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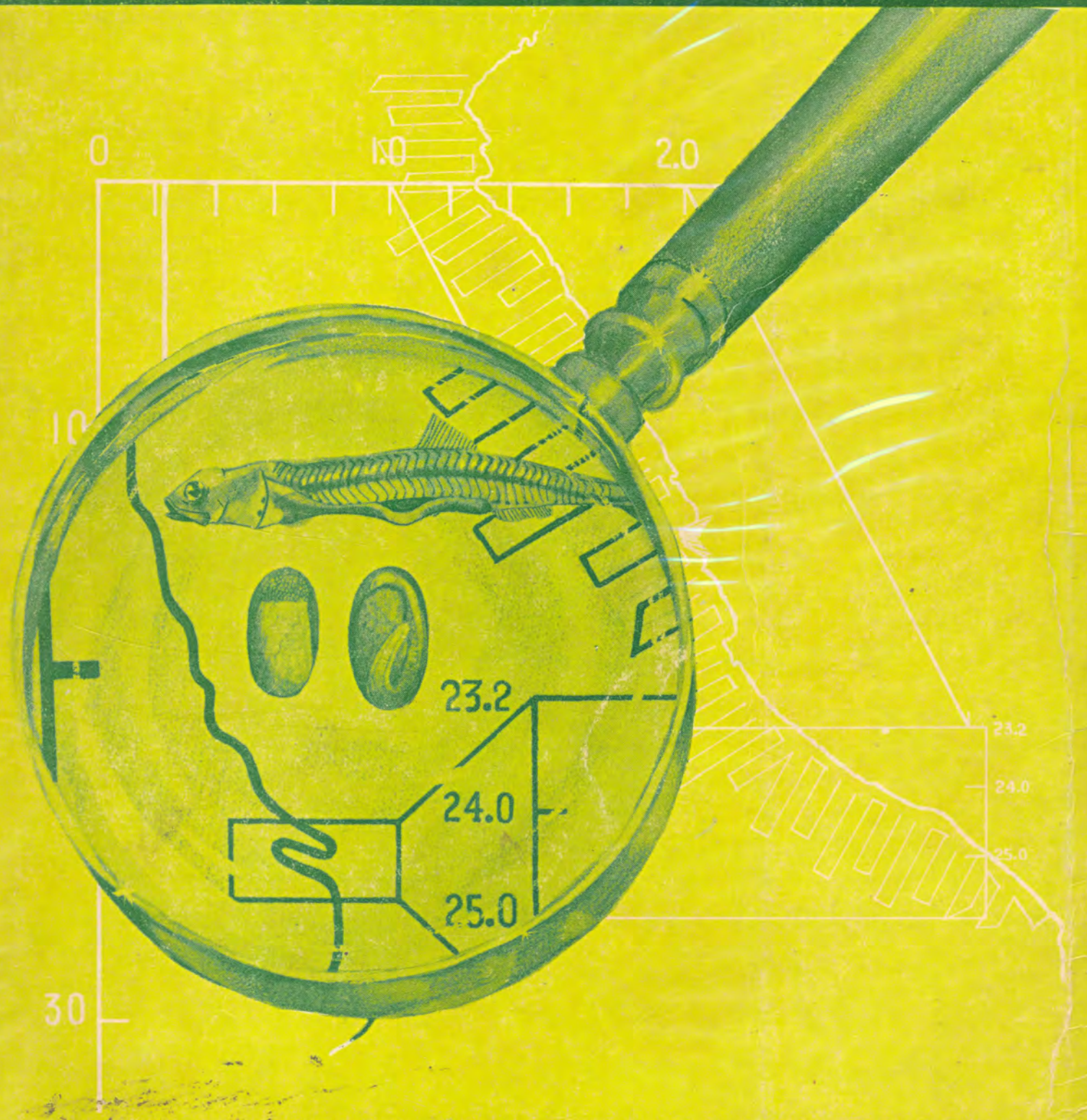

INVESTIGACION COOPERATIVA DE LA ANCHOVETA Y SU ECOSISTEMA - ICANE - ENTRE PERU Y CANADA CALLAO 1981 PERU

DISTRIBUTION AND ABUNDANCE OF SIX SPECIES OF FISH LARVAE IN PERUVIAN WATERS AND THEIR RELATIONSHIP WITH THE PHYSICAL AND BIOLOGICAL ENVIRONMENT

by

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ABSTRACT

Horizontal samples taken with the BIONESS at various depths on thirteen stations showed nine species of fish larvae present with the most common of these being, in order of most abundance, **Leuroglossus stilbius, Sardinops sagax, Diogenichthys laternatus, Merluccius gayi** and **Engraulis ringens.** All the species except **S. sagax** and **E. ringens** showed a diurnal migration to the upper 30 m of water at night. The two latter species were present in the top 30 m at all times. The size of the larvae of all species did not vary with time, depth or sample location. The numbers of larvae increased with zooplankton density up to 1000 copepods m^{-3} above which no further increase in larvae occurred. A significant linear relationship was found between the total number of larvae m^{-2} and biomass of zooplankton m^{-2}, but not between individual species of larvae and zooplankton biomass. Significant correlations were found between **E. ringens** and 7 species of copepods found in the upper 50 m of water.

Polymodal analysis showed that the larval populations of all species with the possible exception of **S. sagax** were made up of more than one subpopulation. From this analysis the length of the spawning season for **E. ringens** was estimated at 54 to 68 days.

A significant correlation was found between the numbers of E. **ringens** larvae m^{-2} and the maximum concentration of chlorophyll **a**, as measured with Batfish, in the area of the BIONESS stations. This showed the largest numbers of larvae in areas of the highest chlorophyll concentrations.

RESUMEN

Las muestras tomadas con el BIONESS a varias profundidades en trece estaciones mostraron la presencia de larvas de nueve especies de peces, las más comunes, y en orden de abundancia, fueron **Leuroglossus stilbius, Sardinops sagax, Diogenichthys laternatus, Merluccius gayi,** y **Engraulis ringens.** Todas las especies excepto **S. sagax** y **E. ringens** migraban de noche a la capa de los 30 m bajo la superficie, capa en la que estas dos especies permanecieron todo el tiempo. El tamaño de las larvas de cualquier especie fue invariable respecto al tiempo, profundidad o localidad. La cantidad de larvas aumentó junto con la densidad del zooplancton hasta 1000 copépodos por m^3 más allá de la cual no se notó aumento de larvas. Se encontró una relación linear significativa entre el número total de larvas por m^2 y la biomasa del zooplancton por m^2, pero no entre especies individuales y biomasa de zooplancton. Se encontró correlaciones significativas entre **E. ringens** y 7 especies de copépodos en la capa superior de 50 m. de profundidad.

Un análisis polimodal indicó que las poblaciones de todas las especies con la posible excepción de **S. sagax** estuvieron compuestas por más de una sub-población. Del mismo análisis se desprende que el período de desove de **E. ringens** puede estimarse entre 54 y 68 días.

Se encontró una correlación positiva entre el número de larvas de E. **ringens** por m^2 y la concentración máxima de clorofila **a**, medida con el Batfish, en el área de las estaciones del BIONESS: las mayores cantidades de larvas ocurrieron en las áreas de mayores concentraciones de clorofila.

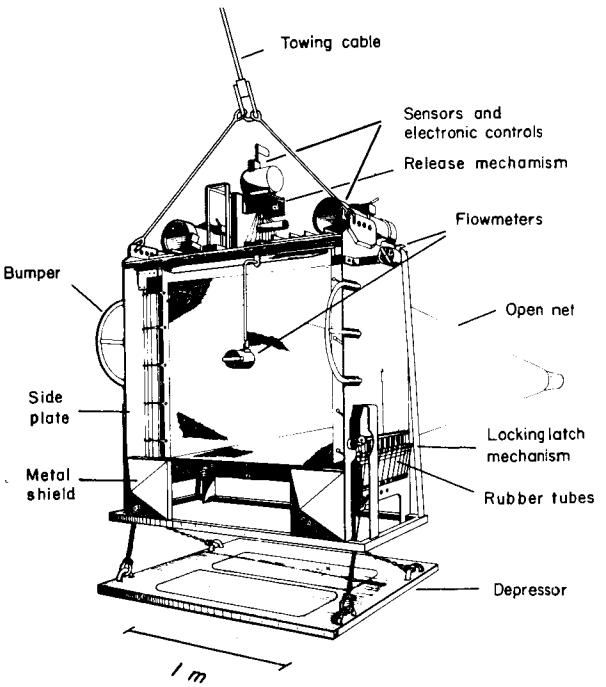
INTRODUCTION

The primary purpose of this study was to determine the patterns of distribution of larvae of **Engraulis ringens** and other fish species associated with them on the continental shelf adjacent to Chimbote. Such data can provide insight into the relationships between the larvae and features of their biological and physical environment. The sampling was therefore designed to yield data on the horizontal and diel vertical distribution patterns of each of the fish larvae species and of the zooplankton. Zooplankton catches were analysed for species numbers and biomass. We also attempted to identify zooplankton predators of fish larvae.

METHODS

The samples of fish larvae and zooplankton were collected with a multiple net sampler (Fig. 1), the BIONESS (Sameoto et **al.**, 1980). This sampler is able to collect 10 independent samples per tow at 10 different depths ranging from the surface to 500 m. At the same time as the biological samples are taken, **in situ** data are collected by the sampler on temperature, volume of water filtered, depth and speed of the net. The mouth area of each net is 1

Fig. 1 The multiple net sampler 'BIONESS'.

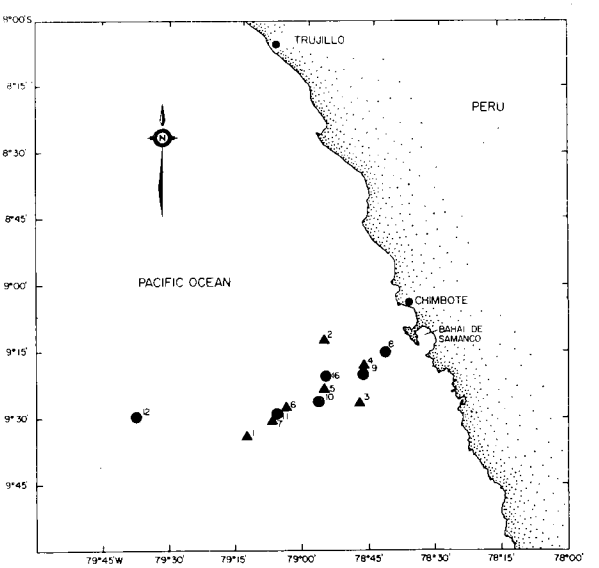


m^2 and the mouth to filtering area ratio is 1:10. The sampler and the nets are painted and dyed a dark blue to reduce their visibility. The mesh size of the nets was 243 μm. The sampler was towed at a speed of 3 knots with a mouth angle from the vertical of 10°. Depth of each sample was controlled to within ± 0.2m.

The volume of water filtered in each of the samples ranged from 200 to 1500 m^3 depending on the length of tow. The sample was preserved in a 5% buffred formalin and sea water solution. The entire sample which was sometimes rather large, was examined for fish larvae and macrozooplankton, such as euphausiids and **Sagitta**, and these removed. The remaining sample was split a number of times, and the species identified and counted in one of the split portions. The identification and counts of animals in the split portions were done by MacLaren Marex Inc. in Dartmouth, Nova Scotia.

Because of other programs needing the ship at different locations it was not possible to establish stations in a continous time or space series. However, two objectives were emphasized. Samples were taken at times that would provide evidence of possible diurnal migrations of the zooplankton and fish larvae. The 13 stations were established to reflect differences in species compositions, distribution and abundance from inshore to the edge of the shelf (Fig. 2).

Fig. 2 Position of the BIONESS sampling stations.



Polymodal Analysis

The fish larvae length frequency data were subject to polymodal analysis as described by Taylor (1965). This method provides estimates of the number of normal curves present in each length frequency distribution. Under the assumption that differences in length represent primarily differences in larval ages, the number of normal curves or modes provides an estimate of the number of spawning pulses that occurred among the different collections and species of ichthyoplankton.

The fish larvae lengths used were the total lengths, from the end of the nose to the tip of the tail.

Abundance Calculations

The numbers of fish larvae and zooplankton per

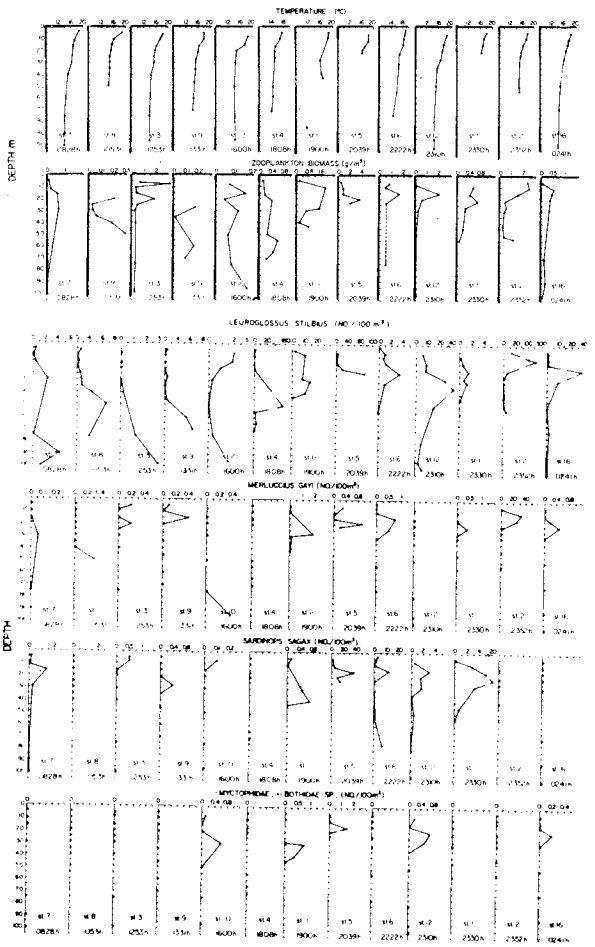
cubic meter of water were calculated from the successive stratified samples of each tow by making the assumption that the horizontal distributions were more or less homogeneous within the distances required to complete a vertical profile. The number of animals under square metre of surface was also calculated by integrating the observed vertical profile of number of animals m^{-3} from surface to the depth of the deepest sample on each station. These values m^{-2} are not all taken to the same depth, but since the majority of the zooplankton and fish larvae occurred in the upper 50 m and the vertical profiles generally exceeded that depth, values given may be regarded as estimates of the total.

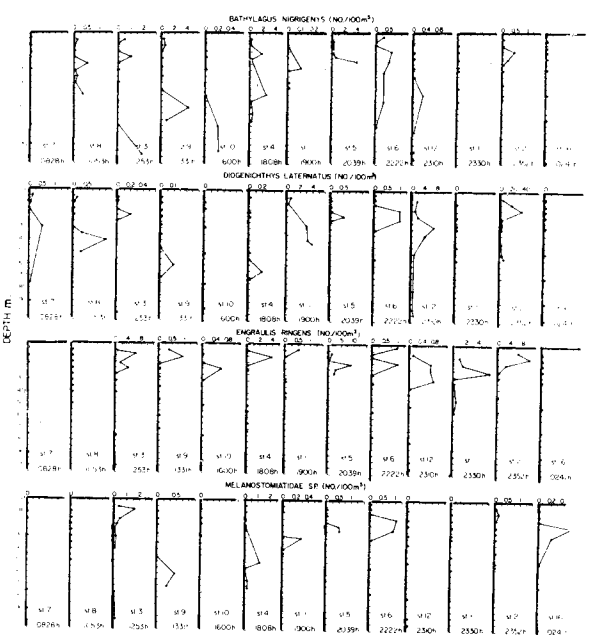
RESULTS

Ichtyoplankton Vertical Migration

The majority of fish larvae were taken at night on stations 1, 2, 5, 6, 11, 12, and 16. Of the two species of principal interest, **Sardinops sagax** and **Engraulis ringens**, only the former showed higher

Fig. 3 Vertical profiles of fish larvae on each of the sampling stations, the times of the stations, the temperature profile and profile of zooplankton biomass on each station. Each point represents the mean depth of a sample.





night catches, but neither showed signs of a significant day night difference in vertical distribution, maintaining the same depth range over all the sampling stations and times (Fig. 3 and 4). Both species were confined to the upper 30 m with the modes at 20 m. The only difference between the distributions of these species was an indication in the data that the numbers of **E. ringens** ramained high between 5 and 10 m while the numbers of **S. Sagax** larvae decreased above 20 m. **Merluccius gayi** larvae had a similar distribution to **S. sagax** and **E. ringens** with a majority of the larvae found in the upper 30 m during both night and day although some were collected at a depth of 90 m during the day. The four other common fish larvae, **Leuroglossus stilbius, Bathylagus nigrenys, Diogenichthys laternatus** and **Melanostomiatidae sp.**, all showed varying degrees of vertical migration with the bulk of the population found below 30 m during the day and above 30 m during the night (Fig. 4).

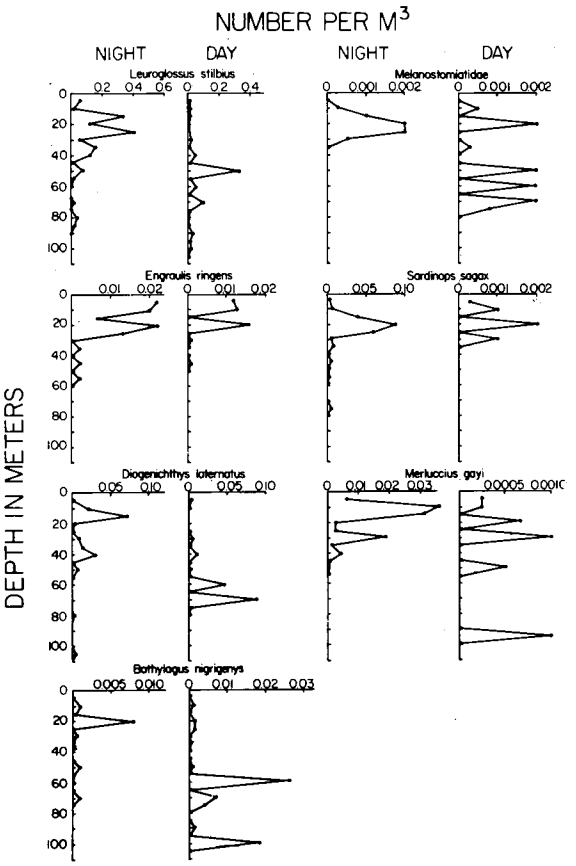
There was no obvious relationship between water temperature and vertical distribution of any of the fish larvae (Fig. 3), except at the thermocline where there appeared to be a reduction in larvae abundance.

Day-Night Catch Differences

A series of 't' tests were run on the mean numbers m^{-2} (Table 1) for the day and night samples. The night samples were those taken from 1900 h and later. The only larvae that showed a significant higher number at night at $P < 0.10$ were **E. ringens** and **S. sagax** ($t = 2.01$; $t = 2.01$ $n = 11$) and these were not significant at $P < 0.05$. The total biomass of copepods was not significantly different between day and night.

These results should be interpreted with caution since the same stations were not sampled during both day and night and therefore these results may reflect stations differences rather than time differences.

Fig. 4 Mean numbers m^{-3} of fish larvae with depth in all tows taken during the day and night (1900 h and later).



Horizontal Distribution and Abundance

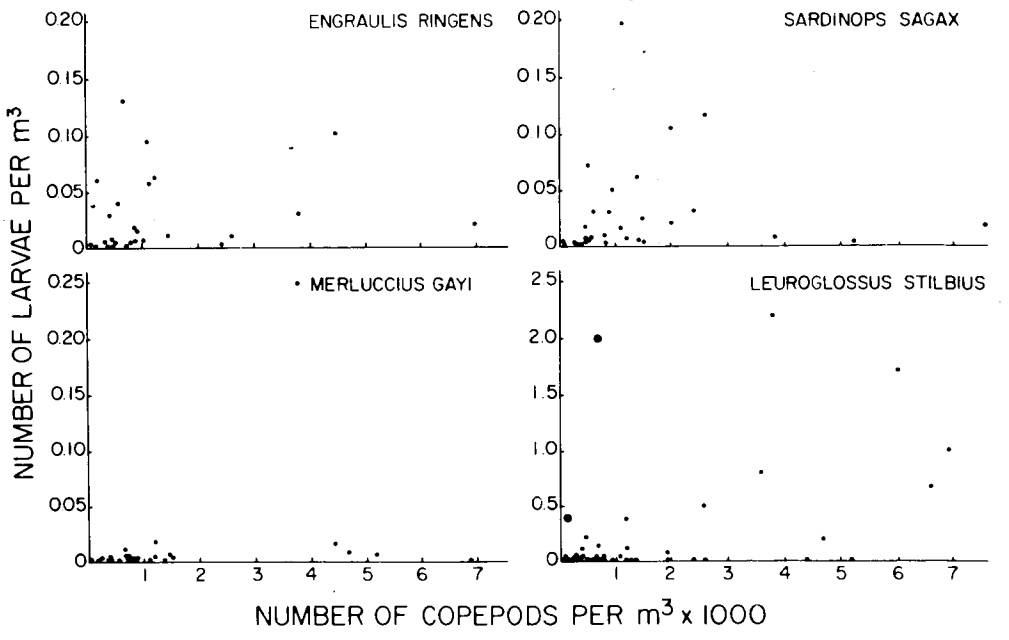
The most abundant fish larvae were **L. stilbius** which dominated both inshore and offshore stations, being especially abundant on stations 2, 4, 12 and 16 (Table 1).

Of the two species of main commercial interest **E. ringens** had highest density on the inner stations 2, 3 and 5, while **S. sagax** had higher densities on stations 1, 6, 11 and 12, stations further offshore than those on which **E. ringens** was most abundant. The stations with the largest number of **M. gayi** were 2, and 11. Station 5 was somewhat an anomaly, for not only did it have the highest zooplankton biomass, it also had the largest densities of **S. Sagax** and **E. ringens.** The mean number m^{-2} of each of the larval species caught over all of the stations was calculated (Table 1). This table showed **S. sagax** occurred three times as often as **E. ringens.**

Table 1. Number of fish larvae and zooplankton per m^2 on the different stations plus mean and standard deviation for all stations combined. Times of the stations are given.

Station	7	8	3	9	10	4	11	5	6	12	1	2	16	Mean No.
Hour	0828	1053	1253	1331	1600	1808	1900	2039	2222	2310	2330	2352	0241	± S.D.
Maximum depth(m)	100	50	98	70	95	71	48	23	75	101	55	54	103	
Bathylagus nigrigenys	0	0.037	0.414	0.706	0.018	0.801	0	0.328	0.157	0.090	0	0.050	0.066	0.21±0.28
Bothidae	0	0	0	0	0.158	0	0.24	0.053	0	0.20	0.02	0	0.01	0.05±0.09
Diogenichthys laternatus	0.07	0.132	0.422	0.014	0	0.024	0.025	0.02	0.12	2.76	0	3.02	0	0.51±1.06
Engraulis ringens	0	0	0.294	0.065	0.150	0.20	0.025	1.38	0.07	0.175	0.57	1.12	0	0.31±0.45
Leuroglossus stilbius	1.145	0.989	1.136	2.020	0.510	43.0	1.53	3.88	0.643	17.8	0.17	18.5	3.153	7.27±12.44
Melanostomiatidae	0	0	0.246	0.076	0	0.312	0.02	0.12	0	0	0	0.02	0.041	0.06±0.10
Merluccius gayi	0.07	0.021	0.008	0.029	0.008	0	2.74	0.113	0.04	0	0.01	3.02	0.033	0.47±1.07
Myctophidae	0	0	0	0	0	0	0	0	0	0.105	0	0	0	
Sardinops sagax	0.08	0	0.02	0.028	0.008	0	0.112	6.82	2.34	0.749	1.80	0.07	0	0.93±1.93
Total No. of larvae	1.37	1.18	2.54	2.94	0.85	44.34	4.67	12.61	3.49	21.91	2.57	25.78	3.30	
Total zooplankton biomass (g wet wt.)	21.5	8.5	40.0	9.6	9.2	20.8	65.6	29.9	45.1	31.0	16.0	57.1	25.4	29.2±18.3
Total No. copepods	41098	12305	175374	26858	13215	155148	211104	48151	58851	60679	37161	88848	29802	

Fig. 5 Number of fish larvae per m^3 related to the number of copepods per m^3. Each point represents one sample, samples not having any fish larvae were omitted. –were deep samples in water with low numbers of zooplankton.



Fish Larvae and Zooplankton Relationship

The four most common species of fish larvae **E. ringens, S. sagax, M. gayi** and **L. stilbius** showed an increase in abundance as the copepod numbers m^{-3} increased up to a density of about 1000 m^{-3}. At densities above this level except for **L. stilbius**, there was no observed increase in larval density (Fig. 5) but rather a levelling out of the larval density with further increases in copepod density.

Table 2. Numbers of copepod nauplii per m^3 collected in each of the samples (top numbers) and number of micro-zooplankton estimated per liter (numbers in brackets) using the equation given by Arthur (1977) for estimating total numbers of nauplii from nets of different mesh size.

Sample tow	1	2	3	4	5	6	7	8	9	10
1		10.5 (390)	2.5 (93)				2.1 (78)	1.3 (48)		0.4 (15)
2	10.2 (379)			1.5 (56)	3.5 (130)	0.4 (15)	1.4 (52)	2.1 (78)	0.6 (22)	2.5 (93)
3		6.8 (252)		42.7 (1586)	14.7 (546)	10.2 (378)	0.2 (7)	1 (37)		
4	2.7 (100)	1 (37)	8.8 (325)	54.9				2.1 (78)	1.2 (44)	2.1 (78)
5				4.7 (174)	9.1 (338)	22.8 (847)	37.2 (1382)			
6							11.6 (430)	2.1 (78)	10.3 (382)	
7				32.9 (1222)						
8	27.1 (1007)	2.0 (74)		6.3 (234)			0.2 (7)	0.7 (26)	0.4 (15)	
9	2.7 (100)	1 (37)	0.2 (7)	37.6 (1597)	16.6 (616)	3.2 (118)	71.7 (2664)	8.5 (315)	1.3 (48)	3.1 (115)
10	3.2 (118)	21.3 (791)			1.2 (44)	1.6 (59)	5.5 (204)	13.3 (494)	145.5 (5406)	3.1 (115)
11	0.6 (22)						1.7 (63)			
12	1.6 (59)			0.9 (33)		0.6 (22)				
16	4.6 (170)				15.1 (561)	11.3 (419)	0.3 (11)	0.5 (18)	0.1 (4)	0.08 (3)

The number of micro-zooplankton in each of the samples was estimated from the count of copepod nauplii found. This was done by using the relationship described by **Arthur (1977)** relating the retention of nauplii by different mesh sizes and extrapolating to a 0 μm mesh size. Arthur showed a linear relationship between the mesh size, up to 150 μm, and the $\log_{10}$ of the number of nauplii per liter. If it is assumed that this linear relationship holds to the mesh size of 243 μm used in this study the nauplii counts in each sample may be used to estimate the number of micro-zooplankton in the water. The calculations are given in Table 2. The number of larvae showed no significant correlation with the calculated micro-zooplankton per liter (Fig. 6). This suggests that the size of the larvae caught were too large to feed on the microzooplankton.

The total number of fish larvae m^{-2} showed a linear increase with the biomass of zooplankton (g m^{-2}) (Fig. 7). The regression equation $y = 0.86 + 0.20\ x$, has a coefficient of correlation of 0.45 which is significant at $P = 0.10$ level when one data point (Station 4) is ommited from the regression. This was the station with the highest number of **L. stilbius**.

No significant relationship can be detected between the number of individual species such as **E. ringens** and **S. sagax**, and the total zooplankton biomass m^{-2} (Fig. 7). However, we have calculated correlation coefficients between the density of larvae of each of the six fish species and each of

Fig. 6 Number of fish larvae per m^3 related to the estimated number of microzooplankton per liter. Each point represents one sample that contained fish larvae of the indicated species.

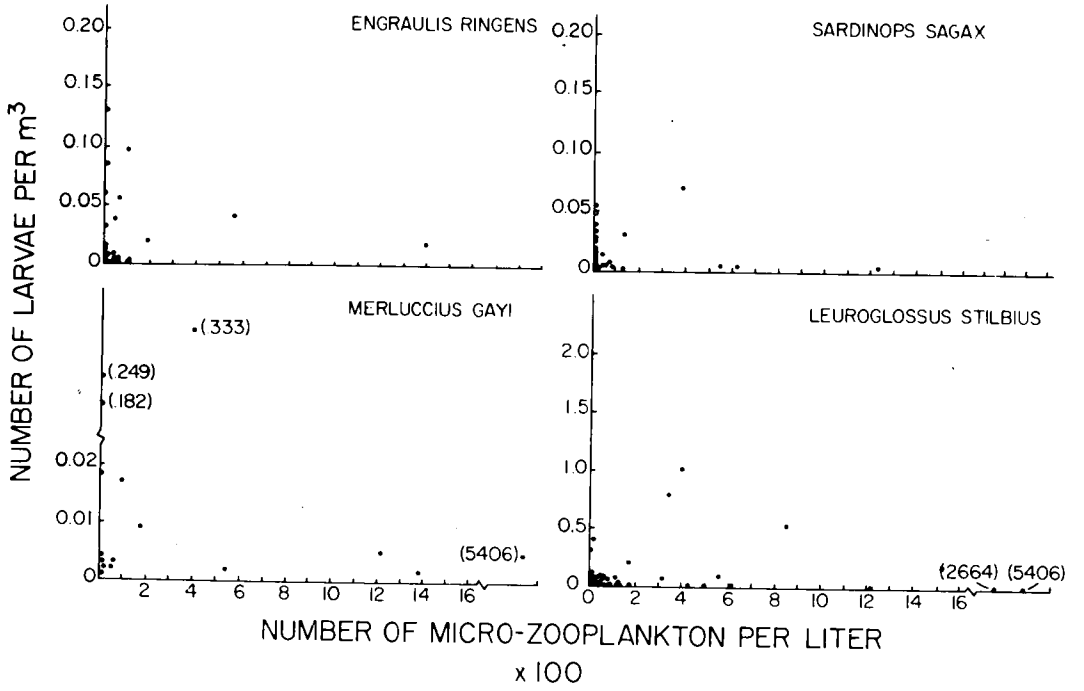
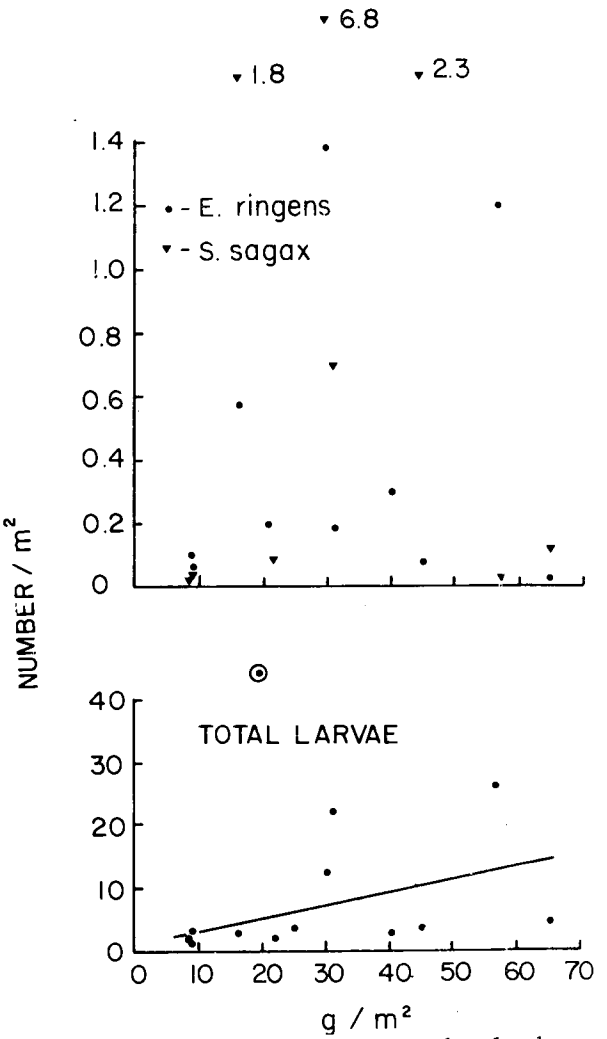


Fig. 7 Relationships between number of **E. ringens, S. sagax** m^{-2} and g of zooplankton m^{-2} (top graph) and total number of fish larvae m^{-2} and g of zooplankton m^{-2} (bottom graph). Value within circle was omitted from the linear regression.



the species of copepods in the samples. In these calculations **Calanus chiliensis**, the most abundant copepod, was significantly correlated with two fish species, **D. laternatus** and **E. ringens.** A further 12 out of the 45 copepod species shared a significant correlation with one or more of the fish species. **E. ringens** was correlated with 7 copepod species which were found to be concentrated in the upper water layers. **L. stilbius**, the most abundant fish larvae, was not significantly correlated with **C. chiliensis** which was found in the upper 50 m, but was correlated with the copepods found in the deeper water (Table 3). **S. sagax** was correlated with only one copepod species, Euchirella bella.

Relationship between Larval Size and the Sample Time and Location

The mean size of each of the four commonest larvae in each sample taken at various depths was plotted against station in relation to distance from the coast and time (Fig. 8) **E. ringens** larvae were largest on the mid-shelf stations 5 and 2, while the largest **M. gayi** larvae were collected on the offshore Station 16. There was no significant change in the larvae size with station location or time of day for each of the other four species listed.

The average sizes of the nine species of larvae did not show any significant change with depth of the sample (Table 4)* during the day or the night.

Table 3. Correlation coefficients (r) between the copepod species and density m^{-3} of the six most abundant fish larvae. Only r values significant at $P \leq 0.05$ are shown. If a copepod species is absent it means there were no significant r values. (d.f. = 110)

Copepod	Fish larvae species B. nigrigenys	D. laternatus	E. ringens	L. stilbius	M. gayi	S. sagax
Aetideus bradyii	0.214		r	0.245		
Calanus chiliensis		0.264	0.305			
Centropages brachiatus			0.323	0.263		
Corycaeus sp.			0.301		0.229	
Eucalanus inermis	0.258			0.286		
Euchirella bella	0.230					0.198
Oncae conifera		0.357	0.241			
Oithona plumifera	0.253	0.265	0.219	0.254		
Paracalanus parvus			0.338			
Pleuromamma gracilis		0.559				
Scolecithrix abyssalis	0.324			0.470		
Scolecithrix bradyii	0.258		0.218			

Values underlined are not significant at $P \leq .01$

Polymodal Frequency Analysis

Polymodal frequency analysis of the six most abundant fish larvae showed that more than one normal curve was necessary to describe the size-composition of all species but **L. stilbius** (Fig. 9). Since there is no **a priori** reason to expect large abnormalities in growth patterns we may interpret each of these normal curves for a species representing progeny from a separate spawning pulse or population. **M. gayi** showed four or five of these curves. The **S. sagax** distributions could be interpretated as a single protracted spawning period or a series of three or four short spawnings occurring in succession. **E. ringens** showed the most complex polymodal distribution requiring as many as six normal curves to describe it. As in the other species this can be seen as the accumulation of several larvae populations from different areas or spawning times.

Using available data on the development rate of the northern anchovy E. **mordax** grown in the laboratory on a diet of wild plankton it is possible to estimate the approximate age or spawning times of each of the **E. ringens** normal curves. The growth curve published by Kramer and Zweifel (1970) was applied to the mean sizes of the calculated normal curves of E. **ringens** to estimate the age of each of the first four modes as follows.

* Table 4. Mean ± standard deviation of the total length of fish larvae collected in each sample of each tow, because of its extension is not published here but is available from the editor.

Fig. 8 Mean body lengths of four species of larvae caught in each of the samples on the different stations. Station positions (x-axis) and arranged in an offshore direction. Times of each station are given.

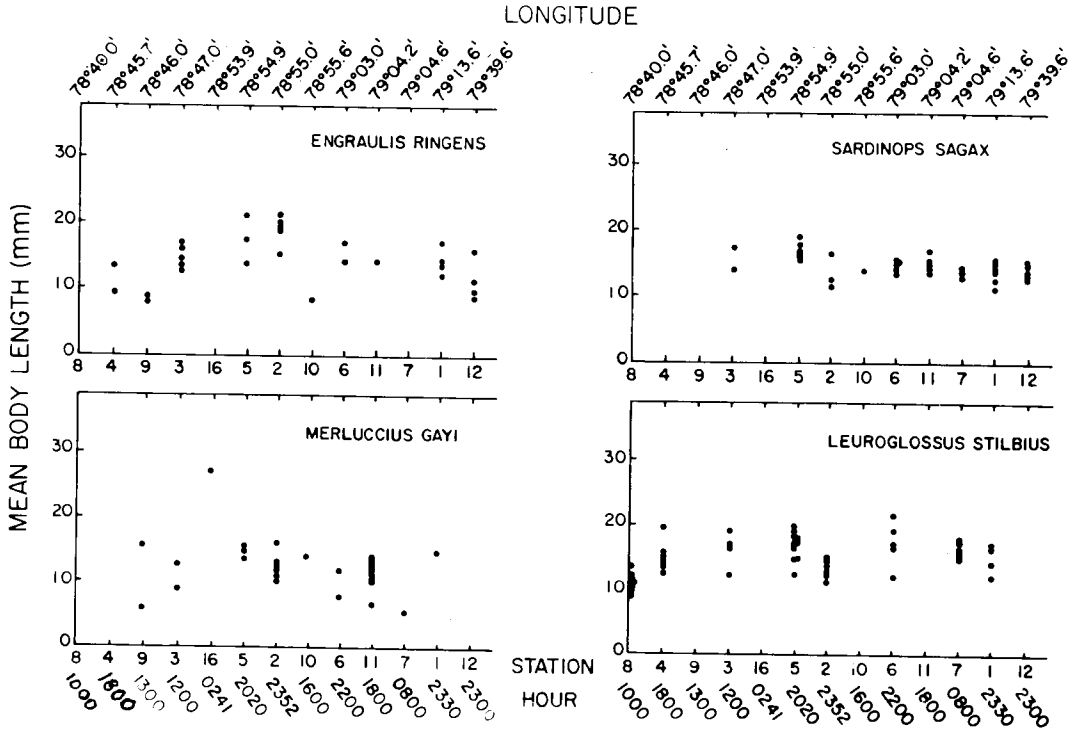
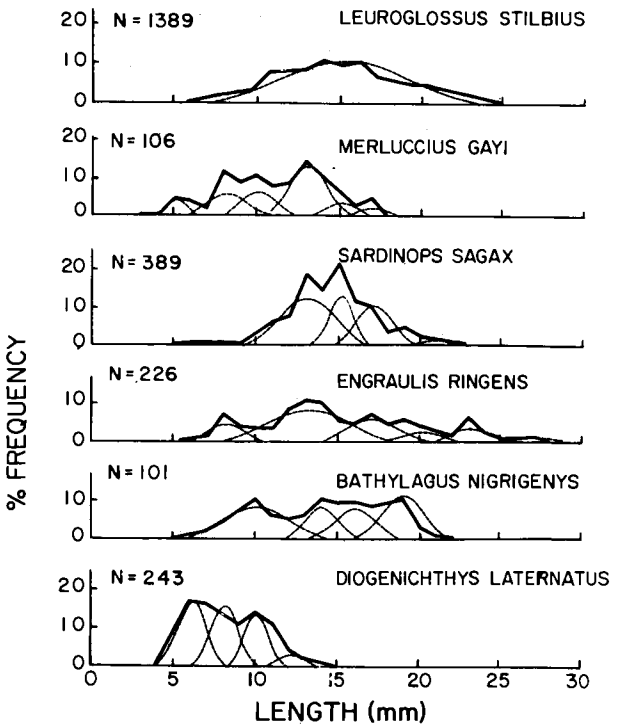


Fig. 9 Length frequency curves (solid lines) and the number of normal curves (dashed lines) as calculated by the method described by Taylor (1965) that made up the polynomial distributions for 6 species of fish larvae. Numbers (N) of each species measured is given.



Population mode	Mean larval length (mm)	Age (days)
1	8	16
2	14	28
3	17	35
4	20	44*

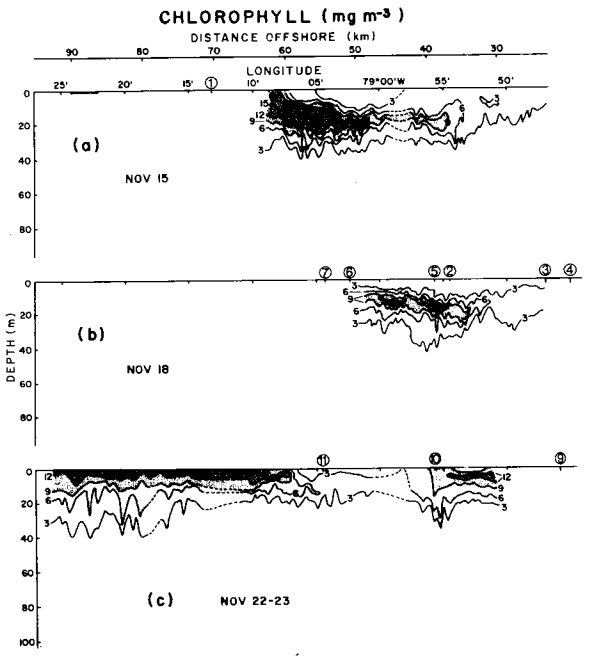
*The age of the last mode (4) was estimated by extrapolating Kramer and Zweifel's curve to a length of 20 mm.

If the growth rates of the two **Engraulis** species are similar, it appears that there was a spawning of **E. ringens** approximately each 7 to 12 days. If an additional 6 to 12 days is counted for the final two modes suggested on Fig. 9, then the larvae caught during this study appear to result from a spawning period lasting a total of 54 to 68 days.

Station Positions Related to Chlorophyll Concentrations

Each ichthyoplankton station, except No. 8, 12 and 16 is related in position to vertical profiles of the chlorophyll concentrations which have been developed by Herman (1980) from sections made by the Batfish. In Fig. 10, the stations have been placed on the profiles taken closest to their positions. The times of the profiles and stations were not the same, but are within 12-24 hours in all cases and in some cases within 2 hours. From the comparisons it appears that Station 5 was taken in a particulary high chlorophyll concentration (12 mg m^{-3}). Stations 1, 2, 6 10 and 11 were

Fig. 10. Chlorophyll profiles made by de Batfish (taken from Herman, 1980) during different times and the BIONESS stations in relation to the chlorophyll concentrations.



likely taken in water with intermediate chlorophyll concentration of about 6 mg m^{-3} or higher. Stations 3 and 4 were probably in water with a chlorophyll concentration of 3 mg m^{-3} or lower. It was not possible to estimate the concentrations for the other stations.

Station 5 was rated earlier as showing highest concentration of both larvae and zooplankton. For all stations the only larvae that showed a relationship with the chlorophyll concentrations was **E. ringens.** They were virtually all found in the upper 30 m of water, the zone with the highest chlorophyll concentrations. The highest densities of **E. ringens** found were on stations 2 and 5 and these were in a zone of chlorophyll with between 9 and 12 mg m^{-3}. A Spearman's rank correlation was calculated on chlorophyll concentration and density of **E. ringens** m^{-2} on stations 2, 7, 5, 6, 10 and 11 and was found to be signficant ($\rho = 0.70$) at the $P < 0.05$ level. This indicates a relationship between **E. ringens** and chlorophyll concentration.

DISCUSSION

This study found six common species of fish larvae present in the study area with the dominant species being **Leuroglossus stilbius,** with **Sardinops sagax** the next most abundant. **Engraulis ringens** was one-third as abundant in the area as **S. sagax.**

The wide size range of the larvae suggested that a prolonged spawning period was common for all species. But due to the lack of literature on the larval growth rates of these species it was impossible to estimate age for other than **E. ringens.** This age estimate suggested a spawning period of about 2 months. The absence of anchoveta larvae below 5 mm in length probably reflects an absence of new recruitment into the water column. A 243 μm mesh was used and it is not only unlikely that larvae could be lost through so fine a mesh, but small sizes are commonly taken in other situations and species. Therefore it appears that the last of the spring seasonal spawning of **E. ringens** was sampled during this study.

If it is assumed that **E. ringens** and **S. sagax** have similar development and growth rates the similarity of body lengths and maximum population modes of the two species suggest that their peak spawning periods occurred at about the same time. They also occurred largely in the same geographic region overlapping in the centre of the study area, although **E. ringens** were more abundant on the inshore stations and **S. sagax** more abundant on the offshore stations. Furthermore, the two species were collected at similar depths on all but two stations, although the vertical distributions suggested that a large percentage of the **E. ringens** larvae were at depths above the main concentrations of **S. sagax** larvae. If the two species fed on the same food it would appear that some effects of potential competition are avoided by a partial fine-scale geographic and vertical separation. Our data show in addition, however, that **S. sagax** was not signficantly correlated with any of the copepod species with which **E. ringens** was correlated, suggesting that the two species fed on different species of copepods so that competition between them may not exist to a great extent, even when they are found in the same water.

The vertical distribution of many of the larvae, particularly **L. stilbius,** suggested that either the oxygen concentration of the deep water was not low at the time of the sampling or else these larvae were able to withstand low oxygen levels. The only relationship between the physical environment and the various species of fish larvae was with the thermocline. All species appeared to have a reduction in density above the thermocline. A similar finding was reported by Sameoto and Lewis (1979) for fish larvae on the Nova Scotian Shelf of Canada where there were indications that the biological environment affects the density and abundance more than does the physical environment. The maximum numbers of **E. ringens** were found on the stations taken in zones of high chlorophyll a concentration with low numbers of larvae present when the chlorophyll a levels were low. The relationship between the zooplankton biomass and numbers was not statistically significant, but the data did indicate the numbers of larvae increased as the density of copepods increased up to about 1000 m^{-3}, after this level the larval density showed no further increase. Due to the length of the tows in these samples and the large volume of water filtered, it was not surprising that these relationships were not clear. It is likely that the relationship between the larvae and their food supply in the form of copepods will only be found in the future with

small scale sampling on both the vertical and horizontal planes.

The data demonstrated that more larvae of **E. ringens** and **S. sagax** were caught during hours of darkness than during the day, however I feel this difference may be an artifact of the different station locations at night having higher densities of larvae since no other species showed this difference. The larvae of both species were all caught in the top 50 m of water at night. Therefore, it would seem reasonable that extensive larval surveys should be carried out during the night whenever possible and sampling below 50 m depth at night would likely be wasted effort. If one is interested only in **E. ringens**, then taking samples below 50 m depth even in the daytime appears to be unnecessary, since 100% of the larvae collected during the day were in the top 50 m.

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