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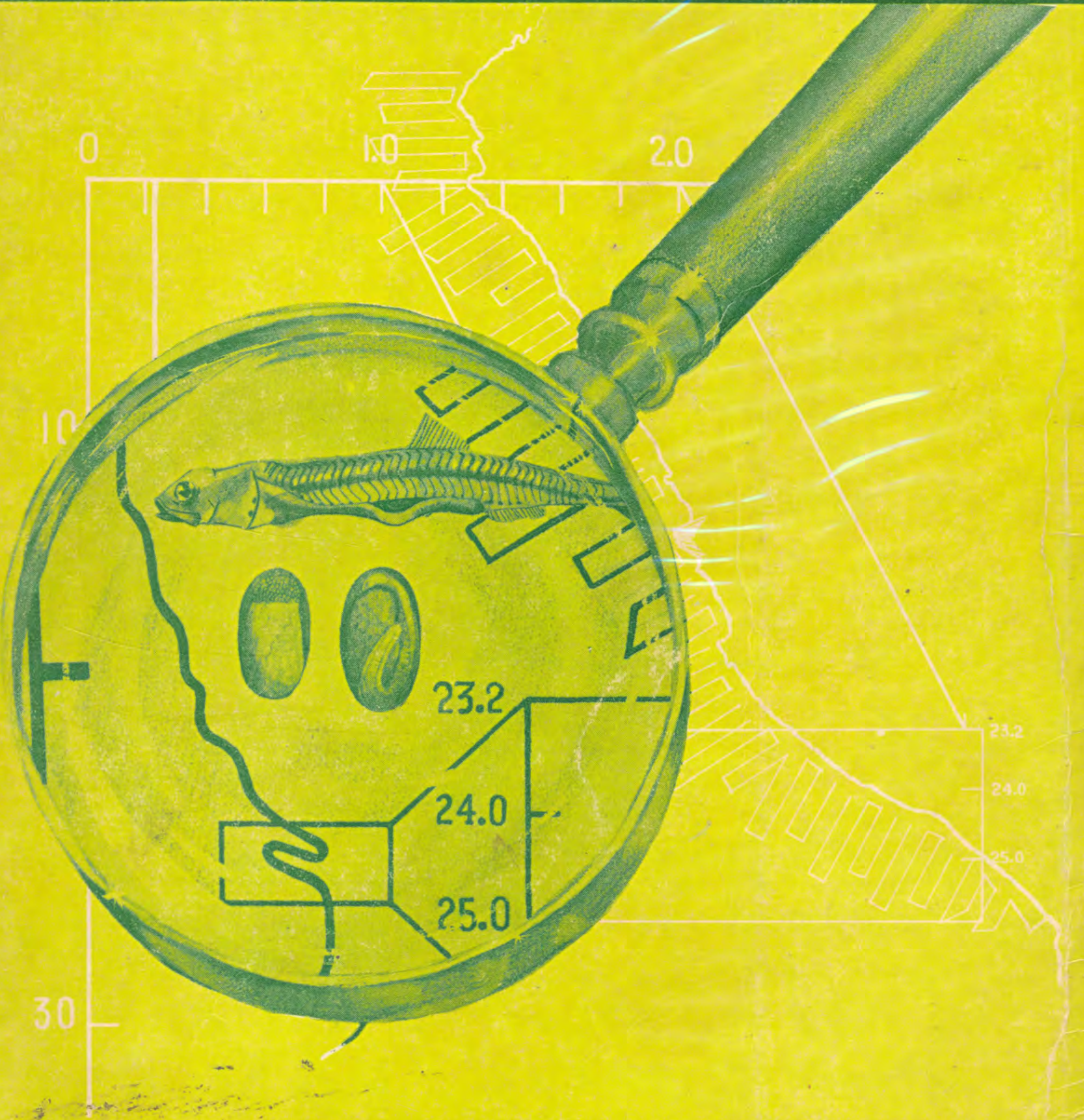

INVESTIGACION COOPERATIVA DE LA ANCHOVETA Y SU ECOSISTEMA - ICANE - ENTRE PERU Y CANADA

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HORIZONTAL AND VERTICAL DISTRIBUTIONS OF ZOOPLANKTON NUMBERS AND BIOMASS OFF THE COAST OF PERU

by
D. Sameoto

Marine Ecology Laboratory
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, Nova Scotia

ABSTRACT

The horizontal and vertical distributions of zooplankton along a transect fron close to the Peru coast to the edge of the Peruvian Shelf were studied. Larger numbers of amphipods and euphausiids were caught during the night than the day but no difference in catch numbers was seen for the other species of zooplankton. Two separate sample series on the same transect taken about one week apart showed large changes in biomass and species composition. A majority of copepod species were found in the top 40 m during both day and night with most species showing some degree of vertical migration into the top 25 m at night. The species composition changed with distance from shore during both sample series with **Calanus chiliensis** dominating the outer stations both times. A complete change in species composition on the mid-shelf stations during the second series demonstrated the high variability that can occur over a short time period. The mean length of the copepods did not change significantly along the onshore-offshore transect but did become larger with depth on most of the stations. The most common species found in the upper layers were positively correlated with one another and three of these species were positively correlated with the numbers of **Engraulis ringens** present.

RESUMEN

Se estudió las distribuciones horizontales y verticales del zooplancton a lo largo de una línea desde cerca de la costa hasta el borde de la plataforma. Los anfípodos y los eufaúsidos fueron más numerosos durante la noche que durante el día pero esta diferencia no se observó para las otras especies de zooplancton. Dos series de muestras de la misma línea pero tomadas una semana aparte mostraron grandes cambios en biomasa y composición de especies. La mayor parte de las especies de copépodos se encontró en los 40 m cerca a la superficie tanto de día como de noche, muchas de las especies mostraron cierto grado de migración vertical nocturna dentro de los 25 m de la superficie. En ambas series de muestras la composición específica cambió con la distancia de la costa dominando siempre en las estaciones exteriores el **Calanus chiliensis**. En la segunda serie ocurrió un cambio completo de la composición específica en estaciones a mitad de la plataforma, lo cual demuestra la gran variabilidad que puede darse en un corto período. La longitud media de los copépodos no cambió significativamente a lo largo de la línea pero aumentó con la profundidad en la mayoría de las estaciones. Las especies mas comunes de las capas superiores estuvieron positivamente correlacionadas entre ellas y tres también presentaron correlación positiva con la cantidad de **Engraulis ringens** presente.

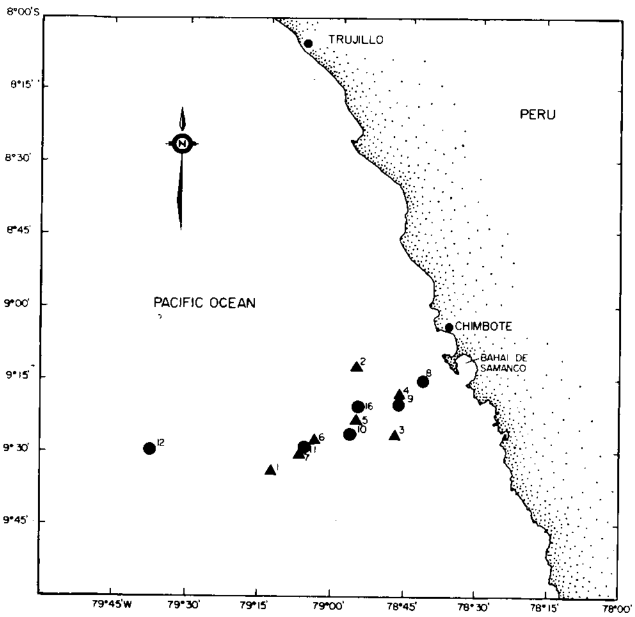
INTRODUCTION

The biomass an species composition of zooplankton associated with ichthyoplankton were studied along a transect perpendicular to the coast of Peru. From both vertical an horizontal samples we have estimated the concentration of zooplankton available as food for the ichthyoplankton. The macrozooplankton were examined for species that may be important as predators of ichthyoplankton.

METHODS

The transect (Fig. 1) was sampled twice, once from November 15 to 19 and again from November

Figure 1. Station positions (▲ stations sampled during first series, ● stations sampled on the second series of samples).



21 to 25, 1977. The positions of the sampling stations are given in Figure 1. Samples were taken with the BIONESS (Sameoto **et al.**, 1980), during the day and the night during both sampling periods. The handling of the samples and the identification of animals are described by Sameoto in an ichthyoplankton paper included in this series (Sameoto, 1980).

The numbers of the stations sampled on the first transect are established here as 1 to 7. Numbers on the second run are 8 to 16.

RESULTS

Day-Night Differences

A comparison of the day and night samples was made for each of the major zooplankton groups (Table 1) by means of an unpaired **t** test. Euphausiid and amphipod numbers were significantly larger in the night samples ($t = 2.5$ for amphipods and $t = 3.3$ for euphausiids, d.f. $= 11, P < 0.05$). There was no day-night difference for the other groups of animals.

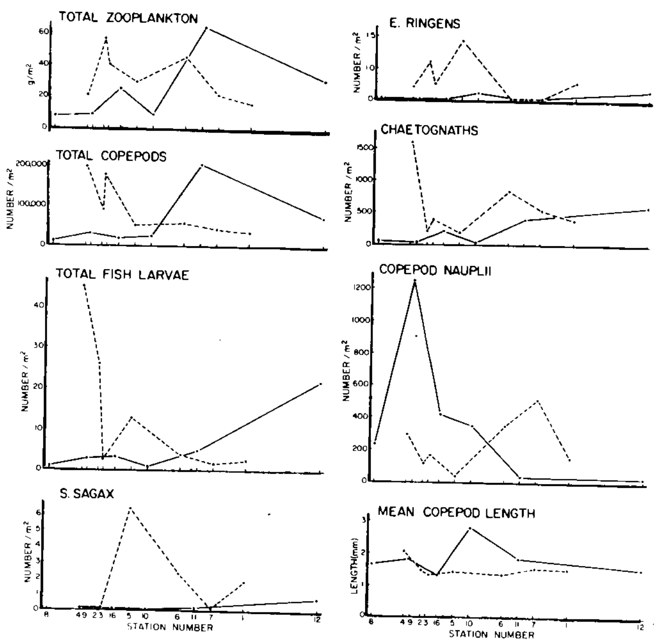
Numbers per Square Metre

For the groups that did not show a day-night difference the pooled numbers were used to compare catches during the two runs of the transect. At all inshore stations larger numbers of total copepods and chaetognaths per square metre were caught on the first run than the second run (Table 1 and Fig. 2). The total fish larvae, larval **E. ringens** and larval **S. sagax** in numbers m^{-2} showed a pattern

Table 1. Numbers per square metre of the common groups of invertebrates on the differen. stations. Day (D) and night (N) stations are indicated.

Sta. No.	km from the coast	Cnidaria	Gastropoda	Polychaeta	Ostracoda	Copepoda	Amphipoda	Euphausiacea	Decapoda	Chaetognatha	Urochordata	Ctenophora	Copepod Nauplii
						First Sample Series, Nov. 15-19							
4 (D)	22	264		912	1228	195,348	219	1884	4	1639			317
2 (N)	33	78		401	569	88,886	3248	3734	31	175			126
3 (D)	33	312	51	524	1349	175,374	100	284	433	122			165
5 (N)	91	324		465	346	48,151	1295	3014	72	199	10		46
6 (N)	57	619	38	890	337	53,653	427	1637	109	844	794	17	
7 (D)	65	150	17	637	1344	41,098	7	1386	123	541	409	28	460
1 (N)	78	192	7	288	274	37,163	499	1109	59	396			164
						Second Sample Series, Nov. 21-25							
8 (D)	11	43		60	196	12,305	18	171	46	75			238
9 (D)	24	111		365	259	26,858	30	162	61	148			1248
16 (N)	35	189		920	453	20,802	572	3035	34	238	5		417
10 (D)	44	306		21	164	13,235	2	316	252	38	7		351
11 (D)	63	296		391	85	200,508		525	41	340	230		30
12 (N)	115	1652	64	500	708	60,679	252	1399	131	626	1658		27

Figure 2. Changes in the numbers of animals per square metre on the different stations during the two sampling series (- - - series 1; —— series 2). Stn. 8 was nearshore and stn. 12 offshore.



similar (Fig. 2) to that of the copepods. During the first run the copepods and fish larvae decreased in density with distance from shore, where the opposite trend appeared during the second run. The number of copepod nauplii, however showed a distribution which was the inverse of total copepods on the second series. Euphausiid and amphipod numbers (Table 1) also showed a trend similar to that of total copepods, being lower on the second series but since numbers in the samples also differed significantly between day and night the significance of the difference on the two runs is difficult to assess.

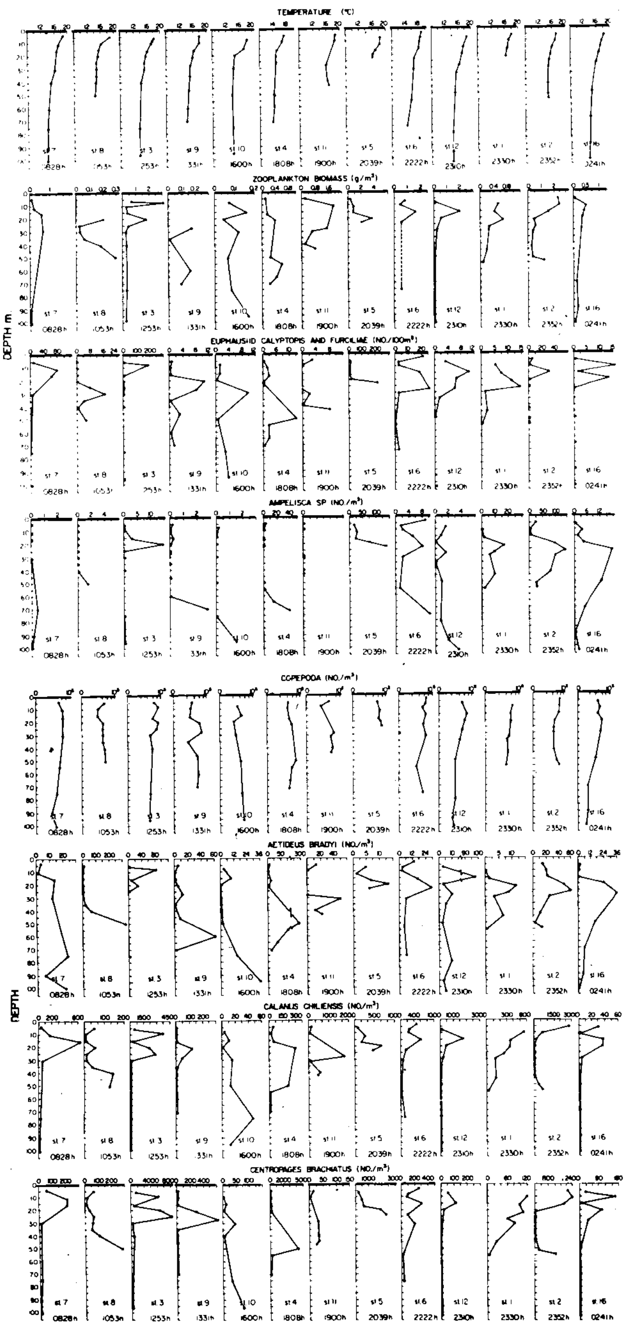
Vertical Distribution

The majority of copepods was found in the top 40 m of water during both day and night. Exceptions to this were found on stations* 4, 8, 9, and 10, but it may be significant that stations 8, 9, and 10 had the lowest zooplankton biomass of all the stations. The vertical distribution of major invertebrate species at different stations and times is shown in Figure 3. The numbers of each species taken at different stations and depths are given in Table 2*.

Diurnal vertical migration was shown by almost all species of copepods with most of the animals of each species in the top 50 m by 2100 h. Euphausiid calyptopis and furciliae and **Ampelisca** amphipods had a diurnal migrations similar to the copepods (Fig. 3). The vertical distribution of the euphausiids indicated a vertical migration to the upper 20 m at night while the chaetognaths **Sagitta decipens** and **S. enflata** were in the upper 50 m at all times (Fig. 3).

* Table 2 is not included here because of its extension, but is available from the editor.

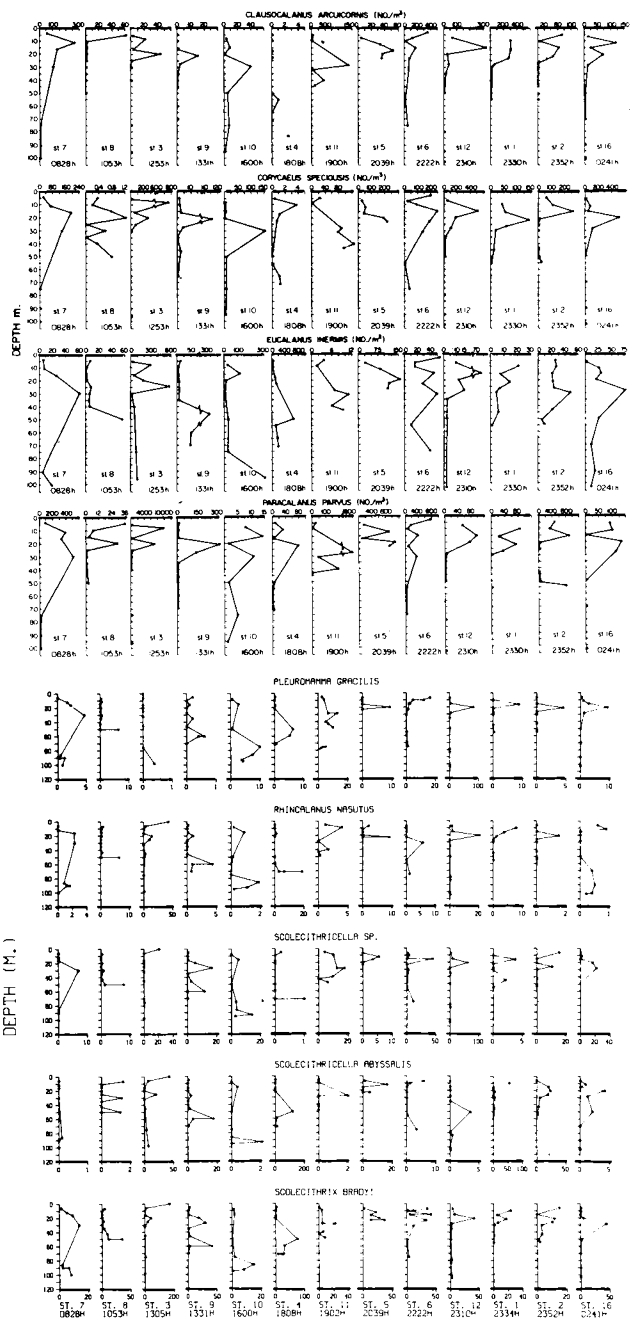
Figure 3. Temperature and changes of species numbers with depth on the different stations.

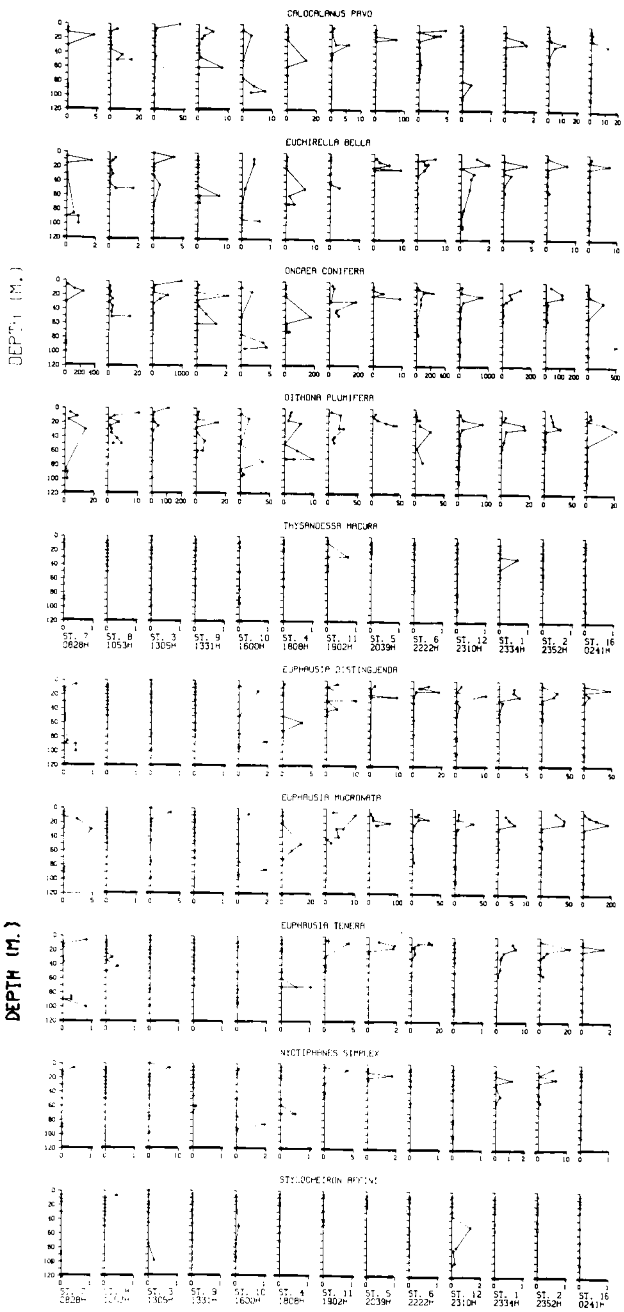


Species Composition

The percentage representation of the copepod species (based on average numbers per square meter) is plotted for each station in Fig. 4. Species comprising less than 1 o/o of the total number are not included. During November 15 to 19 inshore stations 4, 2, 3, and 5 were dominated by **Centropages brachiatus** with **Calanus chiliensis** and **Paracalanus parvus** the next two most abundant species **tus** the second and third most abundant species. (Table 3 and 4, Fig. 4). **Calanus chiliensis** dominated the outer stations with **P. parvus** and **C. brachia-**

During the second run from November 21 to 25 the two nearshore stations, 8 and 9, were again dominated by **C. brachiatus** and had a species composition similar to that during the first run (Table 3, Fig. 4). A completely different species





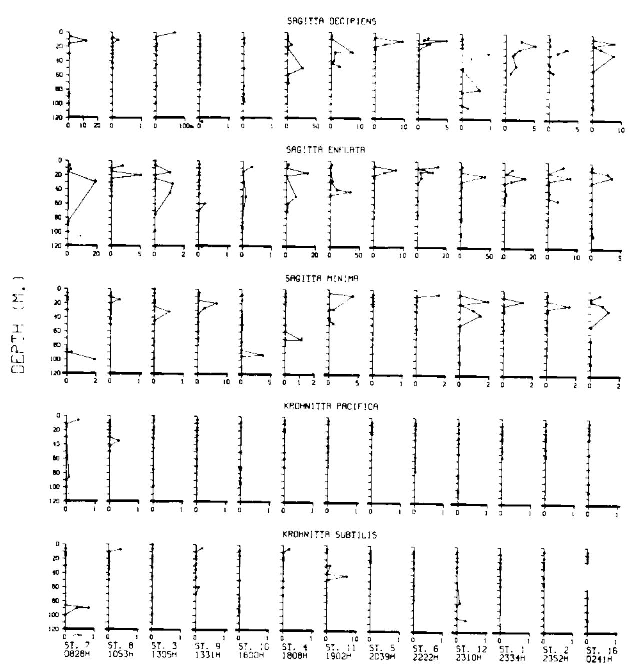


Table 3. Dominant three species of copepods on different stations during the two sampling series, plus distance frm the coast of each station in kilometres.

Station No.	km from the coast	Dominance Rank 1	Dominance Rank 2	Dominance Rank 3
4	22	Centropeges brachiatus	Eucalanus inermis	Calanus chiliensis
2	33	Centropages brachiatus	Calanus chiliensis	Paracalanus parvus
3	33	Centropeges Brachiatus	Paracalanus parvus	Calanus chiliensis
5	41	Centropages Brachiatus	Paracalanus parvus	Calanus chiliensis
6	57	Calanus chiliensis	Paracalanus parvus	Cantropages brachiatus
7	65	Calanus chiliensis	Paracalanus parvus	Centropages brachiatus
1	78	Calanus chiliensis	Clausocalanus acruicornis	Centropages brachiatus
		Series 2		
8	11	Centropeges brachiatus	Aetideus bradyii	Calanus chiliensis
9	24	Centropages brachiatus	Oncae sp.	Aetideus bradyii
16	35	Corycaeus sp.	Paracalanus parvus	Centropages brachiatus
10	44	Corycaeus speciosis	Centropages brachiatus	Clausocalanus acruicornis
11	63	Calanus chiliensis	Clausocalanus acruicornis	Paracalanus parvus
12	115	Calanus chiliensis	Corycaeus speciosis	Oncae conifera

composition was found on the middle stations, 16 and 10, dominated by **Corycaeus** spp. The two outer stations, 11 and 12, were again similar in species composition to the same region during the first run. These data indicate that between the time of the first and second sample series a new water mass passed through the middle stations; not only were there different species of copepods, but the density and biomass of zooplankton was significantly less in the new water mass (Fig. 2).

The new mid-shelf water mass had significantly more copepod nauplii than the first water mass sampled, yet the density of fish larvae in it was much lower (Fig. 2). Fish larvae of all species were more abundant during the first run than during the second.

The only known potential invertebrate predators of fish larvae collected were chaetognaths. Their density tended to be higher when the density of fish larvae was greatest.

Mean Copepod Length

The mean length of the copepods on each of the stations was calculated by multiplying the mean length of each species by the percentage of the total sample it represented and this value was divided by the total percentage of copepods measured to give the mean length. These values are plotted for the two series of tows in Fig. 2. Results for the first run show a slight decrease in copepod mean size for the stations in the mid-shelf region of the transect. Except for station 10 the mean lengths were similar during the second sample series. There was no significant difference in the average size of the

Figure 4. Percentage of total copepods each of the common species represented on the different stations during the two samplig series. The positions and station distance in kilometres from the coast are given.

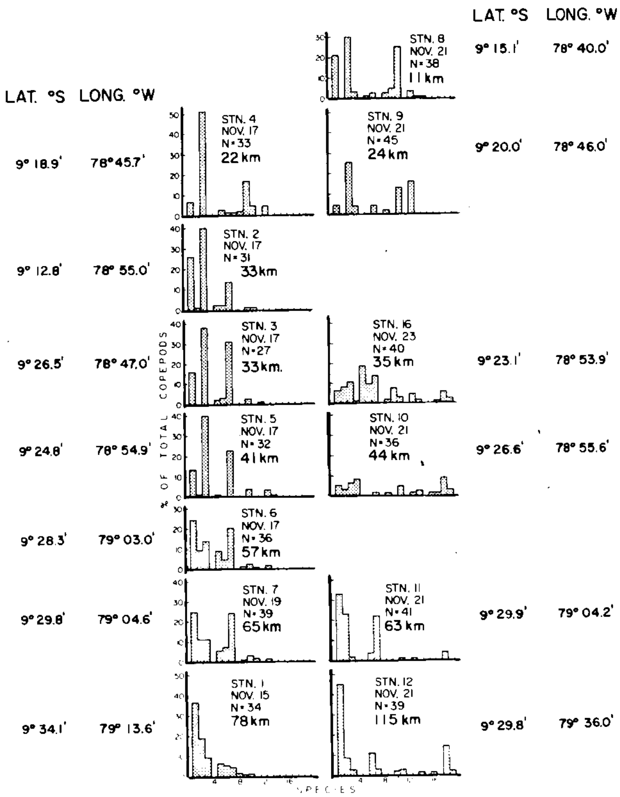


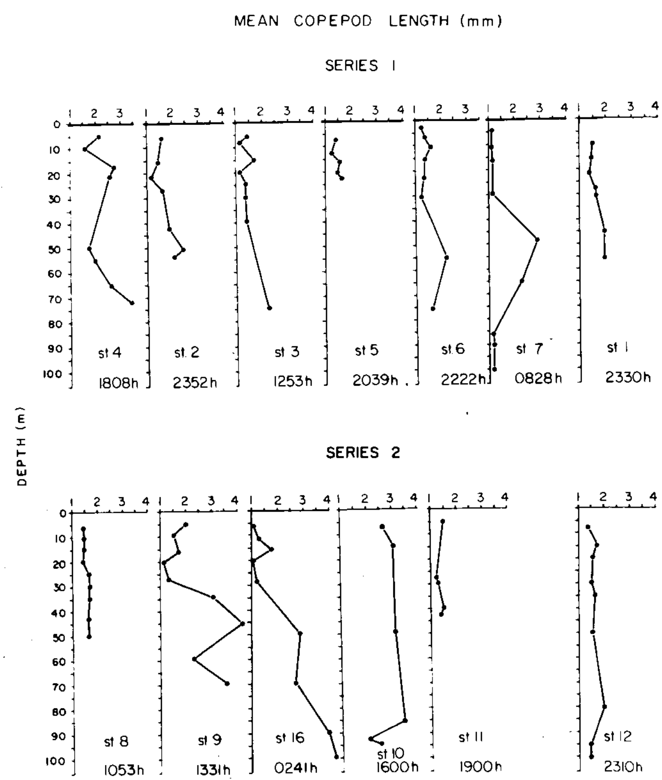
Table 4. List of species corresponding to the species numbers on Figure 4.

Species No.	Species Name
1	Calanus chiliensis
2	Clausocalanus arcuicornis
3	Centropages brachiatus
4	Copepod nauplii
5	Corycaeus sp.
6	Oncaea conifera
7	Paracalanus parvus
8	Scolecithricella abyssalis
9	Scolecithrix bradyi
10	Eucalanus inermis
11	Aetideus bradyi
12	Eucalanus crassus
13	Oncaea sp.
14	Oithona plumifera
15	Calocalanus tenuicornis
16	Pleuromamma gracilis
17	Scolecithrix sp.
18	Corycaeus speciousis
19	Lucicutia flavicornis

Table 5. Mean length of copepods on the different stations at all sample depths.

Tow	Time	Mean length (mm)
7	0828	1.30
8	1053	1.65
3	1253	1.31
9	1331	1.85
10	1600	2.81
4	1808	2.00
11	1902	1.39
5	2039	1.40
6	2222	1.33
12	2310	1.71
1	2334	1.46
2	2352	1.46
16	0241	1.28

Figure 5. Mean body length of copepods with depth on the different stations during the two sampling series. The stations during the two series are alined to correspond to the same position.



copepods between inshore and offshore stations (Table 5). The length differences were more evident when they were compared from samples at different depths (Fig. 5). There was a marked increase in copepod length with depth on stations 9, 16, and 10 during the second series which reflected the change in species composition that occurred between the two series.

Species Associations

Correlation coefficients between species in all the samples within each tow were calculated on the $\log_{10}(x+1)$ of all the density data for each species of zooplankton. If a particular species was absent from more than 15% of the samples it was excluded from the correlation calculations, since a large number of zero values will bias the results (Pielou 1974). The sample correlation coefficients were calculated for day and night samples separately due to the vertical migration shown by some of the species. The results showed there to be more species positively correlated at night than in the day. This was due to different patterns of vertical migration for the species (Table 6).

Table 6. Correlations significant at $P < 0.01$ of $\log_{10}(X+1)$ of numbers of each species in samples taken during the day and night. Degrees of freedom for the day = 54 and for the night = 44. The correlation values have been rounded to the nearest value and multiplied by 10. Values underlined were species pairs significantly correlated at night as well as the day.

	Polychaete larvae	Hypocypridae	Aetideus bradyi	Calanus chiliensis	Centropages brachiatus	Clausocalanus arcuicornis	Eucalanus inermis	Oncae conifera	Oithona plumifera	Paracalanus parvus	Scolecithrix bradyi	Euphausiids
Aetideus bradyi		4					4				7	
Calanus chiliensis					8					7	4	
Centropages brachiatus	4	4		8			4			6	5	
Clausocalanus arcuicornis	4			7	5							
Eucalanus inermis	6			4	6	4					5	
Oncae conifera	3	4	4	6	4	6						
Oithona plumifera	4	4	4	5	6	5	6	5				
Paracalanus parvus	5			7	9	6	6	5	6		5	
Ampelisca sp.		4			6		5			4		
Unidentified euphausiid			7	8								
Euphausiid			4	5	4	5	3	4	4			7

Only four species of zooplankton had a significantly positive correlation ($P < 0.01$) during the day and night. These were **Centropages brachiatus** and **Paracalanus parvus** with **Calanus chiliensis**; **Eucalanus inermis** and **Paracalanus parvus** with **Centropages brachiatus. Eucalanus inermis** was not correlated with **C. Chiliensis** during the day. This suggests that these four species have similar ecological requirements and likely form an ecological grouping.

It is interesting that it was three of these species that were positively correlated with the abundance of **E. ringens**. (Sameoto 1980).

DISCUSSION

One of the main results from the survey data was finding a pronounced concentration of zooplankton in the top 50 m when the total number of copepods per square metre was high (i.e. over 25,000). But when the density per square metre was under 25,000 there was little vertical difference in the density and biomass per cubic metre. As a result, when high biomass values of copepods were found they were due to species that live primarily in the top 50 m of water and not the result of an increased representation of species that live deeper (i.e. below 50 m).

The species that lived in the top-50 m were correlated with occurence and abundance of **E. ringens.** This suggests that the fish larvae are associated with water masses that have a high zooplankton concentration. The changes in zooplankton biomass and numbers between the two series of stations suggest that the water masses containing high concentrations of phytoplankton and zooplankton may be large and widely spaced possibly on the scale of tens of kilometres. It therefore appears that larval survival may depend heavily on the probability of eggs being deposited and hatching in one of these patches, since larval horizontal swimming mobility was probably not great enough for them to locate a water mass with a high concentration of zooplankton and there is no evidence of vertical migrations of either larvae or plankton which could enhance their encounter by physical processes.

The difference in the numbers of zooplankton and species compositions between the stations during the two sampling series indicates high spatial and temporal variability in this region. Thus samples taken on the same geographical location over a short time (one or two weeks) can tell relatively little about changes in population size or growth. Unfortunately, with only the two series of samples it is impossible to say if this variability was characteristic of other times of the year. During the sampling period there was one pattern that was apparently stable; that was the distribution of the dominant copepod species along the transect. During both runs **C. chiliensis** was the dominant species on the outer shelf stations. This species had a mean length of about 2.0 mm so that a large part of the potential zooplankton food for fish larvae was in the upper size range for zooplankton. These sizes are probably near the upper limit for the sizes of larvae found and may thus have restricted the outer stations to the old and larger larvae. It is possibly important that our sampling did not show a significant change in the mean length of the fish larvae with distance from shore and that few early stages of larvae were collected. It was clear that the cruise took place near the end of the spawning season and a different zooplankton distribution may have existed at the start of the season.

No significant numbers of invertebrate predators of fish larvae were found. The one crustacean species that may be a predator was the **Ampelica** amphipod, but since it was only found in the upper 75 m during the night and seldom above 20 m depth where the larvae were abundant, it is unlikely that it has a significant influence on larval abundance. The chaetognaths which are known to prey on fish larvae, were not numerous enough to be considered a major predator. The most likely predators of larvae were pelagic feeding fish since large numbers of these fish were seen on the sounder during the night in the regions of high zooplankton concentration.

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