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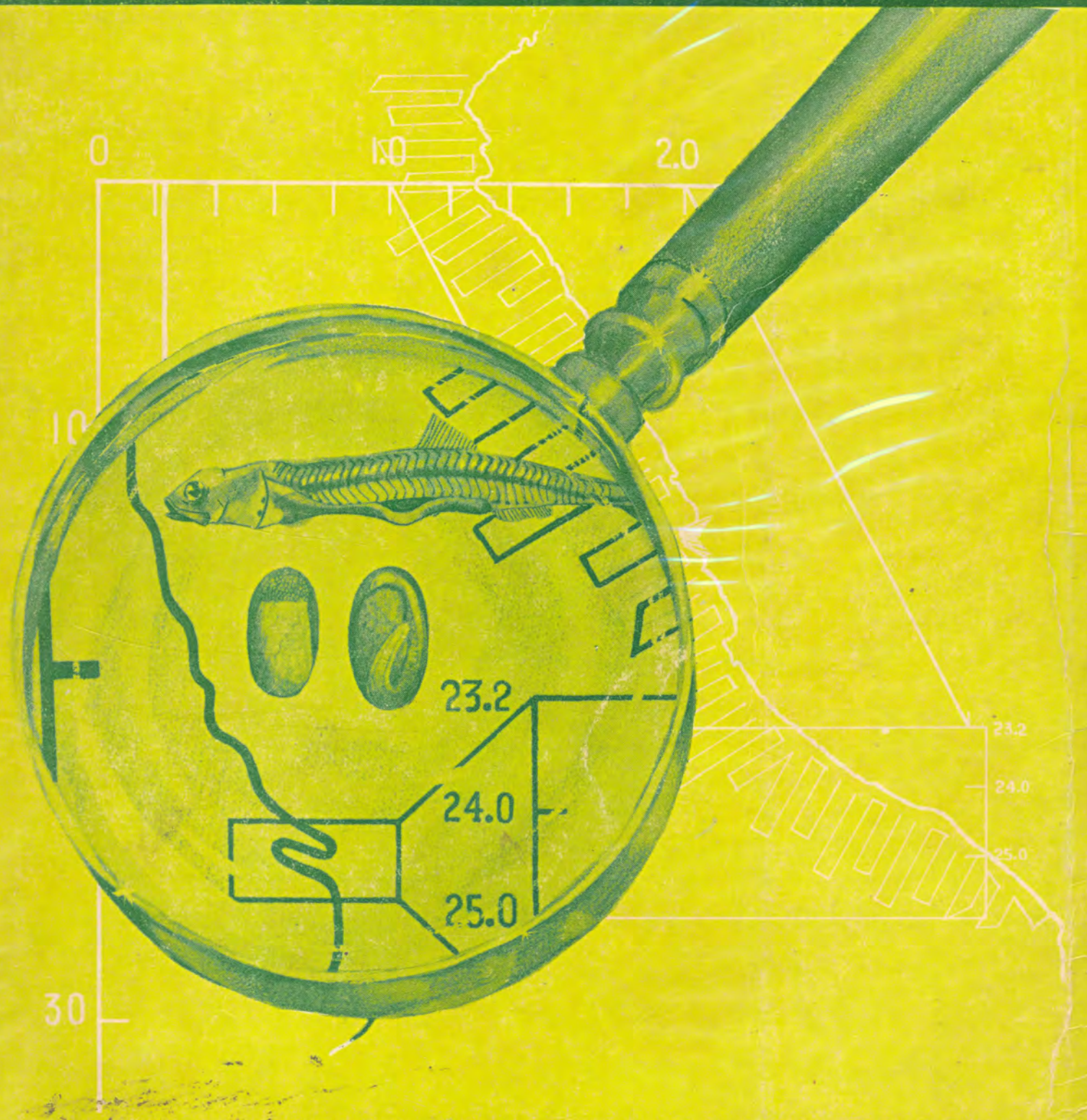

INVESTIGACION COOPERATIVA DE LA ANCHOVETA Y SU ECOSISTEMA - ICANE - ENTRE PERU Y CANADA CALLAO 1981 PERU

MICROSCALE PATCHINESS OF SMALL PLANKTON ON THE CHIMBOTE SHELF, PERU

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ABSTRACT

Vertical microscale patchiness of small plankton organisms was evident off northern Peru in a variety of environmental conditions: in a step-stratified coastal pycnocline, at the sea surface at mid-continental shelf and deep in the mixed layer off the shelf-break. The observations show that neither high standing stocks of plankton, nor vertical gradients of density and nutrients are necessary conditions for sub-meter variation of organism concentrations. Scalar processes (stirring) controlled organism microstructure but behavioral components appear to have enhanced the degree of patchiness of motile plankton types at one site. At each site, anchovy larvae would have encountered substantial changes of food organism concentrations by vertical excursions of less than a meter. In view of these examples, perhaps larvae of **E. ringens** encounter zones of high food concentrations far more frequently than indicated from conventional sampling of larger volumes and intervals.

RESUMEN

La distribución vertical en pequeños grupos de organismos planctónicos de poco tamaño frente a la costa peruana del norte se hizo evidente en variadas condiciones ambientales: con una picnoclina costera estratificada escalonadamente, en la superficie del mar sobre la parte media de la plataforma continental y en la capa de mezcla profunda fuera del extremo de la plataforma. Las observaciones muestran que para la existencia de variaciones de extensión menor que un metro de la concentración de organismos, no es necesaria la existencia de grandes stocks de plancton, ni de gradientes verticales de la densidad ni nutrientes. La micro estructura de la distribución de organismos fue controlada por procesos escalares (agitación) pero componentes de comportamiento de los tipos de plancton móviles parecen haber acentuado el grado de "patchiness" en un sitio dado. En cada uno de los sitios, las larvas de anchoveta podrían haber encontrado cambios sustanciales en la concentración de organismos alimentarios si excursionaban verticalmente por distancia de menos de un metro. En vista de estos ejemplos, tal vez las larvas de **E. ringens** encuentran zonas de alta concentración de alimentos con mucha mayor frecuencia que la indicada por el muestreo convencional de volúmenes mayores a intervalos también mayores.

INTRODUCTION

Samples for measurement and description of biological microstructure were collected at sites spanning northern Peru's broad Chimbote Shelf during the ICANE Project aboard C.C.S. **Baffin** in November 1977. A purpose of the effort was to determine if small predators and grazers such as anchovy larvae encounter patches of higher food density over short feeding excursions: where overall food concentrations appear too low, plankton patches of small extent could still support larval survival and growth.

Plankton patchiness can occur in the ocean on the sub-meter scale (≡ microscale). Cassie (1959) and Owen (1966) showed examples of high variation of plankton concentration in the upper half meter of the surface of the open sea under calm surface conditions; McAlice (1970) and Ragotzie and Pomeroy (1957) documented surface and sub-surface patchiness of estuarine phytoplankton and Owen (1980) showed vertical and horizontal variation of phytoplankton and microzooplankton in sub-surface waters of the Southern California Bight.

METHODS[1]

Samples to assess microscale patchiness at each site were obtained with the micro-patch sampler (MPS) shown in Figure 1. The MPS sampled vertically, either in the mixed layer or in the upper pycnocline as defined by CTD cast profiles, near the main chlorophyll maximum layer as defined by phytoplankton pigment fluorescence in a water stream provided by pump and hose (Mackas, this volume). With the MPS clamped to the ship's hydrowire and lowered to the desired nominal depth, sample tube mouths were oriented by vanes to face a current of ~50 cm/sec induced by moving the ship slowly ahead. This minimized vertical mixing of the water by the MPS as its sample tubes captured water at ten depths at 20-cm intervals in 5-cm i.d. tubes of 600 ml capacity by simultaneous, messenger-activated release of lanyards which restrained ball valves from their seats at either end of each sample tube. Replicates were obtained at top and bottom positions by strapping another sample tube alongside the original. Upon recovery of the MPS, water was aliquoted for various analyses from the stirred contents of the sample tubes.

Particle concentrations were determined within 2 hours after sample collection using a Coulter R Counter with a 280 μm detection pore. Counts in Coulter R channels 3-16 include particles of about 6-160 μm diameter channels 10, 11 of 30-50 μm diameter, and channels 12-16 of 50-160 μm diameter, as derived from calibration with 45-μm diameter spheres. Inorganic nutrient concentrations were determined colorimetrically by Technicon Autoanalyzer on duplicate, unfiltered[2] samples within a few hours of sample collection.

RESULTS

Plankton samples were enumerated from MPS casts near the Peru coast (Station 95), at mid-shelf (Station 125), and seaward of the Chimbote shelf-break (Station 80).

Station 95 was occupied 5 km off the Peru coast under 8 kt winds. The MPS was deployed in late afternoon to sample the layer from 15-17 m depth. A CTD cast made 35 min earlier showed no density stratification in this layer, which lay between a stepped, surface-layer pycnocline that extended to 12 m depth and a weaker pycnocline that extended downward from 22 m depth. Large, uncounted quantities of chain diatoms, mostly **Chaetoceros** species, were present at the sea surface and at the sampled depths. From 15-17 m, concentrations of **Pleurosigma elongatum** and **P. nicobaricum** exhibited nearly monotonic, stepwise

Figure 1. Micro-patch sampler (MPS) showing orientation vanes, closed sampling bottles. Spring-loaded lanyard release rod (center of bottle frame) acts when messenger weight strikes trigger atop cable clamp (top of frame).

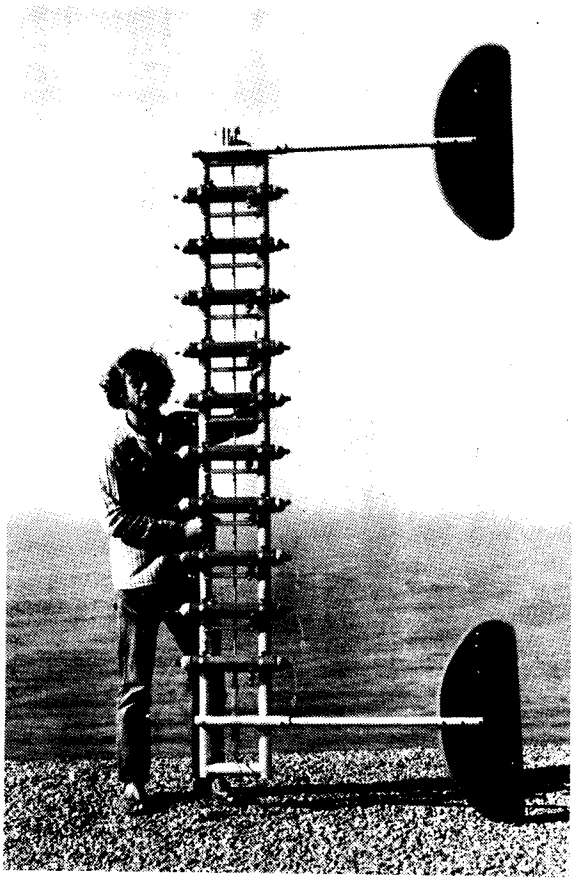
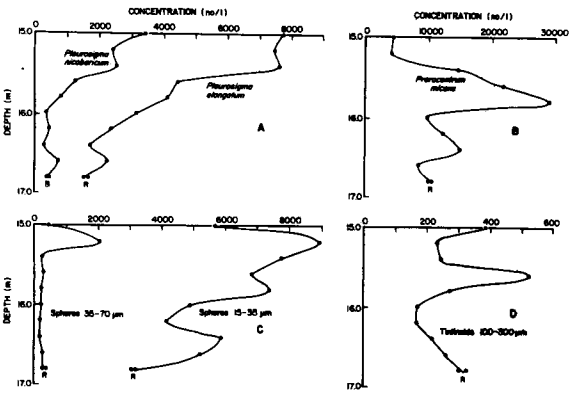


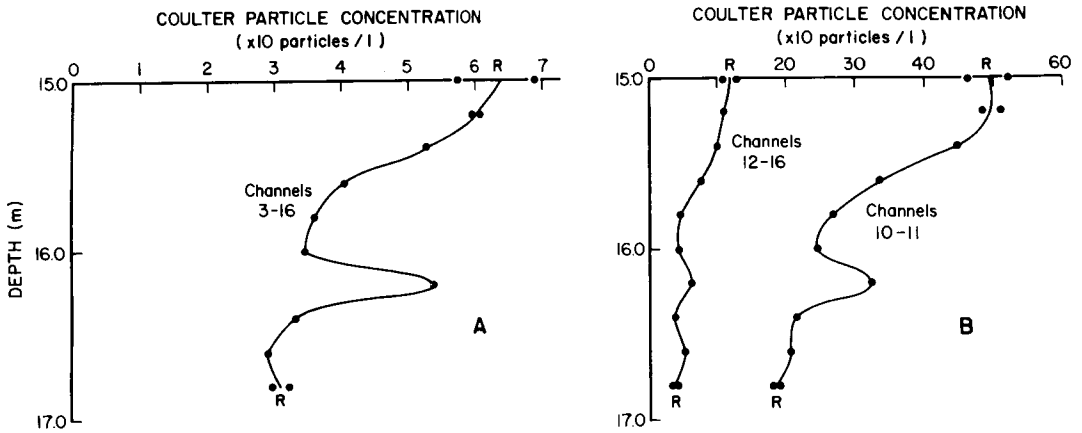
Figure 2. Concentration profiles of microplankton organisms and egglike spheres over a 2-m depth interval in coastal waters of the Chimbote Shelf, Peru, in November 1977. R designates replicate sample values.



[1]My thanks to the ICANE Project and to Drs. Reuben Lasker and L.A.E. Doe for the opportunity and travel funding to participate on C.C.S. **Baffin** Cruise 77030, to Susan Oakley and Jean Painchaud for nutrient analyses aboard **Baffin**, and to Lee Inness-Brown for microscope enumerations of Station 125 samples. My thanks also to Drs. J.R. Hunter and L.M. Dickie for help with manuscript enhancement.

[2]Nutrient concentrations in filtered and unfiltered samples from another shelf station were indistinguishable.

Figure 3. Concentration profiles of particles sensed by Coulter^R counter over a 2-m depth interval in coastal waters of the Chimbote Shelf, Peru, in November 1977. R designates replicate sample values.



decreases with depth over the 2 m interval (Figure 2A), indicating vertical variation on a scale somewhat larger than 2 m. By contrast, **Prorocentrum micans**, large tintinnids, and spheres showed pronounced maxima and minima of concentration (Figure 2B, D), indicating patchiness on the submeter scale. Particle concentrations from Coulter ^{R} counts also indicated sub-meter patchiness of small particulates (Figure 3), which were likely dominated by detritus. Nutrient concentrations in the layer were virtually constant with depth (Figure 4).

Stations 125 was occupied at mid-shelf while the **Baffin** followed a drogue under 10 kt winds. The MPS was deployed in mid-afternoon to obtain a microprofile of the upper 2 m of the sea surface layer. The MPS was positioned about 3 m from the ship's hull to avoid its boundary layer; the top of the sampler skimmed the sea surface as the ship moved upwind. CTD casts 3.5 h before and 2.2 h after the MPS cast indicated no stable stratification of the surface layer to 6 m depth. By volume, detritus dominated the samples. The larger coherent detrital masses appeared to be fresh larvacean houses, consistent with the presence of many oikopleurans in the MPS samples. Despite the absence of physical stratification in the layer, submeter patchiness nevertheless is evident in concentration profiles of oligotrich ciliates, tintinnids, **Prorocentrum** spp., copepod eggs, and nauplii (Figure 5). Ammonia and silicate microprofiles of the surface layer at Station 125 show microscale variations, whereas those of phosphate and of nitrite and nitrate do not (Figure 6). Replicate sample differences (R in Figure 6) indicate that only silicate exhibited significant variation within the layer. Coulter ^{R} particle counts were not made at this station.

Station 80 was occupied about 10 km seaward of the Chimbote Shelfbreak under 20 kt winds. The MPS was deployed at night to sample the layer from

Figure 4. Concentration profiles of nutrient salts over 1 2-m depth interval in coastal waters of the Chimbote Shelf, Peru, in November 1977. R designates replicate sample values.

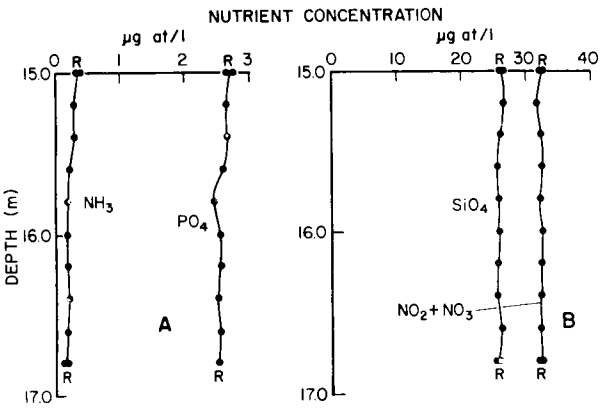


Figure 5. Concentration profiles of 'microplankton organisms and egglike spheres over a 2-m depth interval from the sea surface at mid-Chimbote Shelf, Peru, in November 1977. R designates replicate sample values.

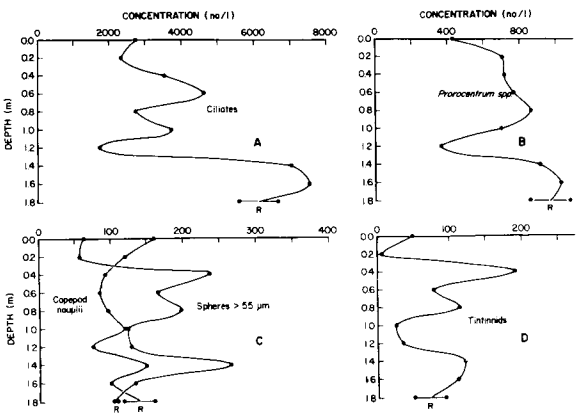
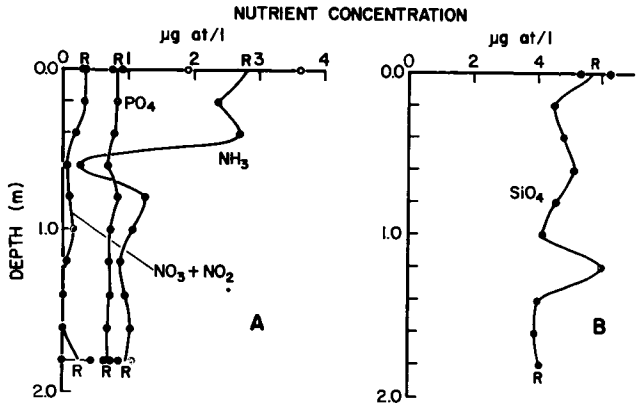


Figure 6. Concentration profiles of nutrient salts over a 2-m depth interval from the sea surface at mid-Chimbote Shelf, Peru, in November 1977. R designates replicate sample values.



15-17 m, located above the base of the surface mixed layer according to a CTD cast made 3 h earlier at the station. Standing stocks of phytoplankton were markedly less than at shelf stations. MPS samples were dominated by floc and flake detritus. Ciliates were numerically the predominant organism present. As at the mid-shelf station, organism patchiness was detected only on the sub-meter scale; no monotonic gradients of concentration were apparent. Organism types showing sub-meter variation were oligotrich ciliates, the diatom **Corethron** sp., copepod eggs, nauplii and small spheres (Figure 7). Coulter ^{R} counts indicate large variations of particle concentration as well as relatively large differences between replicate sample values (Figure 8). As at the coastal site, microscale variation of nutrients was negligible and only ammonia exhibited a discernable gradient over the sampled interval (Figure 9).

The widely understood coefficient of variation, V, was computed to express the degree of variation of organisms between depths within each MPS cast. The V-coefficient is here the ratio (expressed as percentage) of standard deviation of concentration to the average concentration over the 10 depths sampled, i. e., V = 100 s/X. Replicate sample values were averaged for the computation. Table 1 shows V-coefficients for organism types enumerated at more than one sampling site.

DISCUSSION

Population V-coefficients greater than 33% are taken to denote **in situ** vertical microstructure. This value is 3 times the error value derived by Owen (1980) from replicated or recounted sample pairs counted by methods used for this study. By this criterion, Table 1 shows microscale variation of each organism type to have occurred at one or more of the sites sampled by the MPS.

Sub-meter plankton variation, as measured, can

Figure 7. Concentration profiles of microplankton organisms and egglike spheres over a 2-m depth interval off the Chimbote Shelf break, Peru, in November 1977. R designates replicate sample values.

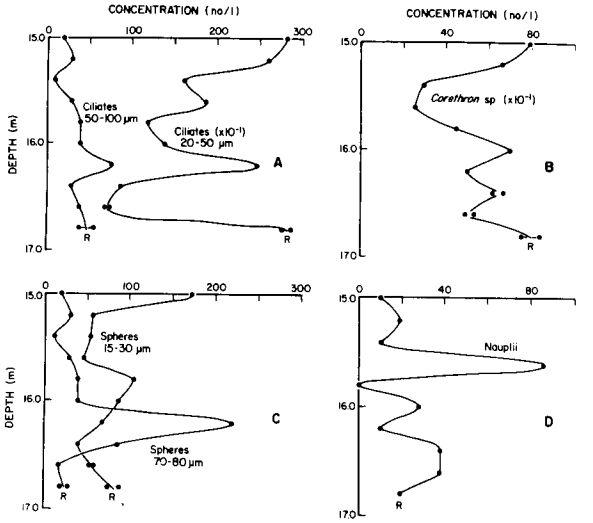


Figure 8. Concentration profiles of particles sensed by Coulter^{R} counter over a 2-m interval off the Chimbote Shelf break, Peru, in November 1977. R designates replicate sample values.

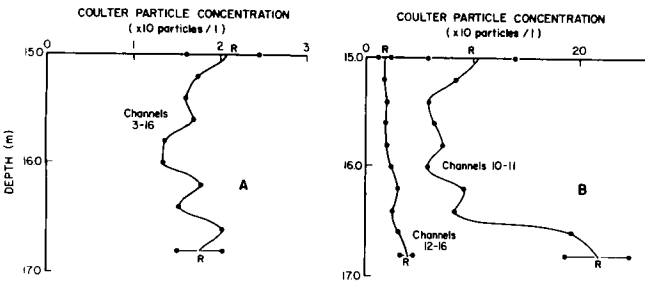
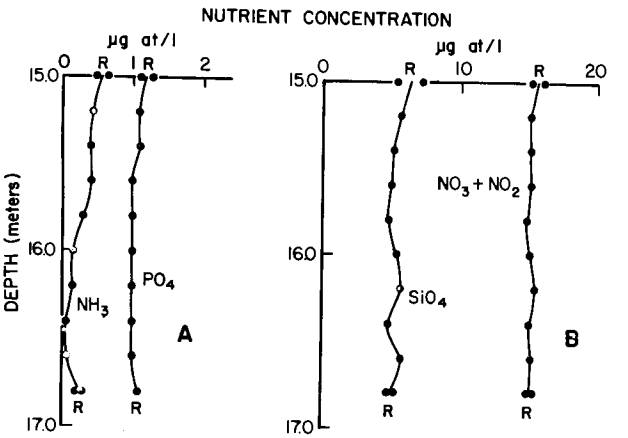


Figure 9. Concentration profiles of nutrient salts over a 2-m depth interval off the Chimbote Shelf break, Peru, in November 1977. R designates replicate sample values.



include a component from the sub-cm scale. Plankters including dinoflagellates and ciliates can associate with suspended organic aggregates (Silver et al. 1978). Detrital particles were numerous in samples from Stations 80 and 125. At Station 125, the larger aggregates were unpopulated larvacean houses. At Station 80, Coulter ^{R} counts of replicate samples were disparate (Figure 8), indicating dissociation by sample handling of a few large, inequally sampled aggregates. Microscope counts of organisms in these replicates, however, were in close agreement (Figure 7). The organisms from these sites therefore were more likely free-living than associated with aggregates.

There is no evidence for microscale relationships between concentrations of nutrient salts and concentrations of organism populations. Microscale variation of nutrient consumers (diatom and dinoflagellate species) and of ammonium producers (microzooplankton) species occurred in the absence of nutrient microgradients (Station 80 and 95), and failed to co-vary where nutrient microgradients may have been present (Station 125). There is little reason to expect such relationships unless organisms maintain their positions in microlayers and unless microlayers persist for at least several days.

Comparisons of the distributions of non-motile and motile organisms reveal certain features of the mixing processes. In each of the sampling intervals the absence of detectable vertical gradients of temperature and salinity indicated a lack of local vertical stability. The most obvious energy source for this, surface wind stress, should be most affective on the sea-surface layer. In keeping with this expectation, microscale variation at the surface at Station 125 was comparable for passive and motile organisms. Evidently in this instance scalar processes were playing such an important role that they obliterated any trace of vectorial components. The same appears true from the samples at Station 80, taken in the lower part of the surface mixed layer. By contrast, at Station 95 where the vertically homogeneous sampled layer was protected from direct external forces by a stable water layer both above and below, motile particles were more clustered than nonmotile, indicating significant influence of vectorial processes.

The distinction drawn by Eckart (1948) between stirring and complete mixing seems applicable here. Exchange processes can initially increase mean gradients of concentration before further mixing obliterates them. This initial stage, stirring, was sufficient to produce variations of comparable scale among small passive and active organisms. Levels of local energy input to the sea off Peru were either too low or too ephemeral to obliterate sub-meter variation of organisms by mixing.

Microscale organism patchiness is not confined to waters with high standing stocks of microplankton. As is common, mean concentration of each organism type decreased with distance offshore (Table 1), yet microscale variation of organisms increased with distance offshore except for **Prorocentrum** and oligotrich ciliates.

Among those organisms represenuted in Table 1 and the figures, Rojas de Mendiola (1974) noted that copepod eggs and nauplii, small spheres and tintinnid ciliates occurred frequently in the diet of larval anchovy 9 mm caught off Peru, whereas the diatom species **Corethron** and **Pleurosigma** did not. **Prorocentrum** and oligotrich ciliate species likely are food organisms as well, but are soft-bodied and not easily detected in larval guts. Ciliates other than tintinnids apparently have received no attention as larval anchovy food. **Prorocentrum micans** was reported by Scura and Jerde (1977) to have been eaten by laboratory anchovy larvae more frequently than were **Peridinium** species at

TABLE 1.- Coefficients of variation, V, and mean concentrations (no/l) of plankton organism types enumerated at more than one site sampled on the microscale by MPS off Peru in November 1977 on CCS Baffin cruise 77030. Values are for 10 depths at 20 cm intervals; replicate sample counts were averaged for computations.

CAST ENVIRONMENT	Baffin 77030 Sta. N°		Non-motile types		Motile types				Depth of top sample (m)
			copepod eggs	small spheres	Prorocentrum spp.	tintinnid ciliates >100 µm	oligotrich ciliates	copepod nauplii	
5 km off Peru coast, pycnocline layer step	95	V	30.7	29.1	59.5	39.6	-	-	15
		$\bar{X}$	(236)	(5692)	(13068)	(536)	-	-	
mid-shelf, sea-surface layer	125	V	46.5	50.4	29.0	68.6	48.2	25.4	0
		$\bar{X}$	(148)	(307)	(749)	(81)	(4214)	(115)	
10 km off shelf-break, base of mixed layer	80	V	123	69.6	-	-	43.2	91.3	15
		$\bar{X}$	(51)	(776)	-	-	(1885)	(27)	

comparable concentrations of predators and prey. The latter are known prey of Peruvian anchovy larvae (Rojas de Mendiola, loc. cit.).

Concentrations of microplankton in one 20 cm stratum at mid-shelf Station 125 may have sustained larval anchovy. Assuming that larvae eat oligotrich ciliates, the volume concentration of food organisms reached that estimated from Houde (1978) as sufficent for 10o/o survival of bay anchovy larvae to metamorphosis. Concentrations fell short, however, of that from Lasker and Zweifel (1978) for larval Northern anchovy. At this station, highest peak concentration of food-types was 1.5 mm^3 /1 and occurred at 1.6 m depth. Mean food concentration in the 2 m surface layer was 1.0 mm^3 /1 and the coefficent of variation was 37.5o/o.

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