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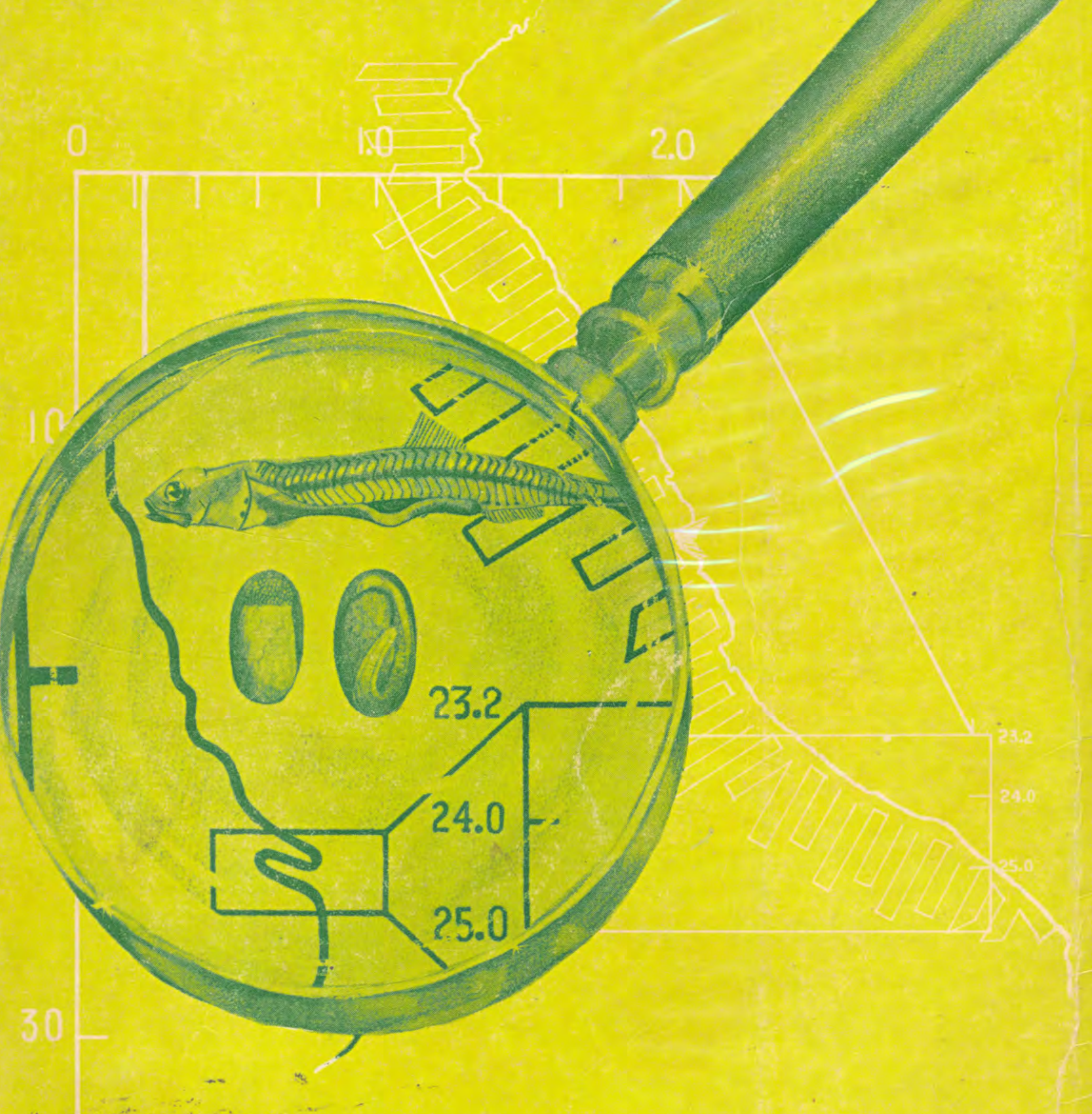

INVESTIGACION COOPERATIVA DE LA ANCHOVETA Y SU ECOSISTEMA - ICANE - ENTRE PERU Y CANADA

CALLAO 1981 PERU

COPEPOD DISTRIBUTIONS ON THE PERU SHELF AT 9°S DURING NOVEMBER, 1977

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ABSTRACT

Copepod distributioons on the Peru shelf at 9°S have been measured with an electronic zooplankton counter simultaneously with salinity, temperature, depth and chlorophyll a. The migration patterns of various species are illustrated and their apparent grazing on the chlorophyll layer at 15 m depth is described. A comparison of the shelf concentrations of copepods is made between the Batfish sample and the BIONESS, a large, efficient zooplankton sampler.

RESUMEN

Se han medido las distribuciones de copépodos en la plataforma continental peruana a los 9° S con un contador electrónico de zooplancton simultáneamente con la salinidad, la temperatura, la profundidad y la clorófila **a**. Se ilustra los patrones de migración de varias especies y se describe su aparente pastoreo de la capa de clorófila a 15 m de profundidad. Se hace una comparación de las concentraciones de copépodos encima de la plataforma según el muestreador Batfish y el BIONESS, un muestreador de zooplancton grande y eficiente.

INTRODUCTION

Copepod distributions on the Peru shelf at 9°S have been measured simultaneously with chlorophyll **a**, conductivity, temperature and depth during the period of November 15 to 23, 1977. Sensors measuring these parameters were mounted on a Batfish vehicle towed behind a ship at 6 kts while undulating in a sawtooth pattern between 3 and 70 metres depth. The Batfish system, instrumentation and deployment have been described by Herman and Denman, (1976) and Herman and Dauphinee, (1980). Interpretation of data consisting of chlorophyll **a**, temperature, and salinity profiled over the Peru shelf has been presented elsewhere (Herman, 1981). The size range of copepods identifiable by the electronic zooplankton counter mounted on Batfish was berween 0.2 and 10 mm^3. The copepods consisted mainly of **Centropages brachiatus, Calanus chiliensis V, VI and Eucalanus inermis V, VI** (males and females) representing the most dominant copepod groups. Data are presented on the migration patterns of the various species as well as their mean depths in the water column. The apparent grazing of copepods on the chlorophyll layer at ≈15 m is described and similarities are noted with data measured on the Nova Scotia shelf. A comparison of the estimated copepod concentrations is made between the Batfish sampler and the BIONESS, (Sameoto, 1980) large multiple plankton net sampler.

RESULTS

The diameter, length and volume frequency distributions of the dominant copepods are shown in Fig. 1 and were measured by the electronic zooplankton counter. From left to right in the volume distribution, the indicated peaks were found to correspond to the following species; **Centropages brachiatus, Calanus chiliensis V, Calanus chiliensis VI, Eucalanus inermis V, VI** males, and **Eucalanus inermis VI** females. The identifications of these species were made by comparing to equivalent distributions measured by microscope and is described elsewhere (Herman and Mitchell, 1981). By selecting the appropriate size range in the volume distribution of Fig. 1 each species could be reasonably separated for analysis.

A Batfish profile from 0 to 60 metres is shown in Fig. 2 consisting of a chlorophyll profile (left) and 4 copepod species (labelled 2 to 5), separated by size and corresponding to a daylight measurement (Fig. 2 a) and a nighttime measurement (Fig. 2 b). In the daylight profile one observes **Centropages** in a single layer at ≈ 15 metres and all other species (3 to 5) distributed throughout the water column. In the nighttime profile, all species migrated to 15 metres depth in a distinct layer.

A 20 km transect from 20 to 40 km offshore shown in Fig. 3 indicates that near surface migration occurred at 1700 hrs. The plot represents the depth centre of gravity of each copepod species and chlorophyll with transect positon and time indicating the shifts in mean vertical position prior to migration (≈ 1700 hrs) and during migration. In general the largest animals, e.g. **Eucalanus inermis**, were deeper and traversed the largest vertical distances during migration. Fig. 4 is a similar plot for the period of the downward migration which is exhibited by all species except **Centropages** at ≈0700 hrs which agree with the findings of Sameoto (1980). Fig. 5 describes the mean layer thickness of 3 copepod species ranging from ΔD = 12 m for **Centropages**, ΔD = 28 m for **Calanus chiliensis** and ΔD = 42 m for **Eucalanus inermis**. In Fig. 5, the region from 30-40 km offshore represents the layer positions during daylight sampling; the region further offshore (> 40 km) represents the nighttime distributions. There were no apparent differences in layer thickness between periods. It was assumed the species in the near and offshore regions displayed similar behavior patterns in their vertical migration.

Sequential Batfish depth profiles (n=10) are shown in Fig. 6 consisting of chlorophyll (shaded region on right hand side of scale) and total copepods (left hand side of scale). Each profile is separated by ≈0.5 km horizontal distance. There existed a depression in the chlorophyll concentration at depths coincident with the copepod layer in each vertical profile, indicating apparent grazing. This effect has also been studied on the Scotian Shelf south of Nova Scotia where our analysis indicated that copepods create the abrupt chlorophyll maximum by grazing on the layer from above, apparently at the depth at which chlorophyll productivity is a maximum. There is evidence (Longhurst 1976) that maximum carbon production per unit

Fig. 1. Frequency distribution of diameter, length and volume of copepods sampled by Batfish.

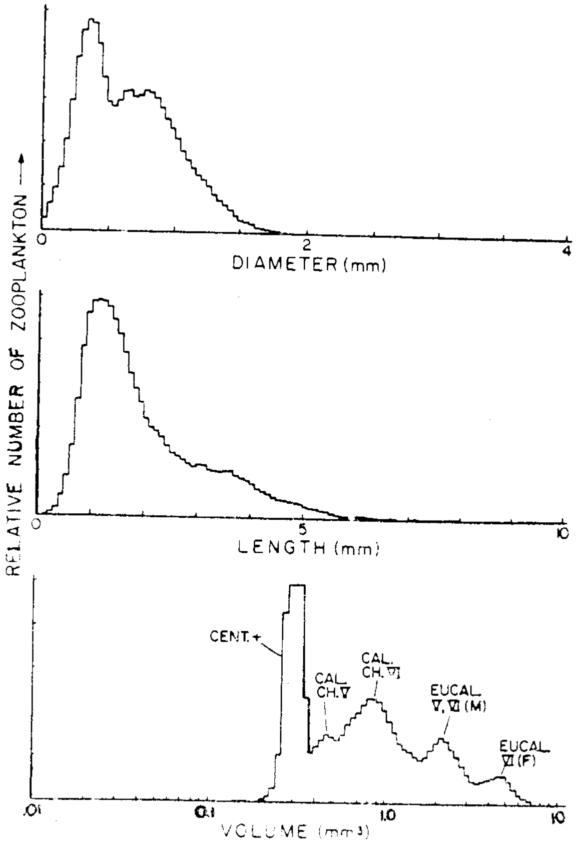


Fig. 2 Vertical distributions of chlorophyll (1) and copepods (2) durign daylight and nighttime periods illustrating migration.

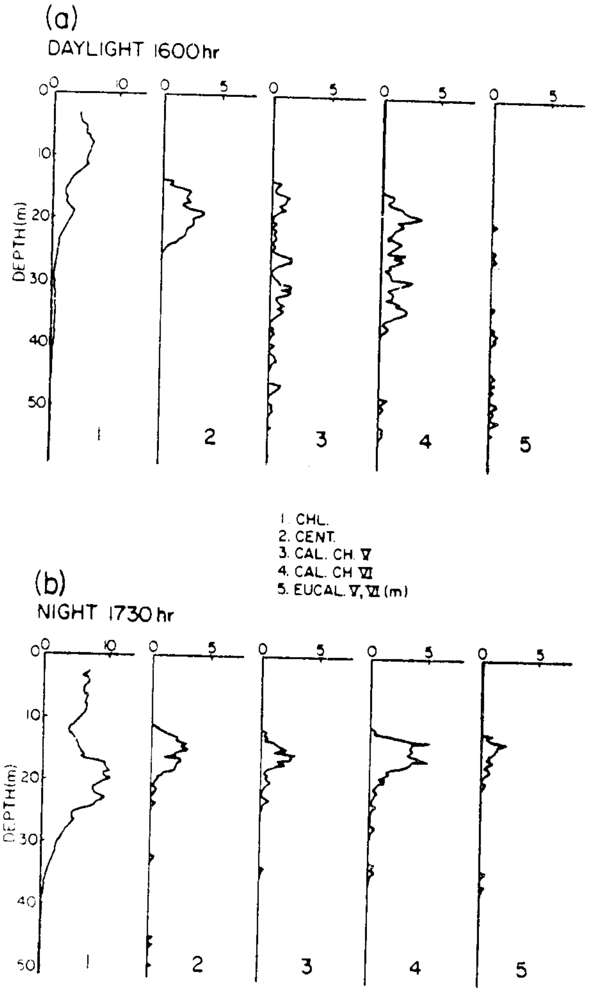


Fig. 3 The mean depth centroid of chlorophyll and several species of copepods vs distance offshore. By towing from right to left, the depth centroid was soon to move towards surface indicating nighttime migration. Temperature contoured on depth is shown in the botton figure.

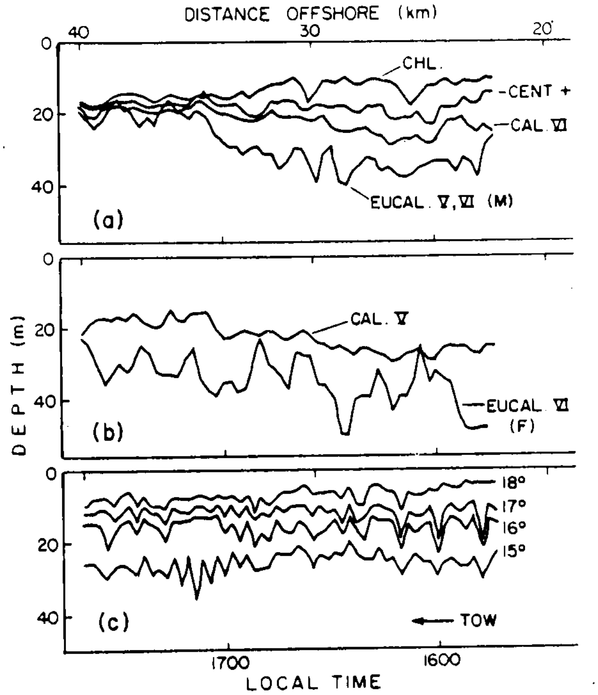


Fig. 4 The mean depth centroid of chlorophyll and several species of copepods vs distance offshore. From right to left, the centroid was seen to move down indicating down migration. Temperature contoured on depth is shown in the botton figure.

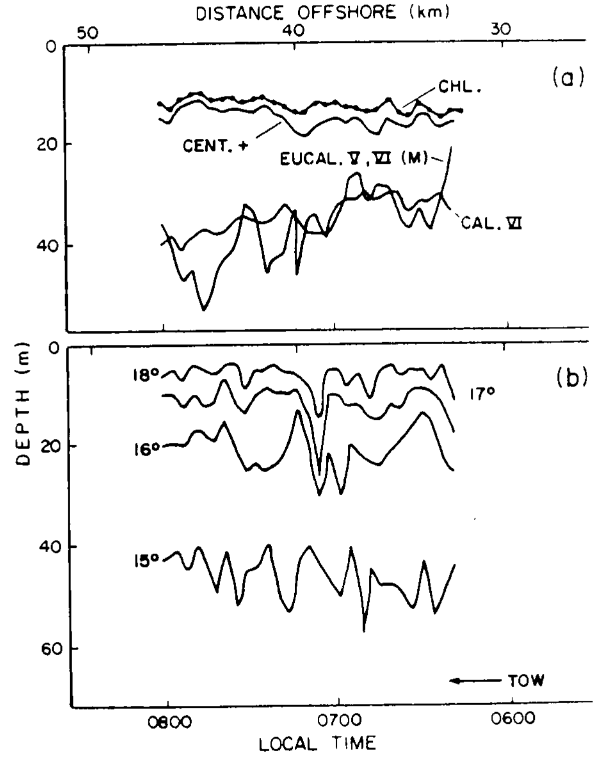
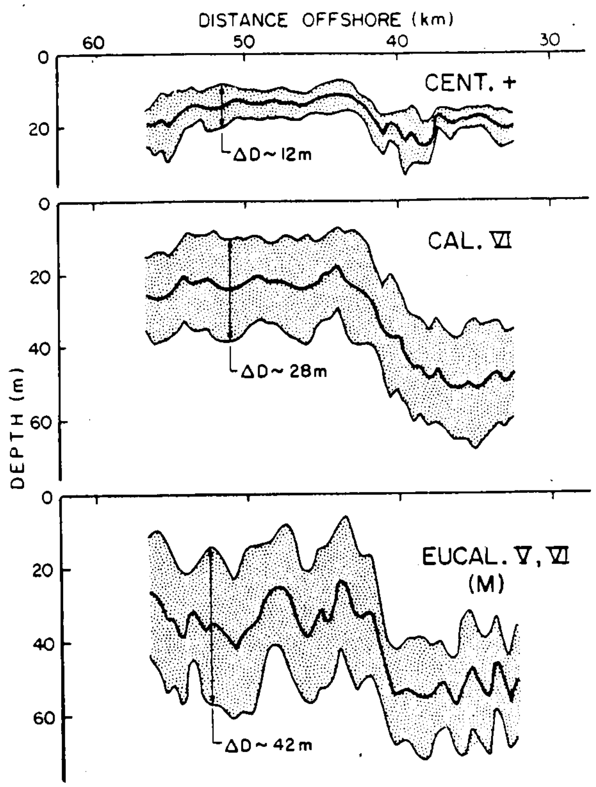


Fig. 5 The standard layer thickness of several species of copepods. The time scale is identical to that of Fig. 4.

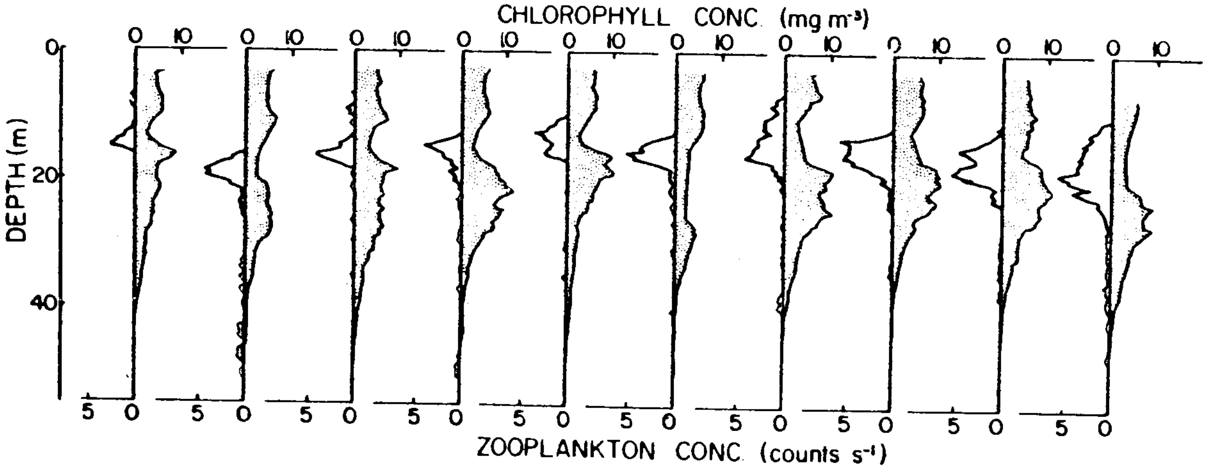


volume occurs above the subsurface chlorophyll maximum and this observation is also (Herman et al, 1981) in agreement with analyzed Batfish data from the Scotian Shelf. Preliminary data analysis indicated that this also occurred on the Peru shelf during our sampling period.

ESTIMATED COPEPOD CONCENTRATIONS

A comparison of the estimated copepod concentrations on the Peru shelf at 9°S was made between the Batfish sampler and the BIONESS sampler described by Sameoto et al. (1980). Details of the zooplankton data from the BIONESS sampled along 9°S during this period are described by Sameoto (1980). Table 1 provides a summary of the mean concentration of dominant copepods from the Batfish sampler, calculated as the integrated total in $\# \mathrm{m}^{-2}$ in the water column to $\leqslant$ 70 m or the naximum depth sampled by Batfish. The mean shelf depth in this region was ~120 m. The integrated total over the water column is calculated in order to minimize biases caused by vertical migration. Each tow represents ~30 km of horizontal samplig while profiling in a sawtooth pattern and the time and location of each tow is listed in Table 3. Sampling occurred during both day and night periods and was distributed across the shelf. The measured concentrations appear to demonstrate a high degree of variability due to horizontal patchiness in this area. Later tows 276-286 on Nov. 22-23

Fig. 6 Sequential Batfish profiles with chlorophyll plotted on right-hand-side of scale (shaded area) and total copepods on the left-hand-side. Copepods appear to be grazing above the chlorophyll maximum creating a depression in the chlorophyll layer.



(Table 3) resulted in lower than average concentrations of all copepods along 9°S corresponding to a similar decrease in chlorophyll concentrations (Herman, 1980). This decrease in copepod concentrations was also observed in the data of Sameoto (1980) and has been attributed by Herman (1981) to sampling variability along 9°S due to rapid poleward advection(~10 to 15 cm s^{-1}).There are no apparent differences in the day and night Batfish samples for the integrated total in the water column.

Table 2 represents the mean concentration of dominant copepods as estimated from the BIONESS samplers. The BIONESS employs 10 individually operated nets samplig over a depth interval of ~10 m from surface to ~100 m. Calculations in Table 2 do not include the entire water column as we have intergrated samples only from surface to 70 m in order to compare with Batfish estimates. Table 2 shows a higher degree of variability, as indicated by the coefficient of variations in the BIONESS samples compared with those of the Batfish. This undoubtedly reflects the shorter horizontal sampling distances of the BIONESS of ~200 m per net sample as compared with the Batfish sample length of ~30 km per tow. An overall decrease in copepod concentrations was also observed during the latter part of the cruise along 9°S (tows 8 to 12) agreeing with the Batfish data. There were no significant day and night differences in the BIONESS catches as determined from an unpaired t-test (Sameoto, 1980).

TABLE 1.- Copepod concentrations # m^{-2} as measured with the Batfish sampler on the Peru Shelf at 9°S

	COPEPOD CONCENTRATION (# m^{-2})						
Tow #	Calanus chiliensis	Eucalanus inermis	Centropages brachiatus	Paracalanus parvus	Clausocalanus arcuicornis	Coryaeus griebriechti	Oncaea conifera
198	19100	3148	19141	375	377	1217	1468
204	24735	1503	1237	8	1138	1095	3053
220*	17041	3085	11802	442	2350	4015	1812
276	17695	595	3045	608	3688	4961	3192
278	2512	991	888	132	227	498	718
280*	10061	1638	1780	230	1708	1798	1673
286*	6813	447	838	42	1050	1356	1035
301	23703	1125	4562	1127	5037	11190	6252
AVG	15207	1566	5410	370	1946	3355	2400

* Indicates nightime tow

TABLE 2.- Copepod concentrations plus means and coefficient of variation (CV) per m^2 as measured with the BIONESS sampler and means and coefficient of variation calculated from Batfish data.

	COPEPOD CONCENTRATION (# m^{-2})						
Tow #	Calanus chiliensis	Eucalanus inermis	Centropages brachiatus	Paracalanus parvus	Clausocalanus arcuicornis	Coryaeus griebriechti	Oncaea conifera
1*	14106	496	3344	1607	7015	2101	2084
2*	23724	1551	46788	11924	940	2443	2154
3	29151	6145	84988	32514	232	1619	3948
4	8043	21718	124942	739	11	38	5050
5*	6431	2237	20677	11152	673	931	41
6*	10613	1526	6498	11321	4852	4065	2159
7	9387	1204	3917	11227	4219	1333	1799
8	3635	410	3725	444	27	3	70
9	915	4927	5746	2286	99	<1	34
10	613	1281	303	354	751	<1	24
11*	10447	500	1043	394	3178	<1	2160
12*	26495	1145	1562	2085	5284	<1	6496
16*	996	1548	1875	2673	1382	2951	7343

mean
and C.V. 11119, 2.68 - 3437, 2.03 - 23494, 4.91 - 6824, 3.56 - 2204, 7.04 - 1191, 38.36 - 2181, 7.81

Batfish
mean
and C.V. 15207, 1.08 - 1566, 0.93 - 5410, 2.06 - 370, 3,60 - 1946, 1.74 - 3355, 1.58 - 2400, 0.91

* Indicates nightime tow.

TABLE 3.- Station positions and Times of BIONESS and Batfish Tows.

BIONESS					BIONESS				
Stn	Position		Time (Loc)	Date (Nov)	Stn	Position		Time (Loc)	Date (Nov)
1	9°34.1'S	79°13.6'W	2330	15	198	9°20.0'S	78°48.0'W	1600	15
2	9°12.8'S	78°55.0'W	0000	16	204	9°06.0'S	79°03.0'W	1000	16
3	9°26.5'S	78°47.0'W	1300	17	220	9°28.7'S	79°03.0'W	0100	18
4	9°18,9'S	78°45,7'W	1820	17	276	9°33.0'S	79°11.0'W	0700	22
5	9°21.8'S	78°54.9'W	2040	17	278	9°24.0'S	78°56.0'W	1120	22
6	9°28.3'S	79°03.0'W	2220	17	280	9°24.0'S	78°54.0'W	1715	22
7	9°29.8'S	79°04.6'W	0830	19	286	9°30.0'S	79°05.0'W	2120	23
8	9°15.1'S	78°40.0'W	1050	21	301	9°26.6'S	79°00.7'W	0620	23
9	9°20.0'S	78°46.0'W	1330	21					
10	9°26.6'S	78°55.6'W	1600	21					
11	9°29.4'S	79°40.2'W	1900	21					
12	9°29.8'S	79°36.0'W	2310	21					
16	9°23.06'S	78°53.9'W	0240	23					

The overall mean copepod concentrations estimated from the BIONESS data are given in Table 2 and listed with the Batfish averages obtained from Table 1. Although there is no biological relevance attached to the concentrations averaged for the week, it is useful in comparing the results obtained with the two samplers. There are two major discrepancies in comparing the total averages of **Paracalanus** and **Centropages** measured by each sampler. A large fraction of **Paracalanus** having a mean diameter of ~300-400 μm may be extruded through the Batfish sampler nets (~333 μm mesh) and not the BIONESS nets (~243 μm mesh) which may account for the lower averages for the Batfish. The BIONESS estimates for **Centropages** are weighted by 3 tows (# 2 to 4) of extremely high concentrations ranging upwards of ~100,000 m^{-2} and if eliminated from the averaging, the estimates would be comparable to the Batfish estimates of ~5400 m^{-2}. For all other species except **Corycaeus** there appears to be very good agreement between the two sets of averages.

SUMMARY

Data have been presented on copepod distributions, species composition and abundances on the Peru shelf at 9ºS. Vertical profiles of copepods and chlorophyll a measured copepod layers were situated ~5 m above the chlorophyll maximum and data analysis is continuing to establish the depth of the production maximum which we believe is also located above the chlorophyll maximum. A comparison of copepod abundance estimates made between the Batfish and BIONESS samplers indicated reasonable agreement; however, the extent of sampling variability in both time and space on the shelf appears to be quite high.

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