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A preliminary report of the vertical distribution of herring larvae on Georges Bank

by

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Introduction

A special vertical distribution study of recently hatched herring larvae (*Clupea harengus harengus L.*) and associated zooplankton was made in conjunction with the Fall 1974 ICNAF Larval Herring Survey aboard *Delaware II* 74-12, 8-16 October. The first station, off Cape Ann near the base of Jeffreys Ledge (42° 40' N, 70° 25' W, 50 m depth), was occupied for a 24 hour period. The second station was located on the northeast part of Georges Bank (42° 00' N, 66° 40' W, 80 m depth) and was occupied for a 44 hour period. Only the preliminary results from a 20-hour portion of the Georges Bank station are reported in this paper.

Methods

An area of high larval concentration was located by oblique tows using a 61 cm bongo-net sampler. A vertical series was made on station every two hours employing six 20 cm bongo-net samplers (.333 and .053 mm mesh) set at 1, 10, 20, 30, 50, and 80 m depth. The vertical array of samplers was towed simultaneously for 30 minutes at 2 knots. Time-depth recorders (TDR) were attached to the towing wire near the bottom sampler and at various other sampler levels. A 100-pound lead ball was attached to the towing wire and, according to the TDR traces, dragged on the bottom during most hauls. The bottom sampler was located within 1 m of the lead ball and the sampler skipped along the bottom collecting some sand and benthic organisms. No opening-closing device was used with the samplers. A control tow was made to estimate contamination by setting the sampler array at depth and then immediately retrieving. About 10-12 minutes were normally required to set and retrieve the entire array.

It was believed little significant difference would be observed between occupying a fixed station and attempting to stay with the same water mass since the currents on Georges Bank are typically rotary (Miller *et al.*, 1963). Logistically, it was simpler to occupy a fixed station than to follow a free-drifting buoy.

Weather and hydrological observations were taken just prior to each tow series. A vertical profile of temperature and salinity was made by XBT drops and Nansen bottle casts.

In the laboratory, herring larvae were sorted, counted, and a subsample of 100 larvae was measured to the nearest mm (standard length). Chaetognaths also were identified and counted. Displacement volumes were made on the total plankton, and the crustacean component (total volume minus large and gelatinous organisms, chaetognaths, fish larvae). Further analyses are in progress of the crustacean component, stomach contents of the herring larvae, and potential food organisms from the fine mesh samples. Herring larvae and the various zooplankton components for five series, covering a 20-hour period on 14 October 1974 have been sorted to date from the .333 mesh samples.

Results

No clearly defined thermocline or halocline was evident during the sampling period, indicating a well-mixed water column (Table 1). Temperatures ranged from 13.6° C near the surface to 11° C at bottom and salinities ranged from 32.635 to 33.047 ppt, respectively. The weather was clear and sunny on 14 October and the sea state was calm, less than two feet in height.

High densities of herring larvae (*ca.* 1000/100 M^3) were observed in all tows (Table 2). Larvae were collected at all depths from surface to bottom, however, most larvae occurred between 10 and 50 m. Although the highest densities of larvae usually were at 30 and 50 m depths, there is some indication that part of the larval population occurred nearer to the surface at night (Figure 1). A comparison of day, night, and twilight catches of larvae in Table 3 supports this observation. Night/day and twilight/day ratios are mostly >1 above 20 m, whereas below 20 m the same ratios are mostly <1. Larval lengths ranged from 4 to 10 mm with the greatest percentage at 7 mm (Table 4). The mean length of larvae generally increased with depth but did not appear to change significantly by time. A greater percentage of larvae in the 4-6 mm length interval were located near the surface, whereas the older larvae, 7-10 mm, were distributed more from mid-depth to bottom. There is some indication that larvae greater than 7 mm were caught more frequently at 1 and 10 m depths by night and twilight than by day hauls. Further analyses of the samples may substantiate this trend. No larvae were observed with yolk-sacs. The guts on almost all larvae were intact and the eyes well pigmented.

Total plankton volume was evenly distributed by depth and time for the most part (Table 5). Higher volumes were collected near the surface. The crustacean component, consisting predominantly of the calanoid copepod *Centropages typicus*, was concentrated near the surface (Table 6). *Salpa fusiformis* comprised the bulk of the gelatinous component and was common at 50 and 80 m. High densities of the chaetognath *Sagitta elegans*, were collected near the bottom at 80 m (Table 7). They appear to exhibit the classical diurnal migration pattern, dispersing towards the surface at night. The various zooplankton components are compared by their weighted mean depth distributions in Table 8 and Figure 2. The integrated mean depth of herring larvae is intermediate between that of the other components and all plankters seem to exhibit some degree of diurnal movement.

Discussion

Seliverstov (1974) has reviewed the pertinent literature on the vertical distribution of herring larvae and made note of the contradictory observations reported by various authors. Night-day comparisons of larval catches, as an indication of diurnal migration, have been observed to be larger by night (Bridger, 1956; Tibbo *et al.*, 1958; Tibbo and Legare, 1960; Colton *et al.*, 1961; Lough *et al.*, 1975). However, others have observed higher catches by day, depending on size of larvae and depth of sampling (Bridger, 1956; Wood, 1971; Seliverstov, 1974).

Post-yolksac larvae were observed by Colton *et al.* (1961) to be more abundant by night than day in the upper 10 m of water; night-day ratios increased with length of larvae. Their evidence indicates that larval herring migrate into the surface waters by night and that the magnitude of these diurnal movements increases with size. Seliverstov (1974) found that night catches of larvae in the upper 25 m were twice that of day catches, while below 25 m, catches were greater by day indicating diurnal vertical migration. A very similar situation was observed in the present study by Lough. Night-day ratios from surface to 20 m depth indicate more larvae caught by night, whereas night-day ratios from 30 to 80 m indicate more larvae caught by day. Avoidance of the sampling gear may play an important role in night-day differences, particularly for larger larvae. Tibbo *et al.* (1958) found that 73% of all larvae were collected by night; night-day ratios were even more pronounced for larvae greater than 20 mm. Tibbo and Legare (1960) calculated a night-day ratio of 4.95 where 50% of the catches of larvae ranged in size from 6 to 10 mm. However, many of his samples were collected at shallow depths, less than 20 m.

Wood (1971) and Schnack (1974) observed that larger larvae were collected more abundantly near the surface by day, while Bridger (1958) observed larger larvae near the bottom during the day. In contrast, Colton *et al.* (1961) and Seliverstov (1973) report larger larvae (>8 mm) near the surface by night. Lough *et al.* (1975) report that surface neuston tows always caught a larger size frequency of larvae compared to oblique bongo hauls. However, an analysis of the bongo hauls shows that larger larvae were collected more by day than by night or twilight. Larvae collected in the present study were recently hatched and the range of lengths was considerably more restricted (4-10 mm) than in the above studies (Bridger, 1958: Stage I-V; Colton *et al.*, 1961: 5-31 mm +; Wood, 1971: 5-29 mm; Seliverstov, 1973: 5-25 mm; Schnack, 1974: 5-29 mm; Lough *et al.*, 1975: 4-33 mm).

Many of these disparate observations are undoubtedly due to differences in sampling gear, towing speed, level of sampling and random sampling errors. Some of the variability, however, must be attributed to the differential behavior of the larvae during their development under different environmental conditions, particularly bottom depth. All investigators agree that herring larvae perform vertical migrations sometime in their early life history, reacting in some manner to light changes. The question is, at

what stage in their development does this occur, and how is their behavior modified by physical and biological factors in their environment? The various stocks of herring undergo hatching and development at different seasons, in a wide range of habitats, experiencing different progressions of light regimes, temperature, food availabliity, etc. Only gross generalizations of the behavior and subsequent vertical distribution may be possible for worldwide studies. Detailed observations on behavior and distribution at certain stages of development may have to be reserved specifically for an isolated stock. Vertical distribution comparisons should be made only for corresponding stages of larvae.

Seliverstov (1974) seems to give the most complete picture of the vertical distribution of herring larvae by age, and his work helps to verify and explain the observations made in this study. Based on both field and laboratory observations of larval reactions to light, Seliverstov concludes that yolksac larvae do not respond to light, during their first 12 h, but by 48 h most larvae have a strong phototactic response and migrate into mid-waters. Woodhead and Woodhead (1955) also observed this phototactic response of yolksac larvae to diffuse light during their first 5 days. According to Seliverstov, at 3-5 days (6.63-7.44 mm) the positive phototaxis weakens so that larvae stay near the bottom during both day and night. This would explain why the mean size of larvae increased with depth (6.56-7.49) in the present study. After 5-7 days, when the larvae reach a length of 7.5 mm, they begin to exhibit diurnal movements migrating into the surface layers by night. Larvae 9-17 mm were observed to migrate from bottom (100 m) to surface. Laboratory studies by Seliverstov show that 8 day larvae respond negatively to light by day but have a weak photopositive response by night.

Some considerations for future work

The vertical movements of herring larvae and associated zooplankton may represent a key element in the understanding of various mortality mechanisms such as dispersal and prey-predator interactions. In view of the complexities of diurnal movements, a quantitative description of them will require a coordinated program of intensive field sampling of all length groups of larval herring under different conditions, in conjunction with laboratory studies of larval behavior. Specific studies which should receive consideration are given below.

1. Highest priority should be the acquisition of opening-closing controlled sampling gear with real-time shipboard environmental sensing monitors to investigate the detailed vertical distribution of larvae, their food organisms, and predators. Sampling needs to be integrated within vertical strata by oblique hauls as opposed to just sampling horizontally on a series of depth levels. Vertical discontinuities of larvae and their food orgainisms are well known. Only when we know the precise level where these organisms occur in relation to the environment can we begin to understand the dynamics of predator-prey interactions, adaptive significance of vertical migration, the causal mechanisms of "patchiness" and its significance. The isolation of critical mortality mechanisms under controlled laboratory conditions has limited value without field documentation of equal technical sophistication. Models of pre-recruit survival should first be based on field evidence and secondarily, laboratory work should corroborate or reject these hypotheses.

2. Laboratory and field studies should be undertaken to analyze the phototactic and/or photokinetic behavior of the larvae at various stages of development as may be modified by extrinsic and intrinsic factors, *i.e.*, temperature, presence of predators and prey, hunger state. *In situ* observations of recently hatched larvae should be made by divers.

3. The preliminary analysis of the zooplankton component associated with herring larvae identified two potential predators; *Sagitta elegans* and *Centropages typicus*. Predation may be the major mortality process of recently hatched larvae. Both of the above species are very abundant on Georges Bank and co-occur with herring larvae. *Sagitta elegans* is a known voracious predator and appeared to be distributed near the bottom, and egg beds are known to occur in this general area. Lebour (1922,1923) cites evidence of chaetognaths preying on fish larvae. *Centropages typicus* is a ubiquitous, surface dwelling copepod (Bigelow, 1926) and is omnivorous, preferring animal food (Anraku and Omori, 1963). Laboratory experiments should be initiated to investigate these potential predators of recently hatched larvae in the manner of Lillelund and Lasker (1974) and Theilacker and Lasker (1974). Transitional experiments of predator-prey relationships should be carried out in enclosed environments within the natural habitat to bridge the gap between field and laboratory observations.

4. A complete series of larvae of known age should be collected in order to stage them by morphological maturity, rather than just by total length. Size of larvae alone is a crude measure of their physiological age and state of development.

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Table 1. Temperatures (°C) and salinities (0/00) by depth and time.

	Time (DST)					
Depth (m)	0600	1000	1400	1800	2200	$\bar{X}$
1	12.20	13.60	13.60	13.10	13.10	13.10
10	12.15	12.70	12.70	12.75	12.70	12.60
20	12.10	12.70	12.70	12.20	12.40	12.42
30	11.40	12.70	12.10	11.90	12.35	12.09
50	11.20	12.20	11.90	11.10	12.20	11.70
80	11.10	12.00	11.85	11.00	12.05	11.60
$\bar{X}w$ (weighted mean)	11.34	12.28	12.05	11.40	12.21	

	Time (DST)					
Depth (m)	0600	1000	1400	1800	2200	$\bar{X}$
1	32.854	32.772	32.635	32.712	32.753	32.745
10	-	32.773	32.635	-	32.749	32.719
20	-	32.735	32.779	-	32.789	32.768
30	-	32.741	32.933	-	-	32.837
50	-	32.772	33.024	-	-	32.898
80	-	32.785	33.047	-	32.816	32.883
$\bar{X}w$	32.854	32.769	32.971	32.712	32.805	

Table 2. Number of herring larvae per $100m^3$ by depth and time.

	Time (DST)						
Depth (m)	0600	1000	1400	1800	2200	Total	%
1	29	7	0	248	717	1001	3.3
10	150	420	265	1526	693	3054	10.0
20	189	1003	1042	1932	1217	5383	17.6
30	398	2367	2520	2417	1266	8968	29.3
50	1720	2137	2352	760	1209	8178	26.7
80	1453	785	872	302	621	4033	13.2
Total	3939	6719	7051	7185	5723	30617	100.1

Sunrise 0610
Sunset 1722

Table 3. A comparison of day, twilight, and night catches of herring larvae.

	Time (DST)					
Depth (m)	Day	Twilight	Night	T/D	N/T	N/D
1	4	139	717	34.8	5.2	179.3
10	343	838	693	2.4	0.8	2.0
20	1023	1061	1217	1.0	1.2	1.2
30	2444	1408	1266	0.6	0.9	0.5
50	2245	1240	1209	0.6	1.0	0.5
80	829	876	621	1.1	0.7	0.8
Total	6888	5562	5723	0.8	1.0	0.8

Day: 1000h + 1400h catches averaged
Twilight: 0600h + 1800h catches averaged
Night: 2200h catches

Table 4. Length frequency and mean length of herring larvae by depth and time.

Length (mm)	Time (DST) 0600	1000	1400	1800	2200	Total	%
1m Depth Level							
4				1		1	0.5
5	1	1		8	1	11	5.0
6	3	2		33	12	50	22.6
7	11	1		55	56	123	55.7
8	2			3	28	33	14.9
9					3	3	1.4
10							
$\bar{X}$	6.80	6.00		6.51	6.93	6.56	
10m Depth Level							
4		1				1	0.2
5	4	2	2	2		10	2.0
6	25	32	21	38	6	122	24.9
7	45	56	66	50	55	272	55.5
8	13	7	11	10	33	74	15.1
9	3	2			6	11	2.3
10							
$\bar{X}$	6.74	6.72	7.46	6.68	7.39	7.00	
20m Depth Level							
4							
5	5	1			1	7	1.4
6	15	24	20	23	5	87	17.4
7	49	55	70	59	39	272	54.4
8	25	20	10	18	49	122	24.4
9	6				6	12	2.4
10							
$\bar{X}$	7.79	6.65	6.76	7.29	7.31	7.16	
30m Depth Level							
4		1				1	0.2
5		6	5		2	13	2.6
6	3	30	24	7	8	72	14.4
7	30	53	62	61	54	260	52.1
8	53	10	8	28	30	129	25.9
9	13		1	4	5	23	4.6
10	1					1	0.2
$\bar{X}$	7.79	6.65	6.76	7.29	7.31	7.16	
50m Depth Level							
4							
5		6		1		7	1.4
6	6	50	7	19	5	87	17.4
7	49	34	53	64	63	263	52.6
8	43	8	39	14	30	134	26.8
9	2	1		2	2	7	1.4
10		1	1			2	0.4
$\bar{X}$	7.41	6.51	7.35	6.97	7.29	7.11	
60m Depth Level							
4							
5							
6	4	5	9	8	7	33	6.6
7	34	21	48	53	51	207	41.4
8	60	66	40	38	40	244	48.8
9	2	8	3	1	2	16	3.2
10							
$\bar{X}$	7.60	7.77	7.37	7.32	7.37	7.49	

Table 5. Total plankton volume ($cm^3/100m^3$) by depth and time.

	Time (DST)						
Depth (m)	0600	1000	1400	1800	2200	Total	%
1	52.8	24.2	39.3	120.5	50.5	287.3	19.2
10	73.1	39.4	62.0	88.7	34.5	297.7	19.9
20	58.7	34.8	65.1	39.9	42.2	240.7	16.1
30	61.0	40.5	64.2	49.8	31.9	247.4	16.6
50	63.4	44.3	39.7	37.1	21.5	206.0	13.8
80	58.9	57.8	47.3	31.0	18.8	213.8	14.3
Total	367.9	241.0	317.6	367.0	199.4	1492.9	

Table 6. Crustacean component plankton volume ($cm^3/100m^3$) by depth and time.

	Time (DST)						
Depth (m)	0600	1000	1400	1800	2200	Total	%
1	51.0	24.2	39.3	93.8	42.0	250.3	20.6
10	70.6	38.5	62.0	54.6	28.5	254.2	20.9
20	57.1	33.9	63.5	33.4	31.5	219.4	18.0
30	58.7	34.9	58.1	35.8	29.5	217.0	17.8
50	42.3	41.3	33.4	27.1	15.6	159.7	13.1
80	27.5	38.5	23.0	17.2	9.8	116.0	9.5
Total	307.2	211.3	279.3	261.9	156.9	1216.6	

Table 7. Number of *Sagitta elegans* per $100m^3$ by depth and time.

	Time (DST)						
Depth (m)	0600	1000	1400	1800	2200	Total	%
1	4	4	0	14	1218	1240	7.0
10	2	10	5	70	355	442	2.5
20	3	40	5	91	316	455	2.6
30	18	71	6	482	358	935	5.2
50	503	59	118	1659	193	2532	14.2
80	3721	2422	4962	732	392	12229	68.6
Total	4251	2606	5096	3048	2832	17833	

Table 8. A comparison of weighted mean depths in meters of herring larvae and other planktonic components by time.

	Time (DST)				
Plankton Component	0600	1000	1400	1800	2200
Herring larvae	55.7	39.4	61.5	26.3	31.5
Total plankton volume	31.7	38.0	30.5	20.8	24.0
Crustacean plankton volume	26.0	34.5	25.7	19.5	21.7
Sagitta elegans	76.1	76.7	79.1	52.0	22.2

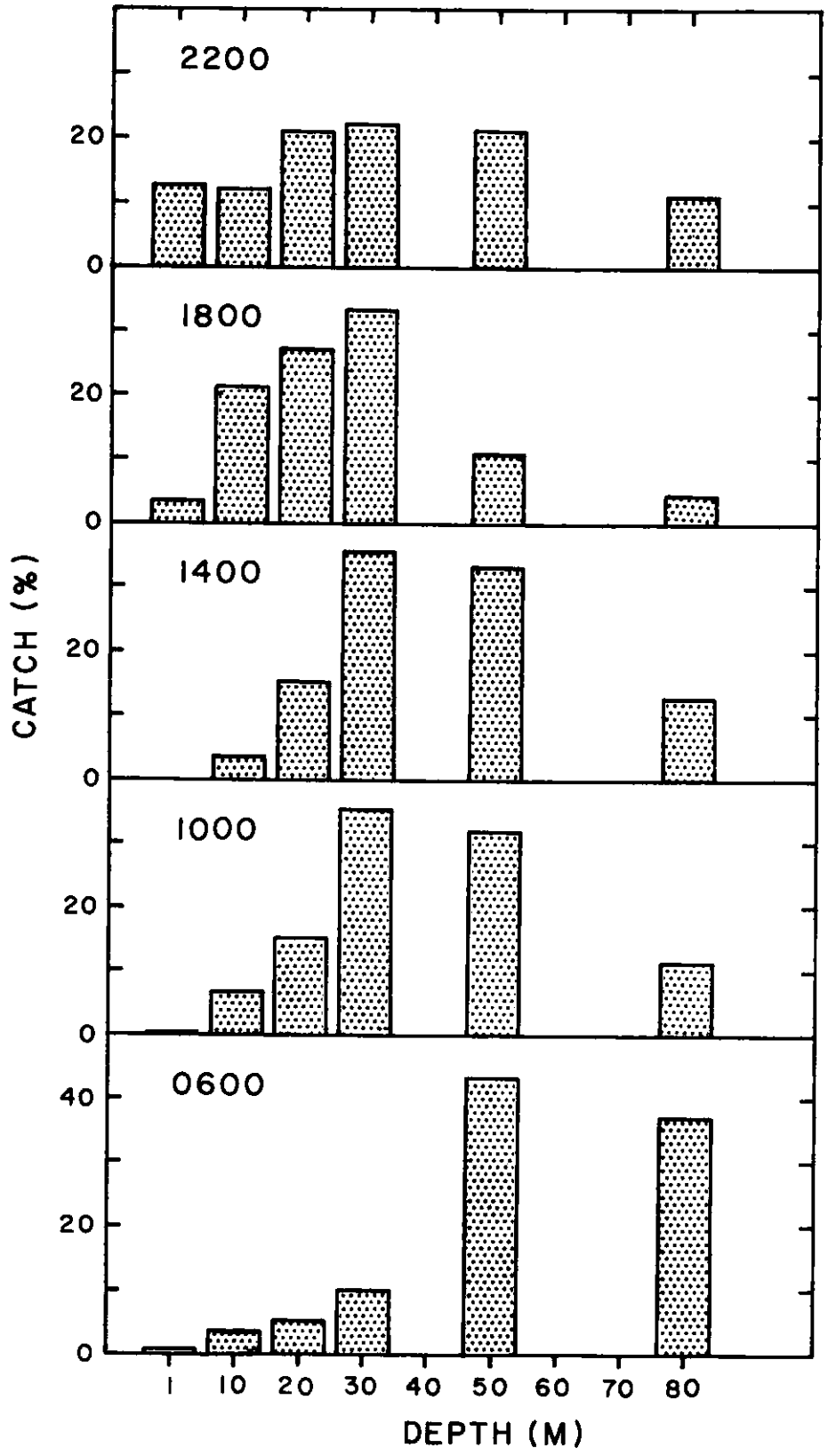

Figure 1. Distribution of herring larvae by depth and time. Georges Bank (42°00', 66°40'), 14 October 1974.

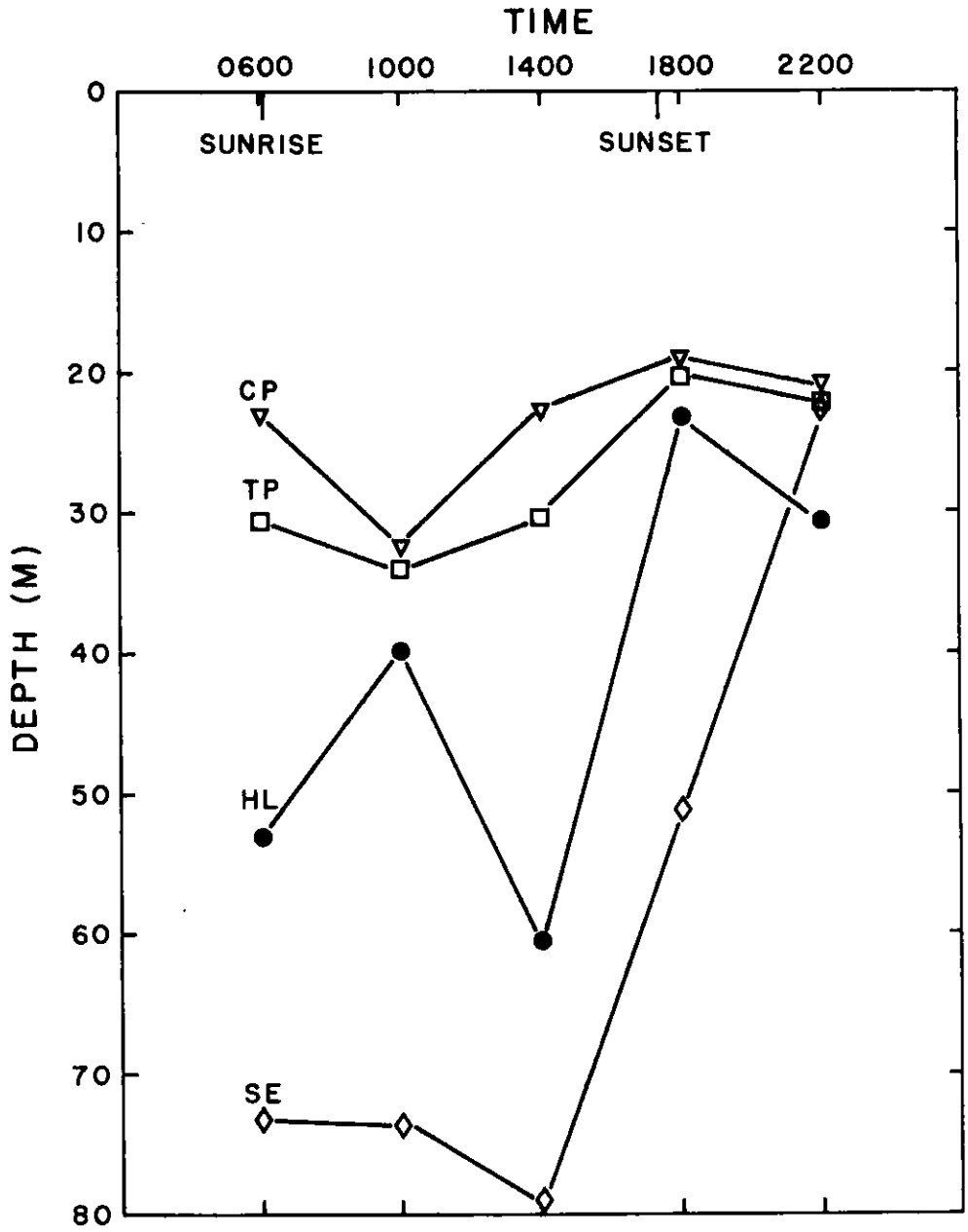

Figure 2. A comparison of various zooplankton components by weighted mean depths in meters. Total Plankton (TP), Crustacean Plankton (CP), Herring Larvae (HL), Sagitta elegans (SE).