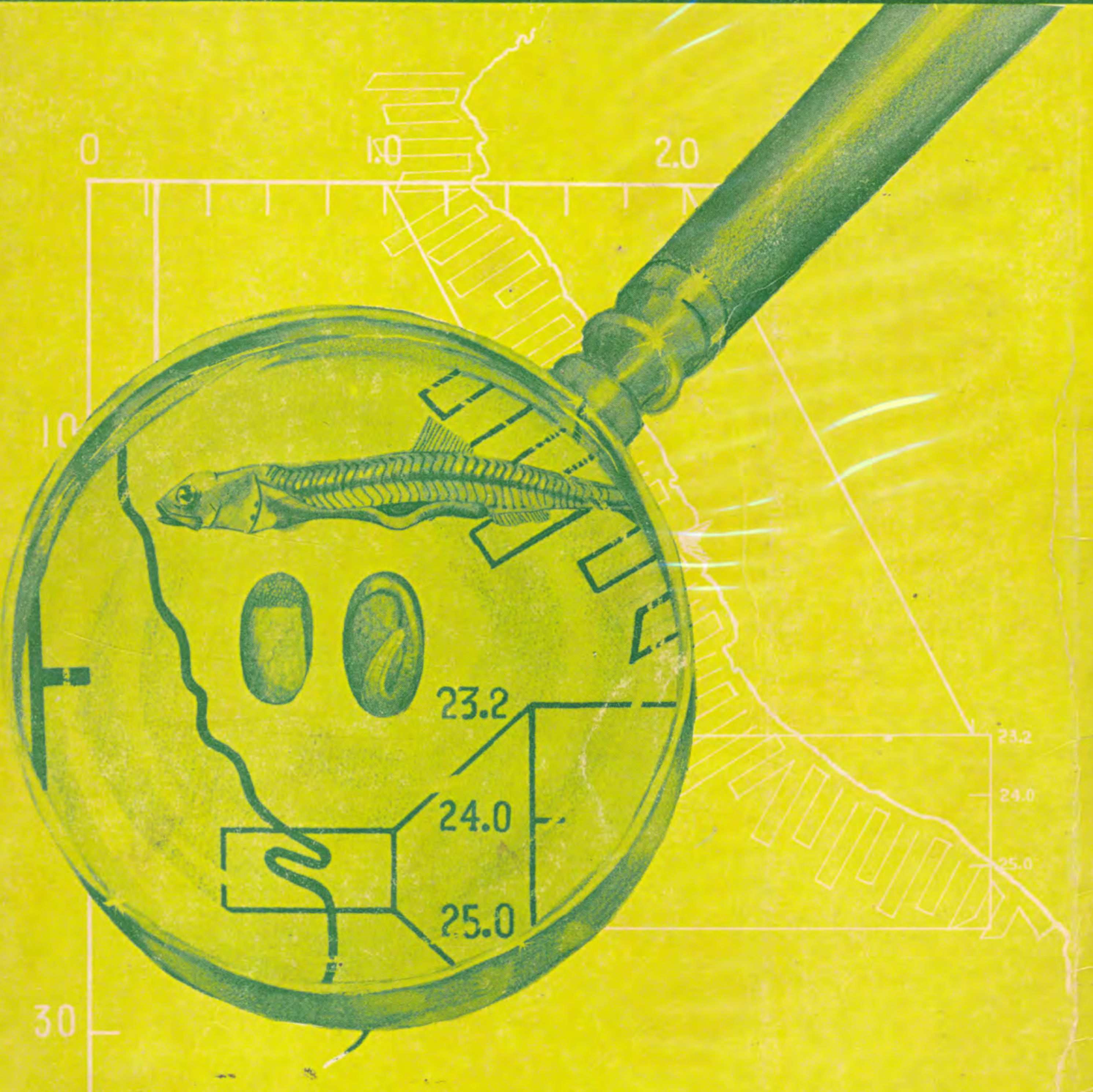
INSTITUTO DEL MAR DEL PERU

Boletín

ISSN - Q 378 - 7699
VOLUMEN EXTRAORDINARIO



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

CALLAO 1981 PERU

SIZE-COMPOSITIONS OF NET PLANKTON SAMPLES TAKEN OFF NORTHERN PERU

L.M. Dickie
Marine Ecology Laboratory
Bedford Institute of Oceanography
Dartmouth, Nova Scotia

ABSTRACT

Statistical analyses are undertaken of plankton samples collected by a 1/2-metre vertical ring-net, an oblique 1-metre bongo net and a neuston sampler in a 10 x 15 nautical mile grid and a cross-shelf transect. Diurnal differences contributed importantly to the total variance, which also contained a micro-geographic component. The main variances, however, appeared in the set of 1-mile long neuston samples, and were not explained by diurnal variations or micro-geographic differences on the 5 nautical mile scale. It is concluded that grid surveys on the scale employed should be suitable for sampling for growth and mortality parameters of fish-larvae if these are spawned in patches on the order of 5 to 10 nautical miles diameter.

RESUMEN

Se ha analizado estadísticamente muestras de plancton tomadas verticalmente con una red de 1/2 metro, oblícuamente con una red bongo de 1 metro y con un muestreador de neuston en un cuadriculado de 10 x 15 millas naúticas en una línea de crucero a través de la plataforma. Las diferencias diurnas contribuyeron notablemente a la variancia total, en la cual también participa un componente micro-geográfico. Las muestras de neuston a lo largo de 1 milla fueron sin embargo las principales contribuyentes de las variancias no atribuibles a variaciones diurnas o diferencias micro-geográficas en la escala de 5 millas náuticas. Se concluye que la escala empleada para esta exploración en cuadrícula es adecuada para muestreos de parámetros de crecimiento y mortalidad de ictio-larvas siempre que ellas procedan de desoves en manchas con diámetro entre 5 y 10 millas naúticas.

During legs 2 and 3 of the ICANE cruise (DOE, 1978), a rectangular grid of 12 oceanographic stations (3 along-shore lines of 4 stations each) was established off Chimbote, parallel to the coast between 9°06.1' and 9°23.5' S. Lat. The outermost line was at about the 100-metre depth contour. Lines and stations on lines were spaced 5 nautical miles apart. A series of observations was made on most stations, including a vertical haul of a 40μm mesh 1/2-metre ring-net, a vertical haul of paired 1-metre bongo nets (243μm mesh), and an oblique haul of paired bongo nets; all three types of hauls were made from a depth of 40 metres. The grid was run 3 times; once on Nov. 13-14 (Stations 183-195) and twice between Nov. 16-19 (Stations 205-215 and 221-232). Following this, on Nov. 22 and 23, a high-speed neuston sampler (Sameoto and Jaroszynski, 1969) was operated along a transect perpendicular to the coast from the outer edge of the grid to about 79°30'W Long., near the edge of the continental shelf.

The grid and transect were established in the expectation of intesive sampling of ichthyoplankton. The aim was to sample on a time and space scale which would be within that necessary to observe growth, mortality and drift of anchoveta eggs and larvae. Unfortunately, the cruise dates were so late that fish eggs and larvae were very dispersed and insufficient numbers were taken to provide estimates of population parameters. However, zooplankton was common and some assessment of the value of the survey technique can be made from an analysis of zooplankton data in the samples retained by the Canadians. These data consist of the 33 40μm vertical tows made at all of the grid stations, single oblique bongo hauls on 4 grid stations and time-replicated hauls taken on 5 others, and the series of 42 neuston hauls.

METHODS

The preserved 40μm vertical hauls were fractioned into size-classes by passing them throough a graded series of 8 screens ranging in size from 40 to 1050μm. After gentle washing through the screens, the organisms from each size fraction were filtered under vacuum for a standard time and weighed. The percentage weight distribution among the fractions on each line of the grid is shown in Fig. 1A where the particle diameter for the fraction is calculated as the mean between the mesh size of the screen on which it was retained and the next largest mesh size. A weighted mean particle size for each station was calculated using this mean equivalent spherical particle diameter and the weight of each fraction.

The preserved samples from oblique bongo hauls and the neuston samples were passed through a HIAC electronic counter with an E-9000 sensor head which had been standardized against known spherical particle diameters. The counter provided an estimate of number of particles per sample, classed into 11 size-classes, between about 300 and 4,500μm. The relative numerical size-frequency distributions of the bongo samples are shown in Fig. 1B and of the neuston samples in Fig. 3.

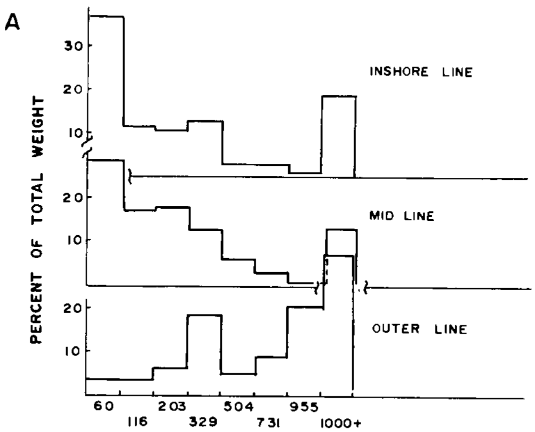
The variances of the size compositions of the plankton samples, in terms of either weights or numbers were analyzed using the Information Statistic approximation to the X^2 distribution. (Kullback, 1968). In this analysis the data are classed in various two-way tables in which the rows are size-classes and columns are frequencies resulting from various groupings of the hauls. Tabled frequencies and marginal totals are replaced by the equivalent $\chi \ln \chi$, which when summed appropriately are readily subjected to an analysis of variance among the groupings. (Dickie & Paloheimo, 1965).

RESULTS

Table 1 provides a summary of the analysis of variance of the size-compositions of the 40μm vertical samples. It shows that the degree of variation (X^2/d.f.) was approximately the same within the day samples as within the night samples. I, therefore, pooled the day and night within-sample variance to provide a better estimate of the within-diurnal period variation. This term is used in the table as a "sampling-error" term to judge the difference between day and night catches. The difference between day and night was 4.8 times the "error" term, indicating that there was a statistically significant difference between the day and night samples of the size-compositions of the small zooplankton which are taken by this net.

Because of the large difference between the day and night catches, it was necessary to study the importance of the remaining survey parameters by performing the calculations within the day and night periods separately. The second part of the table compares the average size-compositions obtained on each of the three successive grid runs

Figure 1A Relative distribution by weight of size-classes of plankton taken by the 40μm ring-net in vertical hauls on the ichthyoplankton grid.



B Relative frequency distribution of plankton taken by oblique hauls of 1-metre bongo nets (243μm mesh net) on the ichthyoplankton grid.

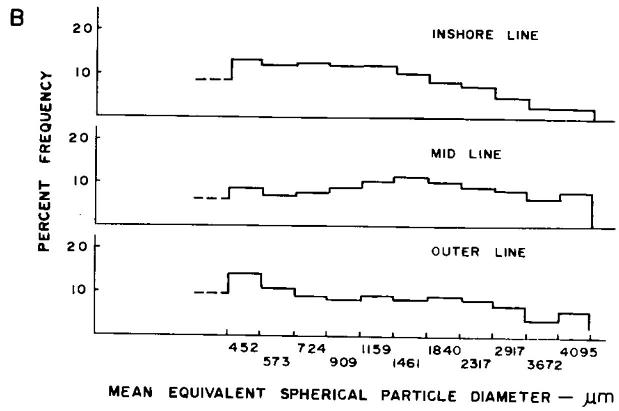


TABLE 1 Analyses of variance of the size-composition of plankton taken by 40μm 1/2-metre ring nets in vertical hauls on the ichthyoplankton grid. The X^2 is calculated using the Information Statistic approximation (see text).

Variance Term		d.f.	X^2	X^2/d.f.	RATIO Between: Within
Total		224	3,373.6	15.1	
Within Days		84	1,149.8	13.7	
Within Nights		133	1,770.6	13.3	
Within Day & Night		217	2,920.4	13.5	
Between Day & Night		7	453.2	64.7	4.8
Within Day and Night	Between Grid Runs	28	356.4	12.7	0.9
	Within Grid Runs	189	2,564.0	13.6	
Within Day and Night	Between Lines	28	1,817.8	64.9	11.2
	Within Lines	189	1,102.6	5.8	

within day and night. The "error" term in this case was derived by subtracting both the "between runs" and "between day and night" terms from the total. The ratio of 0.9 suggests that the variations between the grid runs added nothing to the variations explained by the day-night differences.

A comparable analysis of the size-compositions from the lines of the grid is shown in the last part of Table 1. The variation between the lines within night and day, was over 11 times its error term, indicating an important inshore-offshore component in the total variation.

This size-composition analysis is illustrated in Fig. 1A and 2A and B, which permit a more detailed interpretation of the statistical results. Fig 1A shows that the major difference among the three lines of stations accurs among the smallest organisms, between 40 and 300μm. The highest concentration of smallest particles occurred inshore. The mean sizes, plotted in Fig. 2A illustrate that this micro-geographic difference was maintained for both day and night. Comparison with Fig. 2B shows that the strong day-night difference was primarily a result of changes in the relative abundance of the larger organisms (600 to 1000μm), which were present in much higher concentrations offshore at night.

A parallel analysis for the oblique bongo hauls taken on the grid stations is given in Table 2 and Fig. 1B. As is indicated by the figure, the sizes of organisms sampled overlap with the ring-net sampler but the size-classification is extended into a much larger range of sizes.

In comparing the two parts of Fig. 1 it should be recongnized that Fig. 1A is in terms of weights whereas Fig. 1B is in numbers. If the biomass of individual organisms increases in proportion to the cube of their diameter then in a situation where the frequency distribution in numbers is flat, the relative weight per class would show a sharp increase with size. That is, the apparently relatively large amounts of the largest size classes in the small mesh net catches of Fig. 1A represent a numbers distribution which is roughly comparable to that obtained by the bongo nets (Fig. 1B) or the neuston sampler (Fig. 3) over the same size range. By the same reasoning, Fig. 1A suggests that the numbers of the smaller oganisms, below 400μm, is very large indeed, compared with the numbers in the size ranges sampled by the bongo nets or neuston sampler. Since this smaller size range must include organisms which form the first food of fish larvae (Ware et al., 1979 and this volume), it is a class of particular interest to this study.

The analysis of the bongo net samples in Table 2 is based on relatively few samples but some examination of effects is possible in parallel with Table 1. The most striking difference between the two tables is the generally lower X^2/d.f. values for the bongo net sampling, indicating a greater uniformity among them. The table shows greater heterogeneity of sizes among the samples taken at night than during the day, however there was no significant difference between day and night. A parallel result was obtained for all other classifications of the oblique bongo data. That is, variation within particular stations or within successive runs of the grid or within three replicated stations which were on different lines of the grid, all appeared to be low. But even so, this "within" group variation was higher than the variation between means of the

Figure 2 Day-night differences in the plankton taken by the 40μm ring-net on the 3 lines of the survey grid. A. Average sizes B. Average density.

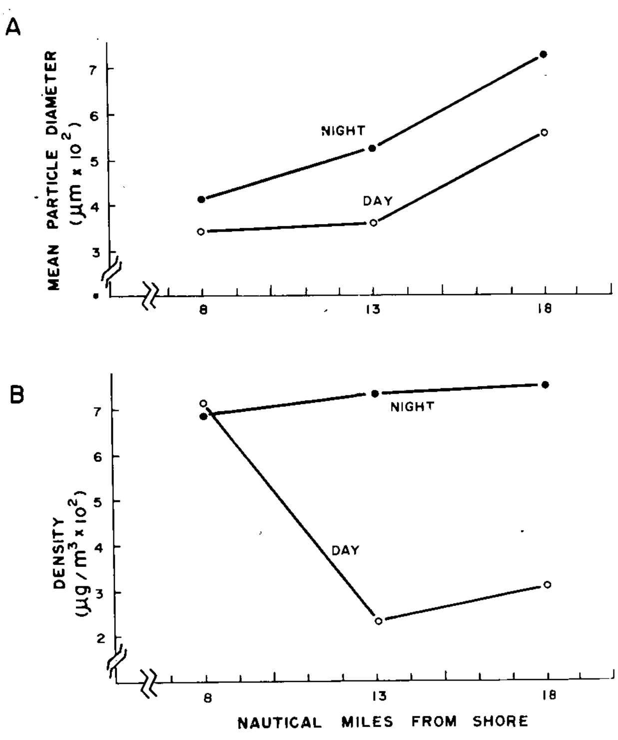


TABLE 2 Analysis of variance of size-compositions of zooplankton samples taken in oblique bongo hauls on the ichthyoplankton grid.

Variance Term	d.f.	x^2	x^2/d.f.	RATIO Between: Within
Total	120	250.4	2.1	
Within Days	80	88.0	1.1	
Within Nights	30	154.0	5.1	
Between Days & Nights	10	8.4	0.8	1.0
Between Grid stn.	70	21.4	0.3	<1.0
Within Grid Stn.	50	229.4	~4.5	
Between Grid Runs	20	13.0	0.65	<1.0
Within Grid Runs	100	237.4	2.37	
Total for Days	80	88.0	1.10	
Between Day Stns.	40	59.8	1.5	<2.0
Within Day Stns.	40	31.8	0.8	
Total Over replicated Stns. on lines	50	87.2	1.74	
Between lines	20	32.4	1.62	<1.0
Within lines	30	54.8	1.8	

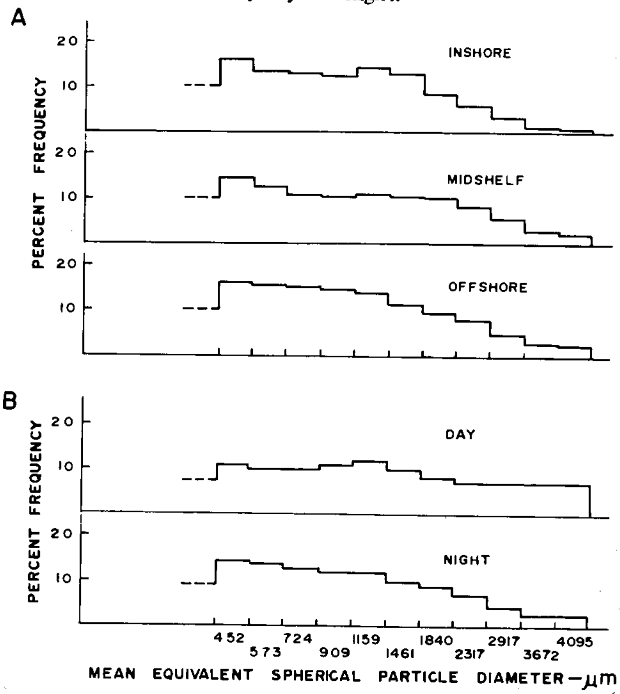
various groupings. The micro-geographic or between grid-lines aspect of the comparison is illustrated in Fig. 1B. From the figure it is clear that the size-compositions for the lines are not exactly alike, but the differences among them are too small to represent a significant pattern change over the space and time of the grid. It is possible that more sampling, especially at night, might provide a different evaluation of the significance of the patterns indicated.

Samples taken by the neuston sampler are analyzed in Table 3 and Fig. 3. The table shows that, in contrast with the oblique bongo hauls on the grid stations, there was a great deal of heterogeneity displayed in the 42 neuston hauls spread over the width of the continental shelf. However, classification of these data in parallel with the analysis of the other sampling does not account for much of the heterogenety. In the Table (excluding an unreplicated day-time inshore haul from the total) the day-time hauls show a relatively small variance, compared with a large variance among the night-time hauls. A pooled estimate of the within-period variance was used to test the difference between the periods, and it turned out to be nearly 5 times larger than its "error"; whereas, grouping of the available samples into "inshore", mid-shelf and offshore stations (within day -since there were no inshore night stations) failed to account for a significant fraction of the between-station variance. The figure indicates that the geographic classification made very little difference in the pattern of the size distributions. The significant day-night difference is apparently assignable to the relatively higher night-time density of organisms in the 400 to 1500µm size-range, which was two times their day-time density, compared with a 20% increase in night-time density of the larger particles.

TABLE 3 Analysis of variance of size-compositions taken in the Neuston Sampler

Variance Term	d.f.	χ^2	χ^2/d.f.	RATIO Between: Within
Total	360	2,782,114.6	7,728.1	
Total (Excluding Inshore Day)	340	2,781,470.6	8,180.8	
Within Day	30	21,676.6	722.6	
Within Night	300	2,401,754.4	8,005.8	
Within Day & Night	330	2,423,431.0	7,343.7	
Between Day & Night	10	358,039.6	35,803.9	4.9
Between Inshore, Midshelf & Offshore, - Within Day	20	29,163.0	1,458.2	<1.0
Within areas & Times	340	2,752,951.6	8,096.9	

Figure 3 Average size–compositions of plankton captured by the neuston sampler. A. By position on the shelf. B. By day and night.



DISCUSSION

The relatively large number of plankton samples, each of which can be sub-divided into a number of size categories containing significant numbers of organisms, seems to have been well suited to analysis by the information statistic. In most cases, the numerical analysis is readily interpreted in the graphs, but gives a more precise appreciation of some of the principal sources of variation. It is unfortunate that our sampling period made it impossible to directly test application of the technique to fish larvae, which would probably fall within a much more restricted size range. However, the analysis undertaken with the zooplankton suggests that significant components of heterogeneity of water masses were detected by the survey, while various space and time groupings of the data show internal consistency. In particular, the variance within grid stations and within "replicate" samplings by the bongo nets was relatively low, and the between-station and between-run comparisons comprised only a small fraction of the total variance. This suggests that the grid size used in the experiment may be generally suitable for sampling for these biological qualities of water-mass types over periods of the order of a week. That is, the grid design and scales might well be used to follow growth and mortality rates of fish larvae spawned in patches of the order of 1 to 10 nautical miles diameter.

The outstanding result of this trial sampling was the relative uniformity of size-compositions for various classifications of the samples taken on the grid, compared with the very large variances within classes in the case of the neuston sampler spread across the shelf. It is significant, however, that a division of the neuston samples into geographic zones did not account for a singificant fraction of the variance. It is reasonable to conclude, that the major source of variation in the zooplankton community was acting on a considerably smaller than shelf-wide spatial scale. Aspects of micro-geographic variation only were reflected by the grid survey.

Part of the measured variability must, of course, be associated with the sampling instruments and techniques themselves. The grid samples with ring and bongo nets both represent integrated water-column data whereas the neuston samples are confined to the top 20–25 centimeters but taken over a line about 1 nautical mile long. In order of amount of water "strained" the 1/2 metre ring net sample is smallest (ca. $8m^3$), the bongo intermediate (ca $125m^3$) and the neuston largest (ca $150m^3$). With the relatively small difference in volume sampled by the latter two nets, it is evident that it must be the extended line pattern of the neuston sampler encountering a larger variety of the types of patches in which the zooplankton occur, which accounts for the higher variances.

Sampling within the grid was characterized by low variances for both of the water-column samplers. Between these two samplers, the lower variances in the oblique bongo hauls is not an unusual experience and suggests that these larger nets are smoothing out some variation in horizontal distributions that is influencing catches by the vertical sampler. It may, however, also simply reflect the few hauls of the bongo nets which were available for this analysis, so that the conclusion needs to be checked.

The results of sampling by the 1/2-metre net suggest that on the scale of the grid there were detectable geographic components of the variation which persisted for the period of a week and which showed up despite the rather large general diurnal changes in composition and density of the populations.

From the point of view of the zooplankton population, the results of this comparison among gears, times and areas of catching indicates that diurnal differences, probably related to vertical migrations, are a major feature of the distributions. While our analyses were not designed to measure vertical migrations, the markedly higher night-time densities of 400 to 1000μm organisms in the 40μm net hauls on the outer grid stations is strongly suggestive of vertical migration. By contrast, the smallest plankton in these nets (<100μm) showed little diurnal change in density but a strong micro-geographical component, probably related to the very high inshore phytoplankton concentrations. If these catches do significantly reflect the concentration of organisms which are chosen as food by the early larvae, it is of interest that their apparent diurnal stability is paralleled by the finding of Sameoto (this volume) that the larvae of the anchovy and sardine showed no significant signs of diurnal vertical migration.

ACKNOWLEDGEMENTS

My thanks to H. Santander, I. Tsukayama and D.M. Ware for comments on the sample design and the analysis; and to H. Santander, Olinda Sandoval de Castillo and T.C. Lambert for field assistance. T.C. Lambert sorted the ring-net samples and D. Sloan operated the HIAC counter.

REFERENCES

DICKIE, L. and J. PALOHEIMO. 1965. Heterogeneity among samples of the length and age compositions of commercial groundfish landings. International Commission for the Northwest Atlantic Fisheries, Bulletin N° 2. pp. 48-52.

DOE, L. 1978. Project ICANE: A progress and data report on a Canada-Peru study of the Peruvian anchovy and its eCosystem. Bedford Institute of Oceanography, Report Series BI-R-78-6. 211 pp. mimeo.

KULLBACK, S. 1968. Information theory and statistics. Dover, New York.

SAMEOTO, D. and L. JAROSZYNSKI. 1969. Otter surface sampler: a new neuston net. **J. Fish. Res. Bd. Canada.** 25:2240-2244.

——— 1981. Horizontal and vertical distributions of ichthyoplankton off the coast of Peru. **Bol. Inst. Mar Perú Callao.** (This volume).

WARE, D., B. de MENDIOLA and D. NEWHOUSE. 1979. Behaviour of firstfeeding Peruvian anchoveta larvae. Cons. International Explor. Mer. Sysposium on "Early Life History of Fish."