	2	3	2	1	1	2	2	3	
Labidocera	1								1						1	
copepod eggs	8	10	1		1		1									
Sagitta	2	2	1	2	2	1	1		5		3					
Ctenophores													1			
Oikopleura					1		2							2		
protozoea									1							
schizopod									1							
zoea	5		1		3	2	1				3			3		
barnacle nauplii				1												
Paracalanus	7	8	7	1	1	6	3	10	9	10	10	4	3	5	12	AFTERNOON SERIES
Oithona	2	6	3	2	7	6	2	2	4	3	2		4	2	2	
Undimula												1				
Sagitta	4	8	14	10	5	21	5	12	7	8	8	11	9	20	8	
Oikopleura															1	
protozoea	1		1													
Lucifer adult	1															
barnacle nauplii									1							
decapod mysis									1							
bivalves		3			2	1	2		1						2	
polychaete		1														



Appendix Figure 8. Location of Clutter's pollution study sampling stations. Samples were collected with nets hauled vertically through the top 11 m of the water column. The net was a ½ m with 0.33 mm mesh.

CLUTTER'S DATA

24 July 1968
Pollution Study
No./2 m^3

	STATION							
	1	2	3	4	5	6	7	9
Copepods	6	19	4	47	28	105	1469	28
Sagitta	741	732	772	170	53	33	30	776
Leucifer			4		4	1		1
Ctenophores	4		19	2	5		3	73
Medusae	20	72	13	5	13	1	1	27
Oikopleura	90	99	28	142	117	9	26	173
Amphipods	10	3	6	2		1	2	3
Ostracods		12	5	11	3			3
Isopods				1		1		
Mysids		7		28	2	54	14	5
Foraminifera				9				
trochophores	27	3			4			25
brachiopods	1		1					7
bivalves	2	7	1		3			3
gastropods	17	11	102	92	16	24	14	194
polychaete	48	28	4	2	2		6	3
protozoea	105	191	38	6	56	15	1	51
schizopod	1			2	17		3	11
zoea	23	41	65	23	66	112	17	45
megalops		1		1				
porcellain zoea	1	1					1	
mysis	38	183	84	90	88	422	20	13
barn nauplii	15	9	3		3			38
stomatopod	2	12	2	6	2	1	3	
echinopluteus					1			
auricularia	5	2	1		4			1
ascidian	1	5					1	8
fish eggs	10	11	16	15	5	2	3	32
fish larvae	12	23	7	10	23	7		17
misc. eggs		3						

These samples were counted by either P. Wagner or V. Cohn.

31 July 1968
Pollution Study
No./2 m^3

	STATION							
	1	2	3	4	5	6	7	9
Copepods	18	33	11	57	42	107	111	10
Sagitta	797	566	722	177	75	126	10	921
Leucifer		2		26				9
Ctenophores	6	248	118	23	5	10	1	279
Medusae	38	57	5	4	10	10	1	6
Oikopleura	267	269	109	289	54	16	64	180
Amphipods	16	5	16	2	2	3		20
Ostracods	8	7	9	17				32
Isopod					1			
Mysids	10	10	13	43	1	1	3	13
trochophore	3							
polychaete	41	9	8	6	2	15	1	34
bivalves	4	1	1		1			4
gastropods	16	11	712	476	84	87	10	824
protozoea	146	52	52	43	16	62	3	16
schozopod	30	47	9	7	5	15	2	27
zoea	92	130	133	70	24	85	62	53
megalops	1	2				1		
porcellanid								1
mysis	79	399	30	149	42	286	49	28
barn nauplii	8		40	56	68	29	3	41
stomatopod	8	7	3	1	1	5	7	
ascidian	7	1	2	3	3	1		3
tornaria	2	1			1			
squid						1		
fish eggs			6	48		1		6
fish larvae	16	30	8	34	4	12	2	7
misc eggs	5	3	2		3		13	

These samples were counted by either P. Wagner or V. Cohn

7 August 1968
Pollution Study
No./2 m^3

	STATION							
	1	2	3	4	5	6	7	9
Copepods	32	61	65	84	48	63	1254	64
Sagitta	1539	1093	1200	439	325	82	20	1391
Leucifer	2	53	13	8	30	21	6	7
Ctenophores	219	57	81	9	15	4		106
Medusae	9	20	13	3	6	4		31
Oikopleura	743	2912	1816	1820	1030	266	171	4585
Ostracods	10	37	17	11	3		4	11
Mysids	12	2			8		52	1
Pteropods			8	1			1	4
polychaetes		1	1					
planula	2	4	2					
trochophores	67	15	2	1		3		12
polychaete	70	64	54	13	14	5	10	80
brachiopod	21	9	3					2
bivalves	20	53	27	8	4		1	46
gastropod	187	64	164	43	23	30	19	52
protozoea	33	112	70	52	104	94		220
schizopod	48		32	31		9		45
zoea	30	31	47	38	90	457	136	41
mysis	20	163	99	87	70	230	110	83
barn nauplii	100	12	11	16	33	35	4	5
stomatopod	2	7	6	5	6	9		5
auricularia	7	5	13	1				7
ascidian	24	17	22	7	7	4		18
porcellanid							2	
fish eggs	75	15	10	42	2	1	1	22
fish larvae	24	43	81	97	69	79	3	79
misc eggs		8	17	9	6	3	10	27

These samples were counted by either P. Wagner or V. Cohn.

14 August 1968
Pollution Study
No./2 m^3

	STATION							
	1	2	3	4	5	6	7	9
Copepods	86	30	64	108	58	255	462	40
<u>Sagitta</u>	1755	1110	1695	180	96	64	5	2268
<u>Leucifer</u>	31	18	25	6	24	26	1	52
Ctenophores	42	197	241	22	5	1		9
Medusae	113	24	9	3	2	1	2	26
Amphipods	44	50	50	11	1	4	17	41
<u>Oikopleura</u>	1622	648	759	889	187	54	155	2748
Ostracods	14	221	22	44		1		43
Mysids							21	
Pteropods	1	10	29	3		1	2	6
Foraminifera				16	3	3	2	2
Radiolarians							2	
planula	7	1	1					
trochophores	4	2	2					
polychaete	92	12	15	4	7	2	3	182
brachiopod	2	3	23	1				
bivalve	107	5	31	8	1		3	25
gastropod	73	47	715	94	66	26	11	70
protozoea	401	69	183	245	122	94	4	327
schizopod	119	47	36	56	176	73	2	38
zoea	47	31	47	20	23	132	72	70
megalops								3
porcellanid	1						3	
mysis	49	79	109	328	63	97	48	194
barn nauplii	3	8	32	33	90	44	1	8
stomatopod	4		1	4	1	1	4	4
octopus							1	
cyphonautes								
<u>Phoronis</u>		1						
auricularia	4	4	30	1	1			9
ascidian	30	2	14	4	10	2		32
fish larvae	40	8	43	51	21	23	12	19
fish eggs	6	2	14	56	12	3	7	10
misc eggs	26	10	48	11	1		1	71
egg clusters	1			1				1

These samples were counted by either P. Wagner or V. Cohn.

Pollution Study
Species Diversity

Shannon-Weiner Function

DATE/STATION	1	2	3	4	5	9
24 July 1968	2.22	2.60	2.01	3.09	3.37	2.67
31 July "	2.64	2.92	2.49	3.11	3.30	2.48
7 Aug "	2.70	2.22	2.40	2.03	2.42	1.80
14 Aug "	2.59	2.67	2.84	2.99	3.30	2.10
Average	2.54	2.60	2.44	2.81	3.10	2.26
Rank	3	4	2	5	6	1

Simpson Index

24 July 1968	.4128	.2867	.4492	.1575	.1266	.2895
31 July "	.2853	.1794	.2667	.1685	.1243	.2621
7 Aug "	.2733	.3689	.3156	.4405	.3333	.4746
14 Aug "	.2655	.2528	.2273	.2099	.1268	.3226
Average	.3092	.2720	.3147	.2441	.1778	.3372
Rank	3	4	2	5	6	1

Pollution Study
Station 9
No./2 m^3

	1968					
	21 Aug	28 Aug	11 Sept	25 Sept	9 Oct	23 Oct
Undinula			1	2		
Labidocera			1	2	45	
Pseudodiaptomus			1			
Unid Calanoids					1	
Acartia	3	86	8	20		1
Oithona			1		5	
Corycaeus			1			
Oncaea				1		
Copilia					1	
Harpacticoids		2				3
Sagitta	985	1420	1038	1314	1225	811
Leucifer	8	20	25	16	14	13
Ctenophores	55	38	148	65	22	80
Medusae-C	18	3	2		6	
Medusae-sp	3	8	5	2	4	11
Oikopleura	319	480	120	60	500	416
Amphipods	22	38	13	8	18	12
Ostracods		1		1		
Evadne					3	15
Isopods						
Mysids	1	1			2	
planula		1	1	1	1	2
trochophore	12	71	47	7		6
polychaete	19	15	29	28	73	33
brachiopod	3	2	2		2	8
bivalves	20	17	28	12	24	6
veliger-A	320	58			81	155
veliger-B		2	6	12	8	8
veliger-C		5	7	8	8	9
auricularia			7	1	3	7
protozoea	198	419	160	158	58	52
schizopod	121	60	90	33	55	16
crab zoea	57	48	69		18	96
megalops	3	3	3			2
mysis	53	68	56	46	29	10
barn nauplii	26	2	11588	1394	10	879
cypris	23	1	167	57	3	
stomatopod		1	2		2	1
Stenopus	1		1		1	
ascidian	8	6	6			282
frog	19	64	50	8	16	15
fish larvae	27	13	26	10	15	18
fish eggs		3				6
Nehu eggs			19	28		16
Omaka eggs		4				

Pollution Study
Station 9
No./2 m^3

	1968				1969	
	6 Nov	20 Nov	18 Dec	8 Jan	15 Jan	23 Jan@
Undinula		5		6		1
Labidocera	1	5	1	1	1	1
Pontellina		1				
Acartia	9	22		20	1	4
Unid Calanoid	1			1		
Harpacticoid	1					
Corycaeus		3	1	1		
Oithona				6		
Sagitta	2421	2023	389	757	355	83
Leucifer	25	16	5	3	6	14
Ctenophores	73	173	262	137	304	13
Medusae-C		6	9			
Medusae-B		1				
Medusae-sp	1	1	1	5		
Oikopleura	171	1180	143	3	280	278
Amphipods	21					
Ostracods		2	5	1	1	
Evadne	13					
Isopods	1					
Medusae-A						1
planula	1	1				
trochophore	4	9	5	1		
polychaete	5	14	28	17		
brachiopod	6	9			1	
bivalve	57			17		
veliger-A	426	37	7		88	8
veliger-B	7	12	81	3	4	
veliger-C	3	10	2	2		
auricularia	6	6				
protozoea	29	25	5	21	60	30
schizopod	9	25	4	3	29	15
zoea	31	80	30	37	11	-
megalops		2				
mysis	10	60	29	14	-	-
stomatopod	1					
barn nauplii	2		18	1083		481
cypris	1		3	13	332	4
Stenopus	1	1	1			
ascidian	4	4		8		
frog	127	12	10	16	-	-
fish larvae	18	10		5		
fish eggs	1		1	1		
Nehu eggs		6		3	2	8

@ = There was sand in the sample. Nets hit the bottom so may not have sampled quantitatively.

Pollution Study
Station 9
No./2 m^3

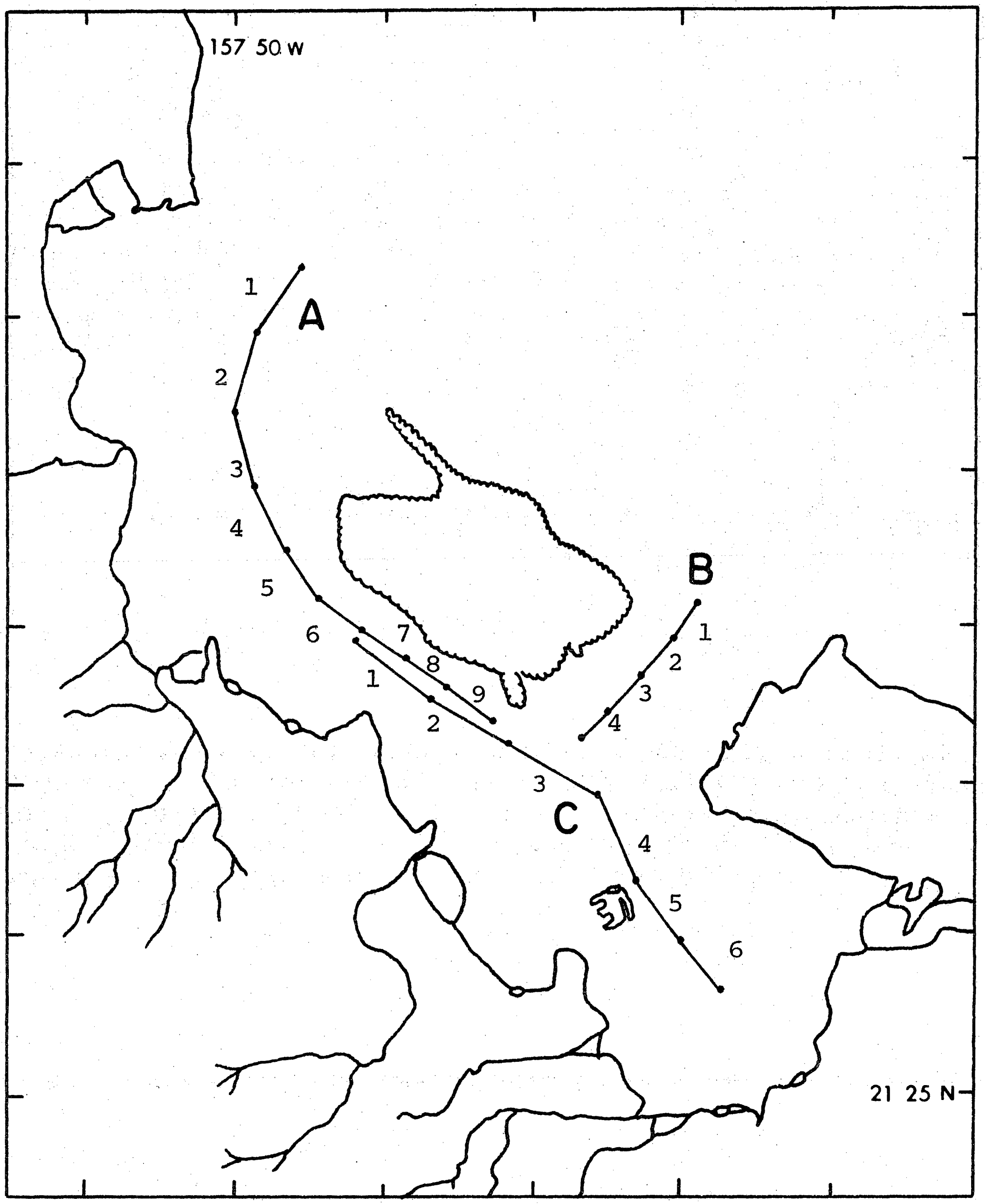
	1969					
	@ 29 Jan	19 Feb	5 Mar	19 Mar	2 Apr	16 Apr
Undinula			3	2	1	13
Eucalanus						2
Labidocera			1		2	1
Acartia				1	1	9
Unid Calanoid					1	
Oithona			1	2	1	5
Corycaeus				4	1	3
Oncaea						3
Sagitta	29	294	78	56	163	586
Leucifer	1	10	1	5	5	8
Ctenophores	10	47	14	2	13	67
Medusae-B						1
Oikopleura	118	31	1	393	58	425
Ostracods		2	1	1	3	1
Creseis						2
Medusae-A		44	1	9	134	49
bivalves			4			2
veliger-A	28	5	111	38	5	26
veliger-B						1
protozoea	5	24	42	1	27	54
schizopod	6	11	9	2	11	22
zoea	-	-	-	-	-	-
megalops			1			5
mysis	-	-	-	-	-	-
barn nauplii	8		25		223	105
cypris	4		128		26	82
frog	-	-	-	-	-	-
fish eggs			1			
Nehu eggs			1	4	3	12

@ = There was sand in this sample. Nets hit bottom so may not have sampled quantitatively.

Pollution Study
Station 4
No./2 m^3

1967

	28Aug	11Sept	25Sept	9Oct	23Oct	6Nov	20Nov	18Dec	21Aug
Undinula		2		44		4	3	10	2
Labidocera	4	1	6			6			2
Acartia	30		37	80	82	194	105	74	29
Oncaea	2								
Sagitta	106	312	145	418	71	153	283	21	248
Lucifer	46	5	17	10	18	20	33	18	13
Ctenophores	12	120	69	24	110	90	81	8	10
Oikopleura	222	196	93	944	148	84	582	224	510
Ostracods	8	30	7	4		24	9	6	17
Pteropods		12							30
Amphipods	4	6	3	4		2	9		
Hydromedusae		1	2	14					
polychaete			6	8			15	1	
bivalve		12							1
veliger-A	6	30	10	12	4	14	6	6	18
protozoea	190	16	54	272	236	56	75	66	82
schizopod	54	1	11	88	42	50	54	52	31
zoea	108	6	35	6	12	66	15	20	17
mysis	252	34	228	68	56	174	48	44	196
barnacle nauplii	6	28	9	8	4	30		64	3
cypris				2					1
stomatopod			2			2	6	2	
bipinnaria		1							
Nehu eggs	6			2					11
fish larvae		8	12	8		4	6		



Appendix Figure 9. Location of samples taken along a 13 December 1970 (A), 30 January 1971 (B) and 4 March 1971 (C) transect lines with the Miller surface sampling nets. Numbered line segments are sample identification numbers. Samples were taken with paired square mouthed nets of 0.36 m^2 and 0.5 mm meshes.

13 December 1970
Serial Sampling
Chinamans Hat to Bouy 21
No./ Five minute tow
R = Right-hand net

	R1	R3	R4	R5	R6	R7
Undinula	438	116	1064	189	13	13
Labidocera	1560	456	1736	1092	837	677
Acartia				1		
Other Copepods	156	16	28	21	6	10
No. of Copepod sp.	10	3	3	3	2	1
Sagitta	6	8	14	35	37	193
Lucifer	5592	2640	6902	10192	2980	3306
Ctenophores				14	Many	7
Oikopleura				21	3	
Ostracods	1					
Amphipods	60			21	6	10
No. of Amphipod sp.	4			3	2	3
gastropod veliger-A	6	4		21		
protozoea				7		
schizopod	42		14	28	30	26
zoea	24	192	1568	1927	387	647
megalops	12					7
mysis	78	60	294	350	60	70
barn nauplii	6					
stomatopod	12	136	350	161	40	8
fish eggs	8910	276	574	42	7	20
Nehu eggs		112	322	756	110	126

13 December 1970
Serial Sampling
Chinamans Hat to Bouy 21
No./Five minute tow
R = Right net, L = Left net

	R8	R9	L1	L2	L3
Undinula	28	35	270	60	104
Labidocera	1148	917	2574	1050	790
Acartia			18	5	
Other Copepods		14	150	35	9
No. of Copepod sp.		2	11	5	4
Sagitta	588	441	12	10	2
Lucifer	17360	12180	6372	5860	2552
Ctenophores		28			
Oikopleura				35	3
Ampphipods				48	
Mysids					3
polychaete					3
bivalve			6		3
gastropod veliger-A	14		18		4
protozoea	1				
schizopod	406	196	12		3
zoea	770	350	30	50	404
megalops		7	6		
mysis	518	826	66	60	144
barn nauplii			6		
cypris				5	
stomatopod	154	70	18	5	138
fish eggs	14	70	15768	435	390
Nehu eggs	434	98		45	160

13 December 1970
Serial Sampling
Chinamans Hat to Bouy 21
No./Five minute tow
L = Left Net

	L4	L5	L6	L7	L8	L9
Undinula	960	336	40	40	54	14
Labidocera	328	2024	1768	1408	1278	728
Acartia	5					
Other Copepods	35	32	8	8		
No. of Copepod sp.	3	2	1	1		
Sagitta	10	8			18	
Lucifer	1000	9968	8672	5696	21024	9394
Ctenophores			1080	80		21
Oikopleura	10	8			18	
Amphipods	20	8	16	64		7
Evadne						14
polychaete	5	8				
gastropod veliger-A	20					
schizopod	20	64	184	160	252	182
zoea	1735	1792	2624	1848	702	308
megalops	10	8		8		
mysis	345	496	336	248	594	525
stomatopod	300	224	144	136	180	63
fish eggs	405	168	16	8		70
Nehu eggs	405	1120	208	232	288	98

30 January 1971
Serial Sampling
Sampan Channel
Left Side Net
No./Five minute tow

	L1	L2	L3	L4
Undinula	5	10	40	20
Labidocera	70	3960	9200	3990
Acartia		5	220	80
Other Copepods	275	20	60	20
No. of Copepod sp.	13	1	2	1
Sagitta	160	20	20	20
Lucifer	5		20	
Oikopleura			20	20
Amphipods	10		40	
protozoea				20
schizopod				20
zoea	4920	27540	2980	3600
mysis	440	7560	4960	480
stomatopod	130	1800	20	
Nehu eggs	5			

Sample 1 = Outside Sampan Channel
Sample 2 = Along course 225T
Sample 3 = Along course 225T
Sample 4 = Along course 225T, terminating at Sampan Bouy 8

4 March 1971
Serial Sampling
Bouy 17-Southeast Basin
Left side net
No./Five minute tow

	L1	L2	L3	L4	L5	L6
Undinula		3	5	5	5	2
Labidocera	983	1226	613	935	1035	1146
Other Copepods		3				
No. of Copepod sp.		2				
Ostracods				1		
Amphipods	1	1	2	1	3	10
Mysids						92
Isopods			2		1	12
Foraminifera						2
Hydromedusae					1	
polychaete		1	1			
gastropod veliger-A	1	4	7	5	4	18
protozoea					1	
schizopod	13	9	6	2	45	42
zoea	4803	3629	988	490	1707	1096
megalops		4				
mysis	33	92	126	40	32	34
barn nauplii		1	2	4	21	104
cypris				3		2
stomatopod	761	2124	105	7	41	16
round eggs	88	168	100	115	238	109
Nehu eggs	9	2	1			

Note: *Sagitta*, *Lucifer* and Ctenophores were not enumerated. There were no *Oikopleura* in these samples.

Sample 1 = Between Bouy 17 and 19, Middle Sector
Sample 2 = Between Bouy 19 and 21, Middle Sector
Sample 3 = Between Bouy 21 and 25, Transition Zone
Sample 4 = Between Bouy 25 and 26, Transition Zone
Sample 5 = Between Bouy 26 and SE Basin, 1352-1357 hrs, along major axis of bay
Sample 6 = In southern sector, 1357-1402 hrs, along major axis of bay

APPENDIX TABLE 1

LENGTH AND DRY-WEIGHT DATA IN MG PER SPECIMEN

CTENOPHORES

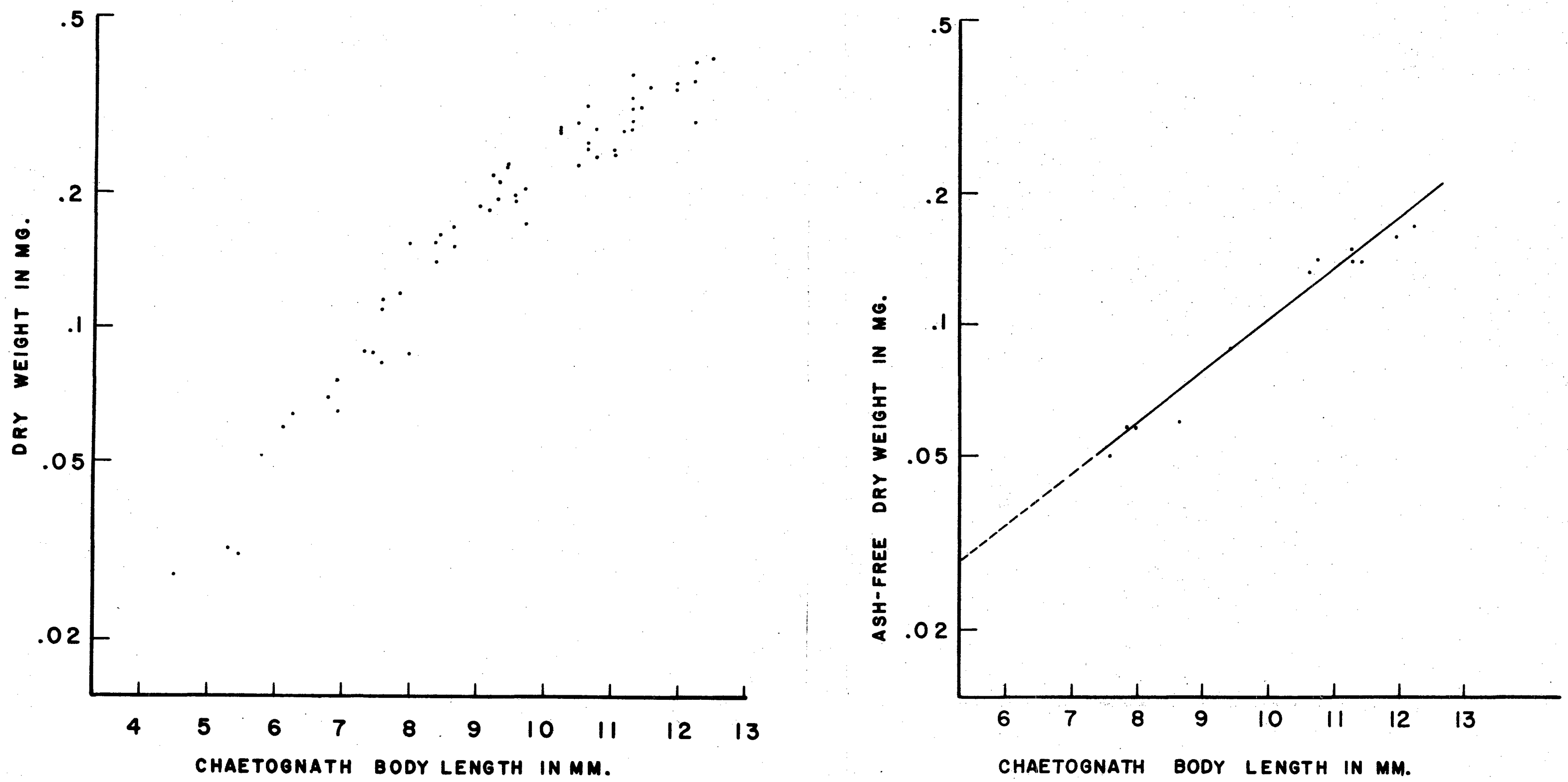
Diameter (mm)	Weight (mg)
3.0	0.395
3.0	0.461
3.3	0.778
3.6	1.310
4.0	0.921
4.3	1.492
4.5	1.792
4.7	1.837
4.8	2.258
5.3	2.924
5.3	2.130
5.7	4.498
6.0	3.784

Length (mm)	Weight (mg)
Decapod Mysis	
1.6	0.057
1.7	0.068
2.3	0.081
2.5	0.103
2.9	0.140
***Lucifer* protozoea**	
1.0	0.0053
1.0	0.0051
1.4	0.0107
1.4	0.0093
***Lucifer* schizopod**	
2.0	0.016
3.0	0.024
3.0	0.024
mixed	0.024

Labidocera

Prosome Length (mm)	Weight (mg)
0.80	0.0090
1.05	0.0160
1.15	0.0296
1.60	0.0728
2.20	0.2070
2.30	0.2130
2.30	0.2560
Paracalanus	
0.5	0.0032
0.5	0.0019
0.5	0.0024
Undinula	
1.30	0.032
1.20	0.040
1.65	0.089

Length (mm)	Weight (mg)
Ostracods	
1.10	0.049
0.85	0.030
0.55	0.012
0.55	0.010
Gastropod veliger-A	
0.75	0.026
0.61	0.024
0.65	0.026



Appendix Figure 10. Scatter diagrams of <u>Sagitta</u> <u>enflata</u> length-dry weight, and length-ash free dry weight.

Miscellaneous Observations

Tows taken near Coconut Island during biomass study for the purpose of collecting live animals for drying.

11 November 1969	Large numbers of protozoeas
12 November	No Oikopleura; many veliger-B
14 November	No Oikopleura or ctenophores. Many barnacle nauplii, crab zoea and Lucifer larvae
18 November	No Oikopleura. Few crab zoeam barnacle nauplii. Ostracods abundant.
26 November	Red tide in the southeast basin. Dominant appeared to be Prorocentrum sp.
3 December	No Oikopleura. Many protozoea at Bouy 26
12 December	Skeletonema bloom
18 December	Large numbers of barnacle nauplii
19 December	Large numbers of barnacle nauplii
6 January 1970	A few Oikopleura finally
15 January	Many stomatopods and Lucifer adults near Bouy 26

25 November 1969
Kuba Station 1

Acartia	6
Sagitta	734
Lucifer	6
Ctenophores	354
Oikopleura	0
Ostracods	16
medusae-A	14
medusae-E	276
Veliger-A	6
Veliger-B	54
protozoea	48
schizopod	48
crab zoea	102
mysis	150
megalops	1
Nehu eggs	10
other eggs	6