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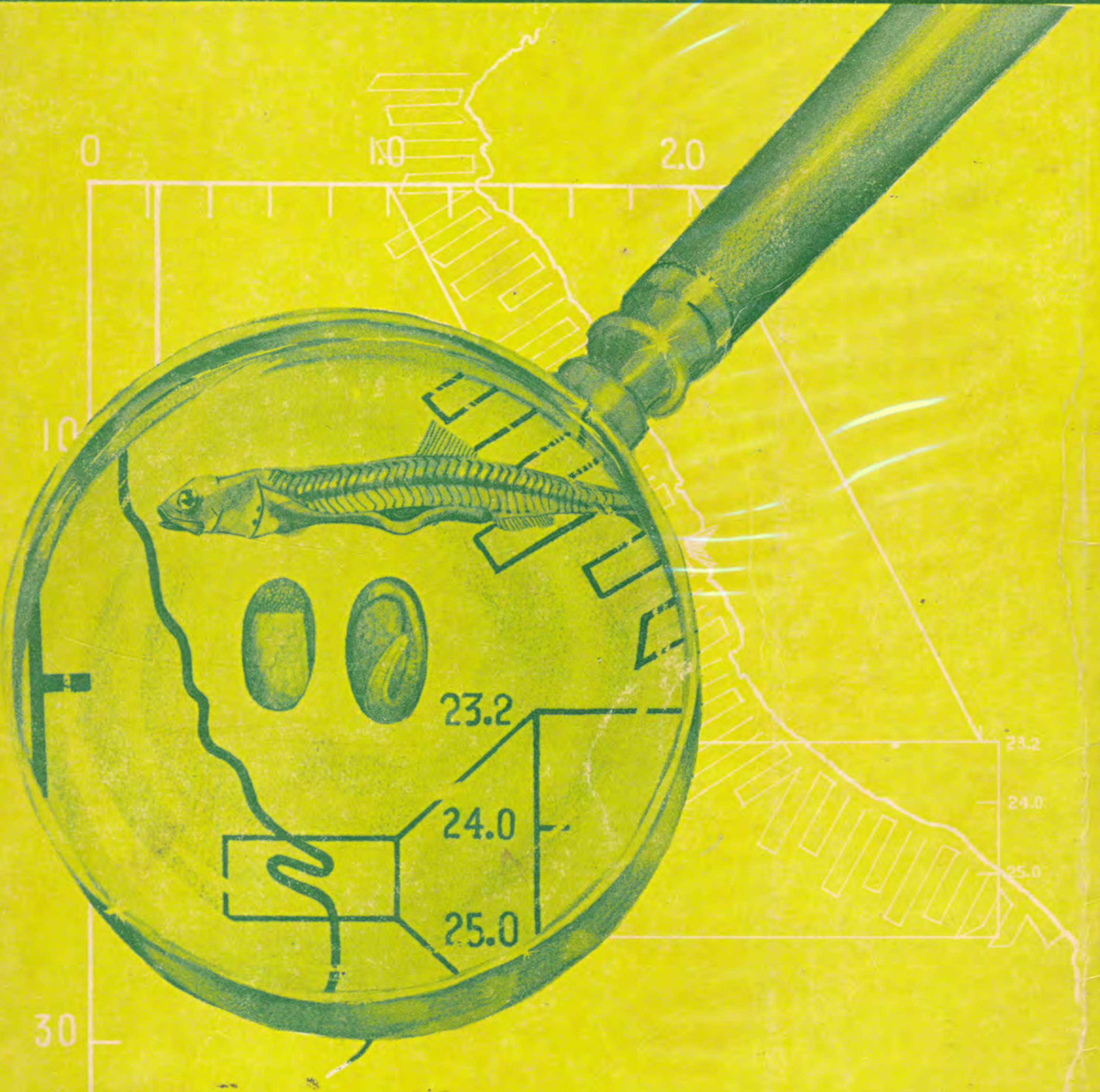

INVESTIGACION COOPERATIVA DE LA ANCHOVETA Y SU ECOSISTEMA - ICANE - ENTRE PERU Y CANADA

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A NOTE ON THE STANDING STOCK AND PRODUCTION OF MICROPLANKTON OFF THE COAST OF PERU AS DETERMINED BY PARTICLE COUNTING

by

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ABSTRACT

Particle counting methods were used to determine the distribution of suspended particulate matter in the size range 2 – 102 μm from the surface to a depth of 40m. An average pattern of particle size distribution over selected depth intervals and the average relationship of particle concentration with depth was established. Particle growth in incubated samples was measured and an estimate of the average growth rate of the phytoplankton was established. From these measurements an average standing stock of 2.4 g C m^{-2} and an average primary production of 8 g C m^{-2} day was estimated. The primary production estimate is probably a little high because phytoplankton growth rates at 5m were applied to the whole water column, but it is clear that reasonable estimates of phytoplankton standing stock and production can be made with particle counting methods.

RESUMEN

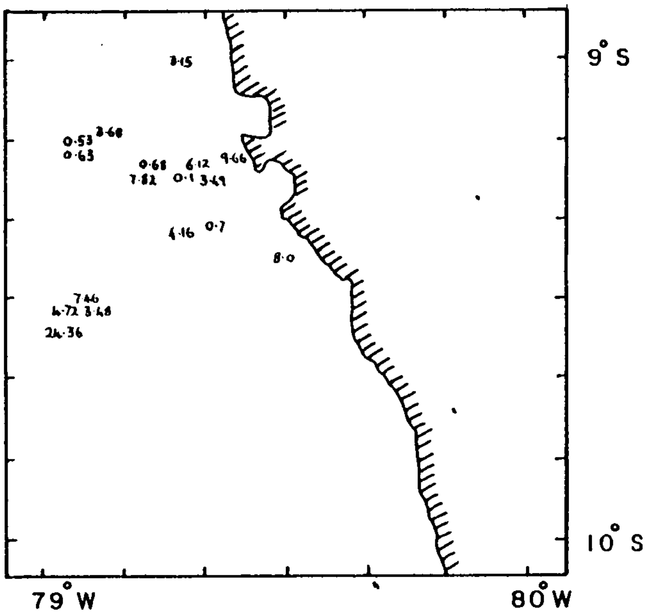
Su usó métodos de conteo de partículas para determinar la distribución de materia particulada suspendida de tamaños entre 2 y 102 μm desde la superficie hasta 40 m de profundidad. Se estableció la existencia de un patrón promedio de la distribución de tamaños en intervalos seleccionados de profundidad, así como la relación promedio entre la concentración de partículas y la profundidad. Se midió el crecimiento de partículas en nuestras incubadas estableciéndose una tasa promedio de crecimiento del fitoplancton. Con estas mediciones se ha estimado un stock permanente promedio de 2.4 g C por m^2 y una producción primaria de 8 g C por m^2 por día en promedio. La estimación de la producción primaria es probablemente algo alta porque a toda la columna se aplicó la tasa de crecimiento del fitoplancton a 5 m de profundiad, pero no hay duda de que la producción y el stock permanente se pueden estimar razonablemente con métodos de conteo de partículas.

Samples for standing stock determinations were collected with 5 litre Niskin bottles at various depths to 40m at the stations shown in Fig. 1. The concentration and size of the suspended particulate material were measured with a model TA II Coulter Counter soon after the samples were taken on board. For measurements of particle growth, water samples were taken at 5m and incubated in 500ml bottles under filtered natural light. The light intensity and quality was adjusted to be similar to that at a depth of 5m. The particle growth in the incubated samples was estimated from a series of standing stock measurements taken at one-hour intervals, and the nature of the particulate material was checked by making photomicrographic records of 125x concentrates (Sheldon, 1979).

Particles of many different kinds were seen in the concentrates but diatom chains were the most common. Pennate diatoms and dinoflagellates also occurred, but non-living particles (detritus) were not abundant. The size range over which measurements were made was usually from 2.0 - 102 μm (equivalent spherical diameter) but for some samples a smaller size range (6.35 - 102 μm) was measured.

It is well known that the distribution of particulate matter in the Peruvian upwelling is very patchy and we found considerable variation from station to station in the amounts present in the water. Within the small area we surveyed there was no indication of a systematic variation in concentration with distance from shore (Fig. 1), and a similar situation seems to exist for zooplankton distributions (Walsh et al., 1971). However, this is not to say that the distribution of particulate material was random. Although there was variation in the amount of particulate matter in the water from place to place, the shape of the size-frequency distributions was constant at any one depth, and it varied systematically with depth. This can be most

Fig. 1 Station locations and the concentration of particles in the size range 6.35 - 102 µm in the surface water.



clearly demonstrated by taking averages of particle concentrations for selected depths. (Fig. 2).

It has been shown that samples of particulate organic carbon are log. normally distributed (Gordon, 1977) and the distribution of total suspended matter also follows this trend (Sheldon, unpublished data). Therefore, the histograms shown in Fig. 2 were formed by taking the logarithmic mean of each size grade for all the samples measured in selected depth intervals. A notable feature of the standing stock distribution was the uniform decrease of concentration with depth. It can be described by an exponential function, as suggested by Nakajima and Nishizawa (1972), but a linear function fits equally well. This decrease was accompanied by a systematic change in the shape of the size-frequency histograms (Fig. 2). In the upper 25m the peak that occurred in the size range 30 - 60 µm was caused mainly by diatoms. At 40m this peak was not prominent and particle standing stocks were similar at all sizes. This is a universal characteristic of sub-surface water (Sheldon et al., 1972). A similar vertical structure and variation in diatom abundance has been noted elsewhere (Sheldon, unpublished data) and it is possible to define the extent of the euphotic zone by the change in shape of the size-frequency distribution of the suspended particulate matter.

Microplankton production was measured as increase in particle standing stock during incubation (Sheldon, 1979). In most cases the increase occurred only in the size range 20 - 80 µm during daylight (Fig. 3) and this was clearly due to phytoplankton

Fig. 2 Left hand side. Depth profile of particle size frequency distributions formed by taking the logarithmic mean of each size grade.
Right hand side. Depth profile of total concentration in the size range 2 - 102 µm. The points on the R. H. S. correspond to the histograms on the L.H.S.

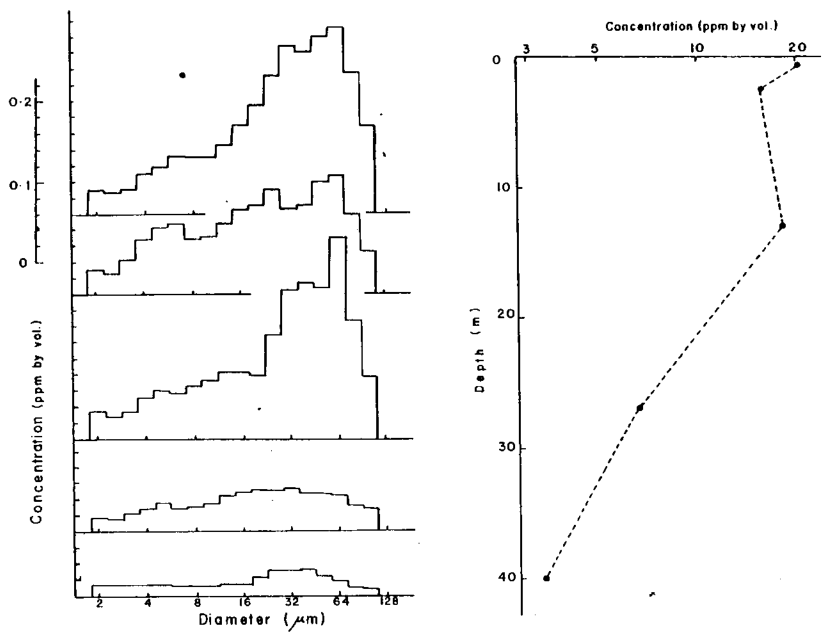
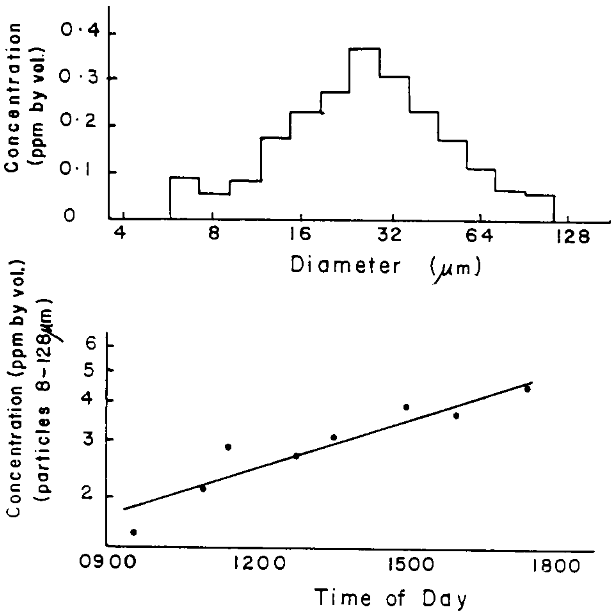


Fig. 3 An example of phytoplankton growth. Upper curve; size-frequency distribution of particulate material. Lower curve; growth of particulate material in the size range 8 - 128 μm.

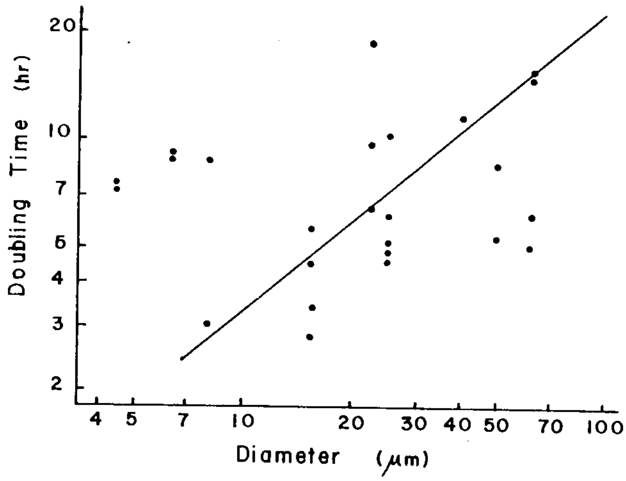


growth. However, in one experiment a particle population with a modal size of 20 - 25 μm continued to increase at the same rate during the night as during the day. This growth must have been caused by either protozoans or non-living particulate material, but the apparent production was not great (about 7.5 μg C l^{-1} day $^{-1}$). As one would expect, the particle production varied with the initial standing stock but the particle growth rates were relatively uniform, (Table 1). It was not possible to demonstrate a relationship between

Table 1 Production and standing stock of phytoplankton. The standing stock represents only those particles that grew and is not the same as the total amount of particulate material in suspension. The measurements were of particle volume; to convert to wet weight a density of 1.0 g mℓ was assumed; to convert to carbon the ratios of Mullin et al (1966) were used.

Modal Size µm	Standing Stock mg ℓ^{-1} (Wet weight)	µg C ℓ^{-1}	Time to Double (T_D) hr	Production µg C ℓ^{-1} day
64	2.07	58	16	29
64	1.00	28	15	16
16	1.87	153	3.4	378
16	1.97	161	2.8	472
16	1.45	118	5.6	174
16	1.45	118	4.5	220
51	7.56	272	8.5	267
51	1.70	61	5.4	93
4.5	0.38	78	7.6	85
6.5	0.61	97	8.9	91
25	0.31	18	4.9	30
6.4	0.72	115	9	106
25	0.56	32	6.1	44
64	0.43	12	6.2	16
25	0.63	37	4.7	65
8	0.59	79	3.1	126
23	1.94	124	6.5	159
25	1.35	79	10.5	62
64	0.32	9	5.2	14
23	0.83	53	10.5	42
8	0.36	47	8.7	45

Fig. 4 Growth rate and cell size. The line represents the relationship suggested by Fenchel (1974).



growth rate and size over the small size range examined but the measured values fell close to the rates predicted for this size range by Fenchel (1974), (Fig. 4).

It is possible to make estimates of primary production if the particle increase in the incubated samples is caused by phytoplankton, because both the standing stock and the growth rate are known. As the size at which the growth occurred is also known, an estimate of production in terms of carbon can be made by using the carbon/volume relationship described by Mullin et al. (1966). Primary production estimated in this way varied from 14 μg C l^{-1} day^{-1} to 472 μg C l^{-1} day $^{-1}$.

The average production per m^2 for the whole of the area sampled can also be estimated by considering averages of biomass and growth rates. To do this it is necessary to calculate the **arithmetic** mean concentrations for the size range 16 - 102 μm. As sample concentrations are distributed approximately log. normally (Gordon, 1977; Sheldon, unpublished data), **logarithmic** means were used in Fig. 2 to represent the most probable configuration for a series of samples. However, in order to measure the abundance of material (to estimate production) the **arithmetic** mean must be used (for example, see Ahrens 1954). Calculated on this basis the average standing stock of phytoplanton to a depth of 20m was 60 g m^{-2} (wet weight) or 2.4 g C m^{-2} (carbon: volume ratio from Mullin **et al.**, 1967). The average growth rate for phytoplankton larger than 16 μm was 0.096hr^{-1} (T_D = 7.24hr) (Table1) and this indicates a production of 200 g m^{-2} day^{-1} (wet weight) or 8 g C m^{-2} day^{-1}. These estimates agree well with previously published data (see Sheldon **et al**, 1977 and refs. quoted therein), and this would seem to indicate that particle counting methods can be used to provide reasonable estimates of both the standing stock and production of phytoplankton.

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