Cephalopods from Deepwater Dumpsite 106 (Western Atlantic): Vertical Distribution and Seasonal Abundance

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and
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ABSTRACT

Lu, C. C., and Clyde F. E. Roper. Cephalopods from the Deepwater Dumpsite 106 (Western Atlantic): Vertical Distribution and Seasonal Abundance. *Smithsonian Contributions to Zoology*, number 288, 36 pages, 11 figures, 5 tables, 1979.—The vertical distribution, seasonal occurrence, relative abundance, spawning cycles, growth trends, and relationship to water types of 36 species of oceanic cephalopods are delineated from the Deepwater Dumpsite 106 (DWD 106) based on four seasonal cruises. The most commonly captured species were *Pterygioteuthis gemmata, Abraliopsis pfefferi, Illex illecebrosus, Histioteuthis reversa,* and *Mastigoteuthis magna*. Information on probable spawning seasons was gained for the first time for *I. illecebrosus, A. pfefferi, P. gemmata, H. reversa, Megalocranchia megalops,* and *Alloposus mollis*. Closing-net captures provided data on several species for which vertical distributions formerly were unknown: *M. magna, Abralia redfieldi, A. veranyi, Ancistroteuthis lichtensteini, Histioteuthis elongata, Egea inermis*. *Mastigoteuthis magna* is recorded for the first time since its original description in 1913. Several species occurred primarily in a particular water type. For example, *H. reversa, A. pfefferi,* and *M. megalops* occurred primarily in slope water, *Chiroteuthis veranyi* occurred only in (warm core) eddy water, while *P. gemmata* occurred about equally in both water types. Tests of co-occurrence of species between water types and cruises indicated that the species compositions were largely dissimilar. Only five species occurred on all four cruises: *A. pfefferi, H. reversa, M. magna, T. pavo,* and *A. mollis,* while five additional species occurred on any three of the four cruises.

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Contents

Cephalopods from Deepwater Dumpsite 106 (Western Atlantic): Vertical Distribution and Seasonal Abundance

C. C. Lu and Clyde F. E. Roper

Introduction

This report concerns the cephalopods (squids and octopods) in the midwater fauna sampled in the deepwater dumpsite (DWD 106). A total of four sampling cruises was made to the dumpsite to conduct baseline studies and to determine the effects on midwater animals of dumping wastes into the oceanic habitat. The dumpsite is used for the disposal of acid waste, industrial chemicals, and radioactive wastes, principally in liquid form either in solution or suspension. (NOAA, 1975).

The objectives of this study on the cephalopod component of the midwater fauna in the area of the deepwater dumpsite are to determine (1) species composition, (2) vertical distribution, (3) seasonal occurrence, (4) relative abundance, (5) spawning tendencies, and (6) relationship to water types. These objectives are achieved to varying degrees within the limitations of the sampling program.

LOCATION.—The dumpsite (DWD 106) is located 90 miles east of Cape Henlopen, Delaware, at 38°40'N to 39°00'N and 72°00'W to 72°30'W (Figure 1). The rectangular site lies over the continental slope and rise, where water depths range from 1550 m in the northwest corner to 2750 m in the southeast corner. Bounded on the west by shelf (coastal) water, the dumpsite is characterized by slope water that is influenced by mixing from the shelf water and Gulf Stream (warm core) eddies. Slope water has characteristics of oceanic water and its temperature-salinity relationship is very similar to North Atlantic central water (Warsh, 1975a). The physical characteristics of the dumpsite water are complicated by the periodic passage of anticyclonic Gulf Stream eddies through the area. Such warm core eddies occur in the dumpsite area about three times a year, so the site is occupied by eddy water about 20% of the year (Bisagni, 1976).

SAMPLING.—Details of the biological sampling program are given by Krueger, et al. (1977) and are summarized here. Four cruises that roughly approximated the four seasons were made to deepwater dumpsite 106: cruise 1, May 1974 (spring); cruise 2, July–August 1975 (summer); cruise 3, February 1976 (winter); cruise 4, August–September 1976 (fall).

Cruises 1 and 4 employed only a non-closing net, a 10-foot (3.09 m) Isaacs-Kidd midwater trawl (IKMT), so actual depths of habitation and vertical migrations could not be determined. The tows during these cruises (10 on cruise 1, 8 on cruise 4) were taken at night with the open IKMT fished with the oblique-haul technique. Depths ranged

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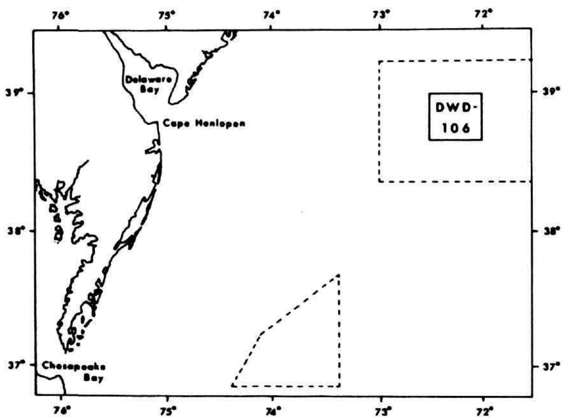

FIGURE 1.—Deepwater dumpsite 106 (solid line box) and areas where sampling was conducted during the study (broken line).

from 550–0 m to 790–0 m during cruise 1 and from 675–0 m to 950–0 m during cruise 4.

Cruises 2 and 3 employed the closing-net technique with a discrete-depth sampler on a 10-foot IKMT, so information was gained on the vertical aspects of distribution, abundance, and stratification of the midwater fauna. The IKMT was lined entirely with 0.95-centimeter (3/8 inch) stretch mesh webbing and terminated with a 1-meter plankton net equipped with a 4-chambered cod-end sampler (Aron, et al., 1964). Four samples, three closed, one open, were taken during each haul, and fishing depth of the net was monitored aboard ship so actual depths for each successive sampling chamber could be selected.

The primary trawling technique during cruises 2 and 3 consisted of oblique tows, in which the net was set to the desired depth with all chambers open to allow free flow of water; then the net was retrieved slowly and the chambers closed at selected, usually equal, intervals of decreasing depth. On cruise 2 only some horizontal tows were made, during which the net was set to a desired fishing depth and the chambers were fished sequentially at that depth. The sampling regime called for trawling at specified depths from the surface to 2000 m both day and night, but during cruise 2 the towing cable had to be cut and sampling was restricted mainly to less than 800 m and sampling during cruise 3 was limited by short time and an unsatisfactory trawling arrangement. Discrete depth samples during cruise 2 were taken from the surface waters to 800 m, with a few samples as deep as 1000 m. Cruise 3 closing-net sampling was limited, so that completion of the sampling regime was not achieved shallower than 200 m during the day or deeper than 500 m at night. A total of 79 IKMT hauls was made during cruise 2 and 14 hauls were taken during cruise 3.

WATER TYPES.—Cruise 1 (11–21 May 1974) took place when the dumpsite was occupied primarily with slope water, but an anticyclonic Gulf Stream (warm core) eddy had recently entered the area from the northeast at about 50–350 m, so one trawl (no. 7) was made entirely in eddy water and numbers 5 and 6 may have been in the influence of eddy water. The upper 100 m were mixed shelf and slope water (7.7°–21.7° C), while slope water occurred below that depth with characteristics of temperature and salinity very like those of North Atlantic central water (8°–16° C at 100–350 m) (Warsh, 1975b).

A major eddy occupied the dumpsite during cruise 2 (22 July–4 August 1975) and samples were taken in slope, eddy, and transitional waters. Slope water occurred where the 13° C isotherm lay at about 50 m and the depth of the 14°–15° C isotherm identified the eddy water (ca 200–500 m). The narrow zone where a trawl sampled both slope and eddy water or mixtures of the two was termed transition water. Eddy water was arbitrarily divided into the eastern eddy area that lay in or near the core of the eddy where warm temperatures were deepest and into the western eddy area where warm temperatures shallowed sharply toward the west (Goulet and Hausknecht, 1977).

Cruise 3 (20–29 February 1976) sampled in the dumpsite in slope water, as well as farther to the south in a decaying eddy that had passed through the dumpsite in December 1975 and January 1976. The eddy was very weak and was characterized by the depression of the 13° C isotherm below 200 m. Outside the confines of the eddy, including the dumpsite, lay several parcels of eddy-like water, presumably the results of the decaying process of the main eddy (Bisagni, 1977). Undoubtedly all samples taken in the area of the eddy were not confined to eddy water sensu stricto.

Cruise 4 (29 August–6 September 1976) was characterized by the presence of a warm core eddy that occupied a narrow zone from the surface to about

200 m. Seven of the eight trawl hauls were made in the area of the eddy, but these open-net tows were made to depths of 675–0 to 950–0 m, undoubtedly well beyond the influence of the eddy water.

The designation of each sample to a particular water type represents our best estimate but does not necessarily assure that the sample was taken in that water type. This is especially the case in zones of transition between water types and, of course, in open-net tows that may have passed through more than one water type; for example, a deep-set haul in slope water that underlay eddy water. Probably all tows below 600–800 m, and certainly below 800 m were not in eddy water and were beyond the influence of eddy water.

The warm core Gulf Stream eddies are a consistent feature of the dumpsite area and pass through from the northeast to the southwest about three times a year. Added to these are the complications of variable current direction and intensity, and the periodic, variable influx of Labrador Current and shelf waters. Thus, deepwater dumpsite 106 clearly is an exceedingly unstable area in its physical features. Any attempt to delineate the biological characteristics in a "baseline" manner must include the physical oceanography, and, consequently, must remain broad and flexible.

ACKNOWLEDGMENTS.—We wish to thank all the biologists who participated in the four cruises for collecting and preserving the cephalopod material, including M. Keene, R. Kleckner, H. Howell, University of Rhode Island; James Craddock, Woods Hole Oceanographic Institute; G. Small, F. Ferrari, Charles Karnella, and Michael Sweeney, Smithsonian Institution. We are especially grateful to Robert H. Gibbs, principle investigator of the Nectonic Sampling Program, for providing the material, for stimulating discussions, and for reading the manuscript. M. Sweeney prepared all graphs and charts and assisted with compilation of data, for which we express our thanks. The manuscript was also kindly read by T. Okutani, Tokai Regional Fisheries Research Laboratory, Japan and J. Wormuth, Texas A&M University. We appreciate the editorial assistance and proofreading of Catherine Lamb and Michael Sweeney. Sherylitta Lee typed the manuscript. This research was supported by NOAA Grant No. 04-5-158-60 to the Smithsonian Institution.

Materials and Methods

The cephalopods reported upon in this paper are listed in the Appendix by cruise and species (Appendix, Table A), along with pertinent collecting data (Appendix, Table B). A total of 343 specimens, representing 36 species in 15 families, was captured during the four deep dumpsite cruises; 172 (50%) specimens came from slope water, 149 (44%) from eddy water and 22 (6%) from transition water. An additional 21 specimens were captured well south of deepwater dumpsite 106 in an area of decaying eddy water. Of the 113 midwater trawl hauls, 65 (58%) captured cephalopods.

All specimens of cephalopods were identified and their mantle lengths (ML) measured to nearest mm. Wet displacement volumes were taken of each specimen within each sample to nearest 0.1 ml. Sex and the developmental stage were determined according to the following code and definitions:

sex	0	undetermined sex, in larval or damaged specimens
	1	male
	2	female
stage	0	undetermined, in damaged specimens
	2	larva: too young to distinguish sexual characters
	3	juvenile: young specimen in which some sexual characters are distinguished
	4	subadult: sexual characters well distinguished but gonads and accessory organs not completely developed
	5	adult: sexually mature with spermatophores in Needham's sac in males; ovaries, nidamental and oviducal glands fully developed and ripe, eggs sometimes in oviducts, in females

As comparatively few cephalopods were captured, it was necessary to use all specimens available regardless of their mode of capture, rather than limit the analyses to specimens captured only in oblique, closing-net tows, for example. Analyses of vertical distributions, however, were made using all closing-net captures and open-net captures from shallow depths of less than 100 m. Specimens captured during the crepuscular periods of one hour before and after sunrise and sunset were eliminated from vertical distribution determinations as were larval specimens too small to have taken up the adult vertical migratory behavior.

To determine relative abundance, the catch rate in terms of specimens captured per hour of trawling within each sample (specimens/hour) was calculated. However, the attempts to standardize the fishing effort were frustrated by the noncomparability of the total samples. The non-comparability resulted from too few samples taken under too great an array of extremes: horizontal vs oblique tows; open nets vs closing nets; duration of tows ranging from a few minutes to several hours. Ultimately, we had to utilize the raw data in discussing relative abundance and occurrence in relation to water type. These data are given for each species (see Table 3) as number of specimens captured/successful sample by season.

Spawning data and seasonal growth trends are available for a few species. Some of these data represent the first information of the kind for these oceanic species.

The discussion of the relationship of species to different water types includes a study of the relative abundance of total cephalopod catches and an analysis of the co-occurrence of species captured between water types.

PREVIOUS STUDIES.—The original work on the distribution of a cephalopod in relation to water masses was that of Pickford (1946), who reported on *Vampyroteuthis infernalis*, a world-wide deep sea form that was restricted to deep oceanic waters. The occurrence and distribution of the deep-sea squid *Bathyteuthis abyssicola* in the Antarctic, Atlantic, and eastern Pacific oceans were determined by particular water masses (Roper, 1969), while those of the Antarctic squid *Galiteuthis glacialis* were restricted by the Antarctic water masses (McSweeny, 1978). The distribution of the migratory squid *Illex illecebrosus* was found to be determined by a rather rigid upper temperature limit of 15° C (Lu, 1973).

The vertical distributions of cephalopods have received little attention until recent years, when several studies have yielded a great deal of information based on closing-net sampling programs. The various patterns of vertical distribution exhibited by cephalopods were first defined and delineated in a general review of the vertical distributions of pelagic cephalopods (Roper and Young, 1975). The vertical distributions of cephalopods in the eastern Atlantic have been delineated by Clarke (1969), Clarke and Lu (1974, 1975), and Lu and Clarke (1975a, 1975b); in the Mediterranean by Roper (1972, 1974); in the western Atlantic off Bermuda by Gibbs and Roper (1970). All these papers have provided useful comparative information for the current study.

Species Accounts

1. *Oregoniateuthis springeri* Voss, 1956

CRUISE 2.—One larval specimen (6.0 specimens/hr, 7.0 mm ML, 0.1 ml) of undetermined sex was captured in the transition zone at 100–0 m (14°–15° C) during the day. This specimen represents the northernmost record of *O. springeri* and the first closing-net capture.

Voss (1962) reported adult specimens from open-nets at 367–0 m and 950–0 m, and suggested that members of the family Lycoteuthidae occupied the zone from 300 to 600 m. The shallow daytime capture in the dumpsite suggests that this specimen had not yet acquired the adult pattern of vertical migration.

2. *Selenoteuthis scintillans*, Voss, 1958

CRUISE 3.—One juvenile female of *S. scintillans* (2.0 specimen/hr, 17 mm ML, 0.5 ml) was captured during the day at 500–400 m in the dumpsite slope water (6°–7° C). This capture represents the northernmost record of the species to date.

In the Ocean Acre study off Bermuda nine specimens (11–32 mm ML) were captured in closing nets, five from 650–610 m during the day and four from 130–90 m at night (Roper and Young, 1975). In the eastern Atlantic at 30° N, 23° W two specimens (19–40 mm ML) were captured in an open net at night at 100–0 m (Clarke and Lu, 1974).

3. *Abralia veranyi* (Ruppell, 1844)

CRUISE 1.—Three specimens were captured at three slope water (5°–21° C) stations at night: 1 adult female (0.5 specimens/hr, 37 mm ML, 4.0 ml) at 550–0 m; 1 subadult female (0.4 specimens/hr, 24 mm ML, 1.2 ml) at 615–0 m; 1 subadult male (0.3 specimens/hr, 19 mm ML, 0.7 ml) from 630–0 m.

CRUISE 2.—Two specimens of *A. veranyi* were captured at night: one adult female (4.0 specimens/hr, 36 mm ML, 3.0 ml) near the western edge of the eddy at 100–0 m (15°–26° C); the other, an adult male (2.0 specimens/hr, 26 mm ML, 1.5 ml), in the transition zone at 36–32 m (16°–20° C).

CRUISE 3.—Two adult female specimens (36 mm ML, 3.0 ml; 37 mm ML, 3.5 ml), were taken in the slope water of the dumpsite at night: 1 at 100–75 m (4.0 specimens/hr), the other at 100–0 m (4.0 specimens/hr). The temperature at the capture sites was around 12° C.

Numerous previous records show that *A. veranyi*

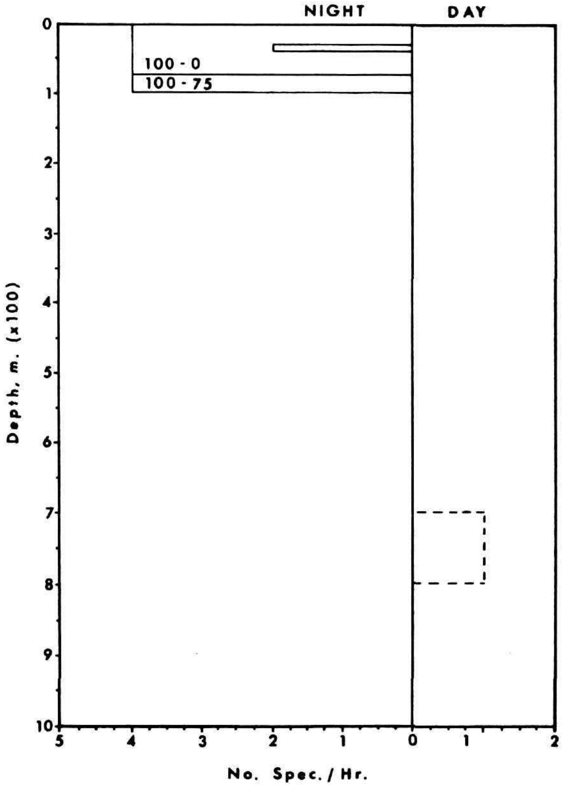

FIGURE 2.—Vertical distribution of *Abralia veranyi* based on closing-net samples (dashed box = a sample from the eastern Atlantic).

is an active vertical migrator (Roper and Young, 1975) that ascends to the upper 100 m at night and descends to 700–800 m during the day (Lu and Clarke, 1975b). These depths of capture and their temperature regimes correspond in general to those of the dumpsite catches. The four dumpsite specimens were taken at night in discrete depth samples: two at 100–0 m, one at 100–75 m and one at 36–32 m (Figure 2).

4. *Abralia redfieldi* Voss, 1955

CRUISE 3.—Two subadult specimens were taken in the area of the eddy during the day. A female (1.6 specimens/hr, 21 mm ML, 1.0 ml) was captured at 300–200 m (8.5°–11.5° C) and a male (1.7 specimens/hr, 19 mm ML, 1.0 ml) at 200–0 m (ca 12° C). The capture site appears to be located in an area just outside the core of the eddy (13° C at 200 m) and probably represents a part of decaying eddy.

Two captures of *Abralia redfieldi* were made off

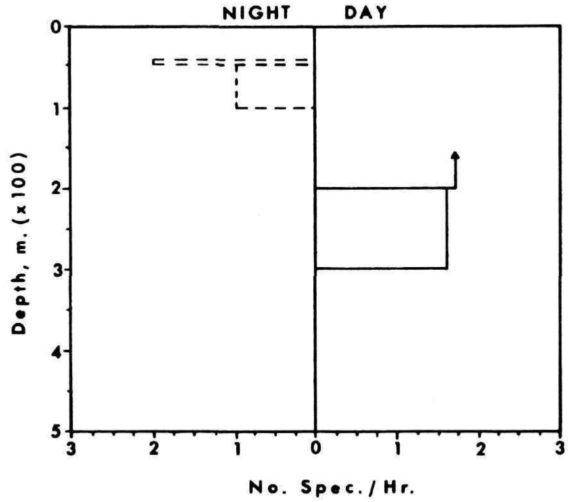

FIGURE 3.—Vertical distribution of *Abralia redfieldi* (boxes = closing-net captures; arrow = open-net captures; dashed box = samples from off Bermuda (50 m) and the eastern Atlantic (50–100 m).

Bermuda in closing nets at 50 m at night, but no captures were made during the day (Roper and Young, 1975). One specimen was captured at night at 50–100 m (Lu and Clarke, 1975b). These data combined with the dumpsite data indicate that *A. redfieldi* apparently is a shallow-living species that undergoes a diel vertical migration of relatively short range from about 200–300 m to the upper 100 m (Figure 3).

5. *Abralia* species

Several specimens of an *Abralia* species were captured that were either damaged or too small to identify precisely. We feel, however, that they most probably are attributable to *A. veranyi* rather than to *A. redfieldi*.

CRUISE 1.—Seven specimens were taken from two stations in the slope water (5°–19° C) at night: 2 subadult females (12, 10 mm ML) and 4 larvae (7, 6, 4, 4 mm ML), total volume 0.6 ml and 3.75 specimns/hr, were caught at 750–0 m; 1 juvenile male (0.6 specimens/hr, 8 mm ML, 0.1 ml at about 550–0 m.

CRUISE 4.—Three specimens in very poor condition (1.0 specimen/hr. unsexable and unmeasurable, 0.6 ml) were captured at night in an open net that fished from 750–0. The specimens probably came from depths considerably less than 750 m, since previous closing-net records of *Abralia* species indicate maximum depths of 600 m during the day (Roper and Young, 1975). The temperature was 13° C at 200 m, the presumed maximum depth of the influence of the eddy.

6. *Abraliopsis pfefferi* (Joubin, 1896)

CRUISE 1.—Six specimens were captured at three locations in the slope water (5°–21° C) at night. One adult female (0.3 specimens/hr, 35 mm ML, 36 ml) was captured at 630–0 m. Three adult females and 1 adult male (2.0 specimens/hr, 34, 28, 26, 18 mm ML, 8.0 ml) were caught at 550–0 m. One adult male (0.4 specimens/hr, 19 mm ML, 1.1 ml) was captured at 615–0 m.

CRUISE 2.—Twenty-eight specimens of *A. pfefferi*, captured in 17 different samples, consisted of 23 adult females (30–37 mm ML) plus 4 adult and 1 juvenile males (11–23 mm ML). Only 2 specimens were captured at night at 25–0 m and 100–75 m. Twenty-three specimens were captured during the day between 1000 m and the surface at the following depths: 1000–0, 900–800, 800–0, 580–535, 550–535, 550–0, 525–0, 500–0, 400–0, 400–0, 300–200, 100–0 m. Three specimens were taken during crepuscular periods: 100–75, 176–0, and 171–167 m. This species clearly undergoes a broad vertical migration that is concentrated in the upper 100 m at night but is scattered over a wide range of depths during the day, as indicated by closing-net captures at the extremes of 900–800 m (1 specimen) and 100–0 m (2 specimens). Five other closing-net captures were made at 495–580 m. There appear to be three distinct peaks in the vertical distribution of *A. pfefferi* (Figure 4), one at night at 100–0 m (13.5 specimens/hr), one during the day at 100–0 m (12.0 specimens/hr), and one during the day at 900–800 m (6.0 specimens/hr).

Specimens of *A. pfefferi* were distributed in all four sampling areas in cruise 2. The eddy area yielded 20 specimens, five in the eastern sector and 15 in the western part, the transition zone six specimens, and the slope water two specimens. The female to male ratio is 2.4:1. All specimens except one male are sexually mature and in breeding con-

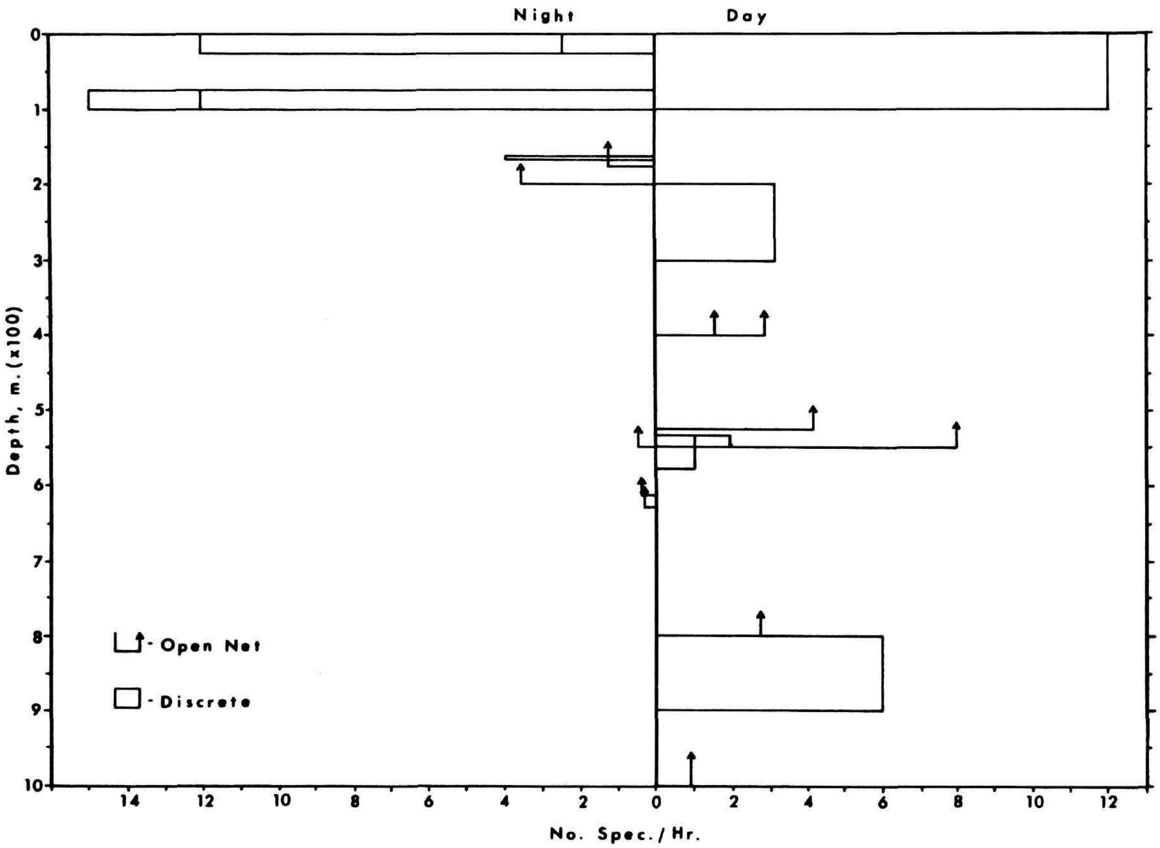

FIGURE 4.—Vertical distribution of *Abraliopsis pfefferi* (boxes = closing-net captures; arrows = open-net captures).

dition. The dumpsite represents a spawning ground in summer for *A. pfefferi*.

CRUISE 3.—Two mature male specimens (21 mm ML, 0.8 ml; 24 mm ML, 1.0 ml) were captured at night in the eddy area at 200–0 m and 25–0 m. These specimens represent 3.5 specimens/hr and 2.4 specimens/hr respectively. Both captures were within the remnants of the core of the eddy where the temperature was around 13° C.

CRUISE 4.—Five open-net tows at night captured 17 specimens consisting of 8 mature males (14–22 mm ML), 5 subadult females (14–20 mm ML) and 4 juvenile females (12–15 mm ML). The female to male ratio is 1.13:1. Four samples from the eddy area contained 8 specimens (0.7 specimens/hr) distributed at the following depths: 950–0 m (0.3 specimens/hr), 825–0 m (1.2 specimens/hr), 750–0 m (0.4 specimens/hr), and 750–0 m (1.0 specimens/hr). The single trawl haul in non-eddy water captured 9 specimens (2.95 specimens/hr) taken at 700–0 m. Thus, the relative abundance appears to be greater in the non-eddy area. Temperatures at 200 m in the eddy area were 12.4°–12.8° C, and in the non-eddy station it was 8.2° C.

A total of 53 specimens of *A. pfefferi* was captured during the four dumpsite cruises; this represents one of the most abundant species in the dumpsite study.

The vertical distributional patterns displayed in the dumpsite area (Figure 4) are similar to those reported elsewhere over the broad geographical range of the species. No differences in vertical distributional patterns are evident between cruises or water types. *Abraliopsis pfefferi* concentrates in the upper 100 m at night and is dispersed throughout the water column to about 1000 m during the day, with apparent peaks of occurrence at 500–600 m and 800–900 m (Clarke and Lu 1974, 1975; Lu and Clarke, 1975b, Roper and Young, 1975). An unusual night time distribution is reported in the Mediterranean Sea from 25 to 600 m by Roper (1972).

A. pfefferi was captured most frequently in the eddy area or eddy-type water as opposed to slope water. Within the influence of the eddy, specimens are relatively evenly distributed throughout the component parts.

The reproductive strategy of *A. pfefferi* may be inferred from the four cruises that fairly well represent the four seasons (Figure 5). During the summer (cruise 2) 27 of the 28 (96%) specimens were mature adults in spawning condition. The lone remaining specimen was a juvenile male (as final maturation appears to be rapid in squids, this specimen undoubtedly would mature in a short time).

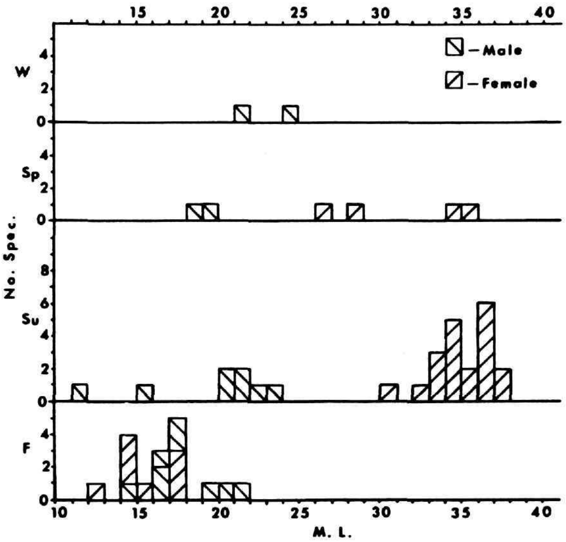

FIGURE 5.—Size-frequency distribution of male and female *Abraliopsis pfefferi* by season (W = winter, Sp = spring, Su = summer, F = fall).

The cruise 2 population contained a high proportion of ripe females vs mature males (2.4:1). During the fall (cruise 4) the female:male ratio fell to 1.13:1, and while all eight males were fully mature, the females were subadult (five specimens) and juvenile (four specimens). In the winter (cruise 3) only two adult males were captured, while in the spring (cruise 1), four adult females and two adult males were caught, a female:male ratio of 2:1.

Males mature at a considerably smaller size than females and presumably at a younger age. The smallest mature male is 14 mm ML while the smallest ripe female is 26 mm ML. Mature males occur throughout the year, while ripe females occur in the spring and summer. Apparently spawning takes place primarily in summer when numbers of large, ripe females are present. The smallest specimens in the summer population probably result from a late spring spawning. Young specimens appear in the sample population in the fall at which time adult females have died off.

7. *Pyroteuthis margaritifera* (Ruppell, 1844)

CRUISE 1.—Four specimens, 1 adult male, 3 unsexed juveniles (1.7 specimens/hr, 24, 12, 11, 9 mm ML, 2.0 ml) were captured at 620–0 m at night in slope water (5°–18° C).

CRUISE 2.—One mature male (1.4 specimens/hr, 34 mm

ML, 5.0 ml) was captured during the day at 525–0 m in the northeastern slope/transition water (15°–24° C).

CRUISE 3.—Two specimens were captured at night in the area of the eddy and none in the dumpsite. One damaged specimen (2.0 specimens/hr, body missing) was taken at 400–300 m (7°–10° C), while the other, a mature female (3.5 specimens/hr, 27 mm ML, 2.0 ml) was captured at 200–0 m (12°–13° C). The captures were in the area of the decaying eddy.

So few specimens are available that little can be said of the vertical distribution of *P. margaritifera* in the study area. This species, however, is widely distributed in warm waters of the Atlantic where its vertical distribution patterns have been studied. Roper and Young (1975) reported that off Bermuda during the day over 80% of the captures were from 375–500 m, and at night the majority of specimens was caught from 75–175 m. At 18° N 25° W the species was caught at 50–400 m in daytime and shallower than 100 m at night (Clarke and Lu, 1975), while at 30° N 23° W it was reported from 0–640 m in daytime and 0–200 m at night (Clarke and Lu, 1974). In the Mediterranean Sea, it was captured primarily from 400–600 m during the day and from 150–250 m at night (Roper, 1972).

8. *Pterygioteuthis gemmata* Chun, 1910

CRUISE 1.—Thirty-six specimens of *P. gemmata* were captured at night in slope water (5°–21° C) in 6 of the 10 stations. Two subadult males (20, 16 mm ML), 4 subadult and 1 juvenile females (21, 21, 20, 16, 14 mm ML) (2.5 specimens/hr, 3.0 ml) were caught at 750–0 m. One adult male (18 mm ML), 2 juvenile females (13, 11 mm ML) and 2 larvae (6, 4 mm ML) (3.1 specimens/hr, 0.8 ml) were caught at 720–0 m. One adult female (25 mm ML) and unsexed juvenile (9 mm ML) (0.8 specimens/hr, 1.3 ml), were captured at 615–0 m. Four adult males (21, 21, 19, 16 mm ML), 2 subadult females (18, 16 mm ML), 1 juvenile female (12 mm ML) and 2 unsexed larvae (7, 7 mm ML) (2.6 specimens/hr, 2.6 ml) were caught at 630–0 m. One each adult and subadult males (17, 14 mm ML), 5 adult and juvenile females (23, 23, 14, 12, 7 mm ML) and 2 larvae (5, 4 mm ML) (4.4 specimens/hr, 2.0 ml) were caught at 550–0 m. One subadult male (16 mm ML) and 3 juvenile females (13, 10, 10 mm ML) (2.3 specimens/hr, 0.6 ml) were taken at 550–0 m.

CRUISE 2.—Two specimens of *P. gemmata* were captured in the transition zone (13°–24° C) during crepuscular periods: 1 subadult female (2.0 specimens/hr, 17 mm ML, 0.4 ml) after sunset at 42–37 m and 1 adult female (6.0 specimens/hr, 26 mm ML, 0.9 ml) before sunrise at 42–0 m. One adult female (4.0 specimens/hr, 27 mm ML, 1.5 ml) was caught in slope water during the day at 500–400 m (5°–7° C).

CRUISE 4.—A total of 47 specimens of *P. gemmata* was captured in 7 of the 8 cruise 4 trawl stations, all of which were taken at night with open-net trawls that were fished at great depths of 675–950 m to the surface. Specimens were captured as follows: 1 subadult male, 1 juvenile female (0.6 specimens/hr, 16, 12 mm ML, 0.5 ml) from 950–0 m; 2 males (1 juvenile, 1 subadult) and 5 females (3 juveniles, 2 subadults) (2.8 specimens/hr, 11–18 mm ML, 1.1 ml) from 825–0 m; 4 males, (2 juveniles, 1 subadult, 1 adult; 11–21 mm ML), 13 females (10 juveniles, 3 adults; 10–27 mm ML) and 1 larva (4 mm ML) from four trawls at 750–0 with a combined volume of 6.0 ml and average abundance of 1.46 specimens/hr; 4 subadult males (12–13 mm ML) and 16 females (14 juveniles, 2 subadults; 6–15 mm ML) from 675–0 m (6.3 specimens/hr, 2.7 ml). All specimens probably were captured in the upper 200 m where the eddy-type water occurred (12°–13° C at 200 m).

The vertical distribution of *P. gemmata* in Californian waters is 300–600 m during the day and in the upper 200 m at night (Roper and Young, 1975). In the eastern Atlantic based on closing-nets it occurs at 710–800 m during the day and at 120 m to near the surface at night (Lu and Clarke, 1975b; Clarke and Lu, 1975). Cruise 2 captures are the only discrete depth samples during the dumpsite study, but they add confirmation to the diel migratory pattern as they were from 500–400 m in daytime to 42–37 m and 42–0 m during the dark segment of crepuscular periods.

In view of the known diel vertical distribution of *P. gemmata* we assume that all the nighttime

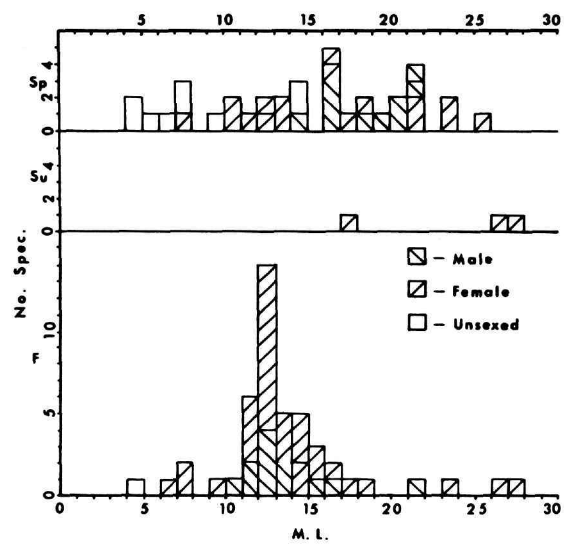

FIGURE 6.—Size-frequency distribution of male, female, and unsexed (larval) *Pterygioteuthis gemmata* by season.

captures in the dumpsite study actually were made at depths far shallower than the fishing depths of the open nets. Specimens probably were captured in the upper 200 m as the nets ascended.

In the spring sample population greater numbers of mature and maturing specimens occur (about 14–26 mm ML) (Figure 6). These would spawn in late spring or early summer with the resultant peak of larval and juvenile specimens (about 4–17 mm ML) in the fall sample. A second spawning, by the fall juveniles, may occur sometime from early spring, which is represented by the larvae and juveniles of the spring sample (approximately 4–14 mm ML).

We are unable to explain the paucity of specimens in the summer cruise and their complete absence in the winter.

9. *Thelidioteuthis alessandrinii* (Verany, 1851)

CRUISE 2.—Two small specimens of undeterminable sex and developmental stage were captured during sunrise crepuscular periods at 42–0 m (13°–14° C) (6.0 specimens/hr, 14 mm ML, 0.2 ml) and at 187–0 m (12°–13° C) (8.6 specimens/hr, 14 mm ML, 1.5 ml) in the transition zone.

CRUISE 4.—A single unsexed juvenile (0.3 specimens/hr, 18 mm ML, 1.5 ml) was captured in non-eddy (slope) water at night at 700–0 m in an open net. The temperature at the 200 m level was 8.2° C, considerably colder than eddy water would be at that depth.

Little is known about the vertical distribution of this species but it has been recorded on several occasions at depths of less than 125 m at night (Roper and Young, 1975), indicative of a diel migration toward surface waters. The shallow crepuscular captures in this study are not unreasonable and the seemingly deep capture of 700–0 m at night undoubtedly occurred at much shallower depths.

10. Enoploteuthid Larvae

Several specimens of enoploteuthid larvae could not be identified because of small size or damaged condition.

CRUISE 1.—All specimens were captured at night in slope water (5°–21° C). Four specimens, 2 larvae plus 2 larval heads, (3.3 specimens/hr, 7.3 mm ML, 0.3 ml) were captured at 675–0 m. One larva (0.4 specimens/hr, 7 mm ML, 0.2 ml) was captured at 620–0 m and 2 larvae (1.4 specimens/hr, 8, 5 mm ML, 0.2 ml) were taken at 790–0 m. Three larvae (0.9 specimens/hr, 7, 5, 4 mm ML, 0.1 ml) were captured at 630–0, and 3 larvae (1.5 specimens/hr, 8, 4, 4 mm ML, 0.2 ml) were caught at 550–0 m.

11. *Illex illecebrosus* (Lesueur, 1821)

CRUISE 1.—All eight specimens were taken at night in the slope water (5°–20° C). One juvenile male (12 mm ML), 2 juvenile females (18, 17 mm ML), and 2 larvae (9, 6 mm ML), with a volume of 1.1 ml and a rate of 2.2 specimens/hr, were captured from 620–0 m. One adult male (0.8 specimens/hr, 192 mm ML, 175 ml) was captured at 675–0 m. One juvenile female (0.3 specimens/hr, 12 mm ML, 0.1 ml) was captured at 630–0 m. One juvenile female (0.6 specimens/hr, 67 mm ML, 5.0 ml) was taken at 550–0 m.

CRUISE 3.—All four specimens were captured at night. Two specimens, a juvenile male and a juvenile female (4.8 specimens/hr, 14 and 11 mm ML, 0.3 ml) were taken in the eddy area at 25–0 m. These captures were made in the remnants of the eddy where the temperature was about 13° C. A single subadult female (2.4 specimens/hr, 97 mm ML, 16 ml) was taken in the deep dumpsite slope water at 25–0 m (12°–12.5° C). One larva (2.5 specimens/hr, 7 mm ML, 0.1 ml) was captured at the dumpsite at 200–0 m where the slope water temperature was 12° C.

CRUISE 4.—Fifteen specimens of *Illex illecebrosus* were taken at 7 stations in open nets at night as follows: 1 adult male, 1 subadult female (0.6 specimens/hr, 217, 236 mm ML, 550 ml) from 950–0 m; 2 adult males (232, 235 mm ML), 8 subadult females (226–282 mm ML), from 4 trawls from 750–0 m with a combined abundance of 0.81 specimens/hr, and a total volume of 3600 ml; 1 adult male (222 mm ML) and 1 subadult female (230 mm ML) (0.6 specimens/hr, 500 ml) from 700–0 m; 1 subadult female (0.3 specimens/hr., 251 mm ML, 325 ml) from 675–0 m. All specimens except two were captured in the area where eddy-type water occurred in the upper 200 m (12°–13° C at 200 m). The non-eddy captures (700–0 m) had a temperature of 8.2° C at the 200 m level.

The vertical distribution of *I. illecebrosus* extends over a broad range of depths depending on season, size, and time of day. Data on subadult/adult specimens from trawling and submersibles show that the species concentrates on or near the bottom during the day and disperses into the water column at night (Roper and Young, 1975). The nighttime only captures during cruises 1, 3, and 4 tend to support this conclusion, but the bottom depths in the sampling area are around 1800–2500 m, so an extreme vertical dispersal and migration must take place if indeed the animals descend to those depths.

Illex illecebrosus also occurs over a broad range of temperatures from 0° C to 15° C with peak occurrence at 7° C to 13° C. *I. illecebrosus* never has been taken in water warmer than 15° C (Lu, 1973), so it seems reasonable to assume that all dumpsite captures were at temperatures of 15° C or less. That being the case, the probable depths of capture can be defined at the location of the 15° C isotherm and deeper. During cruise 1 the depth of the 15° C isotherm lay from about 80 m to 150 m at stations that produced *Illex*. Cruise 4 *Illex* stations had the 15° C isotherm at some level less than 200 m (where the temperatures were 12°–13° C). Cruise 3 occurred in winter and *Illex* captures were made at much shallower depths than in spring (cruise 1) and fall (cruise 4), that is, at 25–0 m. This may indicate a seasonal difference in the vertical distribution of *Illex illecebrosus* in oceanic localities.

Rather than being an oceanic species, *I. illecebrosus* is a neritic species that inhabits the waters of the continental shelf and slope (Lu, 1973). Most dumpsite specimens were taken in known slope water during cruises 1 and 3. Cruise 4 captures are difficult to interpret because eddy-type water apparently occupied the upper 200 m, and *I. illecebrosus* was caught in several of the trawls designated as eddy-type samples, as well as in the single slope water sample. Because we know the habitat of this species, we attribute all the cruise 4 captures to slope water, i.e., below 200 m.

The larval and juvenile specimens recorded from the dumpsite study are the smallest specimens of *Illex illecebrosus* reported to date (6–18 mm ML). These larvae and juveniles occurred only in the winter (cruise 3) and spring (cruise 1) samples (Figure 7). The fall sample (cruise 4) contained only large mature and maturing individuals and no small specimens. The complete absence of specimens in the summer at the oceanic dumpsite (cruise 2) corresponds to their occurrence in northern inshore waters at that time. These data indicate that *Illex illecebrosus* spawns in the late fall and early winter and that hatching occurs in the late winter and in the spring. Additional data recently analyzed from the MARMAP Program (National Marine Fisheries Service) indicate, however, that the spawning situation is more complex; larvae, including Rhynchoteuthion stages, and juveniles may be found nearly year-round, indicating an extended spawning season (Roper and Lu, 1979).

The inshore summer migration cannot be attributed to spawning activity but rather to intensive feeding. The spawning grounds and season of *I. illecebrosus* have yet to be defined, but the dumpsite material strongly indicates that spawning occurs in deep offshore water of less than 15° C.

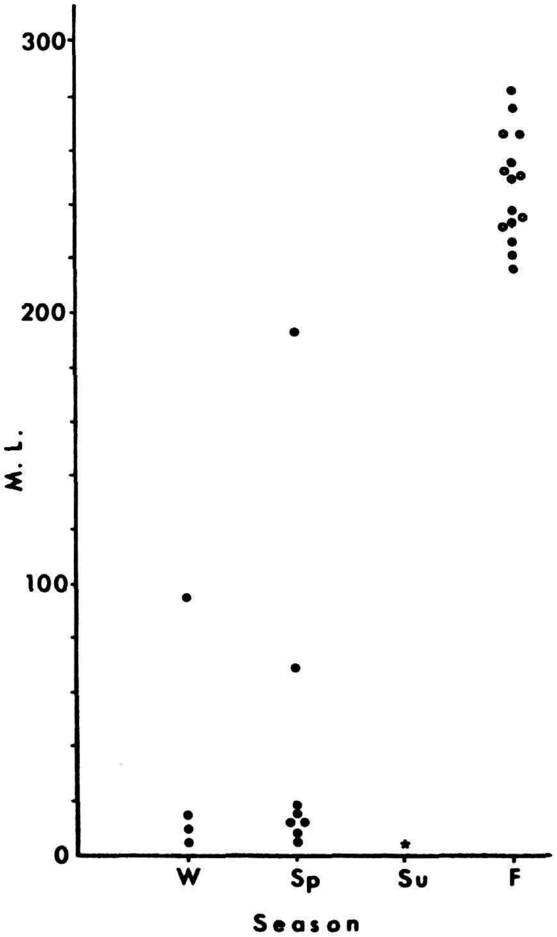

FIGURE 7.—Seasonal distribution by size of *Illex illecebrosus* (star at summer emphasizes absence of specimens in offshore waters because the population migrates inshore during that season).

12. *Ornithoteuthis antillarum* Adam, 1957

CRUISE 1.—All specimens were captured in slope water (5°–21° C) at night. One each juvenile male and female (1.6 specimens/hr, 23, 13 mm ML, 1.3 ml) was taken at 675–0 m. One juvenile male (0.3 specimens/hr, 19 mm ML, 0.6 ml) was captured at 630–0 m. A juvenile female (0.5 specimens/hr, 34 mm ML, 2.0 ml) was caught in 550–0 m.

Ornithoteuthis antillarum has a vertical distribution pattern consisting of a concentration of the population on or near the bottom during the day at depths of 585–1100 m and the dispersal into the middepths at night (Roper and Young, 1975). The nighttime middepth captures in the dumpsite correspond to this pattern, since the bottom depths of these stations were around 1200–2800 m.

13. Ommastrephid Larvae

A number of ommastrephid larvae have been captured, but it is impossible to identify them as to genus and species. Also, it is not possible to deduce their identity, as several species of Ommastrephidae may occur in the study area, e.g., *Illex illecebrosus*, *I. oxygonius*, *Ornithoteuthis antillarum*, *Ommastrephes pteropus*, *O. bartrami*.

CRUISE 1.—All specimens of ommastrephid larvae were caught at night in slope water (5°–21° C). One larva (0.6 specimens/hr, 7 mm ML, 0.1 ml) was captured from 720–0 m. Two larvae (0.8 specimens/hr, 12, 4 mm ML, 0.3 ml) were caught at 615–0 m. Two larvae (1.0 specimens/hr, 8, 3 mm ML, 0.2 ml) were caught at 550–0 m.

Small larval specimens such as those reported here do not exhibit the vertical distribution patterns of the adults until a larger size. Instead, they are concentrated in the near-surface waters day and night.

14. *Onychoteuthis banksi* (Leach, 1817)

CRUISE 1.—Two larvae (1.3 specimens/hr, 12, 10 mm ML, 0.2 ml) were captured at night at 720–0 m in the slope water at 5°–18° C.

CRUISE 2.—One juvenile female (12.0 specimens/hr, 18 mm ML, 0.5 ml) was captured in eddy water at night at 200–150 m, where the water temperature was 15° C.

The known vertical distribution of *O. banksi* is derived from three studies using closing nets. The species occurs from the surface to 150 m both day and night off Bermuda with a large peak concentration at 50–100 m (Roper and Young, 1975). In various eastern Atlantic localities it was reported from 0–900 m during the day and from 0–1250 m at night, but at both diel periods captures were concentrated in the upper 100 m (Lu and Clarke, 1975a, 1975b; Clarke and Lu, 1974, 1975). In the Mediterranean, again the peak abundance was in the upper 100 m both day and night, but one specimen was taken at midday at 800 m (Roper, 1972). Therefore, it appears that this species concentrates in the upper 100–200 m at night and spreads out in the water column during the day.

Onychoteuthis banksi is a cosmopolitan species (or species complex) that inhabits warm waters. Its occurrence in the dumpsite area should coincide with the presence of warm water eddies. The specimens taken during cruise 1 were from station 5, which may have been in the influence of eddy water (see p. 2).

15. *Ancistroteuthis lichtensteini* (Orbigny, 1839)

CRUISE 3.—Two specimens were captured during the day, 1 subadult male (2.0 specimens/hr, 54 mm ML, 5.0 ml) in slope water underlying the eddy area at 600–700 m, and 1 juvenile female (1.0 specimen/hr, 36 mm ML, 2.5 ml) in the dumpsite slope water at 500–0 m. The temperature under the decaying eddy at 600–700 m was around 5° C, so the specimen clearly was outside of eddy water. The temperature of the slope water in the dumpsite at 500–0 m was 6°–12° C.

Ancistroteuthis lichtensteini is a very rarely caught species, so little is known about its vertical distribution. The discrete depth capture at 600–700 m during the day is the first closing-net capture recorded and indicates a deep daytime habitat. The two captures were in slope water of about 5°–6° C, possibly to 12° C if the open-net capture was near the surface.

16. *Octopoteuthis megaptera* Verrill, 1885

CRUISE 1.—Four specimens were captured in the slope water (5°–19° C) at night. Two juvenile males (0.6 specimens/hr, 45, 42 mm ML, 13 ml) were captured at 630–0 m. One male and 1 female juvenile (1.1 specimens/hr, 36, 32 mm ML, 12.0 ml) were captured in 550–0 m.

Knowledge of the vertical distribution of most species of *Octopoteuthis* is sparse. One specimen of *O. danae* was taken at 100–50 m at night in the eastern Atlantic (Lu and Clarke, 1975b) and one *O.* cf. *megaptera* was caught off Bermuda at 230 m at night (Roper and Young, 1975). *Octopoteuthis deletron* from Californian waters is concentrated at 200–400 m during the day, but at night the population spreads out over a broader range from near the surface to 500 m (Roper and Young, 1975).

17. *Brachioteuthis riisei* (Streenstrup, 1882)

CRUISE 1.—Eleven specimens were captured from 6 of the 10 nighttime hauls, 8 from slope water (5°–20° C) and 3 in the eddy area. In slope water 2 juvenile females (0.7 specimens/hr, 35, 27 mm ML, 1.8 ml) were captured at 750–0 m; 1 larva and 1 larval head (0.9 specimens/hr, 17 mm ML, 0.4 ml) were taken at 620 m; 1 juvenile female (0.3 specimens/hr, 23 mm ML, 0.3 ml) was caught at 630–0 m; 1 subadult male and 1 subadult female (1.0 specimen/hr, 40, 28 mm ML, 1.5 ml) were captured at 550–0 m; and 1 subadult male (0.6 specimens/hr, 47 mm ML, 3.0 ml) was captured from 50–0 m. Two subadult males (38, 34 mm ML) and 1 subadult female (34 mm ML) (1.1 specimens/hr, 6.0 ml), were captured from 640–0 m in the eddy area at 5°–17° C.

CRUISE 2.—Three specimens of *B. riisei* were captured in three different water types. One juvenile male (2.0 specimens/hr, 21 mm ML, 0.2 ml) was taken at 43 m in the eddy during the evening crepuscular period (16°–19° C). A subadult female (4.0 specimens/hr, 51 mm ML, 3.0 ml) was captured at 207 m in slope water (12° C) during the morning crepuscular period. A badly damaged specimen (6.0 specimens/hr, 29 mm ML, 0.5 ml mantle only) was caught in transitional water at 43–0 m (15°–24° C, possibly eddy water) during the sunrise crepuscular period.

The vertical distribution patterns of *Brachioteuthis* are not well understood. In the eastern Atlantic specimens have been taken from near the surface to 500 m during the day and from the surface to 100 m at night (Clarke and Lu, 1974; Lu and Clarke 1975b). An unusual pattern was described in the North Atlantic at 53° N, where specimens larger than 5.6 mm ML were captured shallower than 50 m both day and night, while smaller specimens extended from 10–300 m (Lu and Clarke, 1975a). In the Mediterranean the species was limited to the upper 150 m at night (Roper, 1972). Off Hawaii, two specimens of *Brachioteuthis* species were caught in closing nets at 830–975 m during the day and one at 100–150 m at night (Roper and Young, 1975). The data suggest that although larval and juvenile *Brachioteuthis* are limited to the upper 300 m, adults may exhibit extensive diel migration. The three discrete depth captures at relatively shallow depths in the dumpsite during twilight are consistent with earlier data.

18. *Histioteuthis bonnellii* (Ferussac, 1835)

CRUISE 2.—One juvenile female (0.9 specimens/hr, 12 mm ML, 1.0 ml) was captured during the day in the eddy area at 600–0 m. The water temperature at 600 m in the eddy area was about 7° C and at the surface it rose to 26° C.

While the data on vertical distribution of *H. bonnellii* are meager, Lu and Clarke (1975b) reported closing-net captures at 305–400 m during the day and at 240–265 m at night. The dumpsite specimen probably was captured in the 300–600 m stratum.

19. *Histioteuthis elongata* (Voss and Voss, 1962)

CRUISE 2.—One gravid female (5.0 specimens/hr, 146 mm ML, 225 ml) was captured under the eddy area at 1000–800 m during the day where the temperature was around 5° C. This is the deepest record of the species to date.

CRUISE 3.—Two mature adult females were captured, 1 beneath the eddy area at 600–500 m during the day (1.4 specimens/hr, 125 mm ML, 165 ml), the other at the dumpsite at night in slope water at 570–0 m (0.4 specimens/hr, 160 mm ML, 180 ml). Water temperatures below the decaying eddy were 6° C at 600–500 m and 6°–12° C in the slope water of the dumpsite. As *H. elongata* is a deep-living species, the open-net capture in the dumpsite probably occurred in the 600–400 m stratum where water temperatures are 6°–8° C.

Voss (1969) reported two specimens caught by open net at 640–0 m and 732–0 m in waters east of Newfoundland. All other known specimens were found floating on the surface, either dead or dying. The two discrete-depth captures represent the first closing-net data on *H. elongata* and suggest a very deep daytime habitat of 500–1000 m. The open-net nighttime capture in less than 570 m may suggest an upward shift in the population.

It is interesting to note that only females have been recorded (Voss, 1969). The two smallest specimens were taken from a fish stomach and a trawl, and most other specimens are large gravid females that were found dead or dying at the surface; the remaining specimens are large unsexed animals. Voss (1969) further reported that all captures from the western Atlantic were made during July and August and that the two specimens from the Mediterranean were taken in May. The three gravid female specimens reported from the dumpsite were captured during July and February. These combined data suggest that *H. elongata* has an extended, nonseasonal spawning cycle. Since all specimens were gravid females or very large unsexed specimens taken at the surface, Voss (1969:745) suggested that the shallow occurrence of this apparently deep sea species was due to upwellings or regurgitation from predators. Several points argue against these suggestions: few other known deep sea species are found at the surface and surely upwellings do not discriminate against particular species, nor does it seem likely that predators would selectively regurgitate primarily one species, particularly large, gravid females. We suggest that the occurrences of *H. elongata* in the surface and near-surface waters represent mature specimens that have ascended from their deep sea habitat to spawn. The large unsexed specimens probably are degraded, spawned-out females.

20. *Histioteuthis reversa* (Verrill, 1880)

CRUISE 1.—Fourteen specimens were taken at 6 stations at night, 13 from slope water (5°–20° C), 1 from the eddy area. From slope water: 2 juvenile males (14, 12 mm ML) 1 juvenile female (10 mm ML) (0.9 specimens/hr, 1.5 ml) were captured at 720–0 m; 3 juvenile females (18, 10, 10 mm ML) and 4 larvae (13, 12, 7, 4 mm ML) (2.0 specimens/hr, 5.0 ml) were captured at 630–0 m; 1 subadult male (0.6 specimens/hr, 32 mm ML, 8.0 ml) was captured at 550–0 m; 1 larva (0.7 specimens/hr, 6 mm ML, 0.1 ml) was captured from 790–0 m; 1 larva (0.8 specimens/hr, 4 mm ML, 0.1 ml) was captured at 675–0 m. One larva (0.4 specimens/hr, 6 mm ML, 0.1 ml) was taken in the eddy zone at 640–0 m, water temperature 5°–17° C.

CRUISE 2.—Five specimens of *H. reversa* were captured: the eddy area produced a juvenile female and a larva (2.7 specimens/hr, 16, 9 mm ML, 1.0 ml) at daytime from 550–0 m (5.5°–26° C); the slope water, a subadult male and female (3.5 specimens/hr, 34, 35 mm ML, 9.0 ml) at night from 200–0 m (11°–25° C) and the transition zone, a subadult male (0.4 specimens/hr, 33 mm ML, 7.0 ml) during daytime at 700–0 m (5°–25° C).

CRUISE 3.—Four specimens were taken in the deep dumpsite at 3 different stations in slope water of 11.5°–12° C. One subadult female (4.0 specimens/hr, 44 mm ML, 14 ml) was captured at night at 100–0 m. Two subadult males (5.0 specimens/hr, 49, 42 mm ML, 60 ml) were taken at night from 200–0 m. One subadult female (2.0 specimens/hr, 44 mm ML, 19 ml) was taken during the day at 200–0 m.

CRUISE 4.—One subadult female and 1 juvenile male (0.7 specimens/hr, 45, 18 mm ML, 18 ml) were caught at night in the eddy area at 750–0 m, where the temperature at 200 m was 12.5° C.

The vertical distribution of *H. reversa*, a widely distributed species, is reported in the eastern Atlantic as 350–630 m during the day and from 100–260 m at night (Lu and Clarke, 1975b; Clarke and Lu, 1975). In the Mediterranean Sea the species was captured during the day at 700 and 375 m and at night at 250 m (Roper, 1972). Although data are not conclusive, it appears that *H. reversa* lives in deeper waters during the day and spreads into shallower water at night. The open-net captures during the dumpsite study tend to support this supposition.

The seasonal captures of *H. reversa* indicate that spawning takes place in the spring, as primarily larvae and juveniles (4–18 mm ML) were captured on cruise 1 in May (Figure 8). Subsequent cruises show increasing sizes of captured specimens with fewer juveniles and more subadults in the summer (9–34 mm ML). By fall and winter specimens are approaching the spawning condition and in winter no juveniles remain in the sample population (42–49 mm ML).

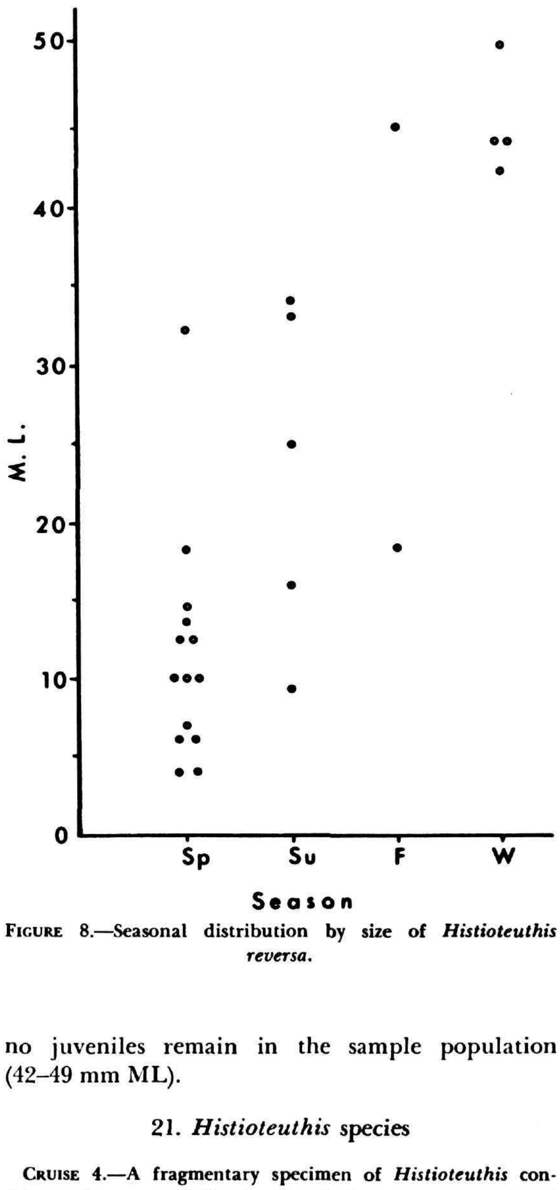

FIGURE 8.—Seasonal distribution by size of *Histioteuthis reversa*.

21. *Histioteuthis* species

CRUISE 4.—A fragmentary specimen of *Histioteuthis* consisting of a part of the head and the arms was captured in the dumpsite at 750–0 m in the eddy area at night. The capture is noteworthy in that it represents a large specimen, as the fragment was 25 ml in volume.

22. *Chiroteuthis veranyi* (Ferussac, 1934)

CRUISE 2.—Two specimens were taken during the daytime. One larva (2.7 specimens/hr, 45 mm ML, 8.0 ml) was captured at 800–0 m in western eddy (5°–26° C). One large specimen consisting of the head only, (0.9 specimens/hr, 85.0 ml) was caught in the eddy area at 1000–0 m (4°–24° C).

CRUISE 3.—Three specimens were taken in the eddy area during daytime. One unsexed juvenile (2.0 specimens/hr, 41 mm ML, 2 ml) was captured at 500–400 m. A subadult female and a subadult male (1.7 specimens/hr, 62, 55 mm ML, 23 ml) were taken at 500–0 m. In the zone of the decaying eddy the water temperature at 400–500 m was 5°–7° C and it rose to 12°–13° C at the surface.

Chiroteuthids are deep-living animals as adults but inhabit a very broad vertical range during ontogeny (Roper and Young, 1975). Nighttime captures were made of subadult specimens of *Chiroteuthis* species from 167–0 m off Bermuda and from 150–0 m from Hawaii, while during the day specimens were caught at 660–600 m in a closing net off Hawaii (Roper and Young, 1975). A single subadult *C. veranyi* (52 mm ML) was taken in a closing net at 400 m at night in the Mediterranean (Roper, 1972).

All *C. veranyi* captured in the dumpsite study area were taken from eddy-type water during the day and those in open nets probably came from the deeper strata of around at least 400–500 m, the locale of the closing-net capture.

23. *Ctenopteryx sicula* (Verany, 1851)

CRUISE 4.—A single juvenile female (0.3 specimens/hr, 13 mm ML, 0.4 ml) was caught in the eddy-type water at night at 675–0 m, where the water temperature at 200 m was 12.8° C.

C. sicula inhabits the upper waters of 100–150 m during the night based on closing-net captures in the Mediterranean, off Bermuda, and off Hawaii. During the day it has been captured in closing nets at 350 m and 150 m (Roper and Young, 1975). One specimen was taken in the eastern Atlantic in a closing net at 600–410 m during the day (Clarke and Lu, 1975). *Ctenopteryx sicula* generally is regarded as a warm water species that is widely distributed around the world.

24. *Mastigoteuthis magna* Joubin, 1913

CRUISE 1.—One subadult male (0.5 specimens/hr, 47 mm ML, 3.0 ml) was captured at night from 550–0 m in slope water (5°–21° C).

CRUISE 2.—Five specimens of *M. magna* were captured in 5 different tows. One subadult (internal organs absent) (0.9 specimens/hr, 76 mm ML, 8.0 ml) was captured at 1000–0 m (4°–24° C) during the day in the eddy area. A subadult female (3.8 specimens/hr, 84 mm ML, 20.0 ml) was taken at night in slope water at 300–200 m (9°–11° C). A subadult male (4.0 specimens/hr, 93 mm ML, 25 ml) was caught in slope water at night at 42 m (15°–16° C). Another subadult male (1.6 specimens/hr, 100 m ML; 30 ml) was taken in the eddy water at night from 500–400 m (14°–15° C). A mature female (2.5 specimens/hr, 130 mm ML, 110 ml) was caught at 400–300 m at night in the eddy water (15° C).

CRUISE 3.—Two juvenile males were captured during the day. One in the dumpsite slope water at 800–700 m was badly damaged so its mantle length and volume can not be ascertained accurately (2.1 specimens/hr, 17+ mm ML, 1+ ml). The other specimen (0.9 specimens/hr, 31 mm ML, 2.0 ml) was caught in the eddy zone at 500–0 m. The temperature in the slope water at the dumpsite at 700–800 m was around 5° C and in the area of the decaying eddy at 500–0 m it was from around 6° C to 13° C.

CRUISE 4.—A single subadult female (0.4 specimens/hr, 78 mm ML, 12 ml) was taken in the eddy water at night at 825–0 m (12.4° C at 200 m).

Although *M. magna* has been recorded only in the original description, it is by no means a rare species, as numerous specimens exist in the collections of the National Museum of Natural History, Smithsonian Institution. The specimens from the

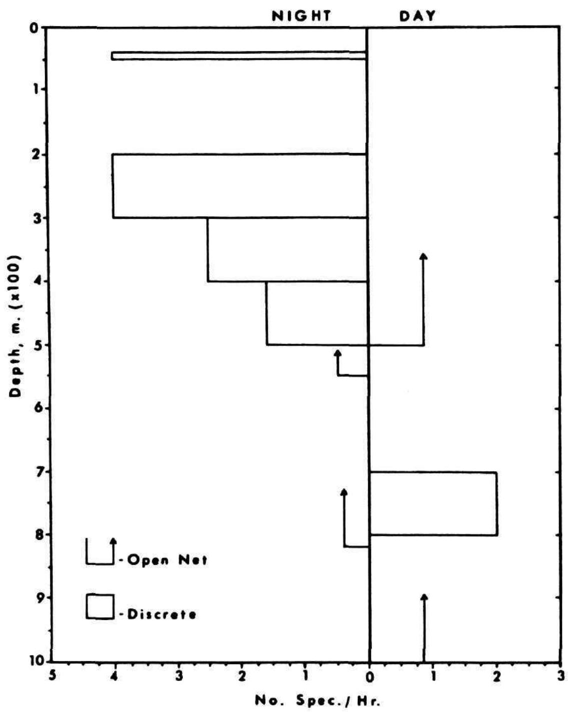

FIGURE 9.—Vertical distribution of *Mastigoteuthis magna* (boxes = closing-net samples; arrows = open-net samples).

dumpsite study represent the first material upon which vertical distribution can be determined. Fortunately many of the captures were made in discrete-depth tows (Figure 9). At night closing-net captures are concentrated at 200–500 m. A most unusual closing-net capture was made at night at 42 m, the shallowest recorded depth for any *Mastigoteuthis* species. During the day a closing-net capture was made at 700–800 m with open-net captures at 500–0 m and 1000–0 m. Other *Mastigoteuthis* species demonstrate a diel distribution of a deep habitat below 600–700 m during the day with a spreading upward into shallower depths up to about 200 m at night (Roper and Young, 1975).

25. *Mastigoteuthis* species

A number of small specimens of *Mastigoteuthis* can not be identified as to species, so they are lumped together for the sake of complete recording of the material.

CRUISE 2.—A subadult male (1.5 specimens/hr, 70 mm ML, 14 ml) was taken in the eddy area at night at 500–0 m (14°–24° C). Another subadult male (4.0 specimens/hr, 68 mm ML, 15 ml) was captured in the transition zone during the day at 800–600 m (5° C), while 2 subadult females (5.2 specimens/hr, 45, 65 mm ML; 25 ml) were caught in the transition zone at daytime at 500–0 m (6°–25° C). A juvenile male (2.7 specimens/hr, 25 mm ML, 0.4 ml) was taken in the eddy area during the day from 800–0 m (5°–24° C).

CRUISE 3.—A subadult female (1.4 specimens/hr, 77 mm ML, 30 ml) was captured at 500–400 m (6°–8° C) in the eddy area at night. A badly damaged larva (1.5 specimens/hr, 21 mm ML, 0.3 ml) was captured at night in the eddy area at 100–0 m (13° C).

The most significant captures are the closing-net tows in which specimens were taken at 800–600 m during the day and at 500–400 m at night.

26. *Cranchia scabra* Leach, 1817

CRUISE 2.—A subadult male (3.8 specimens/hr, 79 mm ML, 13 ml) was captured in the transition zone at night at 187–0 m (15°–24° C).

Closing-net captures indicate an extremely broad vertical distribution that ranges from 0–640 m during the day and 0–1000 m at night (Clarke and Lu, 1974; 1975; Lu and Clarke, 1975b).

27. *Liocranchia reinhardti* (Steenstrup, 1856)

CRUISE 1.—Only one larval specimen of this species was taken (3.0 specimens/hr, 25 mm ML, 1.0 ml). The capture occurred at 750–0 m (5°–20° C) in slope water at night.

Lu and Clarke (1975b) have documented the vertical distribution of *L. reinhardti*. Larval specimens are concentrated in the upper 100 m day and night. At about 30 mm ML an ontogenetic descent begins whereby increasingly larger specimens occur at increasingly greater depths down to about 1000 m.

28. *Pyrgopsis pacificus* (Issel, 1908)

CRUISE 1.—One unsexed juvenile (55 mm ML) and one subadult female (62 mm ML) (0.7 specimens/hr, 0.4 ml) were captured at 750–0 m in slope water (5°–20° C). One subadult male (0.4 specimens/hr, 51 mm ML, 3.0 ml) was caught at 640–0 m in the eddy area (5°–17° C).

The vertical distribution of *P. pacificus* seems to follow the trend of other cranchiids; that is, it concentrates in high abundance in the upper 100 m or so when young, then undergoes an ontogenetic descent into greater depths (Lu and Clarke, 1975b; Clarke and Lu, 1975).

29. *Taonius pavo* (Lesueur, 1821)

CRUISE 1.—Two specimens were taken in slope water (5°–20° C) at night. One unsexed juvenile (0.7 specimens/hr, 85 mm ML, 1.8 ml) was captured at 790–0 m. One subadult female (0.3 specimens/hr, 120 mm ML, 1.8 ml) was caught at 630–0 m.

CRUISE 2.—Two juveniles (0.4 specimens/hr, 140, 144 mm ML, 10.0 ml) were captured in the eddy area at night at 1800–0 m (4°–24° C).

CRUISE 3.—One juvenile male (1.4 specimens/hr, 150 mm ML, 10.0 ml) was captured in the eddy area during the day at 500–600 m. The temperature below the decaying eddy was around 6° C at 500–600 m. A juvenile female (1.0 specimens/hr, 90 mm ML, 1.0 ml) was caught in the dumpsite slope water during the day at 500–0 m (6°–13° C).

CRUISE 4.—Two larval specimens (0.3 and 0.4 specimens/hr, 60 and 58 mm ML, 0.3 and 0.4 ml) were taken in the dumpsite eddy area at night at 750–0 and 825–0 m respectively (12.5° C at 200 m).

Roper and Young (1975) reported on three larval specimens (35–43 mm ML) from off Bermuda caught by a closing net at 610–690 m during the day. Off Hawaii, four specimens (60–115 mm ML) were caught by closing net at 600–800 m. They suggested that *T. pavo* is a deep living species that occurs at 600–700 m. Young (1975) concluded that no diel vertical migration occurs, but an ontogenetic descent exists. Larvae occur in the upper 400 m, juveniles around 600–650 m, and larger juveniles and adults at 700 m and deeper. The single closing-net capture at 500–600 m during the day in the dumpsite is consistent with that suggestion.

30. *Helicocranchia pfefferi* Massey, 1907

CRUISE 2.—One subadult male (4.3 specimens/hr, 57 mm ML, 3.5 ml) was captured in the transition zone in the daytime at 200–0 m 12°–25° C).

CRUISE 3.—One subadult male (1.0 specimen/hr, 40 mm ML, 1.0 ml) was taken in the dumpsite slope water during the day at 500–0 m (6°–13° C).

Helicocranchia pfefferi exhibits a vertical distribution that, in eastern Atlantic studies, extends from 0–500 m during the day and from 0–400 m at night (Clarke, 1969; Clarke and Lu, 1974; 1975; Lu and Clarke, 1975a; 1975b). This species was captured off California from 100 to below 800 m with greatest abundance (59%) at 200–400 m (Roper and Young, 1975). It appears that this species exhibits an ontogenetic descent during growth but a diel migratory behavior is not evident.

31. *Egea inermis* Joubin, 1933

CRUISE 2.—One subadult female (1.1 specimens/hr, 63 mm ML, 2.0 ml) was captured in the eddy zone at night at 800–600 m (5°–7° C).

The dumpsite capture represents the only discrete sample of this species. Voss (1974:952) reporting on 58 specimens from 27 open-net samples, concluded that this species "principally occupies depths of about 35–125 meters and exhibits no tendency to migrate vertically." She also suggested that the two captures from 100 m and 200 m can be considered contaminants from the shallower depths. The present capture extends the proven vertical range of the species considerably to 600–800 m and is especially interesting as it occurred at night.

32. *Sandalops melancholicus* Chun, 1906

CRUISE 1.—One larva (0.3 specimens/hr, 32 mm ML, 0.6 ml) was captured at night in slope water at 630–0 m in temperatures of 5°–19° C.

CRUISE 3.—One larval specimen (2.0 specimens/hr, 24 mm ML, 0.5 ml) was captured in the dumpsite slope water during the day at 200–0 m (12°–11° C).

Young (1975) reported that *S. melancholicus* does not undergo a diel vertical migration as adults, but a vivid ontogenetic descent occurs, wherein larvae of less than 28 mm ML occur at shallower than 400 m, larger specimens occur at gradually increasing depths, and adults inhabit the 800 to 1075 m stratum.

33. *Megalocranchia abyssicola* (Goodrich, 1896)

CRUISE 4.—A single specimen, a juvenile female (0.3 specimens/hr, 48 mm ML, 2.0 ml) was captured in the dumpsite eddy area at night at 675–0 m (12.8° C at 200 m).

Too few recorded specimens of this species are available to enable the definition of vertical distribution, but one closing-net capture is recorded (as *Phasmatopsis oceanica*) from 800–710 m during the day (79 mm ML) (Clarke and Lu, 1975).

34. *Megalocranchia megalops* (Prosch, 1849)

CRUISE 1.—Twenty-two specimens were captured at night in 6 of the 10 tows, and all but 1 of these were taken in the slope water (5°–21° C). One juvenile male (55 mm ML) and five larvae (32, 29, 25, 25, 23 mm ML) (2.0 specimens/hr, 10.0 ml) were captured at 750–0 m. Two larvae (0.9 specimens/hr, 17, 14 mm ML, 0.5 ml) were taken at 620–0 m. One juvenile male (20 mm ML) and 1 unsexed juvenile (35 mm ML) (1.3 specimens/hr, 2.5 ml) were caught at 720–0 m. One larva (0.4 specimens/hr, 22 mm ML; 2.0 ml) was captured in the eddy area at 640–0 m (5°–17° C). Two juvenile males (38, 32 mm ML), 5 juvenile females (55, 45, 42, 40, 30 mm ML), and 1 larva (18 mm ML) (2.3 specimens/hr, 22.0 ml) were captured at 630–0 m. One juvenile male (38 mm ML) and 2 unsexed juveniles (36, 21 mm ML) (1.5 specimens/hr, 3.5 ml) were taken at 550–0 m.

CRUISE 2.—Two specimens were captured in the transition zone during the day. One subadult male (2.0 specimens/hr, 92 mm ML, 9.0 ml) was captured at 700–600 m (5° C). A subadult female (1.2 specimens/hr, 65 mm ML, 4.5 ml) was caught at 800–600 m (5° C).

CRUISE 4.—A subadult male (0.3 specimens/hr, 107 mm ML, 15.0 ml) was taken at 750–0 m in the eddy area at night (12.0° C at 200 m).

The vertical distribution based on closing-net captures in the eastern Atlantic was described by Lu and Clarke (1974; 1975a) under the name of *Taonius megalops*. This species occupies a very broad vertical range during its life history; daytime records range from 0–1250 m and night captures are at 0–1000 m. Although no diel migratory behavior is apparent, an ontogenetic descent during growth is apparent.

The two closing-net records of subadult and adult specimens at 600–800 m and 600–700 m fit into the existing picture rather well.

The capture records indicate that *M. megalops* matures in late summer to fall (Figure 10). It must spawn in winter or early spring as the sample popu-

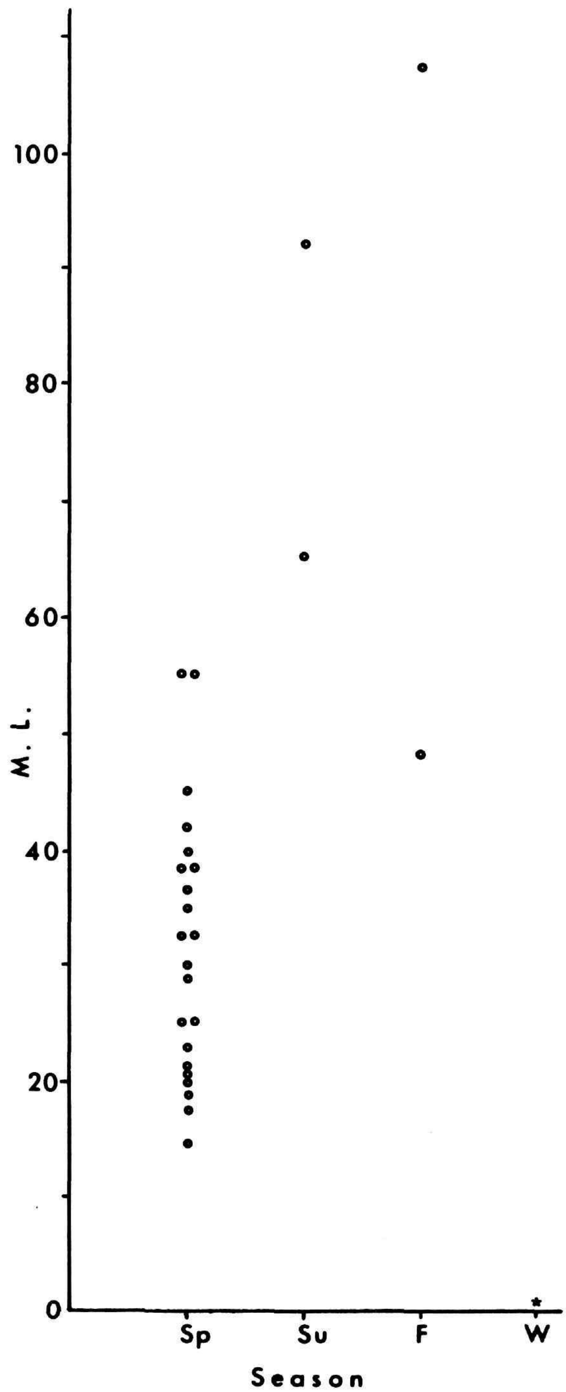

FIGURE 10.—Seasonal distribution by size of *Megalocranchia megalops*.

lation in the spring consists entirely of larvae and juveniles.

35. *Alloposus mollis* Verrill, 1880

CRUISE 1.—Five specimens were taken in four different tows at night in the slope water (5°–20° C). One juvenile male (0.3 specimens/hr, 15 mm ML, 2.4 ml) was captured at 750–0 m. One subadult male (0.8 specimens/hr, 28 mm ML, 10.0 ml) was taken at 675–0 m. One subadult male (0.3 specimens/hr, 35 mm ML, 21.0 ml), was taken at 630–0 m. Two subadult females (1.1 specimens/hr, 27, 24 mm ML, 20.0 ml) were captured at 550–0 m.

CRUISE 2.—One subadult female (8.6 specimens/hr, 41 mm ML, 60.0 ml) was captured in the slope water at night at 50–25 m (13°–20° C).

CRUISE 3.—Two unsexed juveniles (3.0 specimens/hr, 9, 7 mm ML, 0.7 ml) were captured in the eddy zone at night at 100–0 m (13° C). A subadult female (2.0 specimens/hr,

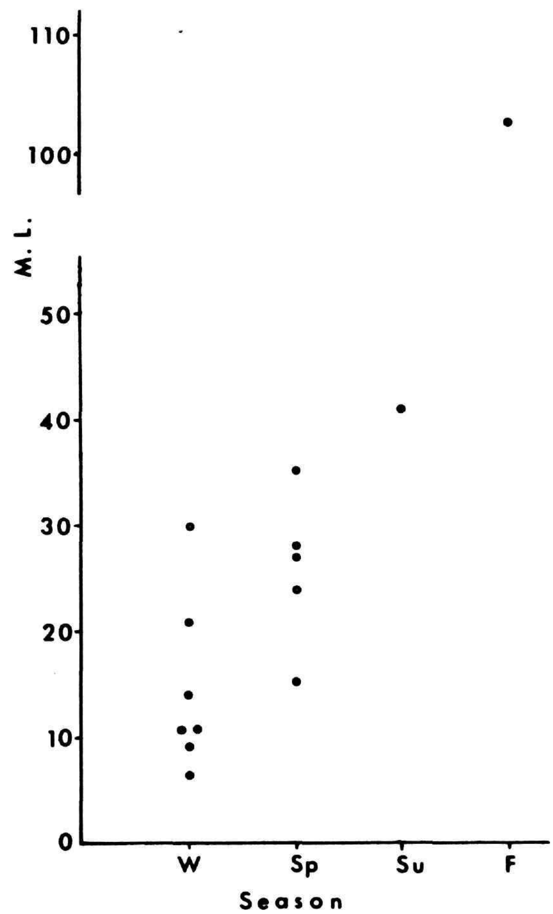

FIGURE 11.—Seasonal distribution by size of *Alloposus mollis*.

21 mm ML, 13.0 ml) was caught in the eddy area during the day at 700–600 m (6° C). Three specimens, a subadult male, a juvenile male, and a juvenile female (12 specimens/hr, 30, 14, 11 mm ML, 17.0 ml), were caught at night in the dumpsite slope water at 100–0 m (12° C). One juvenile female (1.0 specimen/hr, 11 mm ML, 0.5 ml) was taken at daytime in the dumpsite slope water at 500–0 m (6°–7° C).

CRUISE 4.—One adult male (0.4 specimens/hr, 103 mm ML, 300 ml) was captured beneath the eddy area from 750–0 m at night (12° C at 200 m).

Alloposus mollis has been recorded from a great range of depths from the surface to 3180 m in open nets (Roper and Young, 1975), but the very few closing-net captures suggest a narrower vertical range. Lu and Clarke (1975a; 1975b) record daytime captures from 0–1250 m and a single night catch at 50–100 m. There is no doubt that the species occurs in shallow water during the day as well as at night, but the extent of the depth distribution at night is uncertain. The closing-net capture at daytime in 600–700 m is in accord with other records.

A possible trend that may reflect the life cycle of *A. mollis* is seen in the plot of size vs. season (Figure 11). Specimens are maturing in the summer, are mature by fall, and apparently spawn in fall or early winter because primarily larvae and juveniles are present in the winter cruise (February).

36. *Japetella diaphana* (Hoyle, 1885)

CRUISE 1.—Two specimens were captured in the slope water (5°–19° C) at night. One subadult male (0.6 specimens/hr, 18 mm ML, 1.5 ml) was caught from 720–0 m and one larva (0.3 specimens/hr, 8 mm ML; 0.1 ml) was captured at 630–0 m.

CRUISE 3.—One juvenile male (2.0 specimens/hr, 17 mm ML, 1.0 ml) was captured during the day in dumpsite slope water at 800–700 m (ca 5° C).

Japetella diaphana is a widely distributed pelagic octopod with a broad vertical range. It occurs from about 200 m to greater than 1200 m with peak abundance at 600–800 m (Roper and Young, 1975). The dumpsite closing-net captures at 700–800 m correspond to the known distribution.

37. *Argonauta* species

CRUISE 4.—Two specimens were taken at night in the eddy water. One adult male (0.3 specimens/hr, 5 mm ML, 0.1 ml) was captured at 750–0 m and a juvenile female (0.3 specimens/hr, 8 mm ML, 0.3 ml) was taken at 675–0 m. Temperatures at 200 m were 12°–12.8° C.

Argonauta species are shallow-living, widely distributed pelagic octopuses that occur in the upper water masses. Closing-net data from Bermuda record *A. argo* from 50–200 m (Roper and Young, 1975). In the Mediterranean Sea specimens were caught at night at the surface and at 155 m (Roper, 1972). The dumpsite specimens undoubtedly were captured in the near-surface waters as the nets ascended.

38. *Tremoctopus violaceus* delle Chiaje, 1830

CRUISE 4.—One large hectocotylized arm (185 mm long, 25.0 ml) of this species was netted in eddy water at night at 750–0 m (12.8° C at 200 m).

Tremoctopus violaceus is a cosmopolitan pelagic octopus that occurs in all warm and temperate waters of the world. Most records are in the surface and near-surface waters with scattered catches to 300 m. Closing-net captures off Bermuda were made in the daytime at 100 m, at night in 0 and 250 m (Roper and Young, 1975). The dumpsite specimen very probably was taken in the eddy water in the upper 200 m.

39. Octopod Larvae

A number of octopod larvae, probably representative of several species, are present in the collections but their small size make them impossible to identify. Catches are listed below by cruise.

cruise	*station number*	*number of specimens*	*number per hour*	*sex*	*ML*	*stage*	*volume*
1	5 (slope water)	1	0.6	0	6	2	0.2
1	7 (eddy water)	1	0.3	0	7	2	0.3
1	9 (slope water)	1	0.5	0	5	2	0.1
1	10 (slope water)	1	0.5	0	9	2	0.7
2	6C (eastern eddy)	1	5.0	0	15	3	1.0
3	3M (eddy water)	1	0.9	0	5	2	0.1

Relative Abundance: Total Cephalopod Captures

The samples of cephalopods from the deepwater dumpsite study are too limited to enable the proposed detailed study of relative abundance of each species in relation to water type. Also, because sampling techniques varied between cruises 1 and 4 and cruises 2 and 3, comparative analyses among the 4 cruises are not possible. However, some general comparisons can be made of total catches of cephalopods among water types within cruises and between cruises with similar sampling techniques.

Table 1 presents the total capture rate of cephalopods in numbers of species per hour and specimens per hour of total sampling (not number per hour of successful sample) within each water type of each cruise. Such a method of standardizing sampling effort allows within-cruise and between-cruise comparisons when sampling techniques are the same. The "species" include the unidentifiable larvae of certain genera, and all are used in the calculation of capture rate of species.

Most of the sampling effort during cruise 1 (spring) occurred in the slope water, which produced a relative abundance value considerably higher than the value for the eddy-type water, 7.88 specimens/hour vs 2.47 specimens/hour.

During cruise 2 (summer) the sampling effort was concentrated in the eddy area, where 42 hours of sampling yielded 0.90 specimens/hr., whereas less sampling in the slope and transitional waters produced a greater abundance of cephalopods, 1.37 and 2.56 specimens/hr., respectively. Since the transition water was a catchall catagory, we do not attempt to interpret its high capture rates. If the capture rates were to be equivalent between slope and eddy waters, a total of 57 specimens would be required from the eddy water. The capture rate in the eastern segment, that is, near the core of the eddy, was low, but the reason is not clear.

During cruise 4 (fall) the capture rate from the slope water was nearly equivalent to that in the eddy area, and these values represent the highest seasonal capture rates recorded.

TABLE 1.—Relative abundance of cephalopods by water type in deepwater dumpsite (106 SW = slope water, E = eddy-type water, T = transitional water, WE = western portion of eddy area, EE = eastern portion of eddy area near warm core)

Cruise	Water type	Total sampling time (hrs)	Number of "species" captured	Number of "species"/hr	Number of specimens captured	Total capture rate (spec/hr)
1	SW	19.16	22	1.15	151	7.88
1	E	2.83	5	1.77	7	2.47
2	SW	6.58	7	1.06	9	1.37
2	T	8.60	11	1.28	22	2.56
2	WE	22.35	7	0.31	24	1.07
2	EE	19.65	6	0.31	†14	0.71
4	SW	3.16	3	0.95	12	3.80
4	E	21.41	13	0.61	*84	3.92
3	SW	15.00	12	0.80	21	1.40
3	E	13.16	11	0.84	20	1.51

*13 deep captures of *I. illecebrosus* that may have been below the influence of eddy water sensu stricto.
†5 specimens captured in water that could not be designated WE or EE.

TABLE 2.—Seasonal relative abundance of cephalopods from the deepwater dumpsite 106

Cruise	Season	Total sampling time (hrs)	Number of "species" captured	Number of specimens captured	Total capture rate (spec/hr)
1	Spring	22.00	22	158	7.18
2	Summer	57.18	20	69	1.21
4	Fall	24.58	15	96	3.91
3	Winter	28.16	18	41	1.43

Sampling effort was more nearly equivalent during cruise 3 (winter), and the capture rate in the eddy waters was slightly greater than in the slope water. As the eddy was weak and decaying during this period, we do not place much emphasis on the slightly greater catches in eddy water.

In summary, relative abundance based on capture rates of cephalopods is much greater in the slope water than in the eddy-type water during the spring, whereas in the summer the difference is not so pronounced. The relative abundance during fall and winter is nearly the same for both water types.

Table 2 gives the total capture rates of cephalopods by cruise, all water types combined. Since cruises corresponded approximately to seasons, seasonal relative abundance is indicated. Greatest catches were made in the spring, intermediate catches in the fall, and lowest catches in summer and winter.

Relative Abundance by Species

A large number of species was captured only once or twice during the four-cruise sampling program and each species was represented by only a very few specimens, so we do not attempt an analysis of their occurrence and abundance in relation to water types. Table 3 presents data on captures of all species by cruise and water type. For each species the figures give number of specimens captured per number of successful tows catching those specimens.

DISCUSSION.—The following species were caught during several cruises or occurred in reasonable numbers.

Abralia veranyi: This species was captured during cruises 1, 2 and 3 in slope, transitional, and eddy waters. Catches were made in the slope water of cruises 1 and 3 but not in the eddy water. During cruise 2 only two specimens were taken, one in the transition zone and the other in the eddy water.

Abraliopsis pfefferi: Specimens were captured during all four cruises. Slope water was the predominant water type where captures occurred (cruises 1, 2, and 4), where 5 positive samples yielded 3.4 specimens per sample. In the eddy water (cruises 2, 3, and 4) 17 samples yielded only 1.8 specimens per sample. The reverse situation exists in cruise 3, where 2 specimens were taken in eddy water but none were taken in slope water.

In cruise 2 more specimens were captured in the western eddy than in the eastern eddy (2.5 vs 1.0 per positive sample). When captures from both types of eddy water are combined they are proportionally similar to the catches in the slope water, i.e., about 2 specimens per successful sample.

A seasonal comparison shows that the fall cruise was most productive in terms of catch by successful sample (3.4 specimens per successful sample), followed by spring (2.0), summer (1.9), and winter (1.0). This high relative abundance in fall corresponds to the predominance of larvae and juveniles (Figure 4).

Pterygioteuthis gemmata: Specimens were captured during cruises 1, 2, and 4. Few specimens were taken in cruise 2; none from eddy-type water and three from slope and transition water. Very large catches were made during the spring cruise (1) in slope water and the fall cruise (4) in eddy-type water. Because the eddy-type water occurred only in the upper 200 m during the fall cruise and because *P. gemmata* normally occurs in the upper 200 m at night, we assume that specimens were caught in eddy-type water. When they descended to their normal daytime habitat (ca 300–500 m) they would have been in non-eddy water. The absence of closing-net data prevents further analysis. Since sampling and captures at these two sites were proportionally similar, no predominance by water type seems to exist. The relative abundance per successful sample is as follows: fall 6.7; spring 6.0; summer 1.0.

Illex illecebrosus: Specimens were captured during cruises 1, 3, and 4. No particular trend is observed between the captures in slope (2.3 specimens/sample) and eddy-type waters (2.2 specimens/sample), because the proportional captures are all similar. Since the extent of the eddy-type water during cruise 4 was so poorly defined, it is impossible to verify whether *I. illecebrosus* was captured in eddy water. It was pointed out in the species account that the absence of *I. illecebrosus* from the area of the dumpsite in summer corresponds to its occurrence in northern inshore waters at that time.

Brachioteuthis riisei: Specimens were captured during cruises 1 and 2 where they occurred in slope, transitional, and eddy waters. Captures were small and erratic in comparison to water type, but relative abundance during the spring cruise was slightly greater than during the summer, 1.8 vs 1.0 specimens/sample.

TABLE 3.—Number of cephalopods captured in deepwater dumpsite 106 (number of specimens captured/number of tows catching cephalopods)

Species	Cruise 1 (spring)		Cruise 2 (summer)				Cruise 4 (fall)		Cruise 3 (winter)	
	S	E	S	T	WE	EE	S	E	S	E
(Number of tows)	9	1	6	11	30	27	1	7	7	6
Oregoniateuthis springeri				1/1						
Selenoteuthis scintillans									1/1	
Abralia veranyi	3/3			1/1	1/1				2/2	
Abralia redfieldi										2/1
Abralia species	7/2							3/1		
Abraliopsis pfefferi	6/3		2/1	6/3	15/6	5/5	9/1	8/4		2/2
Pyroteuthis margaritifera	4/1			1/1						2/1
Pterygioteuthis gemmata	36/6		1/1	2/2				47/7		
Thelidioteuthis alessandrinii				2/2			1/1			
Enoploteuthid larvae	13/5									
Illex illecebrosus	8/3						2/1	*13/6	2/2	2/1
Ornithoteuthis antillarum	4/3									
Ommastrephid larvae	5/3									
Onychoteuthis banksi	2/1				1/1					
Ancistroteuthis lichtensteini									2/2	
Octopoteuthis megaptera	4/2									
Brachioteuthis riisei	8/5	3/1	1/1	1/1		1/1				
Histioteuthis bonnellii					1/1					
Histioteuthis elongata						*1/1			1/1	1/1
Histioteuthis reversa	13/5	1/1	2/2	1/1	2/1			2/2	4/3	
Histioteuthis species								1/1		
Chiroteuthis veryanyi					1/1	1/1				3/2
Ctenopteryx sicula								1/1		
Mastigoteuthis magna	1/1		2/2		2/1	1/1		*1/1	1/1	1/1
Mastigoteuthis species				3/2	1/1	1/1				2/2
Cranchia scabra				1/1						
Liocranchia reinhardti	1/1									
Pyrgopsis pacificus	2/1	1/1								
Taonius pavo	2/2					2/1		*2/2	1/1	1/1
Helicocranchia pfefferi				1/1					1/1	
Egea inermis						1/1				
Sandalops melancholicus	1/1								1/1	
Megalocranchia abyssicola								1/1		
Megalocranchia megalops	21/5	1/1		2/2				*1/1		
Alloposus mollis	5/4		1/1					*1/1	4/2	3/2
Japetella diaphana	2/2								1/1	
Argonauta species								2/2		
Tremoctopus violaceus								1/1		
Octopod larvae	3/3	1/1				1/1				1/1

*Deep captures that may have been below influence of eddy water sensu stricto.

Histioteuthis reversa: This widely distributed species was captured during all four cruises. Although *H. reversa* occurs in both slope and eddy waters, it is slightly more abundant in slope water samples, 1.9 vs 1.7 specimens/sample.

Seasonal relative abundance by successful sample is greatest in the spring cruise (2.3 specimens/sample) followed by the fall cruise (2.0), the summer cruise, (1.6), and the winter cruise (1.3).

Chiroteuthis veranyi: This deep sea species was taken during cruises 2 and 3 in eddy water only, and it was slightly more abundant during the winter than the summer.

Mastigoteuthis magna: This species was captured during all four cruises and in about equal numbers in both slope and eddy water. One specimen each occurred only in slope water on cruise 1 and only in eddy water on cruise 4, but both cruises were biased in favor of the water type in which specimens presumably were captured. Actually, the cruise 4 specimen probably was taken at a depth considerably deeper than the extent of the eddy-type water, so should not be attributed to eddy water.

Taonius pavo: Catches of this species occurred at all four cruises in slope and eddy water in about equal numbers.

Megalocranchia megalops: Numerous specimens were taken, mostly during cruise 1, but a few specimens were captured during cruises 2 and 4. The relative abundance is highly in favor of the slope water: 21 specimens in 5 successful samples (4.2) vs 2 specimens in 2 samples (1.0) each for eddy and transition water. Likewise the spring catch is considerably greater than that of other seasons.

Alloposus mollis: This species was captured during all four cruises. The relative abundance is slightly greater in slope water (1.4) than in eddy water (1.3). The summer (1.0) and fall (1.0) catches are poor, while the spring (1.3) and winter (1.8) catches are greater.

SUMMARY.—Just as the total catches indicated a predominance of cephalopods in slope water, the limited data on individual species indicate a preference for slope water by several species. Although it is desirable to standardize the captures in a more refined manner, the limited sampling program (horizontal, oblique, open, closed tows) and the small numbers of cephalopods captured, make such an analysis unfeasible.

Species Composition

An analysis of the species composition of each cruise was undertaken to determine the degree of stability of the cephalopod fauna in the dumpsite waters and to designate resident and visitor species. Among the four cruises, cruise 1 captured 22 species, cruise 2 caught 21 species, cruise 3 caught 18 species, and cruise 4 caught 15 species. Of the total of 39 different species captured during the program, only 5 species were captured in all four cruises: *Abraliopsis pfefferi, Histioteuthis reversa, Mastigoteuthis magna, Taonius pavo,* and *Alloposus mollis.* (The larvae of octopods, enoploteuthids, ommastrephids, and *Mastigoteuthis* are each considered as one species in this discussion, but more than one species may actually be represented in each group). Five other species were captured in any combination of three of the four cruises: *Abralia veranyi, Pyroteuthis margaritifera, Pterygioteuthis gemmata, Illex illecebrosus,* and *Megalocranchia megalops.* The absence of *I. illecebrosus* from cruise 2 has been explained by its inshore migratory behavior in summertime. The other four species are absent in either the fall or the winter cruises, for no obvious reason other than the possible shortcomings of the sampling program. Probably all 10 species are permanent residents of the dumpsite area, their occurrence and abundance fluctuating with the vagaries of the seasons and the influence of the intrusions of the eddy water.

In an attempt to quantify the degree of similarity of the species composition between cruises, calculations were made of the Index of Similarity and the Jaccard's Coefficient of Community (Roper, 1977). The Index of Similarity (S) is calculated from the formula

$$S = \frac{2C}{A+B}$$

where A is the number of species in one cruise, B is the number of species in the other cruise, and C is the number of species common to both cruises. As a value of 0.85 is considered the lower limit of similarity, any values below this indicate that the compared cruises are dissimilar.

Jaccard's Coefficient of Community (cc) is expressed by the formula

$$cc = \frac{c}{a+b-c} \times 100$$

where a and b are the total number of species in each of the compared cruises, and c is the number of co-occurring species. On the scale of values 100% represents identical species composition, 0 represents no relationship, and 85% is the limit of similarity.

The table here summarizes the results of the calculations of comparisons between cruises:

S / cc	1	2	3	4
1				
2	0.56 / 39%			
3	0.55 / 38%	0.62 / 44%		
4	0.49 / 32%	0.44 / 29%	0.36 / 22%	

These values show that all cruises are dissimilar in species composition from each other to varying degrees. The dissimilarities are so strong that it is impossible to ascertain the complete picture of the cephalopod fauna in the deepwater dumpsite area. The dissimilarity among the four cruises may be a reflection of the unstable oceanographic conditions produced by the occurrence of warm core eddies that periodically invade the slope water habitat. Possibly the differences are attributable to normal seasonal phenomena or even to the effects of the dumping of pollutants into the area. Or, very likely, the dissimilar species compositions between cruises may be related to the relatively narrow and incomplete coverage of the sampling program.

APPENDIX

Summary of Data

TABLE A.—Summary of data on deepwater dumpsite cephalopods by cruise (SW = slope water, EE = eastern eddy, WE = western eddy, E = eddy, T = transitional waters; underlined number = average ML (mean length) of specimens in sample)

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
		Cruise 1			
Abralia veranyi					
6	1	24	615-0	2.47	SW
8	1	19	630-0	3.43	SW
9	1	37	550-0	2.05	SW
Abralia species					
5	6	4-7.2-12	750-0	1.60	SW
10	1	8	550-0	1.78	SW
Abraliopsis pfefferi					
6	1	19	615-0	2.47	SW
8	1	35	630-0	3.43	SW
9	4	18-26.5-34	550-0	2.05	SW
Pyroteuthis margaritifera					
4	4	9-14-24	620-0	2.30	SW
Pterygioteuthis gemmata					
1	7	14-18.2-21	750-0	3.07	SW
5	5	4-10.2-18	720-0	1.60	SW
6	2	9,25	615-0	2.47	SW
8	9	7-15.2-21	630-0	3.43	SW
9	9	4-13.2-23	550-0	2.05	SW
10	4	10-12.3-16	550-0	1.78	SW
Enoploteuthid larvae					
2	4	3,7, 2 heads	675-0	1.22	SW
3	2	5,8	790-0	1.42	SW
4	1	7	620-0	2.30	SW
8	3	4-5.3-7	630-0	3.43	SW
9	3	4-5.3-8	550-0	2.05	SW

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
Illex illecebrosus					
2	1	192	675-0	1.22	SW
4	5	6-12.4-18	620-0	2.30	SW
8	1	12	630-0	3.43	SW
10	1	67	550-0	1.78	SW
Ornithoteuthis antillarum					
2	2	13,23	675-0	1.22	SW
8	1	19	630-0	3.43	SW
9	1	34	550-0	2.05	SW
Ommastrephid larvae					
5	1	7	720-0	1.60	SW
6	2	4,12	615-0	2.47	SW
9	2	3,8	550-0	2.05	SW
Onychoteuthis banksi					
5	2	10,12	720-0	1.22	SW
Octopoteuthis megaptera					
8	2	42,45	630-0	3.43	SW
10	2	32,36	550-0	1.78	SW
Brachioteuthis riisei					
1	2	27,35	750-0	3.07	SW
4	2	17, 1 head	620-0	2.30	SW
7	3	34,35.3-38	640-0	2.83	E
8	1	23	630-0	3.43	SW
9	2	28,40	550-0	2.05	SW
10	1	47	550-0	1.78	SW
Mastigoteuthis magna					
9	1	47	550-0	2.05	SW
Histioteuthis reversa					
2	1	4	675-0	1.22	SW
3	1	6	790-0	1.42	SW
5	3	10-12-14	720-0	1.60	SW
7	1	6	640-0	2.83	E
8	7	4-10.6-18	630-0	3.43	SW
10	1	32	550-0	1.78	SW
Liocranchia reinhardti					
1	1	25	750-0	3.07	SW

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
Pyrgopsis pacificus					
1	2	55,62	750-0	3.07	SW
7	1	51	640-0	2.83	E
Taonius pavo					
3	1	85	790-0	1.42	SW
8	1	120	630-0	3.43	SW
Sandalops melancholicus					
8	1	32	630-0	3.43	SW
Megalocranchia megalops					
1	6	23-31.5-55	750-0	3.07	SW
4	2	14,17	620-0	2.30	SW
5	2	20,35	720-0	1.60	SW
7	1	22	640-0	2.83	E
8	8	18-37.5-55	630-0	3.43	SW
9	3	21-31.7-38	550-0	2.05	SW
Alloposus mollis					
1	1	15	750-0	3.07	SW
2	1	28	675-0	1.22	SW
8	1	35	630-0	3.43	SW
10	2	24,27	550-0	1.78	SW
Japetella diaphana					
1	1	8	630-0	3.07	SW
5	1	18	720-0	1.60	SW
Octopod larvae					
5	1	6	720-0	1.60	SW
7	1	7	640-0	2.83	E
9	1	5	550-0	2.05	SW
10	1	9	550-0	1.78	SW

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
	Cruise 2				
Oregoniateuthis springeri					
77M	1	7	100-0	0.17	T
Abralia veranyi					
38C	1	26	36-32	0.50	T
81M	1	36	100-0	0.25	WE
Abraliopsis pfefferi					
2M	1	33	25-0	0.08	EE
4A	1	37	100-75	0.08	EE
10A	1	33	100-75	0.07	EE
23M	1	20	1000-0	1.17	EE
26M	1	11	400-0	0.63	EE
36B	1	22	578-535	1.00	WE
36C	2	34,36	552-535	1.00	WE
36M	6	20-25.2-33	552-0	0.75	WE
43M	2	34,36	400-0	0.68	SW
59C	1	36	900-800	0.10	WE
76C	1	36	500-200	0.32	T
77M	2	34,35	100-0	0.17	T
79P	1	15	176-0	0.83	WE
85M	1	35	800-0	0.37	WE
86M	2	30,34	496-0	0.63	WE
87A	1	36	171-167	0.25	WE
94M	3	36-36.3-37	523-0	0.37	T
Pyroteuthis margaritifera					
94M	1	34	525-0	0.37	T
Pterygioteuthis gemmata					
38B	1	17	42-37	1.00	T
43B	1	27	500-400	0.25	SW
74M	1	26	42-0	0.17	T
Thelidioteuthis alessandrinii					
74M	1	14	42-0	0.17	T
92M	1	14	187-0	0.12	T
Onychoteuthis banksi					
50A	1	18	200-150	0.08	WE

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
Brachioteuthis riisei					
18A	1	21	43-43	0.50	EE
42C	1	51	207-207	0.25	SW
74M	1	29	43-0	0.17	T
Histioteuthis bonnellii					
51M	1	12	600-0	1.17	WE
Histioteuthis elongata					
14A	1	146	1000-800	0.20	E?
Histioteuthis reversa					
36M	2	9,16	550-0	0.75	WE
40M	2	35,34	200-0	0.57	SW
44N	1	33	700-0	2.68	T
Chiroteuthis veryanyi					
23M	1	head only	1000-0	1.17	EE
85M	1	8	800-0	0.37	WE
Mastigoteuthis magna					
23M	1	76	1000-0	1.17	EE
40C	1	84	300-200	0.27	SW
41B	1	93	42-42	0.25	SW
70A	1	100	500-400	0.63	WE
70B	1	130	400-300	0.40	WE
Mastigoteuthis species					
24M	1	70	500-0	0.65	EE
45C	1	68	800-600	0.25	T
78M	2	45,65	500-0	0.38	T
85M	1	25	800-0	0.37	WE
Cranchia scabra					
91M	1	79	187-0	0.27	T
Taonius pavo					
24Y	2	140,144	1800-0	5.15	EE
Helicocranchia pfefferi					
76M	1	57	200-0	0.23	T

TABLE A.—Continued.

Station number	Number of specimens	ML Range (mm)	Depth (m)	Time at depth (hr)	Water type
Egea inermis					
24B	1	63	800-600	0.92	EE
Megalocranchia megalops					
45C	1	65	800-600	0.25	T
78B	1	92	700-600	0.50	T
Alloposus mollis					
39C	1	41	50-25	0.12	SW
Octopod larva					
6C	1	15	200-100	0.20	EE
		Cruise 3			
Selenoteuthis scintillans					
15A	1	17	500-400	0.55	SW
Abralia veranyi					
12M	1	37	100-0	0.25	SW
18A	1	36	100-75	0.22	SW
Abralia redfieldi					
8C	1	21	300-200	0.60	E
8M	1	19	200-0	0.57	E
Abraliopsis pfefferi					
2M	1	21	200-0	0.28	E
4M	1	24	25-0	0.42	E
Pyroteuthis margaritifera					
2B	1	Head only	400-300	0.50	E
2M	1	27	200-0	0.28	E
Illex illecebrosus					
4M	2	11,14	25-0	0.42	E
16M	1	7	200-0	0.40	SW
18M	1	97	25-0	0.42	SW

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
Ancistroteuthis lichtensteini					
3B	1	54	700-600	0.50	SW
13M	1	36	500-0	1.00	SW
Histioteuthis elongata					
3C	1	125	600-500	0.70	E
14M	1	160	570-0	2.83	SW
Histioteuthis reversa					
12M	1	44	100-0	0.25	SW
16M	2	42,49	200-0	0.40	SW
19M	1	44	200-0	0.50	SW
Chiroteuthis veranyi					
3M	2	55,62	500-0	1.17	E
8A	1	41	500-400	0.50	E
Mastigoteuthis magna					
3M	1	31	500-0	1.17	E
13A	1	17+	800-700	0.48	SW
Mastigoteuthis species					
1M	1	21	100-0	0.67	E
5A	1	77	500-400	0.73	E
Taonius pavo					
3C	1	150	600-500	0.70	E
13M	1	90	500-0	1.00	SW
Helicocranchia pfefferi					
13M	1	40	500-0	1.00	SW
Sandalops melancholicus					
19M	1	24	200-0	0.50	SW
Alloposus mollis					
1M	2	7,9	100-0	0.67	E
3B	1	21	700-600	0.50	E
12M	3	11-18.3-30	100-0	0.25	SW
13M	1	11	500-0	1.00	SW
Japetella diaphana					
13A	1	17	800-700	0.48	SW
Octopod larva					
3M	1	5	500-0	1.17	E

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
	Cruise 4				
Abralia species					
JEC 76-38	3	unmeasurable	750-0	3.33	E
Abraliopsis pfefferi					
MOC 10-15	9	14-16.7-20	700-0	3.16	SW
JEC 76-30	1	22	950-0	3.42	E
JEC 76-32	1	16	750-0	2.83	E
JEC 76-37	3	12-13.7-15	825-0	2.50	E
JEC 76-40	3	14-16-17	750-0	3.00	E
Pterygioteuthis gemmata					
JEC 76-30	2	12,16	950-0	3.42	E
JEC 76-32	1	26	750-0	2.83	E
JEC 76-36	20	6-11.7-15	675-0	3.16	E
JEC 76-37	7	11-13.3-18	825-0	2.50	E
JEC 76-38	2	11,12	750-0	3.33	E
JEC 76-39	6	11-12.8-16	750-0	3.16	E
JEC 76-40	9	4-15.7-27	750-0	3.00	E
Thelidioteuthis alessandrinii					
MOC 10-15	1	18	700-0	3.16	SW
Illex illecebrosus					
MOC 10-15	2	222,230	700-0	3.16	SW
JEC 76-30	2	217,236	950-0	3.42	E?
JEC 76-32	2	226,247	750-0	2.83	E?
JEC 76-36	1	251	675-0	3.16	E?
JEC 76-38	2	235,255	750-0	3.16	E?
JEC 76-39	4	252-266-282	750-0	3.16	E?
JEC 76-40	2	232,275	750-0	3.00	E?
Histioteuthis reversa					
JEC 76-40	2	18,45	750-0	3.00	E
Histioteuthis species					
JEC 76-32	1	Head only	750-0	2.83	E
Ctenopteryx sicula					
JEC 76-36	1	13	675-0	3.16	E
Mastigoteuthis magna					
JEC 76-37	1	78	825-0	2.50	E?

TABLE A.—Continued.

Station number	Number of specimens	ML range (mm)	Depth (m)	Time at depth (hr)	Water type
Taonius pavo					
JEC 76-37	1	58	825-0	2.50	E?
JEC 76-40	1	60	750-0	3.00	E?
Megalocranchia abyssicola					
JEC 76-36	1	48	675-0	3.16	E
Megalocranchia megalops					
JEC 76-39	1	107	750-0	3.16	E?
Alloposus mollis					
JEC 76-32	1	103	750-0	2.83	E?
Argonauta species					
JEC 76-36	1	8	675-0	3.16	E
JEC 76-40	1	5	750-0	3.00	E
Tremoctopus violaceus					
JEC 76-32	1	Hectocotylized arm	750-0	2.83	E

TABLE B.—Station data for deepwater dumpsite cephalopod samples

Station number	Latitude (°N)	Longitude (°W)	Time	Depth (m)	Duration at depth (hrs)	Water type	Day night crepuscular
			Cruise 1				
MWT 1	38°46'	72°47'	2341–0245	750–0	3.07	SW	N
MWT 2	38°37'	73°00'	2301–0014	675–0	1.22	SW	N
MWT 3	38°37'	73°00'	0035–0200	790–0	1.42	SW	N
MWT 4	39°04'	72°34'	0128–0346	620–0	2.30	SW	N
MWT 5	38°56'	72°18'	0020–0156	720–0	1.60	SW	N
MWT 6	38°42'	72°00'	0007–0235	615–0	2.47	SW	N
MWT 7	38°54'	72°07'	2315–0205	640–0	2.83	E	N
MWT 8	38°40'	72°33'	2347–0303	630–0	3.43	SW	N
MWT 9	38°24'	71°59'	2337–0140	550–0	2.05	SW	N
MWT 10	38°41'	71°29'	2210–2357	550–0	1.78	SW	N
			Cruise 2				
2M	38°58'	72°03'	0140–0145	25–0	0.08	EE	N
4A	38°52'	71°58'	0455–0500	100–75	0.08	EE	C
6C	38°45'	72°07'	1225–1237	200–100	0.20	EE	D
10A	38°47'	72°00'	0010–0014	100–75	0.07	EE	N
14A	38°38'	72°03'	0913–0925	1000–800	0.20	SW	D
18A	38°33'	72°09'	2010–2040	43–43	0.50	EE	C
23M	38°35'	72°08'	1337–1447	1000–0	1.17	EE	D
24B	39°03'	72°04'	2240–2335	800–600	0.92	EE	N
24M	39°03'	72°04'	2356–0035	500–0	0.65	EE	N
26Y	39°03'	72°04'	1731–2240	1800–0	5.15	EE	C
26M	38°43'	72°04'	1413–1451	400–0	0.63	EE	D
36B	38°44'	72°15'	1425–1525	578–535	1.00	WE	D
36C	38°44'	72°15'	1525–1625	552–535	1.00	WE	D
36M	38°44'	72°15'	1625–1710	552–0	0.75	WE	D
38B	38°46'	72°41'	2050–2120	42–37	0.50	T	C
38C	38°46'	72°41'	2120–2150	36–32	0.50	T	N
39C	38°40'	72°45'	2333–2340	50–25	0.12	SW	N
40C	38°40'	72°46'	0230–0246	300–200	0.27	SW	N
40M	38°40'	72°46'	0246–0320	200–0	0.57	SW	N
41B	38°30'	72°55'	0423–0438	42–42	0.25	SW	N
42C	38°28'	72°58'	0631–0646	207–207	0.25	SW	C
43B	38°32'	72°53'	0904–0919	500–400	0.25	SW	D
43M	38°32'	72°53'	0919–1000	400–0	0.68	SW	D
44N	38°38'	72°44'	1114–1355	700–0	2.68	SW	D
45C	38°44'	72°44'	1750–1805	800–600	0.25	T	D
50A	38°54'	72°15'	0305–0310	200–150	0.08	WE	N
51M	38°51'	72°28'	1051–1200	600–0	1.15	WE	D
59C	38°49'	72°24'	0933–0939	900–800	0.10	WE	D
70A	38°48'	72°26'	2255–2333	500–400	0.63	WE	N
70B	38°48'	72°26'	2333–2357	400–300	0.40	WE	N
74M	38°39'	72°42'	0545–0555	42–0	0.17	T	C
76C	38°47'	72°38'	1231–1250	300–200	0.32	T	D
76M	38°47'	72°38'	1250–1304	200–0	0.23	T	D
77M	38°45'	72°44'	1410–1420	100–0	0.17	T	D
78B	38°43'	72°45'	1612–1642	700–600	0.50	T	D
78M	38°43'	72°45'	1717–1740	500–0	0.38	T	D
79P	38°51'	72°35'	2005–2050	176–0	0.83	WE	C
81M	38°39'	72°33'	2327–2342	100–0	0.25	WE	N
85M	38°57'	72°25'	1343–1405	800–0	0.37	WE	D
86M	38°50'	72°32'	1755–1833	496–0	0.63	WE	D
87A	38°44'	72°38'	1945–2000	171–167	0.25	WE	C
91M	39°02'	72°03'	0422–0438	187–0	0.27	T	N
92M	39°02'	71°54'	0617–0624	187–0	0.12	T	C
94M	38°51'	72°04'	1414–1456	523–0	0.37	T	D

TABLE B.—Continued.

Station number	Latitude (°N)	Longitude (°W)	Time	Depth (m)	Duration at depth (hrs)	Water type	Day night crepuscular
			Cruise 3				
1M	36°52'	74°19'	0250–0330	100–0	0.67	E	N
2B	37°01'	74°08'	2334–0014	400–300	0.50	E	N
2M	37°01'	74°08'	0053–0110	200–0	0.28	E	N
3B	37°00'	74°06'	1428–1458	700–600	0.50	SW	D
3C	37°00'	74°06'	1458–1540	600–500	0.70	E	D
3M	37°00'	74°06'	1540–1650	500–0	1.17	E	D
4M	37°05'	73°43'	2230–2255	25–0	0.42	E	N
5A	37°15'	73°54'	0104–0148	500–400	0.73	E	N
8A	37°29'	73°33'	1057–1127	500–400	0.50	E	D
8C	37°29'	73°33'	1200–1236	300–200	0.60	E	D
8M	37°29'	73°33'	1236–1310	200–0	0.57	E	D
12M	38°39'	72°27'	0055–0110	100–0	0.25	SW	N
13A	38°32'	71°46'	1338–1407	800–700	0.48	SW	D
13M	38°32'	71°46'	1510–1610	500–0	1.00	SW	D
14M	38°41'	72°05'	0150–0440	570–0	2.83	SW	N
15A	38°42'	72°04'	1035–1108	500–400	0.55	SW	D
16M	38°49'	72°13'	2251–2315	200–0	0.40	SW	N
18A	38°56'	72°06'	0115–0128	100–75	0.22	SW	N
18M	38°56'	72°06'	0205–0230	25–0	0.42	SW	N
19M	39°08'	71°47'	1300–1330	200–0	0.50	SW	D
			Cruise 4				
JEC 76-30	38°53'	72°22'	0005–0330	950–0	3.42	E	N
JEC 76-32	38°55'	72°28'	0010–0300	750–0	2.83	E	N
JEC 76-36	38°30'	72°10'	0020–0330	700–0	3.16	E	N
MOC 10-15	38°01'	71°29'	0020–0330	675–0	3.16	SW	N
JEC 76-37	38°55'	72°25'	2210–0040	825–0	2.50	E	N
JEC 76-38	38°51'	72°27'	0050–0410	750–0	3.33	E	N
JEC 76-39	38°49'	72°24'	0135–0445	750–0	3.16	E	N
JEC 76-40	38°44'	72°22'	0140–0440	750–0	3.00	E	N

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