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Northwest Atlantic Fisheries Organization

Serial No. N207

NAFO SCR Doc. 80/IX/133 (Revised)

ANNUAL MEETING OF SCIENTIFIC COUNCIL - SEPTEMBER 1980

Vertical Distribution of Herring Larvae (*Clupea harengus* L.) on Nantucket Shoals, November 1977, Collected by MOCNESS Aboard *Anton Dohrn* 77-03

by

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The objectives of the study were to describe the vertical distribution and horizontal variability of larval herring (Clupea harengus L.) in relation to food organisms, predators and environmental mechanisms such as prey-predator interactions and dispersal. Preliminary results of the vertical distribution of herring larvae are presented in this paper.

Samples of autumn-spawned larval herring were collected at discrete depth strata with an electronically-controlled net (MOCNESS[1]) on Nantucket Shoals during two experiments in November 1977, aboard the Federal Republic of Germany's research vessel Anton Dohrn, 77-03 (an ICNAF Larval Herring Survey). The first stratified series of samples (MOC 4-11) was made on 6-7 November 1977 during a 24-hour period at 41°43'N, 69°45'W and a second series (MOC 14-24) was made on 15-17 November during a 36-hour period in the same vicinity (41°40'N, 69°43'W). The site for the stratified collections are in the vicinity of historic herring spawning grounds.

MOCNESS data from four additional cruises (Albatross IV 78-02, 78-13, 78-14, 78-15), will be utilized after future analysis to further provide a more complete description of the vertical distribution of herring larvae in the water during their first six months.

Methods

MOCNESS is a mesoscale plankton sampler which has nine rectangular nets (1 m x 1.4 m) which are opened and closed sequentially by commands through a conducting cable from the vessel. This system permits samples of up to nine discrete depths during a single haul (Wiebe et al. 1976). On-deck, real time

[1]Multiple Opening and Closing Net Environmental Sensing System.

monitoring includes depth (pressure), temperature, net angle, number of the net presently filtering water, and the volume of water filtered. The net system is designed to be towed at 1 1/2 knots, and at a 45^{0} angle, so that each net has an effective mouth opening of 1 m^2.

Once a concentration of herring larvae was located from the standard 61-cm bongo-net survey, two MOCNESS hauls were made at approximately 90^{0} to each other through the center of the concentration, each net sequentially sampling in a double-oblique integrated manner from near bottom to surface. MOCNESS hauls were then repeated every three hours to obtain a discrete series of stratified samples within each 10-m depth interval from near bottom to surface. The standard net mesh size used was 0.333-mm; in some hauls an extra net or two of 0.202-mm mesh was used to collect a finer fraction of the zooplankton at selected depth levels. Each net was opened for approximately 10 minutes to filter approximately 500 m^3 of water to obtain a desired number of larvae. Prior to each haul ancillary observations were made including (1) an XBT temperature profile, (2) light profile by submarine photometer and secchi disc reading, (3) chlorophyll profile by pumping water at depth through a Turner Designs fluorometer on the vessel (Series II only), and (4) one parachute drogue was set (25-m depth) 15 November (2315 EST) and followed until 16 November (1310 EST). All plankton samples were preserved in buffered 5% formalin.

The Canadian vessel R.V. E.E. Prince rendezvoused with R.V. Anton Dohrn on 17 November and made standard ICNAF bongo net hauls on a fine grid of stations, three times in three days. These bongo grid hauls were made in the surrounding area of the second MOCNESS series to define the patchiness of the larvae on a broader scale to augment the vertical distribution data.

Total sample displacement volumes and drip-wet weights were made in the laboratory. All herring larvae were removed from the samples and the crustacean component of the sample biomass was measured. Standard length to the nearest millimeter was measured for up to 300 larvae per sample. Larval herring gut and condition factor analysis, and total zooplankton identification and enumeration will be made on selected samples. All larval data reported here were standardized to the number per 100 m^3 water filtered and grouped into the appropriate depth level and time block for presentation.

Results

Series I

The density (no. per 100 m^3) and mean length and range of herring larvae by

10-meter depth strata over a 24-hour period are shown in Tables 1 and 2. Mean density of the eight hauls was 21.7 larvae/100 m^3 within a range of 0 to 127.6 per 100 m^3. Mean larval length was 15.2 within a 5.1 to 25.5 mm range

MOCNESS hauls 2 and 3 were made prior to Series I at 90^o to each other through the study site encompassing an area of 8.2 km^2, Figures 1 and 2 present larval densities for each net. These data have a mean of 13.89 larvae/100 m^3 and a standard deviation (s.d.) of 11.63. This indicates a large amount of spatial variability or patchiness with 95% confidence intervals on the observations of -9.38 (lower) and 37.16 (upper) and a coefficient of variation of 83.73%.

The 24-hour series began at 2145 hours (EST) on November 6, 1977 and consists of Haul 4 through Haul 11, standardized densities are provided in Figures 3-10, night hauls are shaded dark and day hauls remain unshaded. Sunrise occurred at 0640 and sunset at 1647 EST.

Haul 4 (Figure 3) at 2145 hours, indicated a surface dominated population with 67% of the larvae collected in the upper 20 meters of water. A constant decline in population density was seen with depth.

Haul 5 (Figure 4) at 0100 hours on 7 November, again shows the highest density of larvae at the surface with 35% of the total in the upper 10 meters. The central water column from 20 to 40 meters was now homogeneous in larval density.

Haul 6 (Figure 5), at 0400 hours, indicates that the larvae were evenly distributed in the central and upper column with only a small fraction (2.6%) of the total caught below 50 meters.

Haul 7 (Figure 6), at 0645 hours, return to a heavily surface dominated population with 71% of the larvae collected within the upper 10 meters. The remainder of the water column had a steady decline in larval abundance with depth.

Haul 8 (Figure 7), at 0945 hours, repeated the trend seen in the previous haul, exhibiting a heavily dominated surface population (74% of total) in the upper 10 meters and a constant decrease in abundance with increasing depth.

Haul 9 (Figure 8), 1245 hours, also had a surface dominated population with 44% of the total above 10 meters. The mid-water column from 20 to 40 meters had an increased abundance compared to the strata immediately above and below it.

Haul 10 (Figure 9), 1545 hours, indicates a larval population of increasing density with depth to 50 meters and a slight reduction from there to 70 meters.

Haul 11 (Figure 10), 1835 hours, had a middle and upper water column dominant population with the maximum abundance between 10 and 20 meters. The trend of decreasing population with depth again was evident.

The standardized larval data were separated into day and night categories and their abundance data combined and plotted in Figure 11. The actual data points were included for reference. There was a mean increase in the night haul densities at all depths by a factor of 2.76.

Length-frequency histogram data were combined for each 10-meter depth stratum for both night and day hauls (see Figures 12-15). Both day and night hauls show a distinct bimodal population in the upper water column (i.e., <40 meters) with modal peaks at 7 and 16 mm. The smaller of the two peaks was always the 7-mm mode and was completely absent below 40 meters. Day and night hauls showed a decreasing population density with depth. Larval density in the night hauls was found to be significantly greater than the day hauls using a paired T-test, at the .05 level of significance.

Cumulative length data of day and night hauls are summarized in Figure 16. The mean length $\pm$ 1 standard deviation, and the range are plotted for each stratum. An increase in the mean length of larvae and a decreasing range of lengths were seen with increasing depth.

Series II

The abundance (no. per 100 m^3) and the mean length and the range of herring larvae by 10-meter depth strata over the first 24 hours of the 36-hour period are shown in Tables 3 and 4. Mean density of the hauls was 21.1 larvae/100 m^3 with a range of 0.63 to 100.05 larvae/100 m^3. Mean larval length was 14.99 mm within a 7.1 to 32.1 mm length range.

MOCNESS hauls 12 and 13 were made prior to Series II at 90^o to each other across the study site, encompassing an area of 11.4 km^2. Figures 17 and 18 give larval densities for each net. The results have a mean of 38.25 larvae/ 100 m^3 and a standard deviation (s.d.) of 15.73. Again a large degree of patchiness is indicated with 95% confidence intervals on the observation of 6.78 (lower and 69.70 (upper) and a coefficient of variation of 41.13%.

Series II hauls began at 0100 hours EST on November 16, 1977 and consisted of hauls 14 through 21. Standardized densities are provided in Figures 19-26. Night hauls are shaded and day hauls are unshaded. Sunrise occurred at 0652 and sunset at 1638 EST.

Haul 14 (Figure 19), at 0100 hours, showed the greatest proportion of the population in the lower water column. More than half (57%) of the larvae were below 40 meters.

Haul 15 (Figure 20), at 0355 hours, showed a distinct bimodal split in the population density with peaks at 20-30 meters and again at 50-60 meters. No differences in the standard length of larvae found in these stratum can be correlated with this division.

The first daylight haul, Haul 16 (Figure 21), at 0645 hours, contained the greatest densities of larvae at the surface strata (0-10 m) and at a deeper stratum of 30 to 40 meters. Very low densities occurred in the mid-water (20-30 meters) and deepest sampled strata (below 40 meters). Densities for all strata are lower, although not significantly so (using a paired T-test $P \leq .05$), than in the earlier tows.

Haul 17 (Figure 22), at 0950 hours, had a virtually homogeneous population density with depth. A very low overall density ($\bar{x}$ = 3.75/100 m^3) again was seen in this second daylight haul.

Haul 18 (Figure 23), at 1230 hours, repeated the early morning trend of Haul 16 with the greatest larval densities appearing in the upper stratum (0-30 meters) and again in the deepest strata (50-60 meters).

Haul 19 (Figure 24), at 1540 hours, contained the largest portion of the population (36%) in the surface strata (0-10 meters) and an essentially homogeneous population from 10 to 60 meters.

Haul 20 (Figure 25), at 1835 hours, showed the highest density (39%) of larvae in mid-water (20-30 meters) with densities tapering-off rapidly to the surface and to 60 meters.

Haul 21 (Figure 26), at 2140 hours, repeated the trend seen in the previous haul with the peak abundance of larvae in mid-water (30-40 meters) and the population density declining towards the surface and to 60 meters.

The standardized larval abundance data were lumped into day and night categories, data were combined and plotted in Figure 27, actual data points are included for reference. On the average, almost three times as many larvae were collected at night than during the day hauls. Daytime abundance tend to be uniformly distributed where night hauls indicate an increased density at mid-water depths.

Length-frequency histogram data were combined for each 10 meter depth stratum for day and night hauls (Figures 28-31). Both day and night hauls indicate a bimodal population throughout the water column with peaks at 9 and 16 mm. The smaller larvae, 9 mm, were the greater mode in the mid-water strata (10-30 meters) during the day hauls and in the upper 30 meters in the night hauls. Night hauls indicated an overall increasing population density with depth to 60 meters. Day hauls indicated a greater abundance in the upper water column (<20 meters), reduced densities in the mid-water strata (20-40 meters), and a return to the greater abundance at depth (>40 meters). Higher larval densities were found at night at all depths except near the surface (0-10 m) although not significantly greater at the .05 level of significance.

Cumulative length data of day and night hauls are summarized in Figure 32. The mean length, ± standard deviation, and the range are given for each stratum. Day haul data show a high surface (0-10-meter) mean length with a 4-m decrease in mean length at the 10-20-meter strata, from the surface strata down to 60 meters there was a steady increase in mean length. Night tow data show a steady increase in mean length with depth.

The ranges of larval standard lengths encountered in Series II were similar at most strata, except at 30-40 meters during the day hauls which had a greatly reduced range. The range of larval lengths increased slightly with depth during the night hauls.

Series I and II Comparison and Discussion

The assumption that the vessel returned to the same general larval population is supported by a comparison of the basic statistics for Series I and II standardized haul data as seen below.

	SERIES I	SERIES II
Mean Density	21.7 No/100 m^3	21.1 No/100 m^3
Range	.63-100.5 No/100 m^3	0-127.6 No/100 m^3
Mean Larval Length	15.2 mm	14.9 mm
Range	5.1-25.5 mm	7.1-32.1 mm

These statistics are strikingly similar and indicate that the same larval population that was sampled in Series I again was sampled by Series II 10 days later. The standardized abundance data collected from the four preliminary hauls in which each net was towed in a double oblique fashion (YoYo haul) also supports this contention, for although more than twice the density of larvae was encountered by Series II than Series I, this is normal spatial variability. Bridger (1956) reported a 40-60% coefficient of variation in clupeid larval density between repeated net hauls which compares favorably with our C.V. of 41-84%.

The depth strata for each haul that contained the highest density of herring larvae are plotted in Figure 33 for both series. Although differences in the vertical distribution of larvae are seen in both series, a comparison of the 16 hauls reveals no re-occurring pattern of diel vertical migration between the series.

A comparison of the combined abundance data (Figure 11 and 27) for day and night hauls also demonstrate a lack of similarity between the two series. Wood (1971) found clupeid larvae to have the highest abundance at the surface or in mid-water during the day and to be randomly distributed at night. Series I data would support Wood's findings for the day only, while the night hauls show a clear increased surface abundance. Series II data agrees with Wood's data for the night hauls but also shows a randomly distributed population by day.

The cumulative percentage contribution of day vs. night hauls for both series was treated by the Kolmogorov-Smirnov test (Tate and Clelland 1957). The maximum difference (D) between the two percentages for any given depth strata was calculated at each series at the .05 level of significance. No significant differences in percent contribution of day vs. night hauls for any of the depth ranges were observed for either series. Cumulative percentage plots and the 95% significance values for both series are shown in Figure 34.

A comparison of the length frequencies of larvae collected by each series supports the earlier contention that Series II had been made in the same population of larvae as Series I. Both series were bimodally distributed, the smaller mode had a 2-mm increase between series (see Figures 12 through 15 and 28 through 31). According to Lough et al. (1980), a growth rate of .27 mm/day is expected for larval herring in November, or a 2.7 mm increase in length over the 10-day interval between the two series in this study. There was no increase in the modal length of the larger larvae between the two series, possibly because it was marked by the increased densities and the wide range of lengths observed in Series II.

A comparison of day and night data show a gradual increase in larval length with increasing depth (Figure 16 and 32). Wood (1971) reported on herring larvae captured in 45 meters of water with a mean length of 11-12 mm to also exhibit an increased mean larval length with depth, but at night only. Wood also found an increased mean length of herring caught in the daytime surface layer indicating that the larger larvae were actually preferring vertical migrations. The increased length of daytime larvae in the surface strata (0-10 m) of Series II is similar to his findings; however, there was no increase seen in Series I daytime surface strata hauls.

The results of this study of larval herring collected during two 24-hour series illustrates the high degree of natural variability in the vertical and horizontal distribution of herring larvae.

Further analysis of the MOCNESS haul series in regard to prey selection and available environmental data may provide a better understanding of possible causes for the observed variability in the vertical distribution of herring larvae.

Summary

1. The vertical distribution of herring larvae during 2 24-hour MOCNESS sampling series separated by a 10-day interval was examined. The contention that the same population of larvae was sampled by both Series I and Series II was supported by the data.

2. Mean larval abundance and length were similar between the two series.

3. Spatial variability on the order of 41 to 83% (C.V.) was observed in double oblique hauls made through the center of the study site (8-12 km^2) prior to each series.

4. Vertical migration of larvae was observed in both series although no recurring pattern of vertical distribution could be ascertained between series.

5. Herring larvae were found in greatest abundance in both day and night hauls in the surface layer during Series I, but they were distributed uniformly with depth in day and night hauls in Series II.

6. Larval growth seen in the smaller larvae (5-10 mm) during the 10-day interval was on the order expected from growth models in the literature. Growth of the larger larvae (10-30 mm) was not seen between the two series.

7. The mean length of larvae increases with depth in both series.

References

Bridger, J.P. 1956. "On day and night variation in catches of fish larvae." J. Cons. perm. int. Explor. Mer, 22: 42-57.

Lough, R.G., M.R. Pennington, G.R. Bolz, and A.A. Rosenberg. 1980. A growth model for larval sea herring (Clupea harengus L.) in the Georges Bank - Gulf of Maine area based on otolith growth increments. ICES C.M. 1980/H:65. 23 pp.

Tate, M.W. and R.C. Clelland. 1957. Nonparameters and shortcut statistics. Interstate Printers and Publishers, Inc., Danville, Illinois.

Wiebe, P.H., K.H. Burt, S.H. Boyd, and A.W. Morton. 1976. A multiple opening/closing net and environmental sensing system for sampling zooplankton. J. Mar. Res. 34: 313-326.

Wood, R.J. 1971. Some observations on the vertical distribution of herring larvae. Rapp. P.-v. Réun. Con. perm. int. Explor. Mer, 160: 6064.

TABLE 1. SERIES I, STANDARDIZED NUMBER OF LARVAE PER 100 M3

	N	N	D	D	D	D	N	N	$\bar{x}$/100 m^3	
Hour / Depth	2400-0300	0300-0600	0600-0900	0900-1200	1200-1500	1500-1800	1800-2100	2100-2400	D	N
0-10	47.32	48.9	51.28	35.22	63.21	4.89	81.42	63.23	38.65	60.21
10-20	10.69	28.06	8.24	9.72	18.28	9.48	127.69	37.7	11.43	51.03
20-30	16.38	43.64	3.45	1.61	35.79	12.79	67.54	31.95	13.41	39.84
30-40	12.74	21.28	1.04	0.91	22.50	13.21	65.48	12.76	9.41	28.06
40-50	2.74	28.06	2.8	0	2.52	17.64	52.84	4.45	9.73	22.02
50-60	0	2.28	0.76	0	0	15.37	38.45	0	4.03	10.18
60-70	--	2.46	0	0	0	12.37	3.62	--	3.09	3.04
									$\bar{x}$ 12.82 29.5%	$\bar{x}$ 30.63 70.4%
MEAN	12.83	24.81	9.65	6.78	20.33	12.25	62.43	21.38	COMBINED MEAN 21.72	

TABLE 2. SERIES I, MEAN LENGTHS AND RANGE FOR CLUPEA HARENGUS

Hour / Depth	N 2400-0300	N 0300-0600	D 0600-0900	D 0900-1200	D 1200-1500	D 1500-1800	N 1800-2100	N 2100-2400	$\bar{x}$
0-10	15.36 6.0-18.4	13.93 6.3-17.2	13.18 5.8-23.0	15.45 7.1-22.3	16.35 7.1-18.9	15.81 7.3-22.0	15.23 7.0-24.0	14.54 6.8-18.5	
10-20	12.95 16.3-17.2	14.30 6.1-17.7	14.6 12.1-18.9	13.59 6.8-18.0	15.64 6.3-19.2	15.57 5.3-25.5	15.81 7.3-22.0	14.42 5.1-18.4	
20-30	15.33 5.4-19.2	22.79 6.1-19.6	15.32 13.4-16.8	15.63 14.6-18.0	14.73 5.3-17.3	14.49 6.5-17.0	15.59 7.1-23.0	13.5 5.8-17.9	
30-40	16.11 12.8-24.3	15.48 6.8-19.4	14.52 11.9-16.0	15.0 14.6-15.3	15.44 5.8-18.2	14.55 7.0-17.3	15.38 6.8-18.0	16.0 10.7-22.8	
40-50	15.4 14.6-15.8	15.68 7.7-22.1	14.96 12.9-17.3	0	15.45 14.5-17.2	15.3 10.5-22.0	15.49 8.0-18.2	15.7 13.1-22.1	
50-60	0	15.8 14.6-17.7	15.76 15.5-16.2	0	0	15.47 14.1-17.9	15.72 7.7-21.4	0	
60-70	0	15.02 14.1-17.2	0	0	0	15.67 13.8-18.0	15.77 11.4-17.3	0	
MEAN	15.03	16.14	14.72	14.92	15.52	15.26	15.57	14.83	15.24

TABLE 3. SERIES II, STANDARDIZED NUMBER OF LARVAE PER 100 M3

Hour / Depth	N 2400-0300	N 0300-0600	D 0600-0900	D 0900-1200	D 1200-1500	D 1500-1800	N 1800-2100	N 2100-2400	$\bar{x}$/100 m^3 D	$\bar{x}$/100 m^3 N
0-10	3.66	27.21	12.08	6.17	21.32	12.91	2.73	10.76	13.12	11.09
10-20	6.46	55.04	7.05	4.94	11.41	6.67	20.73	18.63	7.51	25.21
20-30	30.85	100.05	0.63	6.50	16.03	2.64	38.99	60.45	23.82	57.58
30-40	29.55	32.66	31.57	1.31	1.66	0.79	24.60	28.05	8.85	28.71
40-50	46.72	42.46	31.31	0.54	4.58	5.57	12.48	15.76	10.5	29.35
50-60	47.71	67.13	--	2.92	10.11	7.41	0.71	36.00	6.81	37.88
60-70	--	--	--	3.88	--	--	--	--	3.88	--
									$\bar{x}$ 10.63 25.1%	$\bar{x}$ 31.63 74.8%
MEAN	27.49	54.09	13.77	3.75	10.85	5.99	16.70	28.27	COMBINED MEAN 21.13	

TABLE 4. SERIES II, MEAN LENGTHS AND RANGE FOR CLUPEA HARENGUS

Hour / Depth	N 2400-0300	N 0300-0600	D 0600-0900	D 0900-1200	D 1200-1500	D 1500-1800	N 1800-2100	N 2100-2400	
0-10	13.57 9.4-18.2	11.86 8.7-19.2	16.00 8.5-19.4	17.18 14.5-23.8	16.97 8.3-20.2	14.54 8.7-20.9	10.75 8.2-14.5	15.18 9.0-19.7	
10-20	15.80 8.5-32.1	13.78 7.7-24.8	13.29 9.0-17.3	9.77 7.1-15.5	10.20 8.3-15.1	14.10 9.2-24.7	13.97 6.5-26.4	13.11 8.3-21.4	
20-30	15.67 8.8-24.8	13.26 8.0-20.6	16.75 15.8-17.7	11.06 8.7-17.2	11.81 8.3-17.3	16.39 13.8-19.4	15.46 8.3-26.0	12.06 7.3-19.2	
30-40	16.14 8.2-28.1	15.33 8.0-23.9	15.37 8.7-19.7	16.57 15.1-17.2	16.68 13.6-18.4	14.80 13.6-15.5	16.02 9.2-23.0	14.66 8.6-23.5	
40-50	16.02 8.5-25.5	15.29 8.2-21.4	15.53 8.8-20.6	14.80 ---	16.04 15.3-17.3	16.5 14.1-19.3	17.80 15.8-20.4	17.02 8.5-26.2	
50-60	15.95 8.5-30.1	16.53 9.4-29.8	0	16.71 16.0-17.9	16.72 15.1-19.4	15.93 13.3-18.2	17.25 15.3-19.2	16.5 9.7-20.4	
60-70	0	0	0	16.63 15.1-19.2	0	0	0	0	
MEAN	15.53	14.34	15.38	14.67	14.73	15.37	15.20	14.75	$\bar{x}$ 14.99

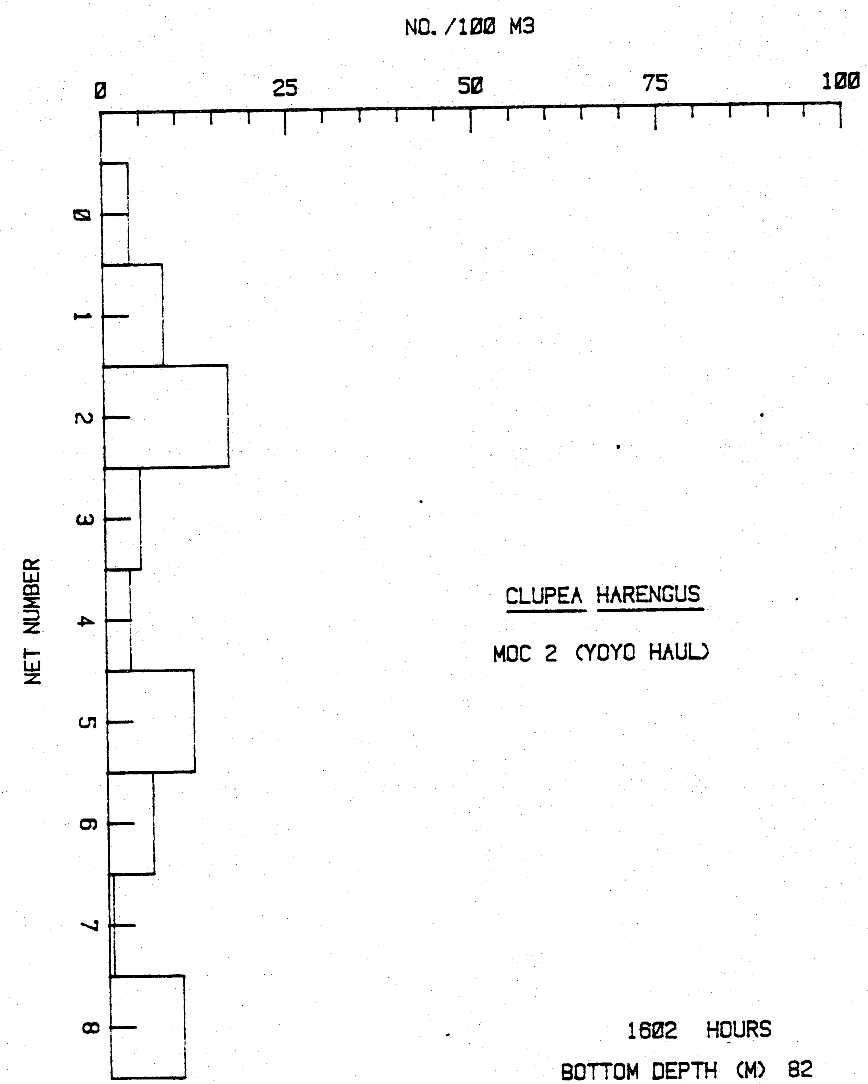


FIGURE 1 MOCNESS HAUL 2 , LARVAL DENSITIES FOR EACH DOUBLE OBLIQUE NET HAUL.

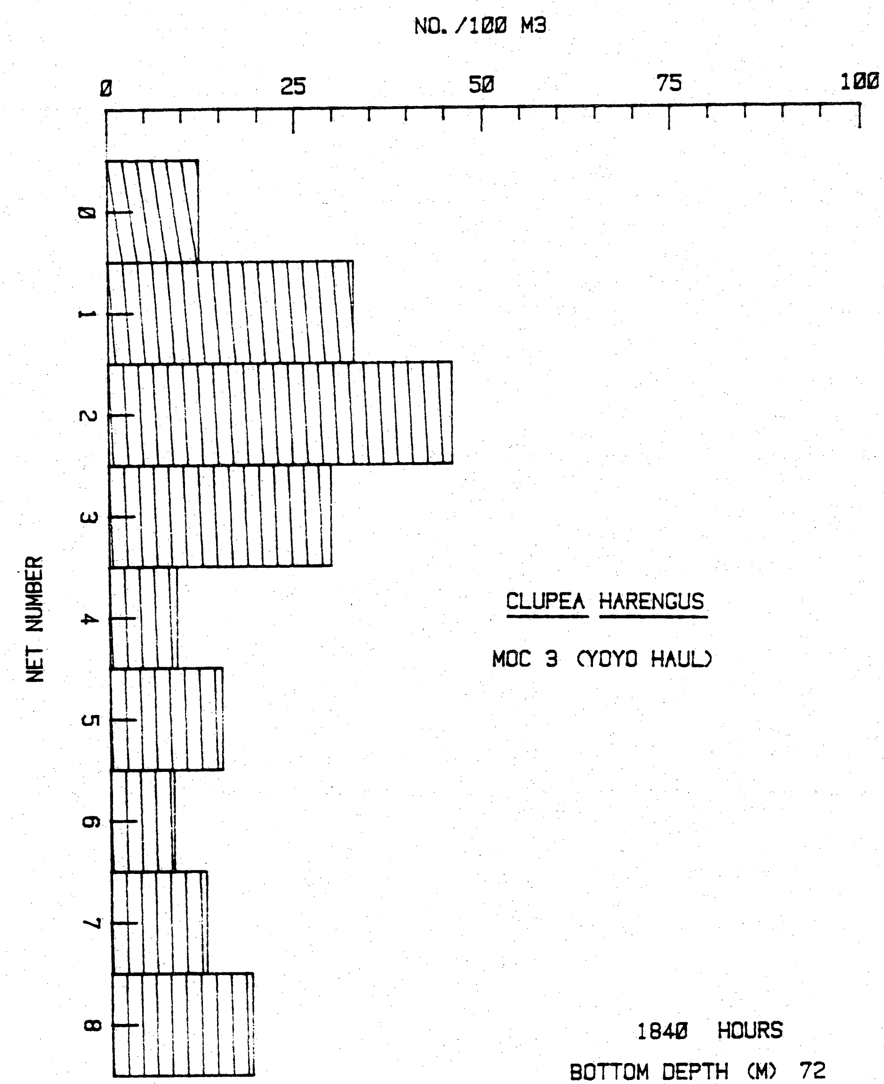


FIGURE 2 MOCNESS HAUL 3 , LARVAL DENSITIES FOR EACH DOUBLE OBLIQUE NET HAUL.

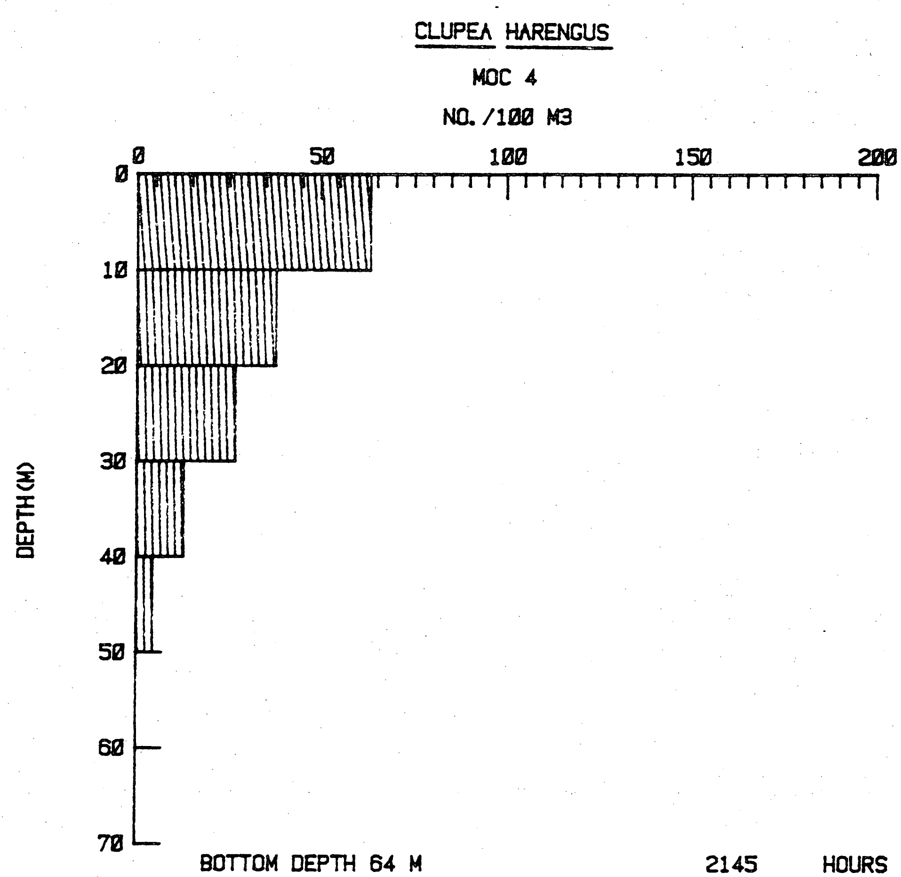


FIGURE 3 MOCNESS HAUL 4 LARVAL DENSITIES PER 10 METER DEPTH STRATA

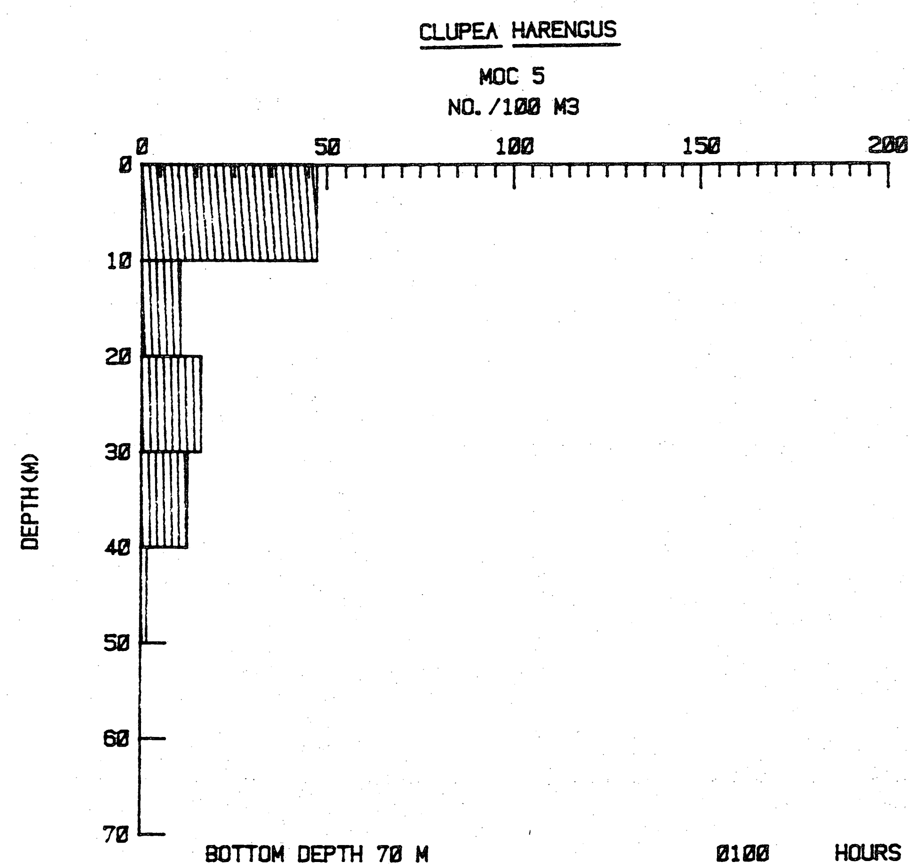


FIGURE 4 MOCNESS HAUL 5 LARVAL DENSITIES PER 10 METER DEPTH STRATA

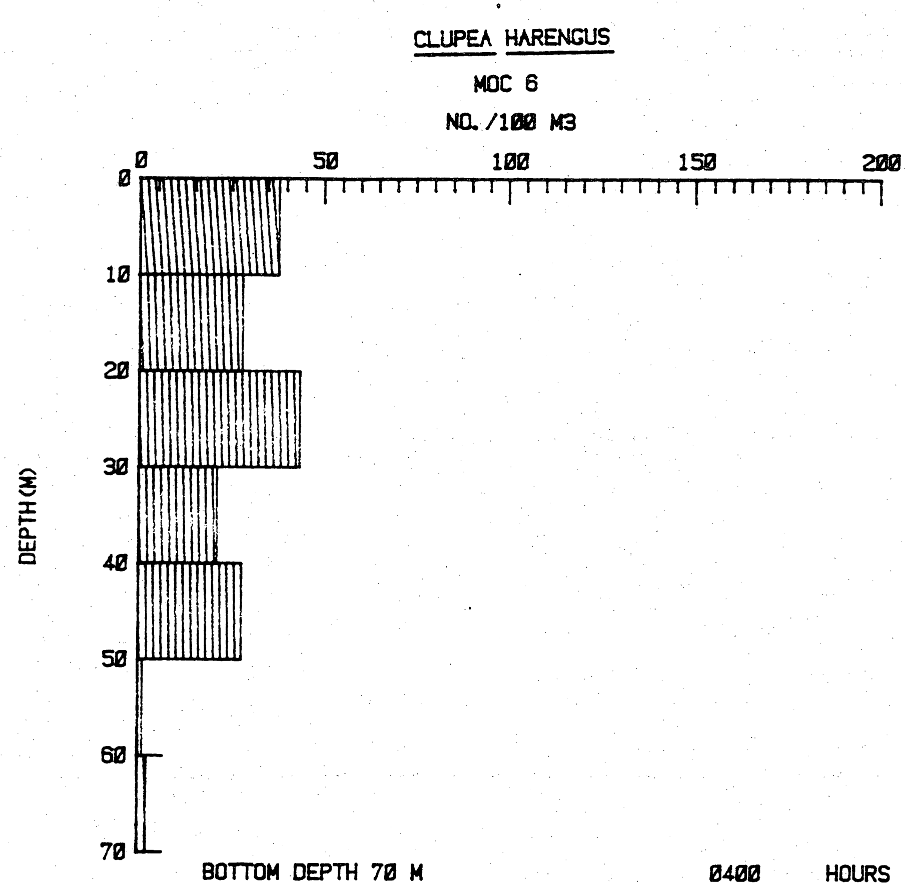


FIGURE 5 MOCNESS HAUL 6 LARVAL DENSITIES PER 10 METER DEPTH STRATA

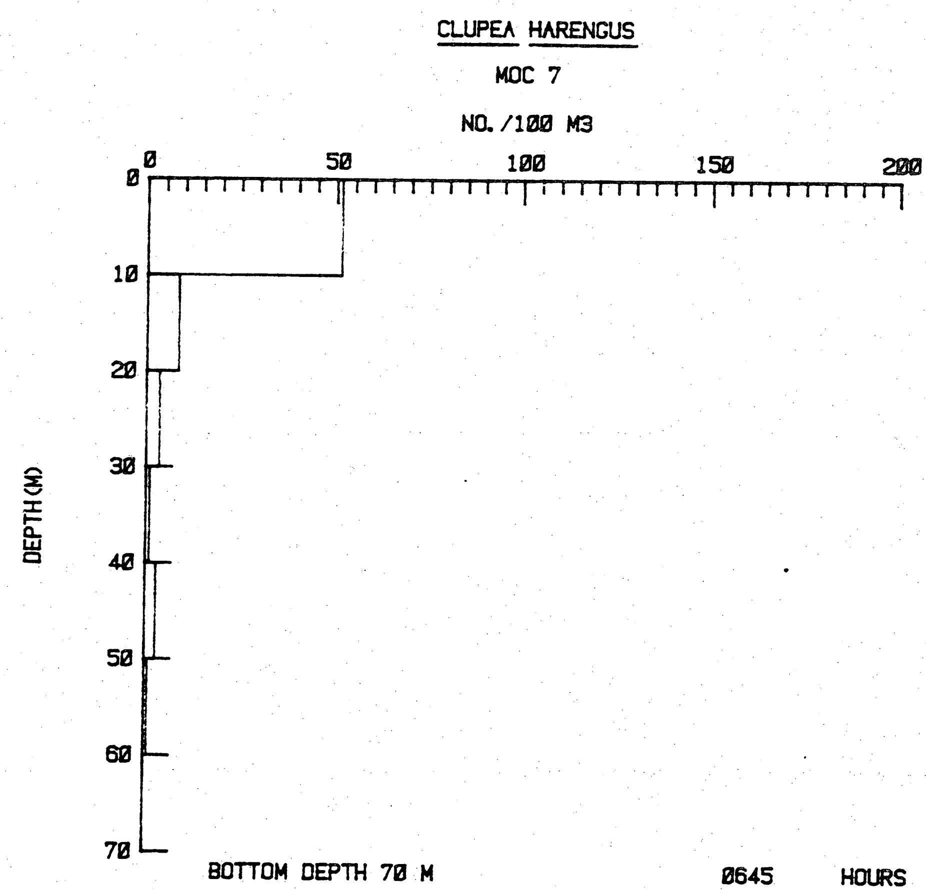


FIGURE 6 MOCNESS HAUL 7 LARVAL DENSITIES PER 10 METER DEPTH STRATA

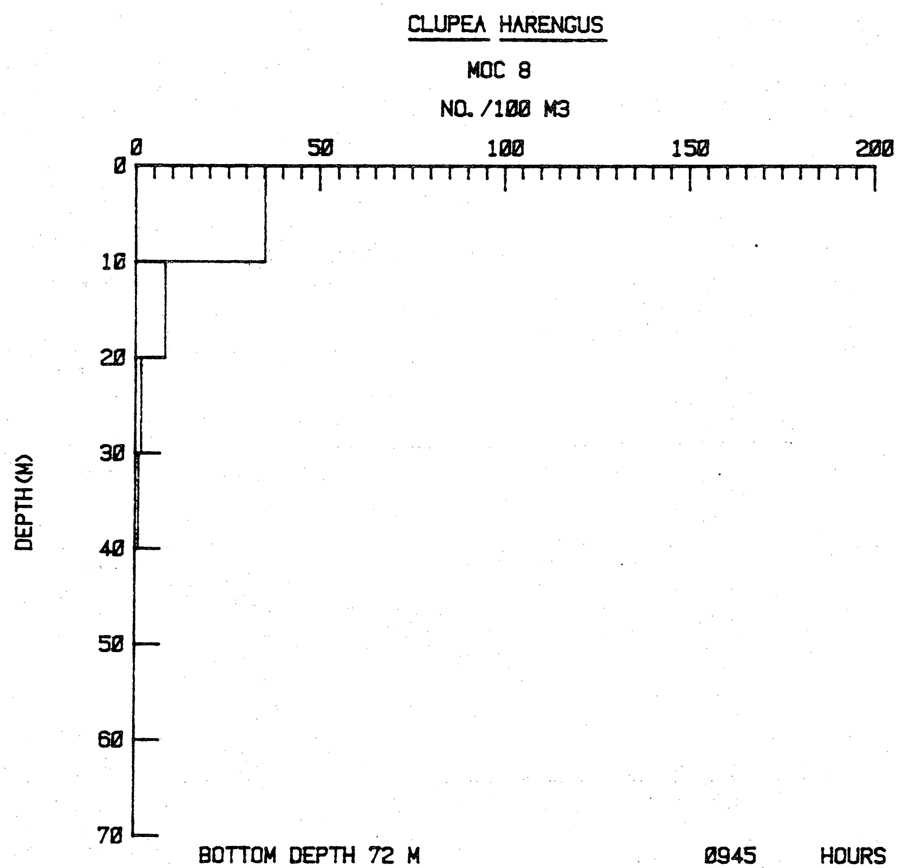


FIGURE 7 MOCNESS HAUL 8 LARVAL DENSITIES PER 10 METER DEPTH STRATA

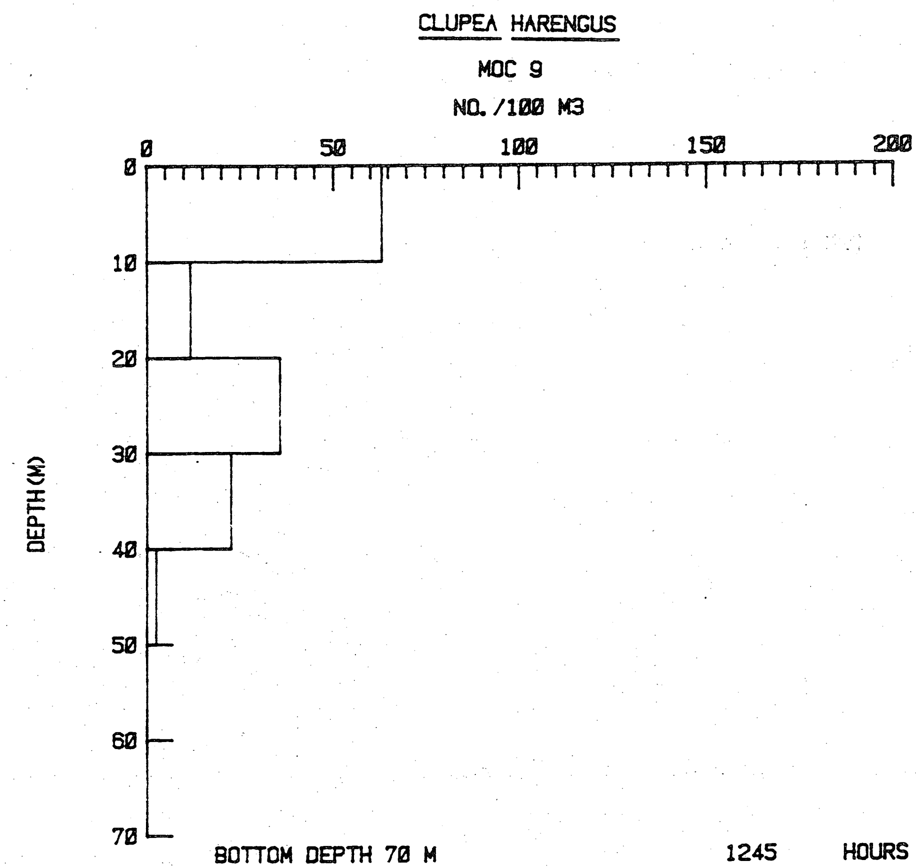


FIGURE 8 MOCNESS HAUL 9 LARVAL DENSITIES PER 10 METER DEPTH STRATA

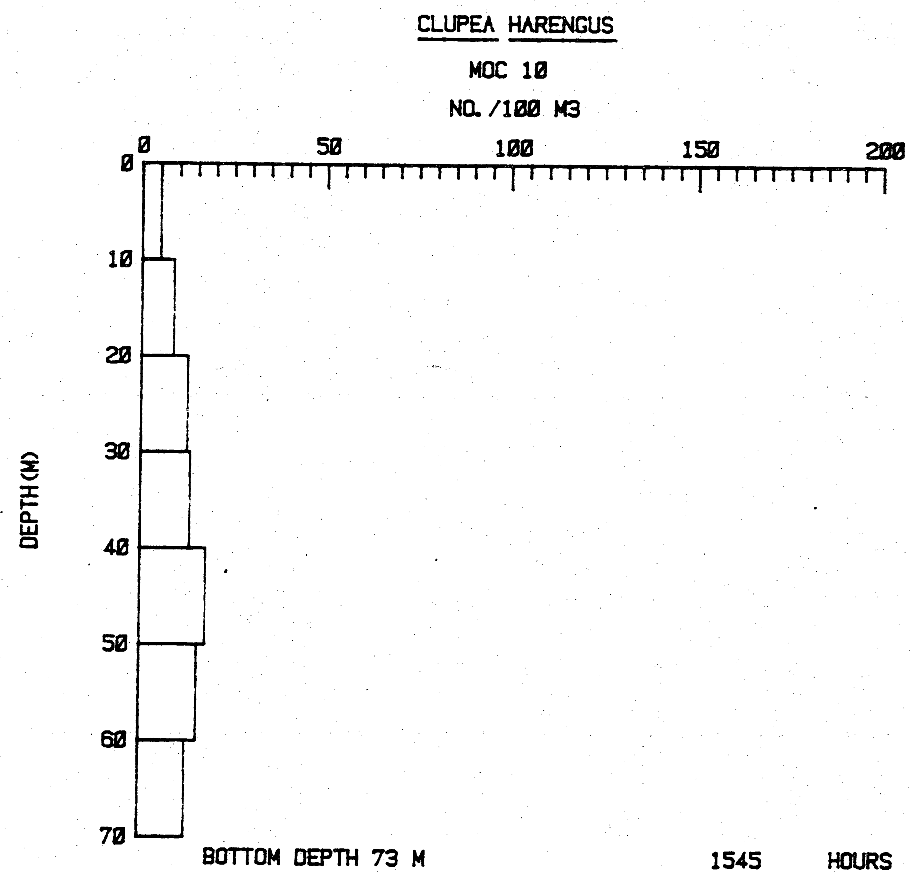


FIGURE 9 MOCNESS HAUL 10 LARVAL DENSITIES PER 10 METER DEPTH STRATA

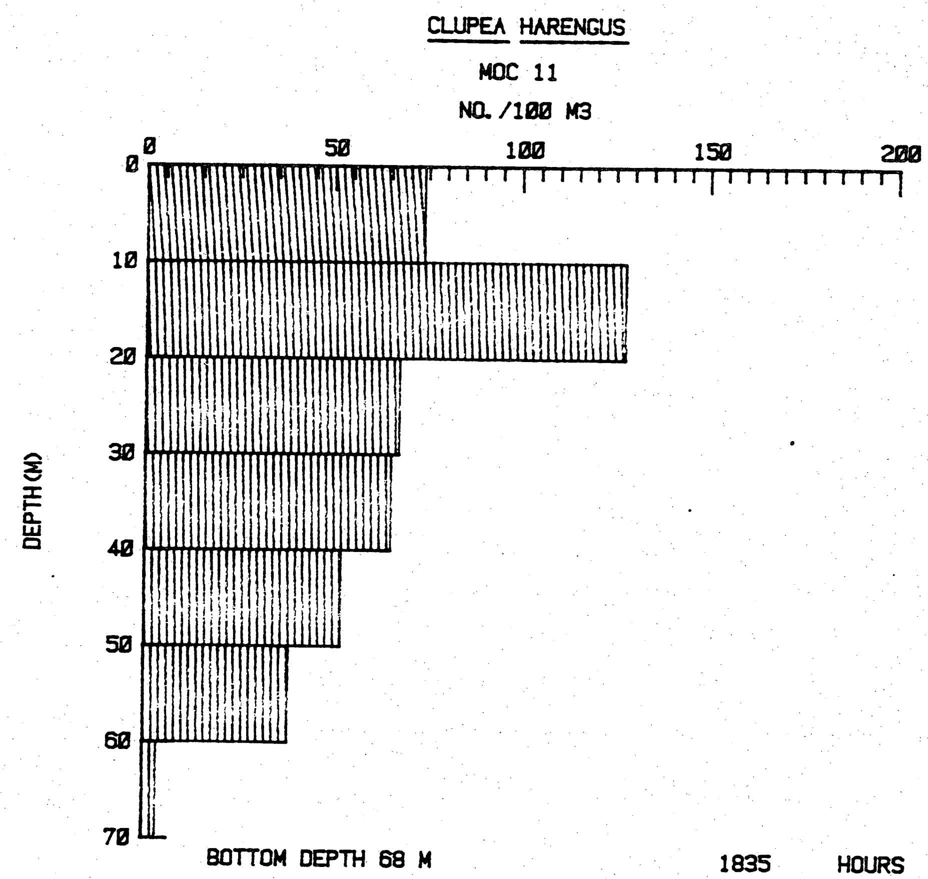
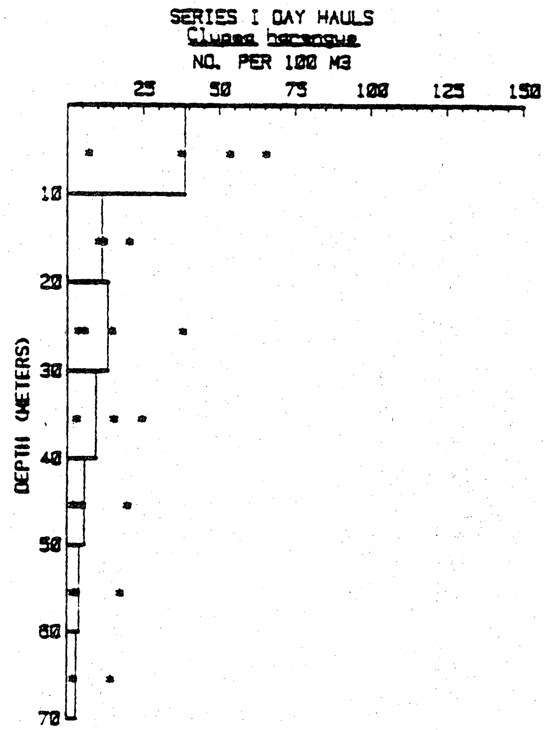


FIGURE 10 MOCNESS HAUL 11 LARVAL DENSITIES PER 10 METER DEPTH STRATA



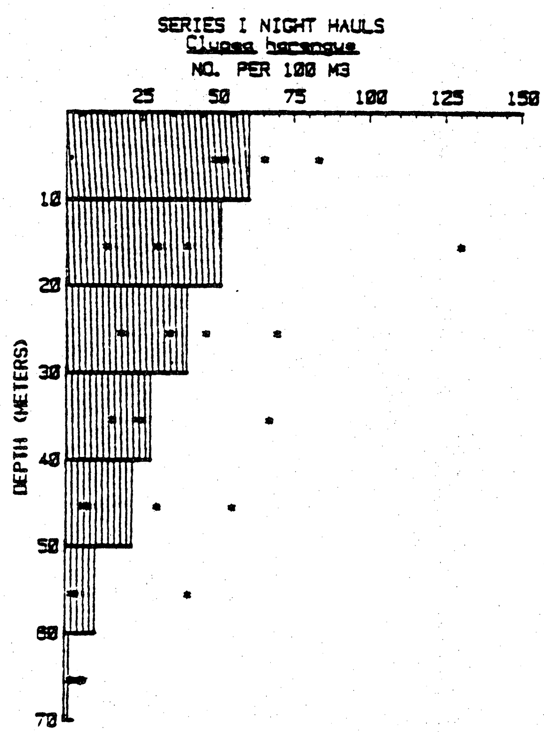


FIGURE 11. SERIES I COMBINED DAY AND COMBINED NIGHT HAUL MEANS WITH ACTUAL DATA POINTS (ZERO VALUES ARE RAISED FOR IDENTIFICATION).

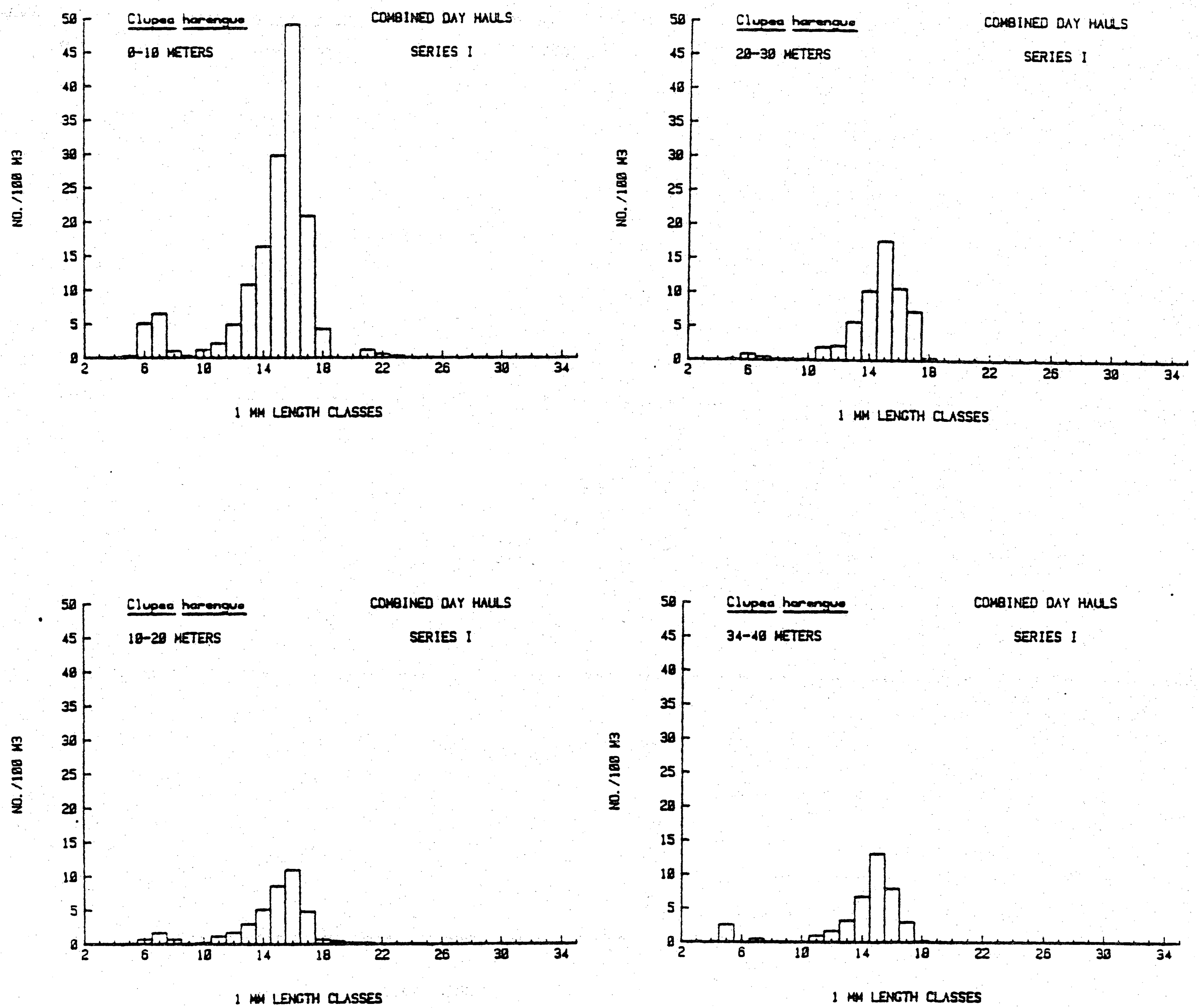
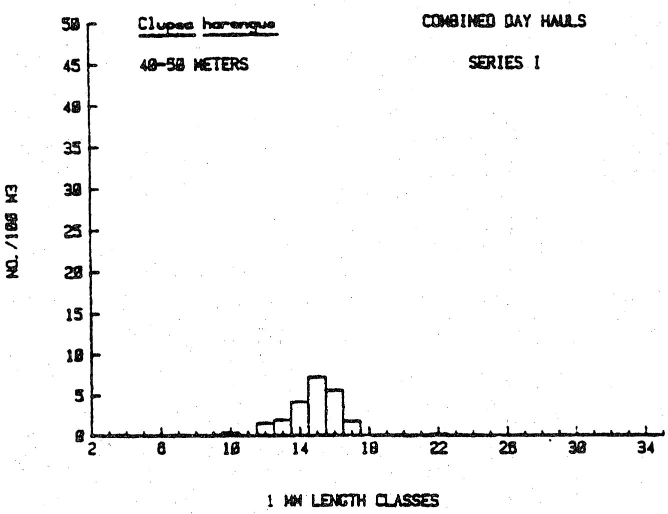
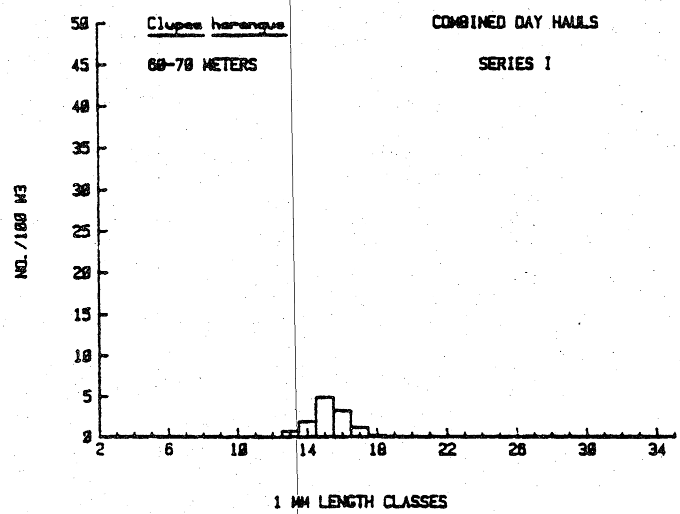


FIGURE 12 . LENGTH FREQUENCY HISTOGRAM FOR SERIES I DAY HAULS.





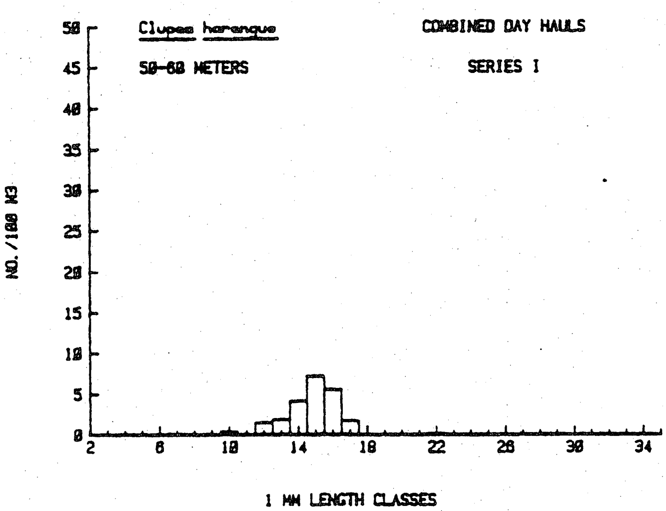


FIGURE 13 .LENGTH FREQUENCY HISTOGRAM FOR SERIES I DAY HAULS (CONT).

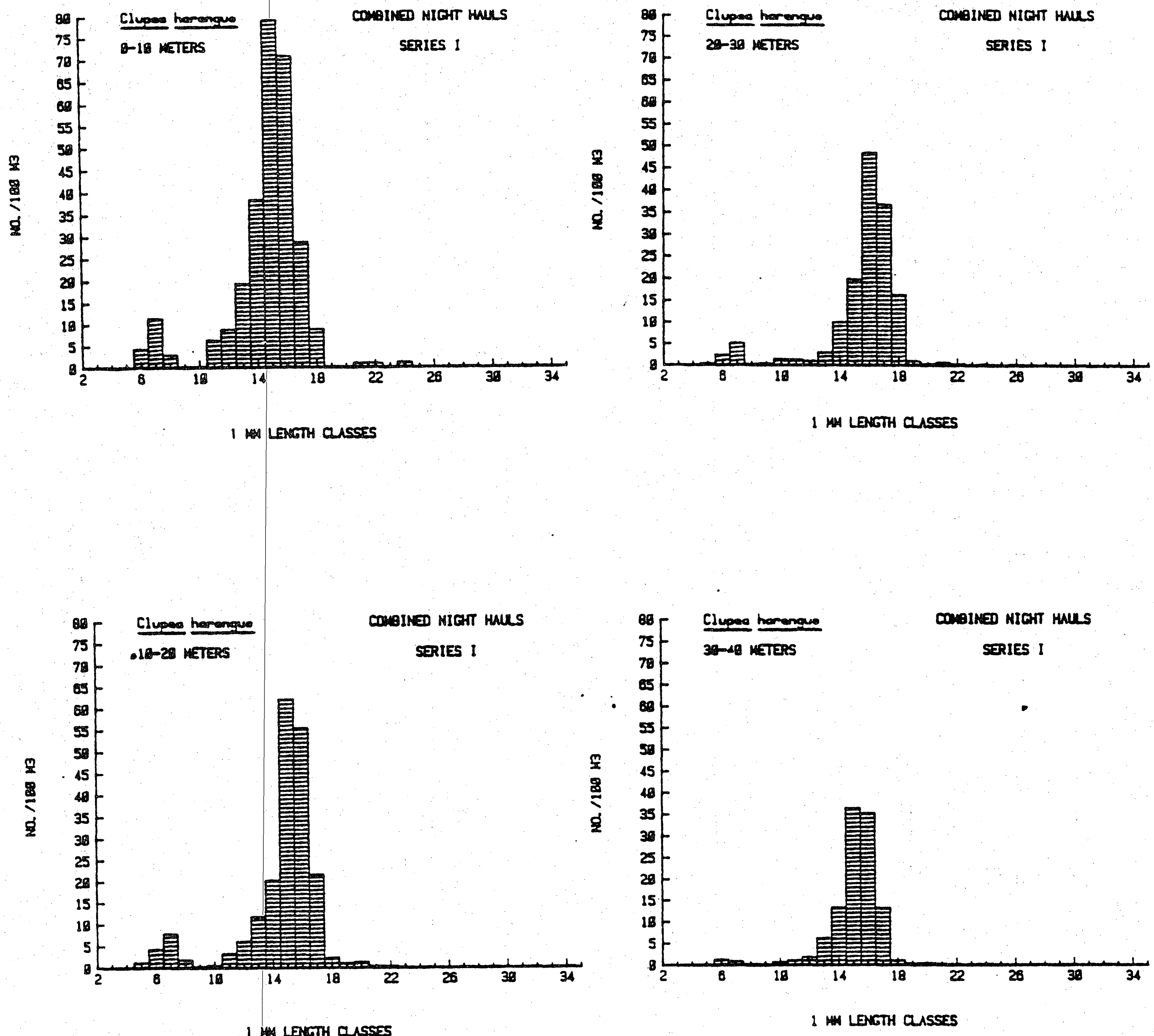
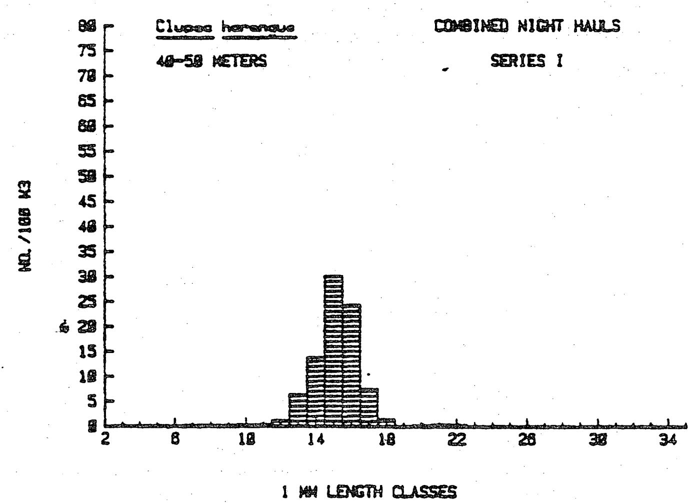
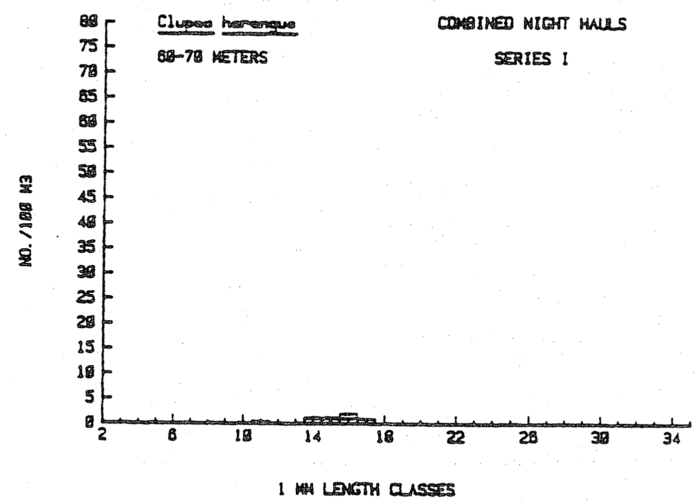


FIGURE 14 . LENGTH FREQUENCY HISTOGRAM FOR SERIES I NIGHT HAULS.





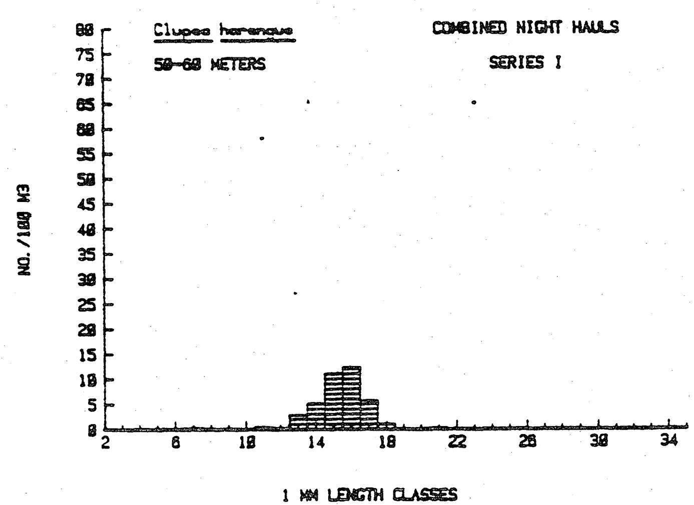
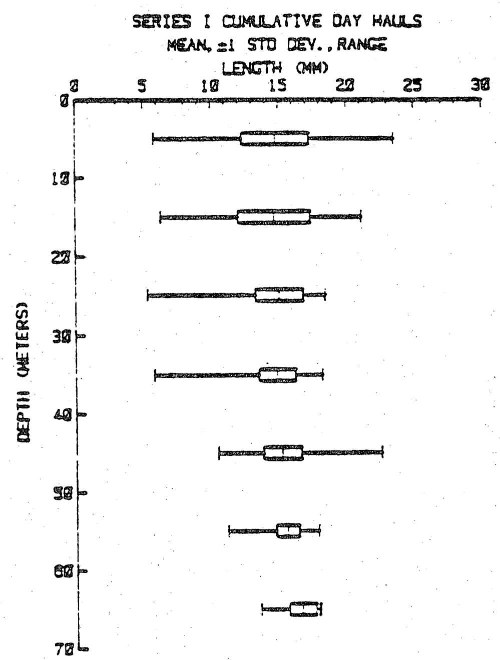


FIGURE 15 . LENGTH FREQUENCY HISTOGRAM FOR SERIES I NIGHT HAULS (CONT).



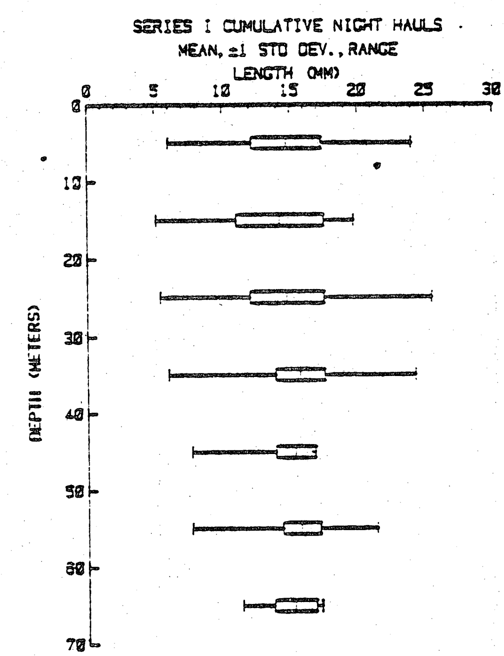


FIGURE 16 . SERIES I CUMULATIVE MEAN LENGTH, ±1 STANDARD DEVIATION AND RANGE.

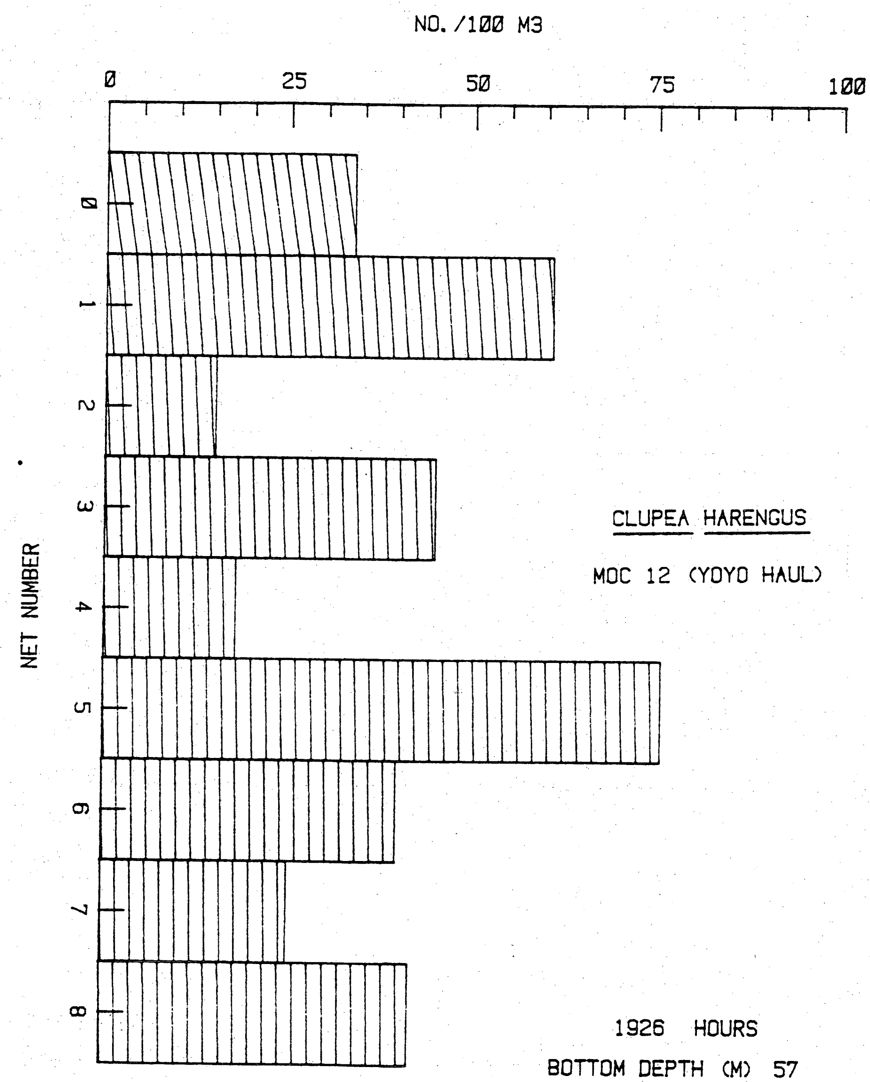


FIGURE 17 MOCNESS HAUL 12 , LARVAL DENSITIES FOR EACH DOUBLE OBLIQUE NET HAUL.

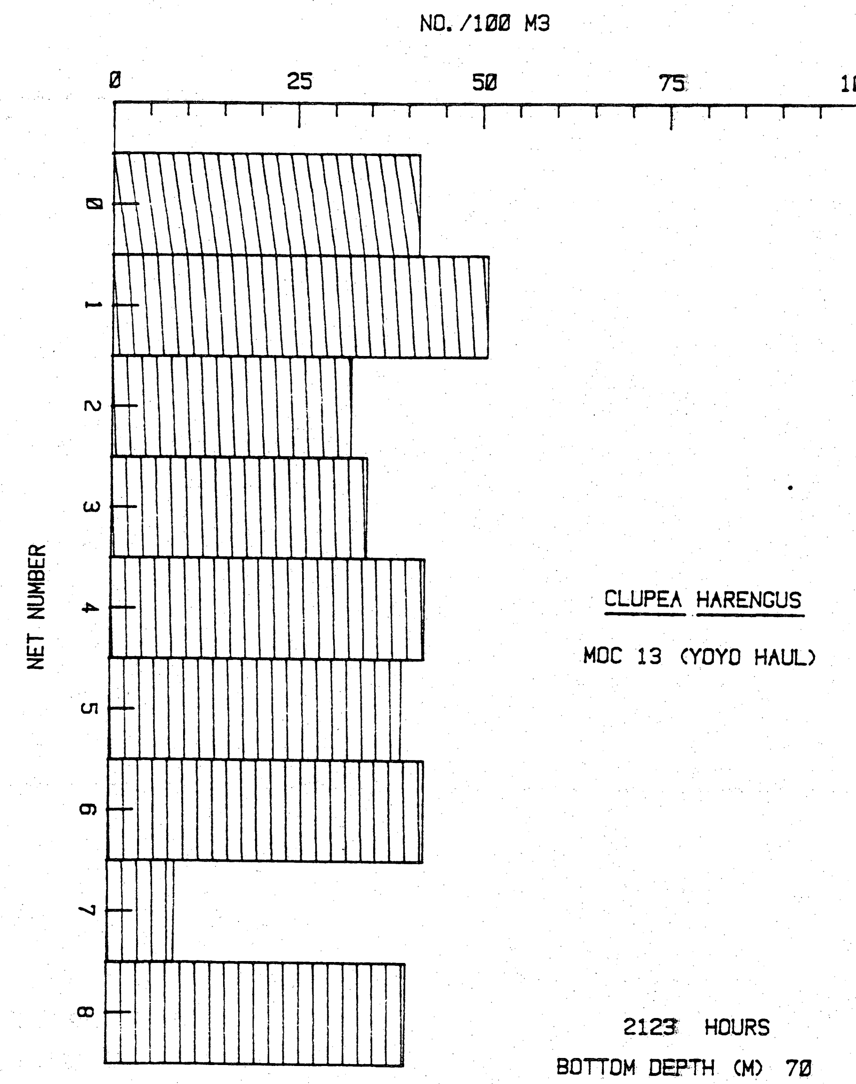


FIGURE 18 MOCNESS HAUL 13 , LARVAL DENSITIES FOR EACH DOUBLE OBLIQUE NET HAUL.

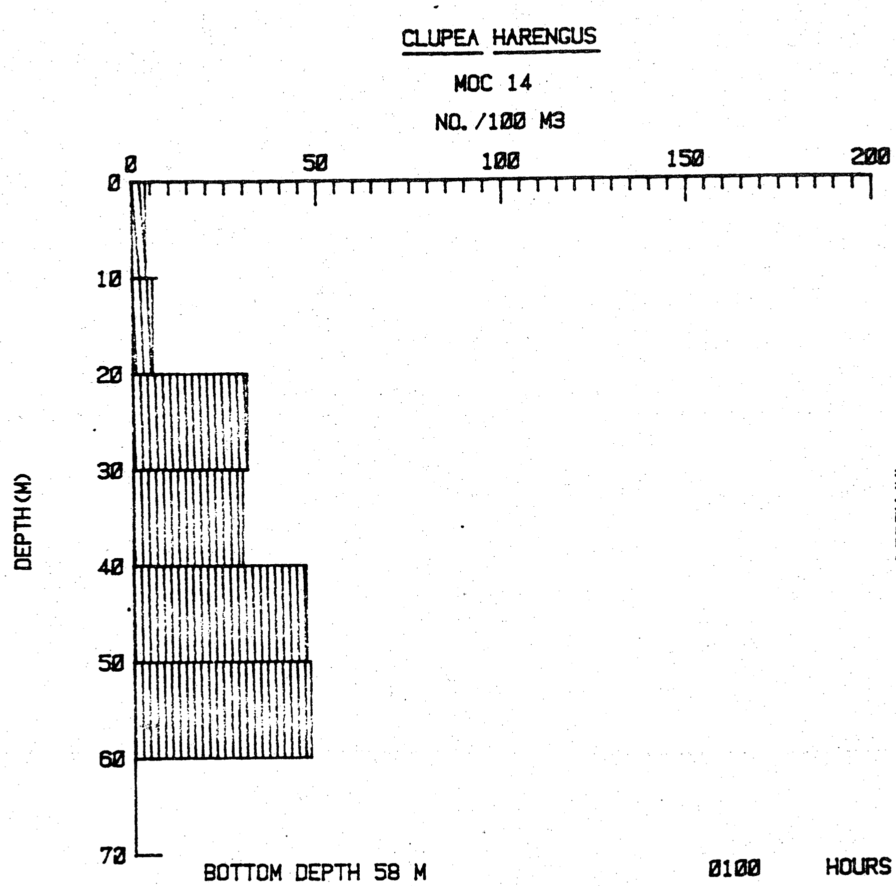


FIGURE 19 MOCNESS HAUL 14 LARVAL DENSITIES PER 10 METER DEPTH STRATA

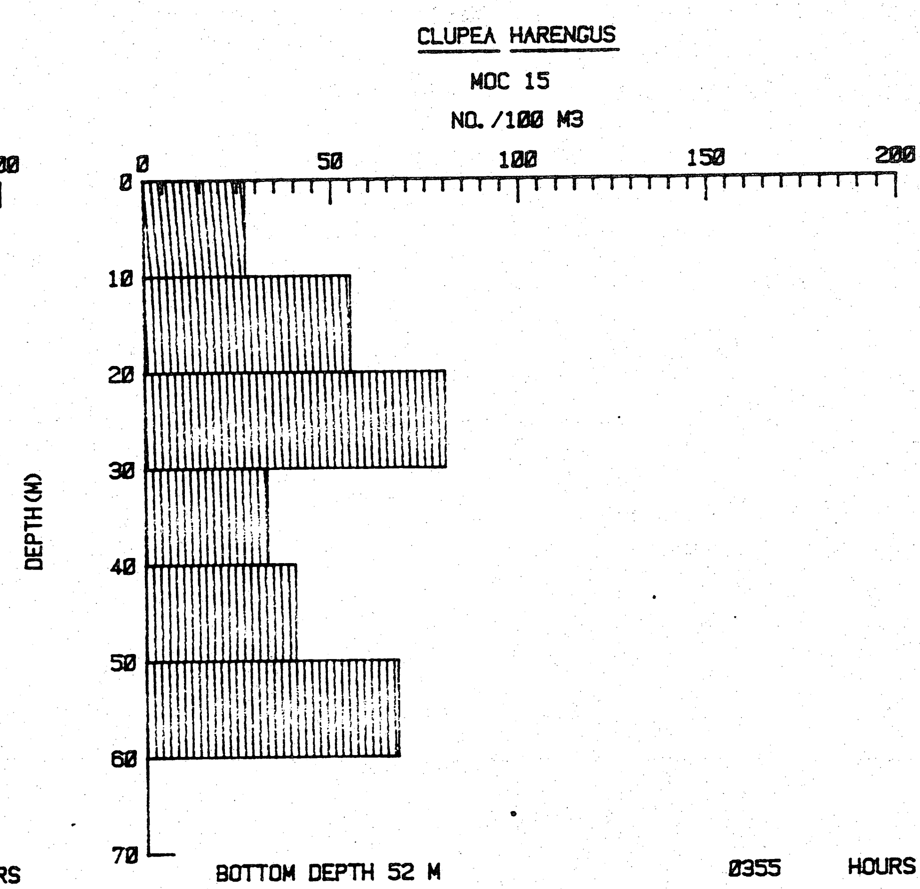


FIGURE 20 MOCNESS HAUL 15 LARVAL DENSITIES PER 10 METER DEPTH STRATA

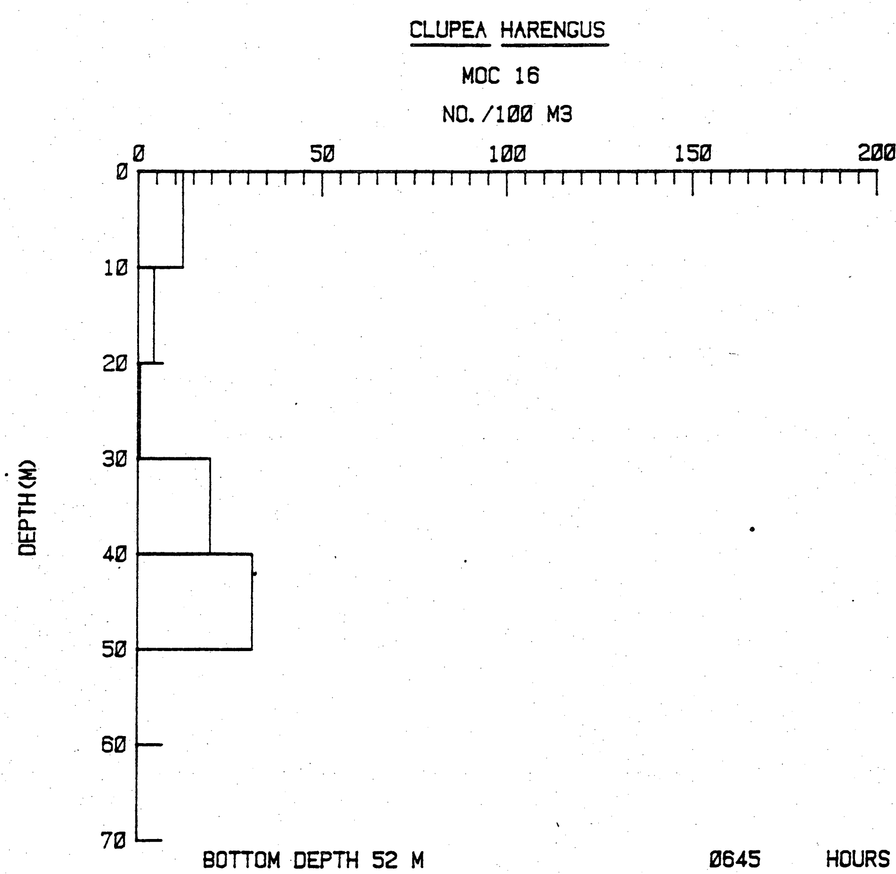


FIGURE 21 MOCNESS HAUL 16 LARVAL DENSITIES PER 10 METER DEPTH STRATA

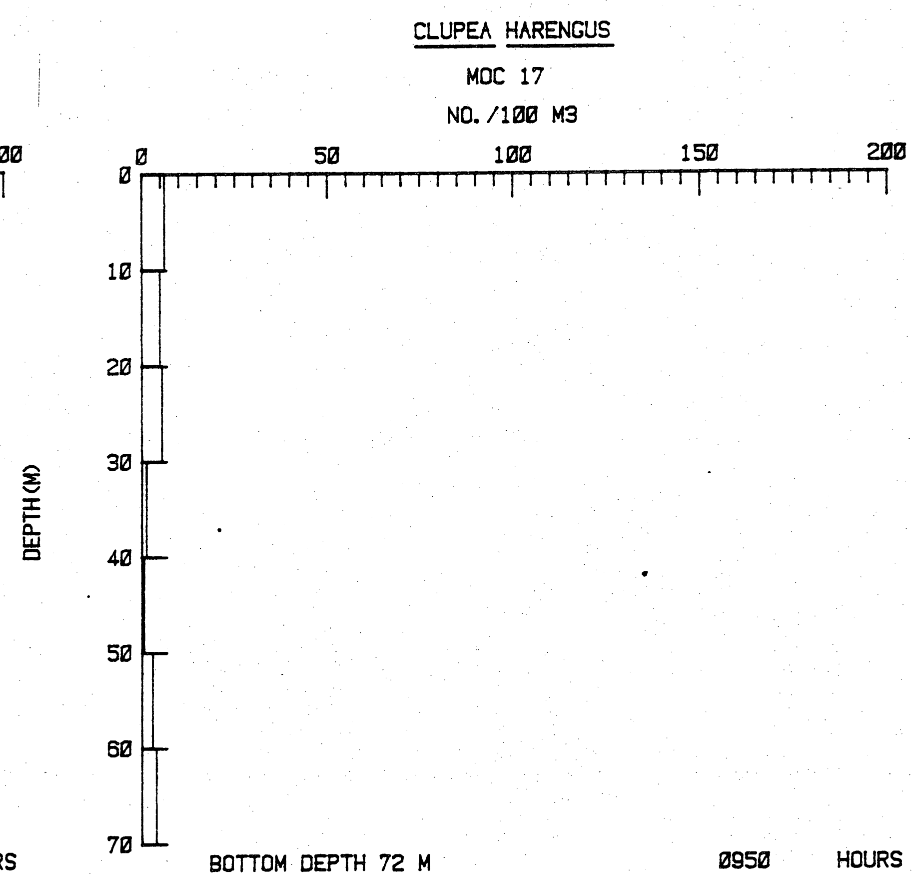


FIGURE 22 MOCNESS HAUL 17 LARVAL DENSITIES PER 10 METER DEPTH STRATA

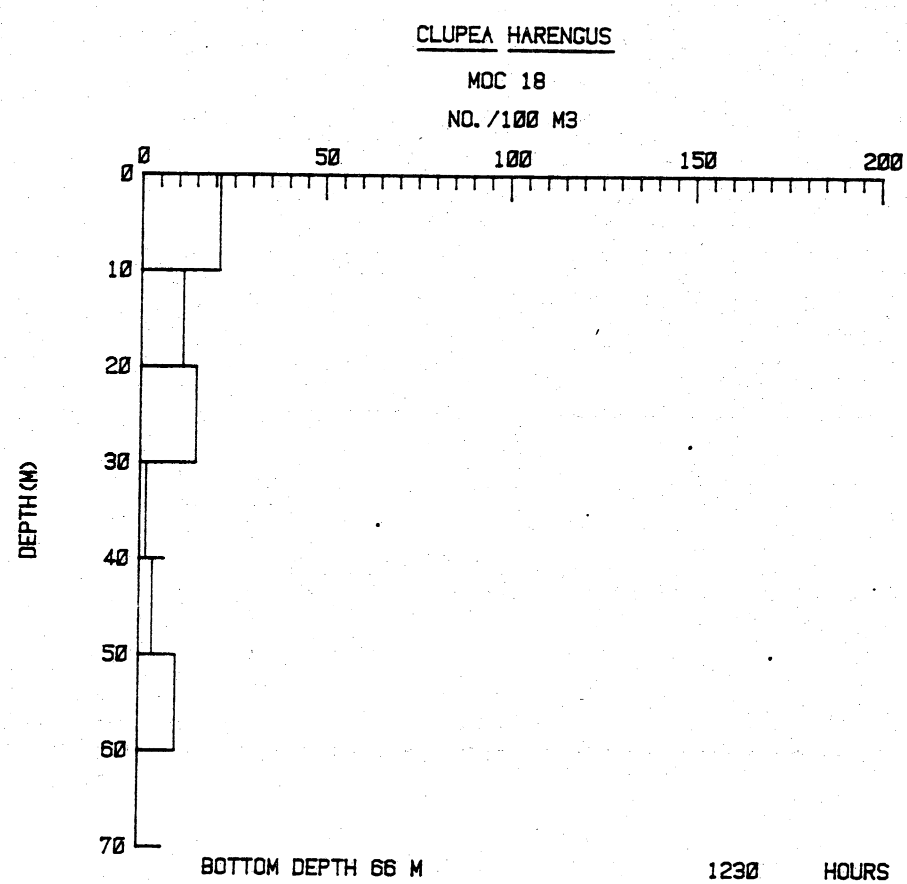


FIGURE 23 MOCNESS HAUL 18 LARVAL DENSITIES PER 10 METER DEPTH STRATA

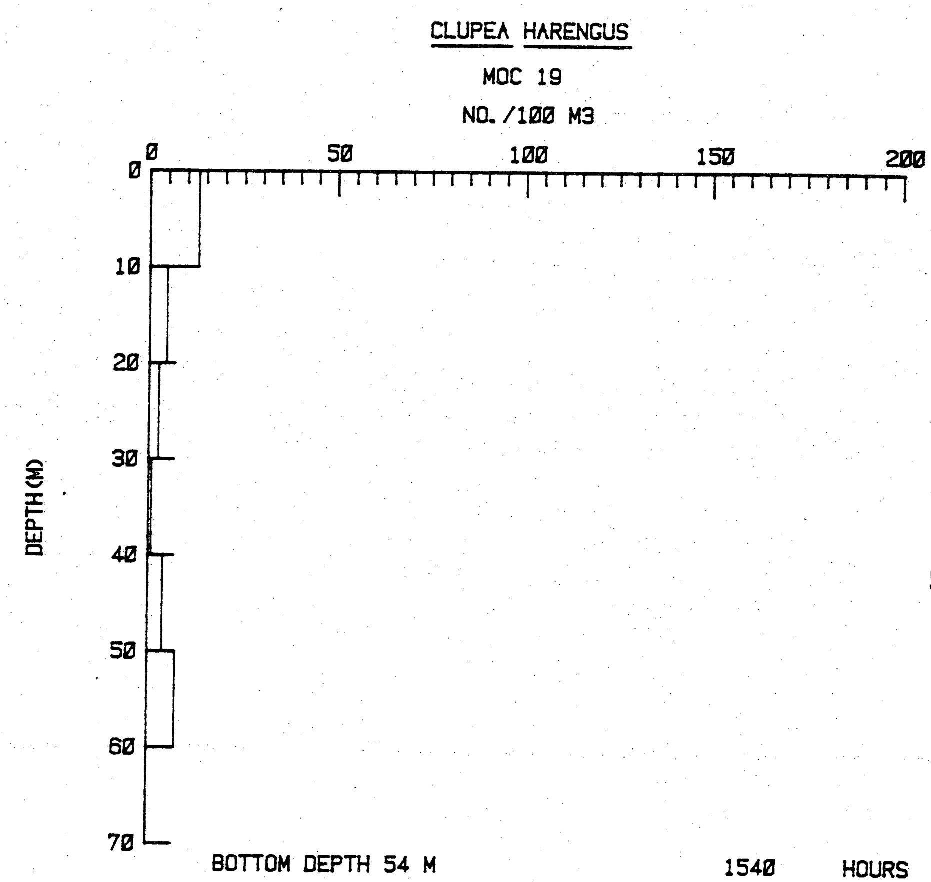


FIGURE 24 MOCNESS HAUL 19 LARVAL DENSITIES PER 10 METER DEPTH STRATA

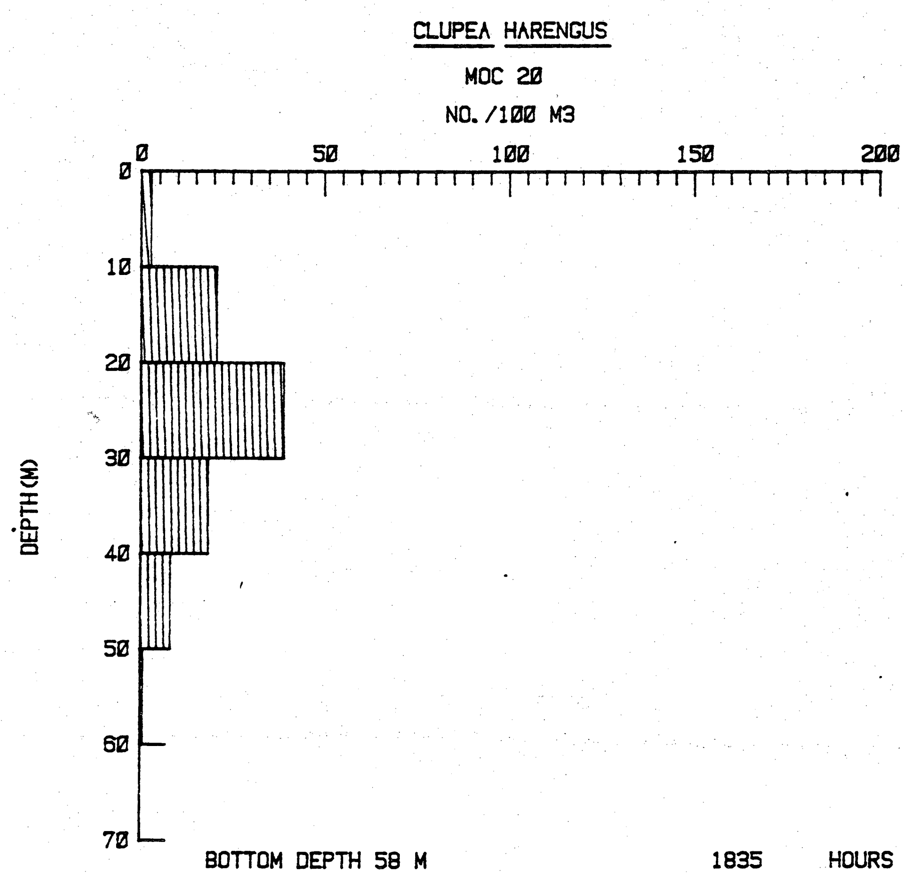


FIGURE 25 MOCNESS HAUL 20 LARVAL DENSITIES PER 10 METER DEPTH STRATA

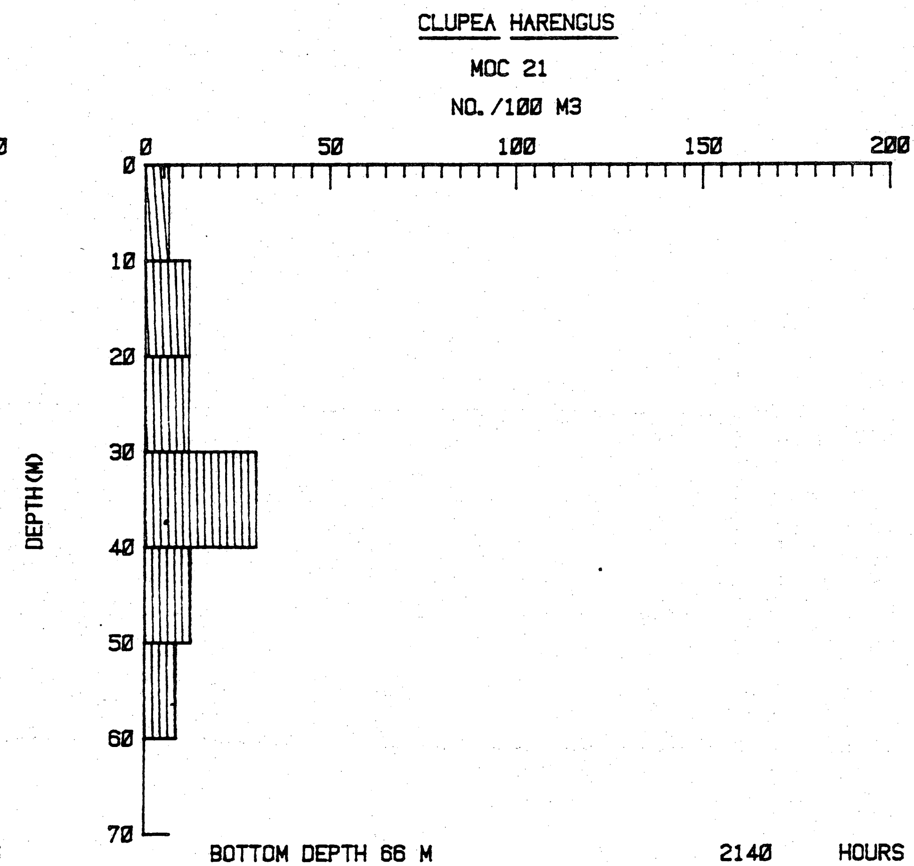
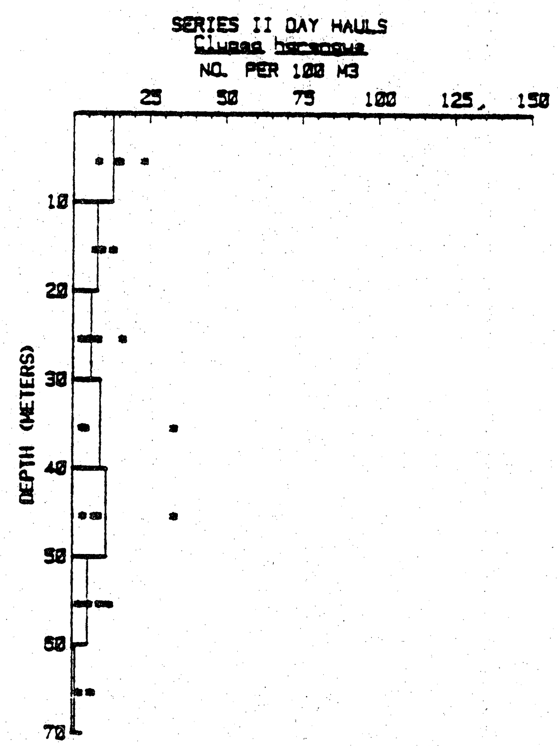


FIGURE 26 MOCNESS HAUL 21 LARVAL DENSITIES PER 10 METER DEPTH STRATA



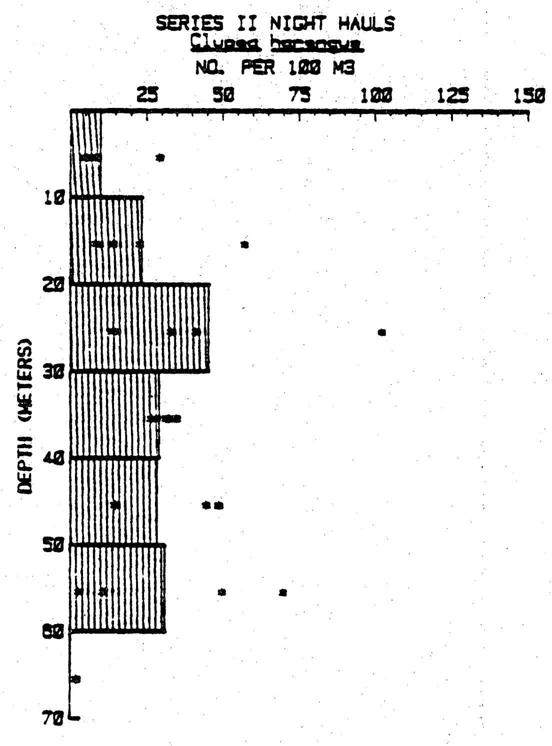


FIGURE 27. SERIES II COMBINED DAY AND COMBINED NIGHT HAUL MEANS WITH ACTUAL DATA POINTS (ZERO VALUES ARE RAISED FOR IDENTIFICATION).

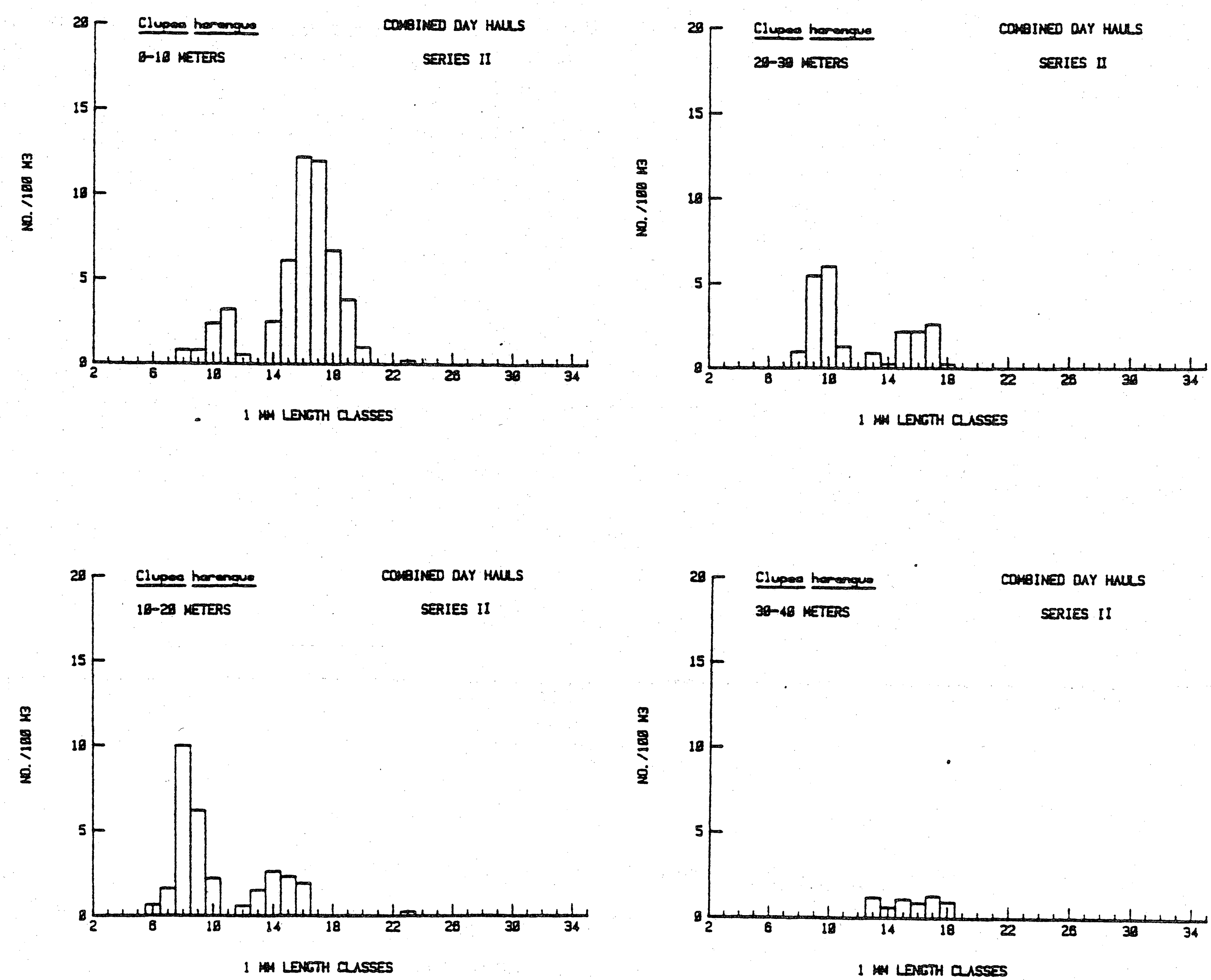
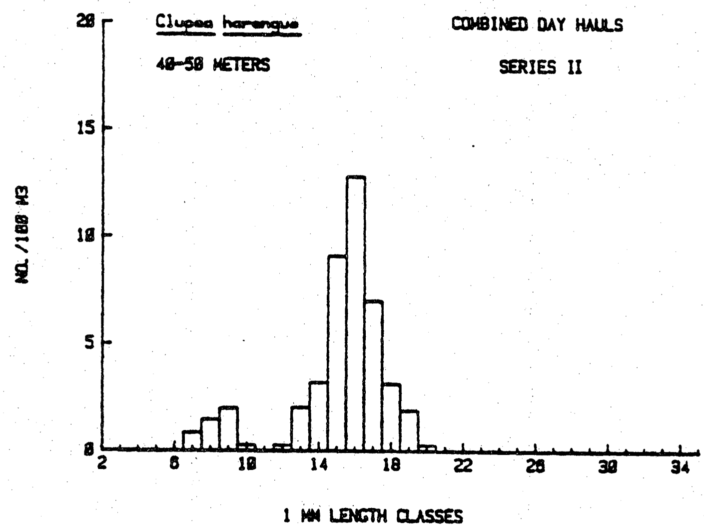


FIGURE 28 . LENGTH FREQUENCY HISTOGRAM FOR SERIES II DAY HAULS.



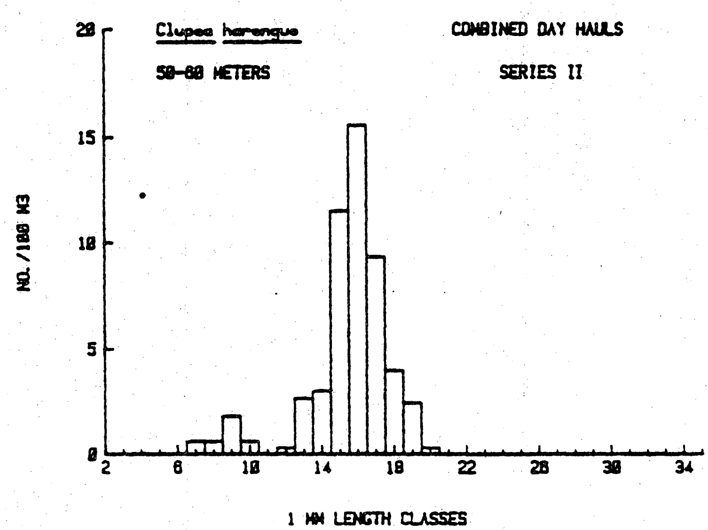


FIGURE 29 . LENGTH FREQUENCY HISTOGRAM FOR SERIES II DAY HAULS (CONT).

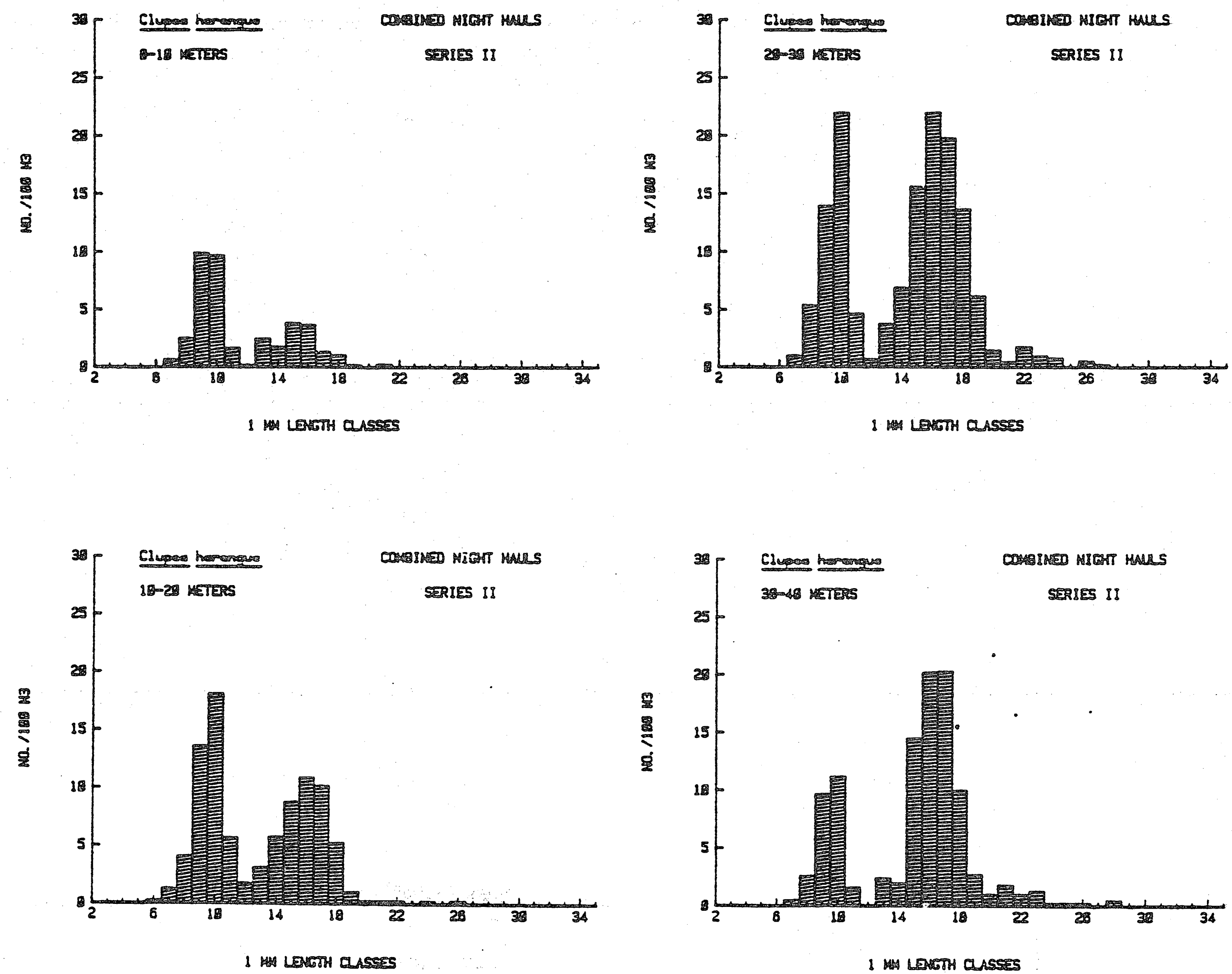
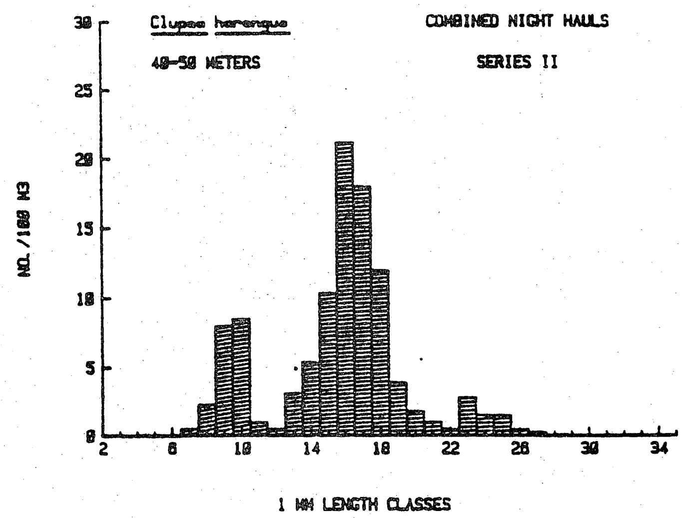


FIGURE 30 . LENGTH FREQUENCY HISTOGRAM FOR SERIES II NIGHT HAULS.



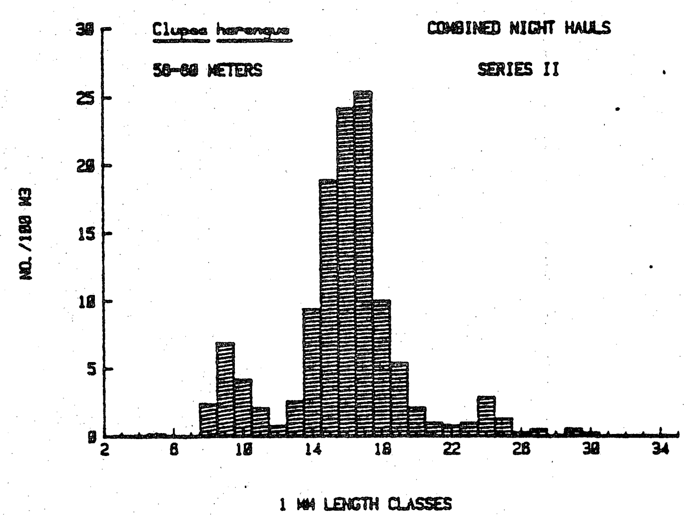
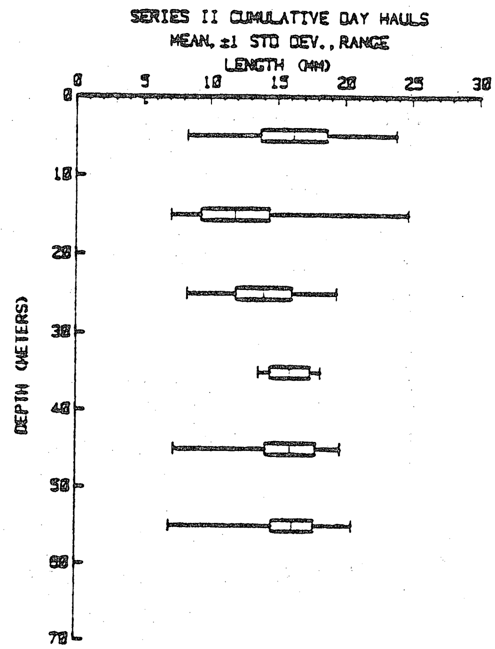


FIGURE 31 . LENGTH FREQUENCY HISTOGRAM FOR SERIES II NIGHT HAULS (CONT).



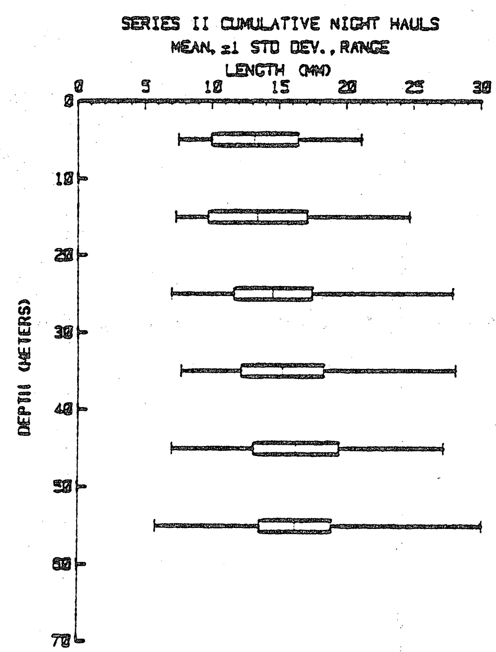


FIGURE 32 . SERIES II CUMULATIVE MEAN LENGTH, ±1 STANDARD DEVIATION AND RANGE.

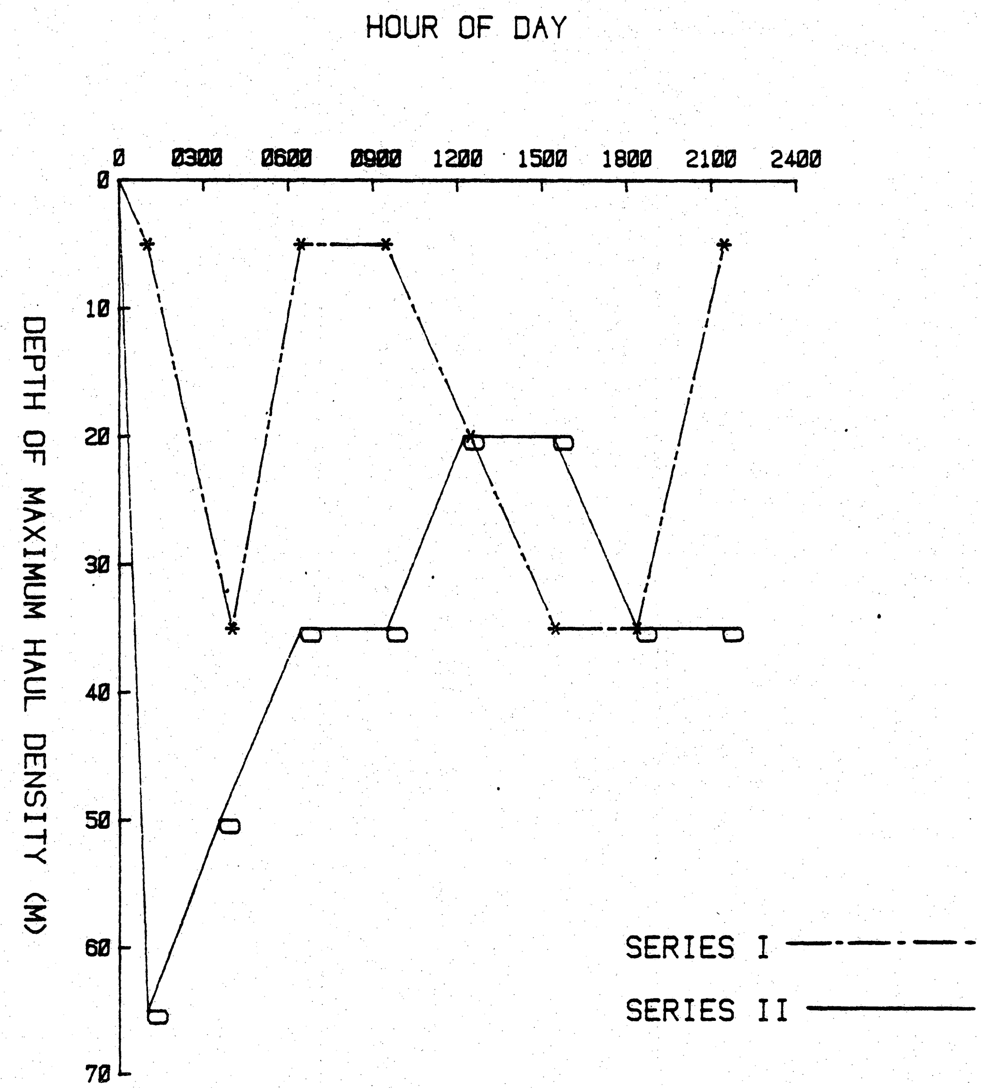
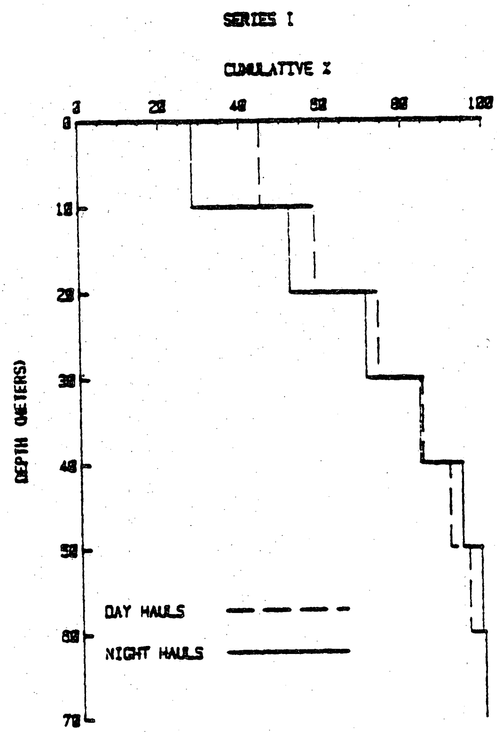
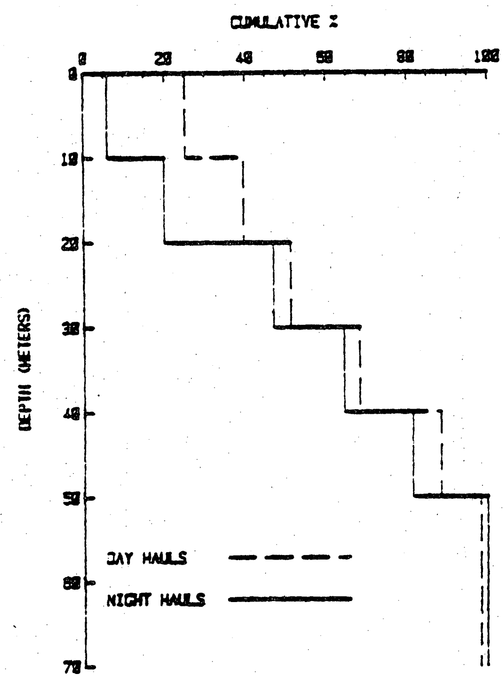


FIGURE 33 . PROFILE OF DEPTH STRATA WITH MAXIMUM HAUL DENSITIES FOR BOTH SERIES.



D = 17.40



D = 21.57

FIGURE 34 . CUMULATIVE PERCENTAGE CONTRIBUTION OF DAY AND NIGHT CATCHES. WITH APPROPRIATE 95% CONFIDENCE LEVEL STATISTIC.