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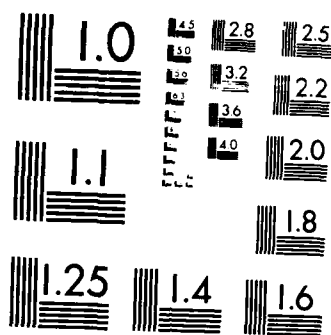
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Biology of Midwater Fishes
of the Bermuda Ocean Acre

ROBERT H. GIBBS, Jr.,
and WILLIAM H. KRUEGER

EDITORS

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Biology of Midwater Fishes
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ABSTRACT

Gibbs, Robert H., Jr., and William H. Krueger, editors. Biology of Midwater Fishes of the Bermuda Ocean Acre. *Smithsonian Contributions to Zoology*, number 452, 187 pages, 4 figures, 169 tables, 1987. — Four papers resulting from the Bermuda "Ocean Acre" program are included in this volume. The data are from 14 cruises conducted between October 1967 and June 1972 to sample the midwater fauna of a roughly one-degree square centered at 32°N, 64°W. The first paper presents information that is pertinent to the entire volume, as well as to any future papers: nature and number of samples, kinds of gear, sampling strategy, treatment of samples, methods of analysis, explanation of terminology, and a general description of the oceanography of the study area. The other three papers present detailed treatment of the life histories and ecology of the species in three families of mesopelagic fishes: Sternoptychidae, the marine hatchetfishes and related species, with 7 species in 4 genera; Myctophidae, the lanternfishes, with 63 species in 18 genera; and Melamphaidae, the so-called bigscales, with 15 species in 4 genera. When data are sufficient, the accounts include descriptions, analyses, and proposed explanations (when appropriate) of size ranges of the developmental stages, sex ratio, life cycle and seasonal abundance, vertical distribution of each growth stage, stage and size stratification, presence or absence of vertical migratory behavior, patchiness of distribution, and differences in day versus night catch rates. All three papers consider the partitioning of resources among species in the treated family. The species and samples of Myctophidae were subjected to factor and cluster analyses by season, and the results are discussed in detail.

Contents

iii

Biology of Midwater Fishes
of the Bermuda Ocean Acre

Background and Methods Used in
Studies of the Biology of Fishes
of the Bermuda Ocean Acre

Robert H. Gibbs, Jr., and Charles Karnella

ABSTRACT

A brief review of the physical and biological oceanography of the Bermuda area is given, and data are presented for the 14 cruises of the Ocean Acre program, the gear that was employed on each, and the 1184 samples that were obtained. Sampling strategy, treatment of samples, and methods of analysis are described. Most analyses used discrete-depth, noncrepuscular data from paired seasonal cruises in winter, late spring, and late summer grouped by 50-m intervals. Catch rates in number of specimens per hour of sampling with the Isaacs-Kidd midwater trawl (IKMT) were used as measures of abundance. Patchiness of distributions was estimated by the coefficient of dispersion. Constraints and methods used for cluster and factor analyses and measures of diversity and evenness are given. The reader is warned to be aware of the limitations of the Isaacs-Kidd-midwater-trawl universe as a basis for drawing conclusions.

Introduction

The Bermuda Ocean Acre program was conceived and initiated in 1967. Between October 1967 and June 1972 14 cruises were conducted to sample the midwater fauna of a roughly one-degree square centered at 32°N, 64°W, off the Bermuda islands. The plan was to sample a selected series of depths between the surface and 1500 m, using

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discrete-depth sampling gear, at each of the four seasons, and from the collections to elucidate the patterns of vertical distribution, life histories, abundance, and seasonality of the organisms occurring there. Few studies of midwater fishes have used discrete-depth samplers or have been conducted over more than one season; fewer still have done both. Although the objectives of the program were not entirely accomplished, the resulting studies provide a degree of detailed coverage seldom before attained.

This paper provides background and descriptions of methodology and analysis that will serve most or all of the papers that treat the biology of the midwater fishes at Ocean Acre. Three such papers are included in this volume, one dealing with the hatchetfishes and relatives (family Sternoptychidae), one with the lanternfishes (Myctophidae), and one with the so-called bigscales (Melamphaidae).

Oceanography of the Study Area

The Ocean Acre is located in the northern Sargasso Sea. The Sargasso Sea, which forms the western part of the North Atlantic subtropical region (Backus et al., 1977), is an anticyclonic gyre, equivalent to the Gulf Stream circulation (Worthington, 1976). It occupies about 26×10^6 cubic kilometers, or about 17 percent of the volume of the North Atlantic Ocean (Brooks, 1972). According to Worthington (1976) the boundaries of the Sargasso Sea can be taken as the extent of water at 300 m with a salinity of 36.4 to 36.6 parts per thousand (‰). The most prominent feature of the Sargasso Sea is the great abundance of 18° C water at a salinity of 36.5‰. This water is formed off Bermuda in winter by atmospheric cooling of surface water

(Worthington, 1976). Although a seasonal thermocline develops in the upper 200 m, 18° C water is found throughout the year in the northern Sargasso Sea between 200 and 400 m, and often extends much deeper (Schroeder and Stommel, 1969; Jahn, 1976).

The Sargasso Sea is divided into northern and southern parts by the "northern subtropical convergence," which may be the same phenomenon as the thermal fronts observed in the Sargasso Sea (Backus et al., 1977). Backus et al. (1969) demonstrated that faunal differences exist between the northern and southern Sargasso Sea and suggested that differences in primary productivity in the two areas could be responsible for the faunal differences. Earlier Ryther and Menzel (1961) attributed this difference in primary production to differences in stability in the upper part of the water column. In the north, winter cooling results in vertical mixing and nutrient replenishment, but in the south the year-round stability of the upper thermocline prevents the replenishment of the euphotic zone.

The physical oceanography of the study area has been discussed at length by Schroeder and Stommel (1969) and Brooks (1972), and briefly by Deevey (1971). The summary given here is excerpted from these authors.

The water column within the study area is 2000-4500 m deep, depending upon location. The surface water, which is highly saline (usually above 36.4‰), ranges from 18° to 29° C. A seasonal thermocline between 25-150 m exists from April to November, being best developed in August. At the top of the seasonal thermocline the temperature ranges between 20° and 27° C; at the bottom it is 18° to 19° C. Gradients of 8° C over a span of 50 m have been observed. Below the seasonal thermocline to about 400 m temperature decreases to 15°-18° C, and salinity remains fairly uniform at about 36.2‰.

A permanent deep thermocline occurs at about 500-1100 m and has the general characteristics of North Atlantic central water. Temperature decreases from about 18° to 6° C, and salinity from about 36.2 to 35.0‰ from top to bottom of the thermocline. Below this is intermediate water of uncertain origin, with temperatures of 4.0° to 5.5° C and salinity of about 35‰ to about 2000 m.

Dissolved oxygen concentration at the surface is between 4.5-5 ml/l and decreases to a minimum of about 3.5 ml/l at 700-900 m. Below this, dissolved oxygen concentration increases, reaching a maximum of 6.0 ml/l below 2000 m.

Plant nutrients in surface waters of the area are highest in winter and early spring, when vertical mixing occurs in the absence of the seasonal thermocline, and are lowest in the summer when the surface waters are stratified (Menzel and Ryther, 1960; Deevey, 1971). Correspondingly, phytoplankton concentrations and primary productivity are highest during winter and early spring, and maximum zooplankton abundance in the upper 500 m tends to follow in spring (Deevey, 1971; Deevey and Brooks, 1971). This tendency for total zooplankton in the upper 500 m, however, does not necessarily apply to individual species or groups of species, many of which have a primary or secondary peak in fall (Deevey and Brooks, 1971). At depths greater than 500 m, Deevey and Brooks (1971) found a tendency for numbers of zooplankton to be inversely correlated with numbers in the upper 500 m, and for peaks in abundance to occur earlier than in the upper layer. There is considerable annual variation in the magnitude of the biological phenomena, depending, in particular, upon the degree of cooling and mixing of waters above the permanent thermocline in winter and spring.

The thermal front, putatively identified with the "northern subtropical convergence" and considered to be the boundary between the northern and southern Sargasso Sea, usually has been located south of Bermuda, between 26° and 30°N. Differences in the fish faunas north and south of the front have been described by Backus et al. (1969) and Hulley and Krefft (1985). It is possible that the front might, occasionally, occur as far north as Bermuda, but even its proximity could facilitate some influx of the southern fauna into the Bermuda area.

Finally, we call attention to the possible influence of eddies on the environment and fauna of the Bermuda area. Cold-core Gulf Stream eddies are a prominent feature of the northern Sargasso Sea. With a core of slope water from off the northeastern United States and adjacent Canada, these eddies are capable of transporting slope-water fishes into the Sargasso Sea (Ring Group, 1981; Backus and Craddock, 1982). Gulf Stream rings usually are found well to the north or west of Bermuda, but an occasional one might reach that area. Even so, the fauna transported by them could be brought close enough to Bermuda to enable the occurrence of some species on a regular basis. It has also been suggested that eddies originating in the Mediterranean outflow have reached the area of the Bahamas (McDowell and Rossby, 1978), and it is possible that such rings may affect the Bermuda area as well.

Cruises and Gear

Table 1 summarizes the cruises and the samples obtained. Discrete-depth samples were obtained from 9 of the 14 cruises, although sampling of the desired range of depths was adequate for detailed seasonal analysis on only 6 of these.

There were 1184 samples made on the 14 cruises: 838 with IKMT's (538 of these from discrete depths), 289 with neuston nets, 48 with Engel midwater trawls (EMT), and 9 with dip nets. During the paired seasonal cruises (see "Methods of Analysis") 197 neuston samples (68% of such samples) and 631 IKMT samples (75% of such samples) were made; 452 of these IKMT samples were from known depths (84% of discrete-depth samples). Noncrepuscular discrete-depth

TABLE 1.—Ocean Acre cruise data arranged chronologically (DDS = discrete-depth sampler; EMT = Engel midwater trawl; IKMT = Isaacs-Kidd midwater trawl; NS = neuston sampler; dash = no samples).

CRUISE NUMBER	NO. OF DISCRETE DEPTH SAMPLES		NO. OF NON DISCRETE DEPTH SAMPLES		NO. OF DIP NET SAMPLES	GEAR EMPLOYED	SAMPLING DATES	VESSEL
	IKMT	NEUSTON	IKMT	EMT				
1	48	-	26	-	-	2M IKMT+DDS	26 OCT-2 NOV 1967	TRIDENT
2	-	-	5	-	-	2M IKMT	6-7 MAR 1968	TRIDENT
3	-	52	14	-	1	3M IKMT+NS	3-6 JUL 1968	GILLISS
4	69	-	31	-	-	3M IKMT+DDS	3-8 SEP 1968	TRIDENT
5	-	-	4	-	-	3M IKMT	6-12 DEC 1968	TRIDENT
6	36	9	24	-	1	3M IKMT+DDS+NS	24-30 APR 1969	SANDS
7	-	17	10	10	-	EMT+NS	5-9 SEP 1969	ALBATROSS IV
8	2	-	5	-	-	3M IKMT	23-25 NOV 1969	TRIDENT
9	-	14	33	-	-	3M IKMT+NS	16-23 MAR 1970	SANDS
10	76	66	35	-	1	3M IKMT+DDS+NS	1-10 JUN 1970	SANDS
11	33	8	12	-	1	3M IKMT+DDS+NS	12-15 JAN 1971	SANDS
12(I)	-	-	-	38	-	EMT	20-24 AUG 1971	DELAWARE II
12(II)	101	31	34	-	5	3M IKMT+DDS+NS	26 AUG-8 SEP 1971	SANDS
13	96	54	38	-	-	3M IKMT+DDS+NS	23 FEB-3 MAR 1972	SANDS
14	77	38	29	-	-	3M IKMT+DDS+NS	4-11 JUNE 1972	SANDS
TOTALS	538	289	300	48	9			

samples from the paired cruises totaled 510, including 359 by the IKMT and 151 neuston samples, their total sampling times 353 and 31 hours, respectively. In Table 2, the number of samples and total sampling times for the surface and each 50-m interval between the surface and 1550 m are given for day and night for each of the three seasons covered by the paired cruises. Figures 1–3 show the depths, time at depth, and depth excursion of all discrete-depth IKMT samples made during the paired seasonal cruises. Table 3 gives data for all samples of all kinds made during the 14 cruises.

The first two cruises employed a 2-m IKMT as the primary sampling device, one employed only an Engel trawl, and all 11 others employed a 3-m IKMT, one of the latter jointly with an Engel trawl. Neuston samples were made concurrently with the primary trawl on 9 cruises.

The 2-m IKMT, used on the first two cruises, was similar to the one described by Aron (1962), with the addition of the depressor modification described by Bercaw (1966).

The 3-m IKMT, the principal sampling device during the remainder of the program, differed little from the basic design of Isaacs and Kidd (1953). Strengthening members were added to the depressing vane, and, later, foldable vanes were constructed (as in Bercaw, 1966). The net itself was either lined with or constructed entirely of 3/8 inch (9.5 mm) stretch mesh knotless nylon, and its cod end was a 1-m ring plankton net with 00 mesh.

The discrete-depth sampler was the cod-end device described by Aron et al. (1964). This was a tubular structure with four chambers, three of which were closed by butterfly doors activated from the vessel via an electrical cable. Dur-

ing each lowering of the trawl, three samples could be collected at specified depths and a fourth during retrieval from depth to surface.

Trawl depth at first was monitored by triangulation based on the wire angle and the amount of cable payed out, and these calculated depths were checked with a nontelemetering time-depth recorder attached to the spreader bar of the trawl. This method limited our ability to select trawling depths with precision. The last five cruises (10–14) employed an electronic sensor mounted on the spreader bar (Battista and Giuliano, 1971), which allowed trawl depth to be monitored constantly on deck.

The large Engel trawls used during cruises 7 and 12 were provided by the Bureau of Commercial Fisheries (now National Marine Fisheries Service), Exploratory Fishing and Gear Research Base, Gloucester, Massachusetts. Two hauls during cruise 7 were made with a smaller version, the dimensions of which were not known. Eight hauls during cruise 7 and all 38 hauls during cruise 12(I) were made with a larger, 1400 mesh version. Its headrope and footrope were about 59 m, its vertical sides about 53 m, its overall length from midbosom to cod end about 106 m. Its mesh tapered from 8 inches (20.3 cm) stretch in the wings to 1.5 inches (3.8 cm) stretch in the cod end. The last 15 m of the cod end were lined with 1.3 cm stretch mesh. The net was fished with two 1610-m lengths of 2.5 cm cable and two 2.4 × 1.2 m Suberkrub doors.

Neuston (surface) samples were made with ring nets with bags made of 00 mesh. A 1/2-meter ring was employed on cruise 3, a 1-meter ring on all others. These nets were equipped with a 3-leg wire rope bridle and were fished from

TABLE 2.—Discrete-depth, noncrepuscular sampling effort during the paired seasonal cruises (H = number of hours; S = number of samples; 50-m depth intervals represented by their deepest depth).

DEPTH (M)	WINTER				LATE SPRING				LATE SUMMER				TOTALS			
	DAY		NIGHT		DAY		NIGHT		DAY		NIGHT		DAY		NIGHT	
	H	S	H	S	H	S	H	S	H	S	H	S	H	S	H	S
SURF	1.2	7	7.9	48	8.5	27	10.0	47	1.4	8	1.7	14	11.1	42	19.6	109
50	4.5	5	9.4	10	1.5	2	1.5	2	2.0	2	2.0	2	8.0	9	12.9	14
100	1.8	2	10.0	11	7.7	9	4.5	6	6.0	6	8.0	8	15.5	17	22.5	25
150	2.3	2	3.5	2	3.0	3	2.5	3	3.2	4	3.0	3	8.5	9	9.0	8
200	1.9	2	6.0	6	9.0	9	1.7	2	4.0	4	6.0	6	14.9	15	13.7	14
250	-	-	3.0	3	-	-	3.0	3	1.0	1	6.0	6	1.0	1	12.0	12
300	1.0	1	-	-	6.0	6	2.2	2	1.0	1	3.0	3	8.0	8	5.2	5
350	1.5	3	1.9	2	3.0	3	-	-	3.0	3	4.5	4	7.5	9	6.4	6
400	2.2	3	3.2	3	6.0	5	3.5	4	3.0	3	2.0	2	11.2	11	8.7	9
450	-	-	3.0	3	-	-	2.0	2	3.0	3	3.0	3	3.0	3	8.0	8
500	2.0	2	2.5	3	3.0	3	3.0	3	5.0	5	5.0	5	10.0	10	10.5	11
550	1.3	1	3.0	3	-	-	3.0	3	4.0	4	1.0	1	5.3	5	7.0	7
600	2.2	3	3.5	4	3.0	3	4.4	4	4.0	4	-	-	9.2	10	7.9	8
650	3.0	3	1.0	1	3.0	3	-	-	3.0	3	1.0	1	9.0	9	2.0	2
700	-	-	-	-	6.0	4	-	-	-	-	2.0	2	6.0	4	2.0	2
750	2.5	3	3.0	3	-	-	-	-	3.0	3	2.0	2	5.5	6	5.0	5
800	-	-	3.0	3	5.0	4	1.6	2	3.0	3	3.0	3	8.0	7	7.6	8
850	3.0	3	1.0	1	-	-	2.0	2	3.0	2	-	-	6.0	5	3.0	3
900	-	-	2.0	2	3.0	3	-	-	-	-	3.0	3	3.0	3	5.0	5
950	-	-	-	-	-	-	-	-	3.0	3	3.0	3	3.0	3	3.0	3
1000	-	-	1.0	1	4.5	5	3.0	3	-	-	3.0	3	4.5	5	7.0	7
1050	2.5	3	2.0	2	-	-	-	-	3.0	3	-	-	5.5	6	2.0	2
1100	-	-	-	-	1.0	1	1.0	1	-	-	-	-	1.0	1	1.0	1
1150	-	-	-	-	1.0	1	-	-	3.0	3	-	-	4.0	4	-	-
1200	-	-	-	-	1.0	1	-	-	2.0	2	-	-	3.0	3	-	-
1250	1.0	1	1.0	1	3.0	3	3.0	3	1.0	1	1.0	1	5.0	5	5.0	5
1300	1.9	2	2.0	2	-	-	-	-	1.0	1	2.0	2	2.9	3	4.0	4
1350	-	-	-	-	-	-	-	-	2.0	2	-	-	2.0	2	-	-
1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1500	-	-	-	-	-	-	-	-	1.0	1	-	-	1.0	1	-	-
1550	3.2	3	3.3	3	3.0	3	-	-	2.0	2	-	-	8.2	8	3.3	3
TOTAL	39.0	49	76.2	117	81.2	98	51.9	92	70.6	77	65.2	77	190.8	224	193.3	286

the side of the ship from a 2–3 m long boom so that the mouth of the net was about half submerged. Usual procedure was to tow the neuston net while the midwater trawl was being towed at 3 to 4 knots. At night the net usually was brought in every half hour; daytime tows usually were for one hour.

Dip nets were used occasionally to catch surface specimens while the ship was hove to. These were of variable construction, with long handles, net rings about 46 cm in diameter, and meshes varying from 1.2 to 2.5 cm stretch.

Sampling Strategy and Sample Treatment

The primary objective of the program was to take horizontal, discrete-depth samples at 14 selected depths from the surface to 1500 m both day and night during each cruise. Surface samples were made with neuston nets. Other discrete-depth samples were made by lowering the IKMT with all chambers open, allowing the net to stabilize at a selected depth, and then sequentially closing the chambers at, usually, one hour intervals. Barring malfunctions, this procedure resulted in three discrete-depth samples from the selected depth and an oblique sample from that depth to the surface. The attempt was made to hold ship speed at 3–4 knots during trawling, but this was not always successful.

For various reasons, the discrete-depth sampling objectives were not fully attained. The triangulation method of determining net depth resulted in inaccurate placement of some trawls, as did mid-tow changes of ship speed or direc-

tion. Gear malfunctions resulted in loss of some samples. Limited ship time often forced the elimination of some desired hauls. Nevertheless, by combining samples from different cruises, reasonably good discrete-depth coverage for three seasons has been obtained.

Upon retrieval of each trawl, the cod-end sampler was placed on a table constructed to prevent contamination between chambers, and the samples were washed with a hose into deep individual trays with fine-mesh screen bottoms. In the ship's laboratory, each sample was placed in a plastic tray and fixed with 10% formalin solution (= 4% actual formaldehyde concentration).

After fixing for about an hour, each sample was sorted into components, which always included eel larvae (leptocephali), other fishes, cephalopods, and other invertebrates, and wet displacement volumes were measured for each component. The samples then were placed in individual containers for storage and transportation to the home laboratory.

Samples were sorted to species in the home laboratory, and the standard length of each specimen was recorded. For the major mesopelagic groups, stage of development and sex also were recorded for each specimen taken in the discrete-depth samples and some others. (In the overwhelmingly abundant genus *Cyclothone*, these data were recorded for only a portion of the specimens.) Approximately 80 families and 300 species of fishes were taken during the Ocean Acre program.

The general criteria for the stages of development are given here, to be expanded as necessary by the authors of the analytic papers.

Prolarva: Yolk sac not fully resorbed. Not pertinent to these studies.

Postlarva: Yolk sac fully resorbed. Body proportions, pigment pattern, and development of photophores (if any) markedly different from those of adults.

Juvenile: Body proportions, pigment pattern, and development of photophores (if any) similar to those of adults. Gonad threadlike or flat and ovoid (depending upon the taxonomic group), without swollen region. Sex difficult or impossible to distinguish without special treatment.

Subadult: In *females*, begins when thread-like gonad begins to exhibit regional enlargement or ovoid ovary begins to enlarge and become plump. Very small, transparent eggs become visible under magnification. Eggs become larger and ovaries increase in diameter throughout this stage. End of stage arbitrarily recognized when large ova (near size at spawning) are visible over about 90% of the surface of the ovary. In *males*, begins when enlargement of the gonad is apparent, or cross-striated appearance becomes evident, or enlarged chamber at cloacal end begins to develop. No satisfactory end point has been determined. Testis changes are usually so gradual that a precise size of transition of male subadults from juveniles or into adults is

virtually impossible to ascertain visibly. In some cases, size-frequencies of all males have been compared with size-frequencies of juveniles and of subadult and adult females, and sizes of demarcation chosen that compare with those of females.

Adult: In *females*, large eggs are visible over 90% or more of the surface of the ovary. In *males*, this category may be established at an arbitrary lower size based on the size of females at the subadult–adult transition. Specimens with greatly enlarged testes (relative to the species) are easily categorized as adults.

While these general criteria may be applied to some extent for most species, it is necessary to examine a series of each species throughout its size range and covering all seasons in order to determine the actual situation. Problems of interpretation arise when, for example, a female well within the adult size range has only small eggs; some of these may be spent, others simply undeveloped. Species that spawn more than once may not meet the stated criteria for adults when they are between spawnings. The criteria are crude at best, and determination of the stages is not precise.

Environmental data, station data, and specimen data were keypunched and entered into computer storage preparatory to analysis.

The collections are or will be housed in the USNM collections of the Division of Fishes, Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, D.C.

Methods of Analysis

PAIRED SEASONAL CRUISES.—Six cruises, two from different years at each of three seasons, provide fairly complete depth coverage both night and day. Data for both cruises of a seasonal pair have been combined, and the three sets of paired data form the basis for the primary analyses. Cruises 10 and 14 constitute the late spring pair, 4 and 12 the late summer pair, and 11 and 13 the winter pair. Figures 1–3 show the time and depth excursions of all discrete-depth samples taken during the three seasons.

For the primary analyses data were grouped by 50-m depth intervals for night and day separately. *Day (diurnal)* is defined as from 1.5 hours after sunrise to 1.5 hours before sunset. *Night (nocturnal)* is from 1.5 hours after sunset to 1.5 hours before sunrise. *Twilight (crepuscular)* times are those within 1.5 hours of either sunrise or sunset. Samples impinging even slightly on these three-hour crepuscular periods are excluded from the primary analyses, but they are used in the analysis of rates of vertical migration. Sampling effort (number of samples and hours of sampling) within each 50-m interval for day and night in each of the three seasons is given in Table 2.

Recourse to the original, ungrouped data was made when
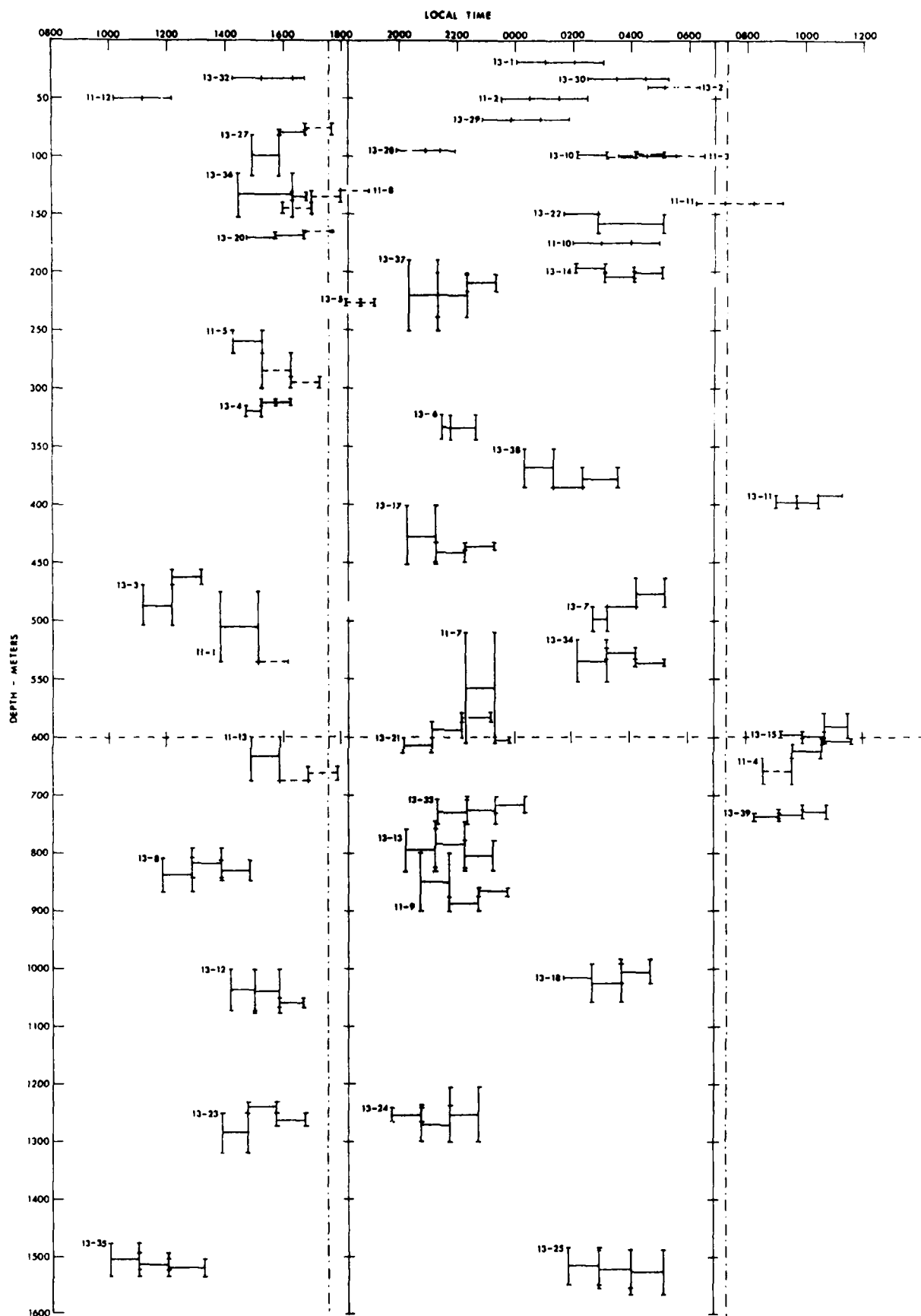
FIGURE 1.—Time and depth for all discrete-depth samples made in winter (cruises 11 and 13). Time of each sample is shown as a horizontal line at the main sampling depth bounded by short vertical lines. Depth excursion is indicated by the extent of the vertical lines. Dashed horizontal lines indicate samples made partly or entirely within 1.5 hours of sunrise or sunset. Sunrise and sunset times are indicated by vertical lines that run from top to bottom of the graph; solid lines are cruise 11, broken lines cruise 13. The dashed horizontal line at 600 m indicates a change in depth scale. Small numbers are the cruise and trawl numbers.
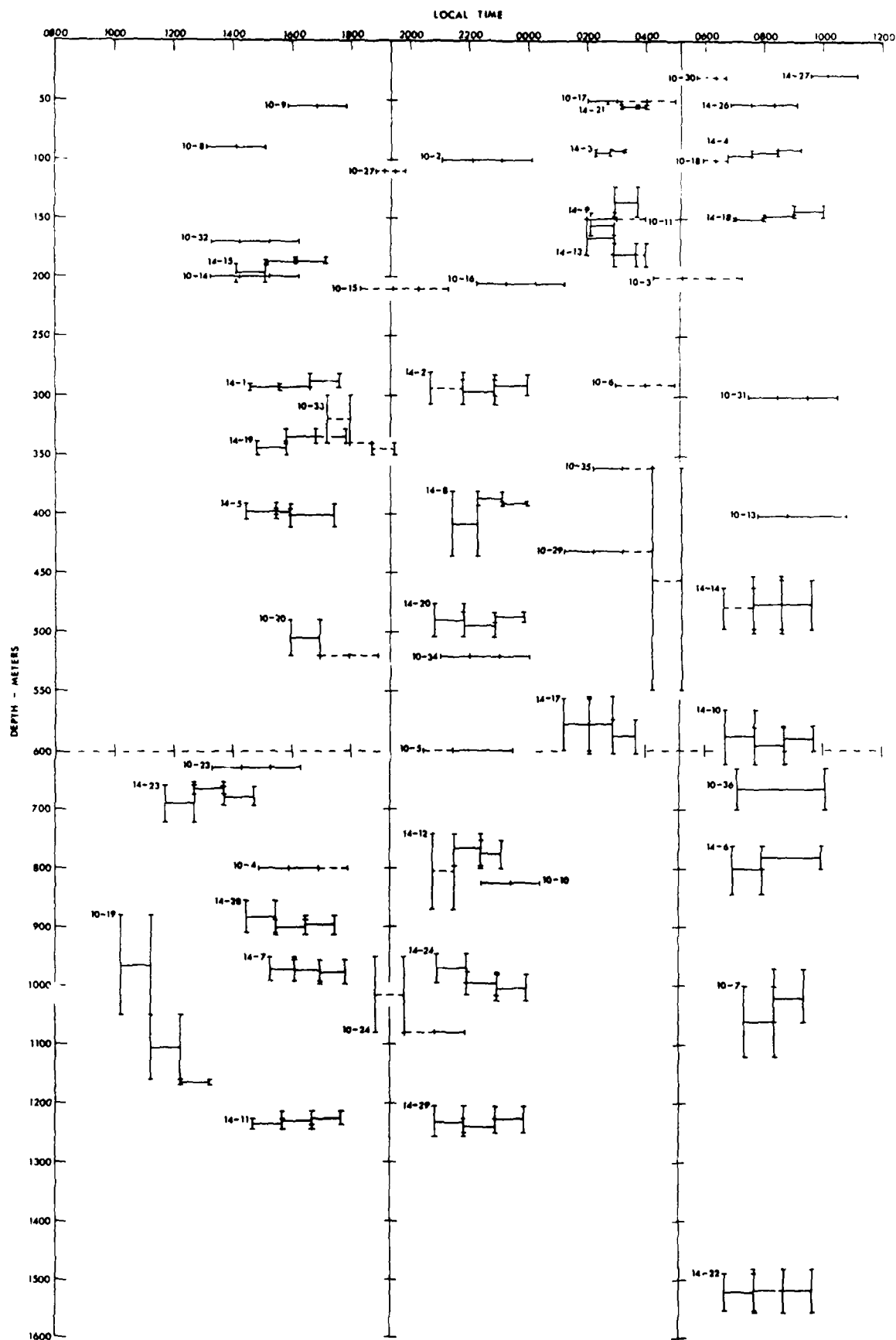
FIGURE 2.—Time and depth for all discrete-depth samples made in late spring (cruises 10 and 14). Time of each sample is shown as a horizontal line at the main sampling depth bounded by short vertical lines. Depth excursion is indicated by the extent of the vertical lines. Dashed horizontal lines indicate samples made partly or entirely within 1.5 hours of sunrise or sunset. Sunrise and sunset times are indicated by vertical lines that run from top to bottom of the graph. The dashed horizontal line at 600 m indicates a change in depth scale. Small numbers are the cruise and trawl numbers.
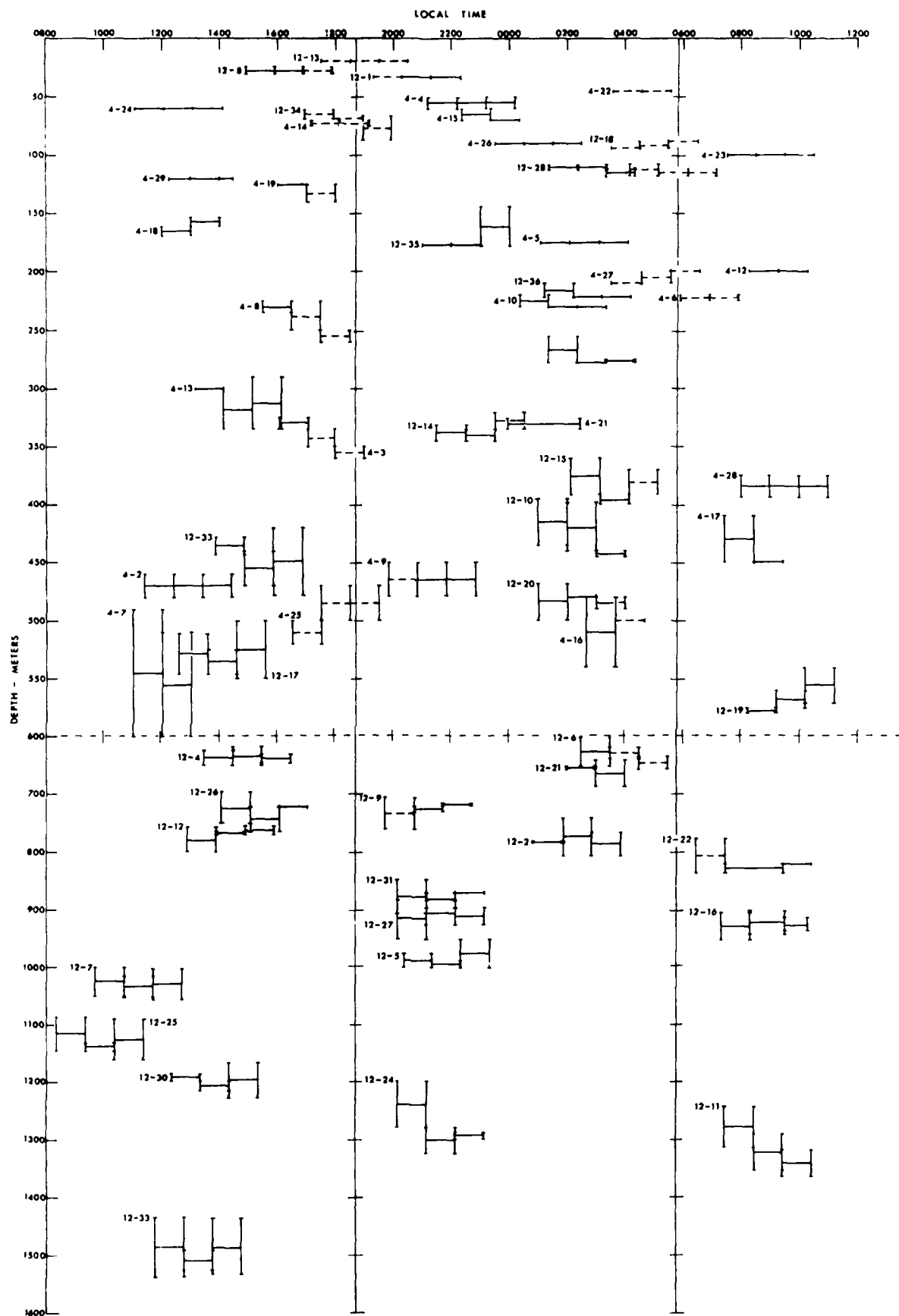
FIGURE 3.—Time and depth for all discrete-depth samples made in late summer (cruises 4 and 12). Time of each sample is shown as a horizontal line at the main sampling depth bounded by short vertical lines. Depth excursion is indicated by the extent of the vertical lines. Dashed horizontal lines indicate samples made partly or entirely within 1.5 hours of sunrise or sunset. Sunrise and sunset times are indicated by vertical lines that run from top to bottom of the graph. The dashed horizontal line at 600 m indicates a change in depth scale. Small numbers are the cruise and trawl numbers.

there was reason to believe that the grouped data led to erroneous interpretation or loss of detail.

SUPPLEMENTAL DATA.—Data from cruises other than the three primary pairs, mainly from nondiscrete samples, but including some neuston tows and a few IKMT discrete-depth samples, were used when they enabled finer analysis to be applied to the primary data. Samples made with the large Engel trawl, which catches larger specimens far more effectively than the IKMT, have been used to supplement many of the analyses, especially for late summer, when sequential cruises employed both kinds of gear (cruise 12, parts I and II).

CATCH RATES.—Catch rates were calculated as numbers of individuals caught per hour of sampling in each 50-m interval. These were derived by adding the catch rates for the individual samples within an interval and dividing by the number of samples (including negative ones). This method gives equal weight to each of the individual samples, and we have chosen it, rather than the sum of specimens divided by the number of hours. Because most samples were one hour in duration, catch rates determined by either method would be similar, but differences in duration were present.

For neuston tows, the individual sample catch rates were divided by 0.37875 to make them equivalent to those of a 3-m IKMT. This is based on the assumption that only the air-sea interface is being sampled, and the figure is the diameter of the 1-m ring net divided by the width of the mouth of an IKMT (2.64 m).

We have not converted catch rates to numbers per unit volume of water. To do so, the area of the mouth of an IKMT (7.44 m²) can be multiplied by the estimated ship speed (3 knots = 5600 m per hour) to give the volume of water sampled in an hour (41,664 m³). The catch rate in number of individuals per hour divided by this figure is an estimate of the average number of specimens per cubic meter of water. An estimate of the number of individuals in the entire 1550-m water column under 1 m² of surface (1550 m³) may be obtained by multiplying the number of specimens per m³ in each 50-m interval by 50 and calculating the sum of the surface figure (not multiplied) plus those of all 31 50-m intervals. The last figure may be multiplied by the surface area in m² to obtain an estimate of the number of individuals in a larger area.

INTERPOLATION IN UNSAMPLED INTERVALS.—Catch rates for unsampled intervals thought to be within the vertical range of the species were estimated by interpolation. For any given developmental stage, if one interval or two adjoining intervals were unsampled, the interpolated catch rate in each interval was the mean of the catch rates of the two adjoining intervals (shallower and deeper). If three or more adjacent intervals were unsampled, the catch rate of the middle one (or two if there was an even number) was

the mean of the adjacent sampled intervals, and a similar interpolation was made for the remaining intervals.

In analyses by size, interpolated catch rates for each size in the middle unsampled interval(s) were determined by using a mean size and catch rate midway between those of the two nearest sampled intervals and then averaging the catch for each millimeter of size larger and smaller than each sampled mean. If an unsampled interval was at the suspected shallow or deep limit, the catch rate was estimated as half that of the adjoining sampled interval, with the mean size equal to that in the sampled interval.

DEFINITIONS.—The abundance of any given category (e.g., stage, species, combination of species) at any diel period within a season was taken as the sum of the catch rates for all 50-m intervals, including interpolated values.

The abundance of a species at any season was the sum of the abundances of all stages at the diel period, night or day, when the highest sum was obtained.

The terms catch, catch rate, and abundance are used interchangeably in the text of the analyses. For example, when a species is said to be most abundant within a given depth range, this means that the catch rate or rates for the 50-m interval(s) within that range were greater than for other depths.

Numerous refers to the actual numbers of specimens caught in the sample or set of samples under discussion. Use of this term implies nothing about the actual or relative abundance of the category referred to, because the term includes samples taken in a nonstandard way and which usually are biased in depth coverage, seasonal coverage, or both.

PATCHINESS.—The coefficient of dispersion (CD) was used to examine the possibility that horizontal distributions were not random (see Pearcy, 1964). Patchiness, or clumping, was said to occur only if the CD was significantly greater than 1.0 (p = 0.05). This analysis was applied only to samples within a single 50-m interval; when clumping was noted for greater intervals, the CD for each of the included 50-m intervals was significant. Not all significant CD values have been accepted as indicative of a clumped or patchy distribution. Such cases are discussed where appropriate.

CLUSTER AND FACTOR ANALYSES.—Cluster analyses and factor analyses have been applied only to the Myctophidae in the present series of papers. These were done separately for night and day for each of the three seasons. Only species represented in discrete-depth samples by 10 or more specimens (species analyses) or discrete-depth samples containing more than 10 specimens (sample analyses) were included.

Cluster analyses of species and samples were performed with the Numerical Taxonomy System (NTSYS) of multivariate statistical programs, using the unweighted pair group arithmetic averaging method on correlation coefficients of catch rates (Sneath and Sokal, 1973).

Factor analyses were run using correlation coefficient matrices of species abundances. They were performed using the programs in the Statistical Package for the Social Sciences (SPSS). Orthogonal rotation was performed to simplify the factor structure using the varimax criterion.

DIVERSITY AND EVENNESS.—Species diversity and evenness also have been examined only in the Myctophidae in this series of papers. *Species diversity* for all 50-m intervals was measured by both the actual number of species caught in that interval and by the information theory index, $H = -Sp_i \log p_i$, where S = sum and p_i is the fraction of the catch rate contributed by species i in that interval. *Evenness,* or the distribution of the catch rate among the species, was measured by the index developed by Heip (1974): $E = e^H - 1/S - 1$, where H is the measure of diversity given above and S the total number of species taken in the particular interval.

Caveats

The reader should be aware that the Ocean Acre studies deal mainly with the IKMT universe. We believe that the IKMT may sample fishes in the size range of about 10 mm to perhaps 50 mm SL fairly efficiently. This means that small species are likely to be represented in the collections by all sizes except larvae and the smallest postlarvae, but that large species are likely to be underrepresented at both the small and large ends of their size spectrum. Thus, the abundance estimates for large species are far more likely to be too low than those of small species. The authors of the papers recognize this, and they discuss it in some cases, but they do not dwell on it. For the most part, the data are treated as if they were complete, and there was no attempt to explain all possible biases.

The large Engel trawl produces a different universe, one in which the average size of individuals is larger and small fishes and stages are underrepresented (Harrisson, 1967:101–106). Small species may be largely or totally absent in its collections. For example, the extremely abundant, small *Cyclothone* species, virtually are absent. In Hulley and Krefft's (1985) analysis of lanternfishes collected with the Engel trawl in the northern Sargasso Sea in April and May, two small species of lanternfishes, *Diogenichthys atlanticus* and *Notolychnus valdiviae,* which attain no more than 25 mm SL, rank 22nd and 29th in abundance; in Ocean Acre analyses for late spring (June) these two species rank 2nd and 6th, respectively, among the myctophids (Karnella, herein). On the other hand, if we remove (1) *D. atlanticus* and *N. valdiviae,* (2) those species taken almost entirely in neuston nets (*Gonichthys cocco, Centrobranchus nigroocellatus*), and (3) temperate species (not included in Hulley and Krefft's tabulation for the northern Sargasso Sea; Table 5), then Hulley and Krefft's 10 most abundant species include 8 of the Ocean Acre top 10.

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TABLE 3.—Date, coordinates, depths sampled, duration, and gear employed for all samples made on all Ocean Acre cruises (DD = day; D-M = degrees and minutes; MAIN = depth at which most of the sampling time was spent; MAX = maximum depth; MIN = minimum depth; MM = month).

SAMPLE	DATE 1967 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		

CRUISE 1

SAMPLE	DATE	NORTH D-M	WEST D-M		NORTH D-M	WEST D-M	MIN-MAX	MAIN	TIME	GEAR
1A	10/26	32-10,	64-29	TO	32-09,	64-18	200- 250	230	1100-1130	2M IKMT
1B	10/26	32-10,	64-29	TO	32-09,	64-18	150- 225	175	1130-1200	2M IKMT
1C	10/26	32-10,	64-29	TO	32-09,	64-18	100- 150	135	1200-1230	2M IKMT
1M	10/26	32-10,	64-29	TO	32-09,	64-18	0- 100	100	1230-1300	2M IKMT
2A	10/26	32-13,	64-18	TO	32-19,	64-18	400- 475	475	1404-1445	2M IKMT
2B	10/26	32-13,	64-18	TO	32-19,	64-18	275- 400	330	1445-1515	2M IKMT
2C	10/26	32-13,	64-18	TO	32-19,	64-18	210- 275	230	1515-1549	2M IKMT
2M	10/26	32-13,	64-18	TO	32-19,	64-18	0- 210	210	1549-1619	2M IKMT
3A	10/26	32-17,	64-25	TO	32-18,	64-20	400- 575	525	2115-2152	2M IKMT
3B	10/26	32-17,	64-25	TO	32-18,	64-20	320- 478	330	2152-2213	2M IKMT
3C	10/26	32-17,	64-25	TO	32-18,	64-20	210- 320	215	2213-2243	2M IKMT
3M	10/26	32-17,	64-25	TO	32-18,	64-20	0- 210	200	2243-2300	2M IKMT
4A	10/26	32-18,	64-20	TO	32-20,	64-14	150- 210	190	2349-0022	2M IKMT
4B	10/26	32-18,	64-20	TO	32-20,	64-14	125- 150	125	0022-0052	2M IKMT
4C	10/26	32-18,	64-20	TO	32-20,	64-14	50- 125	75	0052-0122	2M IKMT
4M	10/26	32-18,	64-20	TO	32-20,	64-14	0- 50	50	0122-0152	2M IKMT
7A	10/27	32-10,	64-23				400- 480	445	1430-1545	2M IKMT
7B	10/27	32-10,	64-23				250- 500	500	1545-1640	2M IKMT
7C	10/27	32-10,	64-23				250- 250	250	1640-1740	2M IKMT
7M	10/27	32-10,	64-23				0- 250	250	1740-1755	2M IKMT
8A	10/27	32-16,	64-18				250- 250	250	1943-2043	2M IKMT
8B	10/27	32-16,	64-18				167- 250	220	2043-2101	2M IKMT
8P	10/27	32-16,	64-18				0- 167	160	2101-2227	2M IKMT
9A	10/27	32-33,	64-21				125- 125	125	2307-0007	2M IKMT
9B	10/27	32-33,	64-21				75- 125	100	0007-0015	2M IKMT
9C	10/27	32-33,	64-21				75- 75	75	0015-0115	2M IKMT
9M	10/27	32-33,	64-21				0- 75	75	0115-0125	2M IKMT
11A	10/28	32-37,	64-10				200- 200	200	0549-0619	2M IKMT
11B	10/28	32-37,	64-10				175- 200	200	0619-0649	2M IKMT
11C	10/28	32-37,	64-10				162- 210	200	0649-0719	2M IKMT
11M	10/28	32-37,	64-10				0- 175	175	0719-0745	2M IKMT
12A	10/28	32-35,	63-58				590- 680	675	0837-0937	2M IKMT
12B	10/28	32-35,	63-58				550- 675	625	0937-0952	2M IKMT
12C	10/28	32-35,	63-58				500- 550	500	0952-1052	2M IKMT
12M	10/28	32-35,	63-58				0- 500	490	1052-1130	2M IKMT
13A	10/28	32-44,	63-37				330- 420	415	1255-1404	2M IKMT
13B	10/28	32-44,	63-37				300- 330	315	1404-1504	2M IKMT
13M	10/28	32-44,	63-37				0- 320	300	1504-1534	2M IKMT
15A	10/28	32-46,	64-00				420- 700	430	2003-2103	2M IKMT
15B	10/28	32-46,	64-00				301- 420	375	2103-2131	2M IKMT
15C	10/28.	32-46,	64-00				267- 301	280	2131-2231	2M IKMT
15M	10/28.	32-46,	64-00				0- 283	280	2231-2307	2M IKMT
16A	10/29	32-44,	63-42				275- 300	275	0337-0437	2M IKMT
16B	10/29	32-44,	63-42				150- 275	230	0437-0458	2M IKMT
16C	10/29	32-44,	63-42				175- 175	175	0458-0558	2M IKMT
16M	10/29	32-44,	63-42				0- 175	175	0558-0615	2M IKMT
17A	10/29	32-51,	63-28				100- 196	190	0655-0810	2M IKMT
17B	10/29	32-51,	63-28				92- 100	100	0810-0910	2M IKMT
17M	10/29	32-51,	63-28				0- 92	90	0910-0925	2M IKMT
18A	10/30	32-10,	63-48				130- 130	130	0034-0134	2M IKMT
18B	10/30	32-10,	63-48				100- 130	115	0134-0145	2M IKMT
18C	10/30	32-10,	63-48				100- 100	100	0145-0245	2M IKMT
18M	10/30	32-10,	63-48				0- 100	95	0245-0255	2M IKMT
19A	10/30	32-09,	64-00				130- 175	130	0337-0437	2M IKMT
19B	10/30	32-09,	64-00				80- 130	105	0437-0455	2M IKMT
19C	10/30	32-09,	64-00				75- 80	80	0455-0555	2M IKMT
19M	10/30	32-09,	64-00				0- 75	75	0555-0610	2M IKMT
20P	10/30	32-14,	64-14				0- 380	370	0630-0940	2M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1967 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST C-M	MIN-MAX	MAIN		
21A	10/30	31-49,	64-25			435- 450	450	1352-1452	2M IKMT
21B	10/30	31-49,	64-25			295- 440	375	1452-1513	2M IKMT
21C	10/30	31-49,	64-25			250- 295	290	1513-1613	2M IKMT
21M	10/30	31-49,	64-25			0- 250	250	1613-1634	2M IKMT
22A	10/30	31-52,	64-41			175- 175	175	1704-1804	2M IKMT
22B	10/30	31-52,	64-41			70- 175	125	1804-1830	2M IKMT
22C	10/30	31-52,	64-41			60- 70	70	1830-1930	2M IKMT
22M	10/30	31-52,	64-41			0- 60	60	1930-1940	2M IKMT
24N	10/31	31-35,	64-18			0- 565	510	1340-1800	3M IKMT
25N	10/31	31-23,	64-07			0- 186	185	1825-2115	3M IKMT
26N	10/31	31-26,	64-00			0- 84	80	2342-0200	3M IKMT
27N	11/ 1	31-27,	64-00			0- 154	140	0201-0425	3M IKMT
28N	11/ 1	31-27,	64-00			0- 205	205	0440-0745	3M IKMT
29N	11/ 1	31-25,	64-02			0- 810	810	0815-1345	2M IKMT
30N	11/ 1	31-59,	63-43			0-2000	2000	1400-2215	2M IKMT
31N	11/ 1	32-14,	63-26			0-1500	1500	2230-0500	2M IKMT
	1968			CRUISE 2					
2N	3/ 6	32-26,	63-44	TO 32-14,	63-44	0- 140	140	2131-0004	2M IKMT
3N	3/ 7	32-14,	63-44	TO 32-05,	63-44	0- 50	50	0043-0310	2M IKMT
4N	3/ 7	32-05,	63-52	TO 31-55,	63-45	0- 200	200	0319-0600	2M IKMT
5N	3/ 7	31-55,	63-45	TO 31-48,	63-47	0- 500	425	0604-0934	2M IKMT
6N	3/ 7	31-51,	63-40	TO 31-29,	64-03	0-1025	1025	1110-1819	2M IKMT
				CRUISE 3					
1D	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		2150-2205	.5 RING
1E	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		2210-2240	.5 RING
1F	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		2250-2320	.5 RING
1G	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		2330-0000	.5 RING
1H	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0004-0034	.5 RING
1J	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0045-0115	.5 RING
1K	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0119-0149	.5 RING
1L	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0155-0225	.5 RING
1N	7/ 3	32-57,	64-29	TO 32-59,	64-51	0-1931	1900	2119-0330	3M IKMT
1Q	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0234-0304	.5 RING
1R	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0315-0345	.5 RING
1T	7/ 3	32-57,	64-29	TO 32-59,	64-51	NEUSTON		0349-0419	.5 RING
2D	7/ 4	32-00,	64-45			NEUSTON		0410-0440	.5 RING
2E	7/ 4	32-00,	54-45			NEUSTON		0445-0515	.5 RING
2F	7/ 4	32-00,	64-45			NEUSTON		0525-0615	.5 RING
2G	7/ 4	32-00,	64-45			NEUSTON		0619-0719	.5 RING
2H	7/ 4	32-00,	64-45			NEUSTON		0725-0825	.5 RING
2J	7/ 4	32-00,	64-45			NEUSTON		0830-0901	.5 RING
2K	7/ 4	32-00,	64-45			NEUSTON		0915-0930	.5 RING
2L	7/ 4	32-00,	64-45			NEUSTON		1025-1055	.5 RING
2N	7/ 4	32-00,	64-45			0-1425	1400	0400-0930	3M IKMT
2Q	7/ 4	32-00,	64-45			NEUSTON		1100-1130	.5 RING
2R	7/ 4	32-00,	64-45			NEUSTON		1130-1200	.5 RING
2T	7/ 4	32-00,	64-45			NEUSTON		1200-1230	.5 RING
3D	7/ 4	32-04,	64-37	TO 33-10,	64-49	NEUSTON		1615-1704	.5 RING
3E	7/ 4	32-04,	64-37	TO 33-10,	64-49	NEUSTON		1704-1719	.5 RING
3F	7/ 4	32-04,	64-37	TO 33-10,	64-49	NEUSTON		1719-1734	.5 RING
3N	7/ 4	32-04,	64-37	TO 33-10,	64-49	0-1060	1050	1234-1719	3M IKMT
4D	7/ 4	33-10,	64-45	TO 33-18,	64-43	NEUSTON		1749-1849	.5 RING
4E	7/ 4	33-10,	64-45	TO 33-18,	64-43	NEUSTON		1900-1930	.5 RING
4F	7/ 4	33-10,	64-45	TO 33-18,	64-43	NEUSTON		1934-2004	.5 RING
4G	7/ 4	33-10,	64-45	TO 33-18,	64-43	NEUSTON		2007-2037	.5 RING
4H	7/ 4	33-10,	64-45	TO 33-18,	64-43	NEUSTON		2045-2115	.5 RING
4J	7/ 4	33-10,	64-45	TO 33-18,	64-43	NEUSTON		2119-2131	.5 RING
4N	7/ 4	33-10,	64-45	TO 33-18,	64-43	0- 480	465	1745-2149	3M IKMT
5D	7/ 4	33-18,	64-43	TO 33-09,	64-33	NEUSTON		2225-2255	.5 RING

Table 3.—Continued.

SAMPLE	DATE 1968 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
5E	7/ 4	33 18,	64-43	TO 33-09,	64-33	NEUSTON		2315-2345	.5 RING
5F	7/ 4	33-18,	64-43	TO 33-09,	64-33	NEUSTON		2349-0019	.5 RING
5G	7/ 4	33-18,	64-43	TO 33-09,	64-33	NEUSTON		0025-0055	.5 RING
5H	7/ 4	33-18,	64-43	TO 33-09,	64-33	NEUSTON		0100-0130	.5 RING
5J	7/ 4	33-18,	64-43	TO 33-09,	64-33	NEUSTON		0130-0200	.5 RING
5N	7/ 4	33-18,	64-43	TO 33-09,	64-33	0- 680	665	2219-0134	3M IKMT
6D	7/ 5	33-09,	64-33	TO 33-12,	64-35	NEUSTON		0225-0255	.5 RING
6E	7/ 5	33-09,	64-33	TO 33-12,	64-35	NEUSTON		0300-0330	.5 RING
6N	7/ 5	33-09,	64-33	TO 33-12,	64-35	0- 250	205	0212-0349	3M IKMT
7D	7/ 5	33-12,	64-35	TO 33-06,	64-41	NEUSTON		0410-0440	.5 RING
7E	7/ 5	33-12,	64-35	TO 33-06,	64-41	NEUSTON		0445-0515	.5 RING
7F	7/ 5	33-12,	64-35	TO 33-06,	64-41	NEUSTON		0519-0534	.5 RING
7N	7/ 5	33-12,	64-35	TO 33-06,	64-41	0- 312	310	0403-0552	3M IKMT
8D	7/ 5	33-06,	64-41	TO 35-00,	64-40	NEUSTON		0615-0645	.5 RING
8N	7/ 5	33-06,	64-41	TO 35-00,	64-40	0- 350	350	0604-0749	3M IKMT
9D	7/ 5	33-06,	64-40			NEUSTON		0804-0834	.5 RING
9N	7/ 5	33-06,	64-40			0- 600	575	0800-1000	3M IKMT
10D	7/ 5					NEUSTON		1015-1115	.5 RING
10E	7/ 5					NEUSTON		1125-1213	.5 RING
10N	7/ 5					0- 880	800	1010-1331	3M IKMT
11D	7/ 5					NEUSTON		1619-1719	.5 RING
11E	7/ 5					NEUSTON		1725-1825	.5 RING
11N	7/ 5					0-1920	1900	1340-1949	3M IKMT
12D	7/ 5					NEUSTON		2004-2104	.5 RING
12E	7/ 5					NEUSTON		2110-2140	.5 RING
12N	7/ 5					0- 700	650	2000-2155	3M IKMT
13D	7/ 5	32-54,	64-45			NEUSTON		2210-2307	.5 RING
13N	7/ 5	32-54,	64-45			0- 161	150	2204-2334	3M IKMT
14D	7/ 6					NEUSTON		2307-0045	.5 RING
14N	7/ 6					0- 110	110	2342-0103	3M IKMT
15X	7/ 3	32-57,	64-29	TO 32-57,	64-29	DIP NET		2100-2119	DIP NET

CRUISE 4

SAMPLE	DATE 1968 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
1N	9/ 3					0- 800	500	0215-0745	3M IKMT
2A	9/ 3	31-58,	64-24	TO 31-49,	64-18	460- 480	480	1125-1225	3M IKMT
2B	9/ 3	31-58,	64-24	TO 31-49,	64-18	460- 480	480	1225-1325	3M IKMT
2C	9/ 3	31-58,	64-24	TO 31-49,	64-18	460- 480	480	1325-1425	3M IKMT
2M	9/ 3	31-58,	64-24	TO 31-49,	64-18	0- 480	480	1425-1510	3M IKMT
3A	9/ 3	31-49,	64-18	TO 32-00,	64-29	325- 335	330	1604-1704	3M IKMT
3B	9/ 3	31-49,	64-18	TO 32-00,	64-29	335- 350	340	1704-1800	3M IKMT
3C	9/ 3	31-49,	64-18	TO 32-00,	64-29	350- 360	350	1800-1900	3M IKMT
3M	9/ 3	31-49,	64-18	TO 32-00,	64-29	0- 360	360	1900-2004	3M IKMT
4A	9/ 3	32-33,	64-25	TO 32-00,	64-23	50- 60	55	2112-2212	3M IKMT
4B	9/ 3	32-33,	64-25	TO 32-00,	64-23	50- 60	55	2212-2312	3M IKMT
4C	9/ 3	32-33,	64-25	TO 32-00,	64-23	50- 60	55	2312-0012	3M IKMT
4M	9/ 3	32-33,	64-25	TO 32-00,	64-23	0- 60	55	0012-0019	3M IKMT
5A	9/ 4	32-00,	64-23	TO 32-06,	64-15	175- 175	175	0104-0204	3M IKMT
5B	9/ 4	32-00,	64-23	TO 32-06,	64-15	175- 175	175	0204-0304	3M IKMT
5C	9/ 4	32-00,	64-23	TO 32-06,	64-15	175- 175	175	0304-0404	3M IKMT
5M	9/ 4	32-00,	64-23	TO 32-06,	64-15	0- 175	170	0404-0445	3M IKMT
6A	9/ 4	32-05,	64-13	TO 32-03,	64-00	220- 225	225	0555-0655	3M IKMT
6B	9/ 4	32-05,	64-13	TO 32-03,	64-00	220- 225	225	0655-0755	3M IKMT
6P	9/ 4	32-05,	64-13	TO 32-03,	64-00	0- 225	220	0755-0942	3M IKMT
7A	9/ 4	32-05,	63-54	TO 31-52,	63-56	490- 600	550	1100-1200	3M IKMT
7B	9/ 4	32-05,	63-54	TO 31-52,	63-56	510- 600	590	1200-1300	3M IKMT
7P	9/ 4	32-05,	63-54	TO 31-52,	63-56	0- 510	475	1300-1449	3M IKMT
8A	9/ 4	31-52,	63-56	TO 31-52,	63-58	225- 235	230	1530-1630	3M IKMT
8B	9/ 4	31-52,	63-56	TO 31-52,	63-58	225- 250	240	1630-1730	3M IKMT
8C	9/ 4	31-52,	63-56	TO 31-52,	63-58	250- 260	260	1730-1830	3M IKMT
8M	9/ 4	31 52,	63-56	TO 31-52,	63-58	0- 260	260	1830-1845	3M IKMT
9A	9/ 4	31-52,	63-58	TO 32-01,	64-03	450- 479	470	1949-2049	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1968 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
9B	9/ 4	31-52,	63-58	TO 32-01,	64-03	450- 479	470	2049-2149	3M IKMT
9C	9/ 4	31-52,	63-58	TO 32-01,	64-03	450- 479	470	2149-2249	3M IKMT
9M	9/ 4	31-52,	63-58	TO 32-01,	64-03	0- 479	470	2249-2345	3M IKMT
10A	9/ 5	32-00,	64-04	TO 31-55,	64-12	220- 230	225	0019-0119	3M IKMT
10B	9/ 5	32-00,	64-04	TO 31-55,	64-12	230- 230	230	0119-0219	3M IKMT
10C	9/ 5	32-00,	64-04	TO 31-55,	64-12	230- 230	230	0219-0319	3M IKMT
10M	9/ 5	32-00,	64-04	TO 31-55,	64-12	0- 230	230	0319-0340	3M IKMT
11A	9/ 5	31-53,	64-12	TO 31-50,	64-08	108- 117	110	0410-0510	3M IKMT
11B	9/ 5	31-53,	64-12	TO 31-50,	64-08	112- 117	115	0510-0610	3M IKMT
11C	9/ 5	31-53,	64-12	TO 31-50,	64-08	112- 117	115	0610-0710	3M IKMT
11M	9/ 5	31-53,	64-12	TO 31-50,	64-08	0- 117	115	0710-0734	3M IKMT
12A	9/ 5	31-50,	64-08	TO 31-54,	64-21	200- 200	200	0815-0915	3M IKMT
12B	9/ 5	31-50,	64-08	TO 31-54,	64-21	200- 200	200	0915-1015	3M IKMT
12P	9/ 5	31-50,	64-08	TO 31-54,	64-21	0- 200	200	1015-1130	3M IKMT
13A	9/ 5	32-00,	64-17	TO 31-59,	64-21	300- 300	300	1310-1410	3M IKMT
13B	9/ 5	32-00,	64-17	TO 31-59,	64-21	300- 335	310	1410-1510	3M IKMT
13C	9/ 5	32-00,	64-17	TO 31-59,	64-21	290- 335	325	1510-1610	3M IKMT
13M	9/ 5	32-00,	64-17	TO 31-59,	64-21	0- 290	290	1610-1634	3M IKMT
14A	9/ 5	31-51,	64-19	TO 31-49,	64-30	70- 75	75	1710-1810	3M IKMT
14B	9/ 5	31-51,	64-19	TO 31-49,	64-30	70- 75	75	1810-1910	3M IKMT
14P	9/ 5	31-51,	64-19	TO 31-49,	64-30	0- 75	75	1910-2025	3M IKMT
15A	9/ 5	31-49,	64-14	TO 32-01,	64-17	60- 70	65	2219-2319	3M IKMT
15B	9/ 5	31-49,	64-14	TO 32-01,	64-17	60- 70	65	2319-0019	3M IKMT
15P	9/ 5	31-49,	64-14	TO 32-01,	64-17	0- 70	65	0019-0134	3M IKMT
16A	9/ 6	32-00,	64-17	TO 31-58,	64-08	480- 540	510	0240-0340	3M IKMT
16B	9/ 6	32-00,	64-17	TO 31-58,	64-08	500- 540	510	0340-0440	3M IKMT
16P	9/ 6	32-00,	64-17	TO 31-58,	64-08	0- 500	500	0440-0630	3M IKMT
17A	9/ 6	31-53,	64-04	TO 31-44,	64-09	410- 450	430	0725-0825	3M IKMT
17B	9/ 6	31-53,	64-04	TO 31-44,	64-09	410- 450	430	0825-0925	3M IKMT
17P	9/ 6	31-53,	64-04	TO 31-44,	64-09	0- 410	410	0925-1110	3M IKMT
18A	9/ 6	31-46,	64-08	TO 31-46,	64-37	161- 169	165	1200-1300	3M IKMT
18B	9/ 6	31-46,	64-08	TO 31-46,	64-37	154- 161	155	1300-1400	3M IKMT
18P	9/ 6	31-46,	64-08	TO 31-46,	64-37	0- 154	154	1400-1530	3M IKMT
19A	9/ 6	31-47,	64-31	TO 31-51,	64-30	125- 125	125	1600-1700	3M IKMT
19B	9/ 6	31-47,	64-31	TO 31-51,	64-30	125- 140	130	1700-1800	3M IKMT
19P	9/ 6	31-47,	64-31	TO 31-51,	64-30	0- 140	140	1800-1925	3M IKMT
20P	9/ 6	31-50,	64-21	TO 31-53,	64-27	0- 110	110	2045-0004	3M IKMT
21A	9/ 7	31-53,	64-27	TO 32-09,	64-13	327- 335	335	0055-0225	3M IKMT
21M	9/ 7	31-53,	64-27	TO 32-09,	64-13	0- 335	335	0225-0255	3M IKMT
22A	9/ 7	32-09,	64-13	TO 32-16,	64-10	45- 45	45	0334-0434	3M IKMT
22B	9/ 7	32-09,	64-13	TO 32-16,	64-10	45- 45	45	0434-0534	3M IKMT
22P	9/ 7	32-09,	64-13	TO 32-16,	64-10	45- 45	45	0534-0645	3M IKMT
23A	9/ 7	32-13,	64-14	TO 32-17,	64-05	100- 100	100	0730-0830	3M IKMT
23B	9/ 7	32-13,	64-14	TO 32-17,	64-05	100- 100	100	0830-0930	3M IKMT
23C	9/ 7	32-13,	64-14	TO 32-17,	64-05	100- 100	100	0930-1030	3M IKMT
23M	9/ 7	32-13,	64-14	TO 32-17,	64-05	0- 100	100	1030-1040	3M IKMT
24A	9/ 7	32-02,	64-08	TO 32-58,	64-05	60- 60	60	1104-1204	3M IKMT
24B	9/ 7	32-02,	64-08	TO 32-58,	64-05	60- 60	60	1204-1304	3M IKMT
24C	9/ 7	32-02,	64-08	TO 32-58,	64-05	60- 60	60	1304-1404	3M IKMT
24M	9/ 7	32-02,	64-08	TO 32-58,	64-05	0- 60	60	1404-1410	3M IKMT
25A	9/ 7	32-14,	64-05	TO 32-08,	64-12	500- 520	510	1630-1730	3M IKMT
25B	9/ 7	32-14,	64-05	TO 32-08,	64-12	470- 500	490	1730-1830	3M IKMT
25C	9/ 7	32-14,	64-05	TO 32-08,	64-12	470- 520	510	1830-1930	3M IKMT
25M	9/ 7	32-14,	64-05	TO 32-08,	64-12	0- 520	520	1930-2049	3M IKMT
26A	9/ 8	31-48,	64-00	TO 31-58,	64-00	90- 90	90	2330-0030	3M IKMT
26B	9/ 8	31-48,	64-00	TO 31-58,	64-00	90- 90	90	0030-0130	3M IKMT
26C	9/ 8	31-48,	64-00	TO 31-58,	64-00	90- 90	90	0130-0230	3M IKMT
26M	9/ 8	31-48,	64-00	TO 31-58,	64-00	0- 90	90	0230-0245	3M IKMT
27A	9/ 8	31-58,	64-01	TO 32-07,	64-04	210- 210	210	0330-0434	3M IKMT
27B	9/ 8	31-58,	64-01	TO 32-07,	64-04	200- 210	205	0434-0534	3M IKMT
27C	9/ 8	31-58,	64-01	TO 32-07,	64-04	200- 200	200	0534-0634	3M IKMT
27M	9/ 8	31-58,	64-01	TO 32-07,	64-04	0- 200	200	0634-0700	3M IKMT
28A	9/ 8	32-05,	64-04	TO 32-12,	64-16	375- 394	375	0800-0900	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1968 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN	START-END	
28B	9/ 8	32-05,	64-04	TO 32-12,	64-16	375- 394	375	0900-1000	3M IKMT
28C	9/ 8	32-05,	64-04	TO 32-12,	64-16	375- 394	375	1000-1100	3M IKMT
28M	9/ 8	32-05,	64-04	TO 32-12,	64-16	0- 375	375	1100-1145	3M IKMT
29A	9/ 8	32-08,	64-11	TO 32-18,	64-15	120- 120	120	1215-1300	3M IKMT
29B	9/ 8	32-08,	64-11	TO 32-18,	64-15	120- 120	120	1300-1400	3M IKMT
29C	9/ 8	32-08,	64-11	TO 32-18,	64-15	120- 120	120	1400-1430	3M IKMT
29M	9/ 8	32-08,	64-11	TO 32-18,	64-15	0- 120	120	1430-1445	3M IKMT
30N	9/ 8	32-10,	64-08	TO 32-18,	64-12	0- 100	100	1537-1904	3M IKMT
31N	9/ 8	31-56,	63-57	TO 32-08,	64-14	0-1690	1675	2330-0300	3M IKMT

CRUISE 5

SAMPLE	DATE 1968 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL	GEAR
1N	12/ 6	32-30,	63-46	TO 32-22,	63-57	0-2441	2400	1810-0134	3M IKMT
2N	12/ 7	32-16,	63-51	TO 32-03,	63-48	0-2150	2100	1319-2015	3M IKMT
3N	12/11	32-10,	64-08	TO 32-25,	64-20	0-1710	1500	1315-1910	3M IKMT
4N	12/11	32-01,	64-15	TO 32-12,	64-28	0-1400	1400	2239-0540	3M IKMT

SAMPLE	1969	COORDINATES		CRUISE 6		DEPTH (M)		TIME LOCAL	GEAR
1D	4/25	32-01,	63-53	TO 32-00,	63-56	NEUSTON		0900-1000	1M RING
2A	4/25	31-56,	63-47	TO 31-48,	63-27	350- 350	350	1431-1531	3M IKMT
2B	4/25	31-56,	63-47	TO 31-48,	63-27	350- 350	350	1531-1631	3M IKMT
2D	4/25	31-56,	63-47	TO 31-48,	63-27	NEUSTON		1630-1730	1M RING
2P	4/25	31-56,	63-47	TO 31-48,	63-27	0- 350	350	1631-1821	3M IKMT
3A	4/25	31-51,	63-37	TO 31-40,	63-46	1200-1330	1275	2030-2130	3M IKMT
3B	4/25	31-51,	63-37	TO 31-40,	63-46	1200-1330	1220	2130-2230	3M IKMT
3D	4/25	31-51,	63-37	TO 31-40,	63-46	NEUSTON		2200-2300	1M RING
3P	4/25	31-51,	63-37	TO 31-40,	63-46	0-1330	1180	2230-0049	3M IKMT
4D	4/26	31-39,	63-35	TO 31-40,	63-35	NEUSTON		0330-0434	1M RING
5A	4/26	31-39,	63-45	TO 31-39,	63-52	500- 500	500	0707-0807	3M IKMT
5B	4/26	31-39,	63-45	TO 31-39,	63-52	500- 500	500	0807-0907	3M IKMT
5D	4/26	31-39,	63-45	TO 31-39,	63-52	NEUSTON		0440-0540	1M RING
5P	4/26	31-39,	63-45	TO 31-39,	63-52	0- 500	500	0907-1100	3M IKMT
6N	4/26	31-39,	63-52	TO 31-50,	63-58	0-1750	1700	1200-1900	3M IKMT
7A	4/26	31-47,	63-53	TO 31-55,	63-57	155- 155	155	2010-2110	3M IKMT
7B	4/26	31-47,	63-53	TO 31-55,	63-57	155- 155	155	2110-2210	3M IKMT
7C	4/26	31-47,	63-53	TO 31-55,	63-57	155- 155	155	2210-2310	3M IKMT
7D	4/26	31-47,	63-53	TO 31-55,	63-57	NEUSTON		1949-2049	1M RING
7M	4/26	31-47,	63-53	TO 31-55,	63-57	0- 155	155	2310-2340	3M IKMT
8A	4/27	31-55,	63-57	TO 31-59,	63-58	300- 300	300	0045-0145	3M IKMT
8B	4/27	31-55,	63-57	TO 31-59,	63-58	300- 300	300	0145-0245	3M IKMT
8D	4/27	31-55,	63-57	TO 31-59,	63-58	NEUSTON		0015-0115	1M RING
8E	4/27	31-55,	63-57	TO 31-59,	63-58	NEUSTON		0200-0304	1M RING
8F	4/27	31-55,	63-57	TO 31-59,	63-58	NEUSTON		0315-0415	1M RING
8P	4/27	31-55,	63-57	TO 31-59,	63-58	0- 300	300	0245-0415	3M IKMT
9A	4/27	31-59,	63-57	TO 31-57,	63-52	425- 425	425	0534-0634	3M IKMT
9B	4/27	31-59,	63-57	TO 31-57,	63-52	425- 425	425	0634-0734	3M IKMT
9P	4/27	31-59,	63-57	TO 31-57,	63-52	0- 425	425	0734-0919	3M IKMT
10A	4/27	31-59,	63-43	TO 31-59,	63-36	900- 900	900	1100-1200	3M IKMT
10B	4/27	31-59,	63-43	TO 31-59,	63-36	900- 900	900	1200-1300	3M IKMT
10P	4/27	31-59,	63-43	TO 31-59,	63-36	0- 900	900	1300-1449	3M IKMT
11A	4/27	31-57,	63-37	TO 32-05,	63-42	800- 800	800	1800-1900	3M IKMT
11B	4/27	31-57,	63-37	TO 32-05,	63-42	800- 800	800	1900-2000	3M IKMT
11P	4/27	31-57,	63-37	TO 32-05,	63-42	0- 800	800	2000-2204	3M IKMT
12A	4/27	32-05,	63-42	TO 32-13,	63-44	50- 50	50	2300-0000	3M IKMT
12B	4/27	32-05,	63-42	TO 32-13,	63-44	50- 50	50	0000-0100	3M IKMT
12C	4/27	32-05,	63-42	TO 32-13,	63-44	50- 50	50	0100-0200	3M IKMT
12M	4/27	32-05,	63-42	TO 32-13,	63-44	0- 50	50	0200-0204	3M IKMT
13A	4/28	32-13,	63-44			175- 175	175	0449-0549	3M IKMT
13B	4/28	32-13,	63-44			175- 175	175	0549-0649	3M IKMT
13P	4/28	32-13,	63-44			0- 175	175	0649-0815	3M IKMT
14A	4/28	32-20,	63-51			55- 60	60	1316-1416	3M IKMT
14B	4/28	32-20,	63-51			58- 60	60	1416-1516	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1969 MM/DD	NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN	TIME LOCAL START-END	GEAR
		COORDINATES				DEPTH (M)			
14C	4/28	32-20, 63-51				58- 58	58	1516-1548	3M IKMT
14M	4/28	32-20, 63-51				0- 58	58	1548-1603	3M IKMT
15A	4/28	32-13, 63-51				160- 160	160	1700-1800	3M IKMT
15B	4/28	32-13, 63-51				160- 160	160	1800-1900	3M IKMT
15P	4/28	32-13, 63-51				0- 160	160	1900-2012	3M IKMT
16A	4/28	32-18, 63-50 TO	32-20, 63-38			130- 140	135	2100-2200	3M IKMT
16B	4/28	32-18, 63-50 TO	32-20, 63-38			130- 140	135	2200-2300	3M IKMT
16C	4/28	32-18, 63-50 TO	32-20, 63-38			130- 140	135	2300-0000	3M IKMT
16M	4/28	32-18, 63-50 TO	32-20, 63-38			0- 140	135	0000-0010	3M IKMT
17A	4/29	32-19, 63-37 TO	32-13, 63-46			225- 235	230	0100-0200	3M IKMT
17B	4/29	32-19, 63-37 TO	32-13, 63-46			225- 235	230	0200-0300	3M IKMT
17P	4/29	32-19, 63-37 TO	32-13, 63-46			0- 235	230	0300-0419	3M IKMT
18A	4/29	32-14, 63-46				750- 750	750	0545-0645	3M IKMT
18B	4/29	32-14, 63-46				750- 750	750	0645-0745	3M IKMT
18P	4/29	32-14, 63-46				0- 750	750	0745-0945	3M IKMT
19A	4/29	32-08, 63-46 TO	31-56, 63-45			225- 225	225	1149-1249	3M IKMT
19B	4/29	32-08, 63-46 TO	31-56, 63-45			225- 225	225	1249-1349	3M IKMT
19P	4/29	32-08, 63-46 TO	31-56, 63-45			0- 225	225	1349-1504	3M IKMT
20N	4/29	31-57, 63-46				0- 550	550	1919-2334	3M IKMT
21N	4/30	32-17, 63-46				0-1050	1050	2349-0500	3M IKMT
22N	4/30	32-17, 63-45 TO	32-23, 63-43			0- 400	400	0510-0915	3M IKMT
23N	4/30	32-23, 63-43 TO	32-15, 63-41			0-2250	2100	0930-1530	3M IKMT
24N	4/30	32-13, 63-40 TO	32-18, 63-53			0- 750	750	1600-2034	3M IKMT
25N	4/30	32-18, 63-53 TO	32-18, 63-55			0- 10	10	2045-2149	3M IKMT
26N	4/30	32-18, 63-55				0- 200	200	2204-0045	3M IKMT
27X	4/24	32-02, 63-53 TO	32-02, 63-53			DIP NET		2230-0000	DIP NET
				CRUISE 7					
2N	9/ 6	32-10, 63-30 TO	32-12, 63-31			0- 520	510	2104-2319	LG. EMT
3D	9/ 7	32-12, 63-12 TO	32-00, 63-00			NEUSTON		0040-0110	1M RING
3N	9/ 7	32-12, 63-12 TO	32-00, 63-00			0- 125	110	2325-0134	LG. EMT
4D	9/ 7	32-02, 63-05 TO	32-05, 63-08			NEUSTON		0155-0225	1M RING
4N	9/ 7	32-02, 63-05 TO	32-05, 63-08			0- 450	300	0149-0400	LG. EMT
5N	9/ 7	32-13, 63-23 TO	32-17, 63-23			0- 200	125	0500-0725	LG. EMT
6N	9/ 7	32-19, 63-25 TO	32-19, 63-28			0- 600	480	1440-1704	LG. EMT
7D	9/ 7	32-18, 63-33 TO	32-20, 63-35			NEUSTON		1734-1815	1M RING
7E	9/ 7	32-18, 63-33 TO	32-20, 63-35			NEUSTON		1825-1845	1M RING
7N	9/ 7	32-18, 63-33 TO	32-20, 63-35			0- 50	50	1715-1855	LG. EMT
8D	9/ 7	32-07, 63-40 TO	32-07, 63-47			NEUSTON		1934-2004	1M RING
8E	9/ 7	32-07, 63-40 TO	32-07,.63-47			NEUSTON		2015-2034	1M RING
8N	9/ 7	32-07, 63-40 TO	32-07, 63-47			0- 125	70	1910-2100	LG. EMT
9D	9/ 7	32-09, 63-45 TO	32-13, 63-45			NEUSTON		2145-2204	1M RING
9E	9/ 7	32-09, 63-45 TO	32-13, 63-45			NEUSTON		2210-2234	1M RING
9N	9/ 7	32-09, 63-45 TO	32-13, 63-45			0- 250	225	2142-0045	LG. EMT
10N	9/ 8	32-17, 63-45 TO	32-20, 63-45			0- 150	150	0234-0425	SM. EMT
11N	9/ 8	32-19, 63-38 TO	32-19, 63-32			0- 450	425	0534-0840	SM. EMT
12N	9/ 8	32-30, 63-30 TO	32-21, 63-30			0- 725	625	1110-1415	3M IKMT
13N	9/ 8	32-18, 63-30 TO	32-11, 63-30			0-1500	1500	1430-1730	3M IKMT
14D	9/ 8	32-12, 63-25 TO	32-20, 63-25			NEUSTON		1830-1915	1M RING
14N	9/ 8	32-12, 63-25 TO	32-20, 63-25			0- 250	210	1740-1958	3M IKMT
15N	9/ 8	32-21, 63-29 TO	32-26, 63-38			0- 450	450	2058-2330	3M IKMT
16D	9/ 9	32-26, 63-38 TO	32-31, 63-41			NEUSTON		0046-0130	1M RING
16N	9/ 9	32-26, 63-38 TO	32-31, 63-41			0- 165	165	0016-0136	3M IKMT
17D	9/ 9	32-31, 63-41 TO	32-34, 63-44			NEUSTON		0222-0304	1M RING
17E	9/ 9	32-31, 63-41 TO	32-34, 63-44			NEUSTON		0310-0345	1M RING
17F	9/ 9	32-31, 63-41 TO	32-34, 63-44			NEUSTON		0349-0424	1M RING
17N	9/ 9	32-31, 63-41 TO	32-34, 63-44			0- 320	320	0204-0431	3M IKMT
18N	9/ 9	32-34, 63-45 TO	32-39, 63-48			0- 580	580	0440-0719	3M IKMT
19N	9/ 9	32-42, 63-49 TO	32-47, 63-53			0- 750	750	0730-1028	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1969 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
20N	9/ 9	32-53,	63-49	TO 32-56,	63-52	0-1500	1450	1318-1625	3M IKMT
21D	9/ 9	32-59,	63-55	TO 33-04,	64-00	NEUSTON		1810-1910	1M RING
21E	9/ 9	32-59,	63-55	TO 33-04,	64-00	NEUSTON		1916-1954	1M RING
21F	9/ 9	32-59,	63-55	TO 33-04,	64-00	NEUSTON		1958-2040	1M RING
21G	9/ 9	32-59,	63-55	TO 33-04,	64-00	NEUSTON		2043-2107	1M RING
21N	9/ 9	32-59,	63-55	TO 33-04,	64-00	0-1275	1225	1652-2110	3M IKMT
				CRUISE 8					
1A	11/23	31-48,	64-10	TO 31-55,	64-13	470- 470	470	1100-1200	3M IKMT
1B	11/23	31-48,	64-10	TO 31-55,	64-13	470- 470	470	1200-1300	3M IKMT
1P	11/23	31-48,	64-10	TO 31-55,	64-13	0- 470	470	1300-1449	3M IKMT
2N	11/23	31-48,	64-10	TO 31-55,	64-14	0- 220	220	2019-2304	3M IKMT
3N	11/24	31-42,	63-51	TO 31-56,	63-57	0-1000	1000	0904-1700	3M IKMT
4N	11/25	32-23,	63-41	TO 32-13,	63-30	0- 220	220	0704-0945	3M IKMT
5N	11/25	32-15,	63-35	TO 31-59,	63-44	0- 550	550	1109-1557	3M IKMT
	1970			CRUISE 9					
2D	3/16	32-17,	64-23	TO 32-11,	64-23	NEUSTON		1434-1534	.5 RING
2P	3/16	32-17,	64-23	TO 32-11,	64-23	0- 440	350	1334-1645	3M IKMT
2Y	3/16	32-17,	64-23	TO 32-11,	64-23	0- 440	440	1300-1334	3M IKMT
3N	3/17	32-04,	64-15	TO 32-03,	64-15	0- 180	160	0230-0334	3M IKMT
4D	3/17	31-55,	64-16	TO 31-54,	64-17	NEUSTON		1325-1425	.5 RING
4N	3/17	31-55,	64-16	TO 31-54,	64-17	0- 870	775	0955-1455	3M IKMT
5D	3/17	31-54,	64-17	TO 31-54,	64-21	NEUSTON		1518-1618	.5 RING
5N	3/17	31-54,	64-17	TO 31-54,	64-21	0- 140	140	1525-1637	3M IKMT
6D	3/17	31-53,	64-22	TO 31-51,	64-22	NEUSTON		2040-2140	.5 RING
6E	3/17	31-53,	64-22	TO 31-51,	64-22	NEUSTON		2145-2245	.5 RING
6N	3/17	31-53,	64-22	TO 31-51,	64-22	0- 400	375	2034-2325	3M IKMT
7D	3/18	31-52,	64-24	TO 31-49,	64-24	NEUSTON		0219-0340	.5 RING
7N	3/18	31-52,	64-24	TO 31-49,	64-24	0- 80	80	0219-0400	3M IKMT
8D	3/18	31-51,	64-26	TO 31-53,	64-13	NEUSTON		0730-0830	.5 RING
8E	3/18	31-51,	64-26	TO 31-53,	64-13	NEUSTON		0840-0940	.5 RING
8N	3/18	31-51,	64-26	TO 31-53,	64-13	0-1200	1175	0849-1355	3M IKMT
9D	3/18	31-58,	64-18	TO 32-01,	64-15	NEUSTON		2019-2119	1M RING
9N	3/18	31-58,	64-18	TO 32-01,	64-15	0-1150	1060	1604-2110	3M IKMT
10D	3/18	32-01,	64-14	TO 32-03,	64-05	NEUSTON		2155-2315	.5 RING
10E	3/18	32-01,	64-14	TO 32-03,	64-05	NEUSTON		2319-0019	.5 RING
10N	3/18	32-01,	64-14	TO 32-03,	64-05	0- 900	850	2125-0100	3M IKMT
11D	3/19	32-03,	64-05	TO 32-00,	64-00	NEUSTON		0030-0130	.5 RING
11E	3/19	32-03,	64-05	TO 32-00,	64-00	NEUSTON		0130-0230	.5 RING
11F	3/19	32-03,	64-05	TO 32-00,	64-00	NEUSTON		0355-0449	.5 RING
11N	3/19	32-03,	64-05	TO 32-00,	64-00	0- 610	560	0110-0440	3M IKMT
12N	3/19	32-00,	64-00	TO 31-57,	63-56	0- 55	55	0445-0649	3M IKMT
13N	3/19	31-57,	63-56	TO 31-51,	63-47	0-1550	1300	0715-1219	3M IKMT
14N	3/19	31-54,	63-46	TO 31-53,	63-43	0- 280	275	1555-1910	3M IKMT
15N	3/19	31-53,	63-42	TO 31-45,	63-34	0- 730	650	1925-2340	3M IKMT
16N	3/19	31-45,	63-34	TO 31-40,	63-29	0- 290	275	2349-0325	3M IKMT
17N	3/20	31-40,	63-29	TO 31-33,	63-26	0- 40	40	0340-0649	3M IKMT
18N	3/20	31-32,	63-26	TO 31-35,	63-30	0- 585	550	0930-1149	3M IKMT
19N	3/20	31-36,	63-30	TO 31-40,	63-31	0- 280	260	1348-1634	3M IKMT
20N	3/20	31-39,	63-31	TO 31-46,	63-47	0- 110	110	1919-2145	3M IKMT
21N	3/20	31-46,	63-47	TO 31-50,	64-02	0- 950	930	2345-0430	3M IKMT
22N	3/21	31-51,	64-06	TO 31-44,	64-01	0- 80	80	0440-0719	3M IKMT
23N	3/21	31-44,	64-01	TO 31-48,	63-56	0- 485	480	0945-1143	3M IKMT
24N	3/21	31-49,	63-55	TO 31-53,	63-48	0- 400	215	1349-1634	3M IKMT
25N	3/21	31-55,	63-47	TO 31-53,	63-57	0- 180	125	1925-2145	3M IKMT
26N	3/22	31-53,	63-55	TO 32-05,	63-51	0-1250	1235	0004-0437	3M IKMT
27N	3/22	32-04,	63-42	TO 32-07,	63-32	0-1070	1050	0830-1300	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1970 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
28N	3/22	32-07,	63-32	TO 32-12,	63-42	0- 700	420	1304-1655	3M IKMT
29N	3/22	32-12,	63-40	TO 32-13,	63-42	0- 100	95	1945-2157	3M IKMT
30N	3/22	32-13,	63-42	TO 32-00,	63-42	0-3500	3500	2210-0710	3M IKMT
31N	3/23	32-04,	63-45	TO 32-19,	63-39	0-1500	1475	0834-1349	3M IKMT
32N	3/23	32-17,	63-36	TO 32-27,	63-33	0- 90	65	1404-1719	3M IKMT
33N	3/23	32-26,	63-36	TO 32-26,	63-41	0- 400	225	1931-2200	3M IKMT
				CRUISE 10					
1D	6/ 1	32-00,	64-29	TO 32-14,	64-27	NEUSTON		1515-1615	1M RING
1E	6/ 1	32-00,	64-29	TO 32-14,	64-27	NEUSTON		1619-1715	1M RING
1F	6/ 1	32-00,	64-29	TO 32-14,	64-27	NEUSTON		1719-1815	1M RING
1G	6/ 1	32-00,	64-29	TO 32-14,	64-27	NEUSTON		1819-1904	1M RING
1N	6/ 1	32-00,	64-29	TO 32-14,	64-27	0- 925	875	1418-1940	3M IKMT
2A	6/ 1	32-13,	64-23	TO 32-22,	64-19	100- 100	100	2104-2204	3M IKMT
2B	6/ 1	32-13,	64-23	TO 32-22,	64-19	100- 100	100	2204-2304	3M IKMT
2C	6/ 1	32-13,	64-23	TO 32-22,	64-19	100- 100	100	2304-0004	3M IKMT
2D	6/ 1	32-13,	64-23	TO 32-22,	64-19	NEUSTON		2045-2115	1M RING
2E	6/ 1	32-13,	64-23	TO 32-22,	64-19	NEUSTON		2125-2155	1M RING
2F	6/ 1	32-13,	64-23	TO 32-22,	64-19	NEUSTON		2204-2234	1M RING
2G	6/ 1	32-13,	64-23	TO 32-22,	64-19	NEUSTON		2240-2310	1M RING
2H	6/ 1	32-13,	64-23	TO 32-22,	64-19	NEUSTON		2319-2349	1M RING
2M	6/ 1	32-13,	64-23	TO 32-22,	64-19	0- 100	100	0004-0019	3M IKMT
3A	6/ 2	32-14,	64-13	TO 32-25,	64-08	200- 200	200	0415-0515	3M IKMT
3B	6/ 2	32-14,	64-13	TO 32-25,	64-08	200- 200	200	0515-0615	3M IKMT
3C	6/ 2	32-14,	64-13	TO 32-25,	64-08	200- 200	200	0615-0715	3M IKMT
3D	6/ 2	32-14,	64-13	TO 32-25,	64-08	NEUSTON		0345-0415	1M RING
3E	6/ 2	32-14,	64-13	TO 32-25,	64-08	NEUSTON		0419-0449	1M RING
3F	6/ 2	32-14,	64-13	TO 32-25,	64-08	NEUSTON		0455-0525	1M RING
3G	6/ 2	32-14,	64-13	TO 32-25,	64-08	NEUSTON		0530-0600	1M RING
3H	6/ 2	32-14,	64-13	TO 32-25,	64-08	NEUSTON		0604-0704	1M RING
3M	6/ 2	32-14,	64-13	TO 32-25,	64-08	0- 200	200	0715-0737	3M IKMT
4A	6/ 2	32-18,	64-12	TO 32-33,	64-05	800- 800	800	1455-1555	3M IKMT
4B	6/ 2	32-18,	64-12	TO 32-33,	64-05	800- 800	800	1555-1655	3M IKMT
4C	6/ 2	32-18,	64-12	TO 32-33,	64-05	800- 800	800	1655-1755	3M IKMT
4D	6/ 2	32-18,	64-12	TO 32-33,	64-05	NEUSTON		1400-1500	1M RING
4E	6/ 2	32-18,	64-12	TO 32-33,	64-05	NEUSTON		1507-1610	1M RING
4F	6/ 2	32-18,	64-12	TO 32-33,	64-05	NEUSTON		1700-1800	1M RING
4G	6/ 2	32-18,	64-12	TO 32-33,	64-05	NEUSTON		1804-1855	1M RING
4M	6/ 2	32-18,	64-12	TO 32-33,	64-05	0- 800	800	1755-1900	3M IKMT
5A	6/ 2	32-33,	64-04	TO 32-23,	64-11	600- 600	600	2030-2130	3M IKMT
5B	6/ 2	32-33,	64-04	TO 32-23,	64-11	600- 600	600	2130-2330	3M IKMT
5D	6/ 2	32-33,	64-04	TO 32-23,	64-11	NEUSTON		1949-2055	1M RING
5E	6/ 2	32-33,	64-04	TO 32-23,	64-11	NEUSTON		2100-2130	1M RING
5F	6/ 2	32-33,	64-04	TO 32-23,	64-11	NEUSTON		2134-2204	1M RING
5G	6/ 2	32-33,	64-04	TO 32-23,	64-11	NEUSTON		2210-2240	1M RING
5H	6/ 2	32-33,	64-04	TO 32-23,	64-11	NEUSTON		2245-2315	1M RING
5M	6/ 2	32-33,	64-04	TO 32-23,	64-11	0- 600	600	2330-0030	3M IKMT
6A	6/ 3	32-22,	64-14	TO 32-16,	64-21	290- 290	290	0300-0400	3M IKMT
6B	6/ 3	32-22,	64-14	TO 32-16,	64-21	290- 290	290	0400-0500	3M IKMT
6M	6/ 3	32-22,	64-14	TO 32-16,	64-21	0- 290	290	0500-0519	3M IKMT
7A	6/ 3	32-16,	64-21	TO 32-03,	64-25	1000-1120	1060	0725-0825	3M IKMT
7B	6/ 3	32-16,	64-21	TO 32-03,	64-25	970-1060	975	0825-0925	3M IKMT
7M	6/ 3	32-16,	64-21	TO 32-03,	64-25	0- 970	950	0925-1037	3M IKMT
8A	6/ 3	32-02,	64-25	TO 31-55,	64-25	90- 90	90	1304-1404	3M IKMT
8B	6/ 3	32-02,	64-25	TO 31-55,	64-25	90- 90	90	1404-1504	3M IKMT
8D	6/ 3	32-02,	64-25	TO 31-55,	64-25	NEUSTON		1440-1525	1M RING
8M	6/ 3	32-02,	64-25	TO 31-55,	64-25	0- 90	90	1504-1518	3M IKMT
9A	6/ 3	31-56,	64 25	TO 31-47,	64-19	55- 55	55	1549-1649	3M IKMT
9B	6/ 3	31-56,	64-25	TO 31-47,	64-19	55- 55	55	1649-1749	3M IKMT
9D	6/ 3	31-56,	64-25	TO 31-47,	64-19	NEUSTON		1545-1645	1M RING

TABLE 3.—Continued.

SAMPLE	DATE 1970 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
9E	6/ 3	31-56,	64-25	TO 31-47,	64-19	NEUSTON		1649-1715	1M RING
9M	6/ 3	31-56,	64-25	TO 31-47,	64-19	0- 55	50	1749-1815	3M IKMT
10A	6/ 3	31-51,	64-19	TO 32-00,	64-16	825- 825	825	2225-2325	3M IKMT
10B	6/ 3	31-51,	64-19	TO 32-00,	64-16	825- 825	825	2325-0025	3M IKMT
10D	6/ 3	31-51,	64-19	TO 32-00,	64-16	NEUSTON		2015-2104	1M RING
10E	6/ 3	31-51,	64-19	TO 32-00,	64-16	NEUSTON		2204-2240	1M RING
10F	6/ 3	31-51,	64-19	TO 32-00,	64-16	NEUSTON		2245-2319	1M RING
10G	6/ 3	31-51,	64-19	TO 32-00,	64-16	NEUSTON		2349-0019	1M RING
10M	6/ 3	31-51,	64-19	TO 32-00,	64-16	0- 825	825	0025-0125	3M IKMT
11A	6/ 4	32-00,	64-16	TO 32-09,	64-17	150- 150	150	0200-0300	3M IKMT
11B	6/ 4	32-00,	64-16	TO 32-09,	64-17	150- 150	150	0300-0400	3M IKMT
11M	6/ 4	32-00,	64-16	TO 32-09,	64-17	0- 150	150	0400-0419	3M IKMT
13A	6/ 5	31-23,	64-46	TO 31-07,	64-43	400- 400	400	0749-0849	3M IKMT
13B	6/ 5	31-23,	64-46	TO 31-07,	64-43	400- 400	400	0849-1049	3M IKMT
13D	6/ 5	31-23,	64-46	TO 31-07,	64-43	NEUSTON		0719-0819	1M RING
13E	6/ 5	31-23,	64-46	TO 31-07,	64-43	NEUSTON		0834-0934	1M RING
13F	6/ 5	31-23,	64-46	TO 31-07,	64-43	NEUSTON		0945-1045	1M RING
13M	6/ 5	31-23,	64-46	TO 31-07,	64-43	0- 400	400	1049-1119	3M IKMT
14A	6/ 5	31-09,	64-42	TO 31-19,	64-41	200- 200	200	1315-1415	3M IKMT
14B	6/ 5	31-09,	64-42	TO 31-19,	64-41	200- 200	200	1415-1515	3M IKMT
14C	6/ 5	31-09,	64-42	TO 31-19,	64-41	200- 200	200	1515-1615	3M IKMT
14M	6/ 5	31-09,	64-42	TO 31-19,	64-41	0- 200	200	1615-1640	3M IKMT
15A	6/ 5	31-24,	64-46	TO 31-19,	64-49	210- 210	210	1819-1925	3M IKMT
15B	6/ 5	31-24,	64-46	TO 31-19,	64-49	210- 210	210	1925-2019	3M IKMT
15C	6/ 5	31-24,	64-46	TO 31-19,	64-49	210- 210	210	2019-2119	3M IKMT
15D	6/ 5	31-24,	64-46	TO 31-19,	64-49	NEUSTON		2000-2030	1M RING
15M	6/ 5	31-24,	64-46	TO 31-19,	64-49	0- 210	210	2119-2137	3M IKMT
16A	6/ 5	31-29,	64-49	TO 31-45,	64-58	205- 205	205	2215-2315	3M IKMT
16B	6/ 5	31-29,	64-49	TO 31-45,	64-58	205- 205	205	2315-2415	3M IKMT
16C	6/ 5	31-29,	64-49	TO 31-45,	64-58	205- 205	205	2415-0115	3M IKMT
16M	6/ 5	31-29,	64-49	TO 31-45,	64-58	0- 205	205	0115-0134	3M IKMT
17A	6/ 6	31-44,	64-57	TO 31-34,	64-55	50- 50	50	0200-0300	3M IKMT
17B	6/ 6	31-44,	64-57	TO 31-34,	64-55	50- 50	50	0300-0400	3M IKMT
17C	6/ 6	31-44,	64-57	TO 31-34,	64-55	50- 50	50	0400-0500	3M IKMT
17D	6/ 6	31-44,	64-57	TO 31-34,	64-55	NEUSTON		0400-0430	1M RING
17M	6/ 6	31-44,	64-57	TO 31-34,	64-55	0- 50	50	0500-0525	3M IKMT
18A	6/ 6	31-34,	64-55	TO 31-29,	64-54	100- 100	100	0555-0619	3M IKMT
18B	6/ 6	31-34,	64-55	TO 31-29,	64-54	100- 100	100	0619-0645	3M IKMT
18P	6/ 6	31-34,	64-55	TO 31-29,	64-54	0- 100	90	0645-0725	3M IKMT
19A	6/ 6	31-25,	64-54	TO 31-16,	64-54	880-1050	975	1015-1115	3M IKMT
19B	6/ 6	31-25,	64-54	TO 31-16,	64-54	1050-1160	1110	1115-1215	3M IKMT
19C	6/ 6	31-25,	64-54	TO 31-16,	64-54	1160-1170	1170	1215-1315	3M IKMT
19M	6/ 6	31-25,	64-54	TO 31-16,	64-54	0-1170	1170	1315-1404	3M IKMT
20A	6/ 6	31-14,	64-52	TO 31-27,	64-49	490-1050	500	1600-1700	3M IKMT
20B	6/ 6	31-14,	64-52	TO 31-27,	64-49	520- 520	520	1700-1800	3M IKMT
20C	6/ 6	31-14,	64-52	TO 31-27,	64-49	520- 520	520	1800-1900	3M IKMT
20M	6/ 6	31-14,	64-52	TO 31-27,	64-49	0- 520	520	1900-1937	3M IKMT
21D	6/ 6	31-27,	64-49	TO 31-50,	64-54	NEUSTON		2210-2240	1M RING
21E	6/ 6	31-27,	64-49	TO 31-50,	64-54	NEUSTON		2245-2315	1M RING
21F	6/ 6	31-27,	64-49	TO 31-50,	64-54	NEUSTON		2319-2349	1M RING
21G	6/ 6	31-27,	64-49	TO 31-50,	64-54	NEUSTON		0000-0030	1M RING
21H	6/ 6	31-27,	64-49	TO 31-50,	64-54	NEUSTON		0049-0119	1M RING
21N	6/ 6	31-27,	64-49	TO 31-50,	64-54	0- 880	880	1955-0134	3M IKMT
23A	6/ 7	31-45,	64-51	TO 31-32,	64-51	630- 630	630	1322-1422	3M IKMT
23B	6/ 7	31-45,	64-51	TO 31-32,	64-51	630- 630	630	1422-1522	3M IKMT
23C	6/ 7	31-45,	64-51	TO 31-32,	64-51	630- 630	630	1522-1622	3M IKMT
23D	6/ 7	31-45,	64-51	TO 31-32,	64-51	NEUSTON		1340-1440	1M RING
23E	6/ 7	31-45,	64-51	TO 31-32,	64-51	NEUSTON		1445-1545	1M RING
23F	6/ 7	31-45,	64-51	TO 31-32,	64-51	NEUSTON		1549-1625	1M RING
23M	6/ 7	31-45,	64-51	TO 31-32,	64-51	0- 630	630	1622-1704	3M IKMT

TABLE 3.—Continued.

| SAMPLE | DATE 1970 MM/DD | COORDINATES | | | | DEPTH (M) | | TIME LOCAL | GEAR |
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN	START-END	
24A	6/ 7	31-26, 64-50	TO	31-15,	64-50	950-1080	1050	1855-1955	3M IKMT
24B	6/ 7	31-26, 64-50	TO	31-15,	64-50	1080-1080	1080	1955-2055	3M IKMT
24C	6/ 7	31-26, 64-50	TO	31-15,	64-50	1080-1080	1080	2055-2155	3M IKMT
24D	6/ 7	31-26, 64-50	TO	31-15,	64-50	NEUSTON		2055-2130	1M RING
24E	6/ 7	31-26, 64-50	TO	31-15,	64-50	NEUSTON		2133-2204	1M RING
24F	6/ 7	31-26, 64-50	TO	31-15,	64-50	NEUSTON		2207-2245	1M RING
24G	6/ 7	31-26, 64-50	TO	31-15,	64-50	NEUSTON		0037-0115	1M RING
24H	6/ 7	31-26, 64-50	TO	31-15,	64-50	NEUSTON		C207-0245	1M RING
24J	6/ 7	31-26, 64-50	TO	31-15,	64-50	NEUSTON		0345-0415	1M RING
24M	6/ 7	31-26, 64-50	TO	31-15,	64-50	0-1080	1080	2155-2319	3M IKMT
25D	6/ 8	31-15, 64-50	TO	31-17,	64-50	NEUSTON		0510-0534	1M RING
25E	6/ 8	31-15, 64-50	TO	31-17,	64-50	NEUSTON		0540-0730	1M RING
25F	6/ 8	31-15, 64-50	TO	31-17,	64-50	NEUSTON		0749-0849	1M RING
26P	6/ 8	31-41, 64-50	TO	31-29,	64-51	0- 170	170	1025-1340	3M IKMT
27A	6/ 8	31-30, 64-53	TO	31-30,	64-53	110- 110	110	1849-1910	3M IKMT
27B	6/ 8	31-30, 64-53	TO	31-30,	64-53	110- 110	110	1910-1930	3M IKMT
27C	6/ 8	31-30, 64-53	TO	31-30,	64-53	110- 110	110	1930-1949	3M IKMT
27M	6/ 8	31-30, 64-53	TO	31-30,	64-53	0- 110	110	1949-2000	3M IKMT
28D	6/ 8	31-30, 64-53	TO	31-18,	64-54	NEUSTON		2100-2134	1M RING
28E	6/ 8	31-30, 64-53	TO	31-18,	64-54	NEUSTON		2140-2204	1M RING
28G	6/ 8	31-30, 64-53	TO	31-18,	64-54	NEUSTON		2340-0004	1M RING
28N	6/ 8	31-30, 64-53	TO	31-18,	64-54	0- 580	580	2016-0030	3M IKMT
29A	6/ 9	31-17, 64-54	TO	31-10,	64-57	430- 430	430	0115-0215	3M IKMT
29B	6/ 9	31-17, 64-54	TO	31-10,	64-57	430- 430	430	0215-0315	3M IKMT
29C	6/ 9	31-17, 64-54	TO	31-10,	64-57	430- 430	430	0315-0415	3M IKMT
29M	6/ 9	31-17, 64-54	TO	31-10,	64-57	0- 430	430	0415-0443	3M IKMT
30A	6/ 9	31-13, 64-51	TO	31-16,	64-55	30- 30	30	0540-0600	3M IKMT
30B	6/ 9	31-13, 64-51	TO	31-16,	64-55	30- 30	30	0600-0619	3M IKMT
30C	6/ 9	31-13, 64-51	TO	31-16,	64-55	30- 30	30	0619-0640	3M IKMT
30M	6/ 9	31-13, 64-51	TO	31-16,	64-55	0- 30	30	0640-0645	3M IKMT
31A	6/ 9	31-17, 64-55	TO	31-30,	64-51	300- 300	300	0730-0830	3M IKMT
31B	6/ 9	31-17, 64-55	TO	31-30,	64-51	300- 300	300	0830-0930	3M IKMT
31C	6/ 9	31-17, 64-55	TO	31-30,	64-51	300- 300	300	0930-1030	3M IKMT
31M	6/ 9	31-17, 64-55	TO	31-30,	64-51	0- 300	300	1030-1049	3M IKMT
32A	6/ 9	31-33, 64-53	TO	31-45,	64-47	170- 170	170	1315-1415	3M IKMT
32B	6/ 9	31-33, 64-53	TO	31-45,	64-47	170- 170	170	1415-1515	3M IKMT
32C	6/ 9	31-33, 64-53	TO	31-45,	64-47	170- 170	170	1515-1615	3M IKMT
32D	6/ 9	31-33, 64-53	TO	31-45,	64-47	NEUSTON		1515-1615	1M RING
32M	6/ 9	31-33, 64-53	TO	31-45,	64-47	0- 170	170	1615-163⅘	3M IKMT
33A	6/ 9	31-41, 64-46	TO	31-36,	64-46	300- 340	320	1715-1800	3M IKMT
33B	6/ 9	31-41, 64-46	TO	31-36,	64-46	340- 340	340	1800-1845	3M IKMT
33C	6/ 9	31-41, 64-46	TO	31-36,	64-46	340- 350	345	1845-1930	3M IKMT
33D	6/ 9	31-41, 64-46	TO.	31-36,	64-46	NEUSTON		1819-1855	1M RING
33E	6/ 9	31-41, 64-46	TO	31-36,	64-46	NEUSTON		1900-1934	1M RING
33M	6/ 9	31-41, 64-46	TO	31-36,	64-46	0- 340	340	1930-2000	3M IKMT
34A	6/ 9	31-33, 64-46	TO	31-23,	64-47	520- 520	520	2104-2204	3M IKMT
34B	6/ 9	31-33, 64-46	TO	31-23,	64-47	520- 520	520	2204-2304	3M IKMT
34C	6/ 9	31-33, 64-46	TO	31-23,	64-47	520- 520	520	2304-0004	3M IKMT
34D	6/ 9	31-33, 64-46	TO	31-23,	64-47	NEUSTON		2025-2110	1M RING
34E	6/ 9	31-33, 64-46	TO	31-23,	64-47	NEUSTON		2 10-2145	1M RING
34F	6/ 9	31-33, 64-46	TO	31-23,	64-47	NEUSTON		2149-2246	1M RING
34G	6/ 9	31-33, 64-46	TO	31-23,	64-47	NEUSTON		2249-2345	1M RING
34M	6/ 9	31-33, 64-46	TO	31-23,	64-47	0- 520	520	0004-0034	3M IKMT
35A	6/10	31-24, 64-48	TO	31-09,	64-52	360- 360	360	0215-0315	3M IKMT
35B	6/10	31-24, 64-48	TO	31-09,	64-52	360- 360	360	0315-0415	3M IKMT
35C	6/10	31-24, 64-48	TO	31-09,	64-52	360- 550	475	0415-0515	3M IKMT
35M	6/10	31-24, 64-48	TO	31-09,	64-52	0- 360	360	0515-0545	3M IKMT
36A	6/10	31-14, 64-52	TO	31-26,	64-50	630- 700	690	0710-1010	3M IKMT
36M	6/10	31-14, 64-52	TO	31-26,	64-50	0- 700	700	1010-1055	3M IKMT
37D	6/10	31-30, 64-53	TO	31-43,	64-50	NEUSTON		1634-1704	1M RING
37E	6/10	31-30, 64-53	TO	31-43,	64-50	NEUSTON		1749-1825	1M RING

Table 3.—Continued.

SAMPLE	DATE 1970 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
37F	6/10	31-30,	64-53 TO	31-43,	64-50	NEUSTON		1749-1825	1M RING
37N	6/10	31-30,	64-53 TO	31-43,	64-50	0- 480	480	1500-1845	3M IKMT
38N	6/10	31-45,	64-48 TO	31-56,	64-47	0- 300	300	2140-0101	3M IKMT
39X	6/ 4	31-39,	64-36 TO	31-39,	64-36	DIP NET		2200-0000	DIP NET
	1971			CRUISE 11					
1A	1/12	31-58,	64-05 TO	31-51,	63-52	475- 535	510	1349-1507	3M IKMT
1B	1/12	31-58,	64-05 TO	31-51,	63-52	535- 535	535	1507-1607	3M IKMT
1M	1/12	31-58,	64-05 TO	31-51,	63-52	0- 535	535	1607-1655	3M IKMT
2A	1/12	31-51,	63-48 TO	31-40,	63-45	50- 50	50	2330-0030	3M IKMT
2B	1/12	31-51,	63-48 TO	31-40,	63-45	50- 50	50	0030-0130	3M IKMT
2C	1/12	31-51,	63-48 TO	31-40,	63-45	50- 50	50	0130-0230	3M IKMT
2D	1/12	31-51,	63-48 TO	31-40,	63-45	NEUSTON		2319-2330	1M RING
2E	1/12	31-51,	63-48 TO	31-40,	63-45	NEUSTON		0025-0034	1M RING
2F	1/12	31-51,	63-48 TO	31-40,	63-45	NEUSTON		0130-0140	1M RING
2M	1/12	31-51,	63-48 TO	31-40,	63-45	0- 50	50	0230-0245	3M IKMT
3A	1/13	31-41,	63-47 TO	31-40,	63-54	100- 100	100	0334-0434	3M IKMT
3B	1/13	31-41,	63-47 TO	31-40,	63-54	100- 100	100	0434-0534	3M IKMT
3C	1/13	31-41,	63-47 TO	31-40,	63-54	100- 100	100	0534-0634	3M IKMT
3D	1/13	31-41,	63-47 TO	31-40,	63-54	NEUSTON		0430-0445	1M RING
3M	1/13	31-41,	63-47 TO	31-40,	63-54	0- 100	100	0634-0640	3M IKMT
4A	1/13	31-40,	63-54 TO	31-38,	64-11	635- 680	650	0834-0934	3M IKMT
4B	1/13	31-40,	63-54 TO	31-38,	64-11	610- 635	615	0934-1034	3M IKMT
4C	1/13	31-40,	63-54 TO	31-38,	64-11	600- 610	605	1034-1134	3M IKMT
4M	1/13	31-40,	63-54 TO	31-38,	64-11	0- 600	600	1134-1222	3M IKMT
5A	1/13	31-39,	64-12 TO	31-48,	64-17	250- 270	260	1415-1515	3M IKMT
5B	1/13	31-39,	64-12 TO	31-48,	64-17	270- 300	285	1515-1615	3M IKMT
5C	1/13	31-39,	64-12 TO	31-48,	64-17	290- 300	295	1615-1715	3M IKMT
5D	1/13	31-39,	64-12 TO	31-48,	64-17	NEUSTON		1445-1500	1M RING
5M	1/13	31-39,	64-12 TO	31-48,	64-17	0- 290	290	1715-1800	3M IKMT
7A	1/13	31-54,	64-19 TO	31-58,	64-22	510- 610	600	2216-2316	3M IKMT
7B	1/13	31-54,	64-19 TO	31-58,	64-22	600- 610	600	2316-2346	3M IKMT
7D	1/13	31-54,	64-19 TO	31-58,	64-22	NEUSTON		2145-2200	1M RING
7M	1/13	31-54,	64-19 TO	31-58,	64-22	0- 600	600	2346-0019	3M IKMT
8A	1/14	32-03,	62-58 TO	32-10,	62-49	140- 150	145	1558-1658	3M IKMT
8B	1/14	32-03,	62-58 TO	32-10,	62-49	130- 140	135	1658-1758	3M IKMT
8C	1/14	32-03,	62-58 TO	32-10,	62-49	130- 130	130	1758-1858	3M IKMT
8D	1/14	32-03,	62-58 TO	32-10,	62-49	NEUSTON		1600-1630	1M RING
8M	1/14	32-03,	62-58 TO	32-10,	62-49	0- 130	130	1858-1915	3M IKMT
9A	1/14	32-10,	62-49 TO	31-58,	62-47	800- 900	850	2045-2145	3M IKMT
9B	1/14	32-10,	62-49 TO	31-58,	62-47	875- 900	880	2145-2245	3M IKMT
9C	1/14	32-10,	62-49 TO	31-58,	62-47	860- 875	870	2245-2345	3M IKMT
9D	1/14	32-10,	62-49 TO	31-58,	62-47	NEUSTON		2200-2230	1M RING
9M	1/14	32-10,	62-49 TO	31-58,	62-47	0- 860	860	2345-0045	3M IKMT
10A	1/15	31-57,	62-48 TO	31-49,	62-50	175- 175	175	0200-0300	3M IKMT
10B	1/15	31-57,	62-48 TO	31-49,	62-50	175- 175	175	0300-0400	3M IKMT
10C	1/15	31-57,	62-48 TO	31-49,	62-50	175- 175	175	0400-0500	3M IKMT
10M	1/15	31-57,	62-48 TO	31-49,	62-50	0- 175	175	0500-0518	3M IKMT
11A	1/15	31-48,	62-51 TO	31-38,	62-54	140- 140	140	0615-0715	3M IKMT
11B	1/15	31-48,	62-51 TO	31-38,	62-54	140- 140	140	0715-0815	3M IKMT
11C	1/15	31-48,	62-51 TO	31-38,	62-54	140- 140	140	0815-0915	3M IKMT
11M	1/15	31-48,	62-51 TO	31-38,	62-54	0- 140	140	0915-0930	3M IKMT
12A	1/15	31-58,	62-51 TO	31-34,	63-02	50- 50	50	1010-1110	3M IKMT
12B	1/15	31-58,	62-51 TO	31-34,	63-02	50- 50	50	1110-1210	3M IKMT
12M	1/15	31-58,	62-51 TO	31-34,	63-02	0- 50	50	1210-1219	3M IKMT
13A	1/15	31-36,	63-04			600- 675	650	1451-1551	3M IKMT
13B	1/15	31-36,	63-04			675- 675	675	1551-1651	3M IKMT
13C	1/15	31-36,	63-04			650- 675	660	1651-1751	3M IKMT
13M	1/15	31-36,	63-04			0- 650	650	1751-1849	3M IKMT
14X	1/13	31-54,	64-20 TO	31-54,	64-20	DIP NET		2030-2200	DIP NET

TABLE 3.—Continued.

SAMPLE	DATE 1971 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		

CRUISE 12

1A	8/26	32-18, 64-03	TO	32-59,	64-04	33- 33	33	1918-2018	3M IKMT
1B	8/26	32-18, 64-03	TO	32-59,	64-04	33- 33	33	2018-2118	3M IKMT
1C	8/26	32-18, 64-03	TO	32-59,	64-04	33- 33	33	2118-2218	3M IKMT
1D	8/26	32-18, 64-03	TO	32-59,	64-04	NEUSTON		1930-1940	1M RING
1E	8/26	32-18, 64-03	TO	32-59,	64-04	NEUSTON		1945-2000	1M RING
1F	8/26	32-18, 64-03	TO	32-59,	64-04	NEUSTON		2045-2100	1M RING
1G	8/26	32-18, 64-03	TO	32-59,	64-04	NEUSTON		2143-2200	1M RING
1M	8/26	32-18, 64-03	TO	32-59,	64-04	0- 33	33	2218-2230	3M IKMT
2A	8/26	32-59, 64-04	TO	32-38,	64-04	780- 783	780	0049-0149	3M IKMT
2B	8/26	32-59, 64-04	TO	32-38,	64-04	740- 805	765	0149-0249	3M IKMT
2C	8/26	32-59, 64-04	TO	32-38,	64-04	765- 805	775	0249-0349	3M IKMT
2D	8/26	32-59, 64-04	TO	32-38,	64-04	NEUSTON		0007-0022	1M RING
2E	8/26	32-59, 64-04	TO	32-38,	64-04	NEUSTON		0107-0122	1M RING
2F	8/26	32-59, 64-04	TO	32-38,	64-04	NEUSTON		0210-0228	1M RING
2G	8/26	32-59, 64-04	TO	32-38,	64-04	NEUSTON		0330-0345	1M RING
2M	8/26	32-59, 64-04	TO	32-38,	64-04	0- 805	805	0349-0440	3M IKMT
3D	8/27	32-39, 64-04	TO	32-47,	64-03	NEUSTON		0910-0925	1M RING
4A	8/27	32-49, 64-07	TO	32-59,	64-06	623- 650	635	1325-1425	3M IKMT
4B	8/27	32-49, 64-07	TO	32-59,	64-06	618- 650	635	1425-1525	3M IKMT
4C	8/27	32-49, 64-07	TO	32-59,	64-06	630- 645	635	1525-1625	3M IKMT
4D	8/27	32-49, 64-07	TO	32-59,	64-06	NEUSTON		1510-1540	1M RING
4E	8/27	32-49, 64-07	TO	32-59,	64-06	NEUSTON		1610-1640	1M RING
4M	8/27	32-49, 64-07	TO	32-59,	64-06	0- 630	630	1625-1715	3M IKMT
5A	8/27	33-00, 64-06	TO	33-17,	64-03	975-1000	990	2022-2122	3M IKMT
5B	8/27	33-00, 64-06	TO	33-17,	64-03	989-1000	995	2122-2222	3M IKMT
5C	8/27	33-00, 64-06	TO	33-17,	64-03	950-1000	975	2222-2322	3M IKMT
5D	8/27	33-00, 64-06	TO	33-17,	64-03	NEUSTON		1810-1840	1M RING
5E	8/27	33-00, 64-06	TO	33-17,	64-03	NEUSTON		1910-1940	1M RING
5F	8/27	33-00, 64-06	TO	33-17,	64-03	NEUSTON		2010-2040	1M RING
5G	8/27	33-00, 64-06	TO	33-17,	64-03	NEUSTON		2110-2130	1M RING
5H	8/27	33-00, 64-06	TO	33-17,	64-03	NEUSTON		2304-2319	1M RING
5M	8/27	33-00, 64-06	TO	33-17,	64-03	0- 950	950	2322-0055	3M IKMT
6A	8/28	33-19, 64-04	TO	33-34,	64-04	600- 650	625	0230-0330	3M IKMT
6B	8/28	33-19, 64-04	TO	33-34,	64-04	618- 638	625	0330-0430	3M IKMT
6C	8/28	33-19, 64-04	TO	33-34,	64-04	633- 654	640	0430-0530	3M IKMT
6D	8/28	33-19, 64-04	TO	33-34,	64-04	NEUSTON		0504-0525	1M RING
6E	8/28	33-19, 64-04	TO	33-34,	64-04	NEUSTON		0604-0619	1M RING
6M	8/28	33-19, 64-04	TO	33-34,	64-04	0- 633	633	0530-0700	3M IKMT
7A	8/28	33-33, 64-04	TO	33-28,	64-15	1000-1050	1025	0940-1040	3M IKMT
7B	8/28	33-33, 64-04	TO	33-28,	64-15	1016-1052	1035	1040-1140	3M IKMT
7C	8/28	33-33, 64-04	TO	33-28,	64-15	1003-1056	1030	1140-1240	3M IKMT
7M	8/28	33-33, 64-04	TO	33-28,	64-15	0-1003	1003	1240-1334	3M IKMT
8A	8/28	33-28, 6--15	TO	33-26,	64-17	24- 30	27	1455-1555	3M IKMT
8B	8/28	33-28, 64-15	TO	33-26,	64-17	24- 30	27	1555-1655	3M IKMT
8C	8/28	33-28, 64-15	TO	33-26,	64-17	25- 30	28	1655-1755	3M IKMT
8M	8/28	33-28, 64-15	TO	33-26,	64-17	0- 25	25	1755-1815	3M IKMT
9A	8/28	33-26, 64-17	TO	33-19,	64-23	705- 760	730	1945-2045	3M IKMT
9B	8/28	33-26, 64-17	TO	33-19,	64-23	720- 730	725	2045-2145	3M IKMT
9C	8/28	33-26, 64-17	TO	33-19,	64-23	715- 720	720	2145-2245	3M IKMT
9D	8/28	33-26, 64-17	TO	33-19,	64-23	NEUSTON		1845-1910	1M RING
9E	8/28	33-26, 64-17	TO	33-19,	64-23	NEUSTON		2110-2130	1M RING
9F	8/28	33-26, 64-17	TO	33-19,	64-23	NEUSTON		2210-2237	1M RING
9M	8/28	33-26, 64-17	TO	33-19,	64-23	0- 715	715	2245-2325	3M IKMT
10A	8/29	33-16, 64-25	TO	33-16,	64-18	395- 435	415	0100-0200	3M IKMT
10B	8/29	33-16, 64-25	TO	33-16,	64-18	398- 440	415	0200-0300	3M IKMT
10C	8/29	33-16, 64-25	TO	33-16,	64-18	440- 445	440	0300-0400	3M IKMT
10D	8/29	33-16, 64-25	TO	33-16,	64-18	NEUSTON		0330-0345	1M RING
10E	8/29	33-16, 64-25	TO	33-16,	64-18	NEUSTON		0530-0600	1M RING

TABLE 3.—Continued.

SAMPLE	DATE 1971 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
10M	8/29	33-16,	64-25 TO	33-16,	64-18	0- 445	445	0400-0434	3M IKMT
11A	8/29	33-15,	64-18 TO	33-08,	64-10	1240-1310	1275	0727-0828	3M IKMT
11B	8/29	33-15,	64-18 TO	33-08,	64-10	1288-1350	1325	0828-0928	3M IKMT
11C	8/29	33-15,	64-18 TO	33-08,	64-10	1315-1360	1340	0928-1028	3M IKMT
11D	8/29	33-15,	64-18 TO	33-08,	64-10	NEUSTON		0800-0830	1M RING
11M	8/29	33-15,	64-18 TO	33-08,	64-10	0-1325	1325	1028-1140	3M IKMT
12A	8/29	33-07,	64-06 TO	33-05,	64-07	757- 800	775	1249-1349	3M IKMT
12B	8/29	33-07,	64-06 TO	33-05,	64-07	764- 769	765	1349-1449	3M IKMT
12C	8/29	33-07,	64-06 TO	33-05,	64-07	755- 769	765	1449-1549	3M IKMT
12M	8/29	33-07,	64-06 TO	33-05,	64-07	0- 760	760	1549-1634	3M IKMT
13A	8/29	33-04,	64-06 TO	33-02,	63-58	19- 19	19	1730-1830	3M IKMT
13B	8/29	33-04,	64-06 TO	33-02,	63-58	19- 19	19	1830-1930	3M IKMT
13C	8/29	33-04,	64-06 TO	33-02,	63-58	19- 19	19	1930-2030	3M IKMT
13M	8/29	33-04,	64-06 TO	33-02,	63-58	0- 19	19	2030-2034	3M IKMT
14A	8/29	33-02,	63-58 TO	32-52,	64-01	332- 345	335	2130-2230	3M IKMT
14B	8/29	33-02,	63-58 TO	32-52,	64-01	335- 345	340	2230-2330	3M IKMT
14C	8/29	33-02,	63-58 TO	32-52,	64-01	321- 335	325	2330-0030	3M IKMT
14D	8/29	33-02,	63-58 TO	32-52,	64-01	NEUSTON		2134-2149	1M RING
14E	8/29	33-02,	63-58 TO	32-52,	64-01	NEUSTON		2303-2343	1M RING
14M	8/29	33-02,	63-58 TO	32-52,	64-01	0- 321	321	0030-0100	3M IKMT
15A	8/30	32-52,	64-01 TO	32-47,	63-56	360- 392	375	0207-0307	3M IKMT
15B	8/30	32-52,	64-01 TO	32-47,	63-56	392- 400	395	0307-0407	3M IKMT
15C	8/30	32-52,	64-01 TO	32-47,	63-56	370- 392	380	0407-0507	3M IKMT
15D	8/30	32-52,	64-01 TO	32-47,	63-56	NEUSTON		0139-0154	1M RING
15M	8/30	32-52,	64-01 TO	32-47,	63-56	0- 370	370	0507-0534	3M IKMT
16A	8/30	32-47,	63-56 TO	32-36,	63-51	903- 951	925	0719-0819	3M IKMT
16B	8/30	32-47,	63-56 TO	32-36,	63-51	900- 940	925	0819-0919	3M IKMT
16C	8/30	32-47,	63-56 TO	32-36,	63-51	911- 935	925	0919-1019	3M IKMT
16M	8/30	32-47,	63-56 TO	32-36,	63-51	0- 930	930	1019-1110	3M IKMT
17A	8/30	32-38,	63-52 TO	32-31,	63-53	512- 546	525	1234-1334	3M IKMT
17B	8/30	32-38,	63-52 TO	32-31,	63-53	525- 546	535	1334-1434	3M IKMT
17C	8/30	32-38,	63-52 TO	32-31,	63-53	500- 549	525	1434-1534	3M IKMT
17D	8/30	32-38,	63-52 TO	32-31,	63-53	NEUSTON		1515-1530	1M RING
17M	8/30	32-38,	63-52 TO	32-31,	63-53	0- 549	549	1534-1619	3M IKMT
18A	8/31	32-31,	63-58 TO	32-28,	63-55	94- 94	94	0330-0430	3M IKMT
18B	8/31	32-31,	63-58 TO	32-28,	63-55	88- 94	90	0430-0530	3M IKMT
18C	8/31	32-31,	63-58 TO	32-28,	63-55	88- 88	88	0530-0630	3M IKMT
18M	8/31	32-31,	63-58 TO	32-28,	63-55	0- 88	88	0630-0645	3M IKMT
19A	8/31	32-27,	63-55 TO	32-19,	63-50	575- 579	575	0815-0915	3M IKMT
19B	8/31	32-27,	63-55 TO	32-19,	63-50	560- 575	570	0915-1015	3M IKMT
19C	8/31	32-27,	63-55 TO	32-19,	63-50	540- 570	560	1015-1115	3M IKMT
19M	8/31	32-27,	63-55 TO	32-19,	63-50	0- 570	570	1115-1149	3M IKMT
20A	9/ 1	32-20,	63-50 TO	32-23,	63-56	468- 499	485	0100-0200	3M IKMT
20B	9/ 1	32-20,	63-50 TO	32-23,	63-56	480- 480	480	0200-0300	3M IKMT
20C	9/ 1	32-20,	63-50 TO	32-23,	63-56	480- 490	485	0300-0400	3M IKMT
20M	9/ 1	32-20,	63-50 TO	32-23,	63-56	0- 490	490	0400-0434	3M IKMT
21A	9/ 2	32-22,	63-43 TO	32-17,	63-48	650- 655	653	0200-0300	3M IKMT
21B	9/ 2	32-22,	63-43 TO	32-17,	63-48	640- 685	665	0300-0400	3M IKMT
21M	9/ 2	32-22,	63-43 TO	32-17,	63-48	0- 685	685	0400-0430	3M IKMT
22A	9/ 2	32-17,	63-52 TO	32-19,	64-04	775- 835	805	0628-0728	3M IKMT
22B	9/ 2	32-17,	63-52 TO	32-19,	64-04	819- 835	825	0728-0928	3M IKMT
22C	9/ 2	32-17,	63-52 TO	32-19,	64-04	819- 820	820	0928-1028	3M IKMT
22M	9/ 2	32-17,	63-52 TO	32-19,	64-04	0- 820	820	1028-1113	3M IKMT
23A	9/ 2	32-20,	64-05 TO	32-30,	64-05	428- 443	435	1349-1449	3M IKMT
23B	9/ 2	32-20,	64-05 TO	32-30,	64-05	440- 470	460	1449-1549	3M IKMT
23C	9/ 2	32-20,	64-05 TO	32-30,	64-05	420- 478	460	1549-1649	3M IKMT
23M	9/ 2	32-20,	64-05 TO	32-30,	64-05	0- 420	420	1649-1719	3M IKMT
24A	9/ 2	32-31,	64-12 TO	32-35,	64-19	1196-1279	1230	2010-2110	3M IKMT
24B	9/ 2	32-31,	64-12 TO	32-35,	64-19	1279-1322	1290	2110-2210	3M IKMT
24C	9/ 2	32-31,	64-12 TO	32-35,	64-19	1285-1297	1290	2210-2310	3M IKMT
24M	9/ 2	32-31,	64-12 TO	32-35,	64-19	0-1297	1297	2310-0034	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1971 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
25A	9/ 3	32-02,	64-10	TO 32-09,	64-10	1087-1145	1120	0819-0919	3M IKMT
25B	9/ 3	32-02,	64-10	TO 32-09,	64-10	1131-1146	1135	0919-1019	3M IKMT
25C	9/ 3	32-02,	64-10	TO 32-09,	64-10	1090-1160	1125	1019-1119	3M IKMT
25M	9/ 3	32-02,	64-10	TO 32-09,	64-10	0-1160	1160	1119-1210	3M IKMT
26A	9/ 3	32-12,	64-12	TO 32-17,	64-12	695- 749	725	1403-1503	3M IKMT
26B	9/ 3	32-12,	64-12	TO 32-17,	64-12	722- 765	740	1503-1603	3M IKMT
26C	9/ 3	32-12,	64-12	TO 32-17,	64-12	722- 722	722	1603-1703	3M IKMT
26M	9/ 3	32-12,	64-12	TO 32-17,	64-12	0- 725	725	1703-1745	3M IKMT
27A	9/ 3	32-21,	64-13	TO 32-30,	64-16	883- 950	920	2010-2110	3M IKMT
27B	9/ 3	32-21,	64-13	TO 32-30,	64-16	883- 925	905	2110-2210	3M IKMT
27C	9/ 3	32-21,	64-13	TO 32-30,	64-16	894- 925	910	2210-2310	3M IKMT
27M	9/ 3	32-21,	64-13	TO 32-30,	64-16	0- 917	917	2310-0000	3M IKMT
28A	9/ 4	32-31,	64-19	TO 32-30,	64-12	109- 113	110	0119-0219	3M IKMT
28B	9/ 4	32 31,	64-19	TO 32-30,	64-12	108- 113	110	0219-0319	3M IKMT
28C	9/ 4	32-31,	64-19	TO 32-30,	64-12	112- 118	115	0319-0419	3M IKMT
28M	9/ 4	32-31,	64-19	TO 32-30,	64-12	0- 118	118	0419-0427	3M IKMT
30A	9/ 4	32-30,	64-01	TO 32-31,	63-53	1185-1197	1190	1218-1318	3M IKMT
30B	9/ 4	32-30,	64-01	TO 32-31,	63-53	1197-1214	1208	1318-1418	3M IKMT
30C	9/ 4	32-30,	64-01	TO 32 31,	63-53	1165-1228	1180	1418-1518	3M IKMT
30M	9/ 4	32-30,	64-01	TO 32-31,	63-53	0-1170	1170	1518-1604	3M IKMT
31A	9/ 4	32-30,	64-01	TO 32-31,	64-16	848- 906	875	2010-2110	3M IKMT
31B	9/ 4	32-30,	64-01	TO 32-31,	64-16	870- 895	880	2110-2210	3M IKMT
31C	9/ 4	32-30,	64-01	TO 32-31,	64-16	870- 870	870	2210-2310	3M IKMT
31M	9/ 4	32-30,	64-01	TO 32-31,	64-16	0- 870	870	2310-0007	3M IKMT
32A	9/ 5	32-30,	64-18	TO 32-26,	64-09	255- 278	265	0119-0219	3M IKMT
32B	9/ 5	32-30,	64-18	TO 32-26,	64-09	277- 278	277	0219-0319	3M IKMT
32C	9/ 5	32-30,	64-18	TO 32-26,	64-09	275- 278	277	0319-0419	3M IKMT
32M	9/ 5	32-30,	64-18	TO 32-26,	64-09	0- 275	275	0419-0445	3M IKMT
33A	9/ 7	32-22,	64-10	TO 32-18,	64-03	1432-1537	1515	1145-1245	3M IKMT
33B	9/ 7	32-22,	64-10	TO 32-18,	64-03	1490-1525	1510	1245-1345	3M IKMT
33C	9/ 7	32-22,	64-10	TO 32-18,	64-03	1435-1531	1475	1345-1445	3M IKMT
33D	9/ 7	32-22,	64-10	TO 32-18,	64-03	NEUSTON		1049-1119	1M RING
33E	9/ 7	32-22,	64-10	TO 32-18,	64-03	NEUSTON		1215-1245	1M RING
33F	9/ 7	32-22,	64-10	TO 32-18,	64-03	NEUSTON		1315-1345	1M RING
33M	9/ 7	32-22,	64-10	TO 32-18,	64-03	0-1435	1435	1445-1610	3M IKMT
34A	9/ 7	32-18,	64-03	TO 32-28,	64-03	62- 69	65	1655-1755	3M IKMT
34B	9/ 7	32-18,	64-03	TO 32-28,	64-03	69- 69	69	1755-1855	3M IKMT
34C	9/ 7	32-18,	64-03	TO 32-28,	64-03	66- 87	75	1855-1955	3M IKMT
34M	9/ 7	32-18,	64-03	TO 32-28,	64-03	0- 66	66	1955-2007	3M IKMT
35A	9/ 7	32-28,	64-02	TO 32-22,	64-08	177- 178	178	2100-2200	3M IKMT
35B	9/ 7	32-28,	64-02	TO 32-22,	64-08	178- 178	178	2200-2300	3M IKMT
35C	9/ 7	32-28,	64-02	TO 32-22,	64-08	144- 178	160	2300-0000	3M IKMT
35M	9/ 7	32-28,	64-02	TO 32-22,	64-08	0- 144	144	0000-0015	3M IKMT
36A	9/ 8	32-22,	64-11	TO 32-26,	64-23	210- 222	215	0112-0212	3M IKMT
36B	9/ 8	32-22,	64-11	TO 32-26,	64-23	222- 222	222	0212-0312	3M IKMT
36C	9/ 8	32-22,	64-11	TO 32-26,	64-23	222- 222	222	0312-0412	3M IKMT
36M	9/ 8	32-22,	64-11	TO 32-26,	64-23	0- 222	222	0412-0430	3M IKMT
37X	8/30	32-29,	63-54	TO 32-29,	63-54	DIP NET		2000-2300	DIP NET
38X	8/31	32-18,	63-45	TO 32-18,	63-45	DIP NET		1630-1631	DIP NET
39X	9/ 1	32-23,	63-45	TO 32-18,	63-45	DIP NET		2000-2100	DIP NET
40X	9/ 5	32-23,	64-15	TO 32-23,	64-15	DIP NET		2100-2300	DIP NET
41X	9/ 6	32-15,	64-06	TO 32-15,	64-06	DIP NET		1945-2200	DIP NET
51N	8/20	32-07,	64-25	TO 32-07,	64-21	0- 23	23	1215-1330	LG. EMT
52N	8/20	32-07,	64-19	TO 32-06,	64-15	0- 110	110	1404-1530	LG. EMT
53N	8/20	32-07,	64-13	TO 32-07,	64-10	0- 600	500	1630-1834	LG. EMT
54N	8/20	32-07,	64-08	TO 32-10,	64-10	0- 25	25	2110-2149	LG. EMT
55N	8/20	32-11,	64-10	TO 32-09,	63-52	0- 150	150	2240-2330	LG. EMT
56N	8/21	32-08,	63-55	TO 32-09,	63-52	0- 660	600	0004-0204	LG. EMT
57N	8/21	32-10,	63-53	TO 32-10,	63-48	0- 760	760	0234-0449	LG. EMT
58N	8/21	32-10,	63-47	TO 32-11,	63-53	0- 150	150	0555-0715	LG. EMT
59N	8/21	32-12,	63-48	TO 32-16,	63-50	0- 700	650	0734-1034	LG. EMT

TABLE 3.—Continued.

SAMPLE	DATE 1971 MM/DD	COORDINATES NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	DEPTH (M) MIN-MAX	MAIN	TIME LOCAL START-END	GEAR
60N	8/21	32-14, 63-40	TO	32-14,	63 42	0- 230	200	1704-1822	LG. EMT
61N	8/21	32-10, 63-45	TO	32-15,	63-55	0- 450	350	1858-2043	LG. EMT
62N	8/21	32-14, 64-00	TO	32-10,	64-00	0-1000	1000	2115-2334	LG. EMT
63N	8/22	32-11, 64-00	TO	32-09,	63-58	0- 780	750	0025-0245	LG. EMT
64N	8/22	32-08, 63-59	TO	32-08,	63-56	0- 200	200	0430-0549	LG. EMT
65N	8/22	32-10, 63-59	TO	32-08,	63-55	0- 50	50	0625-0731	LG. EMT
66N	8/22	32-06, 63-56	TO	32-03,	63-56	0- 350·	250	0757-0940	LG EMT
67N	8/22	32-04, 63-58	TO	32-05,	64-00	0-1025	1025	1149-1434	LG. EMT
68N	8/22	32-07, 64-00	TO	32-12,	64-00	0- 460	400	1549-1749	LG. EMT
69N	8/22	32-14, 64-02	TO	32-21,	64-04	0- 100	100	1819-2007	LG. EMT
70N	8/22	32-22, 64-04	TO	32-29,	64-09	0- 100	100	2046-2207	LG. EMT
71N	8/22	32-26, 64-10	TO	32-25,	64-13	0- 575	500	2255-0040	LG. EMT
72N	8/23	32-25, 64-14	TO	32-27,	64-12	0- 760	725	0115-0400	LG. EMT
73N	8/23	32-32, 64-02	TO	32-28,	64-05	0- 425	350	0549-0716	LG. EMT
74N	8/23	32-26, 64-07	TO	32-20,	64-05	0- 760	760	0755-0957	LG. EMT
75N	8/23	32-18, 64-04	TO	32-06,	64-02	0- 450	450	1045-1252	LG. EMT
76N	8/23	32-09, 64-02	TO	32-06,	64-02	0- 375	330	1604-1728	LG. EMT
77N	8/23	32-00, 63-58	TO	32-04,	64-03	0- 50	50	1804-2019	LG. EMT
78N	8/23	32-05, 64-03	TO	32-07,	64-07	0- 50	50	2043-2155	LG. EMT
79N	8/23	32-08, 64-09	TO	32-09,	64-11	0- 450	350	2234-0016	LG. EMT
80N	8/24	32-09, 64-11	TO	32-07,	64-06	0- 750	750	0100-0345	LG. EMT
81N	8/24	32-09, 64-07	TO	32-10,	64-09	0- 150	150	0440-0555	LG. EMT
82N	8/24	32-14, 64-14	TO	32-17,	64-18	0- 150	150	0628-0740	LG. EMT
83N	8/24	32-13, 64-16	TO	32-12,	64-21	0- 950	900	0810-1052	LG. EMT
84N	8/24	32-14, 64-20	TO	32-17,	64-18	0- 800	760	1142-1425	LG. EMT
85N	8/24	32-17, 64-17	TO	32-11,	64-17	0- 600	500	1304-1734	LG. EMT
86N	8/24	32-10, 64-18	TO	32-07,	64-17	0- 75	75	1807-1915	LG. EMT
87N	8/24	32-07, 64-17	TO	32-13,	64-21	0- 60	60	1946-2104	LG. EMT
88N	8/24	32-13, 64-22	TO	32-09,	64-23	0-1025	1000	2139-0027	LG. EMT
	1972			CRUISE 13					
1A	2/23	31-55, 64-00	TO	31-50,	63-56	18- 19	18	0003-0103	3M IKMT
1B	2/23	31-55, 64-00	TO	31-50,	63-56	18- 19	18	0103-0203	3M IKMT
1C	2/23	31-55, 64-00	TO	31-50,	63-56	18- 19	18	0203-0303	3M IKMT
1M	2/23	31-55, 64-00	TO	31-50,	63-56	0- 19	19	0303-0328	3M IKMT
2A	2/23	31-50, 63-56	TO	31-41,	63-52	40- 40	40	0434-0510	3M IKMT
2B	2/23	31-50, 63-56	TO	31-41,	63-52	40- 40	40	0510-0619	3M IKMT
2M	2/23	31-50, 63-56	TO	31-41,	63-52	0- 40	40	0619-0634	3M IKMT
3B	2/23	31-53, 63-53	TO	31-53,	64-15	469- 504	480	1110-1210	3M IKMT
3C	2/23	31-53, 63-53	TO	31-53,	64-15	456- 469	465	1210-1310	3M IKMT
3M	2/23	31-53, 63-53	TO	31-53,	64-15	0- 456	456	1310-1345	3M IKMT
4A	2/23	31-50, 64-16	TO	31-48,	64-17	315- 325	315	1445-1515	3M IKMT
4B	2/23	31-50, 64-16	TO	31-48,	64-17	309- 315	315	1515-1545	3M IKMT
4C	2/23	31-50, 64-16	TO	31-48,	64-17	309- 315	315	1545-1615	3M IKMT
4M	2/23	31-50, 64-16	TO	31-48,	64-17	0- 315	315	1615-1639	3M IKMT
5B	2/23	31-47, 64-20	TO	31-46,	64-29	224- 229	225	1810-1840	3M IKMT
5C	2/23	31-47, 64-20	TO	31-46,	64-29	224- 229	225	1840-1910	3M IKMT
5D	2/23	31-47, 64-20	TO	31-46,	64-29	NEUSTON		1834-1849	1M RING
5M	2/23	31-47, 64-20	TO	31-46,	64-29	0- 229	229	1910-1939	3M IKMT
6B	2/23	31-46, 64-30	TO	31-55,	64-30	323- 344	330	2045-2148	3M IKMT
6C	2/23	31-46, 64-30	TO	31-55,	64-30	323- 345	330	2148-2237	3M IKMT
6D	2/23	31-46, 64-30	TO	31-55,	64-30	NEUSTON		2025-2040	1M RING
6E	2/23	31-46, 64-30	TO	31-55,	64-30	NEUSTON		2215-2230	1M RING
6F	2/23	31-46, 64 30	TO	31-55,	64-30	NEUSTON		2231-2246	1M RING
6M	2/23	31-46, 64-30	TO	31-55,	64-30	0- 363	363	2237-2310	3M IKMT
7A	2/24	31-56, 64-22	TO	32-01,	64-22	488- 509	490	0240-0312	3M IKMT
7B	2/24	31-56, 64-22	TO	32-01,	64-22	488- 489	489	0312-0412	3M IKMT
7C	2/24	31-56, 64-22	TO	32-01,	64-22	463- 489	480	0412-0510	3M IKMT
7D	2/24	31-56, 64-22	TO	32-01,	64-22	NEUSTON		0200-0230	1M RING
7E	2/24	31-56, 64-22	TO	32-01,	64-22	NEUSTON		0234-0304	1M RING

TABLE 3.—Continued.

SAMPLE	DATE 1972 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
7F	2/24	31-56,	64-22	TO 32-01,	64-22	NEUSTON		0307-0337	1M RING
7G	2/24	31-56,	64-22	TO 32-01,	64-22	NEUSTON		0349-0419	1M RING
7M	2/24	31-56,	64-22	TO 32-01,	64-22	0- 482	482	0510-0555	3M IKMT
8A	2/24	32-02,	63-57	TO 32-18,	63-51	808- 865	830	1149-1249	3M IKMT
8B	2/24	32-02,	63-57	TO 32-18,	63-51	791- 843	835	1249-1349	3M IKMT
8C	2/24	32-02,	63-57	TO 32-18,	63-51	813- 847	825	1349-1449	3M IKMT
8D	2/24.	32-02,	63-57	TO 32-18,	63-51	NEUSTON		1219-1234	1M RING
8M	2/24	32-02.	63-57	TO 32-18,	63-51	0- 866	866	1449-1549	3M IKMT
9D	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		1843-1919	1M RING
9E	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		1925-1955	1M RING
9F	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		1958-2028	1M RING
9G	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		2030-2100	1M RING
9H	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		2103-2133	1M RING
9J	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		2134-2204	1M RING
9K	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		2210-2240	1M RING
9L	2/24	32-17,	63-50	TO 32-16,	63-37	NEUSTON		2245-2315	1M RING
9P	2/24	32-17,	63-50	TO 32-16,	63-37	0- 838	830	2204-0006	3M IKMT
10A	2/25	32-20,	63-33	TO 32-11,	63-30	96- 102	100	0210-0310	3M IKMT
10B	2/25	32-20,	63-33	TO 32-11,	63-30	100- 101	100	0310-0410	3M IKMT
10C	2/25	32-20,	63-33	TO 32-11,	63-30	96- 101	100	0410-0510	3M IKMT
10D	2/25	32-20,	63-33	TO 32-11,	63-30	NEUSTON		0345-0400	1M RING
10E	2/25	32-20,	63-33	TO 32-11,	63-30	NEUSTON		0434-0449	1M RING
10M	2/25	32-20,	63-33	TO 32-11,	63-30	0- 96	96	0510-0527	3M IKMT
11A	2/25	32-00,	64-00	TO 31-54,	63-51	392- 403	400	0901-0946	3M IKMT
11B	2/25	32-00,	64-00	TO 31-54,	63-51	392- 403	400	0946-1031	3M IKMT
11C	2/25	32-00,	64-00	TO 31-54,	63-51	392- 392	392	1031-1116	3M IKMT
11D	2/25	32-00,	64-00	TO 31-54,	63-51	NEUSTON		0928-0958	1M RING
11E	2/25	32-00,	64-00	TO 31-54,	63-51	NEUSTON		1003-1033	1M RING
11M	2/25	32-00,	64-00	TO 31-54,	63-51	0- 392	392	1116-1145	3M IKMT
12A	2/25	31-53,	63-52	TO 31-56,	63-34	1002-1074	1050	1410-1500	3M IKMT
12B	2/25	31-53,	63-52	TO 31-56,	63-34	1002-1078	1050	1500-1549	3M IKMT
12C	2/25	31-53,	63-52	TO 31-56,	63-34	1050-1068	1050	1549-1640	3M IKMT
12D	2/25	31-53,	63-52	TO 31-56,	63-34	NEUSTON		1501-1531	1M RING
12E	2/25	31-53,	63-52	TO 31-56,	63-34	NEUSTON		1534-1604	1M RING
12F	2/25	31-53,	63-52	TO 31-56,	63-34	NEUSTON		1610-1640	1M RING
12G	2/25	31-53,	63-52	TO 31-56,	63-34	NEUSTON		1649-1719	1M RING
12M	2/25	31-53,	63-52	TO 31-56,	63-34	0-1051	1051	1640-1725	3M IKMT
13A	2/25	32-05,	64-00	TO 31-52,	63-48	759- 833	800	2015-2115	3M IKMT
13B	2/25	32-05,	64-00	TO 31-52,	63-48	745- 824	800	2115-2215	3M IKMT
13C	2/25	32-05,	64-00	TO 31-52,	63-48	779- 830	800	2215-2315	3M IKMT
13D	2/25	32-05,	64-00	TO 31-52,	63-48	NEUSTON		1945-2015	1M RING
13E	2/25	32-05,	64-00	TO 31-52,	63-48	NEUSTON		2030-2100	1M RING
13F	2/25	32-05,	64-00	TO 31-52,	63-48	NEUSTON		2130-2145	1M RING
13G	2/25	32-05,	64-00	TO 31-52,	63-48	NEUSTON		2215-2245	1M RING
13M	2/25	32-05,	64-00	TO 31-52,	63-48	0- 798	798	2315-0003	3M IKMT
14A	2/26	31-51,	63-47	TO 31-47,	63-46	193- 201	200	0204-0304	3M IKMT
14B	2/26	31-51,	63-47	TO 31-47,	63-46	200- 208	200	0304-0404	3M IKMT
14C	2/26	31-51,	63-47	TO 31-47,	63-46	196- 206	200	0404-0504	3M IKMT
14D	2/26	31-51,	63-47	TO 31-47,	63-46	NEUSTON		0125-0140	1M RING
14E	2/26	31-51,	63-47	TO 31-47,	63-46	NEUSTON		0200-0230	1M RING
14F	2/26	31-51,	63-47	TO 31-47,	63-46	NEUSTON		0322-0352	1M RING
14G	2/26	31-51,	63-47	TO 31-47,	63-46	NEUSTON		0352-0422	1M RING
14M	2/26	31-51,	63-47	TO 31-47,	63-46	0- 197	197	0504-0527	3M IKMT
15A	2/26	32-04,	64-03	TO 31-58,	63-55	594- 600	598	0910-0955	3M IKMT
15B	2/26	32-04,	64-03	TO 31-58,	63-55	594- 609	600	0955-1040	3M IKMT
15C	2/26	32-04,	64-03	TO 31-58,	63-55	577- 599	580	1040-1125	3M IKMT
15M	2/26	32-04,	64-03	TO 31-58,	63-55	0- 584	584	1125-1158	3M IKMT
16D	2/26	32-02,	63-58	TO 31-51,	63-43	NEUSTON		1715-1745	1M RING
16P	2/26	32-02,	63-58	TO 31-51,	63-43	0-1626	1550	1400-1913	3M IKMT
17A	2/26	31-54,	63-39	TO 31-51,	63-42	401- 452	440	2015-2115	3M IKMT
17B	2/26	31-54,	63-39	TO 31-51,	63-42	433- 450	440	2115-2215	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1972 MM/DD	COORDINATES NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	DEPTH (M) MIN-MAX	MAIN	TIME LOCAL START-END	GEAR
17C	2/26	31-54, 63-39	TO	31-51,	63-42	433- 438	435	2215-2315	3M IKMT
17D	2/26	31-54, 63-39	TO	31-51,	63-42	NEUSTON		2000-2030	1M RING
17E	2/26	31-54, 63-39	TO	31-51,	63-42	NEUSTON		2116-2146	1M RING
17F	2/26	31-54, 63-39	TO	31-51,	63-42	NEUSTON		2149-2219	1M RING
17G	2/26	31-54, 63-39	TO	31-51,	63-42	NEUSTON		2225-2249	1M RING
17M	2/26	31-54, 63-39	TO	31-51,	63-42	0- 438	438	2315-2336	3M IKMT
18A	2/27	31-51, 63-42	TO	31-42,	63-32	1016-1016	1016	0140-0240	3M IKMT
18B	2/27	31-51, 63-42	TO	31-42,	63-32	992-1059	1040	0240-0340	3M IKMT
18C	2/27	31-51, 63-42	TO	31-42,	63-32	984-1026	1000	0340-0440	3M IKMT
18D	2/27	31-51, 63-42	TO	31-42,	63-32	NEUSTON		0330-0400	1M RING
18E	2/27	31-51, 63-42	TO	31-42,	63-32	NEUSTON		0430-0500	1M RING
18M	2/27	31-51, 63-42	TO	31-42,	63-32	0- 984	984	0440-0524	3M IKMT
19P	2/27	32-00, 64-00	TO	31-48,	63-44	0-1340	1320	0930-1325	3M IKMT
20A	2/27	31-47, 63-42	TO	31-40,	63-41	171- 172	171	1446-1546	3M IKMT
20B	2/27	31-47, 63-42	TO	31-40,	63-41	166- 172	170	1546-1643	3M IKMT
20C	2/27	31-47, 63-42	TO	31-40,	63-41	164- 166	165	1643-1743	3M IKMT
20M	2/27	31-47, 63-42	TO	31-40,	63-41	0- 164	164	1743-1755	3M IKMT
21A	2/27	31-41, 63-41	TO	31-55,	63-51	602- 627	615	2010-2110	3M IKMT
21B	2/27	31-41, 63-41	TO	31-55,	63-51	587- 602	600	2110-2210	3M IKMT
21C	2/27	31-41, 63-41	TO	31-55,	63-51	578- 587	580	2210-2310	3M IKMT
21D	2/27	31-41, 63-41	TO	31-55,	63-51	NEUSTON		1910-1943	1M RING
21E	2/27	31-41, 63-41	TO	31-55,	63-51	NEUSTON		1945-2015	1M RING
21F	2/27	31-41, 63-41	TO	31-55,	63-51	NEUSTON		2019-2049	1M RING
21G	2/27	31-41, 63-41	TO	31-55,	63-51	NEUSTON		2055-2125	1M RING
21H	2/27	31-41, 63-41	TO	31-55,	63-51	NEUSTON		2130-2200	1M RING
21J	2/27	31-41, 63-41	TO	31-55,	63-51	NEUSTON		2200-2230	1M RING
21M	2/27	31-41, 63-41	TO	31-55,	63-51	0- 578	578	2310-2343	3M IKMT
22A	2/28	31-55, 63-51	TO	32-12,	63-53	150- 150	150	0140-0249	3M IKMT
22B	2/28	31-55, 63-51	TO	32-12,	63-53	150- 167	150	0249-0510	3M IKMT
22D	2/28	31-55, 63-51	TO	32-12,	63-53	NEUSTON		0400-0430	1M RING
22M	2/28	31-55, 63-51	TO	32-12,	63-53	0- 165	165	0510-0528	3M IKMT
23A	2/28	32-21, 63-55	TO	32-08,	63-54	1251-1321	1280	1351-1446	3M IKMT
23B	2/28	32-21, 63-55	TO	32-08,	63-54	1231-1251	1240	1446-1545	3M IKMT
23C	2/28	32-21, 63-55	TO	32-08,	63-54	1251-1274	1270	1545-1645	3M IKMT
23P	2/28	32-21, 63-55	TO	32-08,	63-54	0-1301	1301	1645-1819	3M IKMT
24A	2/28	32-08, 63-47	TO	32-00,	63-47	1241-1266	1260	1945-2045	3M IKMT
24B	2/28	32-08, 63-47	TO	32-00,	63-47	1237-1300	1270	2045-2145	3M IKMT
24C	2/28	32-08, 63-47	TO	32-00,	63-47	1205-1300	1230	2145-2245	3M IKMT
24D	2/28	32-08, 63-47	TO	32-00,	63-47	NEUSTON		2130-2145	1M RING
24E	2/28	32-08, 63-47	TO	32-00,	63-47	NEUSTON		2215-2230	1M RING
24F	2/28	32-08, 63-47	TO	32-00,	63-47	NEUSTON		2315-2330	1M RING
24M	2/28	32-08, 63-47	TO	32-00,	63-47	0-1236	1236	2245-2331	3M IKMT
25A	2/29	31-57, 63-47	TO	31-50,	63-47	1483-1548	1525	0149-0255	3M IKMT
25B	2/29	31-57, 63-47	TO	31-50,	63-47	1488-1555	1535	0255-0400	3M IKMT
25C	2/29	31-57, 63-47	TO	31-50,	63-47	1488-1565	1535	0400-0510	3M IKMT
25D	2/29	31-57, 63-47	TO	31-50,	63-47	NEUSTON		0145-0200	1M RING
25M	2/29	31-57, 63-47	TO	31-50,	63-47	0-1500	1500	0510-0607	3M IKMT
27A	2/29	31-51, 64-04	TO	31-54,	64-16	82- 117	85	1455-1549	3M IKMT
27B	2/29	31-51, 64-04	TO	31-54,	64-16	77- 82	80	1549-1645	3M IKMT
27C	2/29	31-51, 64-04	TO	31-54,	64-16	72- 82	75	1645-1740	3M IKMT
27M	2/29	31-51, 64-04	TO	31-54,	64-16	0- 82	82	1740-1749	3M IKMT
29A	2/29	31-54, 64-16	TO	32-03,	64-21	95- 95	95	1955-2055	3M IKMT
28B	2/29	31-54, 64-16	TO	32-03,	64-21	95- 95	95	2055-2125	3M IKMT
28C	2/29	31-54, 64-16	TO	32-03,	64-21	95- 95	95	2125-2155	3M IKMT
28M	2/29	31-54, 64-16	TO	32-03,	64-21	0- 95	95	2155-2213	3M IKMT
29A	2/29	32-03, 64-20	TO	32-08,	64-09	68- 68	68	2251-2351	3M IKMT
29B	2/29	32-03, 64-20	TO	32-08,	64-09	68- 68	68	2351-0051	3M IKMT
29C	2/29	32-03, 64-20	TO	32-08,	64-09	68- 68	68	0051-0151	3M IKMT
29M	2/29	32-03, 64-20	TO	32-08,	64-09	0- 68	68	0151-0158	3M IKMT
30A	3/ 1	32-08, 64-09	TO	32-16,	64-08	33- 34	34	0230-0330	3M IKMT
30B	3/ 1	32-08, 64-09	TO	32-16,	64-08	34- 34	34	0330-0430	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1972 MM/DD	COORDINATES NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	DEPTH (M) MIN-MAX	MAIN	TIME LOCAL START-END	GEAR
30C	3/ 1	32-08,	64-09 TO	32-16,	64-08	34- 34	34	0430-0518	3M IKMT
30M	3/ 1	32-08,	64-09 TO	32-16,	64-08	0- 34	34	0518-0522	3M IKMT
31P	3/ 1	32-16,	64-08 TO	32-27,	63-49	0-1557	1480	0819-1330	3M IKMT
32A	3/ 1	32-28,	63-45 TO	32-30,	63-39	33- 33	33	1415-1515	3M IKMT
32B	3/ 1	32-28,	63-45 TO	32-30,	63-39	33- 33	33	1515-1619	3M IKMT
32C	3/ 1	32-28,	63-45 TO	32-30,	63-39	33- 33	33	1619-1645	3M IKMT
32P	3/ 1	32-28,	63-45 TO	32-30,	63-39	0- 33	33	1645-1733	3M IKMT
33A	3/ 1	32-16,	63-57 TO	32-15,	63-41	708- 750	740	2119-2219	3M IKMT
33B	3/ 1	32-16,	63-57 TO	32-15,	63-41	702- 749	720	2219-2319	3M IKMT
33C	3/ 1	32-16,	63-57 TO	32-15,	63-41	702- 730	720	2319-0019	3M IKMT
33D	3/ 1	32-16,	63-57 TO	32-15,	63-41	NEUSTON		2225-2310	1M RING
33M	3/ 1	32-16,	63-57 TO	32-15,	63-41	0- 722	722	0019-0046	3M IKMT
34A	3/ 2	32-14,	63-40 TO	32-24,	63-49	517- 552	530	0210-0310	3M IKMT
34B	3/ 2	32-14,	63-40 TO	32-24,	63-49	523- 533	530	0310-0410	3M IKMT
34C	3/ 2	32-14,	63-40 TO	32-24,	63-49	533- 537	535	0410-0510	3M IKMT
34D	3/ 2	32-14,	63-40 TO	32-24,	63-49	NEUSTON		0200-0230	1M RING
34M	3/ 2	32-14,	63-40 TO	32-24,	63-49	0- 537	537	0510-0601	3M IKMT
35A	3/ 2	32-27,	64-17 TO	32-28,	64-00	1478-1536	1515	1000-1100	3M IKMT
35B	3/ 2	32-27,	64-17 TO	32-28,	64-00	1494-1524	1520	1100-1200	3M IKMT
35C	3/ 2	32-27,	64-17 TO	32-28,	64-00	1504-1536	1525	1200-1313	3M IKMT
35M	3/ 2	32-27,	64-17 TO	32-28,	64-00	0-1504	1504	1313-1400	3M IKMT
36A	3/ 2	32-30,	63-59 TO	32-28,	63-48	115- 153	135	1428-1618	3M IKMT
36C	3/ 2	32-30,	63-59 TO	32-28,	63-48	132- 137	135	1618-1648	3M IKMT
36P	3/ 2	32-30,	63-59 TO	32-28,	63-48	0- 135	135	1648-1734	3M IKMT
37A	3/ 2	32-20,	64-16 TO	32-18,	64-05	190- 251	225	2019-2119	3M IKMT
37B	3/ 2	32-20,	64-16 TO	32-18,	64-05	201- 239	220	2119-2219	3M IKMT
37C	3/ 2	32-20,	64-16 TO	32-18,	64-05	202- 217	215	2219-2319	3M IKMT
37M	3/ 2	32-20,	64-16 TO	32-18,	64-05	0- 217	217	2319-2331	3M IKMT
38A	3/ 3	32-19,	64-07 TO	32-29,	64-15	352- 385	380	0019-0119	3M IKMT
38B	3/ 3	32-19,	64-07 TO	32-29,	64-15	385- 386	385	0119-0219	3M IKMT
38C	3/ 3	32-19,	64-07 TO	32-29,	64-15	368- 386	375	0219-0334	3M IKMT
38D	3/ 3	32-19,	64-07 TO	32-29,	64-15	NEUSTON		0019-0034	1M RING
38M	3/ 3	32-19,	64-07 TO	32-29,	64-15	0- 368	368	0334-0352	3M IKMT
39A	3/ 3	32-15,	64-02 TO	32-28,	64-17	730- 744	735	0816-0906	3M IKMT
39B	3/ 3	32-15,	64-02 TO	32-28,	64-17	724- 739	735	0906-0955	3M IKMT
39C	3/ 3	32-15,	64-02 TO	32-28,	64-17	716- 738	720	0955-1046	3M IKMT
39M	3/ 3	32-15,	64-02 TO	32-28,	64-17	0- 719	719	1046-1130	3M IKMT

CRUISE 14

1A	6/ 4	32-10,	64-10 TO	32-07,	63-50	290- 296	290	1437-1537	3M IKMT
1B	6/ 4	32-10,	64-10 TO	32-07,	63-50	292- 294	294	1537-1637	3M IKMT
1C	6/ 4	32-10,	64-10 TO	32-07,	63-50	282- 293	293	1637-1737	3M IKMT
1D	6/ 4	32-10,	64-10 TO	32-07,	63-50	NEUSTON		1419-1449	1M RING
1E	6/ 4	32-10,	64-10 TO	32-07,	63-50	NEUSTON		1455-1525	1M RING
1F	6/ 4	32-10,	64-10 TO	32-07,	63-50	NEUSTON		1540-1649	1M RING
1M	6/ 4	32-10,	64-10 TO	32-07,	63-50	0- 290	290	1737-1758	3M IKMT
2A	6/ 4	32-10,	63-59 TO	32-11,	63-41	280- 307	290	2045-2149	3M IKMT
2B	6/ 4	32-10,	63-59 TO	32-11,	63-41	287- 306	298	2149-2255	3M IKMT
2C	6/ 4	32-10,	63-59 TO	32-11,	63-41	282- 298	285	2255-2400	3M IKMT
2D	6/ 4	32-10,	63-59 TO	32-11,	63-41	NEUSTON		2019-2049	1M RING
2E	6/ 4	32-10,	63-59 TO	32-11,	63-41	NEUSTON		2052-2122	1M RING
2F	6/ 4	32-10,	63-59 TO	32-11,	63-41	NEUSTON		2125-2155	1M RING
2G	6/ 4	32-10,	63-59 TO	32-11,	63-41	NEUSTON		2200-2230	1M RING
2H	6/ 4	32-10,	63-59 TO	32-11,	63-41	NEUSTON		2234-2304	1M RING
2J	6/ 4	32-10,	63-59 TO	32-11,	63-41	NEUSTON		2310-2340	1M RING
2M	6/ 4	32-10,	63-59 TO	32-11,	63-41	0- 282	282	2400-0034	3M IKMT
3A	6/ 5	32-12,	65-45 TO	32-17,	63-40	91- 96	94	0215-0245	3M IKMT
3B	6/ 5	32-12,	65-45 TO	32-17,	63-40	91- 93	92	0245-0315	3M IKMT
3D	6/ 5	32-12,	65-45 TO	32-17,	63-40	NEUSTON		0257-0327	1M RING
3P	6/ 5	32 12,	65-45 TO	32-17,	63-40	0- 92	92	0315-0404	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1972 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
4A	6/ 5	32-07,	63-52	TO 32-05,	63-35	96- 97	96	0645-0734	3M IKMT
4B	6/ 5	32-07,	63-52	TO 32-05,	63-35	92- 96	94	0734-0825	3M IKMT
4C	6/ 5	32-07,	63-52	TO 32-05,	63-35	92- 93	92	0825-0915	3M IKMT
4M	6/ 5	32-07,	63-52	TO 32-05,	63-35	0- 93	93	0915-0933	3M IKMT
5A	6/ 5	32-08,	63-34	TO 32-00,	63-30	392- 404	398	1430-1530	3M IKMT
5B	6/ 5	32-08,	63-34	TO 32-00,	63-30	396- 401	399	1530-1600	3M IKMT
5C	6/ 5	32-08,	63-34	TO 32-00,	63-30	392- 411	395	1600-1730	3M IKMT
5D	6/ 5	32-08,	63-34	TO 32-00,	63-30	NEUSTON		1515-1615	1M RING
5M	6/ 5	32-08,	63-34	TO 32-00,	63-30	0- 396	396	1730-1800	3M IKMT
6A	6/ 6	32-08,	63-55	TO 31-58,	63-52	761- 842	800	0700-0800	3M IKMT
6B	6/ 6	32-08,	63-55	TO 31-58,	63-52	760- 800	775	0800-1000	3M IKMT
6D	6/ 6	32-08,	63-55	TO 31-58,	63-52	NEUSTON		0534-0604	1M RING
6E	6/ 6	32-08,	63-55	TO 31-58,	63-52	NEUSTON		0625-0655	1M RING
6F	6/ 6	32-08,	63-55	TO 31-58,	63-52	NEUSTON		0734-0804	1M RING
6G	6/ 6	32-08,	63-55	TO 31-58,	63-52	NEUSTON		0910-0940	1M RING
6M	6/ 6	32-08,	63-55	TO 31-58,	63-52	0- 763	763	1000-1034	3M IKMT
7A	6/ 6	32-03,	63-55	TO 31-57,	63-35	951- 993	990	1519-1610	3M IKMT
7B	6/ 6	32-03,	63-55	TO 31-57,	63-35	957- 992	985	1610-1700	3M IKMT
7C	6/ 6	32-03,	63-55	TO 31-57,	63-35	958- 998	990	1700-1749	3M IKMT
7M	6/ 6	32-03,	63-55	TO 31-57,	63-35	0- 962	962	1749-1901	3M IKMT
8A	6/ 6	31-58,	63-38	TO 31-48,	63-38	380- 435	400	2130-2219	3M IKMT
8B	6/ 6	31-58,	63-38	TO 31-48,	63-38	380- 392	390	2219-2310	3M IKMT
8C	6/ 6	31-58,	63-38	TO 31-48,	63-38	388- 392	392	2310-2400	3M IKMT
8D	6/ 6	31-58,	63-38	TO 31-48,	63-38	NEUSTON		2315-2345	1M RING
8M	6/ 6	31-58,	63-38	TO 31-48,	63-38	0- 392	392	2400-0033	3M IKMT
9A	6/ 7	31-46,	63-38	TO 31-39,	63-36	144- 164	149	0210-0255	3M IKMT
9B	6/ 7	31-46,	63-38	TO 31-39,	63-36	122- 148	138	0255-0340	3M IKMT
9D	6/ 7	31-46,	63-38	TO 31-39,	63-36	NEUSTON		0230-0300	1M RING
9E	6/ 7	31-46,	63-38	TO 31-39,	63-36	NEUSTON		0304-0334	1M RING
9F	6/ 7	31-46,	63-38	TO 31-39,	63-36	NEUSTON		0340-0410	1M RING
9P	6/ 7	31-46,	63-38	TO 31-39,	63-36	0- 150	150	0340-0407	3M IKMT
10A	6/ 7	31-48,	63-49	TO 31-36,	63-42	565- 624	595	0645-0745	3M IKMT
10B	6/ 7	31-48,	63-49	TO 31-36,	63-42	580- 622	595	0745-0845	3M IKMT
10C	6/ 7	31-48,	63-49	TO 31-36,	63-42	578- 600	590	0845-0945	3M IKMT
10D	6/ 7	31-48,	63-49	TO 31-36,	63-42	NEUSTON		0800-0900	1M RING
10M	6/ 7	31-48,	63-49	TO 31-36,	63-42	0- 578	578	0945-1012	3M IKMT
11A	6/ 7	31-41,	63-49	TO 31-29,	63-43	1228-1245	1230	1445-1545	3M IKMT
11B	6/ 7	31-41,	63-49	TO 31-29,	63-43	1214-1245	1220	1545-1645	3M IKMT
11C	6/ 7	31-41,	63-49	TO 31-29,	63-43	1214-1237	1225	1645-1745	3M IKMT
11D	6/ 7	31-41,	63-49	TO 31-29,	63-43	NEUSTON		1706-1736	1M RING
11E	6/ 7	31-41,	63-49	TO 31-29,	63-43	NEUSTON		1755-1840	1M RING
11M	6/ 7	31-41,	63-49	TO 31-29,	63-43	0-1250	1250	1745-1915	3M IKMT
12A	6/ 7	31-33,	63-45	TO 31-35,	63-53	741- 870	810	2049-2134	3M IKMT
12B	6/ 7	31-33,	63-45	TO 31-35,	63-53	741- 795	780	2134-2225	3M IKMT
12C	6/ 7	31-33,	63-45	TO 31-35,	63-53	751- 800	775	2225-2310	3M IKMT
12D	6/ 7	31-33,	63-45	TO 31-35,	63-53	NEUSTON		2140-2210	1M RING
12E	6/ 7	31-33,	63-45	TO 31-35,	63-53	NEUSTON		2215-2245	1M RING
12F	6/ 7	31-33,	63-45	TO 31-35,	63-53	NEUSTON		2249-2319	1M RING
12M	6/ 7	31-33,	63-45	TO 31-35,	63-53	0- 799	799	2310-2343	3M IKMT
13A	6/ 8	31-36,	63-54	TO 31-36,	63-49	150- 180	175	0200-0255	3M IKMT
13B	6/ 8	31-36,	63-54	TO 31-36,	63-49	170- 190	175	0255-0340	3M IKMT
13C	6/ 8	31-36,	63-54	TO 31-36,	63-49	170- 190	175	0340-0400	3M IKMT
13D	6/ 8	31-36,	63-54	TO 31-36,	63-49	NEUSTON		0215-0245	1M RING
13E	6/ 8	31-36,	63-54	TO 31-36,	63-49	NEUSTON		0249-0319	1M RING
13M	6/ 8	31-36,	63-54	TO 31-36,	63-49	0- 175	175	0400-0413	3M IKMT
14A	6/ 8	31-51,	63-55	TO 31-42,	63-55	461- 497	475	0640-0740	3M IKMT
14B	6/ 8	31-51,	63-55	TO 31-42,	63-55	452- 500	480	0740-0840	3M IKMT
14C	6/ 8	31-51,	63-55	TO 31-42,	63-55	454- 497	485	0840-0940	3M IKMT
14M	6/ 8	31-51,	63-55	TO 31-42,	63-55	0- 462	462	0940-1010	3M IKMT
15A	6/ 8	31-53,	63-56	TO 31-51,	63-47	190- 205	195	1410-1510	3M IKMT
15B	6/ 8	31-53,	63-56	TO 31-51,	63-47	186- 189	189	1510-1610	3M IKMT

TABLE 3.—Continued.

SAMPLE	DATE 1972 MM/DD	COORDINATES				DEPTH (M)		TIME LOCAL START-END	GEAR
		NORTH D-M	WEST D-M	NORTH D-M	WEST D-M	MIN-MAX	MAIN		
15C	6/ 8	31-53,	63-56	TO 31-51,	63-47	184- 189	188	1610-1710	3M IKMT
15D	6/ 8	31-53,	63-56	TO 31-51,	63-47	NEUSTON		1410-1440	1M RING
15M	6/ 8	31-53,	63-56	TO 31-51,	63-47	0- 184	184	1710-1734	3M IKMT
16D	6/ 8	31-48,	63-43	TO 31-41,	63-38	NEUSTON		1930-2000	1M RING
16E	6/ 8	31-48,	63-43	TO 31-41,	63-38	NEUSTON		2030-2100	1M RING
16F	6/ 8	31-48,	63-43	TO 31-41,	63-38	NEUSTON		2103-2133	1M RING
16G	6/ 8	31-48,	63-43	TO 31-41,	63-38	NEUSTON		2134-2204	1M RING
16P	6/ 8	31-48,	63-43	TO 31-41,	63-38	0-1038	1038	2055-2210	3M IKMT
17A	6/ 9	31-43,	63-45	TO 31-31,	63-53	556- 600	575	0115-0204	3M IKMT
17B	6/ 9	31-43,	63-45	TO 31-31,	63-53	554- 605	575	0204-0255	3M IKMT
17C	6/ 9	31-43,	63-45	TO 31-31,	63-53	574- 604	585	0255-0340	3M IKMT
17M	6/ 9	31-43,	63-45	TO 31-31,	63-53	0- 588	588	0340-0443	3M IKMT
18A	6/ 9	31-43,	64-03	TO 31-46,	63-46	149- 151	150	0700-0800	3M IKMT
18B	6/ 9	31-43,	64-03	TO 31-46,	63-46	147- 148	148	0800-0900	3M IKMT
18C	6/ 9	31-43,	64-03	TO 31-46,	63-46	138- 149	148	0900-1000	3M IKMT
18D	6/ 9	31-43,	64-03	TO 31-46,	63-46	NEUSTON		0910-0940	1M RING
18M	6/ 9	31-43,	64-03	TO 31-46,	63-46	0- 140	140	1000-1012	3M IKMT
19A	6/ 9	31-44,	63-53	TO 31-50,	63-45	338- 350	340	1449-1549	3M IKMT
19B	6/ 9	31-44,	63-53	TO 31-50,	63-45	328- 340	330	1549-1649	3M IKMT
19C	6/ 9	31-44,	63-53	TO 31-50,	63-45	328- 340	330	1649-1749	3M IKMT
19M	6/ 9	31-44,	63-53	TO 31-50,	63-45	0- 331	331	1749-1810	3M IKMT
20A	6/ 9	31-55,	63-53	TO 31-54,	63-42	476- 504	476	2055-2155	3M IKMT
20B	6/ 9	31-55,	63-53	TO 31-54,	63-42	484- 503	485	2155-2255	3M IKMT
20C	6/ 9	31-55,	63-53	TO 31-54,	63-42	483- 491	485	2255-2355	3M IKMT
20M	6/ 9	31-55,	63-53	TO 31-54,	63-42	C- 483	483	2355-0049	3M IKMT
21A	6/10	31-52,	63-39	TO 31-49,	63-39	50- 52	50	0240-0310	3M IKMT
21B	6/10	31-52,	63-39	TO 31-49,	63-39	54- 56	55	0310-0340	3M IKMT
21C	6/10	31-52,	63-39	TO 31-49,	63-39	54- 56	55	0340-0400	3M IKMT
21M	6/10	31-52,	63-39	TO 31-49,	63-39	0- 56	56	0400-0415	3M IKMT
22A	6/10	31-49,	63-39	TO 31-36,	63-40	1485-1550	1525	0645-0745	3M IKMT
22B	6/10	31-49,	63-39	TO 31-36,	63-40	1479-1553	1525	0745-0845	3M IKMT
22C	6/10	31-49,	63-39	TO 31-36,	63-40	1479-1552	1510	0845-0945	3M IKMT
22D	6/10	31-49,	63-39	TO 31-36,	63-40	NEUSTON		0800-0830	1M RING
22M	6/10	31-49,	63-39	TO 31-36,	63-40	0-1530	1530	0945-1045	3M IKMT
23A	6/10	31-33,	63-39	TO 31-26,	63-33	660- 723	700	1145-1245	3M IKMT
23B	6/10	31-33,	63-39	TO 31-26,	63-33	654- 674	665	1245-1345	3M IKMT
23C	6/10	31-33,	63-39	TO 31-26,	63-33	662- 694	685	1345-1445	3M IKMT
23M	6/10	31-33,	63-39	TO 31-26,	63-33	0- 662	662	1445-1536	3M IKMT
24A	6/10	31-56,	63-59	TO 32-01,	63-50	947- 996	985	2100-2200	3M IKMT
24B	6/10	31-56,	63-59	TO 32-01,	63-50	979-1015	1000	2200-2300	3M IKMT
24C	6/10	31-56,	63-59	TO 32-01,	63-50	980-1025	1000	2300-2400	3M IKMT
24D	6/10	31-56,	63-59	TO 32-01,	63-50	NEUSTON		1930-2030	1M RING
24E	6/10	31-56,	63-59	TO 32-01,	63-50	NEUSTON		2255-2325	1M RING
24F	6/10	31-56,	63-59	TO 32-01,	63-50	NEUSTON		2325-2355	1M RING
24M	6/10	31-56,	63-59	TO 32-01,	63-50	0-1019	1019	2400-0057	3M IKMT
25D	6/11	32-01,	63-50	TO 32-01,	63-36	NEUSTON		0204-0234	1M RING
25P	6/11	32-01,	63-50	TO 32-01,	63-36	0- 30	30	0122-0409	3M IKMT
26A	6/11	32-11,	63-52	TO 32-14,	63-40	52- 52	52	0649-0734	3M IKMT
26B	6/11	32-11,	63-52	TO 32-14,	63-40	52- 52	52	0734-0819	3M IKMT
26C	6/11	32-11,	63-52	TO 32-14,	63-40	52- 52	52	0819-0904	3M IKMT
26M	6/11	32-11,	63-52	TO 32-14,	63-40	0- 52	52	0904-0910	3M IKMT
27A	6/11	32-15,	63-38	TO 32-16,	63-40	27- 27	27	0934-1004	3M IKMT
27B	6/11	32-15,	63-38	TO 32-16,	63-40	27- 27	27	1004-1104	3M IKMT
27M	6/11	32-15,	63-38	TO 32-16,	63-40	0- 27	27	1104-1110	3M IKMT
28A	6/11	32-14,	63-46	TO 32-05,	63-45	855- 910	900	1430-1530	3M IKMT
28B	6/11	32-14,	63-46	TO 32-05,	63-45	889- 914	900	1530-1630	3M IKMT
28C	6/11	32-14,	63-46	TO 32-05,	63-45	880- 913	900	1630-1730	3M IKMT
28M	6/11	32-14,	63-46	TO 32-05,	63-45	0- 880	880	1730-1819	3M IKMT
29A	6/11	32-04,	63-43	TO 31-52,	63-40	1205-1257	1250	2055-2155	3M IKMT
29B	6/11	32-04,	63-43	TO 31-52,	63-40	1228-1250	1250	2155-2255	3M IKMT
29C	6/11	32-04,	63-43	TO 31-52,	63-40	1205-1249	1240	2255-2355	3M IKMT
29M	6/11	32-04,	63-43	TO 31-52,	63-40	0-1197	1197	2355-0046	3M IKMT

Family Sternoptychidae,
Marine Hatchetfishes and Related Species

W. Huntting Howell and William H. Krueger

ABSTRACT

The marine hatchetfishes and related species are represented in the Ocean Acre collections by more than 6800 specimens distributed among seven species in four genera. *Argyropelecus hemigymnus* and *Sternoptyx diaphana* were categorized as "abundant," *A. aculeatus* as "common," *Valenciennellus tripunctulatus* as "uncommon," and *A. affinis, S. pseudobscura*, and *Maurolicus muelleri* as "rare." Developmental stages, reproductive cycles, seasonal abundance, vertical distribution, patchiness, and night-to-day catch ratio are discussed for each species for which there are enough data. Of the four well-represented species, *S. diaphana* lives deeper than the others and normally does not migrate vertically. *Argyropelecus aculeatus* and *A. hemigymnus* occupy similar depths during the day, but *A. aculeatus* performs a more extensive vertical migration to shallower depths than *A. hemigymnus*, which migrates only slightly; the two species differ in maximum size, longevity, and spawning season. *Valenciennellus tripunctulatus* resembles *A. hemigymnus* in size, pigmentation, and vertical distribution, but the former spawns year around with no obvious peak, while the latter has a summer peak. The Ocean Acre Sternoptychidae appear to partition their resources partly by vertical segregation and partly by differences in feeding selectivity and spawning time.

Introduction

The Sternoptychidae includes the true marine hatchetfishes (*Argyropelecus* and *Sternoptyx* in the Ocean Acre), and Weitzman (1974) in his reclassification of stomiiform fishes included a number of related species, of which the monotypic species *Maurolicus muelleri* and *Valenciennellus tripunctulatus* are present in the Ocean Acre collections. The family was the third most abundant in the Ocean Acre area, after the Gonostomatidae and Myctophidae. This agrees with Beebe's findings based on numbers of specimens caught in his eight-mile cylinder near Bermuda (Beebe,

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1937). We record more than 6800 specimens distributed among 7 species in 4 genera. Table 4 shows for each species (1) the total number of specimens taken on all 14 cruises, (2) the number taken on the paired seasonal cruises, (3) the number taken in discrete-depth samples during the paired seasonal cruises, and (4) the number taken in noncrepuscular discrete-depth samples during the paired seasonal cruises. The last represents our primary data base. Rank order of seasonal abundance of the species is given in Table 5.

Methods

Methods of analysis, definition of terms, and abbreviations are given in the introductory paper in this volume. A few observations particularly applicable to this study are provided here.

RELATIVE ABUNDANCE.—Each species was categorized as "abundant," "common," "uncommon" or "rare" in the study area, using the abundance criteria of Karnella (this volume). Categories are based on maximum abundance in noncrepuscular discrete-depth samples in any given season, and do not necessarily reflect a given species' overall abundance in all seasons. Abundant species (*Argyropelecus hemigymnus* and *Sternoptyx diaphana*) had a maximum seasonal abundance of 60–85 specimens per hour and were represented by a total of 2728 and 2870 specimens, respectively, for all 14 cruises combined. The single common species, *A. aculeatus*, had a maximum seasonal abundance of 20 specimens per hour and was represented by 857 specimens. The only uncommon species, *Valenciennellus tripunctulatus*, had a maximum seasonal abundance of 7 specimens per hour with a total count of 380 specimens. Rare species (*A. affinis, S. pseudobscura*, and *Maurolicus muelleri*) were completely absent from noncrepuscular discrete-depth samples and were represented by 1–4 specimens.

LIFE HISTORY STAGES.—Postlarvae differ markedly from later stages in body proportions, pigmentation, and photophore development. We made no attempt to determine their sex. Juveniles are similar to subadults and adults in form, pigmentation, and photophore development. Gonads are

TABLE 4.— Numbers of specimens of each species of Sternoptychidae caught in all samples during cruises 1–14, in all samples during the paired seasonal cruises (cruises 4 and 12, 10 and 14, 11 and 13), in all discrete-depth samples made during the paired seasonal cruises, and in all noncrepuscular discrete-depth samples made during the paired seasonal cruises.

| SPECIES | CRUISES 1-14 | PAIRED SEASONAL CRUISES | | |
	TOTAL	TOTAL	DISCRETE	NONCREPUSCULAR DISCRETE
Sternoptyx diaphana	2728	1237	613	541
S. pseudobscura	3	2	0	0
Argyropelecus hemigymnus	2870	1428	733	653
A. aculeatus	857	420	246	207
A. affinis	1	0	0	0
Valenciennellus tripunctulatus	380	230	108	78
Maurolicus muelleri	4	1	0	0
TOTALS	6843	3318	1700	1479

undeveloped and thread-like or flattened; sex could not be determined. Subadult females have small but easily recognizable ovaries with clear eggs <0.1 mm in diameter. Adult females have greatly enlarged ovaries with opaque eggs, mostly larger than about 0.3 mm in diameter. Subadult males have small but distinctly recognizable testes with cross striations evident. Although the testes of adult males usually were larger and more cylindrical (less flattened) than those of subadults, the distinction between the two was often subtle, and in most species these stages were determined, in part, by comparing their standard lengths with those of subadult and adult females, which are much easier to define. As noted in the species accounts, large "subadults" may actually be postspawning adults whose gonads are undergoing a second (or third) maturation.

TABLE 5.—Rank of each species of Sternoptychidae at each season. Rank is based upon the sum of day or night abundances, whichever is greater, for each of the stages.

SPECIES	WINTER	SPRING	SUMMER
Sternoptyx diaphana	1	1	2
Argyropelecus hemigymnus	2	2	1
A. aculeatus	3	3	3
Valenciennellus tripunctulatus	4	4	4

Species Accounts

The following accounts discuss, where possible, developmental stages, reproductive cycle, seasonal abundance, sex ratios, vertical distribution, patchiness, and night-to-day ratios of the seven species of sternoptychids taken during the study. For the abundant or common species, there were enough data to perform detailed analyses for most or all categories. For others, detailed analyses could be done only for certain categories or none.

Sternoptyx diaphana

Sternoptyx diaphana is broadly distributed in the Atlantic, Pacific, and Indian oceans. In terms of the Atlantic faunal regions proposed by Backus et al. (1977), the species is most abundant in the Gulf of Mexico, the North Atlantic subtropical, and the Atlantic tropical regions, but scattered catches have also been made in the North Atlantic temperate, the Mauritanian Upwelling, and the South Atlantic subtropical regions (Baird, 1971).

This is a medium-size sternoptychid, ranging from 5–36 mm SL in the Ocean Acre area, although specimens as large as 46 mm have been reported from the Gulf of Mexico (Schultz, 1961), and as large as 54 mm from the Pacific (Haig, 1955). *S. diaphana* was the most abundant sternoptychid in the Ocean Acre area in winter and late spring and second in abundance in late summer (Table 5). A total of 2728 specimens was captured in the 14 cruises; 1237 were taken during the seasonally paired cruises, including 613 in discrete-depth samples, with 541 of these from noncrepuscular tows (Table 4).

DEVELOPMENTAL STAGES.—Sex and/or developmental stage were determined for 2702 specimens of *S. diaphana*. Postlarvae were 5–9 mm (mean = 6.4 mm), and juveniles 7–15 mm (mean = 9.6 mm). It was not possible to determine sex in these two stages. Subadult females were 10–32 mm (mean = 16.6 mm); adults 20–36 mm (mean = 26.5 mm). Males were difficult to stage due to the gradual and subtle changes in the testes with maturation. On the basis of microscopic examination and sizes of subadult and adult females, an arbitrary demarcation between subadult and adult males was drawn between 18 and 19 mm SL. On this

basis, subadult males ranged from 11–18 mm (mean = 16.0 mm), and adults from 19–32 mm (mean = 23.8 mm). The largest females were 1–3 mm longer than the largest males. However, when length-frequencies of subadults and adults from all cruises are combined for each sex, the mean size is the same for both sexes (21.4 mm), and the median size of males (22.0 mm) is greater than that of females (20.0 mm). Probably there is little or no sexual dimorphism in size.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Sternoptyx diaphana* breeds throughout the year, with an extended peak in spawning from June through November or December. Both sexes appear to have a one-year life cycle, and most die after spawning. The June to December spawning peak is indicated by the increase in both absolute and relative abundance of adults from winter to late summer and by the relative abundance of postlarvae in late summer and winter (Table 6). The presence of some postlarvae and gravid adults in late spring confirms that some spawning also occurs at this time.

A one-year life cycle is suggested by the seasonal abundance of the various life history stages. The combined abundance of postlarvae, juveniles, subadults, and adults was highest in winter, intermediate in late summer, and lowest in late spring (Table 6). In late summer the catch per unit effort of ripe adults was at its highest level, and postlarvae were also relatively abundant. Both are indications of heavy spawning activity. Juveniles also were relatively abundant. These were only slightly longer (about 3 mm) than the postlarvae and represent growth of postlarvae that were spawned during the summer months. The percentage of subadults was at its lowest level in late summer, suggesting a maturation of most subadults into the adult stage.

By winter, the catch per unit effort of postlarvae had increased slightly, indicating that spawning had continued throughout the fall. Juveniles were very abundant, accounting for over half the catch. Since metamorphosis in the genus *Sternoptyx* is protracted (Ahlstrom, 1974), these probably represent continued growth of postlarvae that were produced in the late summer and early fall months. Subadults were also at their peak yearly abundance. They were

about 7 mm longer than the juveniles and probably represent continued growth of juveniles that were present during late summer and early fall. Adults, on the other hand, were relatively scarce from November through February (cruises 1, 5, 11, 13), and their decline from late summer is an indication of postspawning mortality. Two females (26 and 32 mm) taken in winter were staged as subadults on the basis of ovary appearance. These were well into the size range associated with adults and may have spawned previously and survived to approach a second spawning.

In late spring, total abundance was at its lowest level. Postlarvae were at their lowest yearly abundance. This was due to several factors, including a decrease in spawning activity, continued loss through natural mortality, and growth of these individuals into the juvenile stage. Relative to winter catches, the percentage of juveniles had decreased, while the percentage of subadults had increased. This trend is also apparent in data from March (cruise 2) and April/May (cruise 6). This indicates that individuals were moving from the juvenile to the subadult stage through continued growth. The percentage of adults increased from winter to late spring, presumably due to the maturation of winter subadults.

The one-year life span of this species can be illustrated and summarized by following the development of a particular cohort. For example, postlarvae produced in late summer would develop into juveniles by the late fall or winter, and these in turn would grow into subadults by the winter or early spring. Development would then continue through the spring and summer months until maturity was reached the following late summer or early fall. At this time they would spawn and subsequently die. Different cohorts of fish would follow a similar developmental schedule except that their year of life would begin and end in different seasons.

SEX RATIOS.—No significant difference between total numbers of males and females was indicated in any of the three seasons (Table 7). In actual numbers, more females than males were taken in winter (56:39) and more males than females in late spring (141:119) and late summer (88:70). Subadult females were significantly more numerous

TABLE 6.—Seasonal abundance and percent of total abundance (in parentheses) for *Sternoptyx diaphana* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TO
WINTER	8.0(9.4)	45.0(53.1)	21.1(24.9)	10.6(12.5)	84.7
LATE SPRING	1.8(4.0)	15.2(34.0)	16.1(36.0)	11.6(25.9)	44.7
LATE SUMMER	7.3(13.3)	21.7(39.6)	8.4(15.3)	17.4(31.8)	54.8

TABLE 7.—Numbers of each sex for each stage of *Sternoptyx diaphana* (AD = adult; F = female; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	SAD		AD		TOT	
	M	F	M	F	M	F
WINTER	13	52*	26	4*	39	56
LATE SPRING	77	88	64	31*	141	119
LATE SUMMER	14	44*	74	26*	88	70

than subadult males in both winter and late summer, and adult males significantly outnumbered adult females in all seasons. Although this reversal in sex ratios may be partly due to the somewhat arbitrary delineation between subadult and adult males, the data suggest that adult males outnumber adult females.

VERTICAL DISTRIBUTION.—The major concentration of *S. diaphana* is from 700–1000 m. Of the 541 discrete-depth noncrepuscular specimens captured during the paired cruises, 417 were caught between these depths, accounting for 77% of the specimens. Day and night distributions were similar during all three seasons, indicating that this species is a permanent, nonmigrating resident of these depths (Table 8).

In our sampling, *S. diaphana* has been captured in nets fished from the surface to 3500 m. The two specimens captured at the surface, both in late spring, were adults in poor condition, indicating that they may have been dead or dying. Beebe (1926) reported taking an *S. diaphana* at the surface off Bermuda, but commented that it was in very poor condition, being partially eaten by crabs. Günther (1887) also reported the capture of two specimens of *S. diaphana* at the surface near St. Thomas, Virgin Islands, but did not indicate their condition. It is unlikely that *S. diaphana* normally occurs in surface waters. Below 1000 m there were 10 discrete-depth captures. These probably were not the result of contamination from previous trawls, since in some cases the preceeding trawl was at a shallow depth where *S. diaphana* would not be expected. These captures probably represent some scattering of the species toward depths greater than 1000 m. Specimens were captured in open nets fished below 1550 m, but these probably were taken during the oblique portion of the tow as the net passed through their area of major concentration.

The 30 specimens taken in discrete-depth samples shallower than 400 m are considered contaminants from previous deeper tows, since in each case the tow capturing the specimens was immediately preceded by a tow to the depths where *S. diaphana* was normally taken in abundance. These shallow specimens include 1 postlarva, 6 juveniles, 8 subadults, and 14 adults. All were in samples from the upper 300 m, mostly at night (27 specimens), which is 100–300 m shallower than the next shallowest occurrence, and 300–400 m shallower than the major concentrations. Most (26 specimens) were taken in late spring (12) or late summer (14). If *S. diaphana* does occur in shallow water, it seems highly probable that such occurrences involve strays or unsound individuals.

Depth-size stratification exists in this species, with smaller individuals generally found shallower than large ones (Table 8). From 400–700 m 83 specimens were taken, the majority postlarvae and juveniles. Postlarvae were found primarily between 551 m and 750 m both day and night (Table 8). In winter, when postlarvae were most abundant, they

formed the major portion of the catch from 601 m to 650 m, with a few captures as deep as 800 m. In late spring and late summer, most postlarvae were captured from 601–750 m. Juveniles were found primarily between 701 m and 850 m, slightly deeper than the postlarvae (Table 8). In winter, juveniles were very abundant, and the great majority were caught at the 801–850 m interval. At other seasons of the year juveniles were caught at similar depths. Subadults and adults of both sexes were found in greatest numbers at all seasons between 801 m and 950 m (Table 8), where they constituted the largest portion of the catch. There was no apparent stratification of these two stages.

The vertical distribution of *S. diaphana*, based solely on nondiscrete data, was described by Baird (1971) as being primarily between 401 and 1200 m, with the major concentration occurring from 701–900 m. Discrete-depth data from two areas of the eastern Atlantic indicate a depth range of 551–1000 m day and night (Badcock, 1970), and 501–900 m by day, 601–900 m at night (Badcock and Merrett, 1976). Thus our data are in close agreement with the previous literature.

PATCHINESS.—Patchiness of distribution does not appear to characterize *S. diaphana*. Three significant CD's were found. In winter, clumping was indicated at 650 m during the day and at 600 m at night, at which depths postlarvae were taken in greatest abundance. In late spring, there was clumping at 800 m during the day, involving juveniles, subadults, and adults in descending order of abundance; no clumping at night was indicated. In late summer, there was no indication of clumping. These data suggest that occasional aggregations may occur, but that distributions generally are random. Indications of clumping at the surface and at 150 m at night in late spring were disregarded, because they were believed to be based on either contaminants or dying specimens.

Beebe (1934) stated that sternoptychids (not necessarily *Sternoptyx*) observed from the bathysphere usually swam close together in groups of four or five, with occasional schools comprising up to 20 individuals. If such schooling characterizes *Sternoptyx*, then the schools may be presumed to be randomly distributed.

Barham (1970) observed that other sternoptychids were sometimes motionless and oriented horizontally, but that they went into a rapid, usually downward flight as the submersible approached. This suggests that larger sternoptychids may avoid the approaching net, so that, if aggregations occur, they are not adequately sampled.

NIGHT:DAY CATCH RATIOS.—The ratios of total night to day discrete-depth catch rates were slightly different from 1:1 in each season (Table 9). In winter and late spring, slightly more fish per unit effort were caught during the day, while in late summer slightly more fish per unit effort were caught at night. For each life history stage, however, there were considerable differences. Postlarvae were more

TABLE 8.—Vertical distribution by 50-m intervals of *Sternoptyx diaphana* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch; depth intervals are omitted when they are outside of the main range and no specimens were caught).

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
51- 100		<1			<1	1	12.0	12																
151- 200		<1			<1	1	11.0	11		<1			<1	1	13.0	13								
201- 250		<1			<1	*				<1			<1	*										
401- 450	<1				<1	*			<1				<1	*										
451- 500	<1				<1	1	6.0	6	<1				<1	1	7.0	7		<1			<1	2	11.5	11-12
501- 550									<1	<1			<1	*				<1	<1	1	2	6	20.0	14-21
551- 600										<1			<1	1	13.0	13								
601- 650	5	1	<1		6	18	6.7	5-9		<1			<1	1	18.0	18	<1				<1	2	5.5	5-6
651- 700	2	3	<1		6	*			1	<1			2	12	7.0	6-9	<1	4			4	*		
701- 750		6			6	14	8.4	7-14	<1	3	2	<1	6	*			<1	7			8	24	8.5	6-10
751- 800		10	<1		11	*				5	4	2	10	61	13.3	7-28		3	1	<1	5	15	12.4	7-24
801- 850		15	2		17	51	11.4	8-22		3	4	3	9	*				3	2	3	8	23	18.5	11-27
851- 900		8	<1		9	*				<1	4	4	8	25	19.5	12-28		2	2	3	6	*		
901- 950	-	-	-	-	-					<1	2	2	5	*					1	2	3	10	22.8	16-30
951-1000	-	-	-	-	-					<1			<1	3	12.7	8-20			<1	1	2	*		
1001-1050										<1		<1	<1	*										
1051-1100	-	-	-	-	-													<1			<1	*		
1101-1150	-	-	-	-	-													<1			<1	1	12.0	12
1151-1200	-	-	-	-	-													<1			1	1	8.0	8
1201-1250										<1			<1	1	10.0	10								
1251-1300										<1			<1	*										
1301-1350	-	-	-	-	-				-	-	-	-	-					<1			1	1	10.0	10
1351-1400	-	-	-	-	-				-	-	-	-	-					<1			<1	*		
1401-1450	-	-	-	-	-				-	-	-	-	-					<1	<1		<1	*		
1451-1500		<1			<1	*			-	-	-	-	-							1	1	2	19.5	16-23
1501-1550		<1			<1	1	11.0	11																
TOTALS	8	45	3	0	59	87			2	14	16	12	44	106			2	21	8	13	42	87		
NIGHT																								
SURF												<1	<1	2	29.0	26-32								
51- 100									<1	<1	<1		<1	3	18.0	11-27								
101- 150										1	<1		2	5	18.6	15-27				2	2	5	24.6	20-26
151- 200	<1	<1			<1	2	11.3	6-18		<1			<1	1	9.0	9								
251- 300	-	-	-	-	-				-	-	-	-	-				<1	1	2		2	9	19.8	11-26
301- 350									-	-	-	-	-											
401- 450	<1	<1			1	3	8.3	6-11									<1				<1	1	7.0	7
451- 500									<1			<1	<1	2	17.0	8-26								
551- 600	5	<1			6	13	6.9	6-9		<1			<1	2	13.5	11-16		<1			<1	*		
601- 650										<1			<1	*			1				1	1	7.0	7
651- 700	<1	<1	<1		2	*			-	-	-	-	-				3	6			9	17	7.2	6-10
701- 750	<1	1	1		3	10	10.5	6-13		5	<1		6	*			5	5			9	18	6.9	5-9
751- 800	1	10	<1	<1	12	36	10.3	7-22		10	2		11	18	10.5	7-19		5	<1		5	16	11.6	8-17
801- 850			7	2	9	9	19.0	16-23			2	1	3	5	18.4	13-27		3	2	3	8	*		
851- 900			7	5	12	25	21.2	15-35		<1	<1		1	*				<1	4	6	10	31	21.2	8-30
901- 950			4	3	6	*				<1			<1	*					1	4	5	16	20.9	7-28
951-1000				1	1	1	24.0	24		<1			<1	1	29.0	29				<1	1	2	26.5	24-29
1001-1050	<1				<1	1	10.0	10		<1			<1	*						<1	<1	*		
1051-1100	<1				<1	*																		
1101-1150	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1151-1200	-	-	-	-	-					<1			<1	*			-	-	-	-	-			
1201-1250										<1			<1	1	16.0	16								
1251-1300										<1			<1	*						<1	<1	1	21.0	21
1301-1350	-	-	-	-	-				-	-	-	-	-							<1	<1	*		
TOTALS	8	14	21	11	54	100			0	15	8	3	26	40			7	22	8	17	54	117		

TABLE 9.—Seasonal night to day catch ratios of *Sternoptyx diaphana* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; asterisk = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.0:1	0.3:1	6.7:1	*	0.9:1
LATE SPRING	*	1.1:1	0.5:1	0.3:1	0.6:1
LATE SUMMER	3.5:1	1.0:1	1.0:1	1.4:1	1.3:1

abundant in night samples in late summer, slightly more abundant in day samples in late spring, and showed equal abundance in winter. Juveniles were more abundant in day samples in winter and in night samples in late spring, but had a 1:1 ratio in late summer. Subadults and adults reversed the juvenile trends in winter and late spring but also approached a 1:1 ratio in late summer.

No obvious explanation is evocable for the pattern of ratios. There is no correlation with patchiness (i.e., significant CD's, and differential diel net avoidance seems improbable. Either sampling was inadequate to indicate night:day equality, or avoidance behavior changes from season to season and according to life-history stage.

Sternoptyx pseudobscura

This is the largest member of the genus, often exceeding 55 mm SL (Baird, 1971). *S. pseudobscura* was rare in the Ocean Acre area and was completely absent from discrete-depth samples.

Three specimens were taken in open nets, all in late summer. A 36 mm male was taken in an Engel trawl towed at 0–1025 m. The remaining two specimens were IKMT captures. One, a 14 mm juvenile, was captured in a tow from 0–1003 m, while the other, a juvenile 16 mm SL, was taken at 0–1435 m.

Both the rarity and capture depths of *S. pseudobscura* in our study area agree with the findings of Badcock and Baird (1980), who showed that this species is uncommon in the western North Atlantic, where *S. diaphana* is abundant, and that *S. pseudobscura* is consistently deeper wherever the two species are sympatric.

Argyropelecus hemigymnus

Argyropelecus hemigymnus is broadly distributed in the Atlantic, Pacific, and Indian oceans. It is particularly abundant in the Gulf of Mexico, the eastern and western North Atlantic, and the Caribbean Sea (Baird, 1971). This distribution corresponds to the North Atlantic temperate, North Atlantic subtropical, Gulf of Mexico, and Atlantic tropical faunal regions proposed by Backus et al. (1977).

This is a medium-size sternoptychid, ranging from 6 to 37 mm SL in the Ocean Acre area. Our largest specimens are near the maximum size recorded for the species, which rarely exceeds 38 mm (Baird, 1971). *A. hemigymnus* was the most abundant sternoptychid in the Ocean Acre area in late summer and was second in abundance in winter and late spring (Table 5). A total of 2870 specimens was captured in the 14 cruises; 1428 were taken during the seasonally paired cruises, including 733 in discrete-depth samples, with 653 of these from noncrepuscular tows (Table 4).

DEVELOPMENTAL STAGES.—Sex and/or developmental stage were determined for 2831 specimens of *A. hemigymnus*. Postlarvae were 6–9 mm (mean = 7.5 mm) and juveniles 7–15 mm (mean = 10.0 mm). It was not possible to determine sex in these two stages. Subadult females were 10–29 mm (mean = 16.5 mm) and adults 21–33 mm (mean = 26.1 mm). Males were difficult to stage due to the gradual and subtle changes in the testes with maturation. On the basis of microscopic examination and sizes of subadult and adult females, an arbitrary demarcation between subadult and adult males was drawn between 14 and 15 mm SL. On this basis, subadult males were 10–14 mm (mean = 13.0 mm) and adults 15–25 mm (mean = 17.0 mm). The largest females were 5–8 mm longer than the largest males in the seasonally paired cruises. In addition, mean female size for the paired cruises (21.3 mm) was about 5.6 mm longer than mean male size for these cruises (15.7 mm). Thus there is a sexual dimorphism in size, with females being larger.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Argyropelecus hemigymnus* appears to breed continuously throughout the year, with an extended peak in spawning from April through September. This is in agreement with Jespersen (1915) and to some extent with Sanzo (1931), who stated that the breeding period lasts throughout the year in the Mediterranean. Apparently both sexes reach maturity at about one year of age, with most adults dying shortly after spawning. In our collection, several females that were staged as subadults due to the condition of their ovaries were well into the size range usually associated with adults. These specimens may have spawned previously and were approaching a second spawning.

The onset of peak spawning is indicated by an abundance of ripe adults in April (cruise 6). The extended nature of this peak period is indicated by the relative abundance of postlarvae, juveniles, and small subadults in late summer (Table 10). Most spawning seems to be completed by fall since very few adults were taken in November (cruise 1) and December (cruise 5). The presence of some adults and small, young individuals in each season suggests that some spawning occurs year round.

In late summer all life history stages were abundant (Table 10). Postlarvae were more numerous than in any other season of the year, accounting for 27.1% of the catch. They had an average SL of 7.5 mm. Although their age at

TABLE 10.—Seasonal abundance and percent of total abundance (in parentheses) for *Argyropelecus hemigymnus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.6(1.5)	5.8(14.2)	26.7(65.4)	7.7(18.9)	40.8
LATE SPRING	1.5(5.1)	16.5(55.7)	3.5(11.8)	8.1(27.4)	29.6
LATE SUMMER	16.1(27.1)	19.3(32.4)	15.9(26.7)	8.2(13.8)	59.5

this time is difficult to estimate, the fact that members of the genus *Argyropelecus* undergo a protracted metamorphosis (Ahlstrom, 1974) indicates that they were probably spawned several weeks prior to capture. Juveniles, too, were more abundant in late summer than in any other season. They were only slightly larger than postlarvae, averaging 9.9 mm, and were probably about 6–8 weeks old at time of capture. Subadults were also small, averaging 13.6 mm. Presumably these individuals were spawned sometime in the spring and would have matured and spawned the following spring. The abundance of small individuals in late summer clearly indicates that spawning activity had been heavy in the previous months, and the presence of some adults (13.8% of the catch) indicates that some spawning continues into the fall. The scarcity of adults in November and December suggests postspawning mortality of most adults.

By winter the composition of the catch had changed considerably. Subadults were by far the most abundant stage (Table 10). These represent growth of the very abundant late summer postlarvae and juveniles. Presumably they would have continued to develop over the winter and early spring and probably would have spawned in late spring or summer. The growth of these abundant winter subadults would account for the abundance of adults seen in April (cruise 6). During winter, postlarvae and juveniles were at their lowest seasonal abundance (Table 10). Postlarvae were especially scarce, accounting for only 1.5% of the catch, but their presence indicates that some spawning occurs in the winter months, and the presence of juveniles suggests some late fall–early winter spawning. While the abundance of adults was only slightly lower than in other seasons, they were relatively small, averaging only 19.7 mm. These individuals probably were spawned in the preceeding late spring or summer and would have reached sexual maturity the following winter or spring.

In late spring, small juveniles predominated, accounting for 55.7% of the catch (Table 10). Their small size (mean 10.0 mm) indicates that they were spawned six to eight weeks prior to capture, probably at the beginning of the peak spawning season in late April or early May. Postlarvae,

only slightly smaller than the juveniles, probably were spawned several weeks prior to capture. Subadults were at their lowest seasonal abundance. These probably represent continued growth of winter juveniles, and they would have matured and spawned in the upcoming late summer months. The decline in subadults from winter to late spring is almost certainly due to development of winter subadults into late spring adults. Following this logic, a high abundance of late spring adults would be expected, and in fact adults accounted for 27.4% of the catch. Catch per unit effort, however, was not greatly different than in other seasons. This is probably due to loss of adults through postspawning mortality.

Seasonal changes in abundance of the different life history stages indicate a one-year life history for most *A. hemigymnus*. For example, postlarvae spawned in late summer would reach the juvenile stage by early fall and the subadult stage by the winter months. These would continue to develop over the winter, spring, and early summer months, reaching sexual maturity and spawning in late summer. Most individuals would then die.

SEX RATIOS.—No significant difference between total numbers of males and females was indicated at any of the three seasons (Table 11). In actual numbers, more males than females were captured in winter (164:137) and late spring (109:93), and more females than males in late summer (130:97). Subadult females were significantly more numerous than subadult males in all seasons, and adult males significantly outnumbered adult females in all seasons. Although these data indicate that sex ratios within stages are different, they must be viewed with caution, due to the somewhat arbitrary delineation between subadult and adult males. Furthermore, all subadult females were probably recognized as such, while some subadult males may have been staged as juveniles due to the similarity between very small testes and immature gonads. Probably sex ratios are not different than 1:1.

VERTICAL DISTRIBUTION.—In the seasonally paired cruises, *A. hemigymnus* was caught from <50–1550 m during the day and from <50–1250 m at night (Table 12). Of the

TABLE 11.—Numbers of each sex for each stage of *Argyropelecus hemigymnus* (AD = adult; F = female; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	SAD		AD		TOT	
	M	F	M	F	M	F
WINTER	81	127	83	10*	164	137
LATE SPRING	29	65*	80	28*	109	93
LATE SUMMER	34	116*	63	14*	97	130

TABLE 12.—Vertical distribution by 50-m intervals of *Argyropelecus hemigymnus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER — CATCH RATE — PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SPRING — CATCH RATE — PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SUMMER — CATCH RATE — PL	JUV	SA	AD	TOT	N	SL X	RANGE
DAY																								
1- 50																				<1	<1	1	20.0	20
201- 250		<1		<1		*			-	-	-	-	-				1			1	2	2	10.5	9-12
251- 300		1			1	1	14.0	14																
301- 350	<1				<1	1	11.0	11		<1			<1	1	15.0	15								
351- 400	<1		<1	<1	2	5	15.6	6-22	<1	7	<1		9	50	9.8	7-16								
401- 450	<1	2	3	<1	5	*			<1	5	<1	<1	6	*			1	<1			2	6	7.7	6-10
451- 500		3	14	2	18	35	14.1	9-24		3		1	4	12	11.3	8-27	13	7	4	<1	24	121	9.4	6-16
501- 550									2		2		3	*			<1	3	3	2	8	33	14.2	8-20
551- 600											2		2	6	22.2	18-26		4	7	2	13	54	14.1	8-21
601- 650			<1	<1	<1	2	17.0	17	<1		<1	2	3	10	22.8	9-33	<1	<1		2	2	7	20.6	6-29
651- 700	<1	<1	<1		1	*				<1	<1		<1	7	17.7	12-27	<1	<1	<1	<1	1	*		
701- 750	<1				<1	1	10.0	10		<1	<1		<1	*						<1	<1	1	11.0	11
751- 800	<1				<1	*																		
801- 850	-	-	-	-	-				-	-	-	-	-						<1	<1	1	3	22.7	18-23
851- 900	-	-	-	-	-				-	-	-	-	-						<1	<1	<1	*		
901- 950	-	-	-	-	-				-	-	-	-	-					<1			<1	1	10.0	10
951-1000		<1			<1	*												<1			<1	*		
1001-1050		<1			1	2	13.0	13	-	-	-	-	-											
1051-1100		<1			<1	*											-	-	-	-	-			
1101-1150	-	-	-	-	-																			
1151-1200	-	-	-	-	-																			
1201-1250											<1		<1	1	17.0	17								
1251-1300											<1		<1	*										
1301-1350	-	-	-	-	-				-	-	-	-	-											
1351-1400	-	-	-	-	-												-	-	-	-	-			
1401-1450	-	-	-	-	-				-	-	-	-	-											
1451-1500		<1	<1		1	*			-	-	-	-	-											
1501-1550		<1	<1		1	4	15.0	15																
TOTALS	<1	6	21	5	32	51			2	17	3	8	29	87			16	16	16	8	56	229		
NIGHT																								
1- 50										1			1	1	11.0	11								
51- 100																		<1			<1	1	13.0	13
101- 150																		<1		<1	<1	2	15.5	11-20
251- 300		<1	<1		1	*											<1				<1	1	7.0	7
301- 350			1	1	2	4	13.1	10-16		3	<1		3	*			<1	<1			<1	3	8.3	7-10
351- 400	<1	<1	<1	1	3	10	16.2	6-24		5	<1		6	19	10.6	8-14	<1				1	1	8.5	7-10
401- 450	<1	3	4	1	9	28	12.0	6-22	<1			<1	2		12.5	7-18	4	3		<1	7	21	7.9	6-16
451- 500		<1	4	<1	5	14	16.1	9-24	4	1	4		10	30	15.2	8-28	2	12	1	2	17	84	10.2	7-32
501- 550	<1	3	2		5	15	16.2	7-22		<1			<1	2	18.0	13-23		1	5		6	6	14.7	10-20
551- 600											<1	<1	<1	3	19.1	12-24		<1		2	2	*		
601- 650											<1	<1	<1	*						3	3	3	21.3	17-27
651- 700	-	-	-	-	-				-	-	-	-	-					1		<1	2	3	12.7	9-19
701- 750										<1			<1	*					<1	<1	1	2	11.5	9-14
751- 800											<1		<1	1	29.0	29								
801- 850																			<1	<1	<1	*		
851- 900	-	-	-	-	-														<1	<1	1	3	13.3	10-16
901- 950		3			3	*			-	-	-	-	-					<1			<1	1	16.0	16
951-1000		6			6	6	16.0	12-21									<1	<1	<1		2	5	14.0	7-22
1001-1050		3	<1		3	6	15.8	12-19	-	-	-	-	-				<1		<1	<1	1	*		
1051-1100		2	<1		2	*											-	-	-	-	-			
1101-1150	-	-	-	-	-												-	-	-	-	-			
1151-1200	-	-	-	-	-						<1		<1	*			-	-	-	-	-			
1201-1250	-	-	-	-	-						<1		<1	1	14.0	14								
1251-1300	-	-	-	-	-						<1		<1	*										
TOTALS	<1	5	27	8	40	83			<1	13	4	6	24	59			8	19	8	8	44	136		

367 discrete-depth, noncrepuscular specimens captured during the day, 322 (87.7%) were from 351–600 m. Of the remaining 45, 6 were taken shallower than 350 m. These included 1 late summer postlarva, 1 winter juvenile, 3 subadults (1 in each season), and 1 late summer adult. Probably all of these were contaminants from previous tows. Twenty-eight specimens representing all life-history stages and seasons were taken from 601–750 m during the day. These captures indicate that some specimens occupy slightly greater depths. Below 750 m, 11 specimens were captured. These included juveniles (winter and late summer), subadults (winter and late summer), and adults (all three seasons). All of these were considered contaminants, since in each case the previous tow had fished at the preferred depths of *A. hemigymnus*.

Of the 278 discrete-depth specimens captured at night, 232 (83.5%) were caught from 351–550 m (Table 12). Twelve of the remaining 46 specimens were taken shallower than 350 m. Of these, 4 were shallower than 150 m and probably represent contaminants from previous tows. The remaining 8 specimens came from depths of 251–350 m, and their presence indicates some upward scattering of the species to slightly shallower depths. Below 550 m, 34 specimens were captured. Twenty-three of these were taken below 750 m and were probably contaminants. The remaining 11 were captured from 551–750 m, and these probably represent a scattering of individuals to slightly greater depths.

The vertical distribution of *A. hemigymnus* in the Ocean Acre area is similar to that in other localities. Goodyear et al. (1972) gave the daytime depth range of Mediterranean specimens as 150–800 m, with peak concentrations from 300–500 m. Nighttime ranges were from 70–600 m, with peak concentrations from 235–600 m. Badcock (1970) stated that near the Canary Islands the species is concentrated at 450–650 m during the day and 300–450 m at night. Baird (1971), reporting on a variety of locations, gave daytime depth ranges from 200–700 m, with peak concentrations at 350–550 m. Night depth range was given as between 100 and 650 m, with the peak concentration from 150–380 m. In the eastern North Atlantic, Badcock and Merrett (1976) found that this species was distributed from 300–600 m during the day and from 200–600 m at night.

Although the daytime depth distributions of all life-history stages overlap broadly, there is some indication of stage stratification during the day in this species, with older and larger individuals occurring slightly deeper. Similar observations have been made by Jesperson and Taaning (1926), Badcock (1970), Goodyear et al. (1972), and Badcock and Merrett (1976). There is also an indication that some life-history stages are found deeper in late summer and shallower in winter. In late summer, when postlarvae were most abundant, they were found from 401–700 m, but were abundant only from 451–500 m (Table 12). The paucity of

postlarvae taken during the winter and late spring prevents accurate descriptions of their preferred depths during these seasons, but they were generally 50–100 m shallower than in late summer. Juveniles occurred over a wider range of depths than postlarvae in all seasons, and the depths at which they were abundant were generally slightly deeper. In winter, juveniles were found from 301–500 m and were abundant at 401–500 m. In late spring, juveniles were quite abundant from 351–550 m, but seemed to be concentrated at 351–450 m. These depths (351–450 m) overlap those of postlarvae. In late summer, the range of depths inhabited by juveniles during the day was quite wide (401–700 m), but juveniles were concentrated from 451–600 m. This is approximately 100–150 m deeper than their winter distribution and 50–100 m deeper than their late spring distribution. Although the maximum abundance of both postlarvae and juveniles occurred at 451–500 m in late summer, the abundance of juveniles and the scarcity of postlarvae from 501–600 m indicates that juveniles are distributed slightly deeper than postlarvae. Subadults were captured from 351–700 m during the day in winter, but their maximum abundance was at 451–500 m. During this season subadults and juveniles were abundant at similar depths. While subadults were captured from 301–750 m in late spring, too few specimens were taken to allow speculation on their preferred daytime depths. In late summer, subadults were captured from 451–750 m. The shallow end of this range is about 100 m deeper than the range of other seasons, indicating that subadults occupy deeper depths during late summer. This is further substantiated by their relatively deep strata of maximum abundance (451–600 m). Although both juveniles and subadults were abundant within this range, the maximum catch rate for subadults was 150–200 m deeper than that of juveniles. Adults were captured from 351–700 m during the day in winter, with the maximum rate at 451–500 m. Both juveniles and subadults were also abundant at this depth. In late spring adults occupied a deeper range (401–750 m), and were abundant from 501–650 m. This is 50–150 m deeper than their preferred winter depths and deeper than the preferred depths of the other life-history stages present at this time. The late summer depth distribution of adults was similar to that of late spring. Once again there was a tendency for adults to be found deeper than the other life-history stages.

Nighttime depth distributions of the different life-history stages overlap broadly in all seasons (Table 12). There is a tendency for all life-history stages, with the possible exception of postlarvae, to be found deeper in late summer, and also a tendency for larger individuals to be found deeper than small individuals. Postlarvae were taken from 351–450 m in winter and from 401–450 m in late spring. Although they were found slightly deeper in late summer (401–500 m), their maximum catch rate was at 401–450 m. Thus it appears that postlarvae occupy about the same

depths year-round. Juveniles were taken from 351–550 m in winter, with the maximum catch rate at 401–450 m. Their range in late spring was somewhat shallower (301–500 m), and individuals were abundant throughout this range. In late summer juveniles were widely distributed from 351–900 m, but the maximum catch rate was at 451–500 m. This was 50–100 m deeper than depths of maximum catch rate in both late spring and winter. Subadults were taken from 251–550 m in winter. Within this range they were abundant from 401–550 m. A slightly deeper range of depths was occupied in late spring (301–650 m), but the preferred depths (451–500 m) were similar to those of winter. In late summer subadults were taken from 451–1050 m. This range was deeper than in other seasons, and the depths of maximum abundance (501–550) were about 50 m deeper as well. The nighttime depth ranges inhabited by adults in winter (251–550 m), late spring (401–750 m), and late summer (401–700 m) all overlapped broadly (Table 12). Depths of maximum abundance, however, changed seasonally. In winter, adults were abundant from 501–550 m, which was 50–100 m deeper than in late spring. In late summer, adults were abundant from 451–650 m, which was deeper than in other seasons.

All life-history stages of *A. hemigymnus* appear to undergo slight diel vertical migrations (Table 12). In late summer, when postlarvae were abundant, the range of depths inhabited by this stage was shallower at night. This, along with the observation that the depth of maximum abundance was about 50 m shallower at night, strongly indicates that postlarvae undergo a short diel vertical migration. Similar day-night differences were seen among juveniles. In each season the range of depths inhabited at night was shallower than the daytime range. Furthermore, the depths of maximum abundance were 50–100 m shallower at night, indicating a diel vertical migration. In late summer and winter when subadults were abundant, the depths of maximum abundance at night were 50–100 m shallower than during the day. These day-night differences indicate that subadults undergo a diel vertical migration. Among adults, the range of depths inhabited during night and day did not change significantly in any season. Depths of maximum abundance, however, were 50–150 m shallower at night in late spring and late summer, indicating that adults undergo a diel vertical migration in these seasons. This pattern was not evident in winter.

PATCHINESS.—*Argyropelecus hemigymnus* appears to be a patchily distributed species both day and night. Although these patches, or clumps, typically involve more than one life-history stage, one stage usually dominates.

At night, significant CD values were seen in late spring (351–400 m) and in late summer (401–450, 451–500 m). The late spring clumping was dominated by juveniles, but some subadults were also present. In late summer the 401–450 m interval was dominated by postlarvae and juveniles

but contained some adults. The 451–500 m interval at this time was strongly dominated by juveniles, although some members of all other life-history stages were present. The nighttime patchiness is within the preferred nighttime range of depths.

During the day, significant CD values were seen in late spring (351–400 m), late summer (451–500, 501–550, 551–600 m), and winter (351–400, 451–500 m). The late spring depth interval contained a few postlarvae and subadults but was composed primarily of juveniles. In late summer there was a correlation between the depth of patchiness and the dominant life-history stage. The shallowest depth interval (451–500 m) contained mostly postlarvae; the next deepest interval (501–550 m) was composed mainly of both juveniles and subadults, while the deepest interval (551–600 m) was dominated by subadults. In winter, patchiness was indicated at two depths during the day (351–400, 451–500 m). The shallower of these contained all life-history stages except juveniles. The deeper contained all life-history stages except postlarvae and was strongly dominated by subadults. Each of the daytime intervals was within the preferred daytime depth distribution of this species.

While adults were minor contributors to several of the depths where patchiness was indicated, none of these depths were dominated by adults. This may indicate that adults do not aggregate to the same extent as younger individuals. An alternative explanation would be that adults, because of their larger size, are better able to avoid the approaching net.

NIGHT:DAY CATCH RATIOS.—The ratios of total night to day discrete-depth catch rates were slightly different from 1:1 in each season (Table 13). In winter, slightly more fish were caught per unit effort at night, but in late spring and late summer this trend was reversed. The greatest differences in catch ratios were seen among postlarvae in late spring and late summer, when day catches were much higher. This apparent difference is difficult to explain, since in postlarvae no diel difference in patchiness was indicated. It also seems improbable that net avoidance, if it occurs at all in these small individuals, would change from day to night. Among juveniles the night:day catch ratios were not greatly different. This was also the case with subadults except in late summer when nearly twice as many fish per

TABLE 13.—Seasonal night to day catch ratios of *Argyropelecus hemigymnus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.0:1	0.8:1	1.3:1	1.6:1	1.2:1
LATE SPRING	0.3:1	0.8:1	1.1:1	0.8:1	0.8:1
LATE SUMMER	0.5:1	1.2:1	0.5:1	1.0:1	0.8:1

unit effort were taken during the day. This discrepancy may be due to patchiness, since subadults appear to occur in patches during the day but not at night. Among adults, the only real difference in catch ratios was seen in winter, when more fish per unit effort were taken at night. Since adults apparently are not patchily distributed, this difference is difficult to explain.

Although no pattern emerges from these night:day ratios, Badcock (1970) and Badcock and Merrett (1976) have found that catch rates of this species generally were lower at night. They suggested that this may have been due to increased activity at night, presumably associated with feeding, which occurs from late afternoon through early night (Merrett and Roe, 1974).

Argyropelecus aculeatus

Argyropelecus aculeatus is broadly distributed in the Atlantic, Pacific, and Indian oceans. It is particularly abundant in the Caribbean Sea, the Gulf of Mexico, the western North Atlantic, and the eastern North Atlantic along the North African coast (Baird, 1971). These areas of abundance correspond to the Gulf of Mexico, North Atlantic subtropical, and Mauritanian Upwelling faunal regions proposed by Backus et al. (1977).

This is a large sternoptychid, ranging from 6–83 mm SL in the Ocean Acre area. Our largest specimens are among the largest recorded. *Argyropelecus aculeatus* was the third most abundant sternoptychid in the Ocean Acre area in all seasons (Table 5). A total of 857 specimens was captured in the 14 cruises; 420 were taken during the seasonally paired cruises, including 246 in discrete-depth samples, with 207 of these from noncrepuscular tows (Table 4).

DEVELOPMENTAL STAGES.—Sex and/or developmental stage were determined for 841 specimens of *A. aculeatus*. Postlarvae were 6–11 mm (mean = 7.5 mm) and juveniles 7–21 mm (mean = 11.4 mm). It was not possible to determine sex in these two stages. Subadult females were 14–43 mm (mean = 20.5 mm) and adult females 52–75 mm (mean = 60.1 mm). As with other sternoptychid species, males were difficult to stage due to gradual and subtle changes in the testes with maturation. On the basis of microscopic examination and sizes of subadult and adult females, an arbitrary demarcation between subadult and adult males was made between 35 and 36 mm SL. On this basis, subadult males were 14–35 mm (mean = 22.3 mm) and adults from 36–60 mm (mean = 48.7 mm). Although the mean length of all males from the seasonally paired cruises (30.5 mm) was greater than the mean length of all females (25.1 mm), the largest females were about 20 mm longer than the largest males. This suggests a sexual dimorphism, with some females growing to a larger size.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive cycle and seasonal abundance of sub-

adults and adults were difficult to estimate due to the few large specimens taken with the IKMT. On two late summer cruises (7 and 12), much larger Engel trawls were employed. While these nets effectively sampled larger specimens, the seasonal coverage was limited. Despite this limitation, a proposed reproductive cycle can be formulated based upon the seasonal abundance of the early life-history stages.

The presence of some postlarvae and ripe adults in all seasons (Table 14) indicates that *A. aculeatus* breeds continuously throughout the year. An extended peak in spawning from June or July through late fall is indicated by the relative abundance of small individuals in late summer and winter. This species has at least a two-year life cycle, reaching approximately 20–40 mm SL at the end of the first year. At this time a small portion of the year class may become sexually mature. This is indicated by a 34 mm female that was in breeding condition in August. The majority of specimens, however, probably do not reach sexual maturity until the end of their second year, when most spawn and die. Based on IKMT data, overall abundance was highest in winter, intermediate in late summer, and lowest in late spring (Table 14).

In late summer postlarvae accounted for 34% of the catch and juveniles for 47%. The small size of these individuals (mean length less than 11 mm) indicates that they were spawned over the summer months. The relative abundance of these small individuals (Table 14), particularly postlarvae, clearly indicates that spawning is heavy at this time. Subadults were also relatively abundant, accounting for 12% of the IKMT catch and 17% of the EMT catch. In the IKMT samples subadults averaged 22.4 mm, while in the EMT samples the average length was 39 mm. In the EMT samples, 7 females (57–71 mm) were classified as subadults based on the condition of their ovaries. Their relatively large size, however, suggests that these were actually adults in postspawning condition that were approaching a second spawning. It is postulated that subadults captured in late summer were about one year old, having been spawned the preceeding summer or fall. Presumably these would constitute the major portion of the breeding population the following year. Adults accounted for 7% of the IKMT catch

TABLE 14.—Seasonal abundance and percent of total abundance (in parentheses) for *Argyropelecus aculeatus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.6(3.0)	16.5(81.3)	1.0(4.9)	2.2(10.8	20.3
LATE SPRING	0.5(4.6)	8.2(75.2)	2.1(19.3)	0.1(0.9)	10.9
LATE SUMMER	6.1(33.7)	8.2(47.0)	2.2(12.2)	1.3(7.2)	18.1

and 74% of the EMT catch in late summer. Mean lengths using these two types of gear were 59.3 and 56.0 mm, respectively. The relative abundance of ripe adults captured at this time indicates that spawning is heavy and that it will probably continue for some period of time.

In winter, seasonal abundance reached its highest level (Table 14). The great majority of specimens at this time were juveniles (81%), with a mean length of 10.9 mm. The abundance of these small individuals is a clear indication that spawning had been heavy during the preceding fall months. Subadults were at their lowest seasonal abundance, accounting for only 5% of the catch. Based on IKMT catches, adults were at their peak seasonal abundance. Their presence, along with some postlarvae (Table 14), indicates that some spawning is occurring at this time.

Seasonal abundance was lowest in late spring (Table 14). At this time the catch was dominated by juveniles (75%) and subadults (19%), but the presence of some postlarvae and adults indicates that some spawning was occurring. The juveniles averaged 12.5 mm and probably were produced during the late fall or winter months near the end of the extended peak spawning season. Subadults averaged 22.2 mm. These probably were spawned the preceding summer, and would have matured the following year.

To summarize, the life-history of A. aculeatus appears to last for about two years. The majority of adults, which are probably two years old, spawn in the summer or fall months. Following spawning most of these individuals die, but some may live to spawn a second time. Postlarvae produced during these months develop into juveniles by the following winter, and into subadults by the following late summer or fall. At this time some may reproduce, but most spend a second year as subadults, maturing to adults and spawning near the end of their second year.

SEX RATIOS.—No significant difference between total numbers of males and females was indicated at any of the three seasons (Table 15). In actual numbers, more males than females were captured in winter (14:5) and late spring (34:27), and more females than males in late summer (20:10). The only significant difference in sex ratio was seen among late summer subadults, where females outnumbered males 17 to 4. Because of the small number of specimens considered here, little credence is given to this significant difference; sex ratios probably are not different than 1:1.

VERTICAL DISTRIBUTION.—In the seasonally paired cruises, A. aculeatus was caught from <50–1100 m during the day and from 51–1250 m at night (Table 16). Of the 92 discrete-depth specimens captured during the day in these cruises, 79 (86%) were caught from 301–500 m. Of the remaining 13, only one, a winter juvenile, was taken shallower than 301 m. This specimen is considered a contaminant from the previous tow. Ten of the remaining 12 specimens were taken from 501–850 m. These included late spring juveniles and subadults and late summer postlarvae, juveniles, subadults, and adults. These are thought to represent some scattering of the species toward greater depths. Two specimens, a juvenile and an adult, were caught at 1001–1050 m in winter. These were considered contaminants, since in each case the previous tow had fished at the preferred depths of A. aculeatus.

Of the 113 discrete-depth specimens captured at night, 103 (91%) were caught from 201–500 m (Table 16). Nine of the remaining 10 specimens were taken shallower than 200 m. These specimens, which included winter juveniles and subadults and a late summer adult, may represent some upward straying of A. aculeatus at night. The remaining individual, a late spring juvenile taken at 1201–1250 m, is certainly a contaminant.

The vertical distribution of A. aculeatus in the Ocean Acre area is similar to other localities. Badcock (1970) indicates that near the Canary Islands the species is concentrated from 410–450 m during the day and 350–410 m at night. Baird (1971), reporting on a variety of locations, states that daytime depths are from 200–550 m with a concentration from 350–450 m, and that the species is concentrated from 80–200 m at night. Similarly, Badcock and Merrett (1976), working in the eastern North Atlantic, found that daytime depths were 300–500 m, and that nighttime depths were 100–500 m, with peak concentrations at 200–300 m.

Since all life-history stages occupy the same range of daytime depths in all seasons (Table 16), no daytime stage stratification is indicated. In late summer, when postlarvae were most abundant, they were found from 301–700 m, but were concentrated from 351–500 m. The few postlarvae caught during the day in winter and late spring were taken within the same depth range. In winter, when juveniles were most abundant, they were found from 301–450 m and were relatively abundant from 301–400 m. Although the range of daytime depths occupied by juveniles was broader in late spring (301–700 m) and late summer (301–850 m), the depths of abundance were similar to those of winter. The few subadults caught during the day were taken from 351–450 m in winter, 401–700 m in late spring, and

TABLE 15.—Numbers of each sex for each stage of *Argyropelecus aculeatus* (AD = adult; F = female; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	SAD		AD		TOT	
	M	F	M	F	M	F
WINTER	8	5	6	0	14	5
LATE SPRING	29	26	5	1	34	27
LATE SUMMER	4	17*	6	3	10	20

TABLE 16.—Vert.... istribution by 50-m intervals of *Argyropelecus aculeatus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
1- 50		<1			<1	1	14.0	14																
201- 250									-	-	-	-	-											
301- 350		6			6	9	10.0	7-15	<1	1			1	4	11.2	7-14	<1	<1			<1	2	8.5	7-10
351- 400	<1	2	<1	<1	3	8	17.6	7-59	<1	2		<1	2	13	15.1	9-56	3	2		<1	6	17	12.9	7-74
401- 450	<1	1	<1	<1	2	*			<1	<1	<1	<1	2	*			<1	<1			1	3	9.3	8-10
451- 500												1	1	4	22.2	16-25	2	1	<1		4	19	11.2	7-30
501- 550									-	-	-	-	-					<1			<1	1	9.0	9
551- 600																	<1	<1			1	4	9.5	8-13
601- 650																		<1			<1	1	14.0	14
651- 700	-	-	-	-	-					<1	<1		<1	2	13.0	12-14	<1	<1	<1	<1	<1	*		
701- 750									-	-	-	-	-											
751- 800	-	-	-	-	-													<1			<1	1	13.0	13
801- 850									-	-	-	-	-					<1			<1	1	16.0	16
851- 900	-	-	-	-	-													<1			<1	*		
901- 950	-	-	-	-	-				-	-	-	-	-											
951-1000		<1			<1	*											-	-	-	-	-			
1001-1050		<1			<1	2	12.5	12-13	-	-	-	-	-											
1051-1100		<1			<1	*																		
TOTALS	<1	11	<1	<1	13	20			<1	4	2	<1	7	23			6	7	<1	<1	14	49		
NIGHT																								
51- 100																		<1			<1	1	57.0	57
151- 200		<1		1	1	8	19.4	11-27																
201- 250																		<1	<1		<1	3	19.7	18-21
251- 300		5	<1		6	*				2	1		3	7	19.6	10-32		<1	1	<1	3	8	25.7	13-51
301- 350		10		2	12	21	14.4	8-42		2	<1		3	*			<1	2	<1	<1	3	14	18.2	7-56
351- 400	<1	<1	<1		2	6	25.8	8-60		3			3	9	11.2	10-13	2	3			5	9	8.7	7-10
401- 450		<1			<1	2	10.0	10									1	2			4	11	8.9	8-14
451- 500		<1			<1	1	10.0	10		1			1	3	12.0	11-13	<1	1			2	9	9.7	7-13
551- 600																								
601- 650									-	-	-	-	-				-	-	-	-	-			
651- 700	-	-	-	-	-				-	-	-	-	-											
701- 750									-	-	-	-	-											
801- 850																	-	-	-	-	-			
851- 900																	-	-	-	-	-			
901- 950	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1001-1050									-	-	-	-	-				-	-	-	-	-			
1051-1100	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1101-1150	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1151-1200	-	-	-	-	-				<1				<1	*			-	-	-	-	-			
1201-1250									<1				<1	1	12.0	12								
TOTALS	<1	16	1	3	21	38			0	8	2	0	10	20			4	9	2	1	16	55		

451-700 m in late summer. Too few specimens were taken to accurately describe their preferred depths. This is also true of adults, which ranged from 351-450 m in both winter and late spring, and from 351-700 m in late summer.

Although the nighttime depth distributions of the different life-history stages overlap broadly in all seasons, there is an indication of some stage stratification, with older and larger individuals occurring slightly shallower. Late summer

postlarvae were found from 301–500 m at night, with most from 351–400 m. The few caught in winter were taken from 351–400 m. Juveniles tended to occupy a shallower nighttime range of depths. In winter they ranged from 151–500 m, were very abundant from 301–350 m, and were quite abundant from 251–300 m. In late spring juveniles were captured from 251–500 m and were abundant from 251–400 m. A somewhat shallower range (201–500 m) was occupied in late summer, with the greatest catch per unit effort from 301–450 m. Subadults ranged from 251–350 m in late spring and from 201–350 m in late summer. In each of these seasons they were most abundant at 251–300 m. In winter, subadults were captured from 151–200 m at night. Nighttime captures of adults occurred only in late summer and winter. In late summer a single adult was taken from 51–100 m, while others were taken from 251–350 m. In winter, the range of depths for adults was 251–400 m, with most caught from 301–350 m.

All life-history stages of *A. aculeatus* appear to undergo a diel vertical migration (Table 16). In late summer, postlarvae occupied a wide range of depths during the day (301–700 m). The nighttime narrowing of this range to 301–500 m indicates that at least some postlarvae migrate upward at night. A similar situation is seen among juveniles in which the nighttime range of depths is typically 50–100 m shallower than the daytime range. Athough the depths of maximum abundance were similar from day to night in each season, shallower strata, which contained few or no juveniles during the day, had an abundance of juveniles at night. In winter, for example, juveniles were absent from 251–300 m during the day, but were abundant at this depth at night. Similar diel changes in other seasons (Table 16) indicate that juveniles migrate upward 50–100 m at night. The daytime depth range of subadults (approximately 351–700 m) is considerably compressed and shallower at night. In winter, they were found from 151–200 m at night, while in late spring and late summer they occupied depths from 251–300 m. It is apparent then, that subadults migrate upward at night, perhaps as much as 200–400 m. The same compression of depth range and shallower nighttime distribution is seen in adults. The paucity of specimens prohibits an accurate estimate of the magnitude of upward migration, but it is probably about 100 m, which is a shorter migration than that of the subadults.

PATCHINESS.—There is some indication that small specimens of *A. aculeatus* may be patchily distributed during the day. Two significant daytime CD values were found; one in winter at 301–350 m and one in late summer at 351–400 m. The winter depth interval was composed entirely of juveniles, ranging in length from 7–15 mm SL. The late summer interval contained one adult (74 mm SL), but was heavily dominated by postlarvae and juveniles 7–13 mm SL. Each of these intervals was within the preferred daytime depth distribution of this species. No patchiness was indicated at night.

TABLE 17.—Seasonal night to day catch ratios of *Argyropelecus aculeatus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.0:1	1.4:1	1.7:1	3.7:1	1.6:1
LATE SPRING	*	2.0:1	1.0:1	*	1.5:1
LATE SUMMER	0.7:1	1.2:1	3.7:1	4.3:1	1.2:1

NIGHT:DAY CATCH RATIOS.—The ratio of total night to day catch rates was different from 1:1 in each season (Table 17), with slightly more fish per unit effort being caught at night. This trend was reversed only in postlarvae caught in late summer, where the daytime catch rate exceeded the nighttime rate. This may have been due to these small individuals aggregating during the day. In all other life-history stages the nighttime catch rates equaled or exceeded the daytime catch rates in all seasons. The greatest differences were seen among late summer subadults and among winter and late summer adults. Since no clumping was indicated at night, these observed differences probably were due to increased net avoidance during the day. The larger differences in catch ratios among these larger individuals suggests that net avoidance may be enhanced with increased size.

Argyropelecus affinis

One specimen of *Argyropelecus affinis* was captured in the Ocean Acre program. This was a 33 mm male captured in late summer in an Engel trawl towed at 0–1025 m. Since this net had no closing device, it is impossible to tell at what depth the capture was made. According to Baird (1971) this species is taken abundantly in the Gulf of Guinea, off Chile, off California, and in the northern Indian Ocean. Moderate catches are recorded from the Gulf of Mexico and off the coast of Venezuela in the Caribbean. Small catches have been recorded off the southeast coast of the United States. Our single specimen indicates its rarity in our collecting area, and probably it is a stray from more southern waters.

Valenciennellus tripunctulatus

Valenciennellus tripunctulatus is known from the Atlantic, Pacific, and Indian oceans and the Mediterranean Sea (Grey, 1964). It is one of seven mesopelagic fishes characterized as widespread in the Atlantic (Backus et al., 1970), where it occurs in all of the zoogeographic regions defined by Backus et al. (1977).

A medium-size sternoptychid, *V. tripunctulatus* reaches 30 mm SL in our collections. This appears to be the maximum size in most areas, although Hopkins and Baird (1981)

took specimens up to 35 mm in the Gulf of Mexico, and Torchio (1960) described a specimen 70–75 mm total length from the Mediterranean. The species was uncommon in the study area, ranking fourth in abundance among sternoptychids in all seasons (Table 5). Of the 380 specimens captured, 230 were taken during the seasonally paired cruises, including 108 in discrete-depth samples, with 78 of these from noncrepuscular tows (Table 4).

DEVELOPMENTAL STAGES.—Sex and/or stage were determined for 306 specimens. Postlarvae were 10–14 mm, juveniles 13–18 mm, subadult males 15–26 mm, subadult females 16–26 mm, adult males 19–28 mm, and adult females 20–30 mm SL. Despite the broad overlap in size ranges between sexes, mean standard lengths are significantly greater (p = <0.01) in females than in males, both among subadults (22.6 mm vs. 19.6 mm) and adults (24.6 mm vs. 22.1 mm). Subadult females have eggs mostly 0.1 mm in diameter, with a few larger eggs, 0.2–0.3 mm, scattered throughout. In adults, almost the entire surface of the ovary is covered with eggs 0.4–0.7 mm. In most subadult males, one testis (usually the left) is longer and thicker than the other; in adults, the testes are equal in length and diameter.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Valenciennellus tripunctulatus* appears to spawn in all seasons, with no spawning peak(s) evident. Individuals of both sexes probably spawn at least two or three times and live about one year.

Only two postlarvae (in winter) and no juveniles were taken in noncrepuscular discrete depth tows (Table 18). The total number of postlarvae (17) and juveniles (12) captured during cruises 1–14 represent only 5.6% and 3.9%, respectively, of all specimens. Hopkins and Baird (1981) also noted the paucity of small specimens in their samples from the Gulf of Mexico; thus, it appears that these diminutive stages are inadequately sampled by midwater trawling gear. The scarcity of juveniles also may be explained by the protracted metamorphosis of *V. tripunctulatus* (Ahlstrom, 1974; Badcock, 1977), which results in a relatively lengthy postlarval but short juvenile stage.

Our postlarvae were taken from February through September, with most captures (9) in July. Adults were taken

from January through November, and were represented by 10–19 specimens on each cruise made between mid-March and early September. The widespread occurrence of these two life history stages indicates that spawning occurs in all seasons, and the relatively constant abundance of adults (Table 18) suggests little or no seasonal variation in spawning intensity.

Subadults were the most abundant stage in all seasons (Table 18). Their very wide size ranges and the broad overlap with adults (Figure 4) clearly indicate that *V. tripunctulatus* is a repeat spawner. Since very few adults exceeded the maximum sizes of subadults, the larger "subadults" actually were postspawning adults approaching a second (or third) sexual maturation. Furthermore, there is no real indication of seasonal size variation. In late spring and late summer, when specimens were most numerous, subadult males were 17–25 mm and 15–26 mm, respectively, with mean SL's of 19.9 mm and 19.4 mm. Similarly, subadult females were 18–26 mm in late spring and 16–26 mm in late summer, with mean SL's of 22.4 mm and 22.3 mm, respectively. In view of its small maximum length, *V. tripunctulatus* probably lives only about one year. We suspect that sexual maturity is attained 6–9 months after hatching, and that individuals spawn at least two or three times.

In the Central Pacific near Hawaii, where it is one of the more abundant stomioids, *V. tripunctulatus* also spawns year-round (Clarke, 1974). Clarke indicated that mature females

TABLE 18.—Seasonal abundance and percent of total abundance (in parentheses) for *Valenciennellus tripunctulatus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.2 (17.6)	0	3.6 (52.9)	2.0 (29.4)	6.8
LATE SPRING	0	0	1.9 (52.8)	1.7 (47.2)	3.6
LATE SUMMER	0	0	3.3 (57.9)	2.4 (42.1)	5.7

FIGURE 4.—Size-frequency distribution of subadult and adult *Valenciennellus tripunctulatus* from cruises 1–14 ($\bar{X}$ = mean standard length plus or minus standard deviation; N = number of specimens).

were abundant in all seasons and noted that there were no seasonal trends in size composition among his 600 specimens. Hopkins and Baird (1981) also noted little seasonal size variation in collections made from March to October in the Gulf of Mexico. Apparently, *V. tripunctulatus* spawns in all seasons throughout its geographic range.

SEX RATIOS.—Total numbers of males exceeded total numbers of females in all seasons, but the only significant difference was in late spring, when adult males outnumbered adult females by 2.3:1 (Table 19). When all subadults and adults (including damaged, unmeasureable specimens) from cruises 1–14 are compared, the ratio is 144 males:133 females, and the difference is not significant from 1:1. We suspect that the slight tendency for males to predominate is explained by differential susceptibility to the collecting gear, with more females (with average size larger than males) than males avoiding the net.

VERTICAL DISTRIBUTION.—Of 78 specimens taken in noncrepuscular discrete-depth tows, 71 (91%) were from depths of 351–550 m both day and night (Table 20), suggesting that *V. tripunctulatus* is a permanent, nonmigrating resident of these depths at all times. Only two specimens, both subadults, were taken deeper, in a day tow at 651–700 m in late spring. These specimens cannot be dismissed as contaminants, since the preceding tow was from below 1500 m. Only five specimens, two postlarvae and three subadults, were from 301–350 m, our shallowest capture interval. These were night captures, and the presence of subadults at this depth suggests increased susceptibility to capture at night, although the possibility of a very minor upward movement cannot be ruled out. On the other hand, the presence of postlarvae at 301–350 m suggests stage-depth stratification, which is also indicated by the tendency for mean SL's to increase with increasing depth at all times, although the trend is clear only in day catches in late summer, where the number of specimens begins to approach adequacy (Table 20).

Other studies report size-depth stratification and overall

TABLE 19.—Numbers of each sex for each stage of *Valenciennellus tripunctulatus* (AD = adult; F = female; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	11	8	5	3	16	11
LATE SPRING	14	18	23	10*	37	28
LATE SUMMER	33	19	13	17	46	36

TABLE 20.—Vertical distribution by 50-m intervals of *Valenciennellus tripunctulatus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	W PL	W JUV	W SA	W AD	W TOT	W N	W X	W RANGE	LSp PL	LSp JUV	LSp SA	LSp AD	LSp TOT	LSp N	LSp X	LSp RANGE	LSu PL	LSu JUV	LSu SA	LSu AD	LSu TOT	LSu N	LSu X	LSu RANGE
DAY																								
351–400									1			1	2	8	21.0	18–24	1			<1	1	4	18.8	18–21
401–450											<1	<1	*				1				1	3	19.7	18–21
451–500											<1	<1	1	1	20.0	20	1			2	3	13	21.5	18–25
501–550	–	–	–	–	–								–						<1	<1	1	3	23.7	23–24
651–700									<1			<1	2	2	24.5	24–25								
TOTALS									1			2	3	11			3			3	6	23		
NIGHT																								
301–350	1	<1			2	3	18.3	15–24	–	–	–	–	–				<1				<1	2	20.0	15–25
351–400		1			1	3	17.3	7–18			1		1	3	17.3	17–18	1				1	2	20.0	17–23
401–450		2	2		4	12	22.9	19–28									1				1	3	18.3	16–23
451–500											1	2	3	8	22.9	22–25	1		<1		1	6	22.3	21–25
501–550		<1			<1	1	20.0	20												1	1	1	26.0	26
TOTALS	1	4	2		7	19					2	2	4	11			3			1	5	14		

depth ranges similar to ours, but there is some indication of area to area differences in diel depth concentrations. Loeb (1979) reported small (7.1–9.9 mm SL) postlarvae from open net tows made at 100–225 m and 100–350 m in the North Pacific central gyre, but none from shallower or deeper tows. In open net sampling near Hawaii, *V. tripunctulatus* (10–32 mm SL) was taken mostly at 400-550 m by day, and specimens from 525 m were significantly larger than those taken at 500 m (Clarke, 1974). The night depth range was 200–330 m, and Clarke concluded that the species undergoes a small but distinct upward migration. Hopkins and Baird (1981) reported on discrete-depth captures of *V. tripunctulatus* from two stations in the Gulf of Mexico. At 27°N, 86°W the depth distribution was 250–550 m by day and 180–500 m at night, and the authors concluded that any vertical migration is very limited. In the Loop Current gyre, the species was somewhat deeper (370–550 m) with no day-night difference discernible. Discrete-depth sampling in two areas of the eastern Atlantic also produced somewhat different results. Near the Canary Islands, *V. tripunctulatus* was found at 350–500 m by day and at 250–450 m at night, indicating a slight upward migration (Badcock, 1970). At 30°N, 23°W, where the species exhibited size-depth stratification at 200–400 m day and night, there was a slight upward shift in the peak frequencies of larger specimens at night, which Badcock and Merrett (1976) attributed to increased vulnerability to capture in darkness.

Valenciennellus tripunctulatus has been shown to feed almost exclusively by day in three different areas: the eastern North Atlantic (Merrett and Roe, 1974), off Hawaii (Clarke, 1978), and the Gulf of Mexico (Hopkins and Baird, 1981). This commonality of behavior suggests that the most parsimonious explanation for the apparent geographic differences in diel depth distributions is net avoidance, the magnitude of which varies with environmental parameters such as water transparency. If vertical migrations occur, they are very minor, and are usually too difficult to detect by ordinary means.

PATCHINESS.—Only two significant CD values were found, one in the daytime (late spring, 351–400 m) and one at night (late summer, 451–500 m). In each case, subadults and adults were involved. This scarcity of clumping agrees with the feeding study of Baird and Hopkins (1981), who concluded that *V. tripunctulatus* has a sparse, nonaggregated distribution.

NIGHT:DAY CATCH RATIOS.—In late spring, subadults were twice as abundant by day as by night, but adults were equally abundant night and day (Table 21). In late summer, this pattern was reversed, and thus the total abundance differs little from 1:1 in the two seasons. However, when the winter night captures (Table 20) are included, the night:day catch rate for all specimens and all seasons combined is 1.8:1. Furthermore, when all captures (nondiscrete

TABLE 21.—Seasonal night to day catch ratios of *Valenciennellus tripunctulatus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	SAD	AD	TOT
WINTER	*	*	*
LATE SPRING	0.5:1	1.0:1	1.3:1
LATE SUMMER	1.0:1	0.5:1	0.8:1

plus discrete) are considered, night captures exceed day captures by 151 to 108, a ratio of 1.4:1. Thus, *V. tripunctulatus* appears to be more susceptible to capture at night. This is supported by data from two areas of the eastern North Atlantic, where night captures exceeded day captures by 1.6:1 (Badcock, 1970) and 2.6:1 (Badcock and Merrett, 1976).

These night:day catch ratios may be explained by diel differences in behavior. *V. tripunctulatus* feeds almost exclusively by day, and apparently searches a considerable volume of water to obtain its daily ration (Baird and Hopkins, 1981). Thus, the species is more alert by day and better able to avoid capture. At night, its silvery sides become darkened by the expansion of melanophores, which also obscure the luminescent organs (Badcock, 1969; Krueger, 1972). The resulting loss of reflectivity may serve to reduce the likelihood of detection by bioluminescent predators. This nocturnal camouflage, coupled with the cessation of feeding, suggests that *V. tripunctulatus* becomes quiescent at night and thus more vulnerable to midwater trawls.

Maurolicus muelleri

This is a moderate-size species, reaching a maximum length of about 65 mm SL (Grey, 1964). Although the distribution of *M. muelleri* is worldwide (Briggs, 1960), it was rare in the Ocean Acre area and was completely absent from discrete-depth samples.

Four specimens were taken in open nets in July and September, all during crepuscular periods. In July, two postlarvae, 12 and 14 mm SL, were taken in a tow at 0–250 m and a subadult, 18 mm SL, came from 0–1425 m. The lone September capture, a subadult 18 mm SL, was taken at 0–100 m.

Williams and Hart (1974) collected eggs of *M. muelleri* from March to October in the open North Atlantic (59°N, 19°W). Eggs were taken at depths of 100–500 m and temperatures of 8.8°–10.0° C. Most studies have reported spawning to occur near the edge of the continental shelf (Robertson, 1976, and papers cited by him). The presence of two postlarvae in our study area and the report of two smaller larvae (7–8 mm) from Beebe's 8-mile cylinder

(Beebe, 1937) suggest that *M. muelleri* spawns in deep water near Bermuda.

Habitat Segregation and Resource Partitioning

Table 22 shows the maximum standard lengths, depths of concentration, and peak spawning seasons for the four most abundant sternoptychids. *Sternoptyx diaphana* is the deepest dwelling species and is almost completely separated from the other three in the water column. Although the spawning season of *S. diaphana* completely overlaps those of the other sternoptychids, its postlarvae are found primarily between 550 and 750 m, much deeper than postlarvae of the other species. Thus, *S. diaphana* does not compete for any resource with any other member of the family.

The two congeners, *Argyropelecus hemigymnus* and *A. aculeatus*, differ strikingly in size and have different (though overlapping) depth distributions, especially at night. Probably they have very different diets. In both the eastern North Atlantic (Merrett and Roe, 1974) and the Caribbean–central Gulf of Mexico region (Hopkins and Baird, 1977), stomach contents of *A. hemigymnus* were dominated by copepods, while those of comparable size *A. aculeatus* contained mostly ostracods; larger specimens of *A. aculeatus* from the Caribbean–Gulf region also contained significant numbers of larger prey items, such as amphipods, molluscs and tunicates, all of which were rare or absent in *A. hemigymnus*.

A. hemigymnus and *Valenciennellus tripunctulatus* are similar in size and morphology, have nearly identical diel vertical distributions, exhibit similar diel changes in pigmentation (Badcock, 1969), and even share the same feeding period: afternoon and evening (Merrett and Roe, 1974; Hopkins and Baird, 1977). However, in the eastern North Atlantic, Merrett and Roe (1974) found important differences in the diets of these two fishes, with species of the copepod genus *Pleuromamma* predominant in the stomachs of *V. tripunctulatus*. Furthermore, Hopkins and Baird (1977), who compared specimens of both species from the same haul in the eastern Gulf of Mexico, found a greater

Table 22.—Maximum size, main depth distribution, and peak spawning period for the four well represented species of Sternoptychidae.

SPECIES	MAXIMUM SIZE (MM)	MAIN-DEPTH (M) DAY	MAIN-DEPTH (M) NIGHT	PEAK SPAWNING PERIOD
Sternoptyx diaphana	36	700-1000	700-1000	SUMMER-FALL
Argyropelecus hemigymnus	37	351- 600	351- 550	SPRING-SUMMER
A. aculeatus	83	301- 500	201- 500	SUMMER-FALL
Valenciennellus tripunctulatus	30	351- 550	351- 550	YEAR ROUND

diversity of prey in the stomachs of *A. hemigymnus*, which contained a much higher percentage of small (<2 mm) prey items. In addition, our postlarvae of *A. hemigymnus* were abundant only in late summer (corresponding to the spring-summer breeding peak) and were concentrated at 401–450 m in all seasons. In contrast, postlarvae of *V. tripunctulatus* were scarce in the Ocean Acre area, as might be expected in a year-round spawner, and appeared in discrete-depth samples only in winter, at 301–350 m. Thus, these two very similar species probably compete little or not at all.

In summary, Ocean Acre Sternoptychidae appear to partition their resources primarily by habitat segregation in the vertical plane. Where depth distributions overlap or coincide, competition probably is reduced or eliminated by differences in feeding selectivity, which may or may not be related to differences in SL.

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Family Myctophidae, Lanternfishes

Charles Karnella

ABSTRACT

The lanternfishes (Family Myctophidae) are represented in the Ocean Acre collections by more than 47,000 specimens distributed among 63 species in 18 genera. The species are categorized as "rare," "uncommon," "common," "abundant," and "very abundant," based upon maximum seasonal abundance. Twenty species are "rare," 19 "uncommon," 13 "common," 6 "abundant," and 5 "very abundant." The 11 "abundant" and "very abundant" species include only one congeneric pair and have subtropical, temperate-semisubtropical, or tropical-subtropical distributions.

Developmental stages, reproductive cycles, seasonal abundance, sex ratios, vertical distributions, patchiness, and night-to-day catch ratios are discussed for each species for which there are enough data. Diel changes in the vertical distributions of lanternfishes also are described. There is a change in the center of abundance from 450–900 m during the day, to above 250 m at night. Finally, using factor analyses and cluster analysis, species groups and depth strata are defined and discussed. Little consistency was found in species groups between night and day or from season to season, suggesting that resources are well partitioned among the species of Myctophidae.

Introduction

Lanternfishes are represented in the Ocean Acre collections by more than 47,000 specimens distributed among 63 species in 18 genera. Table 23 shows, for each species, (1) the number of specimens taken on all cruises, (2) the number taken on the paired seasonal cruises, (3) the number taken in discrete-depth samples made during the paired seasonal cruises, and (4) the number taken in noncrepuscular discrete-depth samples made during the paired seasonal cruises. The last represents the primary data base that was analyzed.

A preliminary report based on about one-third of the specimens and using different methods of analysis was pre-

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pared by Gibbs et al. (1971). Five species reported here, *Diaphus garmani, Lampanyctus intricarius, L. nobilis, Myctophum asperum,* and *M. obtusirostre,* were not included by Gibbs et al. All are rare in the study area; the five species combined were represented by only 26 specimens. The three specimens referred to as *Myctophum affine* by Gibbs et al. were misidentified and were other species of the genus. No specimens of *M. affine* were found in the Ocean Acre collections, and the species probably does not occur in the study area. *Diaphus elucens,* listed by Gibbs et al., is a synonym of *D. perspicillatus.*

Beebe (1937), in his studies of the deep sea fishes found near Bermuda, noted that lanternfishes accounted for about 25 percent of the total number of species. He listed 57 species of lanternfishes that accounted for about 10 percent of the total number of specimens in his collections. The 57 species he listed probably represented about 30 valid species, but there is no way to be sure of this until his collections are reexamined.

Methods

Methods of analysis used in this study are given in the introductory chapter of this volume. A few observations particulary applicable to this study are provided here.

ONTOGENETIC STAGES.—Lanternfish postlarvae have markedly different body proportions, pigmentation, and development of the photophores (if any) than subadults and adults. Most juveniles (the vast majority) are similar to the older stages in form, pigmentation, and photophore development. Juvenile gonads are thread-like or flattened and show very little or no regional development, all areas being similar in appearance. It was possible to sex some of the juveniles, but generally, only the larger juveniles of most species could be sexed under the dissecting microscope. Juvenile females seldom have eggs larger than 0.05 mm in diameter.

Subadults have large, easily recognizable ovaries or testes that are cylindrical rather than thread-like or flattened. Eggs usually show little development and mostly are clear and <0.10–0.15 mm in diameter. The changes in testes are

TABLE 23.—Numbers of specimens of each species of lanternfish caught in all samples during cruises 1–14, in all samples during the paired seasonal cruises (cruises 4 and 12, 10 and 14, 11 and 13), in all discrete-depth samples made during the paired seasonal cruises, and in all noncrepuscular discrete-depth samples made during the paired seasonal cruises (dash = not taken in the sample type).

SPECIES	CRUISES 1-14	PAIRED SEASONAL CRUISES		
	TOTAL	TOTAL	DISCRETE	NONCREPUSCULAR DISCRETE
Benthosema glaciale	97	53	35	28
B. suborbitale	432	341	255	214
Bolinichthys indicus	3880	2272	1600	1169
B. photothorax	15	4	4	4
B. supralateralis	107	16	12	6
Centrobranchus nigroocellatus	527	434	418	316
Ceratoscopelus maderensis	489	90	47	36
C. warmingii	4683	1862	1226	818
Diaphus bertelseni	5	1	1	1
D. brachycephalus	84	25	22	15
D. dumerilii	37	9	4	4
D. effulgens	120	51	36	30
D. fragilis	1	1	-	-
D. garmani	2	-	-	-
D. lucidus	16	3	2	2
D. luetkeni	3	1	1	1
D. metopoclampus	125	70	51	47
D. mollis	1559	650	461	342
D. perspicillatus	17	5	4	4
D. problematicus	24	8	4	3
D. rafinesquii	342	193	128	93
D. splendidus	82	27	20	20
D. subtilus	5	2	-	-
D. termophilus	9	4	2	1
Diogenichthys atlanticus	4013	2824	1866	1310
Gonichthys cocco	1326	1112	1090	814
Hygophum benoiti	2850	2522	1814	1509
H. hygomii	5350	754	521	475
H. reinhardtii	106	65	51	37
H. taaningi	72	61	35	25
Lampadena anomala	8	5	3	3
L. chavesi	178	52	31	27
L. luminosa	8	2	-	-
L. speculigera	281	237	200	85
L. urophaos	212	63	49	33
Lampanyctus alatus	80	29	13	10
L. ater	414	211	151	143
L. crocodilus	350	142	97	76
L. cuprarius	1462	584	383	340
L. festivus	593	188	131	120
L. intricarius	2	1	-	-
L. lineatus	84	35	19	18
L. nobilis	20	1	1	-
L. photonotus	1074	469	351	247
L. pusillus	4913	2545	1715	1432
Lepidophanes gaussi	951	496	283	249
L. guentheri	365	109	74	56
Lobianchia dofleini	3749	964	601	413
L. gemellarii	627	222	146	112
Loweina interrupta	2	1	1	1
L. rara	78	50	29	26
Myctophum asperum	1	-	-	-
M. nitidulum	543	229	180	163
M. obtusirostre	2	1	1	1
M. punctatum	51	28	27	24
M. selenops	25	18	10	6
Notolychnus valdiviae	3999	2870	1944	1670
Notoscopelus caudispinosus	344	114	90	64
N. resplendens	458	133	96	53
Symbolophorus rufinus	53	17	13	13
S. veranyi	7	6	5	5
Taaningichthys bathyphilus	64	26	17	15
T. minimus	184	47	34	22
TOTALS	47564	23358	16373	12706

generally so gradual that it is difficult to define either the juvenile-subadult or the subadult-adult transition. Males whose testes had any cylindrical portions were considered subadults. For most species the testes of large subadults are noticeably enlarged compared to those of most juveniles.

Males with testes showing moderately enlarged areas were considered adults. Adult males generally have testes that show much regional development; usually one section of the testis is markedly enlarged compared to the other regions. Adult females have greatly enlarged ovaries full of large well developed eggs. In most species ova are larger than about 0.2 mm in diameter.

These criteria were considered only as guidelines, for no two species are exactly alike in their development. For example, large females with small eggs may be subadults that have never spawned, may be spent, or may be underdeveloped as a consequence of expatriation. It is necessary to examine a series of each species covering the entire range of sizes at all seasons to determine the actual situation.

RELATIVE ABUNDANCE.—In the following accounts, the species are categorized as "rare," "uncommon," "common," "abundant," and "very abundant," according to the maximum abundance at any given season. These terms do not imply that a species would be in the same category if the three seasons were considered separately.

Rare species were represented by fewer than 40 specimens, and each had a maximum seasonal abundance of less than 1 specimen per hour.

Uncommon species had a maximum seasonal abundance of 1 to 9 specimens per hour and were represented by 107 to 365 specimens.

Common species had a maximum seasonal abundance of 10 to 36 specimens per hour and were represented by 281 to 1559 specimens.

Abundant species had a maximum seasonal abundance of 50 to 72 specimens per hour and were represented by 432 to 5350 specimens.

Very abundant species had a maximum seasonal abundance of 157 to 245 specimens per hour, and were represented by 2850 to 4913 specimens.

Acknowledgments

Species Accounts

The following accounts discuss, where possible, developmental stages, reproductive cycle, seasonal abundance, sex ratios, vertical distribution, patchiness, and night-to-day catch ratios of the 63 species of lanternfishes taken during the study. For some species, particularly the "abundant" and "very abundant" ones, there were enough data to perform detailed analyses for each subject. For others, detailed analyses could be done only for certain categories, and, for still other species, there were almost no data: these mostly were the "rare" and "uncommon" species.

Benthosema glaciale

This subarctic-temperate species (Backus et al., 1977) is thought to be the most abundant member of the family north of about 37°N in the Atlantic Ocean (Bolin, 1959; Halliday, 1970; Nafpaktitis et al., 1977). It attains a moderately large size near Bermuda; maximum length in the Ocean Acre collections is 60 mm. Maximum size and, presumably, life span increase with latitude; *B. glaciale* grows to 68 mm off Nova Scotia, to 84 mm off Greenland (Halliday, 1970), and to 103 mm off Norway (Gjosaeter, 1973). The species is uncommon in the study area; 97

specimens were collected during the program, about half of these during the paired seasonal cruises. Discrete-depth captures numbered 35, of which 28 were from noncrepuscular times.

DEVELOPMENTAL STAGES.—Juveniles were 20–36 mm, subadults 33–60 mm, and adult males 48–60 mm SL. All but two fish could be sexed; one was the smallest specimen, the other was badly damaged. There were 48 females and 47 males. External sexual dimorphism was evident in fish 25–30 mm, with males having supracaudal and females infracaudal luminous tissue.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Based upon the low abundance and peculiar vertical distribution of B. glaciale in the northern Sargasso Sea, Jahn (1976) concluded that the species was an expatriate and did not reproduce successfully in that region. The Ocean Acre collections, which contain no adult females, or juveniles at the transformation size, or postlarvae, seem to support Jahn's conclusion.

TABLE 24.—Seasonal abundance and percent of total abundance (in parentheses) for Benthosema glaciale (AD = adult, JUV = juvenile; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	JUV	SAD	AD	TOT
WINTER	0	0.9 (64.3)	0.5 (35.7)	1.4
LATE SPRING	1.1 (15.7)	4.7 (67.1)	1.2 (17.1)	7.0
LATE SUMMER	0.5 (16.1)	1.1 (35.5)	1.5 (48.4)	3.1

Fish 20–30 mm were caught in small numbers in March, April, and June and were most numerous in April (cruise 6). According to Halliday (1970), fish of this size found off Nova Scotia were about six months old. Assuming that the Ocean Acre population had a similar growth rate, one would expect to catch fish about 11–12 mm (the size at

TABLE 25.—Vertical distribution by 50-m intervals of Benthosema glaciale (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

	WINTER								LATE SPRING								LATE SUMMER							
DEPTH (M)	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
651– 700	·	-	-	-	-												-	-	-	-	-			
701– 750									<1	<1			<1	*										
751– 800		<1	<1	<1		*			<1	<1			<1	2	37.0	23-51								
801– 850		<1	<1	<1		2	49.5	48-51	<1	<1			<1	*					<1		<1	1	44.0	44
851– 900	-	-	-	-	-														<1		<1	*		
901– 950	-	-	-	-	-				<1	1	<1		1	*										
951–1000	-	-	-	-	-				<1	2	1		3	14	48.4	29-60	-	-	-	-	-			
1001–1050		<1		<1		1	52.0	52	<1	1	<1		1	*										
1051–1100	-	-	-	-	-												-	-	-	-	-			
TOTALS		<1	<1	<1		3			<1	4	1		5	16					<1		<1	1		
NIGHT																								
751– 800																								
801– 850									1				1	1	49.0	49	<1	<1	1		1	*		
851– 900									-	-	-	-	-				<1	1	1		2	6	47.0	36-54
901– 950																								
951–1000																								
1001–1050									-	-	-	-	-				-	-	-	-	-			
1051–1100																	-	-	-	-	-			
1101–1150									-	-	-	-	-				-	-	-	-	-			
1151–1200									-	-	-	-	-				-	-	-	-	-			
1201–1250												<1	<1	1	60.0	60								
TOTALS									1	<1			1	2			<1	1	2		3	6		

transformation (Taaning, 1918; Halliday, 1970) in fall or winter if they were spawned in the study area. Few fish of any size were taken those seasons. The entire catch from October to March consisted of 15 specimens 36–56 mm SL.

Abundance was at its yearly low in winter (Table 24). The entire catch was three specimens. Abundance increased to its maximum by late spring when subadults were dominant; juveniles and adult males were about equal in number but less abundant. The catch was mostly of fish larger than 40 mm, which, according to Halliday (1970), would be one to three years old. By late summer, abundance had decreased to an intermediate level and, as in late spring, the catch was mostly larger than 40 mm.

The conspicuous absence of 10–12 mm juveniles and the predominance of specimens larger than 40 mm in the collections suggest that all fish were at least six-months old and most were more than a year old before they reached the study area (Halliday, 1970). Otoliths from three fish (40, 53, and 56 mm) had two, three, and three transparent rings, respectively, indicating that they were two and three years old (Halliday, 1970).

VERTICAL DISTRIBUTION.—Although *B. glaciale* is known to migrate from day depths of 250–800 m into the upper 200 m at night off Nova Scotia (Halliday, 1970) and in the Mediterranean Sea (Goodyear et al., 1972), near Bermuda the species was taken only deeper than 750 m day and night at all seasons (Table 25). The maximum depth of occurrence is uncertain because of poor samples below 1000 m (Table 2); the deepest catch by day was at 1001–1050 m and by night at 1201–1250 m (Table 25). Maximum abundance was at 951–1000 m by day and 851–900 m by night (Table 25).

Most positive samples (including open net and oblique IKMT tows) caught one fish, a few caught 2 to 4, and one caught 13, indicating a patchy distribution.

Benthosema suborbitale

This species occurs in tropical and subtropical waters of all oceans (Nafpaktitis et al., 1977). Backus et al. (1977) listed *B. suborbitale* as a tropical-subtropical species in the Atlantic. In the North Atlantic it is said to be more abundant in the east than in the west, but it is common in the Gulf of Mexico (Nafpaktitis et al., 1977). It is a small to medium-size lanternfish, reaching a size of about 39 mm in the Atlantic (Hulley, 1981), 38 mm in the Pacific (Clarke, 1973), and about 30–32 mm in the Indian Ocean (Nafpaktitis and Nafpaktitis, 1969). The largest Ocean Acre specimen was 29 mm (Kotthaus, 1972:11, listed a 51.5 mm specimen from the eastern North Atlantic, but it is unlikely that *B. suborbitale* grows to that size.)

Benthosema suborbitale is one of the numerically dominant lanternfishes in the North Atlantic subtropical region and is one of the "abundant" lanternfishes in the study area. This species ranked sixth in abundance in late summer and was represented in the Ocean Acre collections by 432 specimens; 341 were caught during the paired seasonal cruises, 255 of these in discrete-depth samples, 214 of the latter in noncrepuscular tows. (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 8–9 mm, juveniles 10–21 mm, subadults 18–29 mm, and adults 22–29 mm SL. Most fish smaller than 13 mm could not be sexed, and most of those larger than 13 mm had small but recognizable ovaries or testes. External sexual dimorphism was obvious at about 20–25 mm, at which size males developed supracaudal and females infracaudal luminous tissue. Adult females, represented in the Ocean Acre collections by only six specimens, contained eggs as large as 0.4 mm in diameter. Some large (greater than 22 mm) subadult females caught in each season appeared to be in a postspawning condition, and others had occasional ova as large as 0.2–0.4 mm in diameter, but most had eggs less than 0.1 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The life history of *B. suborbitale* in the study area is difficult to determine. Near Bermuda there may be a composite of individuals actually spawned in the study area and those spawned elsewhere. The latter probably account for most of the population. Spawning seems to occur over all or most of the year, with a peak near spring. Size classes could not be traced from season to season but, judging from the maximum size attained, the life span is probably about a year. Total abundance and abundance of each stage was greatest in late summer, intermediate in winter, and least in late spring (Table 26). Juveniles and subadults together accounted for more than 80 percent of the catch at each season.

Evidence that spawning occurs in the study area is the presence of a few postlarvae (none were taken in discrete-depth, noncrepuscular samples made during the paired seasonal cruises) and of small numbers of gravid or nearly gravid females. Juveniles at or near the size at transformation, 10–14 mm (Badcock and Merrett, 1976), were caught during 12 of the 14 cruises, suggesting that spawning occurs over most of the year, and that the parent population was geographically not far removed.

Total abundance in late spring was very low (Table 26), but no samples were taken above 50 m at night where the species was most abundant in late summer. A sample made at 30 m was not used because gear failure resulted in its combination with the 30–0 m oblique sample. The combined sample had a catch rate of 8.6 specimens per hour, of which juveniles accounted for less than 1, subadults about 5, and adults about 3. Inclusion of this sample probably would have resulted in a more accurate estimate of the abundance of *B. suborbitale*.

Abundance of all stages was much higher in late summer (Table 26). Small juveniles (less than 18 mm) had their

TABLE 26.—Seasonal abundance and percent of total abundance (in parentheses) for *Benthosema suborbitale* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total).

SEASON	JUV	SAD	AD	TOT
WINTER	6.2 (59.0)	2.4 (22.8)	1.9 (18.1)	10.5
LATE SPRING	1.3 (46.4)	1.0 (35.7)	0.5 (17.9)	2.8
LATE SUMMER	28.8 (40.0)	34.6 (48.0)	8.6 (11.9)	72.0

greatest abundance at this time, suggesting a spawning peak in spring. However, subadults were the most abundant stage, which suggested that most of the population had not yet spawned and that juveniles would reach their greatest abundance later in the year.

The expected peak abundance was not evident in winter (Table 26). Although juveniles were the most abundant stage, all stages were much less abundant than in late summer.

The extremely low abundance in late spring followed by the great increase in all stages, particularly subadults, in late summer, is difficult to reconcile in terms of a breeding population in the study area. It seems probable that most of the increase was due to an influx of individuals into the area from other regions during summer. This is supported by the fact that fish 18 mm and larger accounted for at least 50 percent of the total abundance in each season, while those 11–14 mm comprised no more than 30 percent of the catch at any season.

SEX RATIOS.—Males were more numerous than females in the collections from winter and late spring, and females were slightly more numerous in late summer, with male-to-female sex ratios of 1.4:1 in winter, 1.8:1 in late spring, and 1.0:1 in late summer. None of these sex ratios differ significantly from unity (Table 27).

Male adults consistently outnumbered female adults; the differences for late spring and late summer collections were statistically significant (Table 27). These differences probably were real, as only six adult females were taken during the program.

There was no pattern of seasonal numerical dominance by either sex for juveniles and subadults. The total number of females was greater than that of males, but the differences were not significant (Table 27).

VERTICAL DISTRIBUTION.—Depth of occurrence by day in winter was 501–650 m (possibly deeper) with a maximum abundance at 551–600 m, in late spring it was 551–700 m (possibly both shallower and deeper), and in late summer 501–650 m. At night, except for single specimens found at 751–800 m in late spring, and 151–200 m and 701–750 m in late summer, all discrete-depth captures were from the upper 100 m (Table 28). The shallow depth limit appears to be about 50 m in winter and 20–30 m during the other

two seasons. Maximum abundance was near 70 m in winter and near 30 m in late summer and probably also in late spring. (See "Night:Day Catch Ratios.")

Night catch data for late summer and late spring, and day catch data for winter (when about half of the discrete-depth day catch was from a single sample taken at 551–600 m) indicate that *B. suborbitale* tended to concentrate within a rather narrow depth range.

Stage and size stratification were evident by day at each season but not at night. Maximum depths of occurrence by day in winter and late spring were similar for all stages, but juveniles were found in shallower waters than the others, and subadults were found in shallower waters than adults. In late summer during the day juveniles were found only near the shallower limit and the older stages only near the deeper limit. In winter juveniles and subadults were most abundant at a shallower depth than adults (Table 28).

In terms of size, during the day fish larger than 20 mm were not taken near the shallower limits, and those 26–28 mm were taken only at or near the deeper limits. Maximum and mean sizes increased with depth.

At night all three fish caught below 100 m were 11–12 mm. However, most fish of that size were taken in the upper 100 m (Table 28). Juveniles 10–12 mm do not migrate on a regular basis near Hawaii (Clarke, 1973) or in the eastern Atlantic (Badcock and Merrett, 1976). Badcock and Merrett (1976) related the degree of development to migratory behavior: light colored juveniles (i.e., recently transformed fish) were not migrators, but dark colored ones were. In contrast, both of the Ocean Acre specimens taken below 700 m at night were dark juveniles.

Upward migrations in late summer apparently began between about 0.8 and 2.3 hours before sunset. Specimens were taken at daytime depths between 1.3 and 2.3 hours before sunset and, at about 350 m no more than 0.8 of an hour before sunset. The upper 50 m were occupied no later than 1.5 hours after sunset. Assuming an upward shift of about 600 m between day and night centers of abundance (601–650 m to 1–50 m) and a migration time of about 3.5 hours, upward migrations occurred at about 170 m/hr. Nothing can be said concerning the morning migrations in

TABLE 27.—Numbers of each sex for each stage of *Benthosema suborbitale* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	9	7	11	7	4	3	24	17
SPRING	2	1	12	14	13	0*	27	15
SUMMER	29	40	42	59	27	1*	98	100

TABLE 28.—Vertical distribution by 50-m intervals of *Benthosema suborbitale* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					N	SL X	RANGE	LATE SPRING CATCH RATE					N	SL X	RANGE	LATE SUMMER CATCH RATE					N	SL X	RANGE
	PL	JUV	SA	AD	TOT				PL	JUV	SA	AD	TOT				PL	JUV	SA	AD	TOT			
DAY																								
451- 500																								
501- 550	1				1	1	11.0	11	<1				<1	*			1				1	2	12.0	11-13
551- 600		4	1		5	13	18.6	12-23	<1				<1	1	12.0	12								
601- 650	<1	1	1		2	7	22.1	12-27	<1	<1			<1	2	21.5	21-22			1	1	2	4	24.2	23-26
651- 700	<1	1	<1		1	*			<1	1	<1		1	6	21.1	14-28	<1	<1		<1		*		
701- 750									<1	<1			<1	*										
751- 800	<1			<1		*																		
801- 850	<1			<1		1	13.0	13	-	-	-	-	-											
TOTALS		5	2	2	9	22			<1	1	<1		1	9			1		1	1	3	6		
NIGHT																								
1- 50	<1			<1		1	11.0	11				1	1	1	25.0	25	26	34	8		68	136	20.1	11-29
51- 100	<1	<1	<1		<1	9	17.2	11-26									2	1	1		4	27	18.3	12-26
101- 150																								
151- 200																	<1				<1	1	12.0	12
701- 750									-	-	-	-	-				1				1	1	11.0	11
751- 800									1				1	1	12.0	12								
TOTALS	<1	<1	<1		<1	10			1			1	2	2			29	35	9		73	165		

late summer or about morning or evening migrations at either of the other two seasons.

PATCHINESS.—A patchy distribution was indicated by day in winter at 551–600 m. Juveniles and subadults accounted for most of the catch from that depth (Table 28).

The catch from 51–100 m at night in late summer had a significant CD value, but this probably resulted from vertical stratification rather than horizontal patchiness. Eight samples were taken at three different depths within that interval. Each sample within a series was similar to the others from that series, and none of the individual series had significant CD values. Samples from the shallowest series had considerably greater catch rates than those from the two deeper series, which resulted in a large CD value.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios (including interpolated values) for discrete-depth captures were 0.1:1 in winter, 0.5:1 in late spring, and 26.7:1 in late summer (Table 29). Except for adults in late spring, which were taken in very low abundance, ratios for the developmental stages followed the overall seasonal trends. The most divergent ratios from 1:1 for total abundance and abundance of each stage occurred in late summer, when these values were at a maximum (Table 29).

TABLE 29.—Seasonal night to day catch ratios of *Benthosema suborbitale* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	JUV	SAD	AD	TOT
WINTER	0.1:1	0.2:1	<0.1:1	0.1:1
LATE SPRING	0.5:1	*	5.0:1	0.5:1
LATE SUMMER	57.6:1	31.4:1	7.8:1	26.7:1

B. suborbitale seemed to be concentrated within a rather narrow depth range day and night. Sampling within this range at one diel period and not during the other would result in greatly different catches. Presumably, this was the major cause for the observed night-to-day catch ratios. For example, more than 94 percent of the night catch in late summer was due to two consecutive samples made at 33 m that caught a total of 136 specimens (Table 28). Almost the entire difference between the day and night catches in late summer was due to these two samples.

Diel differences in net avoidance probably had little, if any, effect on night-to-day catch ratios as the maximum size

was only 29 mm, and all sizes showed the same trend in any one season.

Bolinichthys indicus

This medium-size lanternfish attains a size of 45 mm in the Ocean Acre area. A bipolar subtropical species, *B. indicus* is a ranking myctophid in the North Atlantic subtropical region (Backus et al., 1977). It is one of the "very abundant" lanternfishes found in the study area, being the most abundant one in winter and among the twelve most abundant during the other two seasons (Table 131). *Bolinichthys indicus* was represented in the Ocean Acre collections by 3880 specimens; 2272 were caught during the paired seasonal cruises, 1600 of these in discrete-depth samples, 1169 of the latter in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 4–12 mm, juveniles 10–24 mm, subadults 19–40 mm, and adults 27–41 mm. Most juveniles smaller than 17 mm could not be sexed, and most of those larger than 16 mm had small, but recognizable, ovaries or testes. Some larger females (over 30 mm) categorized as subadults may have been postspawning adults with regenerated ovaries. There was no apparent sexual dimorphism in size for any stage.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Bolinichthys indicus* apparently has a one-year life cycle, with only a few individuals surviving many months beyond a year. Spawning occurs from mid-spring to late fall with a peak in late summer. This species was most abundant in winter, when it was the top ranking lanternfish, and juveniles and subadults had their greatest abundance. Postlarvae and adults were most abundant in late summer. In late spring total abundance and abundance of all stages was lowest (Table 30).

Adult-size females were caught throughout the year, but enlarged ovaries with eggs greater than 0.2 mm in diameter were observed only from April through November. At all other times large females (over 29 mm) had relatively small ovaries with eggs mostly less than 0.1 mm in diameter. The seasonal distribution of adults with maturing eggs and the great abundance of small juveniles (over 16 mm) in late

summer and winter indicate a protracted breeding season over the spring, summer, and fall. Approximately 95 percent of all postlarvae were caught from July through September, suggesting that a peak in spawning intensity occurs from June through August. Occasional postlarvae were taken in January, June, and November. Because the maximum abundance of juveniles occurred in winter, a peak in the numbers of postlarvae would be expected in November or December, but was not indicated by the very few samples made in those months.

In winter more than 98 percent of the population consisted of juveniles and subadults (Table 30). Subadults were spawned early (spring) in the previous breeding season and probably would spawn in the coming spring. Juveniles mostly were spawned the previous fall and would be expected to breed over the coming summer and fall. By far the greatest abundance of juveniles was at this season, indicating that spawning was at a maximum in summer and fall. The few adults caught were all males (Table 31).

Some females categorized as subadults were of adult size (larger than 33 mm). These individuals probably spawned the previous summer or fall at about one year of age and, perhaps, would spawn again the coming spring. The paucity of large fish in winter indicates that most of the population died soon after spawning at about one year of age.

By late spring the spawning season had arrived, and most subadults and the few adults of the winter population had matured, spawned, and died. Recruits from the spring spawn were not yet large enough to be adequately sampled by the gear used. Accordingly, juvenile abundance was at its minimum at this season (Table 30). Juveniles of the winter population now presumably were mostly subadults, but a few were adults. The latter stages comprised nearly 90 percent of the catch in late spring, but their numbers were very small. This low abundance of subadults and adults is puzzling, especially in light of the fact that the abundance of adults in late summer is greater than the total abundance of all stages is late spring (Table 30).

Almost all (97 percent) fish caught in late summer were either smaller than 20 mm or larger than 29 mm. Juvenile

TABLE 30.—Seasonal abundance and percent of total abundance (in parentheses) for *Bolinichthys indicus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.6(0.2)	164.0(66.7)	78.2(31.8)	2.9(1.2)	245.7
LATE SPRING	0.1(0.8)	1.2(9.5)	8.6(68.2)	2.7(21.4)	12.6
LATE SUMMER	13.6(10.6)	75.0(58.5)	12.5(9.8)	27.0(21.1)	128.1

TABLE 31.—Numbers of each sex for each stage of *Bolinichthys indicus* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	144	110	86	115*	6	0	206	225
LATE SPRING	2	3	19	30	15	10	36	43
LATE SUMMER	7	13	15	24	49	33	71	70

recruits from the spring spawn dominated the catch and, together with postlarvae, accounted for about 70 percent of the catch (Table 30). The group of larger fish was made up of the late-spawning one-year-old adults and a few subadults. Large females (greater than 35 mm) categorized as subadults may have spawned already.

SEX RATIOS.—The sexes probably are equally abundant at all seasons. Female-to-male sex ratios were 1.1:1 in winter, 1.2:1 in late spring, and 1.0:1 in late summer. None of these ratios differs significantly from equality. Subadult females were more numerous than subadult males at each season, and adult males were more numerous than adult females in each season. The only statistically significant difference from equality was for subadults in winter (Table 31).

VERTICAL DISTRIBUTION.—Day-depth range in winter was 501–850 m with maximum abundance at 601–650 m, in late spring 601–800 m with a maximum at 651–700 m, and in late summer the upper 50 m and 601–1150 m with maxima at 601–650 m and 801–850 m. At night most specimens were taken in the upper 200 m at all seasons, with maxima at 51–100 m in winter and late spring and 101–150 m in late summer. Some fish were caught deeper than 300 m at night in winter and late summer; most were postlarvae and juveniles (Table 32).

Stage and size stratification were evident in both winter and late summer but not in late spring, when most of the catch was from only one 50-m interval both day and night (Table 32). During the day in winter and in late summer, juveniles were found throughout the vertical range, while the older stages were not taken at the shallowest depths. In late summer only postlarvae were caught in the upper 50 m and only postlarvae and juveniles below 500 m (Table 32). In terms of size, only the smallest specimens were caught in the shallowest depth interval during daytime in winter (all smaller than 15 mm) and late summer (all smaller than 17 mm). During the day in winter there was very little overlap in the sizes caught at 501–650 m and from below 700 m. More than 98 percent of the catch from the shallower depths was smaller than 21 mm, while more than 95 percent from the deeper depths was larger than 22 mm. In late summer, except for a 19 mm juvenile, all fish caught below 900 m were 9–11 mm (Table 32).

At night in winter juveniles dominated in the upper 100 m and subadults dominated at 101–150 m. Adults were not found in the upper 100 m. Migrant juveniles were not taken deeper than 200 m, and the older stages occurred as deep as 350 m. In late summer, except for a single specimen from 301–350 m, postlarvae were found only in the upper 50 m and below 850 m. The remainder of the population was well dispersed vertically, and there was no evidence of stage stratification in the migrant element of the population (Table 32).

Size stratification was not as pronounced at night as by day. In winter all fish larger than 30 mm were caught deeper than 100 m, and in late summer fish caught at 151–300 m had a greater mean size than those from shallower depths. The few specimens caught in the upper 50 m in late summer were postlarvae smaller than 9 mm (Table 32).

Postlarvae were stratified according to size in late summer (and probably at other seasons, but there are few data). The smallest ones (4–8 mm) were taken only at the surface or from the upper 50 m both day and night. Those 9–12 mm were taken almost exclusively at 851–1000 m and did not appear to migrate (Table 32). Initial development of postlarvae obviously occurs in the shallow layer; at a size of about 8 mm they descend to the deeper stratum, where they continue to develop and transform into juveniles before undertaking regular vertical migrations.

Diel vertical migrations occurred at all seasons, but only in late spring were all night captures made above day depths. Presumably the entire population at that season consisted of migrants. About 34 percent of the late summer population and 8 percent of the winter population remained at day depths during the night. Nonmigrants were mostly postlarvae and small juveniles (smaller than 13 mm), but included a few subadults. Regular migratory behavior apparently begins at a size of 11–12 mm; all juveniles larger than 12 mm were migrants, but only a few smaller ones were (Table 32).

Upward migrations apparently started between 2 and 3 hours before sunset in late summer and between 1 and 2 hours before sunset in winter. Nocturnal depths were occupied by one hour after sunset in both seasons, giving upward migration times of about 3.5 hours in late summer and 2.5 hours in winter. These estimates of migration times yield minimum rates of 200 m/hr in winter (600 m to 100 m); and 129 m/hr (600 m to 150 m for smaller fish, mean SL 12.2 mm) and 186 m/hr (800 to 150 m for larger fish, mean SL 23.4 mm) in late summer between diurnal and nocturnal depths of maximum abundance.

Morning downward migrations apparently were somewhat faster than the evening ones. Fish were caught at night depths both in winter and late summer less than an hour before sunrise, and possibly even after sunrise (some positive samples started before sunrise and ended after sunrise). Day depths were reached about 2 hours after sunrise in late summer and about 1.5 hours after sunrise in winter, giving migration times of about 2.5 hours in late summer and about 2 hours in winter. Downward migration between night and day depths of maximum abundance is calculated to occur at minimum rates of about 180 m/hr (for smaller fish, mean SL = 12.2 mm) and 260 m/hr (for larger fish, mean SL = 23.4 mm) in late summer and 250 m/hr in winter.

Captures made at several intermediate depths about the times of sunrise and sunset at both seasons indicate that the population did not migrate as an entity.

TABLE 32.—Vertical distribution by 50-m intervals of *Bolinichthys indicus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE
												DAY											
SURFACE																	1				1	1	6.0	6
1- 50																	1				1	1	10.0	10
501- 550		35			35	45	11.8	11-14	-	-	-	-	-											
551- 600		16			16	35	15.9	13-20																
601- 650		69	2		71	213	14.0	11-25		<1			<1	1	15.0	15		36			36	106	12.2	10-16
651- 700		37	19	1	57	*				1	1	<1	2	8	19.7	13-32		18	1	2	21	*		
701- 750		4	37	1	42	106	26.8	18-38	-	-	-	-	-					1	3	4	8	21	29.8	13-38
751- 800		3	19	1	23	*			<1				<1	1	8.0	8			2	5	7	20	33.0	30-37
801- 850		1	1	<1	2	7	28.4	13-38	-	-	-	-	-					13	4	11	28	66	23.4	10-38
851- 900	-	-	-	-	-													6	2	6	14	*		
901- 950	-	-	-	-	-				-	-	-	-	-				2	<1			2	7	11.3	9-19
951-1000	-	-	-	-	-												4	<1			4	*		
1001-1050									-	-	-	-	-				5				5	16	10.2	9-11
1051-1100	-	-	-	-	-												-	-	-	-	-			
1101-1150	-	-	-	-	-																1	2	10.5	10-11
TOTALS	0	165	78	3	246	406			<1	1	1	<1	2	10			13	75	12	28	128	240		
												NIGHT											
SURFACE																	1				1	2	5.7	4- 8
1- 50		2	1		3	15	18.8	12-30									1				1	1	7.0	7
51- 100		14	4		18	179	18.4	12-30	1	8	3		12	56	27.2	13-37		2	<1	1	3	26	19.8	13-37
101- 150		3	8	<1	11	52	24.9	17-36										20	2	2	24	70	16.0	12-35
151- 200	1	2	1		4	21	17.3	10-37		1			1	2	29.5	19-40		2	<1	1	3	23	23.0	11-36
201- 250			1	<1	1	5	30.8	21-39												<1	<1	1	36.0	36
251- 300	-	-	-	-	-													<1		1	1	3	28.7	14-39
301- 350			1		1	1	29.0	29	-	-	-	-	-				<1				<1	1	8.0	8
351- 400																		1			1	1	16.0	16
551- 600		2			2	3	11.7	11-12									-	-	-	-	-			
601- 650									-	-	-	-	-					2			2	2	11.0	11
651- 700	-	-	-	-	-				-	-	-	-	-											
701- 750									-	-	-	-	-											
751- 800		<1			<1	1	30.0	30																
801- 850																	-	-	-	-	-			
851- 900		1			1	2	11.5	11-12	-	-	-	-	-				.2	1			3	9	10.8	9-12
901- 950	-	-	-	-	-				-	-	-	-	-					1	1		2	6	17.3	11-30
951-1000																	10	<1			10	31	10.2	9-11
TOTALS	1	24	16	<1	41	279			1	9	3		13	58			14	29	3	5	51	176		

Migration times and rates could not be determined for *B. indicus* in late spring because there were no positive samples at day depths near the times of sunset and sunrise.

PATCHINESS.—Patchiness by day was noted only in late summer at 601–650 m and 801–850 m; depths at which juveniles (shallower), and subadults and adults (deeper), respectively, were most abundant (Table 32).

Patchiness was more prevalent at night. Significant clumping was noted in the upper 100 m and at 151–200 m in winter, 51–100 m in late spring, and 51–100 m and 151–200 m in late summer. These were the depths of maximum abundance of juveniles in winter, of juveniles, subadults, and adults in late spring, and of no stage in late summer. Except for adults in winter, the three older stages were each caught at depths where clumping was indicated.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios.

TABLE 33.—Seasonal night to day catch ratios of *Bolinichthys indicus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	0.2:1	0.2:1	0.2:1	0.2:1
LATE SPRING	*	1.3:1	14.3:1	27.0:1	7.5:1
LATE SUMMER	1.1:1	0.4:1	0.3:1	0.2:1	0.4:1

including interpolated values, were 0.2:1 in winter, 7.5:1 in late spring, and 0.4:1 in late summer (Table 33). Except for postlarvae in winter and late summer, ratios for the developmental stages followed the overall seasonal trends. The most divergent ratios for all stages except juveniles occurred in late spring when total abundance, as well as that of each stage, was at a minimum (Table 30).

Significant differences in total day and night depth ranges were not apparent at any of the seasons sampled, eliminating compression as a factor in the differential catch rates. If large aggregations were present in narrow depth strata between those sampled, abundance estimates would be too small. Catch data from oblique samples made at night indicate that this was not the case.

Net avoidance may account partially for the observed discrepancy in late spring. Few juveniles were present at that time, and the population sampled (postlarvae not included) had a larger mean size (27.2 mm) than either that in late summer (18.2 mm) or in winter (17.8 mm). Both the mean and maximum sizes of day captures were much smaller than those of night captures (20.3 vs 27.4 mm and 32 vs 40 mm, respectively), suggesting increased diurnal net avoidance by larger subadults and adults in late spring.

Day and night size ranges were almost identical at the other two seasons, and the mean size (not including postlarvae) for night captures was greater than that for day captures in winter and smaller than that for day captures in late summer. These contradictory data indicate that differential net avoidance probably was not the sole cause of the day-night differences in winter and summer.

Bolinichthys photothorax

This moderately large species reaches maturity at 50–60 mm and grows to about 73 mm (Hulley, 1981). The Ocean Acre collections contain 15 specimens (20–60 mm) of *B. photothorax*, which is a tropical-semitropical species found mainly to the south of the study area (Nafpaktitis el al., 1977). The species probably is an expatriate in Bermuda waters, where presumably it does not reproduce. Juveniles were 30–46 mm, subadults 44–57 mm, and the only adult (a male) 60 mm.

Bolinichthys photothorax is a "rare" lanternfish in the study

area, being represented by 15 specimens in the collections (Table 23). Five specimens were taken in discrete-depth samples: in winter during daytime a juvenile at 601–650 m, and at night a subadult at 151–200 m; in April at night a juvenile from 151–200 m; in late spring during the day a subadult at 751–800 m; and in late summer at night a juvenile at 151–300 m. In late summer, open Engel trawls caught eight specimens (40–60 mm), six from the upper 200 m at night and two from maximum depths of 750–800 m during daytime. The remaining two individuals were caught in late summer in open IKMT's towed at maximum depths of 550 m at night and 750 m at dawn.

Bolinichthys supralateralis

This species, a questionably tropical-subtropical myctophid in the Atlantic, is known to occur in tropical and subtropical waters of the Indian Ocean, off Australia, and near Hawaii (Nafpaktitis et al., 1977). It is a large lanternfish reaching 117 mm (Hulley, 1981); maximum length in the Ocean Acre collections is 97 mm. This "uncommon" lanternfish was represented in the collections by a total of 107 specimens, 36 from IKMT's and 71 from Engle trawls. Six of the 16 specimens taken during the paired seasonal cruises were caught in discrete-depth, noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Juveniles were 11–51 mm, subadults 39–91 mm, and the single adult (a female) 97 mm. Most fish smaller than 30 mm SL could not be sexed, but most of those larger could. The adult female contained ova up to 0.3 mm in diameter, but most were 0.1–0.2 mm. Johnson (1975) indicated that there is no external sexual dimorphism, but Nafpaktitis et al. (1977) noted that the size of the infracaudal luminous gland may be sexually dimorphic. There may also be sexual dimorphism in size. The four largest fish (83–97 mm) in the collections were females; the largest male was a 74 mm subadult. Because only six specimens larger than 70 mm were caught, five of which were subadults, the apparent dimorphism may be the result of the paucity of large specimens.

Females were slightly, but not significantly, more numerous than males in the collections (41 vs 32, respectively; chi-square = 1.1, p nearly equal to 0.3).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive status and life span of *B. supralateralis* in the study area are uncertain. The small juveniles (smaller than 20 mm) and adult females present in the collections suggest that spawning may occur near Bermuda, and the size-frequency distribution (showing three size classes, se below) of all specimens caught in late summer (including those taken by the Engel trawl) suggests a life span of at least two years.

Apparently the parent population has a restricted breeding season. Small juveniles (smaller than 20 mm) were

caught only in late summer and fall, suggesting that spawning occurs in late spring to early summer.

Large fish (larger than 50 mm) were caught in February, April, June, and August, and may have been present, but not sampled, throughout the year. The ineffectiveness of the IKMT in sampling large fish of this species was evident when collections taken in late summer were compared with the Engel trawl catches. IKMT samples from three cruises contained 16 fish 12–42 mm, with only the largest specimen in excess of 20 mm, and Engel samples from a single cruise contained 71 specimens 35–97 mm. Presumably, the IKMT samples large fish equally poorly at all seasons.

Specimens caught in late summer comprise at least three size classes, which may represent spawning classes: recruits 12–20 mm caught only with the IKMT; 35–74 mm fish most of which probably were one year old; and 91–97 m fish at least two years old. The intermediate group may have two size classes (35–54 mm and 56–77 mm), but there were too few specimens to be certain.

VERTICAL DISTRIBUTION.—One fish was caught in a discrete-depth day sample at 601–650 m in late summer. Night depths of occurrence were 701–750 m in winter and 201–300 m in late summer. All positive Engel collections were from deeper than 650 m, both day and night.

Apparently fish larger than about 35 mm undergo little, if any, diel shift in depth; all such specimens were taken in nets that fished deeper than 650 m. Smaller individuals (12–16 mm) may be vertical migrants in late summer. Some were taken at 201–300 m at night and others were caught below 450 m by day and during crepuscular periods.

Centrobranchus nigroocellatus

This slender-tail species is found between about 40°N and 35°S in the Atlantic Ocean, where it is a questionably tropical-subtropical species (Backus et al., 1977), in the Indian Ocean between 5° and 26°S (Nafpaktitis and Nafpaktitis, 1969), and in the South Pacific Ocean (Craddock and Mead, 1970; Wisner, 1976). It is moderate in size, growing to 48 mm in parts of its range (Nafpaktitis et al., 1977). The largest specimen in the Ocean Acre collections is 35 mm.

Centrobranchus nigroocellatus, a "common" lanternfish in the study area, was included in the twenty most abundant lanternfishes only in late spring, when it ranked eighth (Table 23). Most fish were taken at the surface by night. A total of 527 specimens was caught. Slightly more than 91 percent of the fish taken on the paired seasonal cruises (389 of the 434 collected) were from neuston samples. Only 29 individuals were taken in discrete-depth samples made below the surface, 23 of these from noncrepuscular times.

DEVELOPMENTAL STAGES.—Postlarvae were 4–12 mm, juveniles 12–20 mm, subadults 18–35 mm, and adults 28–33 mm. Several large females (larger than 30 mm) catego-

rized as subadults had reduced, flaccid ovaries and apparently were spent adults. Nafpaktitis et al. (1977) reported that C. nigroocellatus reaches sexual maturity at about 34 mm, nearly the maximum size attained by the Bermuda population, suggesting geographic variation in both size at maturity and maximum size for the species. Subadult and adult males have supracaudal luminous tissue, and females of the same stages have infracaudal luminous tissue. There may also be a sexual dimorphism in size. Only females were greater than 32 mm, but the mean size of subadults and adults combined was similar for both sexes (males 25.0 mm, females 24.5 mm).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—This species lives about a year. Spawning probably takes place from fall to summer with a peak in intensity in spring. Abundance was greatest in late spring, shortly after the peak in spawning intensity, when recruits dominated the catch. In late summer total abundance and, except for postlarvae, abundance of all stages was least.

The winter population was predominantly subadults, with juveniles and adults less and about equally abundant (Table 34). The few juveniles caught were mostly 20 mm and smaller and probably represented the earliest spawn. Most subadults presumably would ripen and spawn in spring.

By late spring the peak in spawning was past, and the catch was dominated by juvenile recruits 20 mm and smaller. Most of the winter population had spawned and died. The abundances of subadults and adults showed little change from their winter levels (Table 34). Some earliest spawned recruits were now subadults, some recently spent adults were categorized as subadults, and the smallest subadults of winter were just maturing. Postspawning mortality was evident in the reduced abundance of 23–35 mm fish from that in winter.

In late summer all stages were at or near their yearly minimum. The reduced abundance of larger fish is understandable, and probably is attributable to postspawning mortality, with none of the recent recruits having yet grown large enough to replace them. However, the low abundance of all stages (Table 34) and sizes is perplexing and, clearly, is incongruous with the greater abundance of larger fish in winter. There is no evidence of additional spawning from late summer to winter, and the increased winter abundance cannot be accounted for in that way. Fishing effort at the surface was least in late summer, which may account for the small catch. However, only 2 of 14 nocturnal surface tows captured the species in late summer, by far the lowest proportion of positive neuston samples. This may be due to light conditions. It is well known that neuston species are not taken at the surface on well-lighted nights. Unfortunately, there are not enough observations on moon phase or cloud cover to pursue this in greater detail.

SEX RATIOS.—The sexes were about equally numerous in late spring and late summer, and males were much more

TABLE 34.—Seasonal abundance and percent of total abundance (in parentheses) for *Centrobranchus nigroocellatus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	0.4(4.5)	8.0(90.9)	0.4(4.5)	8.8
LATE SPRING	0.3(1.2)	16.4(68.3)	7.1(29.6)	0.2(0.8)	24.0
LATE SUMMER	0.3(14.3)	0.8(38.1)	1.0(47.6)	0	2.1

TABLE 35.—Numbers of each sex for each stage of *Centrobranchus nigroocellatus* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	8	2	47	28*	1	4	56	34*
SPRING	101	83	50	47	2	3	153	133
SUMMER	10	9	1	6	0	0	10	15

TABLE 36.—Vertical distribution by 50-m intervals of *Centrobranchus nigroocellatus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE						SL		CATCH RATE						SL		CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
							DAY																	
451- 500																								
501- 550		1			1	1	24.0	24		<1			<1	*										
551- 600		<1		<1	1	26.0	26			1			1	2	18.5	18-19		1			1	2	14.0	13-15
601- 650		<1		<1	1	26.0	26			<1	<1		<1	2	18.0	13-23								
651- 700		<1		<1	*				<1		<1		<1	2	21.0	11-31	-	-	-	-	-			
701- 750									-	-	-	-	-											
751- 800	-	-	-	-	-												<1				<1	1	11.0	11
TOTALS		1		1	3				<1	1	<1		1	6			<1	1			1	3		
							NIGHT																	
SURFACE	<1	7	<1		7	69	25.8	13-35		16	7	<1	23	222	17.8	12-32		1	1		2	2	21.2	19-23
51- 100		<1		<1	1	25.0	25			1			1	2	13.0	13			<1		<1	1	21.0	21
101- 150		1			1	3	26.7	25-30	<1				<1	1	9.0	9								
151- 200																	<1	<1	<1		<1	3	15.0	7-23
TOTALS	<1	8	<1		8	73			<1	17	7	<1	24	225			<1	1	1		2	6		

TABLE 37.—Number of specimens per hour of *Centrobranchus nigroocellatus* in neuston samples made approximately between sunset and sunrise local time (dash = no samples made).

MONTH	CRUISE	SUNRISE	SUNSET	1701 1800	1801 1900	1901 2000	2001 2100	2101 2200	2201 2300	2301 2400	0001 0100	0101 0200	0201 0300	0301 0400	0401 0500	0501 0600	0601 0700	0701 0800
JANUARY	11	0717	1730	-	-	-	-	0	-	6	18	0	-	-	0	-	-	-
FEB-MAR	13	0650	1815	0	11	3	0	0	0	1	0	0	18	9	6	-	-	-
JUNE	10	0510	1920	0	0	0	2	2	2	5	5	9	2	1	4	0	0	0
JUNE	14	0512	1925	0	0	6	20	24	29	12	-	-	2	1	2	0	0	0
AUG-SEPT	12	0551	1840	-	1	8	3	0	0	0	0	0	3	0	-	0	0	-

numerous than females in winter, with male-to-female sex ratios of 1.2:1, 0.7:1, and 1.6:.1, respectively (Table 35). Juvenile males were more numerous than juvenile females at all three seasons, but not significantly so. Male subadults were more numerous than female subadults in late spring and winter, with only the latter difference being significant. Only ten adults were caught during the paired seasonal cruises.

VERTICAL DISTRIBUTION.—Day catches in all seasons were poor; a total of 12 fish was collected in the three seasons combined. Combining day samples from the three seasons yields a depth range of 501–800 m, with most fish taken at 501–650 m. Night captures were made mostly at the surface, but in each season a few fish (less than 5) were taken between 51–200 m. Nothing could be determined about stratification according to stage or size.

Apparently, most fish beyond the transformation stage migrate on a regular basis, as all night captures were from the upper 200 m. In late summer, fish 11–13 mm were taken only by day. Their absence from neuston samples at night might be due to nonmigratory behavior, but they were not taken at day depths either, and fish that size were taken in neuston nets in the other two seasons (Table 36).

Surface waters were occupied no later than about one-half hour after sunset in each season. Catch rates for *C. nigroocellatus* taken in neuston samples at hourly intervals are given in Table 37. In January 1971 *C. nigroocellatus* was taken at the surface between 1.0 and 1.5 hours before sunset (not shown in Table 37). In June 1972 and August-September 1971 the species was taken in neuston samples made between about the time of sunset and one-half hour after sunset.

PATCHINESS.—Patchiness was indicated on the surface at night in all three seasons. In late summer two of 14 noncrepuscular samples captured a single fish each (there were other positive samples taken in the evening and morning crepuscular periods), which may indicate a low population density rather than a patch distribution. Table 37 shows that the abundance at the surface changed during the night in winter (January-March) and spring (June). This temporal change in abundance, which was especially prominent in winter, may be the major factor affecting the CD value.

NIGHT:DAY CATCH RATIOS.—Night catches were greater

than day catches at each season, with catch ratios of 2.5:1 in late summer, 5.2:1 in winter, and 12.6:1 in late spring. At each season, the catch of all stages and most sizes taken was greater at night than by day (Table 38).

The small number taken in the Isaccs-Kidd trawl (and nonneuston trawls in general) indicates that *C. nigroocellatus* avoids trawls quite well at all times. This is the major factor for the observed night-to-day catch ratio.

Ceratoscopelus maderensis

This species is found in the North Atlantic Ocean and Mediterranean Sea (Bolin, 1959), where it is distributed in a temperate-semisubtropical pattern (Backus et al., 1977). The species ranges as far north as Iceland (Bolin, 1959), and its southwestern limit is approximated by the Gulf Stream edge (Backus et al., 1970), placing the study area outside of its normal range. This moderately large species is known to grow to a size of about 70 mm in the Northwestern Atlantic slope water (Krueger et al., 1975; Jahn, 1976) and in the Mediterranean (Goodyear et al., 1972); maximum size is 81 mm (Hulley, 1981); maximum size in the Ocean Acre collections is 29 mm. It is a "common" lanternfish in the study area, being represented in the collections by a total of 489 fish, 90 of which are from the paired seasonal cruises. Discrete-depth samples account for 47 specimens, 36 of these from noncrepuscular tows (Table 23).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Ceratoscopelus maderensis is an expatriate, presumably not capable of development or prolonged survival in the Ocean Acre area. About 25 percent of the transformed specimens taken were examined for developmental stage and sex. All were juveniles and only two had recognizable ovaries or testes.

Almost all specimens (475) are from collections taken from July through October. The species is virtually absent during the remainder of the year. These data imply that the species is carried into the area from the spawning grounds to the north and that young individuals die soon after arrival.

The appearance of 171 postlarvae in the study area suggests that spawning occurs nearby. However, it is possible that eggs are carried to the south (perhaps in cold core eddies) after they are spawned and continue to develop until conditions become unfavorable. All but two postlarvae were taken during a single cruise in July 1968. The remaining two were taken in late spring (June). Presumably this reflects a spawning peak in the parent population sometime in late spring and early summer, which is similar to that of *C. maderensis* in the Mediterranean Sea (Taaning, 1918; Goodyear et al., 1972). Jahn (1976) has shown that the species has a strong preference for slope water and has indicated that it probably does not spawn successfully in the

TABLE 38.—Seasonal night to day catch ratios of *Centrobranchus nigroocellatus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	*	4.7:1	*	5.2:1
LATE SPRING	3.0:1	11.7:1	17.8:1	*	12.6:1
LATE SUMMER	0.7:1	1.6:1	*	*	2.5:1

northern Sargasso Sea. The present data support the latter contention. The species was moderately abundant in late summer, absent in winter, and scarce in late spring (Table 39).

VERTICAL DISTRIBUTION.—Day depths of occurrence in late summer were 751–1000 m with a maximum abundance at 751–800 m. In late spring a single specimen was taken at 301–350 m. Depth range at night in late summer was 33–250 m and 651–1000 m with a slight peak at 51–100 m. In late spring a single specimen was caught at 50 m (Table 39).

Small juveniles apparently do not migrate regularly. At night in late summer about half of the catch came from day depths (Table 39). All nonmigrants were less than 20 mm. The smallest migrant was 18 mm. Apparently, *C. maderensis* does not migrate until a size of approximately 19 mm is attained. Goodyear et al. (1972) showed that a similar situation exists in the Mediterranean Sea. Postlarvae were taken at or near the surface; most were from oblique samples.

NIGHT:DAY CATCH RATIOS.—The smaller catch taken at night than by day in late summer (0.4:1) may be due to the greater range of depths occupied at night. Avoidance probably is not a factor, as the largest fish caught in discrete-

TABLE 39.—Vertical dist.ibution by 50-m intervals of *Ceratoscopelus maderensis* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																
1– 50										1			1	1	21.0	21
301– 350		<1			<1	1	20.0	20								
351– 400																
401– 450	–	–	–	–	–											
451– 500																
501– 550	–	–	–	–	–											
551– 600																
601– 650																
651– 700									–	–	–	–	–			
701– 750									–	–	–	–	–			
751– 800										4			4	12	19.2	18–21
801– 850	–	–	–	–	–					2			2	4	17.0	16–18
851– 900										1			1	*		
901– 950	–	–	–	–	–					<1			<1	1	25.0	25
951–1000										<1			<1	*		
1001–1050	–	–	–	–	–											
TOTALS		<1			<1	1				8			8	18		
NIGHT																
1– 50		1			1	1	18.0	18		1			1	1	19.0	19
51– 100										1			1	9	21.4	18–24
101– 150																
151– 200										<1			<1	1	23.0	23
201– 250										<1			<1	1	21.0	21
651– 700	–	–	–	–	–					1			1	1	18.0	18
701– 750	–	–	–	–	–											
751– 800										<1			<1	1	19.0	19
801– 850										<1			<1	*		
851– 900	–	–	–	–	–					<1			<1	1	15.0	15
901– 950	–	–	–	–	–											
951–1000										<1			<1	1	18.0	18
TOTALS		1			1	1				3			3	16		

depth samples is 25 mm. Only two specimens were taken in discrete-depth samples in late spring.

Ceratoscopelus warmingii

This is a moderately large species growing to 81 mm (Hulley, 1981); maximum size in the Ocean Acre collections was 75 mm. A ubiquitous tropical-subtropical species, *C. warmingii* is a dominant lanternfish found in the North Atlantic subtropical region (Backus et al., 1977). Near Bermuda, *C. warmingii* is one of the "abundant" myctophids, being among the eight most abundant at each of the three seasons sampled (Table 131). A total of 4683 specimens was caught; 1862 were taken during the paired seasonal cruises, with 1226 of these from discrete-depth samples, 818 of which were from noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 5–18 mm, juveniles 15–41 mm, subadults 35–36 mm, and adults 43–75 mm. Juveniles smaller than 25 mm could not be sexed; most of those 25–35 mm and all larger ones were sexed. Of those categorized as subadults, females larger than about 55 mm and males larger than about 45 mm may have been spent or recovering adults. Sexual dimorphism in size is apparent in the three older stages, with adult females (53–75 mm) averaging nearly 10 mm larger than adult males (43–55 mm). Adult females contained ova as large as 0.5 mm in diameter, but most eggs were 0.2–0.3 mm. Luminous tissue (other than photophores), for which no sexual dimorphism was apparent, was developed on fish 22–29 mm, sizes 6–13 mm smaller than reported by Nafpaktitis et al. (1977).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Ceratoscopelus warmingii* apparently has a one-year life cycle. Spawning takes place from spring to fall, perhaps extending into winter, with a peak in late spring. Most individuals live about a year and apparently some live longer, perhaps as long as two years. Abundance was lowest in late spring, although all stages except juveniles had their greatest abundance then (Table 40). In both late summer and winter total abundance, which was dominated by juveniles, was about 60 percent greater than that of late spring.

Adult-size females were caught at all seasons, but only from April to October did any of them have enlarged ovaries that either contained ova 0.2 mm or larger or looked spent. There is some indication that spawning may not occur continuously from spring to fall. None of the adult-size females (98 specimens) taken in July had large eggs (all were less than 0.1 mm), and most of them appeared to be in a postspawning condition.

Although they occurred over much of the year, postlarvae were most common from June to October; less than 5 percent of the total came from collections made at other times. They were most numerous in July, when nearly half the total number were caught. Small juveniles (smaller than 25 mm) were abundant in late summer and winter but virtually absent in late spring. Juveniles of all sizes made up nearly 90 percent of the catch in late summer, 80 percent in winter, and slightly more than 10 percent in late spring (Table 40).

The catch in late spring was dominated by subadults and postlarvae, which together accounted for 75 percent of the catch. Juveniles and adults were less and about equally abundant (Table 40). Adults were more than three times as abundant in late spring as in the other two seasons. This, together with the maximum abundance of subadults, suggests that spawning was at or approaching a peak. The presence of fair numbers of postlarvae shows that spawning commenced earlier in the spring. The paucity of juveniles, especially those smaller 33 mm, indicates that minimal spawning occurred over winter.

Larger fish in late spring showed strong sexual dimorphism in size. All those smaller than 43 mm were males, and all but two larger than 50 mm were females (males were 33–54 mm, and females 44–60 mm). Presumably, most of the larger fish of each sex were about a year old and had spawned recently or would spawn soon. Smaller fish probably were spawned the previous fall and had not yet grown to adult size. Males larger than about 50 mm and females larger than about 55 mm may have been more than one year old.

Recruits from the spring spawn dominated the catch in late summer. Juveniles accounted for more than 87 percent of the catch at night, with those 17–26 mm accounting for more than 68 percent and those 27–40 mm an additional 19 percent. Postlarvae made up about half of the remaining catch (Table 40). The largest juveniles probably represent the vanguard of the spring spawn, and the smaller group presumably was spawned near the peak in June. The reduced abundance of large fish (subadults and adults combined were about one-sixth as abundant as they were in late spring) suggests that most spawning already had occurred. Most subadults and adults caught in late summer were later spawners approaching one year in age. Some larger males (larger than 55 mm) probably were more than one year old and presumably had spawned in the spring.

TABLE 40.—Seasonal abundance and percent of total abundance (in parentheses) for *Ceratoscopelus warmingii* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.4(0.7)	42.3(77.6)	11.6(21.3)	0.2(0.4)	54.5
LATE SPRING	8.5(24.9)	4.5(13.2)	17.1(50.1)	4.0(11.7)	34.1
LATE SUMMER	3.3(6.2)	46.9(87.5)	2.1(3.9)	1.3(2.4)	53.6

Winter collections were dominated by recruits from the fall spawn, with fish smaller than 26 mm comprising more than 50 percent of the night catch (these fish were poorly sampled during the day). The catch of fish smaller than 26 mm at night in winter was about two-thirds that of the night catch of fish of the same size in late summer, which is assumed to reflect a decrease in spawning intensity between spring and fall. A peak at 17 mm, representing recently transformed fish, was entirely due to the catch in January and was not seen in late February. If the latest spawning occurred in October-November, development to the juvenile stage took between two and three months. Larger juveniles (25–35 mm) caught in winter probably were spawned the previous late spring and were 7–8 months old. Sexual dimorphism in size was evident in these larger juveniles, and females were, on the average, larger than males (33.0 vs 30.3 mm). Most winter subadults would be the earliest spawned and be about 9–10 months old. Fish larger than 55 mm were all females and may have been in their second year; perhaps some of the larger males also were. Most of these larger fish presumably had spawned during the previous season.

SEX RATIOS.—Significant differences from equality were noted for subadults at all seasons, males being more numerous in late spring and late summer and females in winter, with total male-to-female sex ratios of 2.6:1, 1.5:1, and 0.8:1, respectively (Table 41).

The difference observed in late spring may be due, at least in part, to a spatial segregation between the sexes at certain depths and times. Excluding postlarvae, 48 specimens, mostly subadults, were caught at about 50 m between 0200 hours and sunrise; the 45 that could be sexed were males. In winter at about 100 m at the same time discrete-depth samples caught 228 fish, mostly unsexable juveniles; of the 56 that could be sexed, 52 were females (60 percent were juveniles and 40 percent subadults). Samples from about 100 m between 0200 and 0300 hours in late spring and between 2100 and 2400 hours in winter contained about equal numbers of each sex, indicating that spatial segregation between males and females did not occur at all depths and times. Unfortunately, this matter could not be

pursued in greater detail because most large samples in winter and late summer contained relatively few sexable fish, and in late spring, when nearly all fish could be sexed, most positive samples contained fewer than 10 specimens.

VERTICAL DISTRIBUTION.—Day depths of occurrence in winter were 601–1550 m with maximum abundance at 1001–1200 m, in late spring 50–100 m, 351–400 m, and 651–1100 m with a maximum at 1051–1100 m, and in late summer 751–1150 m with a maximum at 801–850 m. Night depths in winter were 20–200 m, 801–900 m, and scattered between 301 and 600 m, with maximum abundance at 51–100 m and a secondary concentration at 801–900 m. In late spring, night depths were 50–100 m and scattered at 451–800 and 951–1000 m, with a maximum at 50–100 m. In late summer, night depths were 33–200 m, 851–1000 m, and scattered between 301 and 700 m, with a maximum at 51–100 m (Table 42).

Fish caught at 601–650 m during the day in winter actually may have been migrants. Eleven other daytime samples taken between 580 and 850 m failed to capture *C. warmingii*. The only positive sample, which caught five specimens, was made near the evening crepuscular period. The two following crepuscular samples during the same trawl had even larger catches (30 and 39 specimens per hour).

Stage stratification was evident day and night in late summer and during the day in late spring. Size stratification was evident day and night at all three seasons.

During the day in late summer the vertical range of juveniles encompassed that of other stages, but juveniles were concentrated at the upper limit of their range, which was shallower than the adult range and at the shallow end of the subadult range. Both subadults and adults were rather uniformly distributed vertically. In late spring only postlarvae were found shallower than 950 m during the day (Table 42).

Size stratification by day was well developed in late spring and late summer, and was weakly developed in winter. In late spring all fish caught above 900 m were postlarvae 7–16 mm, those from 950–1000 m were 14–50 mm, and those from 1051–1100 m were all greater than 36 mm. In late summer more than 95 percent of the catch from 751–850 m was 15–22 mm, and all fish from greater depths were larger than 22 mm. The mean size of the catch from 751–850 m was less than 20 mm; from greater depths it was more than 30 mm. In winter the smallest fish caught during the day were all from 601–650 m but, as suggested, these may have been migrants. The catch at 1001–1050 m averaged at least 3 mm smaller than that from deeper 50 m intervals (Table 42).

At night in late summer only postlarvae and juveniles were caught above 50 m. At that season the catch from the upper 50 m was 17–26 mm (only one specimen larger than 20 mm); at 51–200 m it was 8–63 mm (only two larger than

TABLE 41.—Numbers of each sex for each stage of *Ceratoscopelus warmingii* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; significant differences indicated by Chi-square test shown by a single asterisk (p = .05) or two asterisks (p = .01)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	118	101	17	75**	1	1	136	177*
SPRING	11	0**	62	23**	7	8	80	31*
SUMMER	19	27	30	4**	5	5	54	36

TABLE 42.—Vertical distribution by 50-m intervals of *Ceratoscopelus warmingii* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
												DAY												
1- 50									4				4	4	10.2	7-13								
51- 100									<1				<1	1	8.0	8								
351- 400									<1				<1	1	10.0	10								
601- 650		2			2	5	17.4	17-18																
651- 700	-	-	-	-	-				<1				<1	1	11.0	11	-	-	-	-	-			
701- 750									-	-	-	-	-											
751- 800	-	-	-	-	-				<1				<1	1	14.0	14		1			1	2	19.0	18-20
801- 850									-	-	-	-	-				1	11	1		13	35	19.7	15-43
851- 900	-	-	-	-					<1				<1	1	16.0	16		<1	<1	<1	<1	*		
901- 950	-	-	-	-					-	-	-	-	-					1	<1	<1	1	6	34.5	26-47
951-1000		3	1		4	*			1		1		2	8	26.0	14-50		1	<1	<1	1	*		
1001-1050		6	1		7	18	31.7	25-42		1	2	1	4	*				1			1	3	25.3	23-30
1051-1100		6	1		7	*				1	3	1	5	5	45.6	37-56		1	<1		1	*		
1101-1150		5	2		7	*												1	<1		1	4	36.0	23-51
1151-1200		5	2		7	*																		
1201-1250		4	2		6	6	35.5	28-49																
1251-1300		4	1		5	8	34.9	28-47	-	-	-	-	-											
1301-1350		3	1		4	*			-	-	-	-	-											
1351-1400		2	1		3	*			-	-	-	-	-				-	-	-	-	-			
1401-1450		2	1		3	*																		
1451-1500		1	1		2	*																		
1501-1550		1	1		2	4	39.2	31-49						1	12.0	12								
TOTALS		44	15		59	41			5	2	6	2	15	23			1	17	1	<1	19	50		
												NIGHT												
1- 50		4	1		5	32	32.6	20-65	6	2	6	2	16	24	31.9	9-54	1	10			11	23	17.8	6-26
51- 100		21	6	<1	27	262	31.7	18-64	<1	2	11	2	15	50	45.5	11-63	<1	25	2	<1	27	220	26.1	8-54
101- 150			<1		<1	1	56.0	56									1	4		1	6	17	25.1	11-63
151- 200	<1	2			2	17	18.4	15-24									<1	1	<1	<1	1	10	29.2	13-49
201- 250																								
251- 300	-	-	-	-	-																			
301- 350		1	1		2	3	48.7	31-61	-	-	-	-	-					1			1	3	29.7	28-31
351- 400	<1				<1	1	40.0	40																
401- 450																								
451- 500			<1		<1	1	58.0	58			<1		<1	1	46.0	46								
501- 550																		1			1	1	22.0	22
501- 600		1			1	1	18.0	18									-	-	-	-	-			
601- 651																								
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	1	21.0	21
701- 750									-	-	-	-	-											
751- 800									2				2	3	14.0	14								
801- 850		9			9	9	16.8	15-18									-	-	-	-	-			
851- 900		4			4	7	17.1	17-18	-	-	-	-					<1	3			3	11	16.9	16-18
901- 950	-	-	-	-					-	-	-	-	-					<1			<1	1	19.0	19
951-1000									<1				<1	1	18.0	18	1	<1			1	4	14.8	13-17
TOTALS	<1	42	8	<1	50	334			8	4	17	4	33	79			3	46	2	1	52	291		

50 mm); and at day depths (nonmigrants) it was 13–18 mm. Only five specimens were caught at intermediate depths. The mean size of the catch at 30–50 m and 851–1000 m was distinctly smaller than that at 51–200 m, where most of the catch was taken (Table 42).

In late spring more than 95 percent of the night catch from the upper 50 m, and only about 50 percent of that from 51–100 m, was 45 mm or smaller. All fish larger than 54 mm were caught at 51–100 m. The mean size of the catch at 51–100 m was 13.6 mm larger than from the upper 50 m (Table 42).

In winter all sizes, including most of the larger specimens, were caught in the upper 100 m at night, but most small fish (less than 20 mm) were taken at depths greater than 100 m. All specimens taken at day depths (nonmigrants) at night were 15–18 mm (Table 42). During late February and early March the spacing of samples detected a smaller scale stratification of fish caught at 51–100 m. Mean sizes were 30.9 mm at 68 m, 38.1 mm at 95 m, and 53.5 mm at 100 m.

Postlarvae were stratified by size in late spring and late summer and probably do not migrate vertically. In late spring most smaller postlarvae (less than 14 mm) were caught in the upper 100 m; all those between 14–18 mm were caught below 750 m both day and night. At night in late summer postlarvae 6–12 mm were caught in the upper 150 m, those 14–16 mm were caught at 851–1000 m, and 13 mm specimens were caught in both strata. Only one postlarva was caught during the day in late summer (Table 42). Postlarvae clearly spend the early part of their lives in the upper 100–200 m and, upon reaching 11–13 mm, descend to the deeper stratum where they continue to develop and metamorphose into juveniles before migrating regularly.

Diel vertical migrations occurred at all three seasons, but at each season part of the night catch came from daytime depths. Very few fish were caught at intermediate depths (201–700 m) at night in each season; those caught in late summer were 21–31 mm, those in winter 18 mm (one specimen) and 31–61 mm, and in late spring 46 mm (one specimen). Nonmigrants were all smaller than 20 mm, but fish of those sizes also were migrators.

All but one of the few 15–16 mm specimens caught at night were from day depths. Fish 17–19 mm were caught during the night at diurnal depths and also in the upper 200 m both in winter and late summer, indicating the onset of migratory behavior at this size range. Most 19 mm fish and all larger fish were caught only above day depths at night. Nonmigrants, including postlarvae, accounted for about 25 percent of the night catch in winter, about 6 percent of that in late spring, and 9 percent of that in late summer. Clarke (1973) noted that, near Hawaii, 15–19 mm fish were taken both in the upper 100 m and at 600–700 m, and that larger fish migrated regularly.

Little could be determined about the chronology of vertical migrations of *C. warmingii* in late spring, and only crude estimates of migration times and rates could be made for winter and late summer. In late spring a single fish was caught near 200 m within an hour after sunset. There were no positive day samples from shallow depths after 1000 hours; the earliest positive night sample in the upper 100 m was 2.5 to 3.5 hours after sunset, and the earliest sample at 50 m (it was positive) started at 0200 hours.

In winter, day depths were still occupied at about 2.5 hours before sunset (and possibly until 1.5 hours or less). Specimens were taken at 650 m and 225 m no more than 0.5 hour after sunset, and at 130 m no more than 1.5 hours after sunset. Fish were captured in the upper 100 m at least 2 to 3 hours after sunset; no samples were taken in the upper 100 m between sunset and those times, so it is possible that fish arrived in the upper 100 m earlier. Assuming that upward migrations were on the order of 3.5 hours in duration, migration between day (1050 m) and night (100 m) depths of maximum abundance averaged about 270 m/hr. Several specimens were caught at about 140 m within an hour of sunrise, but there were no positive day samples until 5 hours after sunrise.

In late summer the latest positive day sample ended more than 2 hours before sunset, but it was taken near the upper depth limit and caught only one specimen. Presumed migrants were taken at 301–350 m and 451–500 m no more than 1.3 hours before sunset. Fish reached the upper 50 m by 1.5 hours after sunset. This results in a migration time of about 2.5 hours and a migration rate of 160 m/hr between 500 and 100 m. Migration time between diurnal and nocturnal depths of maximum abundance (850 m to 100 m) would approximate 4.5 hours, giving a migration rate of about 170 m/hr. Some fish may remain in the upper 100 m as late as 0.5 hour after sunrise, but most probably begin the descent to day depths earlier. A sample made at about 90 m between 1.3 and 0.3 hours before sunrise caught four times as many fish as the following one-hour sample at the same depth, suggesting that a majority of the population begins to migrate within 1.3 hours of sunrise. Daytime depths were reached at least two hours after sunset. This was when the earliest diurnal sample made at day depths ended, so arrival times could have been earlier. Migration time between nocturnal and diurnal depths was, therefore, about 3 hours, yielding a migration rate of 250 m/hr between night and day depths of maximum abundance.

PATCHINESS.—Clumping apparently occurred only at night at each of the three seasons. Clumping was indicated at all three seasons at 51–100 m where, except for juveniles in late spring and adults in late summer, abundance of the three older stages was greatest. The two exceptions were close to the maximum concentration, which was small (Table 42). In late summer clumping was also indicated at 851–900 m, the depth at which nonmigrants were most abun-

dant. There was no indication of a patchy distribution for nonmigrants in winter or late spring.

Other significant CD values were thought to reflect distributional features other than clumping. A significant CD value in late spring at 951–1000 m during the day was due to one of only two positive day samples at that season; one in winter at 601–650 m during the day was due to a sample that probably caught early migrants (see "Vertical Distribution" section).

Night samples from the upper 50 m in late summer and the upper 50 m and 151–200 m in winter also had significant CD values. In late summer only two night samples were taken in the upper 50 m; the one that took fewer fish was made shortly after the crepuscular period, apparently when migrants were just reaching this depth. In winter the CD values obtained for samples taken in the upper 50 m and at 151–200 m may reflect vertical concentration in narrow strata within those depth intervals. In the upper 50 m one fish was taken in three 1-hour samples made at 18 m; none in three 1-hour samples at 34 m; 29 in one 0.6-hour sample at 40 m; and 2 in three 1-hour samples at 50 m. At 151–200 m, three samples each were taken at 175 m and 200 m; all the specimens were caught at 175 m, and neither series, when considered individually, had a significant CD. Year-to-year variation in population size or depth preference may also have contributed to the observed differences. The samples at 175 m were taken in January and those at 200 m in February one year later.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, for discrete-depth captures were 0.9:1 in winter, 2.3:1 in late spring, and 2.0:1 in late summer. Juveniles accounted for more than 75 percent of the catch in winter and late summer, and the total ratio in each of the two seasons was similar to that for juveniles (Table 43). Seasonal differences in stage and size composition, abundance, vertical distribution, and depth coverage were all factors in the observed differences in catch rates.

In late spring, when subadults and adults were most abundant, the difference between day and night catches was mostly due to fish 40 mm and larger, suggesting that increased net avoidance by day was the major cause of the observed difference. However, even fish 33–40 mm were more abundant in night samples, suggesting that the day

vertical range may not have been adequately sampled.

In late summer 65–70 percent of both day and night catches consisted of fish 16–25 mm. It is not likely that these fish effectively avoided the net, yet they were more than twice as abundant in night samples as in day samples. Fish larger than 39 mm, which presumably have a greater ability to avoid the net than smaller fish, were about equally abundant in day and night samples (2.7 and 3.1 per hour, respectively). Failure to sample a narrow concentration by day may account for most of the difference in catch rates.

The day depth range was poorly sampled in winter, but this was apparently compensated for by interpolated values, which accounted for more than half of the calculated abundance (Table 42). However, a poor estimate of the actual size composition of the population resulted from this technique. Therefore, fish 19–24 mm and fish larger than 50 mm were not accounted for by day.

Diaphus bertelseni

This rare, questionably tropical-subtropical (Backus et al., 1977) species is represented in the collections by five specimens, 29–45 mm, taken in August and September. One fish was taken by night at 175 m; the remaining four in Engel trawl collections. The species grows to about 91 mm, the size of the only recorded mature female (Hulley, 1981). Clarke (1973) has taken this or a very similar species near Hawaii.

Diaphus brachycephalus

This is a tropical-subtropical species (Backus et al., 1977). In the western Atlantic it is abundant south of about 25°N, but is not common in the Sargasso Sea (Nafpaktitis et al., 1977). The species also is known in tropical waters of the Pacific (Clarke, 1973). It reaches sexual maturity at about 28–30 mm and grows to a moderately large size of 50–60 mm (Nafpaktitis, 1968); maximum standard length (SL) in the Ocean Acre collections is 43 mm. It is an "uncommon" lanternfish in the study area, being represented by 84 fish in the Ocean Acre collections, and by merely 25 specimens in samples from the paired seasonal cruises (Table 23).

Juveniles were 10–26 mm (a total of three), subadults 25–40 mm, and adults 31–43 mm. Adult females contained ova up to 0.5 mm in diameter. Males larger than 25 mm have an enlarged Vn and can easily be distinguished from females. No sexual dimorphism in size is apparent.

Despite the presence of adult females with large eggs in the study area, the paucity of juveniles in the collections indicates that it is unlikely that the species successfully reproduces there. Two of the three juveniles taken were well beyond the transformation size (9–10 mm). Furthermore, the seasonal distribution of adult females (June to September) suggests that juveniles would predominate in

TABLE 43.—Seasonal night to day catch ratios of *Ceratoscopelus warmingii* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	1.0:1	0.7:1	*	0.9:1
LATE SPRING	1.4:1	3.0:1	3.2:1	2.7:1	2.3:1
LATE SUMMER	6.6:1	2.0:1	1.1:1	1.8:1	2.0:1

TABLE 44.—Vertical distribution by 50-m intervals of *Diaphus brachycephalus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval).

DEPTH (M)	WINTER CATCH RATE						SL		LATE SPRING CATCH RATE						SL		LATE SUMMER CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
												NIGHT											
101– 150				<1	<1	1	36.0	36		1	<1		1	3	37.3	37–38								
151– 200									1				1	1	26.0	26	1				1	4	27.0	25–30
201– 250											<1	1	1	5	37.2	32–41				<1	<1	1	31.0	31
TOTALS				<1	<1	1			1	1		1	3	9			1			<1	1	5		

fall and winter collections, yet this is not the case. No juveniles were taken in fall and winter collections, and only 5 subadults or adults were captured at that time. Abundance is greatest in late spring, when most fish are larger than 30 mm, intermediate in late summmer, and least in winter (Table 44).

All discrete-depth captures were from night tows made between about 150 and 225 m. The smallest fish, 10 mm, was taken in an oblique tow from 0–75 m. Diurnal captures with the Engel trawl suggest a depth range of 250–450 m. Clarke (1973) gave a depth range of 300–600 m by day and 30–200 m by night for *D. brachycephalus* near Hawaii.

Diaphus dumerilii

This tropical species is reported to have two distinct spawning areas, one in the Caribbean Sea and adjacent areas, and the other in the Gulf of Guinea. It probably is the most abundant lanternfish in the Caribbean Sea from which it is believed to be transported in the Gulf Stream system as far as 51°N (Backus et al., 1977). It is a moderately large myctophid, attaining a maximum size of 87 mm (Hulley, 1981) and maturing at 40–42 mm in the Gulf of Guinea and at 52 mm in the Carribbean (Nafpaktitis et al., 1977). Maximum size in the Ocean Acre collections is 53 mm. It is a "rare" myctophid near Bermuda, and is represented by 37 individuals in the Ocean Acre collections.

Juveniles were 17–33 mm, subadults 32–52 mm, and adults (all males) 45–53 mm. None of the females have ova showing any development beyond being recognizable. Males larger than 35 mm have a noticeably larger Dn than females of similar size.

The lack of small juveniles (10 mm) and adult females in the collections implies that the species does not breed in the area. This conclusion is reinforced by the extremely low abundance of *D. dumerilii* at all times.

Most likely, the individuals found near Bermuda are distributional waifs from the spawning area in the Caribbean Sea.

Little information is available concerning the depth range of this species. In discrete-depth samples, one fish was taken by day at 601–650 m in winter; three were caught at night near 50 m, one in late spring and two in late summer.

Diaphus effulgens

This bipolar subtropical species (Backus et al., 1977) is known to exceed 150 mm in length (Nafpaktitis et al., 1977). The largest specimen caught during Ocean Acre was 96 mm. *Diaphus effulgens* was uncommon in the study area at all seasons. The Ocean Acre collections contain 120 specimens; 51 were caught during the paired seasonal cruises, 36 of these in discrete-depth samples, of which 30 of the latter were in discrete-depth noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Juveniles were 12–58 mm, subadults 53–63 mm, and adult males 77–90 mm. Adult females were not taken. Juveniles smaller than 50 mm could not be sexed. The eight largest fish (69–96 mm) were males,

TABLE 45.—Seasonal abundance and percent of total abundance (in parentheses) for *Diaphus effulgens* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	JUV	SAD	AD	TOT
WINTER	0.8 (72.7)	0.3 (27.3)	0	1.1
LATE SPRING	0.8 (66.7)	0.3 (25.0)	0.1 (8.3)	1.2
LATE SUMMER	2.3 (12.0)	0.2 (8.0)	0	2.5

TABLE 46.—Vertical distribution by 50-m intervals of *Diaphus effulgens* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
501- 550	1				1	1	33.0	33	-	-	-	-	-					1			1	4	17.2	14-21
551- 600																		1			1	5	15.0	12-18
601- 650										1	<1		1	3	52.3	40-59								
651- 700	-	-	-	-	-					<1		<1	<1	2	64.5	43-86	-	-	-	-	-			
TOTALS	1				1	1				1	<1	<1	1	5				2			2	9		
NIGHT																								
51- 100	<1				<1	1	40.0	40		1			1	3	29.7	22-37		<1			<1	3	18.3	14-23
101- 150										<1			<1	1	57.0	57								
151- 200		1	<1		1	6	52.7	39-62											<1		<1	1	53.0	53
TOTALS	1	<1			1	7				1			1	4				<1	<1		<1	4		

and the largest female was 63 mm. This apparently is not a reflection of a sexual dimorphism in size, as Nafpaktitis et al. (1977) examined females up to 139 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive cycle and life span of *D. effulgens* in the study area is uncertain. Based upon the relatively large size attained, this species probably lives at least two years. The parent population probably breeds in spring and summer, with a peak in late spring. Abundance, although quite low at all times, is at a maximum in late summer (Table 45).

Recruitment of small fish (less than 20 mm) occurred only in August and September, at which time they made up more than 80 percent of the total number taken in both nondiscrete and discrete-depth samples. Adult males were caught only from June to September. The seasonal distributions of small juveniles and adult males suggest that spawning occurs in spring and summer.

In winter and late spring fish larger than 40 mm predominate, and abundance is about half that in late summer (Table 45). In late summer fish smaller than 20 mm dominated the discrete-depth collections. At that season the combined IKMT and Engel trawl catches apparently consisted of at least three year classes: young-of-the-year fish, 12-23 mm (taken only in the IKMT); fish about one-year old, 35-59 mm; and fish two or more years old, 80-92 mm. Fish of the latter two groups, with one exception, were taken with the Engel trawl.

VERTICAL DISTRIBUTION.—Vertical distribution for all seasons combined was by day, 501-700 m; and by night, 90-200 m. By day, fish taken at 501-600 m were 14-33 mm and those at 601-700 m depths were 40-86 mm; at night all but one fish 40 mm and smaller were taken at 90-100 m, with larger fish near or below 150 m. During both day and night juveniles were found throughout the vertical range; the more advanced stages were only at or near the lower depth limit (Table 46).

Diaphus fragilis

This tropical species (Backus et al., 1977) was represented in the collections by a 31 mm specimen taken in September. *Diaphis fragilis* grows to 99 mm (Hulley, 1981) and matures at about 60-70 mm (Clarke, 1973; Nafpaktitis et al., 1977).

Diaphus garmani

This species, taken only with the Engle trawl, is represented in the Ocean Acre collections by two specimens 27 and 31 mm. It is moderate in size, growing to about 60 mm and maturing at about 40 mm (Nafpaktitis, 1968). Most Atlantic captures are from the Carribbean Sea and Amazonian Province (Nafpaktitis, 1968; Nafpaktitis et al., 1977). The species also is known from the Indian and Pacific oceans (Nafpaktitis, 1968, Bradbury et al., 1971; Hartmann and Clarke, 1975).

Diaphus lucidus

This tropical species (Backus et al., 1977) is represented in the Ocean Acre collections by 16 specimens, 29–75 mm standard length (SL) taken from June to September. It is a large species, attaining 118 mm (Wisner, 1976). The only known gravid females are 98 and 99 mm SL (Nafpaktitis, 1968). Most of the specimens were taken by the Engel trawl; two were taken in discrete-depth samples at about 175 m during the night in late summer.

Diaphus luetkeni

This tropical species (Backus et al., 1977) is poorly represented in the Ocean Acre collections. Three fish, 20–37 mm, were taken: one in July and two in September. It is a moderately large species, maturing at about 42 mm and growing to about 60 mm (Nafpaktitis, 1968). One specimen was taken at night in late summer at 90 m in a discrete-depth tow.

Diaphus metopoclampus

This questionably bipolar, temperate-semisubtropical species (Backus et al., 1977) is found in the Atlantic Ocean mainly south of 30°S (Krefft, 1974) and north of 20°N (Nafpaktitis, 1968). Although everywhere rare, it seems to be most abundant in the slope water areas (Nafpaktitis et al., 1977). This is a fairly large myctophid, reaching a size of about 80 mm; maximum size in the Ocean Acre collections is 79 mm. The species is "uncommon" in the study area; a total of 125 specimens was caught, 70 were taken during the paired seasonal cruises. Discrete-depth samples account for 51 fish, of which 47 are from noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 6–8 mm, juveniles 9–35 mm, subadult females 71–79 mm, and adult males 62–75 mm SL. No subadult males or adult females were taken. With the possible exception of size, there is no sexual dimorphism (Nafpaktitis, 1968). Although no adult females were caught, a 74 mm female taken in August had a few large ova (0.2–0.3 mm) and slightly enlarged ovaries.

TABLE 47.—Vertical distribution by 50-m intervals of Diaphus metopoclampus (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING							
	CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																
501– 550	1				1	1	14.0	14	–	–	–	–	–			
551– 600	1				1	2	14.0	14								
601– 650									1	<1			1	6	32.2	20–79
651– 700	1				1	*			1	<1	<1		1	8	42.3	20–74
701– 750	1				1	3	14.0	13–15	<1		<1		<1	*		
751– 800	1				1	*										
801– 850	1				1	3	14.7	14–16	–	–	–	–	–			
TOTALS	6				6	9			2	<1	<1		2	14		
NIGHT																
301– 350									<1				<1	*		
351– 400									<1				<1	1	24.0	24
401– 450	1				1	3	14.7	13–14								
451– 500	<1				<1	1	13.0	13								
501– 550	1				1	2	15.5	13–17								
551– 600	1				1	2	25.0	15–35	<1		1		1	3	52.9	26–71
601– 650		1			1	1	65.0	65	–	–	–	–	–			
651– 700	2	1			3	*			–	–	–	–	–			
701– 750	3				3	10	15.3	13–19	–	–	–	–	–			
751– 800	<1				<1	1	14.0	14								
TOTALS	8	2			10	20			<1		1		1	4		

Gravid females 55–60 mm have been taken in the Gulf of Mexico (Nafpaktitis et al., 1977). Grey (1955) reported that a 73 mm female taken near Bermuda in August 1948 contained eggs in cleavage. This report has not been confirmed.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The life cycle of *D. metopoclampus* in the Bermuda area apparently is complex and, like that of its congener *D. rafinesquii*, may involve migrations into and possibly out of the area. It cannot be determined whether *D. metopoclampus* spawns in the area. Although the life span cannot be determined from the present data, it probably is at least two years. The parent population spawns over a relatively short time, probably in spring or summer.

All specimens caught were either 6–35 mm or 62–79 mm. The want of intermediate sizes in the Ocean Acre collections almost surely reflects their absence in the study area rather than a sampling bias. If intermediates were present, at least one specimen would have been caught during the 14 cruises. The missing sizes have been taken in midwater trawls fished in the slope water (Krueger et al., 1975; Jahn, 1976; personal observation) and in the Gulf of Mexico (Nafpaktitis et al., 1977). This means that large fish must migrate into the Bermuda area with some regularity to maintain their numbers. Small fish either migrate out of the area or die before they reach about 40 mm.

Small fish were mostly 9–12 mm in September to October, 13–17 mm in January to March, 20–26 mm in June, and 25–30 mm in July. Presumably those taken in June and July were 10–12 months old. It follows that large fish taken at those times were a year or more older than the small fish, and that the life span is at least two years.

The catch in September (one cruise only; none were taken during other September cruises) was almost exclusively 9–12 mm juveniles. The smallest of these fish probably were recently transformed juveniles, which suggests that spawning either takes place in the study area or in close proximity to it. The relatively large number of small fish taken in September (although not in discrete-depth samples) may indicate a peak in spawning activity at or just before that time.

Abundance was greatest in winter (Table 47). In late spring it was only about one-third as great as in winter. No estimate of abundance could be made for late summer because no specimens were caught in noncrepuscular discrete-depth samples. If spawning occurred in spring or summer, abundance would be greater in late summer than in winter.

VERTICAL DISTRIBUTION.—Depth range by day in winter is 501–850 m with no apparent concentration at any depth, and in late spring 601–750 m with a maximum abundance at 601–700 m. By night, depth range is 401–800 m in winter with a maximum at 651–750 m, and in late spring 351–400 m (1 specimen) and 551–600 m (3 specimens)

(Table 47). Three postlarvae were caught at 45 m near dawn in late summer. Gibbs et al. (1971) noted that an 18 mm fish was taken at 201–250 m by night in April.

These data show that small juveniles (13–19 mm) do not migrate regularly, and that at least some large fish over 60 mm remain at day depths during the night (Table 47).

Diaphus mollis

This moderate-sized lanternfish is known to attain 66 mm (Hulley, 1981); it grows to 50 mm in the study area. A tropical-subtropical species, *D. mollis* is a ranking myctophid in the North Atlantic subtropical region (Backus et al., 1977). It is a "common" lanternfish in the study area ranking 11th to 14th in abundance at all seasons (Table 131). It is represented in the Ocean Acre collections by 1559 specimens; 650 were caught during the paired seasonal cruises 461 of these in discrete-depth samples, of which 342 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 5–11 mm, juveniles 9–26 mm, subadults 25–49 mm, and adults 30–48 mm. Most juveniles less than 17 mm had thread-like gonads and could not be sexed. Adult females had eggs as large as 0.5 mm in diameter. Subadult males had a greatly enlarged luminous patch beneath the eye (Nafpaktitis, 1968), and tended to be larger than subadult and adult females (mean SL 38.4 mm vs 35.8 mm). Size ranges of both sexes were similar: males 13–48 mm and females 14–49 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Diaphus mollis* has a one-year life cycle, with only a few individuals surviving much beyond a year. Spawning occurs from early spring to fall, perhaps with a peak in intensity in late spring. Abundance is greatest in late summer, when *D. mollis* was the eleventh most abundant lanternfish. Juveniles were most abundant in late summer, subadults in winter, and adults in late spring (Table 48).

Adult-size females were taken throughout the year, but enlarged ovaries with eggs larger than 0.1 mm in diameter were observed only from April through November. Small juveniles (less than 20 mm) and postlarvae were most numerous in late summer. These seasonal distributions indicate that spawning occurs from spring to fall with a peak in intensity in late spring to early summer. At each season, subadult females within the adult size range (larger than 39 mm) were taken, suggesting that some individuals may live longer than one year and may spawn more than once. Unlike that near Bermuda, some populations of *D. mollis* apparently breed in winter (Nafpaktitis, 1968).

In late spring more than 80 percent of the population consisted of subadults and adults, with subadults half-again as abundant as adults (Table 48). Seasonal abundance of adults and their proportion of the population were greatest at that time. Juveniles were mostly larger than 20 mm and

TABLE 48.—Seasonal abundance and percent of total abundance (in parentheses) for *Diaphus mollis* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	2.1(15.8)	11.0(82.7)	0.2(1.5)	13.3
LATE SPRING	1.0(9.3)	1.0(9.3)	5.2(48.6)	3.5(32.7)	10.7
LATE SUMMER	0.5(2.0)	20.0(79.0)	2.9(11.5)	1.9(7.5)	25.3

TABLE 49.—Numbers of each sex for each stage of *Diaphus mollis* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV M	JUV F	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	5	11	53	45	2	0	60	56
SPRING	2	3	32	13*	22	13	56	29*
SUMMER	40	26	14	15	6	7	60	48

TABLE 50.—Vertical distribution by 50-m intervals of *Diaphus mollis* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	W PL	W JUV	W SA	W AD	W TOT	W N	W X	W RANGE	LS PL	LS JUV	LS SA	LS AD	LS TOT	LS N	LS X	LS RANGE	SU PL	SU JUV	SU SA	SU AD	SU TOT	SU N	SU X	SU RANGE
DAY																								
1- 50									1				1	1	7.0	7								
101- 150																		1		<1	1	3	20.0	13-30
151- 200																								
201- 250	-	-	-	-	-				-	-	-	-	-											
251- 300																								
301- 350											1	<1	1	3	39.0	38-41		<1			<1	1	14.0	14
351- 400																								
401- 450	-	-	-	-	-				-	-	-	-	-											
451- 500		1	4		5	8	34.5	28-40			1		1	2	35.5	30-41		<1	<1		<1	2	25.5	23-28
501- 550									-	-	-	-	-					8	1		9	34	15.9	10-34
551- 600																	<1	4	1		5	22	16.0	9-32
601- 650												1	1	2	44.0	43-45		2			2	5	9.0	9
651- 700	-	-	-	-	-						1		1	4	33.7	31-38	-	-	-	-	-			
801- 850									-	-	-	-	-					1			1	2	12.7	11-16
TOTALS		1	4		5	8			1		3	1	5	12			<1	16	2	<1	18	69		
NIGHT																								
1- 50	1	<1			1	13	16.4	12-27	1				1	2	17.5	14-21		10			10	21	12.2	9-16
51- 100	1	8			9	66	35.6	18-43			3	2	5	30	38.8	29-46		8	2	<1	10	82	18.4	9-41
101- 150		2			2	6	43.1	36-47			1	<1	1	3	43.0	40-45	<1		1	<1	1	5	31.2	10-38
151- 200		<1	<1		<1	3	47.3	45-49									<1			1	1	7	38.4	7-47
201- 250											2	1	3	7	43.7	41-46	<1	<1	<1		<1	4	34.0	11-45
251- 300	-	-	-	-	-													<1			<1	1	9.0	9
301- 350				1	1	1	45.0	45	-	-	-	-	-						<1		<1	1	40.0	40
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	1	17.0	17
TOTALS	2	11	<1		13	89			1		6	3	10	42			<1	19	3	1	23	122		

probably were from the previous year's spawn. Recruits from the spawn underway at that time apparently were too small to be adequately sampled by the nets, as only one postlarva was taken. Subadult and adult females were equally abundant (Table 49), but less than half of the subadults were as large as the smallest adult. This suggests that by late spring less than 25 percent of the female population had spawned and that the peak in spawning had just been reached or was yet to be reached.

In late summer recruits 9–25 mm accounted for more than 80 percent of the catch, subadults for about 12 percent, and adults about 8 percent (Table 48). Abundance of postlarvae almost certainly was underestimated at this season; about 80 percent of the total number were caught in late summer, but very few were included in samples used to estimate abundance. Juveniles 11–16 mm were most abundant and probably represented offspring of the spawning peak.

Juveniles accounted for about 16 percent of the population sampled in winter, subadults more than 82 percent, and adults 1.5 percent (Table 48). The reduced abundance of juveniles from late summer to winter, and the fact that all juveniles less than 19 mm were taken in January and all larger ones were taken in February to March, indicates that little or no recruitment into the population occurred after fall. Continued growth of the spring and early summer spawn resulted in the observed dominance of subadults in winter. A few subadults were greater than 40 mm and may have been in their second year of life. The lack of adult females further indicates a winter hiatus in spawning activity.

SEX RATIOS.—Males were more numerous than females at each of the three seasons (Table 49), with male-to-female ratios of 1.1:1 in winter, 1.9:1 in late spring, and 1.2:1 in late summer. Only the late spring ratio differs significantly from equality (Table 49). The difference in late spring was due mostly to subadults, for which the male-to-female ratio was 2.5:1, but adults also contributed to the difference. Except for subadults in late spring, none of the individual stage sex ratios was significantly different from equality (Table 49). The difference in late spring may be related to postspawning mortality, which presumably is greater for females.

VERTICAL DISTRIBUTION.—Diurnal depth range in winter was 451–500 m; in late spring the upper 50 m and 301–700 m with no concentration at any particular depth; and in late summer 101–150 m and 301–850 m with maximum abundance at 551–600 m. At night most specimens were taken in the upper 250 m with maxima at 51–100 m in winter and late spring, and 33–100 m in late summer (Table 50).

The shallow captures made by day in late spring (301–350 m) and late summer (101–150 m and 301–350 m) may represent valid records. It is unlikely that the specimens were contaminants, because several samples immediately preceding each positive shallow sample contained few or no specimens. However, if these depths are part of its diurnal vertical range, the species has a most unusual dispersal within the water column, with alternating positive and negative depth intervals.

Stage and size stratification were evident only at night. The lack of stratification by day may be an artifact of sampling, especially in winter and late spring, when the day catches were small (Table 50). In late summer almost 90 percent of the diurnal catch was juveniles, with most of the remainder subadults. Juveniles were captured both shallower and deeper than subadults, but both developmental stages had similar depths of maximum abundance. At 601–650 m all specimens captured were 9 mm (Table 50), which is thought to be the size at transformation (Nafpaktitis, 1968).

At night juveniles were most abundant in the upper 50 m at all seasons, subadults at 51–100 m at all seasons, and adults at 51–100 m in late spring and 151–200 m in late summer and winter. Subadults and adults occurred at greater depths than juveniles in winter and late spring, but juveniles were taken both shallower and deeper than subadults and adults in late summer. A 7 mm postlarva was taken in the upper 50 m during the day in late spring, suggesting that smaller postlarvae may inhabit the upper 50 m.

As would be expected from the observed stage stratification, size stratification also was quite prominent at night. Only the smallest individuals migrated into the upper 50 m at night in each season; all but two specimens (one, 27 mm, in winter and one, 21 mm, in late spring) captured at that depth were smaller than 20 mm SL (Table 50). Except for three juveniles taken between 201 m and 700 m in late summer, all individuals less than 35 mm SL were taken in the upper 100 m, and all those greater than 34 mm SL were below 100 m in each season. The mean size of specimens captured in the upper 100 m was noticably smaller than that of those taken below 100 m (Table 50).

Regular diel vertical migrations occurred at all seasons; only a single individual (a 17 mm juvenile in late summer) was taken at day depths during the night.

Migration times could be determined only for late summer due to the poor day catches in winter and late spring. An upward migration time of about 5.0 hours and a downward migration time of about 3.5 hours are suggested by capture data for *D. mollis*. Day depths were still occupied between 3.0 and 4.0 hours before sunset, and the species was taken in the upper 50 m by 1.5 hours after sunset. Day depths were occupied between 2.5 and 3.5 hours after sunrise, and some depths within the nocturnal range were still occupied at or near sunrise; specimens were captured at about 90 m and 200 m, but not at 45 m or 110 m. Assuming an upward migration time of 5.0 hours and a downward migration time of 3.5 hours, migration rates of 92 m/hr and 131 m/hr, respectively, were obtained for diel

TABLE 51. —Seasonal night to day catch ratios of *Diaphus mollis* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages. * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	4.2:1	3.1:1	*	3.3:1
LATE SPRING	*	*	2.1:1	3.5:1	2.2:1
LATE SUMMER	1.7:1	1.2:1	1.9:1	6.3:1	1.4:1

migrations between depths of maximum abundance.

PATCHINESS.—Apparently the species is well dispersed by day at all seasons. The only significant CD value (for samples from 101–150 m in late summer) was the result of a single positive collection taken near the beginning of the evening crepuscular period; specimens captured in that sample may have been early migrants. At night, clumped distributions were indicated at 50–100 m in winter, and 51–100 m in late spring and late summer. At each season the two most abundant developmental stages apparently were responsible for all or most of the clumping (Table 50). Significant clumping was indicated at the depth of maximum abundance of juveniles (50 m) and subadults (51–100 m) in winter, and subadults and adults in late spring. In late summer significant clumping was not indicated at the depth of maximum abundance (33 m) of juveniles, but only two samples were made in the upper 50 m. Clumping was indicated in late summer at 51–100 m where juveniles also dominated the catch. Subadults were most abundant at that depth.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios for discrete-depth samples were 3.3:1 in winter, 2.2:1 in late spring, and 1.4:1 in late summer (Table 51). Catch rates for each of the three older stages were greater at night than by day for each season sampled, but subadults and adults were relatively much more abundant at night than juveniles. In late summer, when juveniles accounted for almost 85 percent of the combined day and night catches, the night-to-day catch ratio was least deviant from 1 to 1. As would be expected from these observations, the mean size of specimens taken at night was greater than that of specimens taken by day at each season (35.6 vs 34.5 mm in winter, 38.2 vs 37.2 mm in late spring, and 18.2 vs 15.6 mm in late summer). In winter and late summer, specimens larger than 40 mm were taken only at night. The fact that the ratios appear related to size suggests that increased net avoidance by day was mainly responsible for low day catches.

Diaphus perspicillatus

This tropical species (Backus et al., 1977) is rare near Bermuda, being represented in the collections by a total of 17 specimens, 19–60 mm. All were caught between February and September. This is a moderate-size lanternfish maturing at 50–54 mm and growing to about 71 mm (Halley, 1981). The Ocean Acre specimens include ten juveniles 19–37 mm, five subadults 40–58 mm, and two adult males 57–60 mm. Based upon the lack of adult females and juveniles at or near the size of transformation at all seasons, and the lack of specimens of all stages in fall and early winter, *D. perspicillatus* probably is not a breeding resident of the study area. Nafpaktitis (1968) indicated that the main spawning area is south of the Sargasso Sea.

Four of the five fish caught during the paired seasonal cruises were taken in discrete-depth tows; three at 18–70 m during the night (all seasons combined), and one, a probable contaminant, at 1501–1550 m by day in late spring. Five specimens (36–60 mm) were taken in the upper 50 m at night in August with the Engel trawl. Clarke (1973) gave a depth range of 490–600 m by day and 15–100 m by night for *D. perspicillatus* (as *D. elucens*) near Hawaii.

Diaphus problematicus

This large tropical lanternfish (Backus et al., 1977) is most abundant in the Caribbean Sea (Nafpaktitis et al., 1977). *Diaphus problematicus* grows to 105 mm (Parin et al., 1977), maturing at about 64–78 mm; maximum size in the Ocean Acre collections was 79 mm. The few gravid or nearly gravid females and very young juveniles (11–12 mm) from the North Atlantic are mostly from the eastern boundary of the Caribbean Sea (Nafpaktitis, 1968). The species is rare in the study area; there are only 24 specimens in the Ocean Acre collections, 8 of which were taken during the paired seasonal cruises.

Juveniles were 32–48 mm, subadults 48–79 mm, and adults (all males) 68–75 mm. At sizes larger than about 55 mm males have noticeably larger Dn and Vn luminous organs than females.

The overall low abundance, the lack of adult females and small juveniles (11–12 mm), and the generally restricted geographical distribution of these stages in the Atlantic indicate that *D. problematicus* is not a breeding resident in the Ocean Acre.

Discrete-depth samples include four fish: two from night samples in late spring at 150 and 205 m; and two in late summer, one at about 625 m during the day, and the other at about 500 m near sunset.

Diaphus rafinesquii

This is a large myctophid, growing to 89 mm in the study area (Gibbs et al., 1971), which is about the maximum size attained (Nafpaktitis et al., 1977). The species reaches sexual maturity at about 65 mm (Nafpaktitis, 1968; 50 mm according to Taaning, 1918). A common temperate-semi-

subtropical species (Backus et al., 1977) it is most abundant in the North Atlantic temperate region (Nafpaktitis et al., 1977). It is common near Bermuda, being represented in the Ocean Acre collections by 342 specimens; 193 were caught during the paired seasonal cruises, 128 of these in discrete-depth samples, of which 93 were caught in noncrepuscular tows.

DEVELOPMENTAL STAGES.—The one postlarva was 11 mm, juveniles 9–26 mm, subadults 61–87 mm, and the only adult (a male) 66 mm. All juveniles had small, barely discernible gonads that could not be sexed under the dissecting microscope. Females showed little development of ovaries or eggs, with most eggs less than 0.1 mm in diameter, the maximum size observed. Subjectively, males seemed to be more developed sexually than females. Males had a larger Vn than females of a comparable size. There also may be a sexual dimorphism in size. Males were 61–82 mm and females 65–87 mm. A greater proportion of females than males were larger than 70 mm (37 vs 17 percent). Data given by Goodyear et al. (1972) for fish taken in the Mediterranean Sea also show a difference in size for the sexes; adult males were 53–69 mm and adult females 54–78 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The life history of *D. rafinesquii* in the study area is quite complex and, as is the case with *D. metopoclampus*, may involve migrations into and out of the study area. Spawning probably does not take place in the study area. Therefore, the population must be maintained by recruitment from outside, possibly from the north or northeast. The parent population spawns in fall-winter. The life span probably is at least two years.

Abundance was greatest in late spring, when the catch consisted only of subadults in excess of 60 mm. It was intermediate in winter and least in late summer. In winter juveniles accounted for nearly 70 percent of the catch (Table 52).

All specimens were either 9–31 mm or 61–87 mm. Small fish were taken from January to April. All those 9–12 mm were caught in January. Large fish were taken at all seasons and constituted the entire catch from June to December.

The lack of specimens 32–60 mm in the Ocean Acre collections, although puzzling, probably reflects the situation in the study area rather than a sampling bias. This suggests that by April most young specimens have either died or migrated out of the study area. Therefore, large fish must migrate into the area to maintain their numbers. To account for their presence at all seasons, they must either be able to survive in the area or must migrate into the area on a regular or periodic basis. This situation apparently is unique to the study area. Most of the missing sizes have been taken east of the area (Huliev, personal communication), in the Mediterranean Sea (Goodyear et al., 1972), in slope water near Hudson Canyon (Krueger et al., 1975; personal observation), and near the Canary Islands (Badcock, 1970). Although all females captured in the

study area were larger than the reported size at sexual maturity for other populations of *D. rafinesquii* (Taaning, 1918; Nafpaktitis, 1968; Goodyear et al., 1972), none were ripe or nearly so. Nafpaktitis (1968) suggested that the species is an expatriate in the western North Atlantic and that spawning does not occur west of 40°W. Although the absence of ripe females in the collections would support this hypothesis, the recruitment of juveniles 9–12 mm (the size at metamorphosis; Taaning, 1918) in January does not, and suggests that there may be a breeding population not too distant from Bermuda. In any case, the parent population must spawn in fall or winter, the spawning season in the Mediterranean Sea (Taaning, 1918; Goodyear et al., 1972), to account for the capture of such small recruits.

In winter small fish predominate. These juveniles are mostly 9–12 mm in January and 18–21 mm in February. By late spring all small fish have died or left the area, and the catch consists exclusively of subadults. Abundance in late spring is nearly twice that in winter (Table 52), suggesting that there has been a migration of large fish into the study area. By late summer abundance is drastically reduced, with only a few 60–65 mm specimens being caught. This reduction in abundance may be due to failure of large fish to survive in the area or to their migrating out of the area.

It is unlikely that the largest juveniles caught in winter (26 mm) and the smallest subadults in late spring (63 mm) represent the same recruit class at different ages. The capture of large fish at all seasons suggests a life span of at least two years.

SEX RATIOS.—Fewer than 10 subadults and adults were taken in either late summer and winter, with the sexes about equally numerous in the collections (Table 53). In late spring females were slightly more numerous than males with a ratio of 1.2:1.

VERTICAL DISTRIBUTION.—Depth range by day in winter was 451–650 m with maximum abundance at 451–500 m, in late spring 451–700 m with no apparent concentration at any depth, and in late summer three fish were taken at 601–650 m. Nocturnal vertical range in winter was 40–200 m and 351–550 m with a slight concentration at 51–100 m, in late spring 351–600 m with a maximum abundance at 501–550 m, and in late summer one fish was taken at 451–500 m (Table 54).

Stage and size stratification were evident day and night in winter, and size stratification by night in late spring.

By day in winter juveniles 15–20 mm were taken at 451–500 m, those 10–11 mm at 601–650 m, and one subadult was taken at 501–550 m and another at 601–650 m. At night in winter all juveniles were taken in the upper 200 m, while subadults were all from 351–550 m. Juveniles were stratified by size, those 10–12 mm long were from 151–200 m and those 23–26 mm from 51–100 m; intermediate sizes were taken at 40–200 m. Subadults also showed a size stratification during the day with an increase in maximum

TABLE 52.—Seasonal abundance and percent of total abundance (in parentheses) for *Diaphus rafinesquii* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	JUV	SAD	AD	TOT
WINTER	4.6 (69.7)	2.0 (30.3)	0	6.6
LATE SPRING	0	12.4 (100.0)	0	12.4
LATE SUMMER	0	1.1 (68.8)	0.5 (31.2)	1.6

TABLE 53.—Numbers of each sex for each stage of *Diaphus rafinesquii* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	0	0	4	5	0	0	4	5
LATE SPRING	0	0	29	35	0	0	29	35
LATE SUMMER	0	0	2	3	1	0	3	3

TABLE 54.—Vertical distribution by 50-m intervals of *Diaphus rafinesquii* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE						SL		CATCH RATE						SL		CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
												DAY												
351- 400																								
401- 450	-	-	-	-	-				-	-	-	-	-											
451- 500	4				4	7	17.0	15-20			<1		<1	1	63.0	63								
501- 550		1			1	1	70.0	70			<1		<1	*										
551- 600											<1		<1	1	76.0	76								
601- 650	1	<1			1	3	36.0	10-87			1		1	2	70.0	67-73					1	<1	1	3	67.0	66-68
651- 700	<1	<1			<1	*					<1		<1	4	70.7	67-74		<1	<1		<1	*		
701- 750									-	-	-	-	-											
TOTALS	5	1			6	11				1			1	8				1	<1		1	3			
												NIGHT												
1- 50	1				1	4	18.2	16-20																
51- 100	2				2	15	20.8	16-26																
101- 150	<1				<1	1	19.0	19																
151- 200	1				1	8	14.4	10-22																
201- 250																								
251- 300	-	-	-	-	-																			
301- 350											<1		<1	*										
351- 400		<1			<1	1	67.0	67			<1		<1	1	70.0	70								
401- 450																								
451- 500		1			1	2	72.8	67-76			2		2	6	66.5	64-70			<1		<1	1	69.0	69
501- 550		1			1	2	74.0	70-78			8		8	24	69.0	64-76								
551- 600											2		2	6	74.1	65-82		-	-	-	-	-		
TOTALS	4	2			6	33				12			12	37					<1		<1	1		

and mean size with depth, but only five fish were taken (Table 54).

By night in late spring larger subadults (77–82 mm) were taken only at 551–600 m, and those 64–76 mm were taken throughout the range. Mean and maximum sizes increased with depth from 451–600 m (Table 54).

Only juveniles undergo extensive diel migrations, but at least some subadults show a slight change in depth over a 24 hour period.

In winter all juveniles were taken at 40–200 m at night, or about 300–450 m shallower than day depths. Few subadults were taken by day, but in each season the upper

TABLE 55.—Seasonal night to day catch ratios of *Diaphus rafinesquii* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	JUV	SAD	AD	TOT
WINTER	0.9:1	1.5:1	*	1.1:1
LATE SPRING	*	6.5:1	*	6.5:1
LATE SUMMER	*	0.2:1	*	0.1:1

depth limit at night was shallower than by day. Although this could be due to enhanced diurnal net avoidance, a slight upward shift of at least some large fish seems a more likely cause for the shallower upper depth limit at night. Goodyear et al. (1972) noted a similar restricted diel migration in large *D. rafinesquii* in the Mediterranean Sea, with small fish having a more extensive diel migration. Badcock (1970) and Badcock and Merrett (1976) noted a similar pattern in the eastern Atlantic.

PATCHINESS.—A patchy distribution was indicated at night at 51–100 m in winter and at 451–500 m in late spring. Only juveniles were caught at 51–100 m in winter, and only subadults were taken at 451–500 m in late spring.

The significant CD value obtained for samples taken in the upper 50 m in winter may have been due to a vertical concentration rather than horizontal patchiness. Of 10 sam-

ples made at 18 m, 34 m, 40 m, and 50 m, only the single sample at 40 m was positive.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios (including interpolated values) for discrete-depth captures were 1.1:1 in winter, 6.5:1 in late spring, and 0.1:1 in late summer (Table 55).

In late spring, when the catch was exclusively subadults, the night catch was considerably greater than the day, suggesting that there was greater net avoidance during daytime. However, there was a diel difference in patchiness, which could have affected catch rates. Sample sizes were so small in late summer that catch rates have little reliability.

Diaphus splendidus

This large myctophid grows to about 90 mm, becoming sexually mature at about 50–55 mm (Nafpaktitis et al., 1977); maximum size in the Ocean Acre collections was 75 mm. A tropical-semitropical species (Backus et al., 1977), it is most abundant in the Caribbean Sea and other parts of the western tropical Atlantic (Nafpaktitis et al., 1977). It is an "uncommon" myctophid near Bermuda, being represented by 82 specimens in the Ocean Acre collections; 27 were caught during the paired seasonal cruises, 20 of these in discrete-depth samples, all in noncrepuscular tows.

Juveniles were 17–35 mm, subadults 38–75 mm, and

TABLE 56.—Vertical distribution by 50-m intervals of *Diaphus splendidus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
501– 550									–	–	–	–	–								<1	<1	1	23.0 23
551– 600		<1		<1		1	56.0	56																
601– 650		1		1		3	53.4	44–64		<1			<1	1	35.0	35								
651– 700		1		1		*											–	–	–	–	–			
701– 750									–	–	–	–	–											
TOTALS		2		2		4				<1			<1	1				<1			<1	1		
NIGHT																								
51– 100										<1	<1		<1	2	44.5	30–59		1	<1		1	7	30.6	24–38
101– 150		<1		<1		2	52.5	50–55																
151– 200																								
201– 250												1	1	3	69.0	65–75								
TOTALS		<1		<1		2				<1	1		1	5				1	<1		1	7		

adults (all males) 54–66 mm. No adults were taken during the paired seasonal cruises.

Because the collections contain neither adult females nor very small juveniles (10–12 mm), it is not likely that *D. splendidus* spawns in the study area. Periodic recruitment from the spawning area, presumably the Caribbean Sea (Nafpaktitis, 1968), is necessary for the population to maintain itself. The size-frequency distribution of the catch in late spring and late summer (including Engel trawl collections) indicates that at least two age groups are present at those times.

Depth for all seasons combined was by day, 501–650 m and, by night, 51–250 m (Table 56).

Diaphus subtilis

This fairly large, uncommon tropical-semisubtropical lanternfish (Nafpaktitis et al., 1977) is represented in the Ocean Acre collections by five specimens, 26–56 mm, taken in open net tows from July to September. This species grows to about 85 mm standard length and matures at about 70 mm (Nafpaktitis et al., 1977).

Diaphus termophilus

This presumed tropical species (Backus et al., 1977) is found in the Atlantic Ocean mainly in the Caribbean Sea and its immediate vicinity (Nafpaktitis, 1968); it is also found in the tropical Pacific, but apparently not in the Indian Ocean (Nafpaktitis et al., 1977). This moderately large myctophid grows to about 75 mm (Nafpaktitis et al., 1977). It is rare near Bermuda. A total of nine fish, 14–60 mm, was taken from April to September. Two individuals were caught in discrete-depth samples; one at 230 m during the night, and the other at 290 m near sunrise.

Diogenichthys atlanticus

This small lanternfish grows to a size of 22 mm in the study area, and very few specimens exceed 18 mm. Nafpaktitis et al. (1977) report it to attain 29 mm. An unevenly distributed tropical-subtropical species, it is one of the ranking myctophids in the North Atlantic subtropical region (Backus et al., 1977). *Diogenichthys atlanticus* is very abundant in the study area, being the second most abundant lanternfish in both winter and late spring and the fifth most abundant in late summer (Table 131). The collections contain 4013 specimens in all; 2824 were caught during the paired seasonal cruises, 1866 of these in discrete-depth samples, of which 1310 were from noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 5–13 mm, juveniles 11–16 mm, subadults 13–21 mm, and adults 14–22 mm. Even the smallest juveniles have recognizable ova-

ries or testes and, as a result, 95 percent of all juveniles examined could be sexed. Adult females contained ova as large as 0.5 mm in diameter, but most had eggs 0.2–0.4 mm. There was no apparent sexual dimorphism in size for any stage. Sexual dimorphism is evident externally at a size of 15–16 mm, with females developing infracaudal luminous tissue and males developing supracaudal luminous tissue and a larger Dn than females.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Diogenichthys atlanticus* has a life cycle of about one year. Spawning apparently takes place most or all of the year, but with very pronounced peaks in spring and fall. The population was dominated by young fish; postlarvae and juveniles together constituted from 59 percent of the catch in late summer to 92 percent in late spring. Total abundance and that of the three younger stages was greatest in winter. In late spring total abundance and the abundance of all stages, except postlarvae, was lowest. Adults were most abundant in late summer, when they accounted for nearly 18 percent of the total catch (Table 57). The maximum abundance of adults in late summer, and of postlarvae and juveniles in winter, suggests that most spawning occurs in fall.

Postlarvae were caught in the greatest numbers in June-July and January, and adults in August-September and February-March. This indicates that the most spawning takes place in fall and spring.

In late summer, juvenile recruits from the spring spawn accounted for about half of the catch, with the remainder being mostly adults and subadults. Postlarvae were at their minimum, indicating that spawning was reduced from late spring to summer. Adults, subadults, and probably large juveniles (larger than 14 mm) were spawned the previous late summer-fall and would soon mature and spawn.

In winter juveniles comprised half of the catch, and postlarvae, most of which were caught in January, made up about one-quarter. Most of these recruits from the fall spawn presumably would mature over the spring and summer and spawn in the fall at about one year of age. Adults, subadults, and perhaps large juveniles, most of which were spawned the previous spring, would soon mature, ripen, and spawn. The combined abundance of subadults and

TABLE 57.—Seasonal abundance and percent of total abundance (in parentheses) for *Diogenichthys atlanticus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	38.6 (24.6)	80.1 (51.0)	28.8 (18.3)	9.5 (60.0)	157.0
LATE SPRING	35.8 (51.4)	28.0 (40.2)	3.6 (5.2)	2.3 (3.3)	69.7
LATE SUMMER	8.6 (10.2)	41.5 (49.5)	19.0 (22.6)	14.8 (17.6)	83.9

adults increased slightly from the late summer level, because those lost through postspawning mortality in fall were replaced in winter by fish that were juveniles in late summer.

By late spring the second spawning peak had passed. Few large fish remained, and postlarvae and juveniles accounted for slightly more than 90 percent of the catch. The estimate of the abundance of recruits probably is much too low, for the catch of postlarvae in July was considerable, and those fish probably were too small to be retained by the nets in June. This low estimate of the abundance of young fish, together with the virtual absence of fish larger than 15 mm (Table 57), resulted in the minimum abundance observed in late spring.

SEX RATIOS.—The sexes probably are equally abundant at all seasons. Males were more numerous than females in winter and late spring, and slightly less numerous than females in late summer, with male-to-female ratios of 1.1:1, 1.2:1, and 1.0:1 for the respective seasons. None of these differences were significantly different from equality (Table 58). Juveniles of each sex were taken in roughly equal numbers at each season. Subadult males were more numerous than subadult females at each season, and adult males were more numerous than adult females in late spring. The differences for subadults in winter and late summer and for adults in late spring were significantly different from equality. Adult females were more numerous than adult males in winter and late summer; the latter difference being significant. The differences noted for adults and subadults may represent a sexual dimorphism in rates of maturity rather than a real difference in the numbers of each sex. The nearly equal numbers of juveniles of both sexes at each season supports this view. Badcock and Merrett (1976) reported a sex ratio of 1:1 for *D. atlanticus* near 30°N, 23°W in the eastern Atlantic.

VERTICAL DISTRIBUTION.—Day depth range in winter was 501–850 m (and probably deeper) with maximum abundance at 601–650 m, in late spring from the surface to 1100 m with a maximum at 751–800 m, and in late summer 25–1150 m with a maximum at 601–650 m. Nighttime vertical range in winter was 20–1050 m with maximum abundance at 851–900 m and a secondary concentration at

51–100 m, in late spring 50–850 m (and probably deeper) with a maximum at 51–100 m and 751–800 m, and in late summer 30–1000 m with a maximum at 51–100 m and a secondary concentration at 851–900 m (Table 59).

Stage and size stratification were evident day and night at each of the three seasons. Except for postlarvae in winter, the diurnal vertical range of juveniles and postlarvae was more extensive than that of subadults and adults; the latter two stages never occurred at either depth limit and were confined to the 551–800 m stratum at each season. Postlarvae were most abundant below 750 m, while the depth of greatest abundance of each of the other stages lay between 551 and 750 m at each season. In winter juveniles and subadults were most abundant at a shallower depth than adults. In terms of size, fish taken in the upper 300 m were all 7–21 mm, and all those taken below 750 m in late spring and below 800 m in winter and late summer were 11–14 mm. Fish larger than 16 mm were concentrated at 701–750 m in winter and at 751–800 m in late summer, depths that accounted for less than 10 percent of the total catch but for more than 80 percent of the catch of larger fish (interpolated values are not included in these figures). The mean size of the catch from those intervals was noticeably larger than for any other 50 m interval at both seasons. Larger fish, although present, were not sampled by discrete-depth daytime tows in late spring.

At night postlarvae and juveniles were caught over a greater range of depths than subadults and adults (excluding the subadult and adult, both suspected contaminants, caught in winter at 1001–1050 m). Adults and subadults (again, excluding the suspected contaminants) were caught only in the upper 500 m and were most abundant in the upper 100 m at each season. Catches of postlarvae and juveniles were greater below 750 m than at shallower depths at each season, although in late spring greatest abundance of postlarvae was at 51–100 m. Fish smaller than 10 mm were taken only in the upper 150 m at all seasons. Those larger than 15 mm (excluding the suspected contaminants) were taken only in the upper 100 m in winter and late spring, and only in the upper 500 m, but mostly the upper 100 m, in late summer. Specimens 10–14 mm were taken over most of the depth range, and constituted the entire catch made below 100 m in both winter (excluding the suspected contaminants) and late spring, and below 650 m in late summer (Table 59).

Postlarvae were stratified by size, and probably either do not migrate vertically or undergo only slight changes in depth during a diel cycle. Those smaller than 10 mm appear to be confined to the upper 150 m, being found deeper than 100 m only in late summer. Postlarvae 10–11 mm were taken throughout the vertical range, but mostly below 750 m. With the exception of one 12 mm specimen taken at the surface during the day in late spring, all larger postlarvae (12–13 mm) were caught below 750 m. Ob-

TABLE 58.—Numbers of each sex for each stage of *Diogenichthys atlanticus* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	242	250	135	63*	58	70	435	383
SPRING	86	83	12	11	25	10*	123	104
SUMMER	124	121	216	170*	84	140*	424	431

TABLE 59.—Vertical distribution by 50-m intervals of *Diogenichthys atlanticus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE						SL		CATCH RATE						SL		CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
SURFACE									<1				<1	4	9.2	7-12								
1- 50																	<1				<1	1	11.0	11
51- 100									1				1	7	9.9	9-10	<1				<i	2	8.5	8- 9
251- 300									<1				<1	1	11.0	11								
401- 450	-	-	-	-					-	-	-	-	-						<1		<1	1	14.0	14
451- 500									<1	<1			<1	3	12.3	11-14								
501- 550		13			13	17	12.8	11-14	<1	3	<1		3	*			<1				<1	1	11.0	11
551- 600		12	7	<1	19	43	13.9	13-16	1	5	1		7	20	13.4	11-15		<1			<1	1	15.0	15
601- 650		32	11	<1	43	133	13.6	12-19		3			3	8	13.6	13-14		19	3	<1	22	70	12.9	12-16
651- 700	<1	17	7	2	26	*			<1	4	1	1	6	29	13.8	11-15	<1	10	2	<1	12	*		
701- 750	<1	1	2	4	7	21	17.1	11-20	4	4	<1	<1	8	*			<1	1			1	4	12.7	12-14
751- 800	2	2	1	2	7	*			8	4			12	66	12.0	11-13		<1	2		2	8	16.4	14-19
801- 850	3	3			6	18	12.2	11-13	4	3			7	*				6			6	17	12.9	12-14
851- 900	-	-	-	-	-					1			1	3	12.0	12	<1	3			3	*		
901- 950	-	-	-	-	-				-	-	-	-	-				<1	<1			<1	3	11.3	11-12
951-1000	-	-	-	-	-					<1			<1	1	13.0	13	1	<1			1	*		
1001-1050									-	-	-	-	-				2	<1			2	7	11.6	11-12
1051-1100	-	-	-	-	-				2				2	2	12.5	12-13	2	<1			2	*		
1101-1150	-	-	-	-	-												1				1	3	11.7	11-12
TOTALS	5	80	28	8	121	232			20	27	2	1	50	144			9	12	8	1	59	118		
NIGHT																								
1- 50	<1	2	1	2	5	45	15.4	10-21	1			2	3	4	15.6	10-20		2	1	2	5	11	14.5	12-17
51- 100	2	2	6	7	17	167	16.0	8-21	13	4	2	<1	19	69	11.8	8-20	<1	2	15	11	28	233	15.8	12-18
101- 150										<1			<1	1	14.0	14	1	2	<1	<1	3	11	13.1	9-17
151- 200		<1			<1	2	11.5	11-12		1			1	2	14.0	14		<1	1	<1	1	14	15.0	10-17
201- 250										<1			<1	1	14.0	14								
251- 300	-	-	-	-	-																			
301- 350		<1			<1	1	14.0	14	-	-	-	-	-				<1		<1	<1	<1	8	15.9	12-19
351- 400									1				1	4	10.3	10-11	<1	1			1	3	11.3	11-12
401- 450	<1				<1	1	11.0	11									<1		<1		<1	4	12.7	10-15
451- 500																			<1	<1	<1	?	14.5	13-16
501- 550																		1			1	1	15.0	15
551- 600		2			2	7	12.1	11-13									-	-	-	-	-			
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	2	13.0	13
701- 750		<1			<1	1	12.0	12	-	-	-	-	-					<1			<1	1	12.0	12
751- 800	<1	<1			<1	3	11.7	11-12	9	8			17	26	12.3	11-14		2			2	5	12.4	12-13
801- 850	3	4			7	7	11.9	11-13	12	<1			12	24	11.8	10-13	<1	5			5	*		
851- 900	33	20			53	106	11.5	10-14	-	-	-	-	-				1	9			10	30	12.1	11-13
901- 950	-	-	-	-	-				-	-	-	-	-				<1	2			2	8	12.1	11-13
951-1000	1				1	1	14.0	14									2	1			3	9	12.1	11-14
1001-1050		<1	<1		<1	2	16.0	16	-	-	-	-	-				-	-	-	-	-			
TOTALS	38	31	7	9	85	343			36	13	2	2	53	131			4	28	17	13	62	342		

viously, initial development occurs at relatively shallow depths, and at 10–11 mm postlarvae descend to the greater depths where they transform into juveniles. Small postlarvae (less than 10 mm) may undertake limited vertical movements; in late spring they were taken in surface samples only at or near the time of sunrise. All nocturnal surface samples and all those taken during daytime (but more than 3.0 hours after sunrise) failed to catch this species (see "Night:Day Catch Ratios").

For juvenile and older stages, diel migrations were evident at all seasons but, as indicated above, not all individuals migrated. Recently transformed juveniles 11–13 mm are mostly nonmigrants, being caught mainly below 500 m both day and night. Most juveniles appear to become regular migrants at about 14 mm, as the majority of juveniles of that size were caught below 550 m in the daytime and in the upper 200 m at night. Except for the suspected contaminants in winter and possibly a few subadults at night in late summer, all nonmigrants were postlarvae and juveniles smaller than 15 mm (Table 59).

About 83 percent of the late spring, 40 percent of the late summer, and 76 percent of the winter populations were nonmigrants. Most nonmigrants were found at depths greater than 700 m (Table 59). In late spring about 33 percent of the nonmigrants were postlarvae found within the upper 100 m.

Times and rates of vertical migration were not estimated for late spring because more than 80 percent of the population apparently did not migrate, and almost all fish caught during the day were the size of nonmigrants (less than 15 mm, Table 59). Migration times in winter and late summer were based only upon the capture of specimens larger than 14 mm. In winter such fish were caught at 535 m no more than 2.3 hours before sunset, and at 95 m no later than 2.7 hours after sunset (the time that the earliest night sample taken in the upper 100 m ended). This gave a maximum of 5.0 hours for the evening migration. Other captures, made near 225 m and at 130 m within 1.2 and 0.8 hours after sunset, respectively, indicate that night depths probably were reached no later than 1.5 hours after sunset, a 3.8-hour migration. In late summer fish larger than 14 mm were caught near 500 m no more than 1.2 hours before sunset, and at 75 m no later than 1.2 hours after sunset, giving a maximum evening migration of 2.5 hours. Based upon this estimate and the 5-hour migration for winter, upward migrations occurred from day depths (650 m) to night depths (100 m) of maximum abundance at minimum rates of 220 m/hour in late summer and 110 m/hours in winter. Downward migrations apparently commenced between 0.7 and 1.7 hours before sunrise in winter and late summer, as fish were taken in the upper 100 m between those times at both seasons. Day depths were reached no later than 2.0 hours after sunrise in winter, giving a maximum migration time of 3.7 hours and a minimum rate of

migration of about 150 m/hour from night (100 m) to day (650 m) depths of maximum abundance of migrant fishes. Fish larger than 14 mm were not caught at day depths by 3 hours after sunrise in late summer; therefore, no estimate of morning migration time was made.

PATCHINESS.—Daytime patchiness was indicated in winter at 551–650 m and in late summer at 601–650 m, the depths of maximum species abundance at both seasons. Juveniles (which accounted for 71–86 percent of the total catch there) and subadults had their greatest abundance at those depths.

Patchiness at night was indicated in winter at 40–100 m and 851–900 m, in late spring near 100 m, and in late summer at 51–100 m and 851–900 m. These are the depths of maximum abundance of each stage in winter, of postlarvae and subadults in late spring, and of all stages except postlarvae in late summer. In winter and late summer patchiness in the shallower stratum probably involved subadults and adults, which together were more than 70 percent of the catch taken in those strata, while at 851–900 m postlarvae and juveniles were involved. In late spring patchiness involved mostly postlarvae and to a lesser extent juveniles.

Significant CD values obtained for day samples at 701–750 m in winter and at the surface in late spring, and for night samples at 551–600 m in winter and 151–200 m and 301–350 m in late summer, may have been a result of distributional features other than patchiness. The variation in catch in samples taken at 701–750 m during the day in winter and at 150–200 m at night in late summer was attributed to a single sample taken near twilight, and probably indicates a change in population density at both depths due to vertical migrations. Although depths of 551–600 m in winter and 301–350 m in late summer were sampled during each of the two cruises made during the two respective seasons, all or nearly all of the catch was from one of the cruises, indicating that year-to-year variation in population density was responsible for the large variance in the catch at both of the 50-m intervals in question. Four postlarvae were caught in 27 daytime surface (neuston) samples in late spring. This indicates the rarity of *D. atlanticus* in superficial waters rather than patchiness.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios for discrete-depth samples were 0.7:1 in winter, 1.0:1 in late spring, and 1.1:1 in late summer (Table 60). Although the total ratios were not significantly different from 1:1, at each season the night and day catches for one or more stages (Table 60) and for several sizes were significantly different. It is not likely that *D. atlanticus* can avoid the nets with any great success; the observed catch ratios can best be explained by diel differences in patchiness, extent of vertical range, and sampling inequities.

The abundance of postlarvae almost certainly was artificially low in winter and in late spring day samples, because

TABLE 60.—Seasonal night to day catch ratios of *Diogenichthys atlanticus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages).

SEASON	PL	JUV	SAD	AD	TOT
WINTER LATE	7.3:1	0.4:1	0.3:1	1.0:1	0.7:1
SPRING LATE	1.6:1	0.5:1	0.4:1	4.6:1	1.0:1
SUMMER	0.7:1	0.7:1	2.4:1	13.4:1	1.1:1

depths of significant concentrations of nonmigrators at night (851–900 m and 801–850 m, respectively) were not sampled during the day. But in late spring the catch of postlarvae at 51–100 m at night was nearly 13 times larger than the day catch at that depth (Table 60), even though the sampling effort during the day was half again greater than that at night (Table 2). All of these postlarvae were taken at 91–96 m; depths that were adequately sampled (4 or more hours) in the daytime. Clearly postlarvae in the upper layers must undergo at least limited diel vertical movements. Because there were no day samples made between 100 and 150 m, a diel shift of as little as 10 m could explain the virtual absence of postlarvae in day samples in the upper layers at that season.

Although the day catch of juveniles was about 1.5–2.5 times larger than the night catch, at each season there was a depth of considerable concentration of juveniles at night (between 751 and 900 m) that was not sampled during the day. At each season some juveniles migrated into the upper 200 m at night, but the catch from these depths was always small. It is possible that at night juveniles may have been concentrated at some depth that was not sampled, or that they were relatively uniformly distributed over a broad depth range. For example at night in winter a total of three fish was caught in discrete-depth samples made shallower than 40 m. But 46 specimens (mostly subadults and adults with a mean size of 17 mm) were taken in an oblique tow from 19 m to the surface which lasted about 25 minutes (a catch rate of 110.4/hour).

Gonichthys cocco

Although this medium-size lanternfish grows to 60 mm, the maximum size in the Ocean Acre collections was 45 mm, with very few exceeding 40 mm. According to Backus et al. (1977), *G. cocco* is a questionably tropical-subtropical species that is not found in the Caribbean Sea. Near Bermuda it is an "abundant" lanternfish. It is the most abundant one that comes to the surface at night, and ranks among the ten most abundant lanternfish at all three seasons. About 95 percent of all specimens caught were from night

neuston samples. Of the 1326 specimens caught, 1112 were taken during the paired seasonal cruises, 1057 of these from surface samples. Discrete-depth samples made with the 3-m Isaccs-Kidd midwater trawl during the paired seasonal cruises accounted for only 35 specimens.

DEVELOPMENTAL STAGES.—Postlarvae were 5–15 mm, juveniles 13–32 mm, subadults 26–45 mm, and adults 34–44 mm. Most juveniles 13–20 mm have slender thread-like gonads and could not be sexed. Several fish larger than 40 mm that were categorized as subadults apparently were spent adults. Adult females contained eggs as large as 0.45 mm, but most eggs were 0.25–0.35 mm in diameter. Subadult and adult males had supracaudal luminescent glands and subadult and adult females infracaudal glands. There was no sexual dimorphism in size.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— *Gonichthys cocco* has a one-year life cycle, with very few, if any, individuals surviving much beyond a year. Spawning occurs from winter to early summer, with a peak in winter or early spring. Abundance was greatest in late spring (Table 61), when *G. cocco* was the fourth most abundant lanternfish, and juveniles were most abundant. Subadults and adults were most abundant in winter.

The winter catch was dominated by juveniles, but subadults and adults were at their yearly high in abundance. Spawning evidently was low over late summer and fall, as most winter juveniles were 20–30 mm, and transformation occurs at about 14 mm (Taaning, 1918). By late spring much of the winter population had matured, spawned, and died, resulting in a decrease in abundance of subadults and adults and an increase in juveniles; in late spring most juveniles were 18–21 mm. Subadults and adults (small juveniles of the winter) would spawn and die by late summer. As a result of postspawning mortality, the older stages virtually were absent at that season (Table 61), and most fish were 20 mm or smaller. This suggests that few fish live more than one year.

Abundance most likely was underestimated both in late spring and late summer, as several 8 mm postlarvae were taken, and fish less than 10 mm probably were not adequately sampled by the nets. In winter small juveniles (16–20 mm) were at a minimum and subadults and adults at a maximum. Continuing mortality in the recruit class should have resulted in a decrease in total abundance from late summer to winter but, because of the underestimation of the late summer population, no significant change was apparent (Table 61).

SEX RATIOS.—The sexes probably are equally abundant at all seasons. Total female-to-male sex ratios were 1.0:1 in winter and 1.3:1 at the other two seasons; only the difference in late spring differed significantly from equality (Table 62). Most of the difference in late spring was due to juveniles, of which about half could be sexed. Adult females outnumbered adult males in winter and late spring, and

TABLE 61.—Seasonal abundance and percent of total abundance (in parentheses) for *Gonichthys cocco* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.7(1.8)	21.8(54.5)	12.2(30.5)	5.3(13.2)	40.0
LATE SPRING	0.3(0.6)	42.1(85.0)	3.9(7.9)	3.2(6.6)	49.5
LATE SUMMER	0.8(2.0)	37.6(96.2)	0.7(1.8)	0	39.1

TABLE 62.—Numbers of each sex for each stage of *Gonichthys cocco* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	102	94	70	66	27	31	199	191
SPRING	97	119	20	33	21	23	138	175*
SUMMER	7	12	2	0	0	0	9	12

TABLE 63.—Vertical distribution by 50-m intervals of *Gonichthys cocco* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
SURFACE										<1			<1	1	20.0	20								
51- 100									<1				<1	2	12.0	12								
501- 550		1			1	1	40.0	40	-	-	-	-	-											
551- 600		1			1	2	33.0	31-35																
601- 650		<1		<1	1	37.0	37											1			1	4	18.5	17-21
651- 700		<1		<1	☆							<1	<1	1	41.0	41		1			1	☆		
701- 750									-	-	-	-	-											
751- 800	-	-	-	-	-												<1				<1	1	13.0	13
801- 850	1				1	2	14.0	13-15	-	-	-	-	-					1			1	2	17.7	17-18
851- 900	-	-	-	-	-												<1	<1			<1	☆		
901- 950	-	-	-	-	-				-	-	-	-	-				<1				<1	1	15.0	15
951-1000	-	-	-	-	-				<1				<1	1	18.0	18	-	-	-	-	-			
TOTALS	1		2		3	6			<1	<1		<1	<1	5			<1	3			3	8		
NIGHT																								
SURFACE	21	12	5		38	267	29.1	18-43	42	4	3		49	462	22.7	16-44		37	1		38	55	20.0	17-30
1- 50																		1			1	1	19.0	19
51- 100									<1				<1	1	19.0	19								
101- 150	<1				<1	3	24.0	14-32									<1				<1	1	7.0	7
151- 200		<1	<1		<1	2	37.5	38-39																
751- 800	<1				<1	1	18.0	18																
801- 850																								
851- 900	1				1	1	16.0	16	-	-	-	-	-						<1		<1	1	19.0	19
TOTALS	<1	22	12	5	39	274			42	4	3		49	463			<1	38	1		39	58		

TABLE 64.—Number of specimens per hour of *Gonichthys cocco* in neuston samples made approximately between sunset and sunrise local time (dash = no samples made).

MONTH	CRUISE	SUNRISE	SUNSET	1701 1800	1801 1900	1901 2000	2001 2100	2101 2200	2201 2300	2301 2400	0001 0100	0101 0200	0201 0300	0301 0400	0401 0500	0501 0600	0601 0700	0701 0800
JANUARY	11	0717	1730	-	-	-	-	0	36	6	30	54	-	-	0	-	-	-
FEB-MAR	13	0650	1815	0	25	32	19	8	20	34	0	38	34	12	4	-	-	-
JUNE	10	0510	1920	0	0	0	7	10	8	15	6	10	2	38	20	0	1	0
JUNE	14	0512	1925	0	0	2	41	29	17	19	-	-	34	50	48	0	0	0
AUG-SEPT	12	0551	1840	-	0	2	29	7	0	0	44	8	13	28	-	0	0	-

juveniles and subadults showed no consistent trend in numerical dominance of either sex. None of the sex ratios for individual stages differed significantly from equality.

VERTICAL DISTRIBUTION.—Diurnal catches in each season were poor; only 19 fish were taken in all daytime discrete-depth samples combined. The combined seasonal day discrete-depth samples give a depth range of 501–1000 m, with no apparent depth preference (Table 63). *Gonichthys cocco* probably was well dispersed vertically by day at all seasons, as all positive samples contained 3 or fewer fish. One specimen, a probable contaminant, was taken at the surface by day in late spring.

A dramatic concentration takes place at night. More than 95 percent of the nocturnal catch in each season came from the surface (Table 63). In winter fish also were taken at 101–200 m and at 751–900 m, in late spring a single specimen was taken at 51–100 m, and in late summer one fish each was taken at 1–50 m and 851–900 m.

Only fish smaller than 20 mm were taken below 750 m day or night at all seasons (Table 63). Because day catches in each season contained mostly one developmental stage and night catches were mostly from the surface, little can be said concerning stage stratification.

Although most migrants were found at or close to the surface, at each season migrants also were taken well below the surface. These individuals were most abundant in winter, when juveniles, subadults, and adults all were taken at 101–200 m (Table 63). In late spring and late summer only a single migrant juvenile was taken well below the surface (at 90 m and 33 m, respectively).

Apparently, regular migratory behavior is assumed at about 16–19 mm. Larger sizes were all migrators, and a few 16–19 mm juveniles were taken at day depths by night in winter and late summer. Nonmigrants accounted for about 2 percent of the winter night catch, and less than 1 percent of that in late summer.

Migrations could not be traced in any season due to poor diurnal and evening crepuscular catches. In late summer one fish was taken at 501–550 m between 2.3 and 1.3 hours before sunset and another at 101–150 m between 1.5 and 0.5 hours before sunset. Surface waters were occupied 1.5 hours or less after sunset in each season. In late spring fish were taken at the surface between 1.5 to 0.5 hours before sunrise, and in late summer samples taken up to 45 minutes before sunrise were negative. Samples were not taken within 1.75 hours of sunrise in winter. Table 64 gives the catch rate (specimens/hour) for selected times for the five cruises during which neuston samples were taken.

PATCHINESS.—Significant patchiness was indicated at the surface by night in each season. Table 64 shows the great variation in catch rates even when samples taken from the same times on different days are combined. Examination of individual samples revealed even greater variation. Sequential samples often had catch rates that differed by a factor

TABLE 65.—Seasonal night to day catch ratios of *Gonichthys cocco* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.3:1	*	0.2:1	*	13.6:1
LATE SPRING	*	140.3:1	*	32.0:1	70.3:1
LATE SUMMER	0.4:1	12.1:1	*	*	9.9:1

of 2 or more. Additionally, on several occasions negative samples were interspersed amongst several positive samples.

A significant CD also was obtained for late spring day surface samples. However, this was due to the capture of a single fish, a probable contaminant. This obviously is not indicative of a patchy distribution even if the capture is a valid record for *G. cocco*.

NIGHT:DAY CATCH RATIOS.—Night catches were consistently larger than those of day, with ratios of 13.6:1 in winter 70.3:1 in late spring, and 9.9:1 in late summer (Table 65). The large night catches must be due, at least partially, to the great constriction of the vertical range at that time. Net avoidance is the obvious explanation for the virtual absence of this species from daytime samples; its effect at night cannot be evaluated.

Hygophum benoiti

This is a medium-size lanternfish known to reach a size of about 55 mm (Nafpaktitis et al., 1977); maximum size in the Ocean Acre collections is 44 mm. *Hygophum benoiti* is known only from the North Atlantic Ocean, where it is a temperate-semisubtropical species (Nafpaktitis et al., 1977) and, according to Backus et al. (1977), is among the dominant lanternfishes only off the west coast of Africa at about 10° to 25°N (Mauritanian Upwelling). It is one of the "very abundant" lanternfishes found in the study area, and was among the nine most abundant lanternfishes at each of the three seasons, ranking first in late summer (Table 131). The Ocean Acre collections contain 2850 specimens; 2522 were taken during the paired seasonal cruises, 1814 of these in discrete-depth samples, 1509 from noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 6–12 mm, juveniles 9–23 mm, subadults 20–36 mm, and adults 24–44 mm. Sex determination was possible in almost all juveniles larger than 16 mm, but in very few smaller than 15 mm. External sexual dimorphism was first apparent in fish 19–22 mm; males larger than about 19 mm have a single large supracaudal luminous gland, and females larger than about 22 mm have 2–4 smaller infracaudal luminous glands. Adult females contained eggs as large as 0.5 mm, but most eggs were 0.2–0.3 mm in diameter.

There appears to be geographical variation in both the

maximum size and size at maturity. Adults caught in the Mediterranean Sea were mostly 33–44 mm (Goodyear et al., 1972) but may grow as large as 48 mm (Taaning 1918); those in the Ocean Acre collections are mostly smaller than 40 mm, although a few are 44 mm; and most gravid females from the North Atlantic (no specific locality given) examined by Nafpaktitis et al. (1977) were 40–50 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Hygophum benoiti* is an annual species with a marked peak of spawning in spring. Although the breeding season may extend from winter to summer, most spawning apparently occurs in April-May, when the bulk of the population is approaching one year of age. Abundance was greatest in late summer, intermediate in winter, and least in late spring (Table 66). The great abundance in late summer was due to juvenile recruits, which accounted for almost the entire catch, with postlarvae accounting for the remainder. In winter subadults and adults were predominant, together comprising more than 90 percent of the catch. The meager catch in late spring was almost exclusively juveniles and postlarvae. These abundance relationships also were evident in the size composition of the catch in each season. Most specimens were 11–13 mm in late summer, 23–30 mm in winter, and smaller than 15 mm in late spring.

Eleven postlarvae 6–9 mm were caught in February at 40 m during the morning crepuscular period, indicating that at least some spawning occurred in December and January. Spawning at that time most likely was at a minimum, as only one juvenile was taken between February and June. Winter adults, which were all taken in February (none in January), presumably represent those fishes spawned earliest during the previous season, subadults those from the peak in April-May, and juveniles those from the end of the peak in June or July. Winter adults probably would ripen and spawn within two months. Most subadults are calculated to be about 8–9 months old and would spawn during the next peak in April-May. Juveniles would not reproduce until June or July and perhaps, in small numbers, even into August.

By late spring the winter population had mostly spawned and died. The scant catch, except for a few 38 mm fish,

consisted of recruits smaller than 15 mm. Abundance was at a minimum because recruits from the April-May peak were still too small to be adequately sampled by the nets. About 40 percent of the total postlarvae were caught in late spring (June), and an additional 45 percent in July.

The catch in late summer was made up of recruits (except for a few taken with the open Engel trawl); most were recently transformed juveniles 10–13 mm. Abundance, then at its maximum, increased tenfold from the late spring level (Table 66).

Otoliths were examined in an attempt to age fish larger than 25 mm. Those taken from winter specimens 29–41 mm all had 7 to 9 well-developed rings. These rings obviously represent a sub-annual growth pattern. Their number suggests that they may represent monthly increments of growth. Daily, fortnightly, and monthly patterns of ring deposition have been observed in temperate fishes (Pannella, 1971), and daily, weekly, fortnightly, and monthly rings have been found on the otoliths of tropical fishes (Brothers et al., 1976; Struhsaker and Uchiyama, 1976).

SEX RATIOS.—Males were much more numerous than females in winter, with a ratio of 1.5:1 (Table 67). Sex ratios for the other two seasons are not considered reliable estimates of the actual values, because only two specimens taken in late spring could be sexed, and little more than 15 percent of those examined from late summer (most smaller than 20 mm) could be sexed.

The numerical dominance of males over females in winter did not hold for each of the three older stages. Adult males were nearly 23 times more numerous than adult females, but female subadults were about 1.5 times more numerous than males of that stage. Both are significant differences from equality. These differences in part may be due to difficulties in staging males, but combining the two stages still resulted in a significant difference from equality, males being about 1.6 times more numerous than females. Juvenile males were more numerous than juvenile females but not significantly so. These differences do not appear to be a result of sampling bias. Males were often more numerous than females in discrete-depth samples made at night in the upper 50 m, where more than 90 percent of the catch was

TABLE 66.—Seasonal abundance and percent of total abundance (in parentheses) for *Hygophum benoiti* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	8.8(9.6)	52.7(57.4)	30.3(33.0)	91.8
LATE SPRING	6.1(30.0)	13.5(66.5)	0	0.7(3.4)	20.3
LATE SUMMER	1.8(0.8)	208.2(99.1)	0	0	210.0

TABLE 67.—Numbers of each sex for each stage of *Hygophum benoiti* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	31	21	194	302*	295	13*	520	336*
SPRING	0	0	0	0	1	1	1	1
SUMMER	50	90*	1	0	0	0	51	90*

taken (Table 68). Males also were more numerous than females in most day samples.

The numerical dominance of juvenile females over juvenile males in late sumer is mostly due to 14–17 mm specimens, for which the female to male ratio is 3.1:1, a significant difference from equality. It is possible that females can be recognized at a smaller size than males.

VERTICAL DISTRIBUTION.—Daytime depth of occurrence in winter was 451–850 m with maximum abundance at 501–550 m, in late spring 551–1050 m with a slight concentration at 751–800 m, and in late summer 451–1100 m with a maximum at 701–850 m. Depth range at night in winter was 18–350 m with maximum abundance at 18–50 m; in late spring 50–250 m, 451–500 m, and 701–1050 m

TABLE 68.—Vertical distribution by 50-m intervals of *Hygophum benoiti* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE
DAY																								
451- 500		1			1	1	29.0	29												<1	<1	1	11.0	11
501- 550	7	15			22	29	23.1	20-29	-	-	-	-	-							1	1	2	11.5	11-12
551- 600			4	2	6	13	27.8	25-36	1				1	3	9.7	9-10								
601- 650	1	10			11	35	24.3	19-31												<1	<1	1	11.0	11
651- 700	1	8	3		12	*			<1				<1	2	9.5	9-10				6	6	*		
701- 750			6	6	12	31	28.9	25-33	1	1		<1	2	*						12	12	35	15.5	11-20
751- 800			5	3	8	*			1	2		<1	3	21	13.2	10-38				14	14	42	13.5	11-21
801- 850			4	1	5	17	26.4	24-29		1		<1	1	*						10	10	28	15.7	11-22
851- 900	-	-	-	-	-															6	6	*		
901- 950	-	-	-	-	-					<1			<1	*						3	3	8	10.5	10-12
951-1000	-	-	-	-	-								1	3	14.0	14				2	2	*		
1001-1050										<1			<1	*						1	1	2	10.5	10-11
1051-1100	-	-	-	-	-															<1	<1	*		
1101-1150	-	-	-	-	-																			
TOTALS	9	53	15		77	126			3	5		<1	8	29						55	55	119		
NIGHT																								
1- 50	1	33	28		62	598	26.9	18-37	1				1	1	6.0	6								
51- 100		1	1		2	19	27.5	23-24	2				2	5	7.6	7- 9		8			8	65	15.8	11-21
101- 150	<1	2	<1		2	8	26.3	25-29	<1				<1	1	11.0	11	<1	8			8	26	13.1	8-19
151- 200		<1			<1	2	25.0	23-27	1				1	1	11.0	11	1	13			14	85	13.0	12-18
201- 250												<1	<1	1	38.0	38		2			2	11	13.3	11-18
251- 300			<1	<1		*												2			2	7	13.1	12-16
301- 350				1	1	1	28.0	28	-	-	-	-	-					4			4	25	13.6	11-19
351- 400																		1			1	2	15.0	15
401- 450																								
451- 500									<1				<1	1	8.0	8		1			1	6	14.2	13-17
501- 550																		1			1	1	19.0	19
551- 600																		1			1	*		
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-					64			64	128	12.3	11-14
701- 750										4			4	*			1	22			23	45	11.3	10-13
751- 800									1	8			9	14	11.1	10-12		25			25	76	11.3	10-18
801- 850										2			2	3	10.0	10		22			22	*		
851- 900	-	-	-	-	-				-	-	-	-	-					18			18	55	11.7	10-13
901- 950	-	-	-	-	-							<1	<1	*				11			11	34	11.3	10-15
951-1000													1	2	14.0	14		4			4	12	10.4	9-11
1001-1050												<1	<1	*			-	-	-	-	-			
1051-1100	-	-	-	-	-												-	-	-	-	-			
TOTALS	1	36	30		67	628			6	14			20	29			2	207			209	578		

with a maximum at 751–800 m: and in late summer 51–1000 m with a maximum at 651–700 m (Table 68).

Stage stratification was evident in winter and late spring, with size stratification evident at all three seasons. By day in winter juveniles and subadults were most abundant at 501–550 m and adults at 701–750 m. Adults were not taken at as shallow a level as juveniles and subadults, and juveniles were not caught as deep as the older two stages. In late spring only postlarvae were taken above 700 m and only juveniles below 850 m.

In terms of size, in winter fish 30 mm and larger were not taken at either depth extreme; those 19–23 mm were taken only between 501 and 650 m; and fish 24–29 mm were taken over the entire vertical range. The smaller mean size of the catch at 501–550 m and 601–650 m, than at other 50 m intervals (Table 68), reflects growth in size in the population from mid-January to late February rather than size stratification. Fish caught in January had an average standard length (SL) of 23.7 mm and those in February (one year later) a mean of 27.7 mm; the difference presumably represented growth during a period of roughly 1.5 months.

The few specimens caught during daytime in late spring appeared to be stratified by size; those caught above 750 m were 9–10 mm and those caught at greater depths were 9–14 mm, including a 38 mm adult. Fish taken below 750 m (excluding the 38 mm adult) averaged 3.4 mm larger than the ones (9.6 mm) from shallower depths. In late summer during the day only fish smaller than 13 mm were caught at or near either depth extreme, where the catches were small. At intermediate depths the size range was 11–22 mm, and the mean size noticeably larger than that at either shallower or greater depths (14.8 vs 11.2 and 10.5 mm, respectively).

Stratification was not evident at night in winter, when about 93 percent of the catch was from 18–50 m: each stage and all sizes taken were most abundant at that depth. In late spring only postlarvae were caught at the shallow extreme and only juveniles at the deep extreme, but the catches were small at both depths. Size stratification was evident at night in late spring, with the catch from the upper 100 m consisting only of fish 6–9 mm, and that at 751–1000 m of specimens 10–14 mm. A 38 mm adult was taken at 201–250 m. In late summer the catch above daytime depths had a size range of 8–21 mm and an average SL of 14.0 mm, and at day depths the size range was 9–19 mm, and the mean size 11.7 mm. Only 7 of the 357 specimens caught at diurnal depths exceeded 13 mm in length. Larger fish from both depth strata were most abundant at or near the upper depth limit, and the mean size of the catch at 51–100 m and 451–700 m was larger than that at 101–400 m and 701–1000 m, respectively (Table 68).

Postlarvae probably do not undergo extensive diel vertical migrations. They were stratified according to size at night in late spring and late summer. Those caught in the upper 150 m were 6–11 mm and averaged 7.9 mm; those caught deeper than 500 m were 9–10 mm. At intermediate depths, postlarvae were 8–12 mm. Postlarvae were caught during the day only at 551–800 m in late spring. They were all 9–10 mm, as were night specimens from the same depths. The absence of postlarvae in day samples from the upper 150 m in late spring and at all depths in late summer almost certainly is due to the lack of samples at appropriate depths. In winter (February-March) the few postlarvae caught, all 6–9 mm, were taken at sunrise at 40 m, suggesting that smaller postlarvae probably are found in superficial waters both day and night in late spring and late summer. Postlarvae apparently spend the early stages of their life in the upper 150 m, and at 8–10 mm they descend to depths greater than 500 m where they transform into juveniles.

Diel migration was apparent at all three seasons; in late spring and late summer most of the population was nonmigratory, but in winter all except postlarvae were migrants. This is a consequence of the size and degree of development of the individual fish. Postlarvae and 9–10 mm juveniles are nonmigrants, and fish larger than 20 mm are regular diel migrants. At intermediate sizes, juveniles 11–13 mm are mostly nonmigrators, and those 14–19 mm are mostly migrators. Only 9 of 360 nonmigrants were larger than 13 mm. Migratory behavior first is assumed at a size of 11 mm and is almost universal at about 14 mm. This is well illustrated at night in late summer, when slightly more than 80 percent of the catch was from diurnal depths. About 85 percent of the 11–13 mm juveniles, but less than 20 percent of those 14–19 mm, were caught at these depths.

Little can be said concerning the chronology of diel vertical migrations at any season. Few *H. benoiti* were caught in the upper 250 m at night in late spring, and most of these were postlarvae, which probably do not migrate.

Although most of the winter population migrated vertically, the depth of maximum abundance (18–50 m) was not sampled until shortly before midnight, so arrival times at nocturnal depths must be estimated. Specimens were taken at day depths in a trawl made from 1.7 to 0.5 hours before sunset, and fish were caught at about 225 m and 125 m no later than 0.7 hours after sunset. Assuming that migrations were started at about 1.7 hours before sunset, roughly 2.5 hours were spent in transit between day depths up to 125 m. Allowing an additional 0.5 hour to reach the upper 50 m, a total upward migration of roughly 3.0 hours and a migration rate of about 165 m per hour between day (501–550 m) and night (18–50 m) depths of maximum abundance are obtained. The reverse migrations commence no earlier than about 1.7 hours before sunrise, and daytime depths are reached by no later than 1.8 hours after sunrise, resulting in a maximum migration time of approximately 3.5 hours. Using this estimate, a minimum rate of downward migration of about 145 m/hour is obtained.

other factors were involved. The catch at each 50-m interval between 650–1050 m sampled both day and night was greater at night, suggesting that the daytime depth of maximum abundance was not sampled. Enhanced daytime avoidance probably was not responsible for this difference. At 650–1050 m the catch during daytime ranged in size from 10 to 22 mm and averaged 14.4 mm, and at night the size range was 9–18 mm with a mean size of 11.8 mm.

The ratio for late spring is based upon a total of 36 specimens, all but 4 of which were caught during one of the two cruises.

Hygophum hygomii

This moderately large myctophid grows to a maximum size of 64 mm in the study area (68 mm is the known maximum; Hulley, 1981), but few specimens caught exceeded 60 mm. A temperate-semisubtropical lanternfish, it is most abundant in the North Atlantic temperate region (Backus et al., 1977). It is one of the "abundant" lanternfishes in the study area, ranking sixth in winter, 16th in late spring, and 20th in late summer (Table 131). The Ocean Acre collections contain 5350 specimens, more than 10 percent of the total number of lanternfish taken, but 3726 of these were taken with the Engel trawl during one cruise. Only 754 specimens were taken during the paired seasonal cruises; 521 of these in discrete-depth samples, of which 475 were caught in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 6–14 mm, juveniles 13–38 mm, subadults 27–63 mm, and adults 47–56 mm. Fewer than 10 adults were taken. Most juveniles less than 25 mm could not be sexed; most larger ones had small but recognizable ovaries or testes. About 89 percent of the winter juveniles and 59 percent of those taken in late spring could not be sexed. Females may grow faster than males; they attain a larger size and can be recognized at a smaller size than males (25 vs 27 mm). Of 78 specimens 56–64 mm long (almost all caught with the Engel trawl) only one 56 mm fish was a male. The dimorphism in size was most prominent in late summer: subadult males were 37–51 mm and averaged 43.0 mm, and subadult females 45–63 mm with a mean of 51.5 mm. Goodyear et al. (1972) also noted a sexual dimorphism in growth rate and size for *H. hygomii* in the Mediterranean Sea, with females growing faster and becoming larger than males. Their material consisted mostly of adults. Presumably adults in the study area also would show this dimorphism. Males have a supracaudal luminous gland and females an infracaudal luminous gland.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Hygophum hygomii* has a one-year life cycle, with only a few individuals living much longer than one year. Spawning apparently occurs in fall and winter, with a peak in intensity in late fall–early winter. Abundance was greatest in winter,

when juvenile recruits 13–16 mm predominated; juveniles made up nearly 86 percent of the catch, with postlarvae accounting for most of the remainder. Abundance fell greatly between winter and late spring. By late summer abundance had reached a minimum, about 1/18 of that in winter (Table 70).

Four females with eggs larger than 0.05 mm in diameter were taken from October to January. A 56 mm female taken in November contained the largest eggs (0.35 mm) and had greatly enlarged ovaries. Poor catches in November and December because of inclement weather, and in October-November because of the smaller 2-m IKMT used, may partially account for the paucity of adult females in the collections. Larger fish also may avoid the 3-m IKMT, judging from the difference between the catch made with the Engel trawl (3726 specimens) and the IKMT (7 specimens) in August-September. Postlarvae and juveniles at or near transformation size are most abundant in winter.

About 93 percent of all postlarvae were caught from January to March. The seasonal distributions of postlarvae, 13–16 mm juveniles, and the few females with relatively large eggs suggest that spawning takes place in fall and winter with a peak intensity in fall. The very low abundance of fish greater than 30 mm in winter suggests that most individuals die shortly after the spawning season at about one-year of age.

In late summer 97 percent of the poor discrete-depth catch consisted of subadults. As indicated above, the great number of specimens taken with the Engel trawl at the same time indicates that this estimate of abundance may be too low, because larger individuals avoid the IKMT.

In winter juvenile recruits 13–20 mm were predominant. Most of these were caught in February-March, suggesting that in January most of the population was represented by postlarvae. The few adults taken were males.

By late spring most recruits of the winter population had grown considerably and were large juveniles (greater than 20 mm) and subadults. Smaller juveniles were not very abundant, indicating that little spawning occurred in mid- to late winter. The tremendous decrease in abundance from winter to late spring (Table 70) is difficult to explain. Total abundance in late spring was only about 16 percent of that

TABLE 70.—Seasonal abundance and percent of total abundance (in parentheses) for *Hygophum hygomii* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

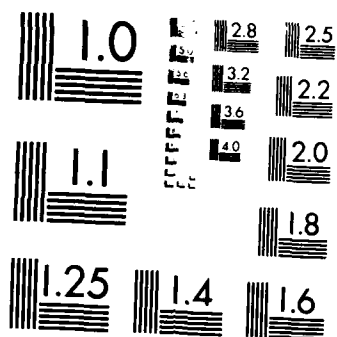| SEASON	PL	JUV	SAD	AD	TOT
WINTER	9.6 (13.7)	59.9 (85.6)	0	0.5 (0.7)	70.0
LATE SPRING	0.3 (3.2)	6.5 (69.9)	2.5 (26.9)	0	9.3
LATE SUMMER	0	0.1 (2.6)	3.7 (97.4)	0	3.8
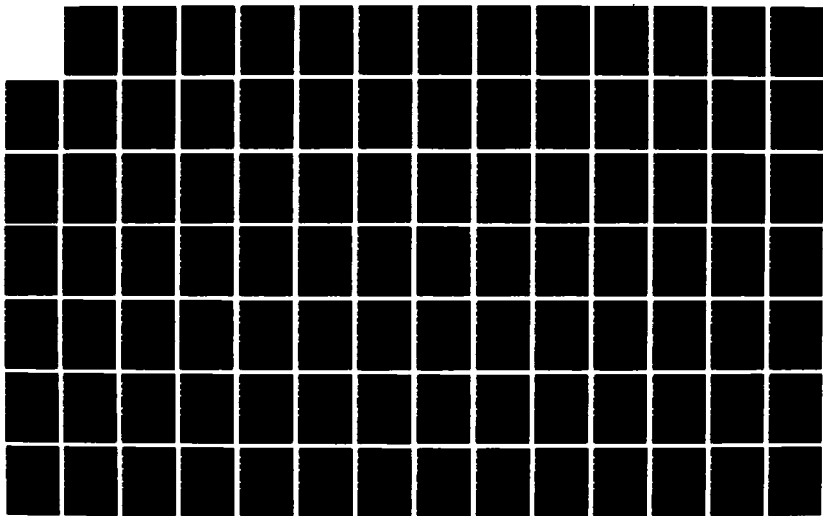
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The low proportion of migrants in late summer made it difficult to estimate migration times. A series of three one-hour evening crepuscular samples was made at 470–520 m; this is above the major concentration of *H. benoiti* during daytime (Table 68). The first sample, beginning about 2.2 hours before sunset, fished at 500–520 m and caught 46 specimens; the following two, both at 470–500 m, caught 38 and one specimen, respectively. This suggests that upward migrations commenced between 1.2 and 2.2 hours before sunset. Specimens were taken at about 325–350 m no more than 1.6 hours before sunset and at about 250 m no more than 1.2 hours before sunset, suggesting that the earlier estimate of starting time may be the more accurate one.

Sampling was inadequate to determine arrival times at the depth of maximum concentration of migrants (151–200 m). At 19 m a single specimen was taken no later than 0.8 hours after sunset, and an additional 5 specimens no more than one hour later. Assuming that upward migrations commence 2.5 hours before sunset and terminate 1.5 hours after sunset, they take about 4.0 hours to complete, occurring at a rate of about 150 m/hour between the day depth of maximum abundance (751–800 m) and the depth of maximum abundance of migrants at night (151–200 m). Downward migrations apparently start no more than about 2.5 hours before sunrise, as specimens taken at near the following depths between about 1.5 and 2.5 hours before sunrise would indicate: 45 m, 65 m, 125 m, and 275 m. Daytime depths were reached by 1.7 hours after sunrise, giving a downward migration time of about 4.0 hours, which is similar to the time for evening migrations.

PATCHINESS.—Patchiness was indicated by day in winter at 701–750 m and 801–850 m, and in late summer at 751–800 m. In winter adults were most abundant at 701–750 m; in late summer juveniles, the only stage caught, were at 751–800 m. The depth of maximum abundance in winter, 501–550 m, was sampled only once, and nothing can be stated concerning patchiness at that depth.

Patchiness was more extensive at night, being indicated at 18–50 m in winter, and at 51–100 m, 151–200 m, 651–700 m, 751–800 m, and 851–1000 m in late summer. These include the depths of maximum abundance of all stages taken in winter (18–50 m), and of nonmigrant (651–700 m) and migrant (151–200 m) juveniles in late summer. Nonmigrators appeared to have a patchy distribution below 600 m at night in late summer, a marked contrast to the daytime situation at that depth.

Significant CD values obtained for day samples at 751–800 m in late spring and for night samples at 51–100 m in winter and 301–350 m in late summer are thought to be due to factors other than patchiness. In late spring the four samples made at 751–800 m were equally divided between two cruises; neither set had a significant CD. Most of the specimens were taken during one of the two cruises, which

suggests year-to-year variation in population density rather than patchiness. Winter night samples made at 51–100 m caught from 0 to 8 specimens, with only 2 of 11 samples having more than 3 specimens. These low numbers indicate that patchiness at this depth occurs only on a small scale. Three of the four samples made at 301–350 m at night in winter were taken during one of the two cruises and accounted for only one of the 25 specimens caught at that depth, suggesting that year-to-year variation in population density rather than patchy distribution was responsible for the large CD value.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios for discrete-depth captures, including interpolated values, were 0.9:1 in winter, 2.0:1 in late spring, and 3.8:1 in late summer (Table 69). Except for adults, each stage taken followed the overall seasonal trends.

The winter ratio is somewhat deceptive, as the night to day catch ratios for each stage were more deviant from 1:1 than the ratio for total specimens (Table 69). Juveniles and subadults were more abundant in day than in night samples; adults the reverse.

Except for adults in winter, the ratios do not seem to be related to diel changes in vertical range. The depth range of adults at night in winter was compressed compared to that of the day, with a large concentration within the 18–50 m stratum. In all other cases abundance was greater in samples made during the diel period in which the depth range was more extensive.

Net avoidance does not seem to be an important factor in the differences between day and night catches. Most fish caught in late spring and late summer were smaller than 20 mm and are not likely to be able to avoid the nets to any great degree. Larger fish formed a good portion of the catch only in winter, but specimens 30 mm and larger, which should have greater ability to avoid the nets, were about equally abundant in day and night samples in winter. The greatest diel difference in abundance in winter was obtained for fish 23–24 mm.

Diel differences in clumping may have contributed to the discrepancy between night and day catches in late summer. Clumping was indicated to be much more extensive at night than by day in late summer, but the difference between day and night catches was so large that it is almost certain that

TABLE 69.—Seasonal night to day catch ratios of *Hygophum benoiti* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	0.2:1	0.7:1	1.8:1	0.9:1
LATE SPRING	2.2:1	2.1:1	*	0.4:1	2.0:1
LATE SUMMER	*	3.8:1	*	*	3.8:1

for juveniles in winter. It is possible that abundance was underestimated at this season because some individuals had grown large enough to avoid the net.

SEX RATIOS.— The sexes probably are equally abundant at all seasons, but sample sizes are too small to be reliable. Male-to-female sex ratios were 0.4:1 in winter, 1.6:1 in late spring, and 1.0:1 in late summer, with only the winter ratio statistically different from equality (Table 71). The difference in winter was due almost exclusively to juveniles, for which the female-to-male ratio was 3.0:1. However, only about 11 percent of the juveniles examined from winter collections could be sexed. Also, as indicated above, females may develop faster and, therefore, be recognized at a smaller size than males. All 25–26 mm juveniles that were sexed were females. When these individuals were excluded, sex ratios for large juveniles and total numbers were not significantly different from equality.

The difference in numbers of each sex also is statistically different from equality for juveniles in late spring. However, at that season juvenile males were more numerous than juvenile females, with a female-to-male ratio of 0.2:1. Again, this difference probably can be explained by different growth rates of the sexes. By late spring most winter females have become subadults while most males remain as juveniles. These differences in numbers of each sex for both stages cancel each other, although males are more numerous than females. Both sexes had developed into subadults by late summer and were present in about equal number (Table 71).

VERTICAL DISTRIBUTION.—Day depth range in winter was the upper 50 m and 501–1050 m with maximum abundance at 551–600 m, in late spring 51–100 m and 551–1000 m with a maximum at 651–700 m, and in late summer 701–800 m (Table 72). Nighttime depth range in winter was from the surface to 1050 m with maximum abundance at 51–150 m, in late spring the upper 100 m with a slight concentration at 50 m, and in late summer 51–100 m and 151–200 m with all but one specimen caught at the first depth.

Stage stratification was evident only during the day in winter and late spring. Size stratification was evident both

day and night in winter and by day in late spring (Table 72). During the day in winter only postlarvae were caught at the shallow extreme of depth. Adults were taken only at 601–700 m, and juveniles and postlarvae were caught over much of the 501–850 m stratum. By day in late spring only postlarvae were caught at either extreme of depth and only juveniles at 551–650 m (Table 72). In terms of size, all specimens taken in the upper 100 m during the day in winter and late spring were 7–11 mm. During the day in winter fish less than 15 mm were most abundant at 701–750 m and 801–850 m, and those larger than 14 mm were taken mostly at 501–650 m. This stratification was evident from the mean of the catches at those depths, 14.1 and 13.7 mm vs 17.8 mm, respectively (Table 72). Badcock and Merrett (1976) caught transforming *H. hygomii* at 500–600 m in the eastern North Atlantic, and the above data indicate that transformation occurs below 700 m in the study area. In late spring, specimens 18–32 mm were caught only at 551–700 m, and those 33–35 mm only at 651–800 m.

At night in winter fish smaller than 10 mm and those larger than 20 mm were taken only in the upper 100 m, and specimens 13–16 mm were taken throughout the depth range (Table 72).

Postlarvae were stratified according to size in winter: smaller ones (6–9 mm) were caught only in the upper 100 m both day and night, and most of those larger than 9 mm were caught below 500 m. As is the case for other species, initial development occurs in the superficial layer and, at a size of about 9–10 mm, postlarvae descend to depths in excess of about 500 m where they continue to develop and transform into juveniles.

Diel vertical migrations occurred at all seasons, but only in late spring and late summer was the entire night catch taken above daytime depths (Table 72). In winter the population included nonmigrants, partial migrants, and complete migrants. Migrants were 13–34 mm (and probably larger); partial migrants and nonmigrants were 13–19 mm, but mostly 13–16 mm. Postlarvae probably do not migrate over any extensive depth range, as migratory behavior apparently is adopted on a regular basis at a size of about 17 mm. Almost all individuals larger than 16 mm were taken in the upper 200 m at night. The smallest juveniles (13 mm) were taken only at 101–150 m and 751–800 m and contained the largest proportion of nonmigrants (71 percent). Juveniles 14–16 mm were taken at all depths; less than 50 percent of these were partial migrants and nonmigrants. Although the late spring population contained juveniles within the size range of winter partial migrants and nonmigrants, all night captures were made in the upper 100 m.

Little could be determined concerning the chronology of diel vertical migrations in late spring and late summer due to sparse catches in the upper 100 m until well after sunset. In winter the onset of evening migrations was difficult to

TABLE 71.—Numbers of each sex for each stage of *Hygophum hygomii* (AD = adult, F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages, asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	9	27*	0	1	2	0	11	28*
SPRING	23	4*	8	16	0	0	31	20
SUMMER	1	1	20	19	0	0	21	20

TABLE 72.—Vertical distribution by 50-m intervals of *Hygophum hygomii* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER — CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SPRING — CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SUMMER — CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE
DAY																								
1- 50	5				5	23	9.1	7-11																
51- 100									<1				<1	1	9.0	9								
501- 550		1			1	1	16.0	16	-	-	-	-	-											
551- 600	1	22			23	53	17.5	12-30			1		1	2	21.0	18-24								
601- 650	1		<1		1	4	26.5	12-53	<1				<1	1	14.0	14								
651- 700		5	<1		5	*					3	1	4	38	31.2	13-53	-	-	-	-	-			
701- 750	<1	11			11	29	14.1	13-27			2	1	3	*					<1		<1	1	50.0	50
751- 800		10			10	*					1	1	2	6	39.0	33-46			1		1	3	53.3	48-63
801- 850	2	10			12	34	13.7	10-26	-	-	-	-	-											
851- 900	-	-	-	-	-												-	-	-	-	-			
901- 950	-	-	-	-	-				-	-	-	-	-											
951-1000	-	-	-	-	-				<1				<1	1	10.0	10	-	-	-	-	-			
1001-1050		1			1	2	17.0	15-19	-	-	-	-	-											
TOTALS	9	60	<1		69	146			<1	7	3		10	49					1		1	4		
NIGHT																								
SURFACE		<1			<1	4	15.0	15		<1			<1	2	15.0	14-16								
1- 50	2	4			6	63	16.7	6-26		2	1		3	5	31.6	19-40								
51- 100	5	8			13	107	18.3	9-34		<1			<1	1	19.0	19	<1	3			3	28	45.6	28-61
101- 150		11			11	35	15.3	13-19																
151- 200		1			1	3	17.0	16-18										<1			<1	2	43.0	28-58
201- 250		<1			<1	1	15.0	15																
251- 300		1			1	*																		
301- 350		1			1	3	15.0	14-16	-	-	-	-	-											
351- 400	<1				<1	1	12.0	12																
401- 450		1			1	2	14.5	14-15																
451- 500		1			1	3	15.5	15-16																
501- 550																								
551- 600	<1	1			1	2	13.5	13-14	-	-	-	-	-											
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-											
701- 750									-	-	-	-	-											
751- 800	<1	3			3	10	13.5	11-15																
801- 850		1			1	1	14.0	14									-	-	-	-	-			
851- 900									-	-	-	-	-											
901- 950	-	-	-	-	-				-	-	-	-	-											
951-1000		2			2	2	15.5	15-16																
1001-1050		1			1	1	19.0	19	-	-	-	-	-				-	-	-	-	-			
TOTALS	7	36			43	238				2	1		3	8			<1	3			3	30		

determine, because the population included nonmigrants. The upper 200 m was occupied by 0.5 hour after sunset, the upper 150 m by 1.4 hours after sunset, and the upper 100 m by 2.7 hours after sunset. As these are all the latest times of arrival, actual times of arrival may be earlier, particularly the last, which is based upon the first sample made within the upper 100 m after sunset.

PATCHINESS.—Patchiness during daytime was evident only in winter at 701-750 m and 801-850 m. No samples were taken at 651-700 m, 751-800 m, and 851-1000 m, and patchiness may have been more extensive than indicated. More than 95 percent of the catch from the depths at which clumping was indicated was made up of 13-14 mm juveniles. By day in winter larger juveniles (15-25 mm)

were most abundant at 551–600 m, where no patchiness was indicated.

Patchiness was more prevalent at night. Significant clumping was noted in winter at 18–100 m and in late summer at 51–100 m. In winter juveniles were most abundant at 18–100 m (postlarvae were not included in the analysis), and in late summer the catch at 51–100 m was almost exclusively subadults.

Significant CD values were obtained for nocturnal surface samples in winter and late spring. However, these probably reflect a low population density rather than patchiness. More than 45 nocturnal surface samples were taken in both seasons, only three in winter and two in late spring were positive; one of the positive samples contained two specimens, the rest only a single specimen.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, were 0.6:1 in winter, 0.3:1 in late spring, and 2.9:1 in late summer (Table 73). The ratios for the developmental stages followed the overall seasonal trends. Juveniles were responsible for most of the diel differences in the catches in winter and late spring, and subadults in late summer.

In winter most of the difference between day and night catches was due to 13–14 mm juveniles for which the night-to-day catch ratio was 0.3:1. The 13 mm juveniles were about 10 times more abundant in day samples than in night samples. The nighttime vertical range of these juveniles was much greater than the daytime range, and patchiness was more prevalent at night, both of which may have contributed to the difference between the day and night catches. Net avoidance probably is not an important factor, because the catch was mostly smaller than 20 mm both day and night.

In late spring the poor night catches may be a result of inadequate discrete-depth sampling in the upper 150 m, and particularly the upper 50 m (Figure 2). The night depth range was compressed compared to the daytime range, yet the day catch was greater than the night catch (Table 72). Increased net avoidance may account partly for the difference in catches, for all specimens greater than 40 mm were caught in day samples.

In late summer the population was mostly 45 mm and larger. Apparently, *H. hygomii* of this size can avoid the 3-

m IKMT both day and night. That large fish were present in some abundance at that season is indicated by the catch of *H. hygomii* made with the Engel trawl. As both the day and night catches with the IKMT were small (less than 4.0 specimens/hour), it is assumed that *H. hygomii* was not adequately sampled either by day or by night.

Hygophum reinhardtii

This medium-size myctophid grows to 45 mm in the study area, to 61 mm elsewhere (Hulley, 1981). A questionably bipolar subtropical species (Backus et al., 1977), it is most abundant in the eastern subtropics of the Atlantic Ocean (Nafpaktitis et al., 1977). It is uncommon in the study area, never being among the twenty most abundant lanternfish. The Ocean Acre collections contain 106 specimens; 65 were caught during the paired seasonal cruises, 51 of these in discrete-depth samples, of which 37 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—The single postlarva was 12 mm, juveniles were 12–24 mm, subadults 24–45 mm, and adult males 32–45 mm. Most juveniles 12–15 mm could not be sexed, but all those greater than 18 mm could be. Subadult females had infracaudal luminous tissue, and subadult and adult males supracaudal luminous tissue. There was no apparent sexual dimorphism in size. Some subadult females larger than 40 mm had slightly enlarged ovaries with occasional ova up to 0.3 mm in diameter, but no females had many eggs of this size.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Hygophum reinhardtii* may or may not be a breeding resident of the study area. The parent population apparently spawns over most of the year, with a peak in fall. Judging from the maximum size attained in the study area, the life span is about one year. Abundance, although never great, is at a maximum in winter, intermediate in late spring, and least in late summer (Table 74).

Because 13–15 mm juveniles mostly were captured in oblique and crepuscular discrete-depth tows, they were not included in the reckoning of abundance. These small fish were taken over most of the year, appearing in greatest number in late summer, when they accounted for half of all *H. reinhardtii* taken. The maximum of juveniles in winter (Table 74) is due mostly to fish 20–24 mm. Collections made in June contain no juveniles of any size, which is puzzling. Fish 15 mm or smaller were taken in April and July when most of the small catch (5 of 6 specimens) was 13–15 mm.

Fish 30 mm and larger were taken in low numbers and were not abundant at any season. They were about equally numerous in winter and late spring collections (4 and 5 specimens, respectively), and only one was taken in late summer. The small number of large fish taken in late summer apparently was an accurate reflection of the popu-

TABLE 73.—Seasonal night to day catch ratios of *Hygophum hygomii* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.8:1	0.6:1	*	*	0.6:1
LATE SPRING	*	0.4:1	0.2:1	*	0.3:1
LATE SUMMER	*	*	2.8:1	*	2.9:1

TABLE 74.—Seasonal abundance and percent of total abundance (in parentheses) for *Hygophum reinhardtii* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult, TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	2.6(65.0)	1.3(32.5)	0.1(2.5)	4.0
LATE SPRING	0	0	1.5(83.3)	0.3(16.7)	1.8
LATE SUMMER	0.3(25.0)	0.5(41.7)	0.2(16.7)	0.2(16.7)	1.2

TABLE 75.—Numbers of each sex for each stage of *Hygophum reinhardtii* (AD = adult, F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV M	JUV F	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	9	17	1	6	1	0	11	23*
SPRING	0	0	0	4	1	0	1	4
SUMMER	2	4	1	1	1	0	4	5

TABLE 76.—Vertical distribution by 50-m intervals of *Hygophum reinhardtii* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
601- 650																								
651- 700	<1	<1			<1	*												<1			<1	*		
701- 750	<1	<1			<1	2	24.0	21-27	-	-	-	-	-					<1			<1	1	13.0	13
751- 800	1	<1			1	*																		
801- 850	1	<1			1	4	26.0	22-36	-	-	-	-	-											
851- 900	-	-	-	-	-												-	-	-	-	-			
901- 950	-	-	-	-	-				-	-	-	-	-											
951-1000	-	-	-	-	-												-	-	-	-	-			
1001-1050												1	1	*										
1051-1100	-	-	-	-	-							1	1	1	35.0	35	-	-	-	-	-			
TOTALS	2	<1			2	6						2	2	1				<1			<1	1		
NIGHT																								
SURFACE	1	<1	<1		1	13	25.2	15-40		<1			<1	1	40.0	40								
1- 50		<1			<1	1	26.0	26																
51- 100	<1				<1	3	20.7	18-23										<1			<1	1	16.0	16
101- 150	1				1	3	23.8	23-24																
151- 200		<1			<1	1	26.0	26										<1		<1	<1	2	33.5	24-43
201- 250												<1	<1	1	42.0	42			<1		<1	1	27.0	27
551- 600	<1				<1	1	22.0	22																
851- 900									-	-	-	-	-				<1				<1	1	12.0	12
TOTALS	2	<1	<1		2	22				<1	<1		<1	2			<1	<1	<1	<1	<1	5		

lation structure, for even the larger Engel trawl captured only 19 specimens larger than 30 mm. Several subadult females larger than 40 mm in the Engel collections were the most sexually developed fish taken. The seasonality of both small (13–15 mm) and large fish (greater than 30 mm) suggests a spawning peak in spring, and that spawning occurs most of the year with only a short interruption in late winter or early spring. This protracted breeding season is similar to that for *H. reinhardtii* found near Hawaii (Clarke, 1973). Clarke also noted that the species matures at a size of approximately 33 mm. However, none of the females that size or larger in the Ocean Acre collections were ripe and only a few showed sexual development. This lack of adult and ripe females casts some doubt on the reproductive status of the species near Bermuda. However, the presence of 13–15 mm juveniles and the 12 mm

postlarva suggest that spawning occurs nearby if not in the area.

Abundance was greatest in winter, when juveniles from the spawning peak were best sampled, and decreased until the late summer low was reached (Table 74). Abundance probably was greatest in the fall soon after the spawning peak.

SEX RATIOS.—Females were more numerous in the collections than males at all seasons, with ratios of 2.1:1 in winter, 4.0:1 in late spring and 1.2:1 in late summer (Table 75). Sample sizes in late spring and late summer were too small (less than 10 specimens) to be statistically meaningful. The difference in winter was significant; it was due mostly to juveniles, but subadults also contributed. The difference for juveniles was not significant and the number of subadults was too small to be meaningful.

VERTICAL DISTRIBUTION.—By day eight fish were taken in discrete-depth tows; six in winter and one each in the other two seasons. Seven were taken at 701–850 m, and

the remaining one at 1051–1100 m (Table 76). Night catches accounted for 29 fish; 22 in winter, 2 in late spring, and 5 in late summer. In winter fish were taken from 0–200 m and at 551–600 m with slight concentrations at the surface and 101–150 m, in late spring at the surface and 201–250 m, and in late summer at 90 m, 151–250 m, and 851–900 m.

Apparently most fish undergo diel migrations, as only one fish was taken near diurnal depths by night. Migrants included fish 15–43 mm.

Hygophum taaningi

This species has a subtropical distribution in the North Atlantic Ocean (Nafpaktitis et al., 1977). It is moderate in size, growing to 44 mm in the study area, 61 mm elsewhere (Hulley, 1981). *Hygophum taaningi* is uncommon near Bermuda, and the Ocean Acre collections attest to this. Only 72 specimens were taken during the program. 61 were

TABLE 77.—Vertical distribution by 50-m intervals of *Hygophum taaningi* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
												DAY												
851- 900	-	-	-	-	-												-	-	-	-	-			
901- 950	-	-	-	-	-				<1	<1			<1	*										
951-1000	-	-	-	-	-				<1	<1			<1	2	27.0	27	-	-	-	-	-			
1001-1050	-	-	-	-	-				<1	<1			<1	*										
1051-1100	-	-	-	-	-																			
TOTALS									<1	<1			<1	2										
												NIGHT												
1- 50	<1	<1	<1		<1	6	21.8	17-34																
51- 100		<1			<1	1	29.0	29									<1	<1	<1		<1	7	30.3	13-37
101- 150																		1			1	2	12.5	12-13
151- 200																	<1	<1			<1	3	27.0	13-36
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	1	10.0	10
701- 750									-	-	-	-	-											
751- 800																								
801- 850	1				1	1	11.0	11									-	-	-	-	-			
851- 900	-	-	-	-	-				-	-	-	-	-											
901- 950									-	-	-	-	-											
951-1000										<1			<1	1	29.0	29								
1001-1050										<1			<1	*			-	-	-	-	-			
1951-1100	-	-	-	-	-												-	-	-	-	-			
1101-1150	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1151-1200	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1201-1250									<1				<1	1	22.0	22								
TOTALS	1	<1	<1		1	8			<1	<1			<1	2			2	<1	<1		2	13		

caught during the paired seasonal cruises, 35 of these in discrete-depth samples, of which 25 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES. -Juveniles were 10–25 mm, subadults 25–35 mm, and adults 34–44 mm. Fish smaller than 16 mm could not be sexed. Luminous tissue was found on the caudal peduncle of fish 23 mm and larger; in males it was found on the dorsal aspect, and in females on the ventral aspect (Bekker, 1965).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Little can be determined concerning the reproductive status or life span of *H. taaningi* from the sparse material at hand. This species was never very abundant (Table 77). Presumably, little reproduction takes place in the study area. Small fish (10–15 mm) were caught from July through September and in January, suggesting that they may be present from July through January. However, the catch from October through December consisted of one 40-mm specimen, and recruitment may not have occurred throughout the above time span. Based upon the abundance of 11–13 mm juveniles, recruitment was greatest in late summer. The only female adult (out of a total of eight adults) was caught in late summer, which agrees with the suspected peak in recruitment.

The life span cannot be determined with any degree of accuracy, because size classes cannot be traced from one season to the next.

Abundance was least in late spring, when the parent population presumably was approaching the spawning season. At this season the catch was about equally divided between larger juveniles (those over 20 mm) and subadults. The maximum abundance in late summer mostly was due to juveniles 11–13 mm, with the remainder about equally divided among subadults and adults. In winter, abundance was intermediate, and most of the catch was 17 mm or larger.

VERTICAL DISTRIBUTION.—Day depths largely are unknown. The only two specimens caught during daytime in discrete-depth samples were taken in late spring at 951–1000 m. Night depths of occurrence were 20–70 m and 801–850 m in winter, 951–1000 m and 1201–1250 m in late spring, and 51–200 m and 651–700 m in late summer (Table 77).

Apparently the smallest juveniles (10–11 mm) either do not migrate vertically or migrate over a restricted depth range. Both specimens of this size were taken below 651 m at night. In late spring at least some larger individuals were nonmigrants, as the only two specimens caught at night at that season were taken at presumed daytime depths.

Lampadena anomala

This rare, large species (to 180 mm; Hulley, 1981) is found in all oceans (Nafpaktitis and Paxton, 1968; Nafpaktitis and Nafpaktitis, 1969; Clarke, 1973). In the Atlantic

L. anomala is thought to be a deep-living species found in tropical and subtropical waters (Backus et al., 1977). The eight specimens in the Ocean Acre collections, three juveniles 22–26 mm and five postlarvae 8–16 mm, were caught from March to September. The largest juvenile was a female; the others could not be sexed. The largest specimen was taken at 451–500 m at night in late spring. In late summer one postlarva was caught at 801–850 m during the day and another at the surface at night.

Lampadena chavesi

This moderately large lanternfish grows to 75 mm in the study area, almost its maximum known size of 80 mm (Hulley, 1981). *Lampadena chavesi* is a bipolar, questionably subtropical, species (Backus et al., 1977). It is uncommon in the study area, not being among the 20 most abundant lanternfish at any season. The collections contain 178 specimens; 52 were caught during the paired seasonal cruises, 31 of these in discrete-depth samples, of which 27 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 6–17 mm, juveniles 17–37 mm, subadults 37–75 mm, and adult males 63–66 mm. No adult females were taken.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Discrete-depth samples provide little information concerning the life history of *L. chavesi*. This may be due, in part, to net avoidance by larger specimens. For example, in late summer all specimens caught by the IKMT were 19–37 mm, and those caught by the Engel trawl were 20–75 mm, with more then 20 percent larger than 37 mm. Additionally, specimens taken with the IKMT have a unimodal size frequency distribution, and those taken with the Engel trawl show a bimodal distribution, with one group 20–43 mm, which presumbly represents the young of the year, and another group 63–75 mm, which were perhaps a year or more older than the smaller group. These data show that population estimates based on IKMT catches are low in late summer and, probably, at all seasons.

Abundance was greatest in late spring, when 18–27 mm juveniles comprised most of the population. In late summer abundance was much reduced, and in winter it was at a minimum (Table 78).

The presence of postlarvae in small numbers in winter and in late spring suggest a limited spawning season, perhaps in fall. Juveniles 18–27 mm were relatively abundant only in late spring. Four specimens, all from the winter cruises, were caught from October to April (6 negative cruises). These observations and the absence of adult females in the collections suggest that *L. chavesi* either does not breed in the study area, or that conditions for normal breeding and survival are marginal there.

VERTICAL DISTRIBUTION.—Day depth range for winter and late spring combined is 601–850 m. Vertical range at night for all three seasons combined is 50–150 m and 751–

TABLE 78.—Vertical distribution by 50-m intervals of *Lampadena chavesi* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
601- 650										1			1	3	21.7	21-22								
651- 700	-	-	-	-	-					<1			<1	3	23.8	23-27								
701- 750										1			1	*										
751- 800	-	-	-	-	-					1			1	4	19.4	18-21								
801- 850	<1				<1	1	16.0	16		<1			<1	*										
851- 900	-	-	-	-	-																			
TOTALS	<1				<1	1				3			3	10										
NIGHT																								
1- 50										1			1	1	27.0	27								
51- 100		<1			<1	1	42.0	42	<1	2	<1		2	9	23.4	12-66	<1				<1	1	26.0	26
101- 150																					1	3	26.0	21-31
751- 800		<1			<1	1	17.0	17																
TOTALS	<1	<1			<1	2			<1	3	<1		3	10							1	4		

800 m (Table 78). The deepest night capture is a 17 mm juvenile, suggesting that recently transformed individuals do not migrate on a regular basis.

Lampadena luminosa

This questionably tropical-semisubtropical species (Backus et al., 1977) is rare in the study area. It is represented in the Ocean Acre collections by only eight juveniles, 20–64 mm, taken from August through September. The four largest (49–64 mm) were females, and the remainder could not be sexed. *Lampadena luminosa* grows to about 180 mm and attains sexual maturity at sizes larger than 150 mm (Nafpaktitis et al., 1977). No fish were taken in discrete-depth samples. Nondiscrete catch data show that the species is found as shallow as 90–100 m by night, which is similar to the upper nocturnal depth limit for the species near Hawaii (Clarke, 1973).

Lampadena speculigera

This bipolar temperate species (Backus et al., 1977) is known to occur in the subtropical Atlantic only near Bermuda (Nafpaktitis et al., 1977). It is a large myctophid, growing to 146 mm (Hulley, 1981), but attains a size of only 30 mm in the study area. *Lampadena speculigera* is a common lanternfish in the study area. The Ocean Acre collections contain 281 specimens; 237 were caught during the paired seasonal cruises, 200 of these in discrete-depth samples, 85 of which were in noncrepuscular tows. (Table 23). Postlarvae account for 193 specimens.

The species obviously is not a permanent resident of the study area, passing only a small fraction of its life cycle there. It either cannot survive long under the prevailing conditions or is a transient.

Only postlarvae 6–18 mm and juveniles 17–30 mm were caught; none showed any sexual development. *Lampadena speculigera* was taken in decreasing abundance from February to September (Table 79), after which it disappeared. The specimens caught probably are distributional waifs expatriated from the species' center of abundance north of the Sargasso Sea.

Day depth range for all seasons combined is 701–850 m, possibly slightly shallower and deeper (Table 79). One specimen, a probable contaminant from a previous tow, was taken at 1251–1300 m in winter.

Nighttime depths in winter ranged from the surface to 800 m, and in late spring from 50 m to 850 m. No specimens were caught at night in late summer. Postlarvae appear to be stratified by size. At about sunset 103 postlarvae 6–16

TABLE 79.—Vertical distribution by 50-m intervals of *Lampadena speculigera* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE
									DAY															
651- 700		2			2	*											-	-	-	-	-			
701- 750	<1	4			4	10	18.7	16-20		1			1	*										
751- 800		2			2	*				2			2	9	20.1	19-21								
801- 850	4				4	12	16.7	15-18		1			1	*				1			1	3	27.0	27
851- 900	-	-	-	-	-													1			1	*		
1251-1300		1			1	1	18.0	18	-	-	-	-	-											
TOTALS	4	9			13	23				4			4	9				2			2	3		
									NIGHT															
SURFACE	2				2	11	11.7	8-14																
51- 100	1	1			2	11	13.8	8-19		1			1	3	21.3	20-23								
101- 150	<1	2			2	11	18.4	13-20	<1				<1	1	21.0	21								
151- 200										1			1	2	20.5	20-21								
201- 250	<1				<1	2	15.5	14-17																
251- 300	-	-	-	-	-					1			1	2	21.0	21								
301- 350									<1				<1	*										
351- 400	<1				<1	1	9.0	9	-	-	-	-	-											
551- 600	<1				<1	1	6.0	6	-	-	-	-	-											
701- 750	<1				<1	1	18.0	18	-	-	-	-	-											
751- 800		1			1	2	16.5	16-17																
801- 850									1	1			2	2	17.0	17								
TOTALS	3	4			7	40			1	4			5	10										

mm, but mostly 10–15 mm, were taken at the surface. Most of the 16–18 mm postlarvae were taken at depths greater than 700 m both day and night.

Lampadena urophaos

This lanternfish is known to attain 237 mm (Krefft, 1970). The maximum size in the Ocean Acre collections is 165 mm, with most specimens smaller than 50 mm. *Lampadena urophaos* is a subtropical species in the Atlantic (Backus et al., 1977), where it is confined to the Northern Hemisphere (Nafpaktitis et al., 1977). According to Nafpaktitis et al. (1977), the largest collections were from the northern Sargasso Sea. Catch data from this study indicate that *L. urophaos* is uncommon near Bermuda. This species is represented in the Ocean Acre collections by 212 specimens; 63 were caught during the paired seasonal cruises, 49 of these in discrete-depth samples, of which 33 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 5–15 mm,

juveniles 17–78 mm, and the lone subadult, a male, 165 mm. Only three juveniles, 61–78 mm, could be sexed, all were females.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive status of this species in the study area is uncertain. The lack of ripe females (or any adults) suggests that spawning may not occur in the study area, but the presence of postlarvae and 17–18 mm juveniles suggests that spawning probably occurs nearby, if not in, the study area. The horizontal distribution of *L. urophaos* (Nafpaktitis et al., 1977:177) also suggests that spawning occurs in the northern Sargasso Sea. The size of the largest specimen caught during the program (165 mm) indicates that the life span is at least two years and probably longer.

Abundance was always low (Table 80). It was about the same in winter and late spring and at a bare minimum in late summer.

The parent population apparently had a prolonged breeding season, probably with a peak in late spring or summer. Postlarvae were taken from June to October, with

TABLE 80.—Vertical distribution by 50-m intervals of *Lampadena urophaos* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval, dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
601- 650	1				1	4	21.7	17-28																
651- 700	1				1	*														<1	<1	*		
701- 750	<1				<1	1	29.0	29	-	-	-	-	-							<1	<1	1	24.0	24
751- 800	<1				<1	*																		
801- 850									-	-	-	-	-											
951-1000	-	-	-	-	-				1				1	4	14.5	14-15	-	-	-	-	-			
TOTALS	2				2	5			1				1	4						<1	<1	1		
NIGHT																								
51- 100	<1				<1	2	37.0	37		1			1	8	25.4	19-31								
101- 150										<1			<1	1	29.0	29								
151- 200	1				1	8	22.1	19-26												<1	<1	1	57.0	57
201- 250																				<1	<1	1	64.0	64
251- 300	<1				<1	*																		
301- 350	1				1	1	24.0	24	-	-	-	-	-											
551- 600	<1				<1	1	17.0	17									-	-	-	-	-			
TOTALS	2				2	12				1			1	9						<1	<1	2		

most caught from July to September. Small (17–20 mm) juveniles were taken at all seasons. In winter most of the catch was smaller than 25 mm, and in late spring most was larger than 25 mm. In late summer too few fish were taken in discrete-depth samples to provide any indication of the size frequency distribution of the population. Specimens caught in late summer with the Engel trawl range from 32 mm to 80 mm.

The absence of mature females may be due to the relatively large size at maturity. Except for the largest, all Ocean Acre specimens are smaller than a ripe female (98 mm) reported from collections taken near Hawaii (Clarke, 1973). Fish of this size can, without doubt, easily avoid the 3-m Isaccs-Kidd midwater trawl.

VERTICAL DISTRIBUTION.—Daytime depth range for all three seasons combined is 601–1000 m. Only postlarvae were taken below 750 m. At night *L. urophaos* was taken between 100 and 250 m at each of the three seasons. In winter it also was found at 301–350 m and 551–600 m (Table 80). The day depth range is similar to that for the species near Hawaii, and nighttime depths are somewhat more extensive than in the Hawaiian population (Clarke, 1973).

Lampanyctus alatus

This is a moderately large species, growing to 61 mm (Hulley, 1981); maximum size in the Ocean Acre collections is 54 mm. *Lampanyctus alatus* tentatively is classified as a tropical species and is listed as one of the ranking myctophids in the North Atlantic subtropical region (Backus et al., 1977), but the Ocean Acre collections do not confirm this. The species is uncommon in the study area, and is represented in these collections by only 80 specimens; 29 were caught during the paired seasonal cruises, 13 of which were taken in discrete-depth samples, of which 10 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Juveniles were 21–37 mm, subadults 33–51 mm, and adults 43–51 mm SL. There was no obvious external sexual dimorphism in fish of any size. All but two adults were males. One of the females contained ova up to 0.5 mm in diameter and appeared to be ripe or nearly so. None of the large (over 40 mm) subadult females appeared to be spent.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive status of this species in the Ocean Acre area is uncertain. Although a large ripe or nearly ripe

TABLE 81.—Vertical distribution by 50-m intervals of *Lampanyctus alatus* (AD = adult; JUV = juvenile; N = number of specimens, PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE
DAY																								
601- 650																								
651- 700	<1	<1			<1	*														-	-			
701- 750	<1	<1			<1	2	39.0	30-48										<1			<1	*		
751- 800	<1	<1			<1	*												<1			<1	1	37.0	37
801- 850		<1			<1	1	34.0	34													-	-		
TOTALS	<1	<1			<1	3												<1			<1	1		
NIGHT																								
51- 100										1			1	4	47.2	46-49								
101- 150																								
151- 200																								
201- 250																		<1			<1	1	51.0	51
251- 300									1				1	1	50.0	50								
301- 350									<1				<1	*										
351- 400																								
TOTALS									1	1			2	5				<1			<1	1		

female was taken, juveniles smaller than 18 mm were not. Individuals smaller than 30 mm SL account for less than 10 percent of the total number taken in the Ocean Acre area. This scarcity of small juveniles in the collections may indicate that recruits into the population were mostly larger fish that were spawned elsewhere. In any case, *L. alatus* was never very abundant in the study area (Table 81), and any spawning must be at a low level.

Fish larger than 40 mm were taken most of the year, and small fish (less than 30 mm) were taken in very low numbers in April and from July through October. These data imply a relatively long breeding season for the parent population.

VERTICAL DISTRIBUTION.—Day depths in winter (based on 3 specimens) are 701-850 m and in late summer (1 specimen) 751-800 m. Nocturnal depths in late spring (5 specimens) are 51-100 m and 251-300 m, and in late summer (1 specimen) 201-250 m (Table 81).

Lampanyctus ater

This is a large myctophid attaining a length of 140 mm (Nafpaktitis et al., 1977); maximum standard length in the Ocean Acre collections is 110 mm. In the Atlantic it is a bipolar species with a questionably subtropical distribution (Backus et al., 1977). Although *L. ater* does not occur in the southern Sargasso Sea, it is common near Bermuda, where it is among the eleven most abundant lanternfish in winter and late spring. The Ocean Acre collections contain 414 specimens; 211 were caught during the paired seasonal cruises, 151 of these in discrete-depth samples, of which 143 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 9-22 mm, juveniles 19-64 mm, subadults 55-106 mm, and adults 82-104 mm. Most juveniles smaller than 30 mm could not be sexed, and most larger ones had recognizable ovaries or testes. All adults were male. The most sexually developed female had ovaries of moderate size with a few eggs as large as 0.25 mm in diameter. There appears to be a sexual dimorphism in size, with males developing faster and females growing to a larger size. Nearly all of the juveniles smaller than 30 mm that could be sexed were males. Juvenile females averaged nearly 5 mm larger than juvenile males (42.6 vs 38.0 mm). This difference probably is due mostly to males being recognized at a smaller size than females. Subadult females were, on the average, nearly 11 mm larger than subadult and adult males (79.6 vs 68.9 mm). A further indication of sexual dimorphism in size is that 12 of the 13 specimens 100 mm and larger were females.

TABLE 82.—Seasonal abundance and percent of total abundance (in parentheses) for *Lampanyctus ater* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.6(2.8)	17.8(84.0)	2.8(13.2)	0	21.2
LATE SPRING	0	9.4(49.5)	8.6(45.3)	1.0(5.3)	19.0
LATE SUMMER	0	5.4(77.1)	1.6(22.9)	0	7.0

TABLE 83.—Numbers of each sex for each stage of *Lampanyctus ater* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV M	JUV F	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	32	15*	3	8	1	0	36	23
SPRING	32	19	10	3	1	0	43	22*
SUMMER	10	11	2	3	0	0	12	14

TABLE 84.—Vertical distribution by 50-m intervals of *Lampanyctus ater* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	W PL	W JUV	W SA	W AD	W TOT	W N	W X	W RANGE	LS PL	LS JUV	LS SA	LS AD	LS TOT	LS N	LS X	LS RANGE	SU PL	SU JUV	SU SA	SU AD	SU TOT	SU N	SU X	SU RANGE
DAY																								
301- 350									<1				<1	1	37.0	37								
601- 650																								
651- 700	-	-	-	-	-												-	-	-	-	-			
701- 750		8			8	19	27.5	22-34	-	-	-	-	-											
751- 800		6	1		7	*				3	<1		3	16	44.5	34-73		1			1	3	36.3	30-41
801- 850		4	2		6	18	46.9	24-60		2	<1		2	*				<1	<1		<1	2	58.5	48-69
851- 900	-	-	-	-	-					1			1	2	47.0	30-64		<1	<1		<1	*		
901- 950	-	-	-	-	-				<1				<1	*										
951-1000	-	-	-	-	-													<1			<1	*		
1001-1050	<1				<1	1	16.0	16			2		2	*				<1			<1	1	79.0	79
1051-1100	-	-	-	-	-						4		4	4	90.7	72-103		<1			<1	*		
1101-1150	-	-	-	-	-						1		1	1	92.0	92		<1			<1	1	72.0	72
1151-1200	-	-	-	-	-						1	1	2	2	97.5	91-104								
1451-1500	-	-	-	-	-				-	-	-	-	-						2		2	2	57.0	56-58
1501-1550		<1	<1		<1	1	99.0	99										1			1	1	44.0	44
TOTALS	<1	18	3		21	39				6	8	1	15	26				4	<1		4	10		
NIGHT																								
51- 100	<1	<1			<1	2	20.5	12-29		3			3	16	34.8	28-42								
101- 150		<1			<1	1	24.0	24																
151- 200		1			1	5	22.8	19-30		2			2	3	27.3	21-37								
201- 250		1			1	2	31.5	27-36		<1			<1	1	46.0	46								
551- 600		1			1	2	40.5	39-42																
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	2	48.0	45-51
701- 750									-	-	-	-	-											
751- 800		1	<1		1	5	46.0	21-72		2			2	3	39.7	37-42								
801- 850		2	1		3	5	50.0	19-70		2			2	5	43.4	34-52		1	<1		1	*		
851- 900	1	2			3	6	24.2	18-46	-	-	-	-						3	<1		3	9	52.3	38-82
901- 950		1			1	*			-	-	-	-	-											
951-1000																		<1			<1	1	52.0	52
1201-1250											1		1	2	68.0	64-72								
TOTALS	1	9	1		11	26				9	1		10	30				5	<1		5	12		

REPRODUCTIVE CYCLE AND ABUNDANCE.—*Lampanyctus ater* has a life span of at least two years and probably does not spawn until two years of age. Recruitment of fish smaller than 30 mm occurred mostly in winter but extended into late spring, indicating that spawning occurred primarily in fall.

Abundance was greatest in winter, when the catch consisted of at least three size groups: fish 12–36 mm representing the most recent recruit class and accounting for about 65 percent of the catch, fish 42–62 mm, presumably about one year old, and fish 70 mm and larger that were probably two years old. All but two individuals 12–20 mm were taken in January, an additional indication that most spawning occurred in fall.

By late spring most recruitment was past and few fish were smaller than 30 mm. Winter recruits had grown to about 30–50 mm. The two older groups were not well represented in the samples and may be 63–73 mm and 86 mm, respectively. Abundance at this season was only slightly lower than in winter (Table 82), which is puzzling in view of the lack of recruitment.

In late summer only the most recent recruit class was adequately sampled by the discrete-depth gear. Those fish had grown to about 38–58 mm. However, specimens caught by the Engel trawl fell into three size groups: 37–58 mm, 64–85 mm, and 87 mm and larger. Presumably these groups represented those in the winter collections at a more advanced age. Abundance was about 33 percent of that at the other two seasons (Table 82).

SEX RATIOS.—Males may be more numerous than females in winter and late spring. Male-to-female ratios were 1.6:1 in winter, 2.0:1 in late spring, and 0.9:1 in late summer; only the difference in late spring was significantly different from equality (Table 83). In both winter and late spring the differences were due mostly to juveniles, and could be influenced by the size dimorphism described above. There was no consistent pattern of numerical dominance by either sex for the older stages.

VERTICAL DISTRIBUTION.—Day depth range in winter was 701–850 m, possibly extending to 1550 m, with maximum abundance at 701–750 m; in late spring 751–1200 m with a maximum at 1051–1100 m (a single specimen caught at 301–350 m probably was a contaminant); and in late summer 751–1550 m with slight concentrations at 751–850 m and 1451–1500 m. Most of the suspected day depth range of *L. ater* was not sampled in winter (Table 84) and little can be said concerning the vertical distribution at that season.

At night in winter and late spring two distinct depth zones were occupied: a shallow one at 51–250 m at both seasons and a deeper one at 751–900 m in winter and 751–850 m in late spring (a few specimens were taken at 551–600 m in winter). The depth of maximum abundance in winter was 801–900 m, and in late spring 51–100 m. At night in late summer *L. ater* was absent from the upper 600

m and was taken at 651–1000 m with maximum abundance at 851–900 m (Table 84).

Stage and size stratification were evident both day and night at each season. By day in winter and late summer juveniles had a shallower upper depth limit than subadults, and in late spring subadults had a deeper lower depth limit than juveniles. In winter and late spring juveniles were most abundant at a shallower depth than subadults were. There was an increase in size with depth at each season. Size stratification was best developed in late spring, when the minimum, maximum, and mean sizes all increased with depth. In winter and late summer the mean size of fish caught at the shallowest 50-m interval occupied was noticeably smaller than at greater depths, and in late spring the mean SL of the catch at 1051–1200 m was about twice that at 751–900 m (Table 84). At all three seasons most fish 22–50 mm were caught at 701–800 m, and all fish 90 mm and larger were below 1000 m.

At night in winter and late spring only juveniles migrated into the upper 200 m. Nonmigrants included both juveniles and subadults. Migrants were 19–46 mm and nonmigrants 18–82 mm. Fish larger than 82 mm were not taken at night.

There was a slight indication that postlarvae were stratified by size. The few 9–12 mm specimens were caught at night near 100 m, and those 15–18 mm were caught below 850 m both day and night.

Diel vertical migrations occurred only in winter and late spring. Little can be learned about the chronology of vertical migrations from the sample data, other than that some migrators arrived in the upper layer between two and three hours after sunset and some remained there until two or three hours before sunset.

PATCHINESS.—Patchiness was not indicated. The only significant CD value was for 51–100 m at night in late spring. This resulted from testing three positive samples from 100 m, showing little variation, with negative samples from 54–56 m and 92–94 m. This probably indicates a stratified abundance within this depth rather than horizontal patchiness.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, were 0.6:1 in winter and late spring, and 1.0:1 in late summer (Table 85). Most of the

TABLE 85.—Seasonal night to day catch ratios of *Lampanyctus ater* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.5:1	0.6:1	0.5:1	*	0.6:1
LATE SPRING	*	1.5:1	0.1:1	*	0.6:1
LATE SUMMER	*	1.4:1	0.3:1	*	1.0:1

difference between day and night catches in winter was due
to juveniles, and most of the difference in late spring to
subadults. In winter juveniles were concentrated below 700
m both day and night, but also were found at 51–250 m at
night. The greater night vertical range may account for
part of the difference between winter day and night catches.
In late spring most of the difference in day and night catches
was due to subadults.

Lampanyctus crocodilus

This large myctophid grows to 200–300 mm (Taaning,
1918); the largest Ocean Acre specimen is 56 mm. *Lampan-
yctus crocodilus* is a temperate-semisubtropical species
(Backus et al., 1977). Although categorized as "common"
in the study area, it was found in moderate abundance only
in late spring, when it was the eleventh most abundant
myctophid; at other seasons it was uncommon (Table 131).
The Ocean Acre collections contain 350 specimens; 142
were caught during the paired seasonal cruises, 97 of these
in discrete-depth samples, of which 76 were caught in
noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 6–22 mm
and juveniles 19–56 mm. Few specimens exceeded 40 mm
in length.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—It
cannot be determined if the entire life cycle is passed in the
study area. The parent population probably spawns from
winter to summer, with the greatest intensity in winter and
late spring. Although the life span cannot be determined,
the catch data show that the species lives for more than one
year and that sexual maturity was not attained by that age.

April collections were solely of postlarvae, which may
reflect a spawning peak in the parent population. By late
spring some postlarvae had transformed, and most of the
catch was 19–24 mm, at or near the size at transformation.
A few specimens were 25–35 mm, and two were about 50
mm; none were 36–49 mm. In late summer the IKMT
catch was exclusively 25–37 mm juveniles, presumably 5–6
months old. At that season the Engel trawl caught a similar
size group and two fish about 50 mm, but none of inter-
mediate size. In winter most specimens were 34–45 mm
and about one year old. Apparently, the larger specimens
(50 mm) taken in late spring and in late summer were
spawned early.

Seasonal abundance reflects the above sequence of
events. Abundance was greatest in late spring when recruits
19–24 mm predominated, and decreased as the year pro-
gressed as a result of the end of spawning and of continuing
mortality in the recruit class (Table 86).

The absence of large fish in the collections is puzzling.
Even the Engel trawl failed to catch fish larger than 56 mm,
despite fishing to 1000 m. Fish more than 100 mm in length
apparently remain below 1000 m (Goodyear et al., 1972),
and may stay as deep as 2500–3000 m (Krefft, personal

communication). It is possible that near Bermuda fish larger
than 50 mm live below the depths sampled during the
Ocean Acre program. Specimens about 100 mm long were
observed from a deep submersible near or on the bottom
in the slope water off New England (J.E. Craddock, personal
communication). If large fish live near the bottom in the
Bermuda area, they would not appear in the collections
because no samples were made near the bottom. Alterna-
tively, large fish may not occur in the area, remaining in
their more temperate habitat, while smaller specimens enter
the area, but never reach spawning size.

VERTICAL DISTRIBUTION.—Depth by day in winter is
801–850 m (1 specimen), in late spring 751–1000 m with
maximum abundance at 751–800 m, and in late summer
801–950 m. Nocturnal depth in winter is 751–900 m, in
late spring about 50–300 m and 551–850 m, and in late
summer 201–950 (Table 86). As indicated earlier, *L. cro-
codilus* may inhabit greater depths than these.

There is no evidence for stratification by stage. In late
spring juveniles and postlarvae were taken over similar
depth ranges, and at the other two seasons only juveniles
were taken (Table 86).

Lampanyctus crocodilus may stratify according to size. At
night this stratification was related to the extent of the
vertical migrations performed by this species. During the
day in late spring the two largest specimens (50 and 52 mm)
were caught at the greatest depth, and smaller fish were
taken throughout the depth range. At the other two seasons
too few specimens were taken during daytime to note
whether or not size stratification existed (Table 86). Good-
year et al. (1972) noted that in the Mediterranean Sea
juveniles smaller than 34 mm were found at shallower
depths than larger juveniles and subadults.

Postlarvae probably were stratified by size. The few taken
in the upper 200 m at night were smaller than 14 mm, and
those caught below 700 m both day and night were larger
than 14 mm. This suggests that, as with other myctophids,
postlarvae do not undergo extensive diel vertical migrations
during initial development which takes place at superficial
depths, and at about 14 mm postlarvae descend to greater
depths to complete development and metamorphosis.

Diel migrations apparently commence soon after meta-
morphosis and continue for a limited time, after which they
gradually diminish in extent until there is no change in
depth during the diel cycle.

Vertical migrations occur only in fish 20–33 mm, with
those 20–24 mm migrating to 50–100 m, and those 28–33
mm migrating to intermediate depths (Table 86). The catch
at night in late spring consisted of migrants 20–24 mm,
partial migrants 28–32 mm, and nonmigrants 19–23 mm,
the size at which metamorphosis takes place. In late summer
the night catch consisted of partial migrants 29–33 mm and
nonmigrants 25–36 mm, and in winter of nonmigrants 34–
42 mm (Table 86).

PATCHINESS.—Clumping was indicated for the depth of

TABLE 86.—Vertical distribution by 50-m intervals of *Lampanyctus crocodilus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE						SL		CATCH RATE						SL		CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
651- 700	-	-	-	-	-												-	-	-	-	-			
701- 750									<1	2			2	*										
751- 800	<1			<1		*				4			4	21	24.0	15-35								
801- 850	<1			<1		1	45.0	45		3			3	*				1			1	3	29.7	26-37
851- 900	-	-	-	-	-				1	1			2	7	22.4	19-26		1			1	*		
901- 950	-	-	-	-	-					1			1	*				<1			<1	1	29.0	29
951-1000	-	-	-	-	-				2	<1			2	9	26.1	18-52		<1			<1	*		
1001-1050										<1			<1	*										
1051-1100	-	-	-	-	-												-	-	-	-	-			
TOTALS	<1			<1		1			3	11			14	37				2			2	4		
NIGHT																								
1- 50										2			2	2	22.0	21-23								
51- 100										1			1	3	22.0	20-24								
101- 150																								
151- 200									1				1	1	13.0	13								
201- 250																		<1			<1	2	32.0	31-33
251- 300	-	-	-	-	-				1				1	1	16.0	16								
301- 350									-	-	-	-	-											
351- 400																								
401- 450																		<1			<1	1	30.0	30
451- 500																		<1			<1	1	29.0	29
501- 550																								
551- 600										<1			<1	2	29.2	28-32	-	-	-	-	-			
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	1	31.0	31
701- 750									-	-	-	-	-					1			1	1	36.0	36
751- 800	<1			<1		1	42.0	42		1			1	2	21.5	21-22								
801- 850	1			1		1	34.0	34	1	2			3	5	20.2	17-23		1			1	*		
851- 900	1			1		1	37.0	37	-	-	-	-	-					2			2	5	27.8	25-32
901- 950	<1			<1		*			-	-	-	-	-					1			1	2	28.0	27-29
951-1000									1				1	2	16.0	15-17								
TOTALS	2			2		3			4	6			10	18				6			6	13		

TABLE 87.—Seasonal night to day catch ratios of *Lampanyctus crocodilus* (JUV = juvenile; PL = postlarva; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	TOT
WINTER	*	4.0:1	4.0:1
LATE SPRING	0.7:1	0.6:1	0.6:1
LATE SUMMER	*	2.4:1	2.4:1

maximum abundance by day in late spring (751–800 m) and by night in late summer (851–900 m).

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios for discrete-depth captures (including interpolated values) are 4.0:1 in winter, 0.6:1 in late spring, and 2.4:1 in late summer (Table 87).

The difference in diel catch rates for winter samples probably was due to poor sampling effort within the presumed day range, 751–1000 m (Table 86). In late spring there were diel differences in clumping and extent of vertical range, which might account for the greater daytime

catch. Also fish 35-52 mm were sampled only by day. In late summer several depths within the diurnal vertical range were not sampled and clumping was noted by night but not by day.

Lampanyctus cuprarius

This is a large species reported to exceed 100 mm in length (Bekker, 1967; Kotthaus, 1972; Parin et al., 1974), but it probably does not grow larger than 80 mm (Zahuranec, 1980). The largest specimen taken during the study was 79 mm. Beebe (1937) listed the size range of *L. cuprarius* taken near Bermuda as 9-101 mm, but did not indicate whether total or standard length was measured. In either case, specimens near either extreme of the range probably were not *L. cuprarius*; transformation occurs at 16-18 mm.

According to Backus et al. (1977:275, table 5), this bipolar subtropical species is not a ranking member of the family in any of their Atlantic mesopelagic regions. However, in the study area *L. cuprarius* is common and was among the eleven most abundant lanternfishes at each season, ranking as high as fifth in late spring. There are 1462 specimens in the Ocean Acre collections; 584 from the paired seasonal cruises, 383 of these in discrete-depth samples, of which 340 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 5-20 mm, juveniles 18-54 mm, subadults 46-74 mm, and adults 62-73 mm. Most juveniles smaller than 30 mm could not be sexed, and most larger juveniles had small but recognizable ovaries or testes. Some females larger than 65 mm and categorized as subadults may have been postspawning adults with regenerating ovaries. Adult females contained eggs as large as 0.5 mm, but mostly ova were 0.2-0.3 mm in diameter. There may be sexual dimorphism in size; all fish larger than 70 mm examined for sex and stage (10 specimens) were females, and the average sizes of subadult and adult females were 2.0 mm and 1.6 mm larger than those of subadult and adult males, respectively.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—The life span of *L. cuprarius* is two or more years, and sexual maturity is not attained until the second year. Although spawning may occur from spring to fall, it probably is minimal except from July through September, when reproduction is at its peak. Abundance was fairly stable over the three sampling periods, perhaps a result of the relatively long life span. Abundance was greatest in late spring and lowest in late summer (Table 88), which is incongruous with the pronounced spawning peak in summer. The low late summer abundance may be due to continuing mortality of postspawning adults and inadequate sampling of new recruits. The increase from winter to late spring was due mostly to juveniles and must be an artifact of sampling. Normal mortality from winter to late spring, together with

TABLE 88.—Seasonal abundance and percent of total abundance (in parentheses) for *Lampanyctus cuprarius* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	15.8 (43.6)	19.9 (55.0)	0.5 (1.4)	36.2
LATE SPRING	0	19.0 (47.5)	18.2 (45.5)	2.8 (7.0)	40.0
LATE SUMMER	9.0 (29.2)	9.7 (31.5)	8.6 (27.9)	3.5 (11.4)	30.8

continuing development into the subadult stage, must deplete the abundance of juveniles between the two times. Presumably the greatest abundance occurs in fall, with postlarvae and juveniles being numerically dominant.

Adult-size females were caught at each season, but greatly distended ovaries with eggs as large as 0.5 mm in diameter were observed only from July to September. Those taken in June had enlarged, but not distended, ovaries with ova up to 0.3 mm in diameter. Postlarvae were caught only during August-September, and juveniles 20-25 mm began to appear in October. Juveniles 25-30 mm were most abundant in winter. These data show that *L. cuprarius* reproduces mostly during the summer and that little additional recruitment occurs at other seasons.

Almost all specimens caught in late spring were either 30-50 mm or 59-74 mm. The smaller group consisted mostly of juveniles approaching one year of age. The age composition of the group of larger fish was uncertain; there may have been more than one age class represented. Those smaller than about 70 mm were approaching two years of age and were about to spawn for the first time. It is possible that fish in excess of 70 mm are more than two years old, but they may be faster-growing fish approaching two years old.

In late summer postlarvae and juveniles smaller than 20 mm begin to appear in the catch. These fish apparently represent offspring from the earliest spawn. Most fish in this group were too small to be sampled adequately by the gear and probably were much more abundant than the samples indicate. Most of the other specimens were either 45-54 mm or 62-71 mm and represented the two size groups noted in late spring (but were slightly older). The smaller group consisted mostly of juveniles about one year old, and the larger one mostly of subadults and adults about two or more years old. Several females larger than 65 mm and categorized as subadults appeared to be spent adults. The abundance of both juveniles and subadults was about half of that in late spring. The abundance of juveniles decreased because some had grown to subadults and others were lost to mortality, and also because recruits were not yet large enough to be sampled adequately. The decrease

in subadults is most likely attributable to most having matured, spawned, and died by late summer.

Spawning was completed by winter when adults were least abundant and no postlarvae were caught (Table 88). Most specimens were either 20–40 mm or 56–74 mm, very few were 41–55 mm. The smaller group mostly consisted of juvenile recruits from the recent spawn with the larger group containing subadults and a few adults at least a year older than the recruits. Older fish were slightly more abundant than the recruits (Table 88), which is the reverse of what would be expected, suggesting that the abundance of juveniles in winter was underestimated. The apparent increase in abundance of juveniles from winter to late spring further suggests that the abundance of juveniles in winter was underestimated.

SEX RATIOS.—The sexes were equally abundant at each season. Female to male ratios were 1.3:1 in winter and late spring, and 0.7:1 in late summer. None of these ratios is significantly different from equality (Table 89). Except for juveniles in late summer and subadults in late spring, there were no significant differences from equality for any stage at any season. Despite the differences noted above, the sexes probably are equally abundant for the three older stages.

VERTICAL DISTRIBUTION.—Diurnal depth range in winter was 601–1050 m (possibly deeper) with maximum abundance at 801–850 m, in late spring 751–1200 m with a maximum at 751–800 m, and in late summer 701–950 and 1451–1500 m with a slight maximum at 801–950 m. Nocturnal depth range in winter was 200–1000 m with maximum abundance at 200–350 m, in late spring 100–1100 m with a maximum at 100 m, and in late summer 33–1000 m with maxima at 33 m and 851–900 m (Table 90).

Stage and size stratification were evident at all three seasons. The daytime depth of greatest abundance of juveniles was shallower than that of adults at all seasons and of subadults in winter and late spring. In winter only juveniles were caught at 601–750 m, and in late summer all stages except adults were caught at 701–850 m. In late spring adults were not taken as deep as juveniles and subadults. Size stratification was well developed in winter and in late

TABLE 89.—Numbers of each sex for each stage of *Lampanyctus cuprarius* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	14	18	33	44	1	0	48	62
SPRING	42	39	14	32*	3	7	59	78
SUMMER	15	6*	15	14	8	6	38	26

summer, when the mean, minimum, and maximum sizes all increased with depth. In late spring fish smaller than 49 mm were taken only above about 1000 m, and in winter those larger than 35 mm were caught at depths greater than 800 m (Table 90).

At night the depth of greatest abundance of juveniles was shallower than that of the other stages in winter and in late spring. In late summer postlarvae were most abundant in the upper 50 m, and the three older stages at 851–900 m. Except for one subadult caught at 51–100 m, only juveniles were taken at either extreme of depth in late spring, and in late summer only postlarvae were taken at extremes of depth (Table 90). Size stratification was well developed only in late spring when all fish larger than 50 mm were caught above about 600 m and smaller fish were taken over the entire vertical range. In the upper 600 m fish also were stratified by size; those taken at 51–100 m had a mean size of 39.8 mm, and those taken at 101–600 m were mostly larger than 45 mm with a mean size of 54.5 mm. Most sizes were taken throughout the depth range in winter and late summer, but the catch below about 700 m consisted mostly of fish larger than 45 mm (Table 90).

Postlarvae also were stratified according to size in late summer. Those caught in the upper 150 m were 6–15 mm, mostly 6–11 mm, and those caught deeper than 700 m were 9–20 mm, mostly 15–20 mm. All postlarvae caught at the shallower depth, and all but two from deeper depths, were taken at night. Based upon the maximum size of postlarvae (20 mm) and the minimum size of juveniles (18 mm) in the collections, metamorphosis probably occurs at 17–20 mm. A few transforming postlarvae 16.4–18.8 mm were taken during the program (H. Zadoretzky, personal communication). Thus, initial development takes place in the upper 150 m. Upon reaching 12–15 mm postlarvae descend to depths greater than about 700 m where they transform into juveniles. Postlarvae probably do not undergo diel vertical migrations of any great extent, but additional daytime catches are needed to verify this.

Diel vertical migrations occurred at each of the three seasons, but only part of the population migrated to waters shallower than the minimum day depths at night. Excluding postlarvae, nonmigrants accounted for about 33 percent of the total night catch at each season. The stage and size composition of nonmigrants varied seasonally. In winter nonmigrants included juveniles and subadults 20–71 mm, in spring all but one were juveniles 43–49 mm, and in late summer they included all stages and were 9–68 mm. Fish larger than 49 mm were predominant among the nonmigrators in winter (69 percent) and late summer (86 percent).

PATCHINESS.—Significant CD values were obtained only for depths at which small catches were made (abundance ranged from 1.3 to 3.9) and at which one or more samples failed to catch the species. It is not likely that significant patchiness occurs at such low population densities.

TABLE 90.—Vertical distribution by 50-m intervals of *Lampanyctus cuprarius* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
601– 650	1				1	4	23.7	22–26	–	–	–	–	–											
651– 700	3				3	*																		
701– 750	5				5	13	31.8	24–36	3	1	<1		4	*			<1				<1	1	13.0	13
751– 800	4	4	<1		8	*			6	2	<1		8	45	50.7	35–70		1	<1		1	5	40.2	29–51
801– 850	2	9	<1		11	35	55.0	24–69	3	2	1		6	*				2	1		3	9	50.8	48–68
851– 900	–	–	–	–	–				1	1	1		3	9	61.2	41–72		1	1	1	3	*		
901– 950	–	–	–	–	–				1	1	1		3	*			<1		1	1	2	8	57.0	16–70
951–1000	–	–	–	–	–				1	1			2	11	52.3	36–72		1		1	2	*		
1001–1050		1			1	2	66.5	64–69	1	2			3	*										
1051–1100	–	–	–	–	–				1	2			3	3	59.7	49–70	–	–	–	–	–			
1101–1150	–	–	–	–	–							4	4	4	66.7	64–71								
1151–1200	–	–	–	–	–				2	3			5	5	61.0	48–74								
1451–1500	–	–	–	–	–				–	–	–	–	–								1	1	67.0	67
TOTALS	15	14	<1		29	54			19	19	3		41	77			<1	4	4	4	12	24		
NIGHT																								
1– 50																	5				5	10	8.6	6–11
51– 100										4	<1		4	23	39.5	31–51								
101– 150										1			1	3	42.5	41–45	1				1	2	12.5	10–15
151– 200		1	1		2	13	45.8	32–69												<1	<1	1	69.0	69
201– 250	3	1			4	12	43.8	35–70		1	1		2	5	56.0	45–63		<1			<1	1	40.0	40
251– 300	2	3			5	*					1	1	2	4	64.7	60–69		<1			<1	1	19.0	19
301– 350		4			4	8	66.0	62–74	<1	1	1		2	*						<1	<1	1	68.0	68
351– 400	1	1			2	4	43.5	26–62	<1	1			1	3	59.2	44–70		1	1	1	3	5	61.0	50–71
401– 450		<1			<1	1	64.0	64										<1			<1	1	64.0	64
451– 500	3				3	8	31.1	27–34																
501– 550	1	1			2	6	56.0	32–69											2	1	3	3	52.3	46–64
551– 600	<1				<1	1	22.0	22		1			1	2	63.6	60–65		1	1		2	*		
601– 650		1			1	1	63.0	63	–	–	–	–	–											
651– 700	<1	1			1	*			–	–	–	–	–					1	2		3	5	63.4	47–21
701– 750	1	1			2	4	48.0	27–67	–	–	–	–	–					1	1		2	2	57.5	52–63
751– 800			3		3	9	65.2	60–71	1				1	2	45.9	45–47	<1	<1			<1	2	28.0	9–47
801– 850									2				2	4	42.0	43–46		1	1	1	3	*		
851– 900	1	2			3	4	50.7	20–65	–	–	–	–	–				1	2	2	1	6	18	53.8	18–68
901– 950	<1	1			1	*			–	–	–	–	–				2	<1	<1	1	3	9	35.4	15–68
951–1000		1			1	1	61.0	61	<1				<1	1	49.0	49	1				1	2	16.0	16
1001–1050									1				1	*			–	–	–	–	–			
1051–1100	–	–	–	–	–				1				1	1	47.0	47	–	–	–	–	–			
1201–1250												<1	<1	*										
TOTALS	13	21			34	72			11	5	2		18	48			10	9	9	4	31	63		

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, were 1.1:1 in winter, 0.4:1 in late spring, and 2.6:1 in late summer (Table 91). Except for juveniles in winter and adults in late summer, ratios for the individual stages followed the seasonal trends. The ratios most divergent from 1:1 were obtained in late summer for postlarvae and juveniles and in late spring for subadults and adults.

The lack of consistency in the total night-to-day ratios from season to season indicates that several factors may have been responsible for the observed differences in catches. Vertical range during daytime was smaller than

TABLE 91.—Seasonal night to day catch ratios of *Lampanyctus cuprarius* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	0.8:1	1.4:1	*	1.1:1
LATE SPRING	*	0.6:1	0.2:1	0.8:1	0.4:1
LATE SUMMER	15.0:1	2.8:1	2.0:1	0.9:1	2.6:1

TABLE 92.—Seasonal abundance and percent of total abundance (in parentheses) for *Lampanyctus festivus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.5(3.2)	13.5(86.0)	0.8(5.1)	0.9(5.7)	15.7
LATE SPRING	4.7(66.2)	2.2(31.0)	0.2(2.8)	0	7.1
LATE SUMMER	1.2(9.3)	10.4(80.6)	1.0(7.8)	0.3(2.3)	12.9

that at night at each season, suggesting that compression could result in larger diurnal catches than nocturnal catches. However, only in late spring did the total day abundance exceed the total night abundance. In late summer, when the diel difference in vertical range was greatest, the night catch was 2.6 times greater than that of day. At that season part of the difference was due to postlarvae and juveniles smaller than 20 mm, for which the ratio was 8.4:1. Large fish (mostly subadults) also were more abundant in night than in day samples, possibly due to enhanced net avoidance during daytime. In winter fish larger than 50 mm also were more abundant in night samples, but in late spring the reverse was true, complicating avoidance as an explanation.

Lampanyctus festivus

This large myctophid grows to 138 mm (Hulley, 1981); maximum size in the Ocean Acre collections is 110 mm. A bipolar questionably subtropical species, *L. festivus* is most abundant in the North Atlantic subtropical region (Backus et al., 1977). It is common in the study area, but ranked no higher than twelfth in winter in abundance. The Ocean Acre collections contain 593 specimens; 188 were taken during the paired seasonal cruises, 131 of these in discrete-depth samples, of which 120 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 6–23 mm, juveniles 21–65 mm, subadults 63–110 mm, and adult males 85–103 mm. All females larger than 80 mm were examined for reproductive state; none were ripe or nearly ripe. The maximum egg diameter observed was 0.1 mm. The 42 specimens (33–110 mm) that could be sexed were divided equally between males and females. There was no apparent sexual dimorphism.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Lampanyctus festivus* probably spawns close to, if not in, the study area. However, until ripe females are taken, the issue is open to question. The parent population apparently spawns over much of the year, with a peak in intensity in winter. The life span is at least two years and probably longer. Abundance was greatest in winter, least in late spring, and intermediate in late summer (Table 92).

Postlarvae were most abundant in late spring, juveniles and adults in winter, and subadults in late summer.

Although the lack of ripe females in the Ocean Acre collections casts some doubt on the reproductive status of *L. festivus* in the study area, the capture of postlarvae and small (less than 25 mm) juveniles suggests that spawning takes place near Bermuda. Young fish were taken over most of the year and probably were present at all times. They were most abundant in late spring and only slightly less abundant in late summer.

In winter recruitment was at a minimum. Very few postlarvae were taken, and most juveniles were larger than 30 mm. Juveniles 30–40 mm dominated the catch. Presumably these represent fish from the previous year's spawning peak. The actual size range of most of the previous year's spawn appears to be 28–57 mm, with few fish larger than 40 mm. The few 63–86 mm specimens taken in late spring probably represent fish two or more years old. The abundance of specimens in excess of 40 mm is too low to note peaks in the size frequency distribution. Size ranges for the various age groups cannot be determined with any certainty.

In late spring postlarvae dominated the small catch, accounting for about 66 percent of the total abundance (Table 92). The relatively low abundance at this season is somewhat puzzling. It probably is due to the relative inefficiency of the 3-m IKMT in sampling postlarvae, which for the most part filter through the net, and specimens larger than about 45 mm. By late summer the abundance of each stage (except postlarvae) increased from its late spring level (Table 92). The increase in juveniles is to be expected, because most postlarvae present in late spring had grown and developed to juveniles. The catch in late spring could be divided into two size groups: recently spawned fish 15–32 mm, and fish larger than 50 mm at least 1.5 years old. Presumably the latter group represented the 28–57 mm fishes of winter at a more advanced age.

VERTICAL DISTRIBUTION.—Depth range by day in winter is 701–850 m with maximum abundance at 701–750 mm, in late spring 51–100 m and 751–800 m (possibly slightly shallower and deeper), and in late summer 501–550 m and 751–1050 m with a maximum at 801–850 m. Vertical range

TABLE 93.—Vertical distribution by 50-m intervals of *Lampanyctus festivus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
51- 100									<1				<1	1	13.0	13								
501- 550																	<1				<1	1	16.0	16
651- 700	-	-	-	-	-												-	-	-	-	-			
701- 750		8			8	20	35.0	28-57		1			1	*										
751- 800		4			4	*				1			1	9	43.9	24-69		1			1	2	27.0	25-29
801- 850		1			1	3	41.7	38-47		1			1	*					6	<1	6	13	33.6	25-63
851- 900	-	-	-	-	-														3	<1	3	*		
901- 950	-	-	-	-	-				-	-	-	~	-				<1	1			1	3	20.0	15-23
951-1000	-	-	-	-	-													<1			<1	*		
1001-1050									-	-	-	~	-				<1				<1	1	20.0	20
TOTALS		13			13	23			<1	3			3	10			<1	11	<1		11	20		
NIGHT																								
1- 50	-	-	-	-	-				4				4	4	9.5	9-11	-	-	-	-	-			
51- 100		1			1	5	30.6	30-32	1	1	<1		2	10	38.3	8-80								
101- 150		5			5	19	35.4	25-53		<1			<1	1	60.0	60	<1				<1	1	8.0	8
151- 200		1	<1		1	6	52.7	29-85										<1	<1	<1	1	6	59.8	28-84
201- 250			<1		<1	1	49.0	49										<1			<1	1	29.0	29
251- 300			<1	<1	<1	*													1	1	2	6	40.8	28-65
301- 350				1	1	1	86.0	86	-	-	-	~	-											
851- 900	1				1	1	17.0	17	-	-	-	~	-				<1				<1	1	23.0	23
901- 950	-	-	-	-	-				-	-	-	~	-				<1	<1			1	2	22.5	20-25
951-1000										<1			<1	1	21.0	21	<1				<1	1	18.0	18
1001-1050										<1			<1	*			-	-	-	-	-			
1051-1100	-	-	-	-	-												-	-	-	-	-			
TOTALS	1	7	1	1	9	33			5	2	<1		7	16			<1	1	1	<1	5	18		

at night in winter is 51-350 m and 851-900 m with maximum abundance at 101-150 m, in late spring 50-150 m and 951-1000 m with a maximum at 50 m, and in late summer 101-300 m and 851-1000 m with a maximum at 251-300 m (Table 93).

Stage and size stratification were evident during the day in late spring and late summer, and by night at each of the three seasons.

During the day only postlarvae were caught above 700 m in late spring and late summer, and deeper than 1000 m in late summer. As a result, mean sizes at those depths were much smaller than those at 751-850 m (Table 93).

At night in winter only juveniles were caught above 150 m and only subadults and adults at 201-350 m. In the upper 200 m size stratification resulted in an increase in the mean and maximum sizes with depth. The only specimen caught at 851-900 m was a 17 mm postlarva. In late spring only postlarvae were taken in the upper 50 m, and the mean size at that depth was much smaller than at other depths. In late summer only postlarvae were caught at 101-150 m and only postlarvae and small juveniles below 850 m. This resulted in smaller mean sizes at those depths than at 151-300 m (Table 93).

Development apparently begins in the upper layers, and transformation takes place at relatively great depths. Postlarvae taken in the upper 120 m are 6-11 mm; those taken at 851-1050 m are 19-23 mm. Four juveniles 21-25 mm (two each day and night) were taken at 901-1000 m. Migrations apparently start at about 25 mm, the size of smallest juvenile size taken in the upper 250 m at night (Table 93).

PATCHINESS.—A patchy distribution was indicated at the depth of maximum abundance by day in each season. Juveniles accounted for all or most of the catch at these depths

TABLE 94.—Seasonal night to day catch ratios of *Lampanyctus festivus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	0.5:1	*	*	0.6:1
LATE SPRING	47.0:1	1.1:1	*	*	3.4:1
LATE SUMMER	1.3:1	0.2:1	2.0:1	*	0.4:1

(Table 93). There was no indication of patchiness at night at any season.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios including interpolated values are 0.6:1 in winter, 3.4:1 in late spring, and 0.4:1 in late summer. Juveniles accounted for most of the diel differences in the catch in winter and late summer, and postlarvae for most of the difference in late spring (Table 94).

The greater catches by day in winter and late summer probably were due to the tendency of juveniles to form aggregations, resulting in large catches when such aggregations were encountered by the net.

In late spring the catch of postlarvae at night accounted for nearly all of the difference between day and night catches. The depth at which most postlarvae were taken at night (50 m) was not sampled during the day. Samples made during the day at 27 m (two samples) and 55 m (one sample) failed to take postlarval *L. festivus*. In any case, abundance was low.

Lampanyctus intricarius

This large lanternfish (attaining 200 mm according to Hulley, 1981) is found in all three oceans. In the Atlantic, where a bipolar temperate or bipolar subpolar-temperate distribution is indicated, *L. intricarius* is found mainly in the east (Backus et al., 1977). This species is rare in the study area, being represented in Ocean Acre collections only by two juveniles, 29 and 55 mm, taken in August-September.

Lampanyctus lineatus

This is a large lanternfish, attaining a size of 221 mm (Hulley, 1981); the largest specimen taken in the study area was 165 mm. *Lampanyctus lineatus* is either a bipolar subtropical species or a tropical-subtropical species (Backus et al. 1977). It is uncommon in the study area, never being among the 20 most abundant species (Table 131). The Ocean Acre collections contain 84 specimens; 35 were caught during the paired seasonal cruises, 19 of these in discrete-depth samples, of which 18 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 7–24 mm,

juveniles 25–92 mm, subadults 93–165 mm, and adults 140–165 mm. Fish larger than 99 mm amounted to 10 females 116–165 mm and 5 males 100–140 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Spawning apparently takes place at low levels for about half of the year. It cannot be established whether the population near Bermuda is self-sustaining or is dependent upon an influx of recruits from elsewhere to maintain its numbers. Judging from the large size, the life span probably is three or more years, but the collections provide little information concerning this due to the paucity of specimens taken at any season (Table 95).

Large fish were taken over most of the year and presumably were permanent residents of the area. Adults were taken only in late spring (a female) and in August (one of each sex). A 152 mm female taken in July, categorized as a subadult, may have been a spent adult. Postlarvae, including transformation stages, were taken only in late summer. Juveniles smaller than 30 mm were taken in September, October, and February. Taken together these data indicate that spawning occurs at least from late spring to winter.

The entire catch in late spring consisted of nine fish 44–165 mm, with only fish 44–92 mm taken in discrete-depth tows. Only postlarvae were caught during the paired late summer cruises. However, the Engel trawl fished at that season took 19 fish 37–165 mm. Four fish 25–85 mm were taken in winter, all in February.

VERTICAL DISTRIBUTION.—No more than six specimens were taken during the day or night at any of the three seasons. Day captures in winter were at 701–750 m and 801–850 m, in late spring 751–800 m and 1101–1150 m, and in late summer 901–950 m and 1001–1050 m. Night captures in winter were at 151–200 m and 301–350 m, in late spring 251–300 m and 951–1000 m, and in late summer the upper 50 m (Table 95).

Postlarvae may be stratified by size. Those taken in the upper 50 m were 9–12 mm and those from 901–1050 m were 20–21 mm. However, the shallow captures were at night and the deep ones during daytime.

Lampanyctus nobilis

This widely ranging species is found in tropical waters of the three oceans. In the North Atlantic it is a questionably tropical species, found mainly south of 30°N (Backus et al., 1977). It has been taken as far north as 50°N (Nafpaktitis et al., 1977). The species is large, growing to at least 125 mm (Hulley, 1981); the largest Ocean Acre specimen is 115 mm. Apparently, the larger fish of this species can easily avoid the discrete-depth gear. The species is rare in the study area, being represented in the collections by 20 fish, 19 of which were caught with the Engel trawl in August. The remaining specimen was taken by discrete-depth trawl in late spring. Clarke (1973) has noted the propensity for net avoidance by *L. nobilis* near Hawaii.

TABLE 95.—Vertical distribution by 50-m intervals of *Lampanyctus lineatus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
												DAY											
601- 650																								
651- 700	<1				<1	*			-	-	-	-	-				-	-	-	-				
701- 750	<1				<1	1	25.0	25	-	-	-	-	-											
751- 800	<1				<1	*				<1			<1	1	47.0	47								
801- 850	<1				<1	1	27.0	27	-	-	-	-	-											
851- 900	-	-	-	-	-																			
901- 950	-	-	-	-	-				-	-	-	-	-				1				1	2	20.0	20
951-1000	-	-	-	-	-																			
1001-1050									-	-	-	-	-				1				1	2	22.5	21-24
1051-1100	-	-	-	-	-																			
1101-1150	-	-	-	-	-				1				1	1	92.0	92								
TOTALS	1				1	2			1				1	2			2				2	2	4	
												NIGHT											
1- 50																	3				3	6	10.7	9-12
151- 200	<1				<1	1	44.0	44																
201- 250																								
251- 300	<1				<1	*			1				1	1	86.0	86								
301- 350	1				1	1	85.0	85	<1				<1	*										
351- 400																								
951-1000									<1				<1	1	44.0	44								
1001-1050									<1				<1	*										
1051-1100	-	-	-	-	-																			
TOTALS	1				1	2			1				1	2			3				3	6		

This species is not a breeding resident of the study area. Presumably the population near Bermuda consists of expatriates from the south. All specimens caught in the study area were larger than 60 mm. There were 16 males 67–115 mm, and 4 females 62–111 mm SL. The discrete-depth capture was made at 290 m near sunrise. Engel captures suggest day depths were greater than 900 m, and night depths were 100–200 m. Clarke (1973) gave a day depth range of 625–1000 m and night range of 40–140 m for fish of all sizes near Hawaii.

Lampanyctus photonotus

This moderately large lanternfish grows to a size of 70 mm in the study area and to 85 mm elsewhere (Hulley, 1981). A tropical-subtropical species, *L. photonotus*, is a ranking myctophid in the North Atlantic subtropical region (Backus et al., 1977). It is common but not abundant in the Ocean Acre area, being among the 20 most abundant lanternfishes at each of the three seasons, and among the top 10 in winter (Table 131). The Ocean Acre collections contain 1074 specimens; 469 were caught during the paired seasonal cruises, 351 of these in discrete-depth samples, of which 247 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 4–20 mm, juveniles 17–37 mm, subadults 30–62 mm, and adults 44–59 mm. Most of the few juveniles smaller than 20 mm had slender thread-like gonads and could not be sexed. Nearly all juveniles greater than 20 mm had recognizable ovaries or testes. Many of the subadult females larger than 45 mm appeared to be spent but had regenerating ovaries. Adult females contained ova as large as 0.4 mm in diameter, but most eggs were 0.2–0.3 mm. There was no apparent sexual dimorphism in size. Adult males have a larger supracaudal luminous gland than adult females (Nafpaktitis et al., 1977).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— *Lampanyctus photonotus* lives for more than one year and probably has a life span of two years. Adult size is reached

TABLE 96.—Seasonal abundance and percent of total abundance (in parentheses) for *Lampanyctus photonotus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	8.7 (29.5)	20.4 (69.2)	0.4 (1.4)	29.5
LATE SPRING	1.0 (15.2)	0	3.8 (57.6)	1.8 (27.3)	6.6
LATE SUMMER	9.1 (68.4)	3.0 (22.6)	1.2 (9.0)	0	13.3

TABLE 97.—Numbers of each sex for each stage of *Lampanyctus photonotus* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV M	JUV F	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	52	39	61	43	2	0	115	82*
SPRING	0	0	12	8	5	7	17	15
SUMMER	3	2	10	7	0	1	13	10

TABLE 98.—Vertical distribution by 50-m intervals of *Lampanyctus photonotus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
51- 100									<1				<1	1	10.0	10								
301- 350										1	<1		1	3	55.7	47-62								
501- 550																	<1				<1	1	10.0	10
601- 650	2				2	5	21.9	21-24																
651- 700	2	1			3	*											-	-	-	-	-			
701- 750	2	1			3	9	31.3	25-37		<1	<1		<1	*										
751- 800	2	2			4	*				1	1		2	5	47.6	42-57								
801- 850	1	3			4	11	38.7	30-53		<1	<1		<1	*			1			1	2	4	36.7	11-54
851- 900	-	-	-	-	-				<1				<1	3	31.3	7-46		<1			<1	*		
901- 950									<1				<1	*			2				2	5	12.4	11-15
951-1000	-	-	-	-	-												-	-	-	-	-			
1001-1050										1			1	*			4				4	12	16.1	14-20
1051-1100	-	-	-	-	-					1			1	1	41.0	41	-	-	-	-	-			
1501-1550	<1	<1			<1	2	42.5	32-53																
TOTALS	9	7			16	27			<1	4	1		5	13			7			1	8	22		
NIGHT																								
1- 50	1				1	5	30.0	24-33	1			1	2	2	29.5	10-49	2				2	3	6.0	6
51- 100	1	2			3	37	33.1	21-42			2	1	3	9	44.9	37-54		<1			<1	1	19.0	19
101- 150	4	17		<1	21	79	36.5	25-59										1			1	4	22.7	21-26
151- 200	<1	1		<1	1	8	49.6	26-57											1		1	4	49.7	47-52
201- 250	<1	<1			<1	2	38.0	35-41											1		1	3	51.3	45-59
251- 300	<1	<1			<1	*																		
301- 350									-	-	-	-	-											
801- 850	1				1	1	18.0	18																
851- 900									-	-	-	-	-				3	<1			3	11	17.4	14-19
901- 950	-	-	-	-	-				-	-	-	-	-					1			1	4	18.0	17-19
951-1000																	4				4	13	15.5	13-18
TOTALS	8	20		<1	29	131			1		2	2	5	11			9	3	1		13	43		

at the end of the first year, when fish probably spawn for the first time. Spawning occurs from spring to fall or winter, with a peak in spring or early summer.

Abundance was greatest in winter, intermediate in late summer, and lowest in late spring (Table 96). Subadults and juveniles were most abundant in winter, adults in late spring, and postlarvae in late summer. In late summer most of the population was either smaller than 20 mm or larger than 40 mm. The smaller sizes probably are not adequately retained by the net, and the larger ones probably can avoid the net with some degree of success. As a result, abundance in late summer probably was much larger than estimated from the actual catches.

Adult-size females (larger than 45 mm) were caught throughout the year, but few were ripe. Of the eight ripe females taken during the paired seasonal cruises, seven were caught in late spring. The remaining one was caught in late summer. Small juveniles (17–22 mm) were most numerous in October–November collections. The seasonal distribution of ripe females, postlarvae, and small juveniles taken together indicate a spawning peak in late spring to midsummer.

In late spring the scant catch was mostly subadults and adults, with most fish being at least 37 mm in length. The remainder of the catch consisted of 6–10 mm postlarvae. Although the abundance of adults was not great, it was at its yearly peak (Table 96). The size frequency distribution indicated that 3-year classes were represented in the catch: recently spawned fish 6-10 mm, fish 34-49 mm about one year old, and a third group 54-62 mm at least two years old. The absence of juveniles 17–30 mm suggests that little spawning occurred during winter. The relatively low abundance in late spring may have been, at least in part, due to net avoidance, as most of the catch consisted of fish greater than 40 mm.

In late summer nearly 70 percent of the catch consisted of postlarvae 6–20 mm, which were more abundant than all other stages together in late spring (Table 96). The increase in abundance from late spring to late summer was almost exclusively due to recruitment of fish 10–20 mm. Presumably these individuals were spawned in late spring–early summer during the peak in spawning. The remainder of the catch consisted mostly of 17–20 mm juveniles. As most of the juveniles were caught below 850 m at night, they probably were recently metamorphosed individuals. The low abundance of juveniles may mean that most of the recently spawned fish were still postlarvae not adequately sampled by the 3-m IKMT. Small juveniles were abundant in 2-m IKMT samples in October–November. In late summer subadults were mostly larger than 44 mm and may have been spent adults or ripening fish about one year old. More than 80 percent of *L. photonotus* taken with the Engel trawl in late summer were greater than 40 mm, with a peak in numbers at 45–56 mm. Several of the females examined

were ripe or nearly ripe, indicating that spawning continued into late summer. Fish larger than about 40 mm may not have been adequately represented in the late summer discrete-depth collections due to their ability to avoid the net.

By winter, spawning and recruitment were largely at an end. Subadults 30 mm and larger were predominant, accounting for nearly 70 percent of the catch. Most of the remainder consisted of 17–33 mm juveniles. Fish from the current year's spawn were 17–42 mm, with most of those from the peak being greater than 35 mm. Larger fish (47–59 mm) probably were at least 1.5 years old. The maximum abundance in winter was due to sampling recruits from the entire spawning season. Most of these recruits still were smaller than 40 mm, and presumably could not avoid the net as well as larger fishes.

SEX RATIOS.—Males were more numerous than females at each of the three seasons, with ratios of 1.4:1 in winter, 1.1:1 in late spring, and 1.3:1 in late summer (Table 97). Only the ratio in winter was significantly different from equality. Except for adults in late spring and late summer, males of each stage were more numerous than females of the same stages at each season. Although none of the ratios for individual stages differed significantly from equality, the consistently greater number of males than females for subadults and for juveniles in winter, suggests that males may be more abundant than females.

VERTICAL DISTRIBUTION.—Day depth range in winter was 601–850 m (2 specimens 32 mm and 53 mm taken at 1501–1550 m may have been contaminants from previous tow) with maximum abundance at 701–850 m, in late spring 51–100 m and 701–1100 m with no apparent concentration (3 specimens 47–62 mm taken at 301–350 m are thought to have been contaminants), and in late summer 501–550 m and 801–1050 m with a maximum at 1001–1050 m. Vertical range at night in winter was 40–250 m and 801–850 m with maximum abundance at 101–150 m, in late spring 50–100 m, and in late summer 33–250 m and 851–1000 m with a maximum at 951–1000 m (Table 98).

Stage and size stratification were evident day and night in winter and late summer. In late spring too few specimens were taken to be sure if stratification according to stage or size existed.

During the day in winter juveniles had a shallower upper depth limit and were more abundant at shallower depths (601–750 m) than subadults. In late summer postlarvae were caught between 501 m and 1050 m, and the few subadults taken were from 801–850 m; a postlarva was the only specimen caught at 51–100 m. In winter there was an increase in the mean, minimum, and maximum sizes with depth. In late summer individuals 10–20 mm were caught at 501–1050 m and larger specimens only at 801–850 m (Table 98).

At night in winter juveniles and subadults were caught at both shallower and greater depths than the few adults that

were taken. Each of the three stages taken was most abundant at 101–150 m. In late summer only postlarvae and small (less than 20 mm) juveniles were taken in the upper 100 m and at 851–1000 m, and only larger juveniles and subadults were captured at 101–250 m. Each of the stages taken was most abundant at a different depth: postlarvae at 951–1000 m, juveniles at 101–150 m and 901–950 m, and subadults at 151–250 m.

Stratification by size in winter was seen in the increase in mean size with depth in the upper 200 m, where most of the catch was made. Individuals larger than 42 mm did not migrate into the upper 100 m and, except for an 18 mm nonmigrant caught at 801–850 m, all specimens smaller than 25 mm were caught in the upper 100 m. Intermediate sizes (25–42 mm) were taken throughout the upper 250 m and comprised most of the catch at 101–150 m. In late summer specimens caught in the upper 100 m and at 851–1000 m were all smaller than 20 mm, and those taken at 101–250 m were 21–59 mm. There was also a size stratification within the 101–250 m stratum; fish caught at 101–150 m were 21–26 mm and those at 151–250 m were 45–59 mm. The mean size at 151–250 m was more than double that at other depths (Table 98).

Postlarvae appeared to be stratified by size both day and night. The few specimens taken in the upper 100 m were all 6–10 mm and, except for a 7 mm postlarva from 851–900 m, all those caught below 800 m were greater than 10 mm. Because these depth relations hold both day and night, postlarvae probably do not undergo diel vertical migrations. Initial development of postlarvae apparently occurs in the upper 100 m, and at about 10 mm they descend to depths in excess of about 800 m, where they continue to develop and transform into juveniles.

Diel vertical migrations occurred at each of the three seasons, but only in late spring were all night captures made above daytime depths. In winter a single nonmigrant juvenile was caught at 801–850 m. Nonmigrants were most abundant in late summer, when 70 percent of the night abundance was due to nonmigrants. Most nonmigrants were postlarvae, with the remainder juveniles. All were 13–19 mm. Regular migratory behavior was assumed at about 20 mm, as all but one migrant were larger than 20 mm and all nonmigrants smaller than 20 mm.

Little could be determined concerning the chronology of vertical migrations. In winter the upper 150 m was occupied by about sunset and the upper 100 m was still occupied between about 0.5–1.5 hours before sunrise. Daytime depths were reached between 1 and 2 hours after sunrise, giving a downward migration time of about 2.5 hours and a rate of migration of about 260 m/hour between night (101–150 m) and day (701–750 m and 801–850 m) depths of maximum abundance. Little could be determined about the time of upward migration in late summer. The upper 100 m was still occupied between 0.2–0.8 hours before

sunrise. Day depths were reached no later than 4.0 hours after sunrise, resulting in a migration time of no more than 4.8 hours and a migration rate of no less than 146 m/hour between the night (101–150 m) and day (801–850 m) depths of maximum abundance.

PATCHINESS.—*Lampanyctus photonotus* probably does not have a patchy distribution at any time, despite significant CD values noted for the upper 100 m at night in winter and at 51–100 m at night in late spring.

At night in winter *L. photonotus* apparently does not regularly inhabit depths shallower than about 100 m. Only one sample, taken at 40 m, in the upper 96 m was positive for the species. (The sample immediately following the positive sample was taken during the morning crepuscular period and caught two specimens.) This positive sample was responsible for the significant CD value obtained for the 1–50 m interval. Although it is possible that this is an indication of patchiness, several other interpretations also are possible.

For example, *L. photonotus* may stray above 50 m only occasionally, it may inhabit the upper 50 m only near dawn, or it may occur regularly with uniform density within a narrow depth stratum near 40 m. No specimens were taken between 40 and 96 m, and all samples near 100 m were positive. The significant CD for 51–100 m was due to the concentration near 100 m and the absence of specimens from 51–96 m.

Year to year variation in the catch near 100 m elevated the CD for 51–100 m both in winter and late spring. In both cases samples from one year were all similar to each other in abundance but differed slightly from those of the other year.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, were 1.8:1 in winter, 0.9:1 in late spring, and 1.7:1 in late summer (Table 99). Most of the difference in winter was due to subadults and most of that in late summer to postlarvae.

Increased net avoidance by day in winter may account for much of the observed difference in diel catch rates. The night-to-day catch ratio for 35–43 mm fish was 2.8:1, and all but two fish larger than 46 mm were taken at night.

Few fish were caught either at night or during the day in late spring, and little can be said concerning the night-to-

TABLE 99.—Seasonal night to day catch ratios of *Lampanyctus photonotus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	0.9:1	2.8:1	*	1.8:1
LATE SPRING	2.5:1	*	0.5:1	1.5:1	0.9:1
LATE SUMMER	1.4:1	*	0.8:1	*	1.7:1

day ratio. Most specimens were larger than 35 mm, sizes that presumably can avoid the net to at least some degree.

In late summer most of the difference in the diel catch rates was due to fish 17–19 mm. The low abundance of specimens this size in day samples almost certainly reflects a bias other than a day-night difference in net avoidance. The abundance of larger fish was quite low both during daytime (0.9 specimens/hour) and at night (1.4 specimens/hour).

Lampanyctus pusillus

This abundant species grows to 39 mm in the study area, perhaps to 43 mm elsewhere (Hulley, 1981). *Lampanyctus pusillus*, a bipolar temperate-semisubtropical species, is a ranking myctophid in the North Atlantic subtropical region (Backus et al., 1977). This is demonstrated in the Ocean Acre collections. The species was very abundant near Bermuda, and was among the four most abundant lanternfishes at all three seasons; it was the most abundant lanternfish in late spring. It is represented in the Ocean Acre collections by a total of 4913 specimens; 2545 were caught during the paired seasonal cruises, 1715 of these in discrete-depth samples, of which 1432 were caught in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 3–14 mm, juveniles 11–27 mm, subadults 20–34 mm, and adults 24–35 mm. Most juveniles smaller than 18 mm could not be sexed. Adult females contained ova as large as 0.6 mm in diameter. Some of the larger females categorized as subadults may have been postspawning adults with regenerating ovaries. Females may be a little larger than males of the same age; at each season females averaged 0.5 mm larger than males for both subadults and adults. This was reversed in juveniles, males of which averaged 0.5–0.8 mm larger than females at each season. However, females were recognized at a smaller size than males; most 14–18 mm juveniles (69 percent) were females.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Lampanyctus pusillus* has a one-year life cycle, with only a few individuals surviving into the second year. Spawning occurred all or most of the year, but mostly in winter and spring. As a result of the peak in recruitment over the winter and spring, abundance was greatest in late summer, when the abundance of recruits alone exceeded the total abundance at either of the other two seasons (Table 100). In winter abundance was lowest due to the minimum of spawning in summer and fall and to continuing mortality. Juveniles and subadults were most abundant in late summer, adults in winter and postlarvae in late spring. The abundance of subadults in winter approached that of late summer. At each season more than 75 percent of the catch was juveniles and subadults (Table 100). Judging from the low abundance of 13–18 mm specimens, there were few recent recruits into the population in winter. Most of the winter

juveniles probably were spawned in late summer or early fall. Adults, subadults, and perhaps larger juveniles were spawned during or near the previous reproductive peak and were approaching one year in age, at about which time they would spawn and die.

In late spring recruits from the winter–early spring spawn were taken in great abundance and constituted 90 percent of the catch. The peak in spawning appeared to be past, and most of the winter population had died. This mortality was evident in the reduced abundance of subadults and adults (Table 100), and of all specimens over 20 mm, particularly those 23–30 mm. The combined abundance of subadults and adults in late spring was little more than 10 percent of the total abundance in winter, indicating that some 90 percent of the winter population had died by that time.

About 75 percent of the late summer population consisted of juveniles 18–26 mm and subadults 20–28 mm that were spawned during the winter–early spring peak and that appeared as recruits smaller than about 23 mm in late spring. Newer recruits, juveniles smaller than 18 mm, and postlarvae accounted for an additional 22 percent of the late summer population. The residual 3 percent was mostly subadults larger than 28 mm, some of which were undoubtedly spent adults or adults that would soon ripen, spawn, and die.

SEX RATIOS.—The sexes probably are equally abundant at each season, despite females being consistently more numerous than males with sex ratios of 1.1:1 in winter and late spring and 1.3:1 in late summer. Only the last difference, which was due to 15–17 mm juveniles, for which the female to male ratio was 5.1:1, is statistically significant (Table 101). Excluding the 15–17 mm juveniles from the late summer analysis resulted in a female to male ratio of 1.1:1 for the remaining juveniles and for total numbers; neither difference was statistically significant. The difference for 15–17 mm juveniles may be due to females developing faster and, therefore, being recognized at a smaller size than males.

VERTICAL DISTRIBUTION.—Vertical range by day in winter was 33 m and 551–850 m with maximum abundance at 601–650 m, in late spring 52 m and 551–900 m with a maximum at 601–700 m, and in late summer 501–950 m with a maximum at 601–650 m. Nighttime depth range in winter was 40–250 m and 751–800 m with maximum abundance at 101–150 m, in late spring 50–150 m and 551–1000 m with a maximum at 51–100 m, and in late summer 33–1000 m, with a maximum at 33 m and a secondary concentration at 101–150 m (Table 102).

Stage and size stratification were evident at each season, and adults were stratified by sex in winter. During the day only postlarvae were taken at the shallow extreme and only juveniles and postlarvae at the deep extreme at each season. During daytime in late spring, juveniles had a more exten-

TABLE 100.—Seasonal abundance and percent of total abundance (in parentheses) for *Lampanyctus pusillus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.5(0.5)	37.2(36.3)	40.1(39.1)	24.7(24.1)	102.5
LATE SPRING	7.2(6.2)	96.4(83.8)	8.2(7.1)	3.3(2.9)	115.1
LATE SUMMER	4.7(2.4)	145.5(75.7)	40.8(21.2)	1.1(0.6)	192.1

TABLE 101.—Numbers of each sex for each stage of *Lampanyctus pusillus* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV M	JUV F	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	39	49	69	85	65	53	173	187
SPRING	110	130	28	31	19	14	157	175
SUMMER	170	230*	79	76	3	10	252	316*

TABLE 102.—Vertical distribution by 50-m intervals of *Lampanyctus pusillus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	N	SL X	RANGE
													DAY											
1- 50	1				1	1	6.0	6																
51- 100									1				1	2	5.5	5- 6								
501- 550																	<1				<1	1	6.0	6
551- 600		4	6	6	16	35	25.5	15-31		16			16	47	17.7	14-25								
601- 650		20	17	3	40	119	23.6	15-33		30	1		31	93	18.1	14-28		79	24	1	104	311	21.5	14-28
651- 700		10	11	5	26	*				29	5	2	36	195	19.8	15-34		45	13	<1	58	*		
701- 750		1	4	7	12	31	27.9	14-32	<1	16	2	1	19	*			1	11	2		14	44	20.2	8-28
751- 800		1	2	4	7	*			1	4			5	20	12.8	11-15			<1		<1	1	27.0	27
801- 850		2			2	5	13.8	13-15	1	2			3	*			1	10	1		12	27	19.3	9-28
851- 900	-	-	-	-	-				1	<1			1	3	14.0	11-19	-	-	-	-	-			
901- 950	-	-	-	-	-				-	-			-				<1				<1	1	5.0	5
TOTALS	1	38	40	25	104	191			4	97	8	3	112	360			2	145	40	1	188	385		
													NIGHT											
1- 50		<1			<1	2	28.0	28		2			2	4	16.6	15-20		30			30	59	17.0	15-23
51- 100	2	1		2	5	49	25.9	14-31	1	22	5	1	29	97	20.5	4-33		3	2	<1	5	41	21.0	16-32
101- 150			3	7	10	46	28.9	24-35	3		<1		3	7	10.0	7-26	3	6	5	1	15	43	19.8	5-33
151- 200	1	3	3		7	42	28.2	21-32									<1	<1	1		1	6	21.5	7-31
201- 250			1	<1	1	3	28.7	28-29										<1	<1		<1	5	19.6	17-27
251- 300	-	-	-	-	-													<1	1		1	5	25.2	16-30
301- 350									-	-	-	-	-				<1				<1	1	7.0	7
351- 400																		2	1		3	7	21.9	17-28
401- 450																								
451- 500																		1	<1		1	8	24.1	21-30
501- 550																	1		1		2	2	23.0	17-29
551- 600										1			1	1	16.0	16			1		1	*		
601- 650										1			1	*										
651- 700	-	-	-	-	-					1			1	*				4			4	8	21.9	18-26
701- 750										2			2	*				1			1	1	26.0	26
751- 800	<1				<1	1	10.0	10	2	2			4	6	13.2	10-16	<1	5			5	15	16.0	11-23
801- 850									2	10			12	22	12.5	10-15		3	<1		3	*		
851- 900									-	-	-	-	-				<1	1	1		2	6	22.7	12-29
901- 950	-	-	-	-	-				-	-	-	-	-					<1			<1	1	23.0	23
951-1000										<1			<1	1	18.0	18		2			2	7	18.4	14-24
TOTALS	<1	3	8	12	23	143			8	41	5	1	55	138			4	58	13	1	76	215		

sive range than subadults and adults, being caught both at shallower and deeper depths than the older stages. In late summer juveniles and subadults were taken at greater depths than adults. At both of those seasons juveniles, subadults, and adults had their greatest abundance at the same depths. Although the depth ranges of juveniles, subadults, and adults were similar in winter, a few juveniles were taken slightly deeper than the others. Juveniles and subadults were most abundant at 601–650 m and adults at 701–750 m and 551–600 m. All adults taken at 551–600 m were females and 94 percent of those from 701–750 m were males. This stratification of the sexes was not noted at the other two seasons.

Size stratification by day was apparent only in winter and late spring. In late summer most sizes were caught throughout the vertical range. In winter fish larger than 24 mm were taken at 551–750 m, and those 16–24 mm only at 551–650 m. The small catch at 801–850 m consisted of fish 13–15 mm. In late spring both the maximum and mean sizes increased from 551 to 700 m, fish 14–25 mm being caught throughout that range and larger ones (with a single exception) only at 651–700 m. Fish caught at 751–900 m were all 11–19 mm; those smaller than 14 mm were confined to that stratum (Table 102).

At night in late spring and late summer the range of juveniles encompassed that of the other stages; only juveniles were found at the upper depth limit at both seasons and only juveniles and postlarvae (late spring only) at the lower depth limit. At both seasons the depth range of adults was restricted to one or two 50-m intervals. In winter the situation was reversed, with the range of subadults and adults enveloping that of juveniles. In late summer juveniles were most abundant in the upper 50 m and subadults and adults at 101–150 m. In winter juveniles were most abundant at 51–100 m and the two older stages at 101–150 m. Juveniles, subadults, and adults were each most abundant at 51–100 m in late spring, with postlarvae showing a slight concentration at 101–150 m. In late summer an upper layer of juveniles was isolated from the remainder of the population (as was the case for *N. valdiviae*); at 33 m only juveniles were taken, at 50–70 m no specimens were taken, at 70–80 m no samples were made, at 90 m about 58 percent of the catch consisted of juveniles, at 110 m 51 percent consisted of juveniles. This situation was not evident at the other two seasons. In winter adults and subadults were stratified by sex; 78 percent of those caught at 95 m were females, and 86 percent of those at 200 m were males. The sexes were approximately equally abundant between those depths. The observed segregation of the sexes may be associated with reproduction, since only subadults and adults were involved, and it was observed only in winter, shortly before the breeding peak.

In terms of size, fish that migrated into the upper 50 m in late spring and late summer all were smaller than 23 mm,

and the mean size of the catch at that depth was noticeably smaller than at other depths above the day range at both seasons. All specimens caught at day depths at night in late spring were 10–18 mm, whereas all sizes except for 30–33 mm were taken at day depths at night in late summer. In winter most sizes were taken at 51–100 m, but only fish larger than 20 mm were caught at 101–250 m (Table 102).

Postlarvae were stratified by size day and night in late spring and late summer and probably also in winter, when very few were caught. All those caught in the upper 150 m day or night were 4–8 mm, all those caught below 700 m, except for a 5 mm specimen caught at 901–950 m in late summer, were 8–12 mm, and those at intermediate depths (200–500 m) were 6–7 mm. These observations indicate that initial development occurs in the upper 150 m, and that at a size of about 6–7 mm, postlarvae descend to depths below the daytime level of subadults and adults, where transformation occurs, before which significant diel vertical migrations do not occur.

Diel vertical migrations occurred at each season, but not all individuals migrated to shallower depths at night. Nonmigrants were most abundant in late spring and late summer, at which seasons they accounted for 37 and 22 percent of the catch, respectively. A single postlarva was caught at day depths during the night in winter. Migratory behavior is assumed at a size of about 15–16 mm. At night in late spring and late summer juveniles smaller than 14 m were taken only at day depths; those 15–16 mm were taken both at day depths and in the upper 200 m, but mostly the latter. At night larger fish were taken almost exclusively in the upper 100 m in late spring, and were well dispersed vertically in late summer but more abundant in the upper 300 m than at day depths.

Upward migrations commenced no earlier than 2 hours before sunset in winter, 3.5 hours before sunset in late spring, and 2.5 hours before sunset in late summer. Nighttime depths were reached no later than 2.5 hours after sunset at each season, giving evening migrations of no more than 4.5 hours in winter, 6 hours in late spring, and 5 hours in late summer. Using these estimates, approximate minimum rates of upward migrations between day and night centers of abundance were 110 m/hour in winter (650 m to 150 m), 90 m/hour in late spring (650 m to 100 m), and 120 m/hour in late summer (625 m to 33 m).

Night depths were occupied until less than 2 hours before sunrise in winter and late summer and less than 2.5 hours before sunrise in late spring. Day depths were reached no later than 3 hours after sunrise in winter, 2.5 hours after sunrise in late spring, and 1.7 hours after sunrise in late summer. These estimates of maximum times spent in returning to daytime depths yield approximate minimum rates of migration from depths of maximum abundance at night to those during the day of 100 m/hour in winter (150 m to 650 m), 110 m/hour in late spring (100 m to 650 m),

and 170 m/hour in late summer (33 m to 625 m).

In both winter and late summer a few specimens were caught at nocturnal depths near or at the time of sunrise, thus the estimate for times of downward migrations at those seasons may be somewhat too large. Estimates of migration times and rates in late summer may be further in error because of the large proportion of nonmigrants, which included most sizes.

At or near sunset in each season and at or near sunrise in late spring, specimens were taken at several intermediate depths, suggesting that the entire population probably does not migrate as a unit.

PATCHINESS.—Clumping was indicated during the day at 551–600 m and 701–750 m in winter, 551–700 m in late spring, and 601–650 m and 801–850 m in late summer. A patchy distribution was indicated at the depth of greatest abundance of all stages, except postlarvae, at each season. In winter, when adults were stratified according to sex, clumping was indicated at the depths of maximum abundance of both sexes.

Patchiness at night was noted at 101–150 m in winter, 51–100 m and 801–850 m in late spring, and 51–100 m and 751–800 m in late summer. Patchiness occurred at the depth of greatest abundance of adults and subadults in winter, of all stages except postlarvae in late spring, and only of nonmigrant juveniles in late summer.

Significant CD values for day samples at 751–800 m in late spring, for night samples in the upper 100 m in winter, and at 33–100 m and 151–300 m in late summer are thought to be due to distributional features other than clumping. Year to year variation in population density may be the cause of the significant CD for the day samples at 751–800 m in late spring. Although the four samples taken at that depth were equally divided between the two cruises, 13 of the 14 fish were caught during one cruise.

At night in winter the 10 samples made in the upper 50 m caught two specimens, which obviously cannot indicate patchiness. Of the samples made at 51–100 m only those from 95–100 m caught *L. pusillus*. The catches at 95–100 m appeared to be random, and the CD for samples made only at that depth was not significant. The large CD obtained for samples made in the upper 50 m in late summer may or may not indicate patchiness, but there are too few data to be sure. The only two samples (both at 33 m) differed by a factor of six, but the earlier one, which caught fewer specimens, was made shortly after the twilight period and may have captured early migrants. Of the 15 samples made at 151–300 m, 4 were positive and contained a total of 6 specimens. These were not concentrated at any depth, but were all caught at 0300–0400 hours, which was approaching the morning crepuscular period, and suggests that the fishes caught may have been migrating to day depths.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios,

TABLE 103.—Seasonal night to day catch ratios of *Lampanyctus pusillus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.6:1	>0.1:1	0.2:1	0.5:1	0.2:1
LATE SPRING	2.6:1	0.4:1	0.6:1	0.3:1	0.5:1
LATE SUMMER	1.8:1	0.4:1	0.3:1	0.9:1	0.4:1

including interpolated values, were 0.2:1 in winter, 0.5:1 in late spring, and 0.4:1 in late summer. Except for postlarvae in late spring and late summer, day catches were greater than night catches for each stage at all three seasons. The greatest deviance from a 1:1 ratio for the three oldest stages occurred in winter (Table 103). The observed ratios seem to be due mainly to diel differences in depth range and clumping, rather than diel differences in net avoidance. Although juveniles were responsible for most of the difference at each season, it was not likely that they were better able to avoid the nets than older, presumably stronger swimming fishes. *Lampanyctus pusillus* was more dispersed vertically at night than by day in late spring and late summer; this may have accounted for some of the difference between night and day catches at those seasons. Another source for the difference in late spring could have been the limited vertical distribution of samples in the upper 100 m; all were made either at the surface, at 50–56 m, or at 91–100 m. If concentrations of *L. pusillus* existed between those depths, the estimate of abundance would have been too low.

In winter, although the day and night vertical ranges were similar, the total day catch was about 5 times larger than that of the night, and for juveniles the day catch was more than 15 times larger the night catches. Differences of that magnitude probably were due to not sampling the depth of maximum concentration at night in winter. For example, if *L. pusillus* was most abundant between 100 and 150 m, a significant proportion of the population was not sampled, as there were no discrete-depth noncrepuscular samples made between the two depths.

At each season clumping was indicated to be more prevalent during daytime than at night. This may have contributed to the observed differences in day and night catches.

Lepidophanes gaussi

This is a medium-size lanternfish, attaining 48 mm (Hulley, 1981). It reaches 44 mm in the study area; most were smaller than 40 mm. A bipolar subtropical species confined to the Atlantic Ocean, *Lepidophanes gaussi* is a ranking myctophid in both the North and South Atlantic subtropical regions (Backus et al., 1977). Near Bermuda, *L. gaussi* is

abundant; it was among the 10 most abundant myctophids only in late summer, when it ranked seventh (Table 131). The collections contain 951 specimens; 496 were caught during the paired seasonal cruises, 283 of these in discrete-depth samples, of which 249 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 10–14 mm, juveniles 13–26 mm, subadults 23–42 mm, and adults 29–43 mm. Most juveniles less than 18 mm had slender thread-like gonads and could not be sexed, and most larger juveniles had small but recognizable ovaries or testes. Adult females had eggs as large as 0.5 mm in diameter, but most ova were less than 0.4 mm. Several females larger than 35 mm categorized as subadults may have been spent adults with reduced ovaries. No sexual differences in size or distribution of luminous tissue were apparent.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Lepidophanes gaussi* has a one-year life cycle, with few individuals surviving much beyond a year. Spawning may occur the entire year, with a strong peak in spring. Abundance was greatest in late summer, when the species was the seventh most abundant lanternfish, and when juveniles and subadults had their peak abundances. Abundance was intermediate in winter and lowest in late spring (Table 104).

Adult females were taken throughout the year but were not abundant in collections from any of the paired seasonal cruises. Samples from April contained, by far, the greatest percentage of adult females (more than 25 percent). Postlarvae were taken only from April to October; most were taken in July (12) and June (8). Juveniles smaller than 20 mm showed a marked peak in abundance in late summer, when they accounted for more than 70 percent of the nighttime catch. These distributions show that spawning was at a peak in mid- or late spring.

In winter the catch consisted mostly of subadults and adults larger than 23 mm that would ripen and spawn in spring. Those fish were mostly 36–43 mm and accounted for about one-half of the total abundance. Fish smaller than 20 mm accounted for about one-tenth of the total abundance, indicating that little spawning occurred in fall.

In late spring juveniles smaller than 20 mm and postlarvae from the earliest spawn accounted for more than 60 percent of the small catch. Subadults and adults were 23–42 mm, but mostly were larger than 35 mm. Subadults and adults were about one-third as abundant as they were in winter (Table 104), suggesting that most winter subadults and adults had spawned and died by late spring. Presumably, most of the population in late spring was represented by postlarvae that were too small to be sampled adequately by the gear used.

In late summer recruits for the spring spawn accounted for more than 80 percent of the total abundance (Table 104). Juveniles 15–17 mm, which presumably were from the spawning peak, comprised slightly more than 63 percent of

the total abundance. Older fish were 23–42 mm, but mostly 28–31 mm. There were two peaks in the size-frequency distribution; one at 23 mm and one at 28–30 mm. This bimodal distribution was not evident at other seasons. Few fish were larger than 33 mm, indicating that spawning essentially was completed. Some of these specimens may live into their second year.

SEX RATIOS.—Males were more numerous than females at each season, with sex ratios of 1.2:1 in winter and late spring, and 1.4:1 in late summer. Only in late summer was the ratio significantly different from equality (Table 105). Juvenile and adult males were more numerous than females of those stages at each of the three seasons, but only the ratio for adults in late spring was significantly different from equality. More subadult females were taken than subadult males in winter and late spring, but the differences were not significant. In late summer subadult males were significantly more numerous than subadult females.

VERTICAL DISTRIBUTION.—Day depth range in winter was 601–850 m (possibly deeper) and 1501–1550 m with no apparent concentrations; in late spring 51–100 m, 301–350 m, 601–900 m, and 1151–1200 m, again with no apparent concentrations; and in late summer 701–800 m (Table 106). Neither of the two specimens taken below 1000 m appeared to be a contaminant from a prior tow, suggesting that *L. gaussi* regularly may inhabit those depths. The specimens from 301–350 m in late spring probably were contaminants.

Nighttime vertical range in winter was 40–250 m, with maximum abundance at 51–100 m, in late spring 50–100 m; and in late summer 33–300 m, 601–650 m, and 751–800 m with a maximum at 33–50 m (Table 106).

Stage and size stratification were evident by day in winter and late spring, and at night in late summer. Few fish were caught at other season/diel-period combinations, and nothing can be said concerning stratification at those times.

During daytime in winter and late spring, juveniles were more abundant at a shallower depth than the two older stages, juveniles and subadults had a shallower upper depth limit than adults, and subadults and adults were taken at greater depths than juveniles. In late spring a single postlarva was taken at 51–100 m. In terms of size, only specimens smaller than 26 mm were caught above 700 m, and all but one specimen taken below 700 m were greater than 30 mm in both winter and late spring (Table 106).

At night in late summer juveniles were most abundant at a shallower depth and had a more extensive depth range than the two older stages. Although the size ranges at 33–50 m and 51–100 m were similar, most fish smaller than 22 mm were taken at the shallower depth and most larger specimens at the greater depth. The mean size at 33–50 m was 17.5 mm, and that at 51–100 m was 26.4 mm. All specimens taken below 600 m were 15–16 mm (Table 106).

Diel vertical migrations occurred at each of the three

TABLE 104.—Seasonal abundance and percent of total abundance (in parentheses) for *Lepidophanes gaussi* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	2.5(25.8)	4.6(47.4)	2.6(26.8)	9.7
LATE SPRING	0.6(7.9)	4.0(52.6)	2.0(26.3)	1.0(13.2)	7.6
LATE SUMMER	0	52.7(84.2)	8.5(13.6)	1.4(2.2)	62.6

TABLE 105.—Numbers of each sex for each stage of *Lepidophanes gaussi* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV M	JUV F	SAD M	SAD F	AD M	AD F	TOT M	TOT F
WINTER	7	4	11	13	6	3	24	20
SPRING	14	11	12	19	15	3*	41	33
SUMMER	66	59	77	50*	17	9	160	118*

TABLE 106.—Vertical distribution by 50-m intervals of *Lepidophanes gaussi* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
51- 100									<1			<1	<1	1	10.0	10								
301- 350										<1			<1	1	23.0	23								
601- 650	2	1			3	7	21.9	17-26		1			1	2	18.0	16-20								
651- 700	1	1		<1	2	*					2	<1	2	14	19.4	16-25		<1			<1	*		
701- 750		1		<1	1	3	38.3	36-41		1		<1	1	*				<1			<1	1	29.0	29
751- 800		1		1	2	*			1				2	4	25.8	14-39		<1			<1	1	29.0	29
801- 850		1		1	2	7	37.6	31-41				<1	<1	*										
851- 900	-	-	-	-	-							<1	<1	1	39.0	39	-	-	-	-	-			
901- 950	-	-	-	-	-							<1	<1	*										
951-1000	-	-	-	-													-	-	-	-	-			
1151-1200	-	-	-	-	-							1	1	1	41.0	41								
1501-1550			<1		<1	1	43.0	43																
TOTALS		3	5	2	10	18			1	4	2	1	7	24				<1			<1	2		
NIGHT																								
1- 50	<1			<1		1	26.0	26		1			1	1	33.0	33	45	3			48	96	17.5	14-32
51- 100		1			1	4	37.2	33-41		1		1	2	5	37.4	31-39	4	5	1		10	83	26.4	16-39
101- 150																								
151- 200	<1				<1	2	14.5	13-16									1	<1			1	7	23.7	16-39
201- 250			<1		<1	1	40.0	40																
251- 300			<1		<1	*											<1				<1	1	22.0	22
301- 350									-	-	-	-	-											
351- 400																								
401- 450																								
451- 500																								
501- 550																								
551- 600																	1				1	*		
601- 650									-	-	-	-	-				1				1	1	16.0	16
651- 700	-	-	-	-	-				-	-	-	-	-											
701- 750									-	-	-	-	-											
751- 800																	1				1	3	15.7	15-16
801- 850																	1				1	*		
851- 900									-	-	-	-	-											
TOTALS	1	1	1		1	8				2		1	3	6			54	8	1		63	191		

seasons. Night catches in both winter and late spring were made entirely above daytime depths. In late summer a few specimens, all recently transformed juveniles, were taken at or near daytime depths at night. However, most specimens of that size were taken in the upper 50 m (Table 106).

Little can be determined concerning the chronology of diel vertical migrations in late spring and late summer, as no specimens were taken at daytime depths at or near either sunrise or sunset. In late summer nighttime depths were occupied at or near both sunset and sunrise. However, appreciable numbers were not taken any earlier than about 1.5 hours after sunset. In late spring a few specimens remained in the upper 50 m between 0.2–1.2 hours before sunrise.

In winter a few specimens were caught at daytime depths up to about 1.5 hours before sunset. A single specimen was caught at 101–150 m about an hour after sunset, giving an upward migration time of 2.5 hours and a rate of about 250 m/hour between 601–650 m and 101–150 m. Nighttime depths (40 m) were occupied no less than 1.7 hours before sunset, and daytime depths (750 m) were reached no later than 2.3 hours after sunrise, resulting in a maximum downward migration time of 4.0 hours and a rate of about 190 m/hour.

PATCHINESS.—The only indication of patchiness at any season was at night at 51–100 m in late summer. Positive discrete-depth samples from that stratum were in three series made at different depths: one series of three samples at 50–60 m, one of two samples at 60–70 m, and one of three samples at 90 m. Samples from 50–60 m and 90 m had significant CD values and those from 60–70 m did not.

The only other significant CD was for a series of three samples taken at 701–750 m by day in winter; it probably resulted from migrations. The earliest samples, made shortly after the morning crepuscular period, caught three specimens, and the later two caught none.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, were 0.2:1 in winter, 0.3:1 in late spring, and 78.2:1 in late summer (Table 107). Ratios for the developmental stages followed the overall seasonal trends.

These ratios may have been due to failure to sample depths where the species was concentrated during the diel

TABLE 107.—Seasonal night to day catch ratios of *Lepidophanes gaussi* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	JUV	SAD	AD	TOT
WINTER	0.2:1	0.1:1	0.2:1	0.2:1
LATE SPRING	*	0.8:1	0.7:1	0.3:1
LATE SUMMER	*	10.6:1	*	78.2:1

periods when catch rates were smaller. More sizes were taken during daytime than at night in winter and late spring, with the reverse being the case in late summer. In late spring and in late summer most of the day-night differences in abundance were due to fish smaller than 30 mm, sizes that probably could not avoid the net to any great extent. In winter, when the day abundance was about six times larger than the night abundance, most of the difference was due to specimens larger than 35 mm, which is the reverse of what would be expected if net avoidance were an important factor.

Lepidophanes guentheri

This moderately large species, which attains 78 mm elsewhere (Hulley, 1981), grows to 63 mm in the study area, but very few specimens were larger than 57 mm. Like its congener, *L. gaussi*, this species is restricted to the Atlantic Ocean, where it is an abundant tropical species (Nafpaktitis et al., 1977). According to Backus et al. (1977) *L. guentheri* is not common in the North Atlantic subtropical region; the Ocean Acre collections substantiate this. The species is uncommon in the study area and never was included among the 15 most abundant lanternfishes. The Ocean Acre collections contain 365 specimens; 109 were collected during the paired seasonal cruises, 74 of these in discrete-depth samples, of which 56 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Juveniles were 16–40 mm, subadults 38–60 mm, and adults 53–58 mm. Only two adults were caught; the smaller was a male and the larger a female. Most juveniles smaller than 25 mm could not be sexed; the few that could be were all females. All juveniles larger than 25 mm could be sexed. The adult female had some eggs as large as 0.4 mm but most were 0.2–0.3 mm in diameter. None of the other females examined contained eggs larger than 0.1 mm. No sexual dimorphism in size or in the distribution or amount of luminous tissue was apparent.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Lepidophanes guentheri* apparently has little reproductive success near Bermuda, with only a very small portion of the population reaching sexual maturity. Recruitment of fish smaller than 20 mm occurred from June to January and was greatest in January, when they accounted for about half of the abundance. The life span cannot be determined, but judging from the moderately large size attained, it could be more than one year.

Although females of adult size, 47 mm or larger (Hulley, 1981, who observed one as small as 41 mm), were taken throughout the year, only one female with eggs larger than 0.1 mm in diameter was observed. The presence of this individual indicates that some spawning may occur in the study area, but the prolonged period of recruitment of fish

TABLE 108.—Seasonal abundance and percent of total abundance (in parentheses) for *Lepidophanes guentheri* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	JUV	SAD	AD	TOT
WINTER	2.9 (60.4)	1.9 (39.6)	0	4.8
LATE SPRING	1.0 (58.8)	0.7 (41.2)	0	1.7
LATE SUMMER	1.7 (35.4)	3.1 (64.6)	0	4.8

TABLE 109.—Numbers of each sex for each stage of *Lepidophanes guentheri* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	3	1	2	5	0	0	5	6
SPRING	1	1	3	5	0	0	4	6
SUMMER	9	13	20	17	1	0	30	30

TABLE 110.—Vertical distribution by 50-m intervals of *Lepidophanes guentheri* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
601- 650																								
651- 700		<1		<1	*												-	-	-	-	-			
701- 750		<1		<1	1	43.0	43			<1		<1	*											
751- 800	<1	1		1	*					<1		<1	2	51.5	50-53		<1			<1	1	35.0	35
801- 850	<1	1		1	3	45.3	45-46		<1		<1	*						<1		<1	1	59.0	59	
851- 900	-	-	-	-	-													<1		<1	*		
901- 950	-	-	-	-	-				-	-	-	-	-					<1		<1	1	54.0	54
951-1000	-	-	-	-	-													<1		<1	*		
1001-1050									-	-	-	-	-											
TOTALS		<1		2	2	4				<1		<1	2					<1		1	1	3		
NIGHT																								
1- 50	<1			<1	1	20.0	20		1			1	1	34.0	34									
51- 100										<1		<1	1	60.0	60		2	1			3	21	36.0	20-56
101- 150																			2		2	5	54.8	51-57
151- 200		3			3	16	17.2	16-18																
201- 250																								
251- 300	-	-	-	-	-																			
301- 350									-	-	-	-	-					<1		<1	1	17.0	17
751- 800																				<1	<1	1	56.0	56
TOTALS		3			3	17			1	<1		1	2					2	3		5	28		

smaller than 20 mm cannot be accounted for by a resident spawning population.

In winter juveniles accounted for most of the abundance, those 16–18 mm comprising more than 50 percent of the total abundance (Table 108). Otherwise, only subadults 43–52 mm were taken. All specimens caught in winter were either smaller than 30 mm or larger than 40 mm, with the smaller group being caught mostly at night in January and the larger mostly by day in February. This bimodal size frequency distribution was not evident at any other season.

In late spring, except for a 16 mm juvenile, all specimens were 34 mm or larger. Abundance was low, and no peaks were evident in the size frequency distribution.

Most sizes contributed to the increase in abundance from

late spring to late summer, suggesting that recruitment may involve fish of all ages and not only recently spawned ones.

SEX RATIOS.—The sexes probably were equally abundant at all seasons. Females and males were caught in approximately equal numbers at each season, with female-to-male ratios of 1.2:1 in winter, 1.5:1 in late spring, and 1:1 in late summer. Neither these ratios or those for individual stages differed significantly from equality (Table 109).

VERTICAL DISTRIBUTION.—Daytime catches were very poor; at each of the three seasons only 2–4 specimens were caught. Depth ranges obtained from these catch data were 701–850 m in winter, 751–800 m in late spring, and 751–950 m in late summer (Table 110).

Except in late spring, when only two specimens were caught, night catches were much better. Depth range at night in winter was 50 m and 151–200 m with nearly the entire catch made at the latter depth, in late spring 50–100 m, and in late summer 51–150 m, 301–350 m, and 751–800 m with maximum abundance at 51–100 m (Table 110).

At night in late summer juveniles were most abundant at 51–100 m and subadults at 101–150 m. Juveniles were not caught at the latter depth. In terms of size, the catch at 51–100 m was 20–56 mm with a mean size of 36.0 mm, and that 101–150 m was 51–57 mm with a mean of 54.8 mm (Table 110).

An even finer stratification existed at 51–100 m. Only juveniles were caught above 90 m. At 90 m both juveniles and subadults were caught, the second being the more abundant stage. All specimens captured above 90 m were smaller than 30 mm, and the size range at 90 m was 26–56 mm.

Diel vertical migrations occurred at each of the three seasons. Only one specimen, a 56 mm subadult taken at 751–800 m in late summer, was caught at daytime depths at night (Table 110).

Little information concerning the chronology of daily vertical migrations is available. In late summer, depths intermediate between those of day and night were occupied by about 1.5 hours before sunset, and nighttime depths were reached no later than 1.5 hours after sunset. In both winter and late summer nocturnal depths were still occupied at about 1.0–1.5 hours before sunrise.

PATCHINESS.—Patchiness was indicated at night at 151–200 m in winter and 51–100 m in late summer. At night in winter *L. guentheri* apparently concentrates at or near 175 m. Within the 151–200 m interval only two of six samples were positive for the species; both were made at 175 m and each contained eight specimens, all juveniles. A third sample taken at 175 m immediately after the two positive ones failed to catch the species. However, this sample was taken near the morning crepuscular period, and migrations may have started by that time.

In late summer most of the variation in catch rates was from samples taken at 90 m. Samples from other depths

TABLE 111.—Seasonal night to day catch ratios of *Lepidophanes guentheri* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	JUV	SAD	AD	TOT
WINTER	5.8:1	*	*	1.2:1
LATE SPRING	*	0.4:1	*	1.4:1
LATE SUMMER	5.7:1	2.8:1	*	3.4:1

within the 51–100 m interval caught one or two specimens. Most of the variation in catch size at 90 m was due to subadults; juveniles were distributed uniformly and apparently did not have a patchy distribution.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios, including interpolated values, were 1.2:1 in winter, 1.4:1 in late spring, and 3.4:1 in late summer (Table 111). Diel differences in the size composition of the catches suggest that most of the differences between day and night catches probably were the result of sampling deficiencies. The daytime catch in winter was 43–46 mm and in late summer 35–39 mm; at night the catches were 16–20 mm and 17–57 mm, respectively. These differences show that specimens taken in daytime samples from both seasons and night samples in winter do not adequately represent the population present at those times. The lack of specimens smaller than 30 mm in day samples indicates that incomplete depth coverage may have been at least partially responsbile for the observed inequities, as smaller fish were not likely to be more capable of avoiding the nets than larger fish. The patchiness noted at night at both seasons also may have contributed to the diel differences in abundances.

Lobianchia dofleini

This medium-size lanternfish is known to grow to 45–50 mm (Nafpaktitis et al., 1977); the largest specimen in the Ocean Acre collections is 38 mm. *Lobianchia dofleini,* a bipolar temperate-semisubtropical species, is a ranking myctophid in the North Atlantic subtropical region (Backus et al., 1977). The Ocean Acre collections are in agreement with this. The species is one of the abundant myctophids found near Bermuda, and was among the 15 most abundant lanternfishes at each of the three seasons, ranking third in late spring when it was most abundant (Table 131). It is represented in the Ocean Acre collections by 3749 specimens; 964 were caught during the paired seasonal cruises, 601 of these in discrete-depth samples, of which 413 were caught in noncrepuscular tows (Table 23). The biology of *L. dofleini* in the study area has been discussed elsewhere by Karnella and Gibbs (1977). The account given here is similar to that presented by those authors and is included for the sake of making the species accounts complete.

DEVELOPMENTAL STAGES.—Postlarvae were 4–10 mm, juveniles 10–24 mm, subadults 19–36 mm, and adults 24–34 mm. Generally only the largest juveniles, 16 mm and larger, could be sexed. Adult females contained eggs as large as 0.6 mm, but mostly 0.2–0.3 mm in diameter. Sexual dimorphism was apparent externally at 18–21 mm, with males developing supracaudal luminous tissue and females infracaudal luminous tissue. Females may grow larger than males. The largest female was 36 mm, the largest male 33 mm (two 38-mm specimens were not sexed); nearly 64 percent of the sexed fishes larger than 29 mm were females. Taaning (1918) and Nafpaktitis (1968) reported that males have noticeably larger eyes than females.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—The species has a one-year life cycle. It breeds from January (possibly December) to June, with a peak of spawning intensity in winter. It was most abundant in late spring, intermediate in late summer, and least abundant in winter. The catch in each season was dominated strongly by a different developmental stage; juveniles were predominant in late spring, subadults in late summer and adults in winter. In each season the dominant stage accounted for about 80 percent of the total catch (Table 112).

Although adult-size females were caught throughout the year, only in winter did many have eggs larger than 0.1 mm in diameter. Most (15) of the relatively few postlarvae (19) caught were taken from February to May. Small juveniles 10–15 mm were caught from February to September and were most abundant in late spring. These seasonal distributions indicate a winter peak in spawning. The capture of postlarvae and small juveniles (10–15 mm) over much of the year suggest a long spawning season for *L. dofleini* in the study area.

In winter, spawning was at or near a peak, abundance was lowest, and adults comprised nearly 80 percent of the abundance (Table 112). None of the other stages accounted for more than 10 percent of the abundance. The capture of postlarvae and small juveniles in low abundance shows that a minimum of spawning occurred over the fall. Most of the specimens caught in winter were larger than 25 mm.

In late spring recruits from the spawning peak were

mostly 10–25 mm juveniles. These individuals made up about 80 percent of the total abundance. The abundances of adults and specimens larger than 25 mm were much lower than in winter, reflecting postspawning mortality. The increase in the abundance of subadults from winter to late spring was partially due to growth of the earliest spawned individuals; some were adult size and probably were spent during the recent spawn and would die soon.

By late summer there was little additional recruitment, as indicated by the low abundance of all individuals smaller than 22 mm. Continued growth and development in the recruit class resulted in an increase in the abundance of subadults and a decrease in the abundance of juveniles (Table 112). Adult abundance remained at its low, late spring level. All adults were males (Table 113), indicating that spawning was completed by early to midsummer.

O'Day and Nafpaktitis (1967) and Nafpaktitis (1968) concluded that *L. dofleini* spawned only east of 34° and south of 48° in the North Atlantic, and that it was non-breeding in the western and northern Atlantic, maintaining its population in the expatriate region by periodic recruitment from the spawning area to the east. These authors found neither gravid females nor juveniles less than 16 mm in the western North Atlantic north of Cape Hatteras. Histological preparations made by O'Day and Nafpaktitis (1967) showed that female *L. dofleini* in the western North Atlantic had only oogonia and oocytes and no large yolk-filled eggs in their ovaries. The oocytes appeared to be normal, but had not undergone vitellogenesis. It was noted that males in the expatriate area had testes that contained mature sperm.

O'Day and Nafpaktitis (1967) noted the presence of 11–12 mm juveniles off Cape Hatteras but offered no explanation for this. Presumably those small specimens were transported from the spawning area via prevailing currents, a crossing that O'Day and Nafpaktitis hypothesized would take about a year, i.e., the total life span of most specimens found near Bermuda. Because this species is known to transform to the juvenile stage at 11–13 mm (Taaning, 1918), the proposed system of recruitment would involve a larval stage nearly a year in duration. Furthermore, as O'Day and Nafpaktitis (1967) observed, the population density of *L. dofleini* in the expatriate area is almost as large as that in the spawning area. This implies that truly astronomical numbers of this species must be transported from the spawning area to account for the population density in the western North Atlantic. One would expect the population density in the spawning area to be much greater than, and not about the same as, that in the expatriate area.

Finally, O'Day and Nafpaktitis (1967) did not examine females collected at all times of the year. Most of their material was collected from June through October; only one female was taken between November and March. The present study shows that Bermuda has a breeding, not

TABLE 112.—Seasonal abundance and percent of total abundance (in parentheses) for *Lobianchia dofleini* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.6(4.6)	1.3(9.9)	0.8(6.1)	10.4(79.4)	13.1
LATE SPRING	0	45.5(82.3)	9.2(16.6)	0.6(1.1)	55.3
LATE SUMMER	0.3(1.3)	3.3(14.0)	19.1(81.3)	0.8(3.4)	23.5

expatriated, population that spawns primarily in winter. If *L. dofleini* found in slope water off the continental United States is a reproductive population, spawning mainly in winter, it is quite possible that O'Day and Nafpaktitis found no gravid females because winter collections were not available.

The Ocean Acre collections analyzed here, the normal but undeveloped oocytes and the mature sperm present in males observed by O'Day and Nafpaktitis, the large population density in the slope water, and the appearance of 12 mm juveniles off Cape Hatteras all speak against the hypothesis of sterile expatriation and indicate that *L. dofleini* maintains a reproductive population in the western North Atlantic.

SEX RATIOS.—Males and females probably were equally abundant at all seasons. They were taken in about equal numbers both in late spring and late summer, and more females than males were taken in winter (1.3:1), but the latter difference was not significant (Table 113). Juvenile males were more numerous than juvenile females in late spring and late summer. Subadult females were more numerous than subadult males in all three seasons. Adult males were more numerous than adult females in late spring and late summer, and less numerous than adult females in winter, when adults were most abundant. The only significant difference from equality was for juveniles in late summer (Table 113), and this probably reflects sexual dimorphism in rate of development rather than a fundamental difference in the numbers of each sex.

VERTICAL DISTRIBUTION.—Diurnal vertical range in winter was 1–50 m and 351–750 m with maximum abundance at 451–500 m, in late spring 351–700 m with a maximum at 601–650 m, and in late summer 451–650 m with a maximum at 501–600 m. Depth range at night in winter was 51–200 m (a 10 mm specimen was taken at 18–19 m) with no apparent concentration within that range, in late spring 50–200 m with a maximum abundance at 50 m, and in late summer 90–175 m (a 16 mm juvenile was caught at 33 m) with a maximum at about 100 m (Table 114).

Stage and size stratification were evident at each of the three seasons and, except for size stratification by day in

late spring, were apparent both day and night. By night at all seasons juveniles were most abundant at shallower depths and had a shallower upper depth limit than adults. In terms of size, the largest fish were taken only at the lower depth limit at all seasons, and in winter and late summer the smallest individuals were taken only at the shallower depth limit. Nocturnal stratification was indicated by the increase in mean size with depth (Table 114).

By day in late spring juveniles and subadults were most abundant at 601–650 m and had similar depth ranges, but juveniles were more abundant above than below 600 m, while the opposite was true for subadults. Only one adult was caught during the day at this season. Small (11–13 mm) and large (25–36 mm) fish were caught only at or near the lower depth limit, while those of intermediate size were taken at all depths within the vertical range (Table 114).

In late summer during the daytime juveniles were most abundant at a shallower depth than subadults and adults, and they and subadults had a shallower upper depth limit than adults. Small juveniles (11–13 mm) were caught only near the lower depth limit, and there was a slight increase in the mean size with depth (Table 114).

By day in winter, stratification apparently was reversed. Adults were most abundant at a shallower depth and had a shallower upper depth limit than the few juveniles and subadults, and juveniles were taken only below the deepest depth at which advanced stages were taken. Fish 10–11 mm were caught only below 500 m, those 26–30 mm were all from shallower depths; a single postlarva was caught in the upper 50 m (Table 114).

Diel migrations occurred at all three seasons and apparently by all stages and sizes. Only one fish, a probable contaminant from a previous tow, was caught at daytime depths during the night. Recently metamorphosed juveniles (10–11 mm) were taken only at or near the deepest day depths and at or near the shallowest night depths both in winter and late spring, suggesting that they may undertake more extensive diel migrations than older fish (Table 114).

Evening migrations were about 2.0 hours in duration in late spring and as long as 3.0 hours in winter and late summer. (Almost certainly they were of shorter duration, because the population at the latter two seasons was mostly made up of larger fish than in late spring). Day depths still were occupied about an hour before sunset in late spring (520 m), about 2.5 hours before sunset in late summer (~650 m), and about 2.0 hours before sunset in winter (535 m). In late summer a single individual was taken at between 470 and 500 m at about sunset. Nocturnal depths were reached within an hour after sunset at all three seasons. Based on these times, estimated migration rates between day and night depths of maximum abundance are about 300 m/hour in late spring, about 140 m/hour in late summer, and about 120 m/hour in winter.

The duration and rate of morning migrations were simi-

TABLE 113.—Numbers of each sex for each stage of *Lobianchia dofleini* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; asterisk = significant differences indicated by Chi-square test (p = .05)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	0	0	3	8	26	30	29	38
SPRING	64	61	47	55	8	2	119	118
SUMMER	24	10*	71	93	4	0	99	103

TABLE 114.—Vertical distribution by 50-m intervals of *Lobianchia dofleini* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch)

DEPTH (M)	WINTER CATCH RATE						SL		LATE SPRING CATCH RATE						SL		LATE SUMMER CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
1- 50	<1				<1	1	8.0	8																
351- 400			1		1	2	28.0	28	<1				<1	3	19.4	15-22								
401- 450				3	3	*			1	<1			1	*										
451- 500				6	6	11	27.2	26-29	2	1			3	10	19.2	15-24			1		1	1	21.0	21
501- 550			1	1	2	2	28.0	26-30	2	<1			2	*				2	4		6	26	22.9	13-28
551- 600		1			1	2	10.5	10-11	1				1	2	16.5	13-20	<1	1	5	<1	6	28	23.4	10-29
601- 650										3	2	<1	5	14	22.1	13-36			3	<1	3	9	24.8	21-33
651- 700	-	-	-	-	-				1	<1			1	9	21.3	11-35			1	<1	1	*		
701- 750		<1			<1	1	11.0	11	<1	<1			<1	*										
TOTALS	<1	1	1	11	13	19			10	3	<1		13	38			<1	3	14	<1	17	64		
NIGHT																								
1- 50	<1				<1	1	10.0	10	34	2			36	60	17.9	11-26	1				1	1	16.0	16
51- 100	<1	1	1		2	12	26.4	12-29	12	7	<1		19	79	21.4	10-32	2	6			8	62	23.5	16-27
101- 150				2	2	8	28.2	26-30										13	1		14	40	26.8	22-30
151- 200			<1	1	1	9	29.1	26-33										1			1	5	27.2	24-34
201- 250				<1	<1	1	28.0	28			1	<1	1	4	29.2	24-34								
551- 600	<1				<1	1	9.0	9									-	-	-	-	-			
701- 750	<1				<1	1	9.0	9	-	-	-	-	-											
TOTALS	<1	<1	1	4	6	33			46	10	<1		56	143			3	20	1		24	108		

lar to evening migrations at each of the three seasons. Descent to diurnal depths apparently starts about the time of sunrise, as specimens were caught in the upper 200 m at or near that time in all three seasons. Daytime depths were reached about 2.0 hours after sunrise in late spring (~475 m) and about 3.0 hours (perhaps less) after sunrise in winter (~400 m and ~750 m) and in late summer (~575 m).

Captures were made at several intermediate depths at or near sunset in late spring and late summer, and at or near sunrise in late spring, suggesting that different migration rates or times or both may exist in various elements of the population.

PATCHINESS.—Patchiness at night was indicated at 50-100 m in late spring and at 51-100 m in late summer. In late spring each of the three most advanced developmental stages occurred in maximum abundance in this interval, but probably only juveniles had a patchy distribution. They accounted for more than 95 percent of the catch at 50-56 m and, hence, were responsible for the observed variation in the catch from that depth. Between 90 and 100 m, where more than 60 percent of the catch consisted of juveniles,

two samples from about 90 m, containing almost exclusively juveniles, suggested clumping, while three samples at 100 m, containing mostly subadults, did not. In late summer clumping was indicated for juveniles and subadults at 51-100 m. Juveniles were most abundant at this depth, but subadults accounted for more than 70 percent of the catch from that depth interval. Subadults were most abundant at 101-150 m, but showed no clumping.

CD values were significantly greater than 1.0 in late summer at night at 151-200 m and during the day at 101-150 m, 451-500 m and 501-600 m, and during the day in late spring at 551-700 m. The significant CD value obtained at 151-200 m at night in late summer resulted from a series of three negative samples taken during one cruise being tested with a series of three samples, two of which were positive, from the other cruise. CD values calculated for each series separately were not significantly greater than 1.0. Additionally the positive samples were taken near the morning crepuscular period and may have caught early migrants.

The CD value for 501-600 m during the day in late

summer barely was significant, and the catches suggest a random distribution. At 451–500 m only one sample was positive, suggesting a low population density at the upper day depth limit. At 101–150 m, a depth much too shallow to be within the diurnal vertical range, only one sample taken near the evening crepuscular period was positive, suggesting that the catch included migrants. By day in late spring at 551–700 m the distribution may be patchy, but more likely is random, similar to that of 501–600 m by day in late summer, only at a lower population density. Patchiness was not indicated in winter for any stage at any depth day or night.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios for discrete-depth captures, including interpolated values, were 0.5:1 in winter, 4.2:1 in late spring and 1.2:1 in late summer (Table 115).

Seasonal differences in clumping, abundance, vertical distribution, discrete-depth coverage, and stage and size composition render it most unlikely that any one factor was the principal cause of the observed differences in diel catch rates. Adults were most abundant in winter and accounted for most of the difference between night and day catches at that season. Juveniles had the greatest proportional difference between day and night catches but they comprised little more than 10 percent of the day abundance and less than 5 percent of the night abundance. Increased net avoidance at night by adults may have been responsible for the higher daytime catches in winter.

Apparently, *L. dofleini* feeds at night or during migrations (Merrett and Roe, 1974), and increased activity associated with feeding may result in enhanced net avoidance. The two largest catches of *L. dofleini* in winter were made in discrete-depth samples taken at 130 m and 140 m at about dusk and dawn, respectively. Night discrete-depth samples were taken at 100 m and 150 m but not between, suggesting the depth of maximum abundance of *L. dofleini* was not sampled, and as a result the abundance at night was artificially low.

Juveniles were responsible for most of the difference between late spring day and night catches, and subadults for most of that in late summer. Patchiness was greater and the vertical range more compressed at night than during the day at these seasons. These differences may have resulted in increased night catches.

TABLE 115.—Seasonal night to day catch ratios of *Lobianchia dofleini* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	3.0:1	0.2:1	0.9:1	0.4:1	0.5:1
LATE SPRING	*	4.9:1	2.6:1	2.0:1	4.2:1
LATE SUMMER	*	0.8:1	1.3:1	0.9:1	1.2:1

Lobianchia gemellarii

This medium-size myctophid seldom exceeds 35 mm in the study area; a few grow to 48 mm. Two specimens nearly 100 mm were caught. Nafpaktitis (1968) noted that a few individuals found in the slope water off New England and further north all with undeveloped gonads were 85–100 mm, and Hulley (1981) commented on the presence of large, sexually undeveloped specimens north of 40° in the eastern Atlantic. There is a question as to whether these large specimens are expatriates or represent a separate population, for they have high gill-raker counts. A tropical-subtropical species (Backus et al., 1977), *L. gemellarii* has a more or less complementary distribution to that of its congener *L. dofleini* in the Atlantic, but when both are found in the same area, one will be much more abundant than the other (Nafpaktitis et al., 1977). This species, although common in the study area, never ranked among the top 10 lanternfishes in abundance. The Ocean Acre collections contain 627 specimens; 222 were caught during the paired seasonal cruises, 146 of those in discrete-depth samples of which 112 were in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 6–12 mm, juveniles 11–38 mm, and subadults 29–98 mm. The sex of only a few (~12 percent of those caught during the paired seasonal cruises) specimens could be determined; even those had barely recognizable ovaries or testes. Only nine specimens exceeded 40 mm, the reported size at sexual maturity (O'Day and Nafpaktitis, 1967). Most specimens lacked luminous tissue on the caudal peduncle, a secondary sex characteristic of *L. gemellarii* found in the spawning area (12°–26°N) of the Atlantic Ocean (O'Day and Nafpaktitis, 1967).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Lobianchia gemellarii* is a nonbreeding resident of the study area. Abundance was greatest in winter and decreased with the progression of the seasons (Table 116). In winter and late spring juveniles were predominant, making up about 79 and 92 percent, respectively, of the catch.

The paucity of specimens of adult size (larger than 40 mm), the lack of ripe females, the absence of luminous tissue on the caudal peduncle of most specimens, and the presence

TABLE 116.—Seasonal abundance and percent of total abundance (in parentheses) for *Lobianchia gemellarii* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	2.4 (16.6)	11.4 (78.6)	0.7 (4.8)	0	14.5
LATE SPRING	0	8.3 (92.2)	0.7 (0.8)	0	9.0
LATE SUMMER	0.3 (12.5)	0.9 (37.5)	1.2 (50.0)	0	2.4

of the two "giant" specimens showing very little sexual development indicate that *L. gemellarii* is a sterile expatriate, whose numbers in the study area must be periodically replenished, presumably from the spawning area to the south.

Recruitment was greatest in winter. The catch at that season consisted almost entirely of specimens 20 mm or smaller. Juveniles comprised nearly 80 percent of the catch in winter. Postlarvae had their peak abundance at this season, accounting for about 17 percent of the catch (Table 116). The small size of winter specimens indicates that the parent population was at a peak in spawning in fall. The relatively high abundance in winter in the study area presumably reflects a peak in abundance in the spawning area.

In June almost all fish were greater than 20 mm; none were smaller than 16 mm. Abundance was only about two-thirds of that in winter. Specimens taken at this time either were winter recruits at an older age or were recent recruits from the parent population, or both. The paucity of small specimens at this early summer season indicates that most spawning was completed by winter.

By late summer most specimens were larger than 25 mm, although a few were 10–20 mm. The smaller specimens may reflect a smaller spawning peak for the parent population in late spring–early summer or may signal the advent of a new spawning season. Abundance was quite low, being about one-sixth of that in winter.

The relatively low abundance at each season probably resulted from very few recruits reaching the study area. Apparently most specimens could not survive long under the prevailing conditions; none had reached sexual maturity. It cannot be determined if the "giant" specimens had survived in the study area for any length of time. The "giants" examined by Nafpaktitis (1968) were taken in slope water off southern New England or further north.

VERTICAL DISTRIBUTION.—Daytime depth range in winter was 1–50 m and 451–650 m with maximum abundance at 451–500 m, in late spring 351–800 m with a maximum at 601–650 m, and in late summer 451–600 m. At night the vertical range in winter was 51–150 m and scattered sporadically between 301 m and 600 m with maximum abundance at 51–100 m, in late spring 51–300 m with a maximum at 201–250 m, and in late summer at scattered intervals between 51 m and 450 m with no apparent concentration (Table 117).

Except by day in late summer, size stratification was evident day and night at each of the three seasons. During the daytime in winter all specimens from the upper 50 m were 7–8 mm postlarvae and those from greater depths were 10–29 mm. During the day in late spring there was an increase in maximum size with depth and the mean size tended to increase with depth. At night in the upper 350 m the mean size at 51–100 m was noticeably smaller than at other 50-m intervals. The largest specimens were taken only between 251 m and 350 m (Table 117).

Postlarvae seemed to be stratified by size; those from the upper 150 m were 7–8 mm and those from greater depths 10–12 mm. As with other species of myctophids, initial development apparently occurs in the upper layers and, at a size of about 10 mm, postlarvae descend to about 500–600 m, where they transform. Postlarvae probably do not undertake vertical migrations of any great extent, but there is little evidence to support this.

Diel vertical migrations occurred at each of the three seasons. Only two specimens were caught at day depths at night, one postlarva and a 12 mm juvenile; this suggests that the smallest juveniles were not regular migrants.

Little could be determined concerning the chronology of vertical migrations. In winter and late spring specimens were caught in the upper 250 m during the evening crepuscular period and in the upper 200 m during the morning crepuscular period. Thus at least some specimens begin upward migrations prior to about 1.0–1.5 hours before sunset, and some do not commence downward migrations until shortly before sunrise.

PATCHINESS.—A patchy distribution was indicated at 451–500 m during the day and at 95 m during the night in winter. The day CD was based upon two samples at different depths within the 451–500 m interval and probably reflects different population densities within that interval. One sample fished at 451–470 m had a catch rate of 2.0, and the other fished at 469–500 m had a catch rate of 13.0.

Eleven samples were taken at 51–100 m at night, three at 68 m, three at 95 m, and five at 100 m. Samples from 68 m and 100 m caught either one specimen or no specimens, and their individual CD values were not significantly greater than 1.0. At 95 m the first of three consecutive samples had a much lower catch rate than the following two. The first sample was taken shortly after the evening crepuscular period, when fish still may have been migrating up to their nighttime depths.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios for discrete-depth captures were 0.4:1 in winter, 0.8:1 in late spring, and 4.2:1 in late summer (Table 118).

Because juveniles smaller than 20 mm dominated the winter catch both day and night, and specimens smaller than 30 mm accounted for most of the difference in day and night catches in late spring, it is unlikely that diel differences in net avoidance had much if any, effect on the diel differences in catch. Apparently, the species concentrates in a narrow stratum both day and night. Most of the catch in each diel period came from a single depth range, and positive samples from other depths contained only one or two fish. The observed diel differences in abundance, then, probably were due to sampling inequities.

Catches in late summer were poor both day and night. Most specimens captured were 30 mm and larger, sizes that may have been able to avoid the net. Avoidance by day was suggested by the fact that only two fish were taken in all discrete-depth diurnal samples combined, despite good sam-

TABLE 117.—Vertical distribution by 50-m intervals of *Lobianchia gemellarii* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DAY

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
1- 50	<1				<1	2	7.5	7- 8																
351- 400									<1				<1	1	16.0	16								
401- 450		4			4	*			1				1	*										
451- 500		7			7	15	15.6	9-18	2				2	6	21.3	20-22	<1				<1	1	31.0	31
501- 550									1				1	*										
551- 600		<1	<1		<1	2	21.5	14-29	<1				<1	2	33.5	32-35	<1				<1	1	10.0	10
601- 650	2	<1			2	7	11.9	11-12	3				3	9	28.7	21-36								
651- 700		<1			<1	*			1				1	6	34.5	31-38	-	-	-	-	-			
701- 750									<1	<1			<1	*										
751- 800	-	-	-	-	-					<1			<1	1	97.0	97								
801- 850										<1			<1	*										
TOTALS	2	11	<1		13	26			8	<1			8	25			<1	<1			<1	2		

NIGHT

DEPTH (M)	WINTER PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER PL	JUV	SA	AD	TOT	N	X	RANGE
51- 100	1	3			4	26	14.6	7	1				1	7	21.7	18-27	<1				<1	2	17.5	15-20
101- 150	<1				<1	1	7.0	7	1				1	3	29.7	28-33								
151- 200									1				1	2	29.5	26-33		<1			<1	2	33.0	33-35
201- 250									2				2	7	31.4	28-35		<1			<1	1	40.0	40
251- 300		<1	<1		<1	*			1	1			2	2	34.0	20-48								
301- 350		1	1		2	2	28.5	14-43	<1	<1			<1	*				<1		1	1	2	35.5	28-43
351- 400																								
401- 450																		<1			<1	1	30.0	30
451- 500	<1				<1	*																		
501- 550																								
551- 600		<1			<1	1	12.0	12									-	-	-	-	-			
TOTALS	1	4	1		6	30			6	1			7	21			1	1			2	8		

TABLE 118.—Seasonal night to day catch ratios of *Lobianchia gemellarii* (JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	TOT
WINTER	0.4:1	0.4:1	1.8:1	0.4:1
LATE SPRING	*	0.8:1	1.0:1	0.8:1
LATE SUMMER	*	4.5:1	*	4.2:1

pling effort within the presumed depth range (Table 117). However, even at night few specimens were caught; the difference may be due to chance.

Loweina interrupta

This rare species is represented in the Ocean Acre collections by two males 24 and 25 mm caught in February and March. The February specimen was caught at night at 800 m.

Loweina rara

This lanternfish is moderate in size, growing to about 45 mm and reaching sexual maturity at about 28–32 mm (Nafpaktitis et al., 1977). The largest specimen in the Ocean Acre collections, and the only one in excess of 30 mm, is 41 mm. Presumably, *L. rara* is a tropical-subtropical species (Backus et al., 1977); it is uncommon throughout its range (Nafpaktitis et al., 1977) and is an "uncommon" lanternfish in the study area. The Ocean Acre collections contain 78 specimens; 50 were caught during the paired seasonal cruises, 29 of these in discrete-depth samples, of which 26 were in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 8–20 mm, juveniles 21–24 mm, subadults 22–30 mm, and the only

adult 41 mm. External sexual dimorphism is obvious soon after transformation; males develop supracaudal luminous tissue and females do not. The adult is a female with ova as large as 0.3 mm in diameter. Of the specimens that could be sexed, 13 were males and 10 were females.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive status and life span of *L. rara* near Bermuda are uncertain. Judging from the numerical dominance of postlarvae (about 70 percent of the total number) and the presence of an adult female in the Ocean Acre collections, *L. rara* may be an uncommon breeding resident. However, the absence of this species in collections from late November through January, and of specimens 31–40 mm at all times, suggest that few individuals survive long enough to reach sexual maturity.

A prolonged reproductive season for the parent population is apparent in the seasonal distribution of postlarvae, which were taken from March to September, and a summer peak is suggested by the late summer catch when 40 were taken.

VERTICAL DISTRIBUTION.—Daytime vertical range in

winter was 801–850 m, in late spring at the surface, and late summer scattered between 251 m and 1150 m. Depth range at night in winter was 101–150 m and 301–350 m, in late spring 51–150 m, and in late summer 101–200 m and 951–1000 m with a slight concentration at 151–200 m (Table 119).

Myctophum asperum

This is a large tropical species (to 77 mm; Nafpaktitis et al., 1977) represented in the collections by a 53 mm subadult female taken with the Engel trawl in August.

Myctophum nitidulum

This large myctophid grows to about 100 mm (Nafpaktitis et al., 1977); the largest specimen caught during the program was 80 mm. *Myctophum nitidulum*, a tropical-subtropical species (Backus et al., 1977) is common but not abundant in the study area, never being among the 10 most abundant lanternfishes (Table 131). It is represented in the

TABLE 119.—Vertical distribution by 50-m intervals of *Loweina rara* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					SL			LATE SPRING CATCH RATE					SL			LATE SUMMER CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
SURFACE									<1			<1		1	15.0	15								
251– 300																	1				1	1	14.0	14
701– 750									–	–	–	–	–											
751– 800		<1			<1	*																		
801– 850		1			1	2	24.0	24	–	–	–	–	–											
851– 900	–	–	–	–	–												<1				<1	*		
901– 950	–	–	–	–	–				–	–	–	–	–				<1				<1	1	14.0	14
951–1000	–	–	–	–	–												<1	<1			<1	*		
1001–1050									–	–	–	–	–					<1			<1	1	30.0	30
1051–1100	–	–	–	–	–												<1	<1			<1	*		
1101–1150	–	–	–	–	–												<1				<1	1	18.0	18
TOTALS		1			1	2			<1			<1		1			2	1			3	4		
NIGHT																								
51– 100											<1		<1	1	24.0	24								
101– 150	<1				<1	1	21.0	21	<1				<1	1	18.0	18	1				1	2	9.5	9–10
151– 200																	2				2	12	12.7	9–16
201– 250																								
251– 300	<1				<1	*																		
301– 350	1				1	1	24.0	24	–	–	–	–	–											
951–1000																	<1				<1	1	19.0	19
TOTALS	1				1	2			<1	<1		<1		2			3				3	15		

Ocean Acre collections by 543 specimens; 229 were taken during the paired seasonal cruises, 180 of these in discrete-depth samples of which 163 were caught in noncrepuscular tows (Table 23). *Myctophum nitidulum* was not well sampled by the IKMT; approximately 95 percent of all specimens were caught at night in neuston nets.

DEVELOPMENTAL STAGES.—Postlarvae were 9–16 mm, juveniles 14–42 mm, subadults 44–69 mm, and adults 55–80 mm. Fish less than 27 mm could not be sexed; most of those 27–31 mm and all larger ones were sexed. Males larger than about 35 mm have luminous tissue dorsally on the caudal peduncle, and females larger than about 45 mm have luminous tissue ventrally on the caudal peduncle (Gibbs, 1957). There is no apparent sexual dimorphism in size among the relatively few large specimens (over 40 mm) in the Ocean Acre collections. Males and females were about equally represented among the 67 specimens examined for sex (34 vs 33, respectively).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Spawning occurs from spring to fall, with a peak in intensity in late spring–early summer. The life span may be two or three years, but too few large specimens were caught to be sure. Abundance was greatest in late summer, when most specimens were smaller than 20 mm, and progressively decreased in winter and late spring (Table 120).

Although juveniles predominated in each season, those 14–16 mm were taken only in late spring and late summer. Those smaller than 20 mm were most abundant in late summer. The seasonal distributions of postlarvae (June-October, most in late summer) and adult females (April-September), combined with that of small juveniles, shows that most reproduction takes place in spring and summer.

By late spring spawning had begun, and the catch consisted of recently spawned postlarvae 8–14 mm and juveniles 14–19 mm, fish 28–44 mm presumed to be about one year old, and fish larger than 54 mm about two or more years old. Abundance was dominated by specimens 17–18 mm, which accounted for about 65 percent of the nighttime catch. Adults, although not taken in abundance at any season, were most abundant in late spring.

TABLE 120.—Vertical distribution by 50-m intervals of *Myctophum nitidulum* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
											DAY												
601– 650			<1	<1	1	61.0	61																	
651– 700			<1	<1	*														<1		<1	*		
701– 750																			<1		<1	1	18.0	18
751– 800	–	–	–	–	–																			
801– 850																			<1		<1	1	28.0	28
851– 900	–	–	–	–	–				<1				<1	1	13.0	13			<1		<1	*		
901– 950	–	–	–	–	–				–	–	–	–	–				<1				<1	1	14.0	14
TOTALS			<1	<1	1				<1				<1	1			<1				1	3		
											NIGHT												
SURFACE 1– 50	8	1	<1		9	69	28.0	17–77		5	<1	1	6	57	24.8	14–74		15			15	24	17.6	15–22
51– 100	<1			<1	1	28.0	28		<1				<1	1	8.0	8		<1			<1	1	20.0	20
101– 150																								
151– 200																		<1			<1	2	19.5	19–20
201– 250																								
251– 300	–	–	–	–	–																			
301– 350									–	–	–	–	–				<1				<1	1	8.0	8
351– 400																								
401– 450																		<1			<1	1	19.0	19
901– 950	–	–	–	–	–				–	–	–	–	–				<1				<1	1	15.0	15
TOTALS	8	1	<1		9	70			<1	5	<1	1	6	58			<1	16			16	30		

TABLE 121.—Number of specimens per hour of *Myctophum nitidulum* in neuston samples made approximately between sunset and sunrise, local time (dash = no samples made).

MONTH	CRUISE	SUNRISE	SUNSET	1701 1800	1801 1900	1901 2000	2001 2100	2101 2200	2201 2300	2301 2400	0001 0100	0101 0200	0201 0300	0301 0400	0401 0500	0501 0600	0601 0700	0701 0800
JANUARY	11	0717	1730	-	-	-	-	0	2	0	6	18	-	-	0	-	-	-
FEB-MAR	13	0650	1815	0	4	4	7	1	6	6	0	0	6	3	3	-	-	-
JUNE	10	0510	1920	0	0	0	0	1	1	3	3	1	0	0	0	0	1	0
JUNE	14	0512	1925	0	0	0	1	3	1	5	-	-	2	4	6	0	0	0
AUG-SEPT	12	0551	1840	-	0	5	15	4	0	6	20	4	7	-	2	0	0	-
SEPTEMBER	7	0552	1839	-	24	56	22	19	2	-	46	16	34	25	3	-	-	-

In late summer recruits 15–19 mm were predominant, accounting for more than 95 percent of the abundance at that season. All specimens caught in discrete-depth samples were 15–28 mm. However, several specimens larger than 60 mm were caught with the Engel trawl at that season, showing that at least two year classes were present. Abundance was greatest at this season (Table 120) as a result of the spawning peak in late spring–early summer.

About 90 percent of the catch in winter was due to juveniles 21–30 mm. Presumably these specimens represented late summer recruits but at an older age. Larger fish were either 34–47 mm or 60–77 mm. These larger specimens probably belonged to different year classes, but their abundance was too low to be certain. The 60–77 mm specimens were at least a year older than the 21–30 mm fish. The age of the 34–47 mm group was uncertain; they may have represented the earliest fish spawned the previous spring.

Additional evidence for a late spring–early summer spawning peak is seen in the catch in September when more than 200 individuals, mostly less than 30 mm, were taken in neuston samples.

VERTICAL DISTRIBUTION.—Little is known about the daytime depth range of *M. nitidulum*. The five specimens caught in discrete-depth trawls were from 601–950 m, with only postlarvae taken below 850 m (Table 120). Clarke (1973) reported a similar diurnal depth range for *M. nitidulum* near Hawaii. Gibbs et al. (1971) reported that two 11-mm juveniles were caught at 301–350 m, during the day. This is in error; the fish in question were *M. selenops* and not *M. nitidulum*. Fully transformed juveniles of *M. nitidulum* are not likely to be as small as 11 mm, as transformation occurs at about 14 mm (Moser and Ahlstrom, 1970; H.S. Zadoretzky, personal communication), the size of the smallest juveniles in the Ocean Acre collections.

At night most specimens were caught in neuston nets, and a few were taken at scattered depths down to 950 m (Table 120).

PATCHINESS.—A patchy or clumped distribution was noted at the surface by night in each season. Table 121 gives the number of specimens per hour taken in neuston samples between sunset and sunrise and, despite averaging samples made within one-hour intervals, shows a clumped distribution.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios are 18.0:1 in winter, 20.7:1 in late spring, and 16.4:1 in late summer. The small day catches may have been related to vertical distribution rather than enhanced net avoidance, because most of the night catch (made in neuston nets) in each season consists of fish smaller than 30 mm (Table 120). Presumably fish of this size cannot avoid the IKMT. However, the daytime distribution of this and other species taken in large numbers at night in neuston nets remains a mystery.

Myctophum obtusirostre

This large tropical species (to 85 mm; Nafpaktitis et al., 1977) is represented in the collections by two males 41 and 53 mm. One was taken at night in a neuston sample, the other by the Engel trawl in August. Apparently *M. obtusirostre* appears in the study area only as a distributional waif.

Myctophum punctatum

This is a large myctophid, known to grow to about 107 mm (Hulley, 1981). All specimens of this "uncommon" lanternfish taken during the Ocean Acre program were either juveniles 17–23 mm or postlarvae 7–18 mm. The 51 specimens were taken as follows: 9 in March, 14 in April, 27 in June, and one in September. *Myctophum punctatum* is a subpolar-temperate species (Backus et al., 1977), and probably is found near Bermuda only as a distributional waif from its center of abundance to the north. Zurbrigg and Scott (1972) concluded that *M. punctatum* did not spawn in the northwest Atlantic, but Jahn's (1976) report of several 16–20 mm juveniles from the presumed expatriate area of those authors suggests that additional study is needed to determine the reproductive status of this lanternfish in the northwestern Atlantic.

VERTICAL DISTRIBUTION.—Nearly half (24) of the specimens were caught in neuston nets at night. One specimen was caught at 50 m at night and another, a postlarva, at 33

135

m during daytime . The remaining eight discrete-depth captures were made during crepuscular periods, seven at 701–800 m, and one 251–300 m.

Myctophum selenops

This moderately large myctophid reaches a size of about 72 mm (Nafpaktitis et al., 1977); the largest specimen in the Ocean Acre collections is 65 mm. *Myctophum selenops* is an uncommon tropical-subtropical species (Backus et al., 1977). It is a "rare" species in the study area, being represented by only 25 specimens. Eighteen specimens were caught during the paired seasonal cruises, 10 of these in discrete-depth samples of which 6 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 6–11 mm, juveniles 10–34 mm, the only subadult was 58 mm, and the two adults were 59 and 65 mm. Sexual dimorphism was evident in the size and number of luminous scale-like structures in the supracaudal gland, which appears in males at about 30 mm and females at about 35 mm (Nafpaktitis et al., 1977).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The reproductive status and life span of *M. selenops* in the study area is uncertain . Judging from the numerical dominance of postlarvae (7 specimens) and, particularly, juveniles (15 specimens) and the presence of an adult of each sex in the Ocean Acre collections, *M. selenops* may be an uncommon breeding resident of the study area.

Apparently spawning takes place in spring or summer. Postlarvae were taken from August to October, and all small (less than 20 mm) juveniles, and both adults (59 and 65 mm) in August to September. The catch from August to October obviously consists of two different year classes and indicates that the species lives at least one year and perhaps longer.

VERTICAL DISTRIBUTION.—Three fish caught in day discrete-depth samples (in winter and late summer) were all taken at 301–350 m. One specimen was caught at night at 100 m in late spring. One fish each was caught at 301–350 m near sunset and at about 200 m near sunrise in late summer.

Notolychnus valdiviae

This slender, diminutive lanternfish grows no larger than about 25 mm (Paxton, 1972; Clarke, 1973), the largest specimen in the Ocean Acre collections being 22 mm; few exceed 20 mm. *Notolychnus valdiviae*, one of the dominant lanternfishes of the North Atlantic subtropical region (Nafpaktitis et al., 1977), is very abundant in the study area and was one of the six most abundant myctophids in the area at each of the three seasons sampled. The collections contain 3999 specimens; 2870 were caught during the

paired seasonal cruises, 1944 of these were from discrete-depth samples of which 1670 were in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 4–10 mm, juveniles 8–17 mm, subadults 15–22 mm, and adults 17–22 mm. Most juveniles smaller than 12 mm could not be sexed; nearly all of those greater than 13 mm were sexed. Some fish (larger than 18 mm) categorized as subadults appeared to be in a postspawning condition. Sexual dimorphism in subadults and adults is manifested externally in several ways: males have a larger supracaudal gland than females (Nafpaktitis et al., 1977); males larger than 16 mm have noticeably larger eyes than females of the same sizes; females average 1–2 mm larger for each of the three older stages and attain a larger maximum size than males 22 vs 21 mm; of the 54 sexed fish larger than 20 mm, 51 are females.

The dimorphism in size appears to be reversed for juveniles in late summer, when males averaged 0.4 mm larger than females. However, females may develop faster and, as a result, be recognized at a smaller size than males. Badcock and Merrett (1976:45) noted that in the eastern North Atlantic (30°N, 23°W) *N. valdiviae* was sexually dimorphic in "eye and snout characteristics" and that females grow larger than males.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Notolychnus valdiviae* appears to be an annual species that spawns primarily in spring and probably at low levels at other times. Most fish live about one year, but a few may survive into their second year. Abundance was greatest in late summer, when juvenile recruits were predominant, intermediate in winter, and lowest in late spring (Table 122). Subadults and adults were most abundant in winter. The low abundance in late spring probably was due to recruits being too small to be adequately sampled by the nets.

Although adult-size females were caught at each season, only in late April to early May did a large proportion (over 90 percent) have enlarged ovaries containing eggs mostly larger than 0.1 mm in diameter. This seasonal distribution of females with ripening eggs, together with the great abundance of 10–15 mm juvenile recruits in late summer, indicates that *N. valdiviae* spawns mostly in spring. Postlarvae, although only 19 specimens, were all caught from July to September, further indicating a spring spawning peak. Clarke (1973) noted that near Hawaii *N. valdiviae* has a similar cycle, with smaller juveniles (less than 15 mm) being most numerous in September, and the proportion of females with developed ova being greater in March and June than in September and December.

Winter collections were dominated by subadults, with juveniles and adults less and about equally abundant (Table 122). Subadults were spawned during the previous spring spawning peak, appeared as the large juvenile recruitment of the late summer, and matured and spawned during the

TABLE 122.—Seasonal abundance and percent of total abundance (in parentheses) for *Notolychnus valdiviae* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	JUV	SAD	AD	TOT
WINTER	31.1(28.8)	48.4(44.9)	29.3(26.9)	108.8
LATE SPRING	2.3(6.6)	16.4(47.1)	16.1(46.3)	34.8
LATE SUMMER	151.3(86.8)	11.0(6.3)	12.0(6.9)	174.3

TABLE 123.—Numbers of each sex for each stage of *Notolychnus valdiviae* (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; significant differences indicated by Chi-square test shown by a single asterisk (p = .05) or two asterisks (p = .01)).

SEASON	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
WINTER	49	98**	166	254**	125	48**	340	400*
SPRING	1	7	59	113**	122	103	182	223*
SUMMER	227	448**	82	42**	74	122*	383	612**

TABLE 124.—Vertical distribution by 50-m intervals of *Notolychnus valdiviae* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE						SL		CATCH RATE						SL		CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
351- 400									<1				<1	1	20.0	20								
401- 450		6	8	6	20	*			<1	3	3		6	*										
451- 500		13	16	12	41	87	16.8	12-21	<1	6	6		12	37	18.2	13-21	<1				<1	1	11.0	11
501- 550			2	2	4	4	17.5	17-18	<1	4	4		8	*			32	4	4		40	163	13.3	10-21
551- 600			8	6	14	38	18.7	17-21			3	1	4	12	19.4	19-20	34	4	4		42	174	12.8	10-21
601- 650		7	5	1	13	47	16.9	14-21				2	2	7	19.1	18-20		2	2		4	12	19.0	17-20
651- 700		4	4	1	9	*						1	1	6	19.2	18-21		1	1		2	*		
701- 750			2	1	3	9	17.9	16-20	-	-	-	-	-					<1			<1	1	14.0	14
751- 800	<1	2	1		3	*																		
801- 850	1	1	<1		2	6	17.5	16-19	-	-	-	-	-											
TOTALS	31	48	30		109	191			<1	16	17		33	63			66	11	11		88	351		
NIGHT																								
1- 50	<1				<1	3	13.7	11-16	1	2			3	4	16.5	11-19	111	4			115	232	12.1	10-18
51- 100		6	12	7	25	218	17.4	11-21	<1	12	8		20	96	19.2	12-22	34	3	4		41	336	13.9	9-21
101- 150	<1	2	<1		2	12	17.6	16-19	<1	<1	1		1	4	17.1	15-18	2	<1	<1		2	8	14.6	11-21
151- 200	1	4	1		6	39	17.7	13-21		2			2	3	19.0	19	1		1		2	10	14.7	10-20
201- 250		<1	<1		<1	3	17.0	15-19		<1	1		1	3	18.3	16-20	2	1	1		4	27	16.0	9-20
251- 300	<1	<1	<1		<1	*											<1	<1	2		2	7	18.4	17-20
301- 350	1	1	1		3	3	18.3	17-20	-	-	-	-	-						1		1	5	17.6	17-18
351- 400			1		1	2	19.0	19										1	1		2	3	18.3	17-20
401- 450																								
451- 500		2	1		3	9	17.8	16-19																
501- 550		1			1	2	18.5	18-19																
551- 600	<1	2	1		3	10	17.3	15-19									-	-	-	-	-			
601- 650									-	-	-	-	-											
651- 700	<1	1	1		2	*			-	-	-	-	-				1				1	1	10.0	10
701- 750	1	2	2		5	12	18.4	16-21	-	-	-	-	-											
751- 800		1	1		2	6	19.2	18-20	1				1	1	10.0	10	<1				<1	1	11.0	11
801- 850																	-	-	-	-	-			
851- 900	1				1	1	11.0	11	-	-	-	-	-				<1				<1	1	14.0	14
901- 950	<1	1			1	*			-	-	-	-	-						<1		<1	1	19.0	19
951-1000		1			1	1	19.0	19																
1001-1050			1		1	1	20.0	20									-	-	-	-	-			
TOTALS	10	30	17		57	322			2	16	10		28	111			151	9	10		170	632		

subsequent spring. Most winter adults were spawned late in the previous winter or early spring, appeared as juveniles just approaching catchable size in late spring, and were the larger juveniles and smaller subadults of the late summer population.

By late spring the peak of spawning was past, and the adults and most subadults of the winter population had matured, spawned, and died. This mortality was reflected in the decreased abundance of adults and subadults (Table 122) and of all individuals 16–20 mm. The combined catch of subadults and adults in late spring, which was about one-third of the winter catch of all stages, suggests that by late spring about two-thirds of the winter population had died. Subadults and adults accounted for 93 percent of the late spring catch and were about equally abundant (Table 122). However, many females categorized as subadults were judged to be spent adults with reduced, somewhat flaccid ovaries. Presumably postlarvae from the spring spawn were present in great abundance and dominated the population, but were not yet large enough to be sampled adequately by the nets.

In late summer juvenile recruits 10–15 mm accounted for more than 86 percent of the catch. Adults were spawned about one year earlier, appeared as juveniles in winter, as subadults in late spring, and soon would spawn and die, marking the end of the previous winter population. Adult mortality resulted in the decreased abundance of subadults and adults, and of all specimens larger than 17 mm from late spring to late summer.

Further confirmation of a one-year life cycle is in the seasonal progression of size dominance (11–13 mm in late summer, 16–19 mm in winter, and 18–20 mm in late spring) and in the lack of an annular ring on the otoliths of two 22-mm females caught in winter and late spring. Otoliths were not routinely sampled, these being the only two from individuals of maximum size.

SEX RATIOS.—Unbiased sex ratios could not be determined for any developmental stage during any season for two reasons: females generally could be recognized at a smaller size than males, and spent adults, especially females, may have been categorized as subadults. The total number of females was significantly greater than that of males at each season: juveniles accounted for most of the difference in late summer, and subadults for most of the difference in winter and late spring (Table 123).

Females were significantly more numerous than males for the following stages: juveniles in late summer and winter, subadults in winter and late spring, and adults in late summer. Males were significantly more numerous than females for adults in winter and subadults in late summer (Table 123). Considering only subadults and adults, females still were more numerous than males, but the ratios were nearly equal at any season. Because neither sex was consistently more numerous than the other for either of the two oldest stages, the observed differences in the numbers of males and females for subadults and adults probably were due to the criteria used to allocate individuals to stages rather than actual differences in the numbers of each sex.

The female to male ratio for juveniles in late summer, which is slightly less than 2:1, was due largely to fish 9–12 mm. However, less than half of the fish within that size range could be sexed. The predominance of females may be due to their developing faster and, as a result, being recognized at a smaller size than males. Males and females have been taken in about equal numbers off Hawaii (Clarke, 1973) and in the eastern North Atlantic at 30°N, 25°W (Badcock and Merrett, 1976).

VERTICAL DISTRIBUTION.—Daytime depth range in winter was 451–850 m (possibly shallower) with maximum abundance at 451–500 m, in late spring 400–700 m with a maximum at 451–500 m, and in late summer 451–750 m with a maximum at 501–600 m. Vertical range at night in winter was 30–1050 m with maximum abundance at 51–100 m, in late spring 50–250 m (one specimen also was caught at 751–800 m) with a maximum at 51–100 m, and in late summer 33–400 m and scattered between 651 and 950 m, with a maximum at 33–50 m (Table 124).

During daytime six specimens caught shallower than 400 m during the three seasonal cruise pairs combined were taken near the evening crepuscular period and may have been migrants. Two of the specimens were suspected contaminants and may have been taken during a previous tow. Day depths for *N. valdiviae* near Hawaii (Clarke, 1973) and in the eastern North Atlantic (Badcock and Merrett, 1976) were deeper than 400 m.

Stage and size stratification were evident day and night at all three seasons, except for stage stratification by day in winter. During the day in late spring and late summer the two older stages had greater depth ranges than juveniles, which were caught only in the shallower portion of the vertical range. In late spring only adults were taken deeper than 600 m (Table 124). During the day in each season, smaller fishes were caught mostly at or near the upper depth limit, and larger ones were found over most or all of the vertical range. In winter most (87 percent) fish smaller than 16 mm were caught at 451–500 m, in late spring all those smaller than 18 mm at 451–500 m, and in late summer all but one smaller than 17 mm at 451–600 m (Table 124).

Adults were not taken in the upper 50 m at night at any season, whereas juveniles were taken at that depth at all three seasons. Subadults were taken in the upper 50 m in late spring and late summer. Migrant subadults and adults were caught over a greater depth range than migrant juveniles at each of the three seasons, and the latter did not occur as deep as the former.

Stage stratification was most pronounced at night in late summer, when juveniles accounted for more than 95 per-

cent of the catch from the upper 50 m, a decreasing percentage of the catch from each deeper 50-m interval to 300 m, and none from 301–400 m (Table 124). A smaller scale stratification existed in the upper 100 m in late summer. An upper, predominantly juvenile, layer at 33–60 m apparently was isolated from the remainder of the population. No adults and very few subadults were caught in that layer. No specimens were taken at 60–70 m. There were no samples taken between 70 and 90 m. The deeper layer was sampled at 90–92 m, where only 42 percent of the individuals were juveniles. In late summer both a seasonal thermocline and halocline were developed at about 25–75 m, and dissolved oxygen content at those depths was greater than at shallower and deeper waters (Morris and Schroeder, 1973). Perhaps these relatively large changes between 25 and 75 m inhibited subadults and adults from migrating up to shallower waters.

Diel vertical migrations occurred at all three seasons, but not all of the population migrated regularly. Nonmigrants were most abundant in winter, when nearly 32 percent of the night catch was from day depths. Less than 3 percent of the night catch in late spring and late summer came from day depths. Nonmigrants were predominantly subadults and adults in winter and juveniles at the other two seasons (Table 124). Nonmigratory behavior of adults and subadults in winter may be associated with the approaching spring spawn. Nonmigrants also are known to occur in the eastern North Atlantic (Badcock and Merrett, 1976) and near Hawaii (Clarke, 1973). Nonmigrants were abundant in winter but not in late spring near both Bermuda and Hawaii. However, in late summer about 70 percent of the population near Hawaii remained at daytime depths at night (Clarke, 1973), in contrast to about 3 percent near Bermuda (Table 124). Partial migrants and nonmigrants were found in the eastern North Atlantic at 30°N, 23°W in late March–early April (Badcock and Merrett, 1976), but not off Fuerteventura (Canary Is.) in October-November (Badcock, 1970). Partial migrants and nonmigrants found in both Atlantic localities were mostly subadults and adults. Near Hawaii they consisted of a higher proportion of larger fish than migrants in late summer but not in winter. The proportion of ripe or nearly ripe females in the partial-migrant and nonmigrant element was not noticeably different from the migrant fraction of the population at any of the three localities.

Evening migrations apparently begin between 1.5 and 2.5 hours before sunset in winter and late spring and between 2.2 and 3 hours before sunset in late summer. Because night depths were reached no later than 1.5–2.5 hours after sunset at each of the three seasons, upward migration times were about 4 hours in winter and late spring and 4.5 hours in late summer. These estimates of migration times indicate upward migration between day and night depths of maximum abundance averaging about 100 m/

hour in winter (500 to 100 m) and late spring (500 to 100 m), and about 115 m/hour in late summer (550 to 30 m).

Morning migrations apparently begin within about 1.5 hours before sunrise at each season. Because in late summer fish were caught in the upper 100 m possibly as late as 0.3 hours before sunrise or later and none were caught in the upper 50 m within 1.3 hours of sunrise, the starting time of migrations may depend upon depth. Day depths were reached no later than 2.5 hours after sunset in winter (650 and 750 m) and late spring (600 m), and by 3.5 hours after sunset in late summer (580 m), possibly an hour or more earlier. Assuming a starting time of 1.5 hours before sunset in each season, total downward migration times probably were not greater than 3.5 hours in winter and late spring and 4.5 hours in late summer. These estimates of migration times indicate that the average rate of descent from the depth of maximum abundance at night to that during daytime is about 115 m/hour at all three seasons, which is similar to the upward migrations.

PATCHINESS.—Patchiness by day was indicated in winter at 451–500 m and 601–650 m, and in late summer at 501–600 m. Juveniles, subadults, and adults were all taken in greatest abundance at 451–500 m in winter and at 501–600 m in late summer. In winter the catch of each stage at 451–500 m was similar, with subadults slightly more abundant than the other two stages, suggesting that each of the three stages had a patchy distribution. Because there were only two samples, each from different depths (456–469 m and 469–504 m), these conclusions must be accepted with reservation. The catch at 501–600 m in late summer was dominated by juveniles (over 79 percent), for which the variation in catch rates was much greater than for either subadults or adults. This suggests that only juveniles had a clumped distribution.

Patchiness at night was indicated at 51–100 m at each of the three seasons; subadults accounted for most of the catch at this depth in winter and late spring, and juveniles were dominant in late summer (Table 124). Juveniles, subadults, and adults were most abundant at that depth in winter, subadults and adults in late spring, and adults in late summer.

Other significant CD values were thought to be due to factors other than a patchy distribution. The CD values for day samples in winter at 801–850 m and in late spring at 451–500 m were significant. Only 6 specimens were caught at 801–850 m during daytime in winter, and all but one were from a single sample. Such a small catch and barely significant CD (3.5) suggests that significant clumping was unlikely. Three samples were taken at 451–500 m in late spring, two of which caught no fish. The CD value probably reflects year to year variation in abundance or vertical distribution rather than patchiness.

Night samples taken in winter at 151–200 m and 451–500 m and in late summer in the upper 50 m, 151–200 m,

201–250 m, and 301–350 m also had significant CD values. Differences in the catches in samples at 151–200 m and 451–500 m in winter and 151–200 m in late summer probably were due to changes in population density that were related to migratory movements. In each case the significant CD value resulted from a single sample taken near dawn that had a much larger catch than the remaining samples from the particular depth. The significant CD values for samples at 201–250 m and 301–350 m in late summer apparently were due to year to year variation in population density. Samples at both 50-m intervals were taken in two different years; CD values calculated for each year separately at both depths were not significant.

Two samples from the upper 50 m in late summer leave doubt as to whether the variation was due to upward migrations or to patchiness. There was a series of three one-hour samples starting at 0.5 hours after sunset taken at 33 m that caught 1, 76, and 156 specimens, respectively. The difference in catch between the first and second samples probably was due to migratory movement, because the first sample was taken during twilight and was not considered in the analysis. The difference between the second and third samples, although probably due to migration, may reflect patchiness.

NIGHT:DAY CATCH RATIOS.—Night-to-day catch ratios including interpolated values were 0.5:1 in winter 0.8:1 in late spring, and 1.9:1 in late summer (Table 125). The greater night depth range at each season (Table 124) may explain in part the catch ratios obtained for winter and late spring. In late summer the catch at night from the upper 50 m, which accounted for 67 percent of the total catch at night, was greater than the entire day catch. However, the value given for the upper 50 m at night, is based on two samples and may not be representative of the entire 50 m, as both samples were made at 33 m. Although no samples were taken between the surface and 33 m, the catch from oblique samples and from samples taken near sunset suggests that *N. valdiviae* does not inhabit depths shallower than 30 m. This indicates that abundance at 33 m was much greater than at shallower depths. There are no reliable catch data for 34–50 m at night.

TABLE 125.—Seasonal night to day catch ratios of *Notolychnus valdiviae* (AD = adult; JUV = juvenile; SAD = subadult; TOT = total of all stages).

SEASON	JUV	SAD	AD	TOT
WINTER	0.3:1	0.6:1	0.5:1	0.5:1
LATE SPRING	3.3:1	1.0:1	0.6:1	0.8:1
LATE SUMMER	2.3:1	0.9:1	0.8:1	1.9:1

Notoscopelus caudispinosus

This large lanternfish is known to reach a size of about 140 mm (Nafpaktitis, 1975); the largest in the Ocean Acre collections is 130 mm. *Notoscopelus caudispinosus*, an uncommon species, is questionably distributed according to the tropical-subtropical pattern in the Atlantic (Backus et al., 1977) and apparently is most abundant in the northern Sargasso Sea and the adjacent slope water (Nafpaktitis et al., 1977). The species is uncommon in the study area, never being among the 20 most abundant myctophids. It is represented in the Ocean Acre collections by 344 specimens; 114 were caught during the paired seasonal cruises, 90 of these in discrete-depth samples, of which 64 were in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 7–16 mm, juveniles 16–55 mm, subadults 54–130 mm, and adults 101–121 mm. There were only two adults; the larger, a female, was caught in November and appeared to be ripe or nearly so and the smaller, a male, was caught in July. Juveniles could not be sexed. Males larger than about 65 mm had a supracaudal luminous gland (Nafpaktitis, 1975).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— This species may be a spawning resident of the Ocean Acre area, but there are not enough data to be certain. The parent population spawns in fall and winter, probably with the greatest intensity in fall. Although the life span cannot be determined from the limited number of specimens, particularly of larger ones, *N. caudispinosus* probably lives at least two years, perhaps longer. Abundance was greatest in winter and decreased with the progression of the year (Table 126).

Postlarvae and small juveniles (16–20 mm) both show a restricted seasonal distribution, postlarvae being taken from November to February and juveniles less than 20 mm from December to March. These distributions, together with the capture of the gravid female in November, indicate that spawning occurred in fall and winter near Bermuda.

In late summer the catch (from all collections) consisted only of specimens larger than 55 mm, sizes that probably easily avoid the IKMT. Together, the large size of the specimens and the expected low abundance resulted in the very small catch from discrete-depth samples.

Specimens caught in late summer with the Engel trawl fell into two size classes, one 55–84 mm with a peak at about 64–70 mm, the other greater than 100 mm. Fish belonging to the smaller size group probably were approaching one year old, and those in the larger size group were two or more years old.

In winter, when abundance was at its maximum, juveniles 16 to 54 mm accounted for nearly the entire catch. Apparently even the largest juveniles were from the recent spawn, for all of the fish caught in late summer were larger than 54 mm.

TABLE 126.—Vertical distribution by 50-m intervals of *Notoscopelus caudispinosus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
601– 650	<1	<1			<1	2	16.5	16–17																
651– 700	<1	1			1	*																		
701– 750		1			1	2	17.0	17	–	–	–	–	–											
751– 800		1			1	*																		
801– 850		1			1	2	25.0	19–31	–	–	–	–	–											
851– 900	–	–	–	–	–																			
901– 950											<1		<1	*										
951–1000											<1		<1	1	63.0	63								
1001–1050											<1		<1	*										
1051–1100	–	–	–	–	–																			
1101–1150	–	–	–	–	–				1				1	1	45.0	45								
TOTALS	<1	4			4	6			1	<1			1	2										
NIGHT																								
1– 50		1			1	7	34.9	20–43																
51– 100		4	<1		4	38	37.9	18–94	1	1			2	4	57.7	52–67	1				1	6	67.0	64–72
451– 500	<1				<1	1	11.0	11																
TOTALS	<1	5	<1		5	46			1	1			2	4			1				1	6		

In winter, juveniles smaller than 25 mm were taken from January to March and large juveniles (35–54 mm) only in February and March, indicating that spawning may occur into January. Assuming that the largest juveniles in winter were spawned earliest, they were about 4–5 months old when caught.

VERTICAL DISTRIBUTION.—Daytime depth range in winter was 601–850 m and probably deeper, with no apparent concentration, and in late spring (based upon two specimens) 951–1000 m and 1101–1150 m. Nocturnal depth range in winter was 20–100 m and 451–500 m, with maximum abundance at 51–100 m, and in late spring and late summer 51–100 m (Table 126).

Notoscopelus resplendens

This species is moderately large in size, growing to about 95 mm in length (Hulley, 1981). The Ocean Acre specimens range from 5 mm to 73 mm, most being 20–40 mm. *Notoscopelus resplendens* was tentatively assigned a tropical-subtropical distribution pattern by Backus et al. (1977). This species is common in the study area, ranking among the 20 most abundant myctophids only in late spring, but even then its total abundance was low. The Ocean Acre collections contain 458 specimens; 133 were caught during the paired seasonal cruises, 96 of these in discrete-depth samples, of which 53 were caught in noncrepuscular tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 5–22 mm, juveniles 21–77 mm, subadults 40–73 mm, and adults 63–70 mm. All adults were males taken with the Engel trawl. About two-thirds of the juveniles examined (all sizes) could not be sexed. Most juveniles that were sexed were females, reflecting a sexual dimorphism in size. Males larger than 38 mm have luminous tissue on the dorsal aspect of the caudal peduncle (Nafpaktitis, 1975).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Notoscopelus resplendens* may be a breeding resident of the study area. Spawning occurred in the parent population from winter to about spring, with a peak in intensity in winter–early spring. The life span may be two years. Abundance was, by far, greatest in late spring, when juveniles 21–31 mm were predominant. It decreased to very low levels in late summer and winter (Table 127).

TABLE 127.—Vertical distribution by 50-m intervals of *Notoscopelus resplendens* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE						SL		CATCH RATE						SL		CATCH RATE						SL	
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
51- 100									1				1	10	14.5	12-16								
451- 500																								
501- 550										<1			<1	*										
551- 600										<1			<1	1	21.0	21								
601- 650																								
651- 700									<1				<1	4	16.5	14-18	-	-	-	-	-			
701- 750									<1	<1			<1	*										
751- 800										1			1	3	22.2	22-23								
801- 850										1			1	*										
851- 900										1			1	2	24.0	22-26		<1			<1	*		
901- 950										1			1	*				<1			<1	1	30.0	30
951-1000										<1			<1	2	24.0	24		<1			<1	*		
1001-1050										1			1	*										
1051-1100										2			2	2	36.5	36-37	-	-	-	-	-			
1101-1150										3			3	3	29.3	27-31								
1501-1550										<1			<1	1	28.0	28								
TOTALS									1	10			11	28				<1			<1	1		
NIGHT																								
1- 50	<1				<1	1	8.0	8		1			1	1	27.0	27								
51- 100	<1				<1	1	8.0	8	1	4			5	17	22.4	12-31								
101- 150									1				1	2	14.0	14								
151- 200																		<1			<1	1	67.0	67
751- 800									1				1	1	22.0	22								
TOTALS	<1				<1	2			3	5			8	21				<1			<1	1		

Although no adult females were taken, the presence of numerous postlarvae (188 specimens) indicates that spawning probably occurred near the study area. Nafpaktitis et al. (1977) similarly noted the absence of gravid females among 230 specimens (20–77 mm) examined.

Postlarvae were caught from winter to late spring, appearing in greatest numbers in April, when more than 100 were caught. Postlarvae taken in January–March were mostly less than 10 mm and those in April mostly bigger than 12 mm. This suggests that spawning began prior to January and reached a peak in late February–early March.

In winter the entire catch consisted of two postlarvae and a 68 mm subadult female. The low abundance at this season probably was due to most recruits being too small to be retained by the IKMT and to most older fish being big enough to avoid the net easily. Presumably even recruits were not very abundant at this season.

By late spring spawning was mostly over and most of the catch consisted of juveniles from the winter spawning peak. As a result of this recruitment, abundance was at its maximum. Only one fish, a 67 mm subadult female, was greater than 37 mm. Again the paucity of large fish probably was due to their ability to avoid the IKMT.

The sharp decrease in abundance from late spring to late summer is perplexing. Only four specimens 30–67 mm were taken in all late summer samples with the IKMT. Engel trawl collections, however, contained 63 specimens, which can be divided into two size groups: a smaller size group, 26–46 mm, with a peak at about 31–33 mm, that presumably represents young of the year; and a larger size group, mostly 66–73 mm, at least a year older than the former group. About 75 percent of the specimens caught with the Engel trawl belonged to the smaller group. The biggest catches made with the Engel trawl were from the upper 100 m and upper 50 m, at night, depths that were well sampled by the IKMT.

It is possible that the low abundances in winter and late summer were the result of *N. resplendens* not being able to survive long in the study area.

VERTICAL DISTRIBUTION.—Daytime vertical range for late spring and late summer combined was 51–100 m, 551–1150 m, and 1501–1550 m. Nighttime depth range for all three seasons combined was about 50–200 m (one postlava was taken at 751–800 m). In late spring maximum abundance was at 51–100 m (Table 127).

The catches in the Engel collections referred to above suggest that *N. resplendens* may be stratified by size. Specimens caught in the 0–50 m sample were 27–37 mm and those in the 0–100 m samples 57–73 mm.

As Gibbs et al. (1971) noted, postlarvae are found in the upper 100 m and apparently do not migrate. Transformation occurs at 20–23 mm, after which the species inhabits progressively greater depths as it grows.

Symbolophorus rufinus

This uncommon lanternfish appears to be distributed according to the tropical-subtropical or the tropical-semi-subtropical pattern (Backus et al., 1977). It is a large species growing to about 94 mm (Hulley, 1981); the largest in the Ocean Acre collections is 89 mm. *Symbolophorus rufinus* is uncommon in the study area, being represented in the Ocean Acre collections by 53 specimens; 17 of these were caught during the paired seasonal cruises, of which 13 were in noncrepuscular, discrete-depth tows (Table 23).

DEVELOPMENTAL STAGES.—Postlarvae were 11–19 mm, juveniles 20–49 mm, a subadult female was 70 mm, and female adults were 82–89 mm. Juveniles smaller than 36 mm could not be sexed. Of the 53 specimens taken, 40 were juveniles and 9 were postlarvae.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Symbolophorus rufinus* may be an uncommon breeding resident of the study area, as only postlarvae, small juveniles, and three adult females were caught. However, there are too few specimens to be certain of the reproductive status of the species in the area.

The parent population appears to spawn during much of the year; specimens 20–25 mm were caught in January, March, April, June, and August-September. All three female adults were taken with the Engel trawl in late summer. Judging from the relatively large size attained, the life span probably is more than one year.

VERTICAL DISTRIBUTION.—Two juveniles were taken by day at 751–850 m in late summer. At night fish were taken only in neuston samples in winter (one juvenile) and late spring (four juveniles). In late summer none were taken at

TABLE 128. —Vertical distribution by 50-m intervals of *Symbolophorus rufinus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE					WINTER SL			LATE SPRING CATCH RATE					LATE SPRING SL			LATE SUMMER CATCH RATE					LATE SUMMER SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
													DAY											
751– 800																		<1			<1	1	30.0	30
801– 850																		1			1	1	22.0	22
851– 900																		<1			<1	*		
901– 950																								
TOTALS																		1			1	2		
													NIGHT											
SURFACE	<1				<1	1	30.0	30	<1				<1	4	26.7	24–32								
1– 50																	1				1	1	11.0	11
51– 100																								
101– 150																	1				1	3	12.0	12
151– 200																		<1			<1	1	29.0	29
751– 800																								
801– 850																		<1			<1	*		
851– 900									–	–	–	–	–					<1			<1	1	20.0	20
TOTALS	<1				<1	1			<1				<1	4			2	<1			2	6		

the surface, and catches were scattered between the upper 50 m and 900 m; four postlarvae were caught in the upper 150 m, and two juveniles were taken between 151 m and 900 m (Table 128).

Symbolophorus veranyi

This large temperate species (Backus et al., 1977),which attains at least 120 mm (Nafpaktitis et al., 1977), is represented in the Ocean Acre collections by six juveniles 21–29 mm and by a 12 mm postlarva. One juvenile was taken in late spring, five juveniles in winter, and the postlarva in July. Apparently the study area is inhabited only by distributional waifs from the North Atlantic temperate region that cannot survive long under the prevailing conditions.

The winter specimens were all caught at night: two at the surface, one at about 20 m, one at about 175 m, and one at about 800 m.

Taaningichthys bathyphilus

This is a large myctophid, growing to about 80 mm (Davy, 1972). The largest specimen taken during the program was 68 mm. *Taaningichthys bathyphilus* does not conform well to any of the distribution patterns described by Backus et al. (1977). Most capture records are from tropical and subtropical waters (Davy, 1972; Nafpaktitis et al., 1977). This species is uncommon in the Ocean Acre area. The collections contain 64 specimens; 26 were caught during the paired seasonal cruises, of which 17 were in discrete-depth samples, 15 of these in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Juveniles were 17–30 mm, subadults 31–68 mm, and adults 48–66 mm. Except for a 28 mm male, juveniles could not be sexed. Females may grow to a larger size than males; all 12 specimens larger than 58 mm were females. No other external sexual dimorphism is apparent. Adult females contain ova as large as 0.4 mm in diameter, but most eggs were about 0.2 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— This species may be an uncommon breeding resident of the study area. There are too few specimens to determine the life span. Spawning seems to be confined to spring and summer, as small juveniles and adults were caught only at those seasons.

The catch in late spring consisted of 18–20 mm juveniles, which presumably were recently spawned (all were caught

TABLE 129.—Vertical distribution by 50-m intervals of *Taaningichthys bathyphilus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total, X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
801– 850									–	–	–	–	–				1				1	1	21.0	21
851– 900	–	–	–	–	–												<1				<1	*		
901– 950	–	–	–	–	–					<1		<1	*											
951–1000	–	–	–	–	–					<1		<1	1	57.0	57			<1		<1	*			
1001–1050		<1			<1	1	41.0	41		1			1	*				<1		<1	1	56.0	56	
1051–1100	–	–	–	–	–					1			1	1	63.0	63		<1		<1	*			
1101–1150	–	–	–	–	–				1				1	1	33.0	33								
1151–1200	–	–	–	–	–																			
1201–1250																								
1251–1300		1			1	1	45.0	45	–	–	–	–	–											
1301–1350	–	–	–	–	–				–	–	–	–	–				1				1	1	56.0	56
1501–1550										<1		<1	1	52.0	52									
TOTALS		1			1	2			1	2			3	4			1				1	2	3	
NIGHT																								
801– 850	1				1	1	30.0	30									–	–	–	–	–			
851– 900	1	1			2	3	45.3	26–68																
901– 950	<1	1			1	*											<1				<1	1	20.0	20
951–1000																		<1		<1	1	53.0	53	
TOTALS	2	2			4	4											<1	<1			<1	2		

in oblique samples), subadults 31–35 mm and adults 52–66 mm. This indicates the presence of two or more age classes. It is virtually certain that the juveniles and adults were at least a year apart in age; the subadults may or may not represent an additional year class.

By late summer additional spawning had occurred. Four of the seven fish caught by the IKMT were 17–21 mm (the smallest two are from oblique samples); the remaining three were adults 53–56 mm SL. Intermediate sizes were sampled by the Engel trawl, which took fish 35–66 mm.

Seven fish were taken in winter: two juveniles 26–30 mm, and five subadults 41–68 mm. The two smaller fish were approaching one year of age and the larger fish at least two years of age.

VERTICAL DISTRIBUTION.—This species was found below 800 m day and night. Diurnal depth range for all seasons combined was 801–1550 m, with one fish in each season taken deeper than 1250 m. Depth of maximum abundance could not be determined from day samples. Depth range at night in winter was 801–900 m (possibly deeper) and in late summer 901–1000 m. No discrete-depth captures were made at night in late spring (Table 129).

Taaningichthys bathyphilus was considered to be a bathypelagic species by Nafpaktitis et al. (1977). The above catch data show that the species inhabits depths within the mesopelagial near Bermuda.

Taaningichthys minimus

This moderately large lanternfish grows to about 65 mm (Davy, 1972); the largest in the Ocean Acre collections was 55 mm. Backus et al. (1977) suggested that *T. minimus* was an uncommon bipolar subtropical species. Clarke (1973) noted that it was one of several myctophids found in central or equatorial-central waters of the Pacific, but not in abundance anywhere. This species is uncommon in the study area. The Ocean Acre collections contain 184 specimens; 47 were caught during the paired seasonal cruises, 34 of

TABLE 130.—Vertical distribution by 50-m intervals of *Taaningichthys minimus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE FL	JUV	SA	AD	TOT	WINTER SL N	X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	LATE SPRING SL N	X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	LATE SUMMER SL N	X	RANGE
DAY																								
601– 650		1			1	2	20.0	20																
651– 700		1	<1		1	*				<1			<1	1	19.0	19	–	–	–	–	–			
701– 750		<1	<1		<1	2	32.0	28–36		<1	<1		<1	*										
751– 800		<1	<1		<1	*				<1	<1		<1	4	36.2	22–44								
801– 850										<1	<1		<1	*						1	1	3	40.5	38–43
851– 900	–	–	–	–	–															1	1	*		
901– 950	–	–	–	–	–				–	–	–	–	–											
951–1000	–	–	–	–	–				<1				<1	1	16.0	16								
TOTALS		2	1		3	4			<1	1	1		2	6						2	2	3		
NIGHT																								
51– 100									<1				<1	1	24.0	24								
101– 150																								
151– 200																								
201– 250										<1			<1	1	39.0	39								
251– 300		<1			<1	*																		
301– 350		1			1	1	23.0	23		<1			<1	*										
351– 400										<1			<1	1	43.0	43								
401– 450																								
451– 500		<1			<1	1	21.0	21										<1			<1	2	41.0	40–42
501– 550																								
551– 600		<1			<1	1	30.0	30									–	–	–	–	–			
951–1000																		<1			<1	1	44.0	44
TOTALS		1			1	3			<1	<1			1	3				<1			<1	3		

these in discrete-depth samples, of which 22 were caught in noncrepuscular tows.

DEVELOPMENTAL STAGES.—Postlarvae were 7–16 mm, juveniles 18–33 mm, subadults 34–50 mm, and adults 47–55 mm. Juveniles greater than 23 mm could be sexed; smaller ones could not. The smallest females with ripening eggs were about 45 mm, but none appeared to be fully ripe. Davy (1972) found gravid females as small as 40 mm. The sexually dimorphic supracaudal gland is twice as large in males as in females of comparable size 40 mm and larger (Davy, 1972).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—All developmental stages, except ripe females, were represented in the collections, indicating that spawning probably occurs in or near the Ocean Acre. Spawning probably takes place mainly in fall and perhaps in early winter at low levels. The species apparently lives for about a year.

Females with the largest ova were taken from July through September, but ripe females were not taken at any time. The species was not taken in October–December, and it is possible that ripe females were most abundant in those months but were large enough to avoid the nets. It seems certain that females were not in spawning condition in August, for no ripe or ripening females were taken in the Engel trawl collections. Perhaps they inhabit depths below those sampled, but this is not likely, for the species lives mostly above 800 m. The IKMT catch in late summer consisted mostly of fish larger than 38 mm that presumably would ripen and spawn a little later in the season. (Engel collections made in August 1971 contained several fish 25–40 mm, although most were 41–55 mm.)

By winter the size composition of the catch had changed greatly; all fish were 36 mm or smaller (Table 130), indicating that large fish of late summer matured, spawned, and died in the interim.

The catch in late spring consisted of two size classes: recently spawned juveniles 19–25 mm, and fish 33–50 mm that spawned the previous fall and winter.

Abundance was low at all seasons and showed little change during the course of the year (Table 130), perhaps due to the extended breeding season.

VERTICAL DISTRIBUTION.—Little can be said concerning the vertical distribution of *T. minimus*. Discrete-depth tows caught few fish at any depth, the maximum taken from any 50-m interval being four.

Except for a postlarva taken at 951–1000 m, all discrete-depth day captures were at 601–850 m, with the depth limits apparently increasing from winter to late summer, perhaps due to increasing size of fish (Table 130). Nocturnal depths were shallower than day depths in each season. Fish were taken at night in winter at 301–600 m, in late spring at 100–400 m, and in late summer at 451–500 m and 951–1000 m. The 24 mm juvenile taken near 100 m by night in late spring probably is a contaminant from a previous tow. The species appeared to have a discontinuous vertical dis-

tribution during the night at all seasons (Table 130). Davy (1972) stated that *T. minimus* does not migrate vertically within a diel cycle; the Ocean Acre data clearly show that the species does migrate, at least near Bermuda. Clarke (1973) also noted an upward shift in depth at night for this species near Hawaii.

Relative Abundance of Species and Genera

Although the lanternfish fauna of the study area was quite diverse in terms of the number of species (the 63 species represent 20 to 25 percent of the total number of fish species taken during the program), neither total abundance nor total numbers taken was equitably distributed among these species. As is the case in most sampling programs, some species were very rare, others very numerous or abundant, but most species were taken in moderate numbers or abundance. These are categorized here as "rare," "uncommon," "common," "abundant," and "very abundant" according to the maximum abundance at any given season (see "Methods"). If the three seasons were considered separately, a given species might be in different abundance categories in different seasons.

The following 20 species were "rare" in the study area: *Bolinichthys photothorax, Diaphus bertelseni, D. dumerilii, D. fragilis, D. garmani, D. lucidus, D. luetkeni, D. perspicillatus, D. problematicus, D. subtilis, D. termophilus, Lampadena anomala, L. luminosa, Lampanyctus intricarius, L. nobilis, Loweina interrupta, Myctophum asperum, M. obtusirostre, M. selenops*, and *Symbolophorus veranyi*.

The following 19 species were "uncommon" in the study area: *Benthosema glaciale, Bolinichthys supralateralis, Diaphus brachycephalus, D. effulgens, D. metopoclampus, D. splendidus, Hygophum reinhardtii, H. taaningi, Lampadena chavesi, L. urophaos, Lampanyctus alatus, L. lineatus, Lepidophanes guentheri, Loweina rara, Myctophum punctatum, Notoscopelus caudispinosus, Symbolophorus rufinus, Taaningichthys bathyphilus*, and *T. minimus*.

The following 13 species were "common" in the study area: *Centrobranchus nigroocellatus, Ceratoscopelus maderensis, Diaphus mollis, D. rafinesquii, Lampadena speculigera, Lampanyctus ater, L. crocodilus, L. cuprarius, L. festivus, L. photonotus, Lobianchia gemellarii, Myctophum nitidulum*, and *Notoscopelus resplendens*. Only three of these species, *D. mollis, L. cuprarius*, and *L. photonotus*, were represented by more than 650 specimens.

Six species were "abundant" in the study area: *Benthosema suborbitale, Ceratoscopelus warmingii, Gonichthys cocco, Hygophum hygomii, Lepidophanes gaussi*, and *Lobianchia dofleini*.

Five species were "very abundant" in the study area: *Bolinichthys indicus, Diogenichthys atlanticus, Hygophum benoiti, Lampanyctus pusillus*, and *Notolychnus valdiviae*.

The 11 "abundant" and "very abundant" species represented 10 genera, the only congeneric pair being *H. benoiti* and *H. hygomii*. There are some interesting differences

between *H. benoiti* and *H. hygomii.* In the study area *H. benoiti* grows to a size of about 44 mm and *H. hygomii* to about 64 mm. *Hygophum benoiti* spawns mostly in spring and *H. hygomii* mostly in fall. As a result of this difference in spawning seasons, the two species are represented by different sizes at each season. In winter most *H. hygomii* were smaller than 20 mm and most *H. benoiti* larger than 25 mm; in late spring most *H. hygomii* were larger than 15 mm, while most *H. benoiti* were 9–12 mm; and in late summer the few *H. hygomii* caught were mostly larger than 30 mm, but all *H. benoiti* were smaller than 25 mm. These differences suggest that the two species probably do not directly compete for any resources.

In their earlier report, Gibbs et al. (1971) noted that nine species were numerically dominant in the study area, together making up approximately 75 percent of the total number of lanternfish specimens. Except for *Diaphus mollis,* each of those species was among the very abundant or abundant ones as determined in this study. Here, *D. mollis* is considered as a common species. The three species included among the abundant ones here, but not in the numerically dominant species of Gibbs et al. (1971), are *Benthosema suborbitale, Gonichthys cocco,* and *Lepidophanes gaussi.*

At each season the single most abundant species comprised 19 to 22 percent of the total myctophid abundance, and the four or five most abundant ones made up 54 to 58 percent. In any season, only six or seven species each made up more than 5 percent of the abundance of all lanternfishes combined.

At each season the 10 most abundant species made up 75 to 87 percent of the total abundance of lanternfishes. Of the 16 species included among the 10 most abundant lanternfishes at any of the three seasons, the following 7 were included at all three seasons: *Ceratoscopelus warmingii, Diogenichthys atlanticus, Gonichthys cocco, Hygophum benoiti, Lampanyctus cuprarius, L. pusillus,* and *Notolychnus valdiviae.* One species, *Bolinichthys indicus,* was included in winter and late summer, and the remaining eight species were included only at one season (Table 131). Except for *B. indicus,* all the "very abundant" species were among the top 10 in abundance at each season. In winter and late summer the five most abundant species were the five "very abundant" ones. *Lampanyctus cuprarius* was the only species included among the 10 most abundant at each of the three seasons, and not included in the "abundant" or "very abundant" species. The seven species that were among the 10 most abundant lanternfishes at all three seasons, along with *B. indicus,* accounted for 61 to 76 percent of the total abundance of lanternfishes at each of the seasons.

The greatest total abundance for a species, 246 specimens per hour, was obtained for *B. indicus* in winter. A close second was *H. benoiti* in late summer with a total abundance of 210 specimens per hour. No other species had a maxi-

TABLE 131.—Rank of each species of Myctophidae at each season. Rank is based upon the sum of the day or night abundances, whichever is greater, for each of the stages (dash = not taken in samples used to determine abundance).

SPECIES	WINTER	SPRING	SUMMER
Bolinichthys indicus	1	12	4
Diogenichthys atlanticus	2	2	5
Notolychnus valdiviae	3	6	3
Lampanyctus pusillus	4	1	2
Hygophum benoiti	5	9	1
Hygophum hygomii	6	16	20
Ceratoscopelus warmingii	7	7	8
Gonichthys cocco	8	4	9
Lampanyctus cuprarius	9	5	10
Lampanyctus photonotus	10	21	14
Lampanyctus ater	11	10	17
Lampanyctus festivus	12	19	15
Lobianchia gemellarii	13	17	27
Diaphus mollis	14	14	11
Lobianchia dofleini	15	3	12
Lampadena speculigera	16	23	29
Benthosema suborbitale	17	28	6
Lepidophanes gaussi	18	18	7
Myctophum nitidulum	19	22	13
Diaphus metopoclampus	19	24	-
Centrobranchus nigroocellatus	21	8	28
Diaphus rafinesquii	22	13	31
Notoscopelus caudispinosus	23	33	39
Lepidophanes guentheri	24	33	19
Hygophum reinhardtii	25	32	33
Taaningichthys bathyphilus	26	26	29
Taaningichthys minimus	27	31	32
Lampadena urophaos	27	29	40
Loweina rara	29	43	21
Lampanyctus alatus	30	36	40
Lampanyctus crocodilus	31	11	18
Diaphus splendidus	32	35	36
Hygophum taaningi	33	40	24
Benthosema glaciale	34	20	22
Lampanyctus lineatus	35	37	23
Diaphus effulgens	36	37	25
Symbolophorus veranyi	37	-	-
Myctophum selenops	38	48	-
Lampadena chavesi	38	24	34
Bolinichthys photothorax	38	41	45
Bolinichthys supralateralis	41	-	35
Diaphus dumerilii	41	45	43
Diaphus brachycephalus	43	27	36
Loweina interrupta	44	-	-
Notoscopelus resplendens	44	15	36
Symbolophorus rufinus	46	44	25
Diaphus perspicillatus	46	45	48
Myctophum obtusirostre	46	-	-
Myctophum punctatum	-	30	-
Ceratoscopelus maderensis	-	39	16
Diaphus problematicus	-	42	40
Lampadena anomala	-	45	-
Diaphus lucidus	-	-	43
Diaphus termophilus	-	-	45
Diaphus bertelseni	-	-	45
Diaphus luetkeni	-	-	48

mum abundance of more than 200 specimens per hour. In both winter and late summer four species had total abundances in excess of 100 specimens per hour, but in late spring only the most abundant species did, *L. pusillus,* with 115 specimens per hour.

Neither number of species, nor total abundance, nor total numbers was evenly distributed among the 18 genera. Only 5 of the genera were represented by more than 3 species, and only 2 by 10 or more species. *Diaphus,* the most speciose

genus of lanternfish, was represented in the study area by 16 species, or about 25 percent of the total number, but all of its species combined never were responsible for more than 17 percent of the total abundance and accounted for only about 5 percent of the total number of specimens. *Lampanyctus*, which was represented by 10 species (about 16 percent of the total number), comprised 20 to 35 percent of the total abundance at each season and accounted for about 19 percent of the total number of specimens. *Diogenichthys* and *Notolychnus*, each represented in the study area by a single species, each were responsible for 6 to 14 percent of the total abundance at each season and for 8 to 9 percent of the total number of specimens. Only *Lampanyctus* h. 1 a total abundance in excess of 100 specimens per hour at each of the three seasons.

Patterns of Geographic Distribution and Abundance

One factor for the observed uneven abundances is apparent in the distribution patterns of the species involved. Backus et al. (1977) divided the Atlantic Ocean, between about 35°S and 60°N, into a system of seven zoogeographic regions based upon midwater trawl collections of more than 200,000 lanternfishes of 106 species. Their system depends upon faunal and physical similarities within any given area as well as the distribution patterns of the individual species. Nine patterns of distribution shown by myctophids were described in terms of those seven regions, or parts or combinations of them. (See Backus et al., 1977:272–274, table 4). Of the nine patterns, three include Bermuda and six do not; all of the former and four of the latter were represented among the Ocean Acre lanternfishes (Table 132).

The study area is in the northern Sargasso Sea province of North Atlantic subtropical region and, according to Backus et al. (1977), species with the following distribution

TABLE 132.—Numbers and percent of species and specimens of Ocean Acre Myctophidae distributed according to the North Atlantic patterns given by Backus et al. (1977) (Number of specimens is the total number taken on all cruises combined, including Engel trawl collections).

DISTRIBUTION PATTERN	SPECIES		SPECIMENS	
	NO.	% OF TOTAL	NO.	% OF TOTAL
SUBPOLAR- TEMPERATE	2	3.2	148	0.3
TEMPERATE	4	6.3	292	0.6
TEMPERATE- SEMISUBTROPICAL	8	13.0	18,168	38.3
SUBTROPICAL	12	19.0	8,256	17.4
TROPICAL- SUBTROPICAL	18	28.6	19,715	41.6
TROPICAL- SEMISUBTROPICAL	5	7.9	198	0.4
TROPICAL	13	20.6	577	1.2
UNCATEGORIZED	1	1.6	64	0.1

patterns would not be expected to occur there in any numbers: subpolar-temperate, temperate, tropical-semisubtropical, and tropical. Eleven of the Bermuda lanternfishes have one of the first three patterns. These 11 species, comprising 17 percent of the total number of species, accounted for slightly more than 1 percent of the total number of specimens. Thirteen other Bermuda species have a tropical distribution, making up about 21 percent of the species, and account for only 1.2 percent of the total number of specimens. Thus 24 species (not including *T. bathyphilus*), about 38 percent of the total number, have their main distributions outside the North Atlantic subtropical region and are represented by less than 4 percent of the total number of specimens taken. Of these 24 species, 17 were "rare," six were "uncommon," and one was "common." Eleven of these belong to the genus *Diaphus*, which was represented in the study area by 16 species. Only *Lampadena speculigera*, a temperate species, was not "rare" or "uncommon." It was represented by only 281 specimens and had a maximum abundance of 12 specimens per hour, which was close to the lower limit for common species.

Seventeen of the 20 "rare" species had either a temperate, a tropical, or a tropical-semisubtropical distribution. The remaining three, *Diaphus bertelseni*, *Lampadena anomala*, and *Myctophum selenops*, are questionably tropical-subtropical species.

The remaining 38 species, accounting for 61 percent of the number of species, were assigned by Backus et al. (1977) to either the temperate-semisubtropical, subtropical, or tropical-subtropical patterns. These species accounted for almost 97 percent of the total number of myctophids taken, which is very close to the 93 percent obtained for species with these patterns in the North Atlantic subtropical region by Backus et al. (1977).

Of these 38 species, 18 (29 percent of the 63 species taken near Bermuda), represented by 19,715 specimens (42 percent), had a tropical-subtropical distribution; eight (13 percent), represented by 18,168 specimens (38 percent), had a temperate-semisubtropical distribution; and 12 (19 percent), represented by 8,256 specimens (17 percent), had a subtropical distribution. Backus et al. (1977) noted that, in their collections from the North Atlantic subtropical region, tropical-subtropical species accounted for 59 percent of the specimens (vs. 42 percent in this study), temperate-semisubtropical species for 20 percent (vs. 38 percent), and subtropical species for about 14 percent of the specimens (vs. 17 percent).

The 38 species were distributed among the abundance categories as follows: 12 were "uncommon," 12 "common," 6 "abundant," 5 "very abundant," and 3 "rare." Thus all the abundant and very abundant species, and all except one common species, were distributed according to one of the three patterns that would be predicted to be predominant among the lanternfishes of the study area from the zoogeographic work of Backus et al. (1977).

Of the 11 abundant or very abundant species at Bermuda, two (*B. indicus* and *L. gaussi*) had subtropical distributions, four (*H. benoiti, H. hygomii, L. pusillus,* and *L. dofleini*) had temperate-semisubtropical distributions, and five (*B. suborbitale, C. warmingii, D. atlanticus, G. cocco,* and *N. valdiviae*) had tropical-subtropical distributions. According to Backus et al. (1977) only four of these species (*B. indicus, D. atlanticus, L. gaussi,* and *N. valdiviae*) were most abundant in the North Atlantic subtropical region. Five (*G. cocco, H. benoiti, H. hygomii, L. pusillus,* and *L. dofleini*) were most abundant in the temperate region, and two (*B. suborbitale* and *C. warmingii*) in the tropical region. One species, *Taaningichthys bathyphilus,* was not categorized by Backus et al. (1977) because it is a bathypelagic species. It made up about 0.1 percent of the total number of myctophids taken during the Ocean Acre program.

Combined Vertical Distribution

DEPTH DISTRIBUTION.—Lanternfishes have an extensive vertical range throughout the day and night, and most undergo a considerable diel vertical migration (Badcock, 1970; Gibbs et al., 1971; Goodyear et al., 1972; Clarke, 1973; Badcock and Merrett, 1976; Krueger et al., 1977; Pearcy et al., 1977). The Ocean Acre discrete-depth samples, regardless of season and time of day contain some lanternfishes from nearly all 50-m intervals between the surface and 1000 m (Table 133). Moreover, lanternfishes have been taken in the study area at depths at least as great

as 1500–2000 m (see Table 42). There is, however, no single species that inhabits this entire range of depths at any one time, although a number of species may inhabit much of this vast depth range at different stages of growth and development.

A salient feature of the depth distribution of myctophids is the pronounced diel shift in centers of abundance from approximately 450–900 m by day to above 250 m at night. Based on catch rates from discrete-depth samples, about 60 percent of the night catch of myctophids and less than 4 percent of the day catch is from above about 250 m, and about 25 percent of the night catch and 86–93 percent of the day catch is from 451–900 m (Table 133). This reflects the diel vertical migration of about 500–700 m undertaken by a considerable portion of the lanternfish population.

Significant catches during the night at daytime depths of abundance indicate that some portion of the population does not migrate on a regular basis, or that it migrates up to those depths from deeper ones. Most of the lanternfish at those depths are postlarvae and recently metamorphosed juveniles, although at least some adults and subadults of some species do not migrate (e.g., *Notolychnus valdiviae*).

DAY CATCH.—During the day few specimens were taken in the upper 450 m at any season. Most of the valid captures from this stratum are postlarvae of various species, while most larger fishes probably are contaminants left in the net from previous samples made at different depths and times. The catch at 451–500 m in winter and late spring (and perhaps at 401–450 m, where no samples were taken), and at 501–550 m in late summer is noticably larger than that at shallower depths. The increase in the minimum depth of appreciable abundance in late summer may be related to increased light penetration, but there are no data available to support this.

About 9 percent of the total day catch from the upper 1000 m (including interpolated values) came from 401–500 m in winter and late spring, and nearly 18 percent came from 501–600 m in late summer (Table 133). Abundance increases from those depths to maxima at 601–650 m in winter and late summer and 601–700 m in late spring, where 18.3 to 27.8 percent of the catch (including interpolated values) was taken (Table 133). Samples were not made at 651–700 m in winter and late summer or at 701–750 m in late spring. It is possible that maximum abundances occur at the unsampled depths at any or all of the three seasons.

At 601–650 m in winter the dominant lanternfishes during daytime are *Bolinichthys indicus, Diogenichthys atlanticus,* and *Lampanyctus pusillus,* the three making up 78 percent of the catch in that depth interval. In late spring *L. pusillus* dominates the catch at 601–700 m, accounting for slightly more than 62 percent of the catch from that stratum, where no other species accounts for as much as 6 percent of the catch. In late summer *L. pusillus* again dominates at the depth of maximum abundance, 601–650 m, comprising

TABLE 133.—Seasonal day and night catch rates of all lanternfishes combined by 50-m intervals within the upper 1000 m (D = day; N = night; NS = no samples taken and interpolations not used; asterisk = interpolated values).

DEPTH (M)	WINTER		LATE SPRING		LATE SUMMER	
	D	N	D	N	D	N
SURF	0	59	2	81	1	56
50	4	91	5	80	2	303
100	<1	134	4	165	<1	158
150	0	77	0	12	2	82
200	0	35	0	10	0	36
250	NS	11	NS	13	2	11
300	4	12*	<1	5	1	11
350	2	14	4	4*	1	8
400	1	3	2	4	0	10
450	32*	2	13*	0	<1	2
500	64	10	24	3	2	4
550	79	4	28*	8	59	7
600	107	12	33	5	58	5
650	199	2	52	15*	176	3
700	166*	6*	55	25*	106*	76
750	137	10	51*	35*	37	26
800	102*	15	47	45	35	35
850	67	24	29*	33	88	45
900	53*	66	11	18*	52	56
950	38*	35*	12*	18*	17	24
1000	24*	5	14	3	17*	30

about 59 percent of the catch. *Bolinichthys indicus* and *D. atlanticus*, which together account for about 33 percent of the catch, are the only other species that occur in any abundance at 601–650 m.

Abundance is high to moderate from the depth of maximum abundance to about 800–900 m. At depths greater than about 850 m abundance decreases, but it is greater than in the upper 450 m. The catch from 851–1000 m ranges from 9.5 to 13.2 percent of the catch made in the upper 1000 m depending upon season. In winter no samples were made at 851–1000 m, and the entire catch given for the three included 50-m intervals was estimated by interpolation. In winter *B. indicus* is the dominant lanternfish at 701–750 m, and *Lampanyctus cuprarius* and *Hygophum hygomii* at 801–850 m. In late spring only *D. atlanticus* and *L. cuprarius* occur in moderate abundance between 751 and 1000 m. In late summer at 701–950 m *B. indicus* and *Hygophum benoiti* are the dominant myctophids, while *L. pusillus* and *Ceratoscopelus warmingii* occur in moderate abundance.

There were few discrete-depth samples below 1000 m at all seasons (Table 2). The catch in winter at these relatively great depths was almost exclusively due to *C. warmingii*. *Lampanyctus ater*, *L. cuprarius*, and *C. warmingii* are the most abundant species in late spring, but even these species occur in low abundance. Discrete-depth sampling below 1000 m was best in late summer, when only three (of 11) 50-m intervals between 1001 and 1550 m were not sampled (Table 2). Despite this moderately good sampling, the catch was very small. Only at 1001–1050 m did the catch (16.7 specimens per hour) exceed 5 specimens per hour, and no species was even moderately abundant at this depth. The daytime vertical distribution of myctophids in the eastern Atlantic Ocean (Badcock, 1970) is similar to the one given herein.

NIGHT CATCH.—Shortly before sunset this daytime pattern of vertical distribution begins to change. Migrants begin their ascent to the upper layers, resulting in a shallowing of the depths of maximum abundance and a consequent reduction in the catch between 451 and 800 m. At night most specimens are caught in the upper 250 m. Depths of maximum abundance are 51–100 m in winter and in late spring, and 33–50 m in late summer (when only surface samples were made above 33 m) from which strata about 21 percent, 28 percent, and 31 percent, respectively, of the night catch from the upper 1000 m was calculated to occur.

In winter *C. warmingii*, *N. valdiviae*, *B. indicus*, and *D. atlanticus* are all taken in fair abundance at the depth of maximum abundance, 51–100 m, where the four species together constitute about 65 percent of the catch. In late spring the above four species, together with *Lobianchia dofleini* and *Lampanyctus pusillus*, are the dominant lanternfishes, accounting for 69 percent of the catch at that depth. In late summer *N. valdiviae* is dominant, making up 38 percent of the catch; *Benthosema suborbitale*, *Lepidophanes*

gaussi, and *L. pusillus* are abundant at 33–50 m, together accounting for an additional 48 percent. A similar nighttime concentration of lanternfishes in the upper 100 m has also been noted in the eastern Atlantic (Badcock, 1970).

Between 6 and 14 percent of the night catch from the upper 1000 m was from the surface, where *Gonichthys cocco* is the dominant species at all seasons. *Myctophum nitidulum* is abundant at the surface at all three seasons, with *Centrobranchus nigroocellatus* abundant in winter and late spring. Nafpaktitis et al. (1977) and Devany (1969) have noted that these three species, among others, are common in neuston collections made at night.

Secondary concentrations are found at night at about 701–950 m in winter 601–950 m in late spring, and 651–1000 m in late summer (Table 133). At those depths the lanternfishes are mostly young nonmigrants rather than migrants from greater depths. These depths account for about 24 percent, 32 percent, and 29 percent, respectively, of the catches from the upper 1000 m.

The catch at intermediate depths is generally low at all seasons and accounts for 5 to 10 percent of the catch for the upper 1000 m, with no 50-m interval comprising more than 2.5 percent (Table 133). Except for *Diaphus rafinesquii* in late spring, no species occurs in any abundance at these depths at any season.

Little can be said concerning the catch at depths greater than 1000 m because of poor sampling (Table 2). *Lampanyctus cuprarius* apparently is a regular nighttime resident at those great depths, although it is not abundant (Table 90).

SIZE STRATIFICATION.—During the day, more than 65 percent of the catch of small (less than 31 mm) fish was from the upper 700 m, and more than 79 percent of that of larger fish was from 701–1550 m (Table 134). Gibbs et al. (1971) noted that the average minimum and maximum sizes of lanternfishes increased with depth.

Stratification according to size also is evident at night (Table 134), but the depth relations are not similar to those of daytime. Although most sizes are found over much of the vertical range, they are not uniformly distributed. The average size of the specimens caught at 701–1000 m is noticeably smaller than that of specimens from shallower depths at each season (Table 134). At about 201 to 600 m (or 650 m), depending upon season, the mean size of the fishes caught is larger than for either shallower or greater depths. This stratification was most pronounced in late spring, when the mean size of the specimens caught at 201–600 m was more than twice as large as that from shallower or greater depths. Fishes smaller than 51 mm are most abundant at 1–200 m, and fishes larger than 60 mm are most abundant at greater depths. In addition to their maximum abundance in the upper 200 m, fish 11–20 mm show a secondary concentration (which is approximately half of that in the upper 200 m) at about 701–900 m in winter, 751–850 m in late spring, and 651–1000 m in late summer. These fishes probably are, for the most part, recently me-

TABLE 134.—Characteristics of the lanternfish communities at each of the depth strata during night and day (ranges and mean values (in parentheses) are given for the 50-m intervals within each stratum; abundance is the catch rate for all 50-m intervals, including interpolation in unsampled intervals; overall mean size in mm).

STRATUM (M)	NO. OF SPECIES	NO. OF GROUPS	SPECIES DIVERSITY	EVENNESS	TOTAL ABUNDANCE	OVERALL MEAN SIZE
			DAY			
451-600	6-13 (9.0)	2-5 (3.1)	0.8-2.0 (1.3)	0.2-0.6 (0.4)	24-107 (62)	17.0
601-700	12-22 (17.0)	4-7 (5.2)	1.2-1.8 (1.5)	0.2-0.3 (0.2)	52-199 (120)	19.1
701-850	10-22 (18.0)	4-6 (4.8)	1.4-2.6 (2.1)	0.4-0.6 (0.4)	35-137 (68)	25.3
>850	1-13 (6.4)	1-4 (3.0)	0.9-2.2 (1.4)	0.4-0.8 (0.7)	1-19 (8)	36.3
			NIGHT			
SURFACE	3-8 (6.0)	1-2 (1.3)	0.7-1.0 (0.9)	0.2-0.5 (0.3)	56-81 (65)	22.6
SHALLOW	7-30 (18.3)	2-7 (4.9)	1.2-2.6 (2.1)	0.1-0.9 (0.5)	10-303 (86)	21.9
INTERMEDIATE	1-14 (6.4)	1-6 (3.7)	0.0-2.3 (1.4)	0.0-0.9 (0.7)	2-14 (7)	30.0
DEEP	6-14 (9.4)	3-7 (4.8)	0.6-1.4 (1.3)	0.1-0.6 (0.3)	24-76 (42)	16.1

tamorphosed juveniles of various species that do not migrate or do not do so on a regular basis.

Species Associations and Resource Partitioning

Factor analyses of daytime and nighttime data (separately for winter, late spring, and late summer) resulted in 40 groups, in each of which the species all have very similar vertical distributions. No two species groups have the same bathymetric distributions. Groups with similar vertical ranges have different depths of maximum abundance, and those whose maximum abundances occurred at similar depths have different vertical ranges. Tables 135-140 contain the daytime data; Tables 141-146 the nighttime data.

Depending upon the season and diel period, five to eight groups were formed. Each of the 19 daytime and 21 nighttime groups consisted of 1 to 7 species: 10 groups had a single species, 10 had 2, 8 had 3, 7 had 4, 2 had 5, 1 had 6, and 2 groups had 7 species. The mean number of species per group was 2.8: 2.5 for day groups and 3.1 for night groups.

Daytime Species Groups

Five to eight groups per season were recognized from daytime data, each group consisting of one to five species. These groups accounted for 83-93 percent of the daytime abundance of all lanternfishes at each of the three seasons. In Tables 135-140, the groups and their constituent species are listed by season in order of increasing depth of maximum abundance. They will be referred to as follows: daytime winter, WD1 through WD6; late spring SPD1-SPD8;

and late summer SUD1-SUD5; nighttime winter, WN1-WN8; late spring SPN1-SPN6; and late summer SUN1-SUN7. The number corresponds to the group's relative depth of maximum abundance (e.g., 1 indicating the group with maximum abundance at the shallowest depth, 2 the next deeper group).

The depths of maximum abundance of the six winter groups were: WD1 at 451-500 m, WD2 at 551-600 m, WD3 at 601-650 m, WD4 at 701-750 m, WD5 at 701-750 m and 801-850 m, and WD6 at 1001-1050 m. The most abundant group, WD3, comprised about 61 percent of the abundance of all groups combined and dominated the catch at 501-750 m, even though groups WD2, 4, and 5, had their maximum abundances there (Table 135).

The eight late spring groups had their depths of maximum abundance as follows: SPD1 at 451-500 m, SPD2 and SPD3 at 601-650 m, SPD4 and SPD5 at 651-700 m, SPD6 and SPD7 at 751-800 m, and SPD8 at 851-1000 m and 1101-1150 m. SPD4 was the most abundant group, accounting for about 42 percent of the abundance of all groups combined. It was the most abundant group at 551-700 m, despite groups SPD2, 3, and 5 having their maximum abundances there. Groups SPD3, 5, and 6 were not very abundant, together comprising less than 5 percent of the total for all groups combined. SPD2, 4, and 7 had their maximum abundances at the same depths as SPD3, 5, and 6, respectively, but the two groups in each pair had different overall vertical ranges (Table 137). The depths of maximum abundance for late summer groups were 501-600 m for SUD1, 601-650 m for SUD2, 701-800 m for SUD3, 751-850 for SUD4, and 801-850 m for SUD5. The most abundant group, SUD 2, dominated the catch at 601-650

TABLE 135.—Vertical distribution (in 50-m intervals) of daytime winter catch rates by species groups (numbers = catch rates of specimens per hour; dash = no specimens of the species group taken.)

SPECIES GROUPS	451-500	501-550	551-600	601-650	701-750	801-850	1001-1050	1201-1250	1251-1300	1501-1550	TOT
WD 1	60	5	19	17	4	2	-	-	-	1	108
WD 2	-	2	28	3	11	10	1	-	1	-	55
WD 3	1	69	56	167	76	16	-	-	<1	-	385
WD 4	-	-	-	-	11	6	-	-	<1	<1	18
WD 5	-	-	-	5	18	19	1	-	-	1	44
WD 6	-	-	-	2	-	-	7	6	4	1	20

TABLE 136.—Vertical distribution (in 50-m intervals) of daytime winter catch rates by species (numbers = catch rates of specimens per hour; dash = no specimens of the species taken).

SPECIES	451-500	501-550	551-600	601-650	701-750	801-850	1001-1050	1201-1250	1251-1300	1501-1550
WD1										
N. valdivae	44	3	17	16	4	2	-	-	-	1
L. dofleini	6	2	1	-	<1	-	-	-	-	-
L. gemellarii	7	-	1	<1	-	-	-	-	-	-
D. rafinesquii	4	1	-	1	-	-	-	-	-	-
WD2										
H. hygomii	-	1	22	<1	11	10	1	-	1	-
B. suborbitale	-	1	6	2	-	<1	-	-	-	-
WD3										
H. benoiti	1	22	6	12	12	6	-	-	-	-
D. atlanticus	1	13	19	44	8	6	-	-	-	-
L. pusillus	-	-	16	40	12	2	-	-	1	-
B. indicus	-	35	16	71	42	2	-	-	-	-
WD4										
L. ater	-	-	-	-	8	6	-	-	-	<1
L. speculigera	-	-	-	-	4	4	-	-	1	-
WD5										
L. cuprarius	-	-	-	1	5	12	1	-	-	-
L. festivus	-	-	-	-	8	1	-	-	-	-
L. photonotus	-	-	-	2	4	4	-	-	-	1
L. gaussi	-	-	-	2	1	2	-	-	-	<1
WD6										
C. warmingii	-	-	-	2	-	-	7	6	4	1

TABLE 137.—Vertical distribution (in 50-m intervals) of daytime late spring catch rates by species groups (numbers = catch rates of specimens per hour; dash = no specimens of the species group taken).

SPECIES GROUPS	451-500	551-600	601-650	651-700	751-800	851-900	951-1000	1051-1100	1101-1150	1151-1200	1201-1250	TOT
SPD 1	12	4	2	<1	-	-	-	-	-	-	-	19
SPD 2	5	1	8	1	<1	-	-	-	-	-	-	16
SPD 3	-	-	3	1	1	-	-	-	-	-	-	5
SPD 4	-	16	32	42	8	1	-	-	-	2	<1	101
SPD 5	1	-	1	1	-	-	-	-	-	-	-	4
SPD 6	-	-	-	-	2	<1	-	1	-	-	-	3
SPD 7	<1	7	3	6	31	5	4	9	5	7	1	77
SPD 8	-	<1	-	<1	1	1	3	2	3	-	-	10

m and constituted slightly more than 37 percent of the total group abundance (Table 139). Catches of lanternfishes above 450 m during daytime were small (Table 133). Only in late spring, when about 4.5 percent of the total day abundance came for these shallow depths (25 percent were suspected contaminants), was more than 2 percent of the total abundance from the surface-to-450 m stratum. Either few lanternfishes inhabit the upper 450 m during the daytime, or they avoid the IKMT. Evidence from larger nets supports the former. Most of the catch from this stratum consisted of postlarvae of various species. It probably is safe to assume that such shallow depths serve only as nursery grounds for some species of lanternfishes and have little ecological significance for the older stages during daylight hours.

DAY DEPTH STRATA

For daytime, the water column below 450 m can be divided on the basis of factor analysis and population characteristics into the following four depth strata: 451–600 m, 601–700 m, 701–850 m, and in excess of 850 m. The last probably can be divided into two or more strata, but catches below about 1000 m were so poor that there is no solid basis for doing so here. (See Marshall 1971, for a discussion of pelagic zonation with respect to the vertical distributions of various families of deep-sea fishes.) These strata can be characterized by maximum abundance of one or more species groups (except for the deepest stratum in late summer), overall abundance, total group abundance, numbers of species groups, numbers of species, abundant species, species diversity and evenness, and mean size of specimens for the constituent 50-m intervals (Table 134).

Cluster analyses of samples (based upon correlation coefficients of species abundances) supported the recognition of these four strata. Few samples from the deepest stratum were included in the cluster analyses, because catch rates of most deep samples were too small to meet the abundance criterion (at least 10 specimens) to be included in the analyses.

Clusters of samples in winter were from 451–500 m, 601–650 m, and 701–850 m; in late spring from 451–500 m, 601–700 m, and deeper than 750 m; and in late summer from 501–600 m, 625 m, and deeper than 700 m.

DAY 451-600 M STRATUM.—The 50-m intervals comprising the 451-600 m stratum were characterized by the occurrence of the maximum abundance of one or two groups at each season, by intermediate total and combined group abundances, by the presence of relatively few species groups and species, by low species diversity, by moderate evenness, and by the relatively small mean size of the specimens caught there (Table 134).

Notolychnus valdiviae, the only species whose maximum abundance occurred within 451–600 m at each of the three

SMITHSONIAN CONTRIBUTIONS TO ZOOLOGY

seasons, was the dominant species in this stratum. Of the remaining 23 species used in the three daytime factor analyses, six were most abundant within the 451–600 m stratum at one of the three seasons, and one, *Lobianchia dofleini*, was at two of the seasons (and possibly at all three seasons, see below).

The groups with maximum abundances between 451 and 600 m (WD1 and WD2; SPD1; and SUD1) consist of one to four species each, representing a total of seven species in five genera. SPD2 might be regarded as belonging with SPD1: no species are added, the two groups had nearly identical vertical ranges and, although SPD2 was most abundant at 601–650 m, it was only slightly less abundant at 451–500 m, where SPD1 was most abundant. The factor loadings of SPD1 were nearly the same, but of opposite sign, on two of the factors (0.36 vs −0.38), the smaller (0.36) being on the same factor on which the species comprising SPD2 had their highest loadings.

Species of the shallowest-dwelling groups, WD1, SPD1, and SUD1, had their peak abundance at 451–500 m in winter and late spring and at 501–600 m in late summer. These groups consisted of one to four species each, representing a total of five species in three genera. Again, association of SPD2 with SPD1 adds no species to the total. In winter and late summer WD1 and SUD1 comprised more than 98 percent of the combined group abundance at 451–500 m and 501–600 m, respectively. In late spring, SPD1 and SPD2 contributed about 93 percent of the total at 451–500 m. Dominance of few species was reflected in the low diversity index and low evenness (Table 134). These groups were intermediate in abundance, WD1 contributing little more than 17 percent of the abundance of all winter groups, SPD1 about 8 percent and SPD2 about 7 percent of late spring groups, and SUD1 almost 27 percent of late summer groups.

The species comprising the shallowest groups (SPD2 in-

TABLE 138.—Vertical distribution (in 50-m intervals) of daytime late spring catch rates by species (numbers = catch rates of specimens per hour; dash = no specimens of the species taken).

SPECIES	451-500	551-600	601-650	651-700	751-800	851-900	951-1000	1051-1100	1101-1150	1151-1200	1201-1250
SPD1											
N. valdiviae	12	4	2	1	-	-	-	-	-	-	-
SPD2											
L. dofleini	3	1	5	1	-	-	-	-	-	-	-
L. gemellarii	2	<1	3	1	<1	-	-	-	-	-	-
SPD3											
D. metopoclampus	-	-	1	1	-	-	-	-	-	-	-
L. chavesi	-	-	1	<1	1	-	-	-	-	-	-
SPD4											
L. pusillus	-	16	31	36	5	1	-	-	-	-	<1
H. hygomii	-	1	<1	4	2	-	<1	-	-	1	-
L. gaussi	-	-	1	2	2	<1	-	-	-	1	-
SPD5											
B. indicus	-	-	<1	2	<1	-	-	-	-	-	-
D. mollis	1	-	1	1	-	-	-	-	-	-	-
SPD6											
L. photonotus	-	-	-	-	2	<1	-	1	-	-	-
SPD7											
D. atlanticus	<1	7	3	6	12	1	<1	2	-	-	1
H. benoiti	-	1	-	<1	3	-	1	-	-	-	-
L. crocodilus	-	-	-	-	4	2	2	-	-	-	-
L. cuprarius	-	-	-	-	8	3	2	3	4	5	-
L. ater	-	-	-	-	3	1	-	4	1	2	-
SPD8											
B. glaciale	-	-	-	-	<1	-	3	-	-	-	-
N. resplendens	-	<1	-	<1	1	1	<1	2	3	-	-

cluded) were *Notolychnus valdiviae* and *Lobianchia dofleini* at all three seasons, *L. gemellarii* at the two seasons when it was abundant enough to be included, and two species of *Diaphus, D. rafinesquii* and *D. mollis,* each at one season (Tables 136, 138, 140). Of these, *N. valdiviae* was by far the most abundant at all three seasons, ranking third or sixth at each season and accounting for more than 70 percent of the combined group abundance at 451–500 m in winter and at 501–600 m in late summer, and about 65 percent at 451–500 m in late spring. *Lobianchia dofleini* ranked among the eight most abundant lanternfishes during the day in late spring and late summer, and was 13th in winter. *Diaphus mollis* was the eighth most abundant species in late summer. The other two species, *L. gemellarii* and *D. rafinesquii,* did not rank among the top ten in abundance during the day at any season.

The genera *Notolychnus, Lobianchia,* and *Diaphus,* which comprise the shallowest groups, appear to be dominant in shallow groupings in many oceanic areas. Records of the vertical distributions of these three genera from other geographical areas (Badcock, 1970; Goodyear et al., 1972; Clarke, 1973; Amesbury, 1975; Badcock and Merrett, 1976) are in general agreement with those given here. Amesbury (1975), using factor analyses, found that near Hawaii *N. valdiviae, L. gemellarii,* and several species of *Diaphus* were included in species assemblages whose centers of abundance were between 400 and 625 m.

Another group associated with the 451–600 m stratum, WD2, was most abundant in winter at 551–600 m. It accounted for 27 percent of the total group abundance at that depth (WD3 was twice as abundant there, despite a deeper maximum), and 9 percent of the combined group abundance in winter. Of the two included species, *Hygophum hygomii* was the most abundant species at that depth interval. *Benthosema suborbitale,* the other group member, was not abundant at that depth (Table 136). *Hygophum hygomii* was the sixth most abundant species in winter (Table 131).

Hygophum benoiti, although not in a group having its maximum abundance at 451–600 m, nevertheless was most

abundant at 501–550 m in winter. It ranked fifth in abundance in winter.

The combined group abundance in the 451–600 m stratum was 38 percent of that in all strata in winter, 21 percent in late spring, and nearly 25 percent in late summer.

DAY 601–700 M STRATUM.—The 50-m intervals within the 601–700 m stratum were characterized by the occurrence of the maximum abundances of one to four groups at each season, by the highest total and total group abundances of all strata, by the presence of many species and species groups, by low species diversity, by very low evenness, and by the relatively small mean size of the specimens caught there (Table 134).

At each of the three seasons both the most abundant species and the most abundant species group had their peak abundances within this stratum. *Lampanyctus pusillus* was the most abundant myctophid in the 601–700 m stratum in late spring and late summer, and *Bolinichthys indicus* was the most abundant one in winter. *Diogenichthys atlanticus* was most abundant within this stratum in both winter and late summer. Six other species had their peak abundances there at one season.

The 6 groups with maximum abundances between 601 and 700 m (WD3; SPD2, SPD3, SPD4, SPD5; and SUD2) consisted of 2 to 4 species each, representing a total of 11 species in 8 genera. Of the six, only WD3, SPD4, and SUD2 were very abundant. The remaining three groups each accounted for less than 7 percent of the total group abundance in all strata and, collectively, for only about 11 percent of the total group abundance in this stratum in late spring (Tables 135, 137, 139). WD3, SPD4, and SUD2 were the most abundant species groups overall in their respective seasons. Despite this, none of the three groups dominated the abundance at any depth to the degree (98 percent) that WD1 did at 451–500 m in winter and that SUD1 did at 501–600 m in late summer. The closest was WD3, which was the most abundant group at any season and was more abundant (167 specimens per hour) than any other group at any single 50-m interval. However, even at

TABLE 139.—Vertical distribution (in 50-m intervals, except last column) of daytime late summer catch rates by species groups (number = catch rate of specimens per hour; dash = no specimens of the species group taken).

SPECIES GROUPS	501–550	551–600	601–650	701–750	751–800	801–850	901–950	1001–1050	1101–1150	>1150	TOT
SUD 1	56	56	9	<1	–	1	–	–	–	–	121
SUD 2	<1	<1	127	15	3	17	1	2	1	1	169
SUD 3	<1	–	<1	12	14	10	3	1	–	–	40
SUD 4	–	–	–	<1	7	5	3	<1	<1	4	18
SUD 5	–	–	36	7	8	46	4	1	2	–	104

TABLE 140.—Vertical distribution (in 50-m intervals) of daytime late summer catch rates by species (numbers = catch rates of specimens per hour; dash = no specimens of the species taken).

SPECIES	451-500	501-550	551-600	601-650	701-750	751-800	801-850	901-950	1001-1050	1101-1150	1301-1350	1451-1500	1501-1550
SUD1													
N. valdiviae	<1	40	42	4	<1	-	-	-	-	-	-	-	-
L. dofleini	1	6	6	3	-	-	-	-	-	-	-	-	-
D. mollis	<1	9	5	2	-	-	1	-	-	-	-	-	-
SUD2													
L. pusillus	-	<1	-	104	14	<1	12	<1	-	-	1	-	-
D. atlanticus	-	<1	<1	22	1	2	6	<1	2	1	-	-	-
SUD3													
H. benoiti	<1	1	-	<1	12	14	10	3	1	-	-	-	-
SUD4													
L. cuprarius	-	-	-	-	<1	1	3	2	-	-	-	1	-
L. ater	-	-	-	-	-	1	<1	-	<1	<1	-	2	1
C. maderensis	-	-	-	-	-	4	2	<1	-	-	-	-	-
SUD5													
B. indicus	-	-	-	36	8	7	28	2	5	1	-	-	-
L. festivus	-	<1	-	-	-	1	6	1	<1	-	-	-	-
C. warmingii	-	-	-	-	-	1	13	1	1	1	-	-	-

601–650 m, WD3 made up only 86 percent of the combined group abundance in winter (Table 135). SPD4 comprised about 72 percent of the combined group abundance at 601–700 m in late spring, and SUD2 nearly 74 percent of that at 601-650 m in late summer (Tables 137, 139).

Group WD3 contributed about 61 percent of the abundance of all groups in winter, SPD4 about 42 percent in late spring (SPD2, 3, and 5 combined about 11 percent), and SUD2 about 37 percent in late summer. This dominance is seen in the low species diversity and the low evenness, the former in spite of the large number of species taken at 601–700 m (Table 134).

The species comprising the groups with maximum abundance at 601–700 m were L. pusillus and possibly B. indicus (see below) at each of the three seasons, Diogenichthys atlanticus in winter and late summer, and Diaphus mollis, D. metopoclampus, Hygophum benoiti, H. hygomii, Lampadena chavesi, Lepidophanes gaussi, and, possibly, Lobianchia dofleini and L. gemellarii at only one season (see discussion of SPD2 in "Day 451–600 m Stratum"). Except for H. benoiti, which was in winter group WD3, all species belonging during only one season in groups with peak abundances at 601–700 m did so in late spring (Table 138).

Factor analyses indicated that B. indicus was included in WD3, SPD5, and SUD5, but not in SUD2. Like the species comprising SUD2, B. indicus was most abundant at 601–650 m, but unlike those species it was not taken at shallower depths and had a secondary peak in abundance at 801–850

m. The other species in SUD5 were most abundant at the latter depth (Table 140). This suggests that B. indicus was closely associated with both SUD2 and SUD5. Bolinichthys indicus had relatively high loadings on two of the factors (0.35 and 0.43). The larger one was on the factor on which the other species of SUD5 had their highest loadings, and the smaller one was on the factor on which the species of SUD2 had their highest loadings. At 601–650 m, B. indicus was represented only by 10–16 mm juveniles, and at 801–850 m mostly by subadults and adults larger than 25 mm. This indicates that the younger and older stages of B. indicus were associated with different species.

Of the species included in groups with maximum abundance at 601–700 m, L. pusillus was by far the most abundant in late spring and late summer, and B. indicus was the most abundant in winter; the two were the most abundant species during the day in the stated seasons. Only in late spring, when L. pusillus accounted for about 65 percent of the combined group abundance at 601–700 m, did either species dominate the catch to the extent that N. valdiviae did within the shallow stratum. In winter B. indicus made up about 37 percent of the combined group abundance at 601–650 m. Diogenichthys atlanticus was the second most abundant (23 percent) lanternfish in winter and fourth most abundant (14 percent) one in late summer in the 601–700 m stratum. The abundance of all three species combined at 601–700 m made up about 80 percent of the total group catch at that stratum in winter, about 76 percent in late

spring, and about 95 percent in late summer. The remaining species included in groups with maximum abundances at 601–700 m each accounted for less than 7 percent of the total group catch there.

The combined group abundance in the 601–700 m stratum was 31 percent of that in all strata in winter, 44 percent in late spring, and 38 percent in late summer.

DAY 701–850 M STRATUM.—The 50-m intervals within the 701–850 m stratum were characterized by the occurrence of the maximum abundance of two or three groups at each season, by intermediate total and total group abundance, by a large number of species and species groups, by high species diversity, by moderate evenness, and by the moderate mean size of the catch (Table 134).

Of the species used in the factor analyses, only *Lampanyctus cuprarius* was most abundant within this stratum at each of the three seasons. *Hygophum benoiti* was most abundant there in late spring and late summer, *Lampanyctus festivus* in winter and late summer (and also in late spring, but it did not meet the abundance criterion at that season), and *L. photonotus* in winter and late spring. Seven additional species included in the factor analyses were most abundant within the 701–850 m stratum during only one of the three seasons.

The seven groups with maximum abundance between 701 and 850 m (WD4, WD5; SPD6, SPD7; SUD3, SUD4, and SUD5) each consisted of one to five species, representing a total of 12 species in seven genera. Only SPD7 and SUD5 were abundant; SPD7 accounted for 33 percent of the abundance of all groups combined in late spring and SUD5 for nearly 23 percent in late summer. The remaining five groups each comprised less than 9 percent of the combined group abundance at their respective seasons. None of the groups dominated the abundance at any depth to the degree (98 percent) that WD1 did in winter at 451–500 m and SUD1 did in late summer at 501–600 m. SPD7 made up 78 percent of the combined group abundance at 751–800 m in late spring and SUD5 58 percent of that at 801–850 m in late summer. In winter the most abundant group in the 701–850 m stratum was WD3, despite its shallower abundance maximum (601–700 m). WD3 was responsible for 53 percent of the combined group abundance at 701–850 m, and WD5, the second most abundant group in that stratum, accounted for about 21 percent. SPD7 was the second most abundant of all late spring groups, SUD5 the third most abundant group in late summer, and WD5 the fourth most abundant in winter (Tables 135, 137, 139).

The species comprising groups with maximum abundance at 701–850 m were *L. cuprarius* and *L. ater* at each of the three seasons (*L. ater* was most abundant below 850 m in late spring and late summer, see Tables 138 and 140); *L. festivus* in winter and late summer; *L. photonotus* in winter and late spring; *H. benoiti* in late spring and late summer;

Ceratoscopelus warmingii, *C. maderensis* and *Bolinichthys indicus*, in late summer; *Lampadena speculigera* and *Lepidophanes gaussi* in winter; and *Lampanyctus crocodilus* and *Diogenichthys atlanticus* in late spring.

In winter *L. cuprarius* and *L. ater* were the two most abundant species included in groups with maximum abundance at 701–850 m, together comprising nearly 18 percent of the combined group abundance at that stratum. However, *Bolinichthys indicus*, the most abundant species overall in winter, was the dominant species in that stratum, accounting for 26 percent of the combined group abundance there; but it belonged to WD3, the most abundant of all winter groups, which was most abundant at 601–700 m. Both *Hygophum benoiti* (WD3) and *H. hygomii* (WD2) also were more abundant in this stratum than either *L. cuprarius* or *L. ater* although having shallower maximum abundances. The latter two species ranked ninth and eleventh in total abundance, respectively, in winter.

In late spring *Diogenichthys atlanticus* and *L. cuprarius* were the two most abundant species within the 701–850 m stratum, the first accounting for about 32 percent and the latter for about 21 percent of the combined group abundance in that stratum. Both species belong to SPD7, the most abundant group at 701–850 m. *Diogenichthys atlanticus* ranked second in overall abundance and *L. cuprarius* fifth in late spring.

In late summer *B. indicus*, *H. benoiti*, and *Lampanyctus pusillus*, in that order, were the three most abundant species in the 701–850 m stratum, collectively accounting for nearly 71 percent of the combined group abundance there. In late summer *B. indicus*, the fourth most abundant species, accounted for nearly 29 percent of the combined group abundance at 701–850 m. *Bolinichthys indicus* belonged to group SUD5 (but see p. 154). *Hygophum benoiti*, the only species in SUD3, comprised nearly 25 percent of the combined group abundance at 701–850 m and was the most abundant species overall in late summer. *Lampanyctus pusillus*, although most abundant at 601–700 m (as was its group, SUD2), made up about 25 percent of the abundance of all groups combined at 701–850 m. No other species accounted for as much as 9 percent of the combined group catch at that stratum, *C. warmingii* being the most abundant of these (Table 140).

The combined group abundance at 701–850 m was about 27 percent of that in all strata in winter, 17 percent in late spring, and about 32 percent in late summer.

DAY DEEPER THAN 850 M STRATUM.—Within the deepest stratum (below 850 m), the 50-m intervals were characterized by the occurrence of the maximum abundances of one or no groups, by very low overall and total group abundance, by very few species, by relatively few species groups, by low species diversity, by high evenness, and by the relatively large mean size of the catch (Table 134). None of the species used in the factor analyses was most abundant

within this stratum at all of the three seasons. *Lampanyctus ater* was most abundant there in late spring and late summer, *C. warmingii* in winter and late spring, and *Notoscopelus resplendens*, *L. photonotus*, and *Benthosema glaciale* in late spring. The last species was most abundant in this stratum at each of the three seasons but failed to meet the abundance criterion in winter or late summer.

Only two groups, WD6 and SPD8, were most abundant in the deepest stratum. WD6 consisted of only *C. warmingii*, and SPD8 of *B. glaciale* and *N. resplendens*. Neither of the two groups was abundant; both contributed less than 5 percent of the abundance of all groups combined. In winter WD6 was the dominant group in the deepest stratum, accounting for slightly more than 76 percent of the combined group abundance there. Although each was represented below 850 m, none of the other winter groups was abundant there (Table 135). In late spring SPD8 comprised nearly 21 percent of the combined group abundance below 850 m. However, SPD7 was more than three times as abundant in that stratum (69 percent) as SPD8, despite having a shallower maximum abundance (Table 137). In late summer members of all groups except SUD1 occurred below 850 m in low abundance (Table 140).

In winter only *C. warmingii* was taken in any abundance below 850 m. It accounted for 76 percent of the combined group catch at that stratum (Table 136) and was the seventh most abundant species in winter.

In late spring the most abundant species below 850 m, *L. cuprarius*, belonged to a group with peak abundance in the 701–850 m stratum; yet it accounted for 40 percent of the combined group abundance at the deeper stratum, or about twice that of *B. glaciale* and *N. resplendens* combined. The latter two species comprised SPD8, the only late spring group with maximum abundance below 850 m. *Lampanyctus ater* also was more abundant in the deepest stratum than either species included in SPD8 (Table 138).

No species dominated the catch below 850 m in late summer. The combined group abundance below 850 m was 4 percent of that at all strata in winter, 18 percent in late spring, and 5 percent in late summer.

NIGHTTIME SPECIES GROUPS

Six to eight groups per season were recognized from nighttime data, each consisting of one to seven species. Species comprising these groups accounted for 82–94 percent of the nighttime abundance of all lanternfishes at each of the three seasons. The groups and their constituent species are listed by season in order of increasing depth of maximum abundance in Tables 141–146.

At night most species and species groups occurred in the upper 200 m. A few regularly migrated to the very surface or just below it, but the upper depth limit for most lanternfishes was between 18 and 100 m. A few species migrated only up to 200–500 m. Several species consisted of both migrant and nonmigrant individuals, and were found both at shallower depths and at daytime depths at night. The deeper dwelling individuals were usually, but not always, recently transformed juveniles. Most other nonmigrants were larger individuals of the species that grow to a relatively large size: e.g., *Lampanyctus cuprarius*, *L. ater*, and *Diaphus rafinesquii*.

The compression into the upper 200 m resulted in a smaller scale partitioning of the water column at night than by day. It should be noted that sampling at night, particularly in the upper 100 m, was conducted on a much finer scale than either daytime or deep nighttime sampling (Figures 1–3), which may have allowed for detecting the smaller scale partitioning of the water column at night. However, few day groups had their depths of maximum abundance within the same 50-m interval, and the finer scale partitioning of the water column at night probably reflects a real compression of the vertical ranges and the depths of maximum concentration of most migrant species.

At each of the three seasons each group, except for SPN2 and SPN3, had a unique depth of maximum abundance (Tables 141, 143, and 145). For most groups, this depth was in the upper 100 m.

The depths of maximum abundance of the eight winter groups were: WN1 at the surface, WN2 at 18 and 34 m, WN3 at 40 m and 68 m WN4 at 95 m, WN5 at 150 m,

TABLE 141.—Vertical distribution (in m) of nighttime winter catch rates by species groups (numbers = catch rates of specimens per hour; dash = no specimens of the species group taken).

SPECIES GROUPS	SURF	18	34	40	50	68	95	100	150	175	200	201–800	801–900
WN 1	56	–	–	–	<1	–	–	<1	2	–	<1	<1	<1
WN 2	–	80	80	19	46	2	–	2	2	<1	<1	<1	–
WN 3	<1	14	–	94	9	91	54	44	11	6	1	4	74
WN 4	–	<1	<1	24	5	32	142	46	30	20	20	14	4
WN 5	–	–	–	9	–	–	–	8	29	3	2	2	<1
WN 6	–	–	–	2	–	–	–	<1	–	8	–	1	–
WN 7	–	–	–	–	–	–	–	–	–	–	2	12	3
WN 8	–	–	–	–	–	–	–	<1	<1	0	1	1	6

TABLE 142.—Vertical distribution (in m) of nighttime winter catch rates by species (numbers = catch rates of specimens per hour; dash = no specimens of the species taken).

	SURF	18	34	40	50	68	95	100	150	175	200	201-250	301-350	701-800	801-850	851-900
WN1																
G. cocco	38	-	-	-	-	-	-	-	<1	-	<1	-	-	-	-	1
M. nitidulum	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. nigroocellatus	7	-	-	-	-	-	-	<1	1	-	-	-	-	-	-	-
H. reinhardtii	1	-	-	-	<1	-	-	-	1	-	-	-	-	-	<1	-	-
WN2																
H. benoiti	-	80	80	19	46	2	-	2	2	<1	<1	-	1	-	-	-
WN3																
H. hygomii	<1	13	-	5	-	13	8	4	11	-	1	<1	1	<1	1	-
B. suborbitale	-	-	-	-	<1	2	-	1	-	-	-	-	-	-	-	-
N. caudispinosus	-	<1	-	5	1	8	2	2	-	-	-	-	<1	-	-	-
C. warmingii	-	<1	-	50	1	23	26	32	<1	5	-	-	2	<1	9	4
D. atlanticus	-	1	-	34	7	38	18	5	-	1	-	-	<1	<1	7	53
WN4																
L. dofleini	-	<1	-	-	-	2	2	1	2	2	1	<1	-	<1	-	-
L. gemellarii	-	-	-	-	-	<1	11	<1	<1	-	-	-	1	-	-	-
O. mollis	-	-	-	2	3	2	24	4	2	<1	1	-	1	-	-	-
D. rafinesquii	-	-	-	1	-	1	6	-	<1	2	1	-	-	-	-	-
N. valdiviae	-	-	<1	-	1	26	41	15	3	4	9	<1	3	2	-	1
L. pusillus	-	-	-	2	1	-	10	16	11	6	8	1	-	<1	-	1
B. indicus	-	-	-	19	-	1	47	10	12	6	<1	1	1	<1	-	1
WN5																
L. speculigera	2	-	-	-	-	-	-	1	2	-	-	<1	-	<1	-	-
L. festivus	-	-	-	-	-	-	-	1	5	1	1	<1	1	-	-	1
L. photonotus	-	-	-	9	-	-	-	6	21	1	1	<1	-	-	1	-
WN6																
L. urophaos	-	-	-	-	-	-	-	<1	-	3	-	-	1	<1	-	-
L. guentheri	-	-	-	2	-	-	-	-	-	5	-	-	-	-	-	-
WN7																
L. cuprarius	-	-	-	-	-	-	-	-	-	-	-	2	4	4	1	3
D. metopoclampus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-
WN8																
L. ater	-	-	-	-	-	-	-	<1	<1	-	1	1	-	<1	3	3

TABLE 143.—Vertical distribution (in m) of nighttime late spring catch rates by species groups (numbers = catch rates of specimens per hour; dash = no specimens of the species group taken).

SPECIES GROUPS	SURF	50	55	92-94	100	101-150	151-200	201-250	251-600	751-850
SPN 1	78	-	-	-	1	-	-	-	-	-
SPN 2	-	2	-	3	-	-	-	-	<1	3
SPN 3	-	56	20	238	54	2	3	3	2	45
SPN 4	-	1	-	17	41	4	4	7	<1	4
SPN 5	-	-	-	-	-	-	-	<1	12	-
SPN 6	-	-	-	-	-	-	<1	<1	-	8

WN6 at 175 m, WN7 at 201-310 m and 701-750 m, and WN8 at 801-900 m. WN3 was the most abundant group, and accounted for 33 percent the abundance of all groups combined. It was the most abundant group at 40 m, 68 m, and 851-900 m. WN4 was nearly as abundant as WN3, accounting for about 27 percent of the abundance of all groups combined. It was, by far, the most abundant group at 95 m. Groups WN3 and WN4 together accounted for

TABLE 144.—Vertical distribution (in m) of nighttime late spring catch rates by species
(numbers = catch rates of specimens per hour; dash = no specimens of the species taken).

SPECIES	SURF	50	55	92-94	100	101-150	151-200	201-250	251-500	501-550	551-600	751-800	801-850
SPN1													
M. nitidulum	6	-	-	-	-	-	-	-	-	-	-	-	-
G. cocco	49	-	-	-	<1	-	-	-	-	-	-	-	-
C. nigroocellatus	23	-	-	-	<1	-	-	-	-	-	-	-	-
M. punctatum	2	<1	-	-	-	-	-	-	-	-	-	-	-
SPN2													
L. crocodilus	-	2	-	3	-	-	-	-	-	-	<1	1	2
SPN3													
L. dofleini	-	36	12	26	16	-	-	1	-	-	-	-	-
C. warmingii	..	11	4	43	1	-	-	-	<1	-	-	-	-
L. pusillus	--	2	2	70	8	1	-	-	-	-	1	2	11
N. valdiviae	-	3	2	31	21	2	-	1	-	-	-	1	-
D. atlanticus	-	2	-	51	6	1	2	<1	-	-	-	17	14
L. photonotus	-	1	-	8	<1	-	1	-	-	-	-	-	-
N. resplendens	-	1	-	9	2	-	-	-	-	-	-	-	-
SPN4													
B. indicus	-	-	-	12	15	2	1	-	-	-	-	-	-
L. gemellarii	-	-	-	-	2	2	1	2	-	-	-	-	-
D. mollis	-	1	-	4	9	1	-	2	-	-	-	-	-
L. cuprarius	-	-	-	-	8	-	-	2	-	-	1	1	2
L. ater	-	-	-	-	5	-	2	<1	-	-	-	2	2
L. festivus	-	-	-	-	2	-	-	-	-	-	-	-	-
SPN5													
D. rafinesquii	-	-	-	-	-	-	-	-	2	8	2	-	-
SPN6													
H. benoiti	-	-	-	-	-	-	1	<1	-	-	-	8	-

TABLE 145.—Vertical distribution (in m) of nighttime late summer catch rates by species
groups (numbers = catch rates of specimens per hour; dash = no specimens of the species
group taken).

SPECIES GROUPS	SURF	33	55	65	90	110-115	160-178	175	201-250	251-600	651-1000
SUN 1	53	-	-	-	<1	-	-	<1	-	<1	1
SUN 2	-	262	121	4	39	17	2	6	6	14	17
SUN 3	-	11	47	4	31	6	1	4	<1	2	6
SUN 4	-	6	36	54	5	4	<1	4	-	5	19
SUN 5	-	-	-	-	9	25	4	8	1	6	14
SUN 6	-	11	14	8	58	25	24	6	2	11	146
SUN 7	-	-	-	-	-	-	-	<1	<1	7	18

88-100 percent of the combined group catch at 68 m, 95 m, and 100 m (Table 141).

In late spring the depths of maximum abundance for each of the groups were as follows: SPN1 at the surface, SPN2 and SPN3 at 92-94 m, SPN4 at 100 m, SPN5 at 501-550 m, and SPN6 at 751-800 m. The most abundant group, SPN3, accounted for nearly 58 percent of the catch of all groups combined. SPN3 made up about 93 percent for the total group catch at 50 m and 92-94 m, the entire

catch at 55 m, and about 57 percent of that at 100 m. SPN2 probably is best considered a part of SPN3. SPN2 consisted only of Lampanyctus crocodilus, was the least abundant group, was most abundant at the same depth as SPN3, and had a similar overall vertical distribution to SPN3 (Table 143).

The seven late summer groups were most abundant at the following depths: SUN1 at the surface, SUN2 at 33 m, SUN3 at 55 m, SUN4 at 65 m, SUN5 at 110-115 m, SUN6

TABLE 146.—Vertical distribution (in m) of nighttime late summer catch rates by species (numbers = catch rates of specimens per hours; dash = no specimens of the species taken).

SPECIES	SURF	33	55	65	90	110-115	160-178	201-250	251-600	651-700	701-750	751-800	851-900	901-950	951-1000
SUN1															
M. nitidulum	15	-	-	-	<1	-	<1	-	<1	-	-	-	<1	<1	-
G. cocco	38	-	-	-	-	-	-	-	-	-	-	-	<1	-	-
SUN2															
B. suborbitale	-	68	8	-	1	-	<1	-	-	-	1	-	-	-	-
N. valdiviae	-	116	87	-	25	2	2	4	5	1	1	<1	<1	<1	-
L. gaussi	-	48	12	4	13	-	2	-	1	-	-	1	-	-	-
L. pusillus	-	30	14	-	-	15	1	1	8	4	1	5	2	<1	2
SUN3															
H. hygomii	-	-	6	2	2	-	<1	-	-	-	-	-	-	-	-
C. warmingii	-	10	36	-	29	5	2	-	2	1	-	-	3	<1	1
H. taaningi	-	-	1	1	<1	1	1	-	-	1	-	-	-	-	-
C. maderensis	-	1	3	-	-	-	<1	<1	-	1	-	<1	<1	-	1
SUN4															
D. atlanticus	-	6	36	54	5	4	2	-	5	1	1	2	10	3	3
SUN5															
B. indicus	-	-	-	-	9	23	4	<1	3	2	1	-	1	2	-
L. photonotus	-	-	-	-	<1	1	1	1	-	1	1	-	<1	1	4
L. festivus	-	-	-	-	-	-	1	<1	2	1	-	-	-	<1	<1
SUN6															
L. dofleini	-	1	-	-	21	13	1	-	-	1	-	-	-	-	-
D. mollis	-	10	10	4	14	1	1	?	1	1	-	-	-	-	-
L. guentheri	-	-	1	2	5	2	-	-	<1	-	-	<1	-	-	-
H. benoiti	-	-	3	2	18	8	13	2	10	64	22	25	18	11	4
SUN7															
L. cuprarius	-	-	-	-	-	-	<1	<1	7	2	1	<1	5	1	1
L. crocodilus	-	-	-	-	-	-	-	<1	<1	1	1	-	2	1	-
L. ater	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-

at 651–700 m, and SUN7 at 851–900 m. SUN2 was the most abundant group, making up about 44 percent of the abundance of all groups combined. This group was responsible for 90 percent of the group abundance at 33 m and about 55 percent of that at 55 m, and was by far the most abundant group at each of those depths (Table 145).

In contrast to daytime, abundance at night was greatest above 450 m, with about 45–61 percent of the total abundance of all lanternfishes concentrated in the upper 100 m at each season (Table 133). Abundance was lowest between about 300 m and 650 m. Secondary peaks occurred between about 651 and 950 m.

NIGHT DEPTH STRATA

The water column could be divided on the basis of factor analyses and population characteristics into the following four strata: the surface, a shallow stratum from about 20 m to about 200 m, an intermediate stratum from about 201 m to about 600 m, and a deep stratum between about 601 m and 1000 m. Except for the surface, the limits of each of the strata vary from season to season. The shallow stratum could be subdivided at each season. However, within this stratum the same depths were not sampled at each season, the subdivisions for each season were unique, and few if any general patterns were evident.

The strata could be characterized by the maximum abundance of one or more groups (except for the intermediate stratum in late summer), total abundance, total group abundance, numbers of species groups, numbers of species, abundant species, species diversity, evenness, and mean size of specimens (Table 134).

Cluster analyses of samples (based upon correlation coefficients of species abundance) supported the recognition of these strata. Most samples made at the intermediate depths were not included in the analyses because they failed to meet the abundance criterion. I have chosen to group them together on the basis of their low abundance of lanternfishes.

In winter, clusters of samples were from the surface, 18

and 34 m, 68–175 m, and 801–900 m. The 68–175 m cluster consisted of three subsets: one at 68 m, one at 95–100 m, and a third at 150–175 m. Late spring samples were divided among clusters at the surface, at 50–94 m, at 100–150 m, and at 750–850 m. In late summer clusters were from 33–90 m, 100–178 m, and deeper than 650 m. Although none of the surface samples made in late summer met the abundance criterion, it can be assumed that they would cluster together, as the only species taken in any abundance in neuston samples, *Gonichthys cocco* and *Myctophum nitidulum*, were grouped together in the factor analyses.

NIGHT SURFACE STRATUM.—The surface stratum was characterized by the occurrence of the maximum abundance of one group at each season, by intermediate total and total group abundances, by the presence of only one or two species groups and of few species, and by low species diversity and evenness (Table 134). The maximum abundance of two species, *Gonichthys cocco* and *Myctophum nitidulum* ocurred at the surface at each of the three seasons. Of the remaining 28 species used in the nighttime factor analyses, one, *Centrobranchus nigroocellatus*, was most abundant at the surface at each of the three seasons but met the abundance criterion only in winter and late spring. *Hygophum reinhardtii* was most abundant at the surface only in winter. This species was not included in the factor analyses at the other two seasons.

The groups with maximum abundances at the surface (WN1, SPN1, and SUN1) consisted of two to four species each, representing a total of four species in four genera. At each of the three seasons the group with maximum abundance at the surface comprised at least 99 percent of the combined group catch there. Only in winter was more than one group represented in the surface stratum. This dominance of few species was reflected in the relatively low diversity and evenness.

The species making up the surface groups were *Gonichthys cocco* and *Myctophum nitidulum* at all three seasons, *Centrobranchus nigroocellatus* in winter and late summer spring, and *Hygophum reinhardtii* in winter (Tables 142, 144, 146). *Gonichthys cocco* was the dominant surface species at each season, making up about 62–71 percent of the abundance of all groups occurring at the surface. *Gonichthys cocco* was the fourth most abundant lanternfish in late spring, eighth in winter, and ninth in late summer. Of the remaining three species belonging to surface groups, only *C. nigroocellatus*, which ranked eighth in abundance in late summer, was included among the 10 most abundant lanternfishes at any season.

In late spring *Myctophum punctatum* barely met the abundance criterion and did not have a loading as high as 0.1 on any of the factors. It was most abundant at the surface and probably was part of the surface group. However, because of its low abundance and very low factor loadings,

it was not included in any of the species groups and was not considered further.

None of the species comprising the surface groups was included in the daytime analyses. All failed to meet the abundance criterion, and little can be determined about their daytime depth distributions except that they were taken between 500 and 850 m.

Devany (1969) noted that the four species included in the surface groups near Bermuda also formed part of a "nocturnal surface community" in the Straits of Florida. Also included in Devany's community were other species of *Myctophum*, two species of *Diaphus*, and *Symbolophorus rufinus*. Of these, only *Diaphus* did not occur at the surface during the night near Bermuda.

The combined group abundance in the surface stratum was 6 percent of that in all strata in winter, 10 percent in late spring, and 20 percent in late summer.

NIGHT 20–200 M STRATUM.—The 50-m intervals within the shallow stratum were characterized by the occurrence of the maximum abundances of three to five groups at each season, by the highest total and total group abundances for all strata, by the presence of many species and species groups, by high diversity and evenness, and by the relatively small mean size of specimens caught (Table 134). Twenty-five species were most abundant within the shallow stratum during at least one season. Eight of these (*Notolychnus valdiviae*, *Lampanyctus pusillus*, *L. festivus*, *L. photonotus*, *Diaphus mollis*, *Lobianchia dofleini*, *Bolinichthys indicus*, and *Ceratoscopelus warmingii*) were most abundant within the shallow stratum at all three seasons. An additional five species were most abundant in the shallow stratum at two of the seasons.

In late spring and late summer the most abundant species group had its maximum abundance in the shallow stratum, and in winter the most abundant group had two nearly equal peaks in abundance, one in the shallow stratum and one in the deep stratum (Tables 141, 143, 145). The most abundant species had its maximum abundance in the shallow stratum only in late spring.

The 12 groups with maximum abundance in the shallow stratum (WN2, 3, 4, 5 and 6; SPN 2, 3, and 4; and SUN 2, 3, 4, and 5) each consisted of one to seven species, representing a total of 23 species in 12 genera. Groups WN2, WN4, SPN3, and SUN2 were very abundant, each accounting for 27–70 percent of the total group abundance in their respective seasons. Groups WN2, WN5, SPN4, SUN3, and SUN4 were moderately abundant, each comprising 7–15 percent of the total group abundance. Of these groups only WN5 had a total abundance of less than 56 specimens per hour (Table 141). The remaining three groups made up 1–5 percent of the total group abundance. The most abundant group at each season, WN3, SPN3, and SUN2, comprised about 33 percent of the abundance of all groups combined in winter, about 58 percent in late spring, and about 44

percent in late summer, respectively. SPN3 comprised the entire group abundance at 55 m in late spring (Table 143). Otherwise, none of these groups dominated the catch at a specific depth as completely as WN1, SPN1, and SUN1 did at the surface (99–100 percent). SPN3 also comprised about 95 percent of the total group abundance at 50 m. SUN2 was responsible for about 90 percent of the total group abundance at 33 m in late summer (Table 145). Another group, WN2, one of the moderately abundant groups with a peak in the shallow stratum, accounted for nearly the entire catch at 34 m in winter (Table 141).

In winter the five groups with maximum abundances in the shallow stratum accounted for 98 percent of the combined group catch there. The most abundant group in that stratum, WN4, made up about 37 percent of the combined group catch there. Each of the five groups had its peak abundance at a different depth. Groups WN3 and 4 were most abundant within the same 50-m interval (51–100 m), but the former was most abundant at 40 m and 68 m and the latter at 95 m (Table 141).

In late spring the three groups with maximum abundance in the shallow stratum made up more than 99 percent of the total group abundance there. SPN3 accounted for nearly 80 percent of the combined group abundance in that stratum and SPN4 for almost all of the rest. The integrity of SPN2 as a group is somewhat dubious. The group consisted only of Lampanyctus crocodilus, which was not abundant. It had an overall vertical distribution similar to that of Lampanyctus pusillus and Diogenichthys atlanticus, both of which belonged to SPN3 (Table 144). Lampanyctus crocodilus had a fairly high loading (0.4) on the same factor as the species of SPN3 did, but had an even higher one (0.8) on another factor on which no other species had a high loading.

The four late summer groups with maximum abundance in the shallow stratum accounted for 85 percent of the combined group abundance there. SUN2 was, by far, the most abundant group in that stratum accounting for a little more than 62 percent of the combined group abundance. The remaining three groups each contributed less than 10 percent of the combined group catch in the shallow stratum. The second most abundant group there, SUN6, accounted for about 19 percent of the combined group abundance but was most abundant in the deep stratum. SUN3 and 4 were most abundant at 51–100 m, but the first group had its peak abundance at 55 m and the second at 65 m (Table 145).

At all three seasons each of the groups with maximum abundance in the shallow stratum was most abundant between 18 and 175 m. Only 3 of the 12 groups, WN5, WN6, SUN5, had their highest abundances below 100 m, and one of these, SUN5, was most abundant just below 100 m (110–115 m).

The groups with their highest abundances in the shallow stratum included 23 species, of which the following 9 were members of such groups at each of the 3 seasons: Notolychnus valdiviae, Lampanyctus pusillus, L. photonotus, L. festivus, Ceratoscopelus warmingii, Diogenichthys atlanticus, Lobianchia dofleini, Diaphus mollis, and Bolinichthys indicus. Of these nine, D. atlanticus did not have its maximum abundance in the shallow stratum at each of the three seasons; it was most abundant there in late spring and late summer and in the deep stratum in winter (Tables 142, 144, 146). Benthosema suborbitale, Hygophum benoiti, H. hygomii, Lepidophanes guentheri, and Lobianchia gemellarii had their maximum abundances in the shallow stratum in two of the seasons; only the first three occurred in abundance there during at least one season. Nine species had their maximum abundances in the shallow stratum during only one season. Among these, only L. gaussi in late summer was abundant there.

The combined group abundance in the shallow stratum was 59 percent of that from all strata in winter, 57 percent in late spring, and 64 percent in late summer.

Night Upper 50-m Interval: Groups WN2, WN3, and SUN2 had their highest abundance in the upper 50 m of the shallow stratum (Tables 141, 145). In winter WN2 was about equally abundant at 18 m and 34 m and comprised more than 90 percent of the total group abundance at the two depths. More than 90 percent of WN2 occurred between 18 m and 50 m. WN3 had one peak in abundance at 40 m, but was also abundant at 68 m, 95 m, 100 m, and 851–900 m (Table 141). In terms of 50-m intervals, WN3 was most abundant at 51–100 m and 851–900 m. The peak at 40 m was mostly due to two species that were the most abundant ones at that depth, despite both having deeper maxima. The other three species included in WN3 were most abundant at 68 m (Table 142). SUN2 was most abundant at 33 m, at which depth it comprised about 90 percent of the total group abundance in late summer (Table 145); about 56 percent of SUN2 was from 33 m.

In late spring no discrete-depth samples were made between the surface and 50 m. Although no group was most abundant at 50 m in late spring, it is possible that one or more groups were most abundant between the surface and 50 m.

Groups WN2 and SUN2 had no species in common, and WN3 and SUN2 both contained Benthosema suborbitale. This species was most abundant at 33 m in late summer, when it was by far most abundant, and at 68 m in winter.

Eight species had their highest abundances in the upper 50 m and an additional three had abundances close to their highest. No species was most abundant in the upper 50 m during more than one season.

In winter H. benoiti, the only species included in WN2, was most abundant at 18 m and at 34 m, where it accounted for more than 84 percent of the total group abundance. Hygophum benoiti was also the most abundant myctophid at 50 m. At 18 m H. hygomii also was taken in maximum

abundance, but accounted for little more than 13 percent of the total group abundance at that depth. At 40 m *C. warmingii* was taken in maximum abundance (Table 142) but was less abundant in the whole upper 50 m than at some deeper 50 m interval.

In late spring *L. dofleini* was most abundant in the upper 50 m of the shallow stratum. Although *L. dofleini* accounted for nearly 90 percent of the total group abundance at 50 m, it was included in SPN3, which had a peak abundance at 92–94 m. *Lampanyctus crocodilus,* the only species in SPN2 (see the discussion of the entire 20–200 m stratum in late spring), occurred in maximum abundance at 50 m, but was not very abundant (Table 144).

In late summer *B. suborbitale, N. valdiviae, L. gaussi,* and *L. pusillus* all were most abundant at 33 m. *Notolychnus valdiviae* was by far the most abundant one at that depth, contributing a little more than 40 percent of the total group abundance there. These four species made up SPN2, which accounted for slightly more than 90 percent of the total group abundance at 33 m (Table 146).

Night 51–100 m Interval: Six groups (neglecting SPN2), two at each season, had their maximum abundance between 51–100 m. In late summer only SUN3 was most abundant at 55 m. However, the most abundant group at that depth was SUN2, which contributed about 55 percent of the combined group abundance there, while SUN3 accounted for 21 percent. SUN3 was moderately abundant, comprising about 7 percent of the abundance of all late summer groups combined (Table 145).

WN3 and SUN4 both had their peak abundances between 65 and 70 m, the former at 68 m in winter and the latter at 65 m in late summer (Tables 141, 145). WN3, the most abundant winter group, was discussed under the upper 50-m interval. SUN4 consisted only of *Diogenichthys atlanticus.* Although *D. atlanticus* also belonged to WN3, it was most abundant in the deep stratum in winter (Table 142). WN3 accounted for about 73 percent of the combined group abundance at 68 m and for nearly 33 percent of the overall abundance of all groups combined in winter. SUN4 made up about 78 percent of the combined group abundance at 65 m and almost 8 percent of the overall abundance of all groups combined in late summer.

WN4 and SPN3 both were most abundant between 92 and 95 m, and were the dominant groups at that depth in winter and late spring, respectively. WN4, the second most abundant winter group, accounted for 72 percent of the combined group abundance at 95 m and for 27 percent of the abundance of all groups combined (Table 141). SPN3, the most abundant late spring group, comprised 92 percent of the combined group abundance at 92–94 m, and for nearly 58 percent of the abundance of all groups combined (Table 143).

Two groups, SPN4 and SUN5, had their maximum abundances at 100 m and 110–115 m, respectively. In late spring

although SPN4 had its peak abundance at 100 m, SPN3 was the most abundant group at that depth, contributing about 57 percent of the combined group abundance there (Table 143). SPN4 accounted for nearly 43 percent of the combined group abundance at 100 m and about 14 percent of the overall abundance of all groups combined. In late summer SUN5 and SUN6 were equally abundant at 110–115 m, together making up about 80 percent of the group abundance there (Table 145). SUN6, however, was much more abundant in the deep stratum. SUN5 accounted for little more than 5 percent of the overall total group abundance in late summer.

Twenty-two species had their peak abundances between 55 m and 100 m during at least one season. Two of these, *C. warmingii* and *D. mollis,* were most abundant there during each of the three seasons. Although it was most abundant at 110–115 m in late summer, *B. indicus* probably also can be considered among the species with peak abundance at 55–100 m at all three seasons.

In winter *H. hygomii, B. suborbitale,* and *N. caudispinosus* all had their greatest abundances at 68 m, but none of the three was very abundant there. Their combined abundances comprised only 19 percent of the total group abundance at that depth. *Ceratoscopelus warmingii, D. atlanticus,* and *N. valdiviae* were each more abundant than the above three species combined, despite having maxima at other depths (Table 142). Six of the seven species included in WN4 had their maximum abundance at 95 m, but only *B. indicus* and *N. valdiviae* were abundant (Table 142); the latter two species accounted for nearly 45 percent of the total group abundance there. *Ceratoscopelus warmingii* and *D. atlanticus* (both in WN3) were each more abundant at that depth than four of the species included in WN4. At 100 m *C. warmingii* was the most abundant species and accounted for 32 percent of the total group abundance there (Table 142), although it was most abundant at 40 m.

In late spring no species had its maximum abundance at 55 m. The most abundant species at that depth, *L. dofleini,* had its greatest abundance at 50 m and belonged to SPN3, which was most abundant at 93 m (Table 144). Except for *L. dofleini,* each species belonging to SPN3 was most abundant at 93 m. Four of the included species (*L. pusillus, D. atlanticus, C. warmingii,* and *N. valdiviae*) were abundant, together accounting for 76 percent of the total group abundance there (*L. dofleini* accounted for an additional 10 percent). All the species included in SPN4 had peak abundances at 100 m, but none were very abundant. The two most abundant species at that depth, *N. valdiviae* and *L. dofleini,* belonged to SPN3 and had their peak abundances at shallower depths; even these species were not very abundant at 100 m (Table 144).

In late summer all four species of SUN3 had their greatest abundances at 55 m. Even the most abundant of the four, *C. warmingii,* was not very abundant. Despite a shallower

maximum, the diminutive *N. valdiviae* was, by far, the most abundant species at 55 m, being more abundant than all of group SUN3 (Table 146). *Diogenichthys atlanticus* and *C. warmingii* were second in abundance at 55 m. However, *D. atlanticus* had its peak abundance at 65 m, where it was the most abundant species and comprised 78 percent of the total group abundance there (Table 146). At 90 m three of the four species in SUN6 (*L. dofleini, D. mollis,* and *L. guentheri*) had their greatest abundances; none was very abundant. The most abundant species at that depth, *C. warmingii,* had its peak abundance at a shallower depth. No species group had its highest abundance at 90 m. (However, see p. 164 concerning *H. benoiti* and its relation to the other three species included in SUN6.) *Bolinichthys indicus,* one of the three species comprising SUN5, was most abundant at 110–115 m, but was not very abundant. This species made up 31 percent of the total group abundance at that depth (Table 146).

Night 150–200 m Interval: WN5 and WN6 had their maximum abundances at 150 m and 175 m, respectively. The latter group was uncommon even at 175 m and accounted for less than 1 percent of the total group abundance in winter. WN5 was not very abundant either, but accounted for slightly more than 7 percent of the total group abundance; it comprised about 39 percent of the total group abundance at 150 m and was only slightly less abundant than WN4, the most abundant group at that depth (Table 141). In late spring and late summer no group had its maximum abundance within this interval.

NIGHT 201–600 M STRATUM.—The 50-m intervals within the intermediate stratum were characterized by the occurrence of the maximum abundances of zero to two groups at each season; the lowest total and total group abundances for all strata; the presence of relatively few species and of an intermediate number of species groups; intermediate diversity; high evenness; and the relatively large mean size of the specimens (Table 134). No species was very abundant in the stratum. Only three species had their highest abundances there, *Diaphus metopoclampus* and *Lampanyctus cuprarius* in winter, and *Diaphus rafinesquii* in late spring (Tables 142, 144).

The two groups with maximum abundances in the intermediate stratum (WN7 and SPN5) each consisted of one or two species, representing a total of three species in two genera. Neither group accounted for more than 6 percent of the combined group abundance in their respective seasons. In the intermediate stratum in winter WN7 contributed slightly more than 36 percent of the total group abundance (Table 141). SPN5 comprised nearly 75 percent of the total group abundance in the intermediate stratum in late spring (Table 143).

In winter *L. cuprarius* and *D. metopoclampus,* the two species forming WN7, were most abundant at 201–350 m and at 701–750 m, respectively (Table 142). In late spring

D. rafinesquii, the only species included in SPN5, had its highest abundance at 501–550 m (Table 144).

The combined group abundance in the intermediate stratum was 14 percent of that of all strata in winter, and 5 percent in late spring and late summer.

NIGHT 601–1000 M DEEP STRATUM.—The 50-m intervals within the deep stratum were characterized by: the occurrence of the maximum abundances of one or two groups at each season, intermediate total abundances and total group abundances, the presence of an intermediate number of species and of a large number of species groups, intermediate diversity, low evenness, and the smallest mean size of specimens of all strata (Table 134). In winter and late summer the most abundant species had its highest abundance in this stratum. The most abundant group in winter WN3, had two peaks in abundance, one in the deep stratum and one in the shallow stratum (Table 141).

The five groups with maximum abundances in the deep stratum (WN3, WN8, SPN6, SUN6, and SUN7) each consisted of 1 to 5 species, representing a total of 12 species in 9 genera. However, not all species of each of the above groups were represented in the deep stratum, and many of the species had their highest abundance in the shallow stratum (Tables 142, 144, 146). Of the above groups only WN3 and SUN6 were abundant. The remaining three groups each accounted for less than 5 percent of the total group abundance in their respective seasons (Tables 141, 145). WN3, the most abundant winter group, accounted for 33 percent of the total group abundance in winter, but had two peaks in abundance, one at 851–900 m and one in the shallow zone (Table 141). SUN6, the second most abundant late summer group, was most abundant at 651–700 m, and accounted for 28 percent of the combined group catch in late summer (Table 145). In the deep stratum WN3 comprised about 84 percent of the total group abundance in winter, and SUN6 about 69 percent in late summer. In late spring the most abundant group in the deep stratum, SPN3, accounted for 75 percent of the total group catch in the deep stratum, despite a maximum in the shallow stratum (Table 143).

At each season postlarvae and recently transformed juveniles accounted for most of the abundance in the deep stratum. In winter WN3 was mostly represented by postlarvae and recently transformed juveniles of *D. atlanticus. Ceratoscopelus warmingii,* although taken in low abundance there, also occurred as recently transformed juveniles in the deep stratum (Table 142). In the deep stratum the mean size of *D. atlanticus* was about 12 mm and of *C. warmingii* about 17 mm, compared to about 16 mm and 32 mm, respectively, in the shallow stratum.

In late spring the only group with maximum abundance in the deep stratum, SPN6, consisted of recently transformed juveniles and postlarvae of *H. benoiti.* The most abundant group in that stratum, SPN3, was represented

mostly by recently transformed juveniles and postlarvae of *D. atlanticus* and *L. pusillus*, both of which had maxima in the shallow stratum (Table 144). *Diogenichthys atlanticus* was the most abundant species in the deep stratum in late spring.

SUN6 was the most abundant group in the deep stratum in late summer. The group was represented almost exclusively in the deep stratum by 11–15 mm juveniles of *H. benoiti*, the most abundant species overall at night in late summer. There is some doubt about including *H. benoiti* in SUN6 along with *L. dofleini*, *D. mollis*, and *L. guentheri*. Only *H. benoiti* had a loading of less than 0.7 on the factor uniting the group. In fact, *H. benoiti* had very similar loadings (0.28–0.32) on four of the seven factors extracted. This suggests that *H. benoiti* was not particularly closely associated with the other three species included in SUN6. The bathymetric distributions of the four species support this hypothesis. Only *H. benoiti* occurred in abundance below the shallow stratum. The other three species were most abundant in the shallow stratum, while *H. benoiti* was most abundant in the deep stratum. Only 16 percent of *H. benoiti* came from the shallow stratum and more than 60 percent from the deep stratum (Table 146). The specimens of *H. benoiti* from the shallow stratum averaged 2 to 3 mm larger and were more pigmented than those from the deeper stratum. It is probably best to consider the smaller specimens of *H. benoiti* that remain deeper than 600 m both day and night as belonging to one group, and the larger specimens, which apparently migrate regularly, as belonging to the shallow-stratum group, together with *L. dofleini*, *D. mollis*, and *L. guentheri*.

The two remaining deep groups, WN8 and SUN7, consisted only of species of *Lampanyctus* and were not abundant. WN8, which consisted only of *L. ater*, was about equally abundant in both the deep and the intermediate strata but had a slight peak at 801–900 m (Table 142). The three species included in SUN7, *L. ater*, *L. crocodilus*, and *L. cuprarius*, were all most abundant at 851–900 m in late summer (Table 146).

The combined group abundance in the deep stratum was 17 percent of that of all strata in winter, 18 percent in late spring, and 25 percent in late summer.

Congeneric Association

The small size of the species groups and their species composition suggest that competitive exclusion of phylogenetically closely related species has resulted in a partitioning of the water column by lanternfishes.

Of the 30 groups made up of more than one species, 18 did not include congeneric species, six contained one pair of congeners, and two contained two pairs of congeneric species. Four groups contained three congeners; all were species of the taxonomically poorly resolved genus *Lampanyctus*, which apparently consists of at least three evolutionary

lineages (Fraser-Brunner, 1949; Bolin, 1959; Paxton, 1972:69–70). Most of the *Lampanyctus* species included in the same group belonged to presumably different lineages.

Congeners belonging to the same factor groups generally had either different size-frequency distributions, different depths of maximum abundance, different vertical distributions, one or both were not very abundant, or they had some combination of these differences. No pair of congeners belonged to the same group at all of the six diel period–season combinations. One pair of congeners (*Lampanyctus ater* and *L. cuprarius*) belonged to the same group four times, and two other pairs (*Lobianchia dofleini* and *L. gemellarii*, and *Lampanyctus festivus* and *L. photonotus*) belonged to the same group three times. *Lampanyctus ater*, *L. cuprarius*, and *L. crocodilus* were together in two different groups.

Lobianchia dofleini and *L. gemellarii* both belonged to WN4, WD3, and SPD2. In winter *L. dofleini* averaged about 10 mm larger than its congener, and neither species was very abundant. In late spring *L. gemellarii* was, on the average, about 7 mm larger than *L. dofleini*, and neither was very abundant. At night in late spring only *L. dofleini* met the abundance criterion. Of the two species, only *L. dofleini* is a breeding resident of the study area.

Lampanyctus ater and *L. cuprarius* both belonged to groups SPD7, SPN4, SUD4, and SUN7. *Lampanyctus crocodilus* was also included in SPD7 and SUN7. During the daytime in late spring each of the three species was most abundant, or nearly so, at 751–800 m. *Lampanyctus crocodilus* was, on the average, at least 20 mm smaller than the other two species. At 751–800 m, *L. cuprarius* averaged about 7 mm larger than *L. ater*, and at depths greater than about 1000 m *L. ater* was on the average about 30 mm larger than *L. cuprarius*. Of the three species, only *L. cuprarius* was even moderately abundant, being nearly three times as abundant as either of the other two species. At night in late spring *L. festivus*, *L. ater*, and *L. cuprarius* all belonged to the same group (SPN4). Each was most abundant at 100 m and had a mean size of 35–39 mm. Although none was even moderately abundant, *L. cuprarius* was nearly twice as abundant as *L. ater*, and three times as abundant as *L. festivus*. In addition, *L. festivus* had a much different overall vertical distribution than the other two species (Table 144).

In late summer, although both *L. ater* and *L. cuprarius* were mostly larger than about 40 mm, about 20 percent of *L. cuprarius* but none of *L. ater* were smaller than 30 mm. In addition to this difference in size-frequency distributions, *L. cuprarius* was three (day samples) to six (night samples) times more abundant than *L. ater*. During the nighttime, *L. crocodilus* was also included in group SUN7 with *L. ater* and *L. cuprarius*. The first species had a much smaller mean size (28 mm vs 50 mm) than the latter two species, and was not very abundant.

Lampanyctus festivus and *L. photonotus* both belonged to

groups WD5, WN5, and SUN5. In winter the two species had similar depth ranges, depths of maximum abundance, and size-frequency distributions. *Lampanyctus photonotus* was more abundant than *L. festivus*, but neither was very abundant (Tables 136, 142). *Lampanyctus cuprarius* was also included in WD5, but it had a very different size frequency distribution than either of the other two species and was about twice as abundant as either of the two. In late summer *L. photonotus* and *L. festivus* had very different size-frequency distributions, and had different depths of maximum abundance (Table 146). Neither species was very abundant.

These differences among congeners belonging to the same groups, the relatively small number of groups containing congeners, and the relatively small number of species per group all suggest that interspecific competition among the lanternfishes is minimal, allowing the many species of lanternfishes to coexist in a well-structured ecological equilibrium.

Diel and Seasonal Changes in Species Associations

Species groups undergo both daily and seasonal (within a given diel period) changes in composition; no group retains its integrity over either time span. These changes in species associations appear to provide the mechanism for a high degree of partitioning of the water column by lanternfishes over the span of a year.

In winter the four species comprising WD1 (*N. valdiviae, L. dofleini, L. gemellarii*, and *D. rafinesquii*) also belonged to night group WN4 along with three other species, *L. pusillus, B. indicus*, and *D. mollis*. Although the last species was not used in the daytime analysis because it failed to meet the abundance criterion, *D. mollis* was most abundant at the same depth (451–500 m) as the four species in WD1, and probably also would have been included in WD1 if it had been used in the analysis. The remaining two species in WN4, *L. pusillus* and *B. indicus*, were members of day group WD3, which had its greatest abundance at 601–650 m (Table 135).

Only the shallowest groups showed any consistency in species composition from season to season. The night surface groups contained *G. cocco* and *M. nitidulum* at each of the three seasons. An additional species, *C. nigroocellatus*, was included in winter and late spring but was not included in the late summer analysis because it failed to meet the abundance criterion. However, it was most abundant at the surface at the last season and probably should be considered as a member of the surface group at all seasons. During the daytime the shallowest groups at each season (WD1, SPD1, and SUD1) all contained *N. valdiviae* and, if SPD1 and SPD2 can be considered a single group (see discussion of SPD2 in "Day 451–600 m Stratum"), also *L. dofleini*. No other group maintains its integrity from season to season or within a diel cycle. This lack of consistency in species associations over either time span appears to be yet another method by which the lanternfishes partition the resources of the mesopelagial.

At least some of the differences in species group composition can be explained by the differences in the number of species used in each of the six analyses. Most species were sampled better at night than during the day and, as a result, more species were included in the night analysis than in the day analysis at each season. At each season 12 to 16 species were common to both the day and night analyses. In winter one species was unique to the day subset and nine were unique to the night subset; in late spring five were used only in the day subset and six only in the night subset; and in late summer no species was unique to the day subset but nine were unique to the night subset. Because of these differences, the results of the daytime and nighttime analyses were not strictly comparable. However, the diel changes in the relations among those species common to both day and night subsets suggest that the differences between the day and night abundances at any season are not exclusively due to the differences in the subsets analyzed, and that the associations among some of the species do indeed change during the course of a day.

Similarly, within each diel period there are seasonal changes in the species included in the analyses; and the results from one season are not directly comparable to those from the other two. As was the case with diel associations, species common to the three seasonal subsets for each diel period also underwent changes in species associations from season to season again suggesting that the changes were not completely due to the differences in the subsets used.

As most of the species included in the subsets have a one-year life span, the population structure of most species changes from season to season. This means that even though some species may be closely associated over most of or throughout the year, the ecological relationship between those species would be different at each season. *Notolychnus valdiviae* and *L. dofleini* belonged to the same group during at least four, and probably five, of the six diel period-season combinations and, at each season, different stages (and sizes) were associated with each other. For example, in winter subadults were the most abundant stage for *N. valdiviae*, and adults for *L. dofleini*; in late spring subadults and adults were the dominant stages for *N. valdiviae*, and most *L. dofleini* were juveniles; and in late summer most *N. valdiviae* were juveniles and most *L. dofleini* were subadults. Differences in size between closely associated congeners have been discussed above.

General Conclusions

During the daytime the depth of maximum abundance of all species groups combined and the most abundant species group is found between 601 and 700 m at each

season. Diversity measured both by the number of species taken and the Shannon-Weiner Information Function is greatest between 601 and 950 m at each season.

At night the depth of maximum abundance of all species groups combined and of the most abundant species group is within the upper 100 m at each season. Diversity, as measured by both methods mentioned above, is greatest in the upper 250 m at each season.

Species groups were small, consisting of one to seven species each, and less than half of the groups included congeneric species. Congeners in the same group generally differed in size, depth of maximum abundance, overall vertical distribution, and/or relative abundance. Group species composition was seldom the same at different diel periods or different seasons.

The 32 species of lanternfishes used in the factor analyses probably represent no more than about 25 percent of the total number of the mesopelagic fish species found in the study area. It is most likely that the individual lanternfish species form closer ecological associations with species of other fish groups, or species of invertebrates, than with other species of lanternfishes. Studies of the mesopelagic fishes found off Hawaii (Amesbury, 1975), those found in the Santa Catalina Basin off southern California (Rainwater, 1975), and of the fishes and selected invertebrates found in the San Pedro Basin off southern California (Ebeling et al., 1970) indicate that the above was true in those locations. Although the methods used in each of the three studies cited were different, the groups formed in each location contained on the average two to three species of lanternfishes, which is similar to the value obtained in this study.

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Family Melamphaidae, Bigscales

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ABSTRACT

The bigscales of the family Melamphaidae are represented in the Ocean Acre collections by more than 4000 specimens distributed among 15 species in four genera. *Melamphaes pumilus* and *Scopeloberyx opisthopterus* were categorized as "abundant," *Poromitra capito* as "common," *Melamphaes typhlops* and *Scopelogadus m. mizolepis* as "uncommon," and the other ten species (6 *Melamphaes*, 1 *Poromitra*, 1 *Scopelogadus*, and 2 *Scopeloberyx*) as "rare." Developmental stages, reproductive cycles, seasonal abundance, vertical distribution, patchiness, and night-to-day catch ratio are discussed for each species for which there are enough data. Four of the five species that were not "rare" apparently breed in the Ocean Acre area. *Scopelogadus mizolepis* enters the area from the south in fair numbers during the warmer months, but does not appear to breed in the Ocean Acre. The other four species, *M. pumilus, M. typhlops, P. capito,* and *S. opisthopterus* differ in maximum size, longevity, depth distribution, presence or absence of vertical migratory behavior, and peak spawning period. The deepest-dwelling species, *S. opisthopterus*, a small species, lives at 800–1500 m and does not migrate vertically. The shallowest dweller, *M. pumilus*, a dwarf species, lives below 550 m during the day and migrates to as shallow as 50 m at night. Of the other two species, *M. typhlops*, a moderately large species, lives below 550 m and *P. capito*, a large species, below 800 m during the day, but neither appears to migrate regularly to depths shallower than 150 m. Five "rare" species also may breed in the Ocean Acre area: *Melamphaes ebelingi, M. longivelis, Melamphaes* sp., *Scopeloberyx robustus*, and *Scopeloberyx* sp. All five are represented in the area by at least one or two postlarvae and also by adults. The other five "rare" species do not breed in the area; two are represented by single specimens, the others by stages other than postlarvae and adults.

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Introduction

The Melamphaidae was the fourth most abundant family of fishes in the Ocean Acre area, behind the Gonostomatidae, Myctophidae, and Sternoptychidae in total number of specimens. This agrees with the relative numbers of these four families taken in Beebe's 8-mile cylinder near Bermuda (Beebe, 1937), although exactly which species are associated with Beebe's names is uncertain. Melamphaids are represented in the Ocean Acre collections by more than 4000 specimens distributed among 15 species in 4 genera. Table 147 shows, for each species, (1) the number of specimens taken on all cruises, (2) the number taken on the paired seasonal cruises, (3) the number taken in discrete-depth samples during the paired seasonal cruises, and (4) the number taken in noncrepuscular discrete-depth samples during the paired seasonal cruises. The last represents the primary database that was analyzed.

Methods

Methods of analysis, definition of terms, and abbreviations are given in the introductory paper in this volume. Abundance categories for each species follow the criteria of Karnella (this volume). The two "abundant" species of melamphaids, *Melamphaes pumilus* and *Scopeloberyx opisthopterus*, had a maximum seasonal abundance of 75 and 64 specimens per hour and were represented by 2604 and 595 specimens, respectively. The one "common" species, *Poromitra capito*, had a maximum abundance of 24 specimens per hour and was represented by 437 specimens. Two "uncommon" species, *M. typhlops* and *Scopelogadus mizolepis*, had a maximum abundance of 5 and 4 specimens per hour and were represented by 135 and 127 specimens, respectively. All ten other species (Table 147) were designated as "rare," with maximum abundance of 0–2 specimens per hour and represented by 1–40 specimens. Atlantic distributions are described on the basis of unpublished maps prepared by Keene.

TABLE 147.—Numbers of specimens of each species of Melamphaidae caught in all samples during cruises 1–14, in all samples, in all discrete-depth samples, and in all noncrepuscular discrete-depth samples made during the paired seasonal cruises (cruises 4 and 12, 10 and 14, 11 and 13).

SPECIES	CRUISES 1-14	PAIRED SEASONAL CRUISES		
	TOTAL	TOTAL	DISCRETE	NONCREPUSCULAR DISCRETE
Melamphaes ebelingi	11	10	4	4
M. longivelis	18	16	11	11
M. polylepis	1	0	0	0
M. pumilus	2604	1675	747	638
M. simus	1	0	0	0
M. suborbitalis	20	17	10	10
M. typhlops	135	111	47	41
Melamphaes sp.	14	9	4	4
Poromitra capito	437	333	177	112
P. megalops	4	3	2	2
Scopeloberyx opisthopterus	595	356	205	195
S. robustus	20	8	5	5
Scopeloberyx sp.	40	13	9	9
Scopelogadus beanii	16	10	5	5
S. m. mizolepis	127	97	29	23
TOTALS	4043	2658	1255	1059

Species Accounts

The following accounts discuss, where possible, developmental stages, reproductive cycle, seasonal abundance, sex ratios, vertical distribution, patchiness, and night-to-day catch ratios of the 15 species of melamphaids taken during the study. For the abundant and common species, there were enough data to perform detailed analyses for most or all categories. For others, detailed analyses could be done only for certain categories, and, for still other species, there were almost no data, and only vertical distribution or not even that could be discussed.

Melamphaes pumilus

The most abundant melamphaid at all seasons in the Ocean Acre area, this species is confined to the western gyre of the North Atlantic, west of 25°W between 10° and 45°N, but mostly between 20° and 40°N. It is a diminutive species, rarely exceeding 22 mm SL; its maximum size is 24 mm. It was represented in the Ocean Acre collections by 2604 specimens; 1675 were taken during the seasonally paired cruises, including 747 in discrete-depth samples, with 638 of these from noncrepuscular tows (Table 147).

DEVELOPMENTAL STAGES.—Postlarvae were characterized by the absence of pigment and small size (10 mm or less). Juveniles ranged from those just developing adult

coloration (9–10 mm) up to 15 mm; their gonads were small and located posterodorsad to the terminal enlargement of the intestine (rectum). Subadults were 14–18 mm and showed progressive enlargement of the gonads that was obvious in both sexes, but moreso in females; the gonads were mainly lateral to the rectum and extended anteriorly beyond the rectal enlargement. Adults were 18–24 mm. Adult females had large eggs, and the ovaries extended well forward, occupying most of the coelom. In adult males the testes were larger than in subadults, but the size difference was less obvious than for ovaries. External sexual dimorphism was not evident in any of the stages.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Melamphaes pumilus appears to have a one-year life cycle. It apparently breeds throughout the year, with a peak in spring and early summer (Table 169). This species was most abundant in winter, when subadults and adults comprised most of the catch, least abundant in late spring, and intermediate in abundance in late summer, when postlarvae and juveniles were at their greatest abundance (Table 148).

All stages occurred at all seasons, indicating year-around spawning. The peak of spawning probably is in spring and early summer, as indicated by the large number of postlarvae and juveniles caught in July and September (Table 149; includes nondiscrete samples) and the greatest abundance of these stages in the late summer in the paired cruises (Table 148). The ovaries of adult females taken throughout

the year had fairly large eggs, 0.25–0.35 mm in diameter, but three adult females captured in March and June possessed eggs twice as large (0.6–0.7 mm). These eggs were swollen and had a much thicker translucent area surrounding the yolk than those of most adult females. Presumably these females were caught just prior to spawning, reinforcing the suggested time of peak spawning.

In winter, over 95% of the population consisted of subadults and adults, with adults about twice as abundant as subadults (Table 148). By late spring, the few winter postlarvae and juveniles had become juveniles and subadults, respectively, and almost 70% of the sampled population consisted of adults. Adults, however, were less abundant at this time than in winter, which may be attributed to mortality following spawning. Postlarvae probably were small and undersampled. In July and September (Table 149) juveniles appear in abundance, and subadults were more numerous. These probably represent mainly the recruits from the spring spawning. At the same time, adults have become still less abundant, due to continuing mortality. Continued into the fall and winter, this sequence of events should result in juveniles becoming less abundant as they become subadults, and both subadults and adults increasing in abundance. The data in Table 149 suggest that juveniles are, indeed, the most abundant stage in October–November (almost 65% of the total) and subadults the most abundant stage in December (almost 64%). This would lead to the predominance of adults in winter, already noted.

The seasonal progression of developmental stages and the fact that adults compose a majority of the catch only in winter and spring indicate a one-year life cycle. Further evidence was provided by otoliths from 10 of the largest adults (22–23 mm) from different seasons, all of which have only the initial opaque central ring surrounded by a translucent area, indicating that they are less than a year old. The central ring is present in the otoliths of juveniles, but the translucent belt surrounding it is narrower than that of subadults and adults.

SEX RATIOS.—Table 150 shows the numbers of each sex for each sampling period. During no period was there a significant difference in the number of juvenile males and females. A trend toward males being more abundant than females is seen in subadults, although only one sample showed a statistically significant difference. Adult males outnumber adult females at all times except in April, which was represented by a relatively small sample, and in August, when sampling was done with the large Engel trawl (EMT). If the two discordant samples of adults are ignored, and adult males do, indeed, outnumber adult females, a differential mortality during reproduction would explain the phenomenon. Females might die soon after spawning, but males might not die for some time, possibly spawning several times during the season.

TABLE 148.—Seasonal abundance and percent of total abundance (in parentheses) for *Melamphaes pumilus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.2 (1.6)	2.1 (2.8)	23.5 (31.5)	47.8 (64.1)	74.6
LATE SPRING	0.3 (0.8)	3.0 (8.1)	8.5 (23.0)	25.1 (68.0)	36.9
LATE SUMMER	9.7 (17.4)	11.7 (20.9)	15.1 (27.0)	19.4 (34.7)	55.9

TABLE 149.—Numbers caught of each stage of *Melamphaes pumilus* by month, with percent of monthly total in parentheses (AD = adults; JUV = juveniles; PL = postlarvae; SAD = subadults).

MONTH	PL	JUV	SAD	AD
JAN–FEB	12 (4.7)	31 (12.0)	59 (22.8)	156 (60.5)
MARCH	3 (1.5)	16 (7.5)	34 (16.0)	159 (75.0)
APRIL	0	7 (11.5)	11 (17.5)	45 (72.4)
JUNE	16 (4.6)	38 (10.8)	64 (18.2)	233 (66.4)
JULY	58 (27.6)	59 (28.1)	29 (13.8)	64 (30.5)
SEPTEMBER	71 (9.7)	259 (35.6)	203 (27.8)	196 (26.9)
OCT–NOV	0	192 (64.6)	94 (31.6)	11 (3.8)
DECEMBER	1 (1.8)	3 (5.5)	35 (63.6)	16 (29.1)

TABLE 150—Numbers of each sex for each stage of *Melamphaes pumilus* by months (AD = adult; F = female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; significant differences indicated by Chi-square test shown by a single asterisk (p = .05) or two asterisks (p = .01)).

MONTH	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
JAN–FEB	11	20	30	28	92	62*	133	110
MARCH	7	8	21	11	87	56**	115	75*
APRIL	4	3	8	3	14	31*	26	37
JUNE	18	17	38	22*	125	99	181	138*
JULY	23	36	10	17	45	18**	78	71
AUG (EMT)	0	0	27	26	162	206*	189	232
SEPTEMBER	121	128	109	85	120	75**	350	288*
OCT–NOV	83	86	44	38	6	2	133	126
DECEMBER	2	1	12	21	11	4	25	26

VERTICAL DISTRIBUTION.—This species is most abundant from 51 to 400 m at night and from 551 to 1300 or 1350 m during the day (Table 151). It is rare in the upper 50 m at night, and only one subadult male was taken at the surface in a crepuscular sample in July. Diel migratory behavior is indicated clearly in juveniles, subadults, and adults.

TABLE 151.—Vertical distribution by 50-m intervals of *Melamphaes pumilus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
51- 100									<1				<1	3	10.0	10	1				1	5	8.2	8-9
101- 150																	<1				<1	1	9.0	9
501- 550									-	-	-	-	-						<1		<1	1	18.0	18
551- 600				3	3	6	20.3	20-21				1	1	2	20.5	20-21	<1			1	1	5	17.4	7-21
601- 650		1			1	2	10.0	10				1	1	3	21.7	21-22				1	1	2	20.5	19-22
651- 700		1			1	*			<1	<1	<1		1	7	11.7	9-22	<1			<1	1	*		
701- 750	<1				<1	1	11.0	11		1	<1	<1	1	*			<1	1	<1		1	4	13.5	10-18
751- 800	-	-	-	-	-					1	1	<1	2	13	14.7	13-19		4	1	<1	5	15	14.0	12-21
801- 850											1	1	2	*				2	1	1	3	7	15.5	13-22
851- 900	-	-	-	-	-						1	1	2	7	17.7	15-21			1	<1	1	*		
901- 950	-	-	-	-	-						1	4	6	*					<1	<1	1	2	18.5	17-20
951-1000	-	-	-	-	-						1	7	9	36	19.5	16-21				<1	<1	*		
1001-1050			1		1	2	18.0	18				4	4	*						<1	<1	1	20.0	20
1051-1100			1		1	*						1	1	1	21.0	21				1	1	*		
1101-1150			1		1	*														1	1	2	21.5	21-22
1151-1200			1		1	*														1	1	1	17.0	17
1201-1250			1	1	2	2	20.0	18-22				3	3	8	21.5	19-23								
1251-1300				3	3	6	21.3	21-22	-	-	-	-	-							1	1	1	19.0	19
1301-1350	-	-	-	-	-				-	-	-	-	-							2	2	3	21.3	21-22
1351-1400	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1401-1450	-	-	-	-	-				-	-	-	-	-				-	-	-	-	-			
1451-1500	-	-	-	-	-				-	-	-	-	-											
1501-1550	<1				<1	1	12.0	12																
TOTALS	0	2	5	7	13	20			1	2	6	23	31	80			2	6	4	8	20	50		
NIGHT																								
1- 50												1	1	1	21.0	21	2				2	3	6.7	6-7
51- 100	<1	<1			<1	4	10.5	9-13	<1	2	<1	<1	3	15	12.0	8-20		1	<1		1	10	12.9	11-16
101- 150		1			1	2	11.5	10-13		<1	2	4	7	17	18.7	14-22	6	4	5		14	43	12.1	9-17
151- 200		1	1	<1	2	9	14.6	10-20		1	3	4	7	12	18.4	12-22	<1	2	5	2	9	55	16.3	9-23
201- 250			1	1	2	6	18.2	15-21			2	9	11	32	20.1	15-23		2	2	3	7	41	17.1	10-22
251- 300			6	10	16	*					1	1	2	5	18.8	17-21	<1	2	1	7	10	31	17.7	9-23
301- 350			11	18	30	62	18.7	16-21			<1	2	3	*				<1	2	4	6	30	18.9	10-22
351- 400			4	18	22	73	19.6	17-22				3	3	10	21.5	20-22				2	2	4	21.2	20-22
401- 450	<1				<1	1	10.0	10											<1		<1	1	15.0	15
451- 500				<1	<1	1	20.0	20	<1		<1	<1	1	2	16.5	11-22				1	1	4	21.0	20-22
501- 550				1	1	2	21.0	19-23			<1	<1	1	1	22.0	22								
551- 600	1				1	2	10.0	10				1	1	2	22.0	22	-	-	-	-	-			
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-				2			1	2	4	12.2	9-20
701- 750									-	-	-	-	-				1				1	1	9.0	9
751- 800																								
801- 850																	-	-	-	-	-			
851- 900	-	-	-	-	-				-	-	-	-	-					<1			<1	1	13.0	13
901- 950	-	-	-	-	-																			
951-1000																		<1			<1	1	10.0	10
TOTALS	1	2	24	48	75	162			<1	3	9	25	37	97			10	12	15	19	56	229		

Both stage- and size-stratification are apparent both day and night. Postlarvae were taken at 51–100 m during the day and between 33 and 300 m at night, most of them between 51 and 150 m. The latter depths correspond to the maximal seasonal thermocline. Larger postlarvae were taken at 551–750 m, to which depths they descend prior to transformation to the juvenile stage. The possibility of diel vertical migration by some of the deeper postlarvae cannot be ruled out, but we suspect that it does not occur. That vertical migration begins in juveniles is suggested by two small transitional juveniles that had not migrated upward, but were caught in late summer between 851 and 1000 m at night (Table 151). Later developmental stages and larger sizes tend to occupy greater depths (Table 151), a fact noted by Ebeling (1962). This is most obvious at night because of the greater number of specimens caught. Each succeeding stage inhabits a more extensive range of depths, is most abundant at a greater depth, and extends to greater maximum depths than the preceding stage. There is, however, considerable overlap in vertical ranges, with adults occurring throughout most or all of the ranges of the other stages and sometimes exceeding both their upper and lower limits. This is illustrated well by the late spring data and by the night data for the other two seasons (Table 151).

Depths occupied by males and females appeared to be identical at any stage.

PATCHINESS.—Patchiness of distribution appears to be characteristic of all stages of *M. pumilus*. Significant clumping at night was indicated in winter at 151–200 m, 301–400 m, and 501–600 m; in late spring at 51–100 m and 201–250 m; and in late summer at 51–150 m and 451–500 m. The only significant clumping during the day was in late spring at 951–1000 m. At 7 of the 11 50-m intervals for which clumping was indicated, the seasonal maximum catch rate occurred for at least one developmental stage, and two other intervals had catch rates very near the maximum for one stage.

With one exception, all stages appear to have patchy distributions at all seasons. In late summer, adults were apparently randomly distributed; no clumping was indicated from 151 to 400 meters at night, at which depths almost all adults were taken. Most adults are probably in a postspawning condition in late summer, with death imminent, and

their normal tendency toward aggregation presumably is lost under such conditions.

NIGHT:DAY CATCH RATIOS.—The ratios of night to day discrete-depth captures, using interpolation in unsampled depth intervals, were 5.6:1 in winter, 1.2:1 in late spring, and 2.9:1 in late summer (Table 152). Adults and subadults are responsible for most of the catch rates, but postlarvae and juveniles generally show the same propensity to be more abundant in night samples.

The nearly equal ratio in late spring suggests that factors other than enhanced daytime avoidance alone may be responsible for the predominance of night over day captures. One possibility is the constriction of the vertical ranges at night, while another is seasonal differences in clumping.

Constriction of the vertical range would enhance the chances that either randomly distributed or aggregated populations would be sampled. The degree of constriction of the vertical range at night increases in the same seasonal order as the night:day catch ratios. If all postlarvae and those small juveniles that remain deep at night are ignored, the vertical ranges of all other stages are included within that of adults both day and night (Table 151) with two exceptions. At night, adults were taken 100 m shallower than juveniles and subadults in winter, and in late summer both juveniles and subadults were taken 100 m shallower than adults. As defined, the night vertical range was 53% of the daytime range in winter, 86% in late spring, and 69–81% in late summer (shallow juveniles and subadults made up a significant part of the catch at this time).

The effect of night constriction of the vertical range is magnified for adults, which were taken in greatest abundance in only part of the night vertical range. In winter, most adults were taken in a 100 m stratum (150 m with interpolation) within a vertical range of 400 m; in late spring most were taken in 300 m within a 600-m breadth; and in late summer most were taken in 250 m within a 550-m breadth. Considering both total vertical ranges and adult concentrations, the compression is greatest in winter, when the night:day ratio also is greatest, next greatest in late summer, and least in late spring, which has the lowest ratio (Table 152).

The presence of aggregations of *M. pumilus* during the day, indicated as being uncommon, nevertheless may involve a significant part of the population that was not adequately sampled. The only instance of significant daytime clumping was at one 50-m depth interval in late spring, the only season when the night:day catch ratio approached 1:1. If the catch rate for adults alone in this interval had been 1.0, as in both adjacent sampled (not interpolated) intervals, instead of 7.2 (Table 151), the ratio would have been 1.9:1 instead of 1.2:1, approaching that for late summer.

Net avoidance remains a possible contributor to the night:day imbalance. If *M. pumilus* is inactive during the

TABLE 152.—Seasonal night to day catch ratios of *Melamphaes pumilus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	1.1:1	5.2:1	7.0:1	5.6:1
LATE SPRING	0.5:1	1.5:1	1.5:1	1.1:1	1.2:1
LATE SUMMER	5.1:1	1.9:1	4.3:1	2.5:1	2.9:1

day, and rests in a vertical position, as Barham (1971) noted in several myctophids, this would enhance the likelihood that they would dart out of the net's path. No direct observations of *M. pumilus* have been made, however, and this possibility is conjectural.

Melamphaes typhlops

This species is uncommon in the Ocean Acre. It inhabits the Atlantic between 30°S and 45°N. It is one of the few large *Melamphaes* species (reaching 100 mm SL elsewhere, 73 mm in the Ocean Acre) that seems to occur in relatively sterile as well as productive waters. A total of 135 specimens was taken: 23 postlarvae, 75 juveniles, 19 subadults, and 18 adults. Of these, 51 were taken in discrete-depth samples, 41 of the 51 in noncrepuscular samples from the paired cruises (Table 147).

DEVELOPMENTAL STAGES.—Postlarvae, with light pigmentation on certain parts of the body (Ebeling, 1962), were 5–13 mm, the largest beginning to acquire adult coloration. Juveniles were 12–40 mm. The juvenile-subadult transition occurs at about 35–40 mm, and the subadult-adult transition at approximately 45–54 mm. Subadults in Ocean Acre samples were 35–54 mm, adults 46–73 mm.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—Captures of postlarvae from January to September (Table 153) indicate that *M. typhlops* breeds during most of the year. No obvious peak spawning period can be discerned. This species probably spawns for the first time when it is 45–50 mm. Specimens as large as 70 mm suggest that *M. typhlops* lives as long as two years and probably spawns more than once. Two March specimens 53–54 mm (Table 153), called subadults, were of adult size but had immature gonads. Probably they were adults which already had spawned once.

M. typhlops was most abundant in winter and decreased in numbers through late spring and late summer (Table 154). The specimens that comprise the catch on which these figures are based are almost entirely postlarvae and juve-

TABLE 154.—Seasonal abundance and percent of total abundance (in parentheses) for *Melamphaes typhlops* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0.7 (15.2)	3.3 (71.7)	0	0.3 (6.5)	4.6
LATE SPRING	1.6 (44.4)	1.7 (47.2)	0	0.3 (8.3)	3.6
LATE SUMMER	0	1.1 (100)	0	0	1.1

niles. Most of the subadults and adults were caught by the EMT in late August; their absence in an adjacent IKMT cruise in early September suggests that older specimens could have been present at other times but were not taken.

VERTICAL DISTRIBUTION.—Discrete-depth samples (Table 155) captured 3 postlarvae at 51–100 m during the day, and 6 at 1–100 m at night. All were 5–11 mm, and none were metamorphosing; presumably they do not migrate vertically. One 8-mm postlarva was caught at night at 701–750 m. Probably it is a contaminant. Two metamorphosing postlarvae (both 12 mm SL), were caught at 551–750 m during the day, indicating that metamorphosis occurs at depth. At night, several specimens arbitrarily called juveniles (13–15 mm), but still metamorphosing, were caught at 150–200 m, suggesting that vertical migration begins before metamorphosis is completed.

All stages from juvenile to adult apparently undertake diel vertical migrations. Twelve juveniles were taken between 551 and 1000 m during the day and 12 between 151 and 1000 m at night, most of them above 500 m. The only subadult was taken during the day at 1001–1050 m. Two adults were taken during the day at 1001–1150 m, and two at night at 551–600 m.

Ten of 13 adults taken at night by the EMT were caught at maximum depths between 725 and 1000 m; the remaining three were from maximum depths of 450 m and 575 m. Although the EMT sampled to 1000 m during the day, it caught no adults, suggesting that adults inhabit depths below 1000 m during this time. This is also indicated by the IKMT data. Juveniles and subadults were taken below 700 m during the day and as shallow as 200 m at night in EMT and other open-net samples. Both the discrete-depth data (Table 155) and open-net data indicate that larger specimens tend to occupy greater depths both day and night.

NIGHT:DAY CATCH RATIOS.—The ratios of night to day discrete-depth captures, using interpolation for unsampled depth intervals, were 1.2:1 in winter, 1.6:1 in late spring, and 3.7:1 in late summer (Table 156). These data suggest daytime avoidance, but the numbers of specimens involved,

TABLE 153.—Numbers caught and range of sizes (in mm) of each stage of *Melamphaes typhlops* arranged by month (AD = adults; JUV = juveniles; PL = postlarvae; SAD = subadults).

MONTH	PL		JUV		SAD		AD	
	NO.	SIZE	NO.	SIZE	NO.	SIZE	NO.	SIZE
JAN-FEB	9	5-12	11	12-27	1	39	2	46-50
MARCH	0		1	13	2	53-54	0	
APRIL	1	13	0		0		0	
JUNE	6	8-12	22	12-35	1	45	1	47
JULY	3	10-13	2	21-21	1	47	0	
AUG-SEPT	4	7-12	37	17-40	11	35-46	14	47-73
NOV-DEC	0		2	26-33	3	38-39	1	71

TABLE 155.—Vertical distribution by 50-m intervals of *Melamphaes typhlops* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE	LATE SPRING CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE	LATE SUMMER CATCH RATE PL	JUV	SA	AD	TOT	SL N	X	RANGE
								DAY																
51- 100									<1				<1	3	10.0	9-11								
101- 150																								
151- 200																								
201- 250	-	-	-	-	-				-	-	-	-	-											
251- 300																								
301- 350																								
351- 400																								
401- 450	-	-	-		-				-	-	-	-	-											
451- 500																								
501- 550									-	-	-	-												
551- 600	<1	<1			1	2	18.5	12-25																
601- 650																								
651- 700		<1		<1		*											-	-	-	-	-			
701- 750		<1		<1		1	17.0	17	-	-	-	-	-											
751- 800		1			1	*					1		1	6	17.5	14-20								
801- 850		1			1	2	12.5	12-13		<1			<1	*										
851- 900	-	-	-		-												-	-	-	-	-			
901- 950	-	-	-		-					<1			<1	*										
951-1000	-	-	-		-					<1			<1	2	33.9	33-35	-	-	-	-	-			
1001-1050		<1	<1		1	2	44.5	39-50	-	-	-	-	-											
1051-1100	-	-	-		-												-	-	-	-	-			
1101-1150	-	-	-		-															<1	<1	1	48.0	48
TOTALS	<1	2	<1	<1	4	7			<1	2	0	0	2	11			0	0	0	<1	<1	1		
								NIGHT																
1- 50									1				1	1	9.0	9								
51- 100	<1				<1	4	8.0	5-10	<1				<1	1	8.0	8								
101- 150																								
151- 200										1			1	1	13.0	13								
201- 250		<1			<1	1	13.0	13										<1			<1	1	17.0	17
251- 300		<1			<1	*				1			1	1	16.0	16								
301- 350		1			1	1	18.0	18		<1			<1	*										
351- 400		<1			<1	1	20.0	20		<1			<1	1	27.0	27								
401- 450		<1			<1	1	13.0	13																
451- 500																		<1			<1	2	24.0	23-25
501- 550																								
551- 600			<1		<1	1	46.0	46	<1			<1	1	2	28.5	12-45	-	-	-	-	-			
601- 650									-	-	-	-	-											
651- 700	-	-	-	-	-				-	-	-	-	-					1			1	1	40.0	40
701- 750	<1				<1	1	8.0	8	-	-	-	-	-											
751- 800																								
801- 850																								
851- 900									-	-	-	-	-											
901- 950		1			1	*			-	-	-	-	-											
951-1000		1			1	1	27.0	27																
TOTALS	1	3	0	<1	4	11			2	2	0	<1	4	7			0	1	0	0	1	4		

TABLE 156.—Seasonal night to day catch ratios of *Melamphaes typhlops* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.8:1	1.4:1	*	0.8:1	1.2:1
LATE SPRING	4.0:1	0.9:1	*	*	1.6:1
LATE SUMMER	*	*	*	*	3.7:1

especially in late summer, are so small that such a conclusion is uncertain. The higher night ratio is attributable mainly to juveniles in winter and late summer, and to postlarvae in late spring. The day and night vertical ranges of juveniles were similar (250–300 m breadth) in winter and late spring, no compression of range at night being indicated (no juveniles were taken in discrete-depth samples during the day in late summer).

Melamphaes suborbitalis

This is one of the larger melamphaids, attaining a standard length of at least 90 mm. It is rare in the Ocean Acre area, tending to favor the more productive waters off the coasts of Africa and North America. In the North Atlantic, its range is from 30° to 40°N west of 40°W and, east of 30°W, from the equator to 55°N. Twenty juveniles 20 to 44 mm were taken in the Ocean Acre, 10 of these in discrete-depth, noncrepuscular samples from the paired cruises (Table 147).

Juveniles undergo a diel vertical migration. Daytime discrete-depth sampling at 800, 900, and 1025 m took 5 specimens, and open nets fishing at a maximum depth of 950 m caught two. At night, six specimens were taken in discrete-depth samples at 125, 175, 205, 275, 290, and 800 m, and open nets sampling at maximum depths of 150 to 680 m captured seven.

M. suborbitalis was taken in the Ocean Acre in January, February, April, June, July, August, and September.

Melamphaes longivelis

This is another large melamphaid that prefers productive waters. It is rare in the Ocean Acre area, being more common south of 25°N. Eighteen specimens were taken, 11 of these in discrete-depth, noncrepuscular samples from the paired cruises. They include one postlarva (15 mm), 16 juveniles (19–46 mm), and one adult female (127 mm).

The postlarva was caught in a discrete-depth sample near dawn at 140 m. Juvenile *M. longivelis* appear to migrate to shallow depths at night. Six were taken in discrete-depth samples from 825 to 1025 m during the day; at night, four were caught in discrete-depth samples from 140, 175, and

215 m, and six in open nets sampling at maximum depths of 150 to 1250 m. The adult came from an open-net haul to a maximum depth of 750 m.

M. longivelis was taken in the Ocean Acre in January, February, March, June, August, and September.

Melamphaes sp.

This undescribed species of *Melamphaes* is closely related to *M. indicus* and *M. janae* (Keene, personal communication). The species inhabits the North Atlantic between about 25°S and 30°N; in the northwestern part, it has not been taken between 10° and 25°N. Ocean Acre collections contain 14 specimens of this species, 4 of them from discrete-depth, noncrepuscular samples from the paired cruises (Table 147). They include two postlarvae (15–16 mm), ten juveniles (16–37 mm), and two adults (51–54 mm).

One postlarva was caught in a daytime discrete-depth sample at 635–680 m, the other in an open-net sample from a maximum of 1150 m during the dusk migration period. One juvenile was taken in a daytime discrete-depth sample at 808–865 m and another in a daytime open-net sample from a maximum depth of 1550 m. At night two juveniles were taken in discrete-depth samples at 230 and 175 m and six in open-net samples at maximum depths of 290 to 780 m. Both adults were taken by the large EMT, one during the day at a maximum depth of 800 m, one at night at a maximum depth of 760 m. The data for juveniles indicate that they undergo diel vertical migration.

This species was taken in the Ocean Acre from January to August. Three specimens (16–18 mm) were taken in January and February, four (15–20 mm) in March, one (25 mm) in April, one (18 mm) in June, and three juveniles (24, 33, 37 mm) in August. The two adults were taken in August.

Melamphaes ebelingi

Most known specimens of this species are from near Bermuda (Keene, 1973). The few others have been taken across the Atlantic between 20° and 25°N, with one at 5°S, 16°W. Ocean Acre collections contain 11 specimens, 4 of which are from discrete-depth, noncrepuscular samples from the paired cruises. They include 1 postlarva (17 mm), 7 juveniles (20.8–37.8), 1 subadult male (50.0), and 2 adult females (124.8–137.4).

During the day one juvenile was taken in a discrete-depth sample at 970–1060 m, and one postlarva, one juvenile, and the only subadult were taken by open nets sampling to maximum depths of 870–1060 m. At night juveniles were taken in discrete-depth samples at 290 m and 520 m and in nonclosing nets fishing to maximum depths of 300–780 m. One adult was taken at night in a discrete-depth sample at 1483–1548 m, the other in an EMT at a maximum depth of 1025 m. The adult from the eastern Atlantic was cap-

TABLE 157.—Numbers caught and sizes (in mm) of each stage of *Poromitra capito* arranged by month (AD = adults; JUV = juveniles; PL = postlarvae; SAD = subadults; X = mean size).

MONTH	PL			JUV			SAD			AD		
	NO.	SIZE	X	NO.	SIZE	X	NO.	SIZE	X	NO.	SIZE	X
JAN-FEB	112	5-15	10.2	108	15-31	19.4	1	58	58.0	0		
MARCH	8	8-15	12.2	76	13-33	22.2	0			1	79	79.0
APRIL	1	13	13.0	4	23-38	31.1	0			0		
JUNE	0			27	24-47	35.9	4	65-73	68.3	1	87	87.0
JULY	0			4	39-48	43.3	1	61	61.0	0		
AUG-OCT	0			63	36-56	45.1	8	51-80	63.5	13	72-99	84.1
NOV-DEC	0			0			0			5	82-99	86.8

tured at night in an open net fished to 2100 m. These data suggest that juveniles undertake diel vertical migrations, but that adults may not.

The Ocean Acre specimens were taken from February through August. The 17 mm postlarva was taken in March, suggesting a late fall or winter spawning period. Specimens in June were 21-31 mm; in July 50 mm; in August, 29, 38, 51, and 137 mm; and in February, 125 mm. The 17-38 mm specimens almost certainly represent year class zero. The 50 mm specimen taken in July, a subadult, probably was in its second year of life, suggesting that sexual maturity may first be attained in the second fall or winter. The presence of 125 and 137 mm specimens suggests a life span of at least three or four years.

Melamphaes simus

One adult female (28.0 mm) *M. simus* was taken in the Ocean Acre in August during the day by an Engel trawl fishing to 1025 m. The main populations of this species are in the eastern Atlantic and the Gulf of Mexico. The Ocean Acre specimen probably was a waif from the latter population in the Gulf Stream circulation.

Melamphaes polylepis

M. polylepis has been recorded in the Atlantic mostly between 20°S and 20°N, but has been taken in the Straits of Florida. One juvenile female (37.0 mm) was captured in the Ocean Acre area in August during the day by an EMT fishing at 1025 m.

Poromitra capito

This is one of the larger melamphaids, reaching 99 mm. It is limited in distribution mainly to the subtropical North Atlantic, with eastern populations reaching 50°N. In the Ocean Acre it was common in winter, but uncommon in

other seasons. A total of 437 specimens was taken during all cruises. During the seasonal paired cruises 333 specimens were taken, 177 of these in discrete-depth samples: 34 during the day, 78 at night, and 65 during crepuscular periods (Table 147).

DEVELOPMENTAL STAGES.—Samples from all cruises included 121 postlarvae, 282 juveniles, 14 subadults and 20 adults. Postlarvae were 5-15 mm, juveniles 13-56 mm, subadults 51-80 mm, and adults 72-99 mm. All specimens larger than 30 mm were sexed. Adult females are larger than adult males (92-99 mm, mean 96.7 mm vs. 72-87 mm, mean 82.7 mm).

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Poromitra capito* probably has a spawning peak in November or December as manifested by the numbers of postlarvae in January and February (Table 157). During other parts of the year postlarvae were rare or absent in our samples. Juveniles also were abundant in January and February, and they predominated at all other times. This may be due to the scarcity of larger sizes or the ability of large specimens to avoid the IKMT. Engel trawls caught 18 of the 34 subadults and adults.

The average size of juveniles increases progressively from 19.4 mm in January to 45.1 mm in September (Table 157). By the end of their first year they probably attain a length of about 50 mm. They appear to reach a length of about

TABLE 158.—Seasonal abundance and percent of total abundance (in parentheses) for *Poromitra capito* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	6.3(26.3)	17.7(73.8)	0	0	24.0
LATE SPRING	2.3(65.7)	0.8(22.9)	0.4(11.4)	0	3.5
LATE SUMMER	0	2.9(100)	0	0	2.9

TABLE 159.—Vertical distribution by 50-m intervals of *Poromitra capito* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER								LATE SPRING								LATE SUMMER							
	CATCH RATE					SL			CATCH RATE					SL			CATCH RATE					SL		
	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE	PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
1- 50	<1				<1	1	7.0	7																
51- 100	1				1	2	11.5	10-13																
101- 150	1				1	1	11.0	11																
151- 200																								
201- 250	-	-	-	-	-				-	-	-	-	-											
251- 300																								
301- 350																								
351- 400																								
401- 450	-	-	-	-	-				-	-	-	-	-											
451- 500																								
501- 550	1				1	1	14.0	14	-	-	-	-	-											
551- 600																								
601- 650																								
651- 700	<1				<1	*											-	-	-	-	-			
701- 750	<1				<1	1	15.0	15	<1				<1	*										
751- 800	<1	2	1		3	*			<1				<1	1	39.0	39								
801- 850		5			5	14	15.7	15-17	<1				<1	*										
851- 900		4			4	*											<1				<1	*		
901- 950		2			2	*			<1	<1	<1		1	*				1			1	2	42.5	40-45
951-1000		1			1	*				1	<1	<1	1	7	52.4	26-87		1			1	*		
1001-1050									<1	<1	<1		1	*				1			1	2	49.5	49-50
1051-1100	-	-	-		-	-											<1				<1	*		
1101-1150		1			1	2	22.2	15-31																
TOTALS	4	14	0	0	18	22			0	2	1	<1	4	8			0	3	0	0	3	4		
NIGHT																								
101- 150	3				3	15	11.1	9-13																
151- 200	2	<1			2	12	12.9	11-21																
201- 250	<1	6			6	19	23.2	10-29																
251- 300	<1	3			3	*				1			1	1	25.0	25	<1				<1	1	48.0	48
301- 350		1			1	1	19.0	19		1			1	*				1	<1		1	5	45.4	37-48
351- 400		1			1	4	21.4	17-24		1			1	2	33.5	29-38								
401- 450		3			3	9	21.7	16-29																
451- 500																								
501- 550										<1			<1	1	65.0	65								
551- 600	1	1			1	3	15.0	14-16									-	-	-	-	-			
601- 650									-	-	-	-	-											
651- 700		<1			<1	*			-	-	-	-	-											
701- 750		1			1	2	15.5	15-16	-	-	-	-	-											
751- 800	<1				<1	1	15.0	15																
801- 850																	-	-	-	-	-			
851- 900									-	-	-	-	-											
901- 950		1			1	*																		
951-1000		1			1	1	16.0	16																
1001-1050		1			1	1	16.0	16	-	-	-	-	-											
TOTALS	6	18	0	0	24	68			0	2	<1	0	2	4			0	1	<1	0	1	6		

70 mm by the end of their second year, and in their third year they become adults and spawn. There is no evidence to suggest that they live beyond three years.

P. capito was abundant in winter, but uncommon in late spring and late summer (Table 158). Postlarvae and juveniles constitute the vast majority of the catch in discrete-depth samples, and these stages are at peak abundance in winter. The radical decline in catch rate for the other two seasons must be the result of juveniles attaining a size and development that allowed them to avoid the IKMT. The large winter catch in discrete-depth samples was composed almost entirely of specimens smaller than 30 mm SL, and it would seem that avoidance ability becomes increasingly effective at sizes larger than 30 mm.

VERTICAL DISTRIBUTION.—Discrete-depth noncrepuscular sampling by the paired cruises resulted in the capture of 112 specimens: 90 in winter, 12 in late spring, and 10 in late summer. All of the winter specimens were postlarvae and juveniles up to 31 mm SL. During June and September mostly larger sizes (over 30 mm) were taken, but not in abundance. Consequently the vertical distribution picture based on discrete-depth samples is limited mainly to postlarvae and juveniles (Table 159).

In winter 4 postlarvae were caught during the day between 50–150 m and 2 metamorphosing postlarvae at 501–750 m. At night 26 postlarvae were caught between 101–200 m and 2 metamorphosing postlarvae at 551–600 m. Postlarvae inhabiting the 50–200 m stratum do not appear to migrate. Transitional postlarvae and small juveniles (up to 17 mm SL) occur in deeper water, 551–1050 m, where metamorphosis apparently occurs.

Some small juveniles (16–19 mm) were taken at 301–450 m, indicating that some individuals begin to undertake vertical migrations at this size. Juveniles larger than about 20 mm and subadults show a definite vertical migration. They occurred between about 751 m and 1050 or 1100 m during the day (perhaps to 1550 m) and were taken at 251–550 m at night.

The only adult taken in a discrete-depth sample was from 951–1000 m during the day. In open nets, mostly EMT samples in September, adults were caught only below 1000 m during the day, while at night they were taken as shallow as 750 m.

Stage stratification is apparent in winter (Table 159). During daytime, small postlarvae were taken in the upper 150 m, larger ones at 501–800 m; juveniles occurred between 751–1000 m. At night, postlarvae were taken at 101–300 m (some of these apparently were new migrators; a nonmigrator was at 551–600 m); juveniles occurred at 151–450 m, nonmigrators below 550 m.

Size stratification is indicated at other seasons, and the few subadults and adults suggest stage stratification as well. During the day in late spring (Table 159), juveniles occurred at 701–1050 m, subadults and adults only at 901–

TABLE 160.—Seasonal night to day catch ratios of *Poromitra capito* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	1.6:1	1.2:1	*	*	1.3:1
LATE SPRING	*	0.7:1	0.4:1	*	0.6:1
LATE SUMMER	*	0.4:1	*	*	0.5:1

1050 m. The largest individuals were taken at the latter depth. During the day in late summer, both specimens taken at 901–950 m were smaller than the two taken at 1001–1050 m. At night, size increases with depth in late spring. The late summer data are inconclusive.

The extent of vertical migration appears to decrease with increasing size of fish. Small juveniles migrate from about 700–850 m to 150–250 m (Table 159, winter), larger juveniles from 750–1050 m to 250–400 m (Table 159, late spring and late summer). Subadults migrate from about 951–1000 m only to 501–550 m (Table 159, late spring). Adults, as already indicated, were not taken above 750 m at night in open nets (mostly EMT's).

PATCHINESS.—Patchiness of distribution was indicated only in winter, at which time clumping was shown at 801–850 m during the day and at 101–150 m and 551–600 m at night. The largest specimen at any of these depth intervals was 17 mm SL; thus it appears that, at sizes larger than 17 mm, the distribution is not characterized by patchiness.

NIGHT:DAY CATCH RATIOS.—The ratios of night to day discrete-depth captures, using interpolation in unsampled depth intervals, were 1.3:1 in winter, 0.6:1 in late spring, and 0.5:1 in late summer (Table 160). Postlarvae appear to be almost solely responsible for the winter ratio, at which time those postlarvae at shallow depths appear to avoid the net during daytime. The winter ratio for shallow postlarvae alone is 2.4:1, that for all postlarvae 1.6:1, and that for juveniles 1.2:1. When catch rates are considered without interpolation at unsampled intervals, the winter juveniles (up to 31 mm SL) also show a pronounced night bias (2.6:1). Possibly these smaller juveniles also avoid the net.

It seems highly doubtful that the ratios for late spring and late summer are meaningful, because the actual samples consisted of only 12 and 10 specimens, respectively. Without interpolation, the ratios of the catch rates were 0.8:1 and 1:1, respectively. Furthermore, the probability that all larger sizes avoid the net at all times already has been suggested.

Poromitra megalops

This species has a circumtropical distribution (Ebeling and Weed, 1973). In the western North Atlantic north of

15°N, it has been taken in the Gulf of Mexico, the western part of the northern Sargasso Sea, and in temperate waters east of 55°W between 40° and 50°N. Four specimens were taken in the Ocean Acre, two of these in discrete-depth, noncrepuscular samples from the paired cruises. They include one 20-mm juvenile and three subadult males, 35–45 mm.

The juvenile was taken at night in September in a discrete-depth sample at 894–925 m. One subadult was taken in April by an open net fishing to 750 m; the other two were caught in June during the day, one in a discrete-depth sample at 970–1060 m, the other in an oblique haul from 970 m.

Scopelogadus mizolepis mizolepis

This species is uncommon in the Ocean Acre. It has a tropical-semisubtropical distribution in the Atlantic, occurring in reduced numbers north of 30°N in the western North Atlantic. Ebeling and Weed (1973) examined 743 specimens captured north of 10°N, of which only 55 were taken north of about 30°N. A total of 127 specimens was taken in the Ocean Acre, 31 in discrete-depth samples, 23 of these in noncrepuscular samples on the paired cruises.

DEVELOPMENTAL STAGES.—No postlarvae were taken. The 49 juveniles were 9–47 mm. At 9–10 mm they had acquired the large scale pockets and pigmentation characteristic of the larger stages, and at 35–40 mm a small degree of gonad development was evident. Fifty-four subadults were 38–58 mm, and 24 adults 52–66 mm (Table 161). Ebeling and Weed (1963) recorded adults as large as 90 mm but observed that, in unproductive waters such as the Sargasso Sea, S. m. mizolepis does not attain as large a size as in productive waters.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.— The absence of postlarvae indicates that this species probably does not breed as far north as the Ocean Acre area. Older stages presumably stray into the area from the warmer waters of the Southern Sargasso Sea.

TABLE 161.—Numbers caught and range of sizes (in mm) of each stage of Scopelogadus m. mizolepis arranged by month (AD = adults; JUV = juveniles; SAD = subadults).

MONTH	JUV		SAD		AD	
	NO.	SIZE	NO.	SIZE	NO.	SIZE
JAN-FEB	1	17	1	49	0	
MARCH	5	15-39	5	41-54	4	54-62
APRIL	2	28-29	2	42-50	0	
JUNE	21	9-39	15	44-58	4	52-66
JULY	0		2	46-50	1	60
AUG-SEPT	20	15-47	28	38-55	15	54-65
NOV-DEC	0		1	42	0	

TABLE 162.—Catch rate of Scopelogadus m. mizolepis by 50-m intervals for the diel period having the maximum rate at each season (interpolated values in parentheses).

DEPTH (M)	LATE SPRING DAY	LATE SUMMER DAY	WINTER NIGHT
351- 400	0	0	0.3
401- 450	(0)	0	0
451- 500	0	0	0
501- 550	(0)	0	0
551- 600	0	0	0
601- 650	0	0	0
651- 700	0.3	(0)	(0)
701- 750	(0.6)	0	0
751- 800	0.8	0	0
801- 850	(0.8)	0	0
851- 900	0.7	(0.5)	0.5
901- 950	(0.5)	1.0	(0.3)
951-1000	0.2	(0.5)	0
1001-1050	(0.1)	0	0
TOTALS	4.0	2.0	1.1

The presence of small specimens (9–15 mm SL) in March, June, and September (Table 161) indicates that the breeding season probably extends from late winter to summer.

Scopelogadus m. mizolepis was most abundant in late spring, decreasing in numbers by late summer through winter; total abundances (Table 162) were: late spring 4.0, late summer 2.0, winter 1.1. These figures are based on a total of only 23 discrete-depth captures, but the numbers in Table 161 suggest that the relative abundances probably are correct. More specimens were taken in August-September than in June, but the vast majority were taken by the EMT, whereas June includes only IKMT samples. From November through February, although 91 net hauls were made, only 3 specimens were captured.

The dearth of late fall and winter captures suggest that S. m. mizolepis enters the Ocean Acre area only during the warmer seasons.

VERTICAL DISTRIBUTION.—In discrete-depth noncrepuscular samples from the paired cruises, all 11 specimens taken during the day were from between 651 and 1000 m. At night, 12 were taken between 51 and 400 m and one (17 mm SL) at 851–900 m. Open-net captures support the discrete-depth data: daytime captures were from 650 m or deeper, night captures as shallow as 100 m.

Only the data for late spring are extensive enough to clearly indicate diel migratory behavior for all three stages, and the night data show size-depth stratification. During the day, they occupy depths of 651–1050 m. The 10 specimens taken at night were distributed as follows: 3 specimens, 9–20 mm, at 51–100 m; one specimen 28 mm, at 151–200 m; 6 specimens, 45–58 mm, at 201–250 m.

Ebeling and Weed (1963) calculated that the average daytime depth of capture of postlarvae and young of this species was 533 m, while the average nighttime depth was 268 m; for large young and adults, the average daytime

depth was 1150 m, the nighttime average depth 447 m. However, they concluded that much of the difference between the daytime and nighttime averages might be artificial, because a large number of their specimens came from the *Dana* collections, which comprised mostly shallow nighttime hauls (average depth 150 m) and deep daytime hauls (average depth 717 m). They did conclude that younger individuals occupied shallower depths than older ones.

The Ocean Acre data indicate that members of this species undergo a diel vertical migration, and they support Ebeling and Weed's observations on size-depth stratification.

NIGHT:DAY CATCH RATIOS.—Sums of catch rates for all 50-m depth intervals, using interpolation in unsampled intervals, were greater during the day than at night in late spring (0.8:1) and late summer (0.1:1). The only two winter specimens were taken at night. Without interpolation the late spring catch was higher at night. The data are, thus, equivocal as to the relative effectiveness of day or night sampling.

Scopelogadus beanii

This species is rare in the Ocean Acre, where it is at the southern extent of its western North Atlantic range. Only 16 juveniles (13–35 mm) were taken. All undoubtedly were strays from more northern waters.

VERTICAL DISTRIBUTION.—During the day, one was taken in a discrete-depth sample at 1000–1070 m, and 7 were caught in nondiscrete samples from maximum depths of 950 to 1920 m. At night, four specimens were taken in discrete-depth samples at 725, 975, and 1000 m, and four in open nets sampling maximum depths from 880 to 2440 m. These data suggest a limited diel migration.

Ebeling and Weed (1973) found that the upper limit of *S. beanii* adults was 800–1000 m, halfgrown 500–600 m, and young about 150 m. All the Ocean Acre juveniles, however, were caught below 700 m, suggesting that these strays prefer cooler deeper water.

The few specimens of *S. beanii* were taken during February, March, June, July, August, and December.

Scopeloberyx opisthopterus

A fairly small species, *S. opisthopterus* attains a maximum length of about 39 mm. It occurs in the Atlantic from about 10°S to 40°N, but appears to be absent in the polygon between the equator and 30°N bounded by 30° and 60°W. This was the second most abundant melamphaid in the Ocean Acre area at all seasons; only *M. pumilus* was more abundant. A total of 595 specimens was taken, 206 of them in discrete-depth samples, 195 from noncrepuscular samples during the paired cruises (Table 147).

DEVELOPMENTAL STAGES.—The 595 specimens include 19 postlarvae, 241 juveniles, 84 subadults, and 251 adults. Postlarvae possess small melanophores scattered over their otherwise unpigmented bodies and range from 4–13 mm. Juveniles are 12–27 mm, subadults 25–32 mm, and adults 29–39 mm.

Sexual dimorphism in size exists in this species, females being slightly larger than males. Subadult males are 25 to 31 mm (mean 27.6 mm), females 27 to 32 mm (mean 29.9 mm). Adult males are 29 to 37 mm (mean 31.7 mm), females 29 to 39 mm (mean 34.7 mm).

SEX RATIOS.—Among juveniles, males outnumbered females at every season represented by a reasonable sample, although the difference was statistically significant only for June (Table 164). The same tendency characterizes subadults, but is less obvious because of the small number of specimens of this stage. Among adults, the tendency appears to reverse, with females more abundant than males during the first six months of the year. This suggests a greater male mortality prior to or just after spawning. From July through December, an equalization or reversal again appears, possibly due to the gradual decimation of postspawning females.

REPRODUCTIVE CYCLE AND SEASONAL ABUNDANCE.—*Scopeloberyx opisthopterus* appears to breed at least from spring through summer, as reflected by the occurrence of postlarvae from June to September (Table 163). The life cycle may be deduced from the seasonal length-frequencies (Table 165). The winter length-frequency is bimodal, one mode (30–39 mm) comprising adults that presumably will breed in the spring and summer, the other mode being medium-size juveniles (16–22 mm) recruited from the past year's spawning. In late spring, night data especially show one mode (22–28 mm) including both large juveniles and subadults that probably represent the medium-size winter juveniles, and a second mode in the adult size range (32–34 mm), which may represent the later-spawning adults. The paucity of large adults (35–39 mm) in late spring suggests that these have died after an earlier spawning. The data for late summer show three modes: one comprised mostly of large juveniles (23–25 mm), presumably representing the smaller juveniles of late spring; one of subadults and small adults (29–33 mm), presumed to represent the larger juveniles from late spring; and one of postlarvae and very small juveniles (12–15 mm) that will become the larger winter juveniles.

A 2-year life cycle is suggested by the progression of size modes. Postlarvae (8–9 mm) just entering the catch in late spring form a mode at the smallest juvenile sizes (12–15 mm) in late summer, which progresses to the mid-juvenile stage (16–22 mm) in winter, to the large juvenile-subadult stage (22–28 mm) by the following spring. In late summer of their second year this modal group attains the small-adult stage (29–33 mm) that will become the large adults of winter and spawn in the spring of their second year.

TABLE 163.—Numbers caught and sizes (in mm) of each stage of *Scopeloberyx opisthopterus* arranged by month (AD = adults; JUV = juveniles; PL = postlarvae; SAD = subadults; X = mean size).

MONTH	PL			JUV			SAD			AD		
	NO.	SIZE	X	NO.	SIZE	X	NO.	SIZE	X	NO.	SIZE	X
JAN-FEB	0			60	16-25	19.8	4	26-30	28.2	64	29-39	34.1
MARCH	0			29	17-27	21.9	20	27-31	29.1	50	31-38	34.9
APRIL	0			17	16-25	20.2	2	27-29	28.0	14	31-36	33.3
JUNE	5	8-13	10.4	37	12-25	22.0	9	26-32	28.8	30	29-36	32.8
JULY	5	6-12	7.8	6	20-25	23.2	11	25-32	28.2	21	30-35	32.5
AUGUST (EMT)	0			33	21-27	24.0	10	26-31	28.7	13	31-37	33.8
SEPTEMBER	9	4-13	9.6	57	12-26	20.0	14	26-31	28.9	30	30-39	33.2
NOVEMBER	0			1		26.0	2	25-27	26.0	10	32-37	34.1
LATE NOV-DEC	0			1		26.0	12	26-32	28.7	19	30-37	32.9

TABLE 164.—Numbers of each sex for each stage of *Scopeloberyx opisthopterus* by months (AD = adult; F — female; JUV = juvenile; M = male; SAD = subadult; TOT = total of all three stages; significant differences indicated by Chi-square test shown by a single asterisk (p = .05) or two asterisks (p = .01)).

MONTH	JUV		SAD		AD		TOT	
	M	F	M	F	M	F	M	F
JAN-FEB	32	28	2	1	27	34	61	63
MARCH	17	12	9	11	21	28	47	51
APRIL	9	8	1	1	4	9	14	18
JUNE	25	12*	4	2	3	24**	32	38
JULY	4	2	6	5	10	11	20	18
AUG (EMT)	18	11	5	5	10	0	0	0
SEPTEMBER	23	12	8	5	15	13	79	46*
OCT-NOV	0	1	2	0	4	6	6	7
NOV-DEC	1	0	7	4	11	8	19	12

TABLE 165.—Seasonal day and night catch rates of *Scopeloberyx opisthopterus* for each mm of standard length (SL). Interpolation was used for unsampled 50-m intervals judged to be within the depth range of the species. (Blank space = no specimens taken.)

SL (MM)	LATE SPRING		LATE SUMMER		WINTER	
	DAY	NIGHT	DAY	NIGHT	DAY	NIGHT
8		0.2				
9		0.3				
10						
11			0.3			
12		0.5		0.3		
13	0.45			0.75		
14		0.3		2.85		
15	0.1	0.3		2.55		
16						1.5
17	0.25	0.3				0.75
18	0.4					6.0
19	0.3					12.0
20	0.5		0.75			16.5
21	0.2		0.45			6.0
22	2.35	0.45	0.8			1.5
23	1.75	0.95	3.85	0.75		
24	0.3	2.3	3.75	1.05		
25	0.8	1.15	1.5	0.3		3.0
26	0.6	0.75	0.8	0.7	0.75	
27	0.15	0.5	0.5		0.75	
28	0.3	1.0	0.3			
29	0.55		0.7		0.45	
30	0.2	0.3	1.25		1.2	0.75
31	0.55		2.15		2.2	1.5
32	0.4	1.9	0.95		2.25	1.95
33	2.1	1.55	0.6		1.65	1.5
34	0.3	2.0			0.35	2.25
35	0.45		0.15	0.3	0.75	3.0
36	0.2		0.6		2.25	3.0
37			0.5			4.5
38						1.25
39					1.5	

TABLE 166.—Seasonal abundance and percent of total abundance (in parentheses) for *Scopeloberyx opisthopterus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total. The figure for abundance is the sum of the catch rates for all 50-m intervals, with interpolation for unsampled intervals, at the diel period showing the greatest total abundance).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	0	45.3(70.7)	0	18.7(29.2)	64.0
LATE SPRING	0.5(3.2)	6.0(38.7)	4.0(25.8)	5.0(32.2)	15.5
LATE SUMMER	0.3(1.5)	12.3(60.3)	3.5(17.2)	4.3(21.1)	20.4

The possibility of two spawning peaks is suggested by similar progression from the small juveniles (14–17 mm) in late spring, to the large juveniles (12–27 mm) of late summer and the small adults (29–33 mm) of winter that will be the late spring and summer spawners of the coming season.

Scopeloberyx opisthopterus was most abundant in winter, least abundant in late spring, and slightly more abundant in late summer than in late spring (Table 166). These estimates of relative abundance probably are reasonable for most juveniles, subadults, and adults, but postlarvae and the smallest juveniles are not adequately sampled. The figure for winter probably represents the actual population, with juveniles and adults representing the 2-year classes, and with postlarvae and subadults absent or scarce. In late

TABLE 167.—Vertical distribution by 50-m intervals of *Scopeloberyx opisthopterus* (AD = adult; JUV = juvenile; N = number of specimens; PL = postlarva; SA = subadult; SL = standard length in mm; TOT = total; X = mean; blank space in column = no catch in a sampled interval; dash = unsampled interval without interpolated catch; asterisk in N column = unsampled interval with interpolated catch).

DEPTH (M)	WINTER — PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SPRING — PL	JUV	SA	AD	TOT	N	X	RANGE	LATE SUMMER — PL	JUV	SA	AD	TOT	N	X	RANGE
DAY																								
101- 150																	<1				<1	1	11.0	11
801- 850									<1	<1			1	*										
851- 900									<1	1			1	3	19.3	13-23	1	<1			2	*		
901- 950									<1	1	<1	<1	2	*				3		<1	3	9	25.1	20-36
951-1000		<1		<1		*				2	<1	1	3	13	26.5	19-36		3		<1	3	*		
1001-1050		<1		<1		1	31.0	31		1	<1	<1	2	*				3		<1	3	9	24.2	21-33
1051-1100				1	1	*				1				1	23.0	23		2	1	1	3	*		
1101-1150				1	1	*						1		1	33.0	33		1	1	1	3	8	28.4	25-33
1151-1200				1	1	*				1				1	22.0	22				1		1	32.0	32
1201-1250				1	1	1	36.0	36			<1	<1	1	2	29.5	26-33								
1251-1300			1	4	5	10	32.8	26-39			<1	<1	<1	*										
1301-1350			1	2	3	*			-	-	-	-	-											
1351-1400	-	-	-	-	-				-	-	-	-	-							1	1	*		
1401-1450	-	-	-	-	-				-	-	-	-	-							1	1	*		
1451-1500				1	1	*	31.5	29-33				1	1	*						1	1	1	31.0	31
1501-1550				3	3	8						1	1	4	32.0	29-35			2		2	3	32.7	30-37
TOTALS	0	0	2	14	16	20			1	7	1	5	14	25			<1	12	4	4	20	32		
NIGHT																								
51- 100									1				1	3	8.7	8-9								
101- 150																								
151- 200																								
201- 250												1	1	3	31.3	30-32								
251- 300	-	-	-	-	-												<1				<1	1	12.0	12
801- 850		4		1	5	5	21.8	16-35	1				1	1	12.0	12		2			2	*		
851- 900		26			26	51	19.6	17-22	1		<1	<1	1	*				3			3	10	14.5	14-15
901- 950		13			13	*			1		<1	<1	1	*			<1	2		<1	2	7	23.1	13-35
951-1000									1		<1	1	2	6	28.0	22-33		1			1	4	21.0	13-24
1001-1050									1	1		1	3	*				1			1	*		
1051-1100	-	-	-	-	-					1	1	1	3	3	28.7	24-34	-	-	-	-	-			
1101-1150	-	-	-	-	-				1		<1	1	2	*			-	-	-	-	-			
1151-1200		1		2	3	*			1		<1	1	2	*			-	-	-	-	-			
1201-1250		2		4	6	6	30.8	25-36			<1	<1	1	2	29.0	26-32	-	-	-	-	-			
1251-1300				8	8	15	35.2	30-38			<1	<1	<1	*			-	-	-	-	-			
1301-1350				4	4	*			-	-	-	-	-				-	-	-	-	-			
1351-1400	-	-	-	-	-												-	-	-	-	-			
1401-1450	-	-	-	-	-												-	-	-	-	-			
1451-1500				<1	<1	*			-	-	-	-	-				-	-	-	-	-			
1501-1550				<1	<1	1	32.0	32	-	-	-	-	-				-	-	-	-	-			
TOTALS	0	45	0	19	64	78			1	6	4	5	16	18			1	9	0	<1	10	22		

TABLE 168.—Seasonal night to day catch ratios of *Scopeloberyx opisthopterus* (AD = adult; JUV = juvenile; PL = postlarva; SAD = subadult; TOT = total of all stages; * = no catch during one or both diel periods).

SEASON	PL	JUV	SAD	AD	TOT
WINTER	*	*	*	1.3:1	4.1:1
LATE SPRING	0.8:1	0.8:1	4.4:1	1.0:1	1.1:1
LATE SUMMER	2.0:1	0.7:1	*	0.1:1	0.5:1

spring, much of the adult population is assumed to have spawned and died, accounting for the considerable decline. By late summer, the subadult and adult populations are further decimated, but juveniles, representing the offspring of the year's spawning, have begun to enter the catch and counterbalance the loss of adults. If postlarvae had been sampled adequately, their greatest abundance probably would have been in late summer, with late spring intermediate, and winter least.

VERTICAL DISTRIBUTION.—Day and night vertical distributions were essentially similar during all three seasons (Table 167), indicating that this species does not migrate vertically. Smaller postlarvae occur between 50 and 300 m. Larger postlarvae and all other stages inhabit depths between 800 m and at least 1550 m. Specimens were caught in open nets fishing as deep as 3500 m, but these could have been taken during the oblique portions of these tows. Two adult males and one adult female were caught at night in the late spring at 201–250 m. It is not likely that these specimens were contaminants, for the preceding five tows were made at 200–400 m. Presumably, these individuals were strays.

Stage stratification is suggested, with juveniles occurring mainly from 850–1050 m and subadults and adults concentrating in deeper water (Table 167). The latter two stages were taken over the full depth range of the species, occupying a greater range than juveniles, but tended to be most abundant below 1100 m.

PATCHINESS.—Coefficients of dispersion are not significant for any 50-m depth interval at any season or time of day, which can be interpreted to indicate lack of clumping. However, the exceptionally large catch of juveniles in two winter night samples from the same trawl and depth, and the absence of juveniles in winter daytime catches, suggest that clumping may, indeed, characterize juveniles.

NIGHT:DAY CATCH RATIOS.—The ratios of night to day discrete-depth catch rates, using interpolation in unsampled depth intervals, were 4.1:1 in winter, 1.1:1 in late spring, and 0.5:1 in late summer (Table 168). In late spring, when the ratio approached 1:1, juveniles, subadults, and adults were in comparable numbers and sizes both day and night. In both late summer and winter, entire size ranges were absent in samples made during the diel period with the lower catch rate but present in the other period. In late

summer the gaps occurred at night at 16–22 mm (medium-size juveniles) and at 27 mm and larger (subadults and adults). In winter a gap occurred during daytime at 16–25 mm (all juveniles). The results are not supportive of enhanced day or night net avoidance, but point to sampling deficiencies as the probable cause.

Scopeloberyx robustus

This species is rare in the Ocean Acre area. It is represented by 20 specimens in the Ocean Acre collections, 5 of these in discrete-depth, noncrepuscular samples from the paired cruises. Five were taken between June and September and 15 between December and April. Evidently the Ocean Acre is near the southern limits of its range in the northwestern Atlantic, where it occurs between about 30° to 40°N.

DEVELOPMENTAL STAGES.—The 20 captures consist of 2 postlarvae 13–15 mm; 14 juveniles 16–27 mm; and 4 adults 46–50 mm.

VERTICAL DISTRIBUTION.—The 13 mm postlarva was caught at night at 125–150 m in a discrete-depth sample. The 15 mm postlarva, which was undergoing metamorphosis, was taken during the day in a discrete-depth sample at 950–1000 m. At night, a juvenile was caught in a discrete-depth sample from 1200–1300 m. Ten juveniles came from open-nets sampling maximum depths from 970–1550 m during the day and three from open nets to 1250–1400 m at night. Two adults were caught in discrete-depth samples; one during the day at 1500–1550 m and one at night at 1475–1550 m. The other two adults came from open-nets sampling maximum depths of 2250 and 3500 m. Based on their minimum depths of capture, juveniles probably occupy somewhat shallower depths than adults. This species shows no evidence of diel migratory behavior.

Scopeloberyx sp.

This undescribed species (Keene, ms.) is found only in the western North Atlantic west of 55°W and between 10° and 40°N, where it has been confused with *S. robustus* by many authors. It attains only 28 mm, while *robustus* reaches 50 mm SL. It is rare in the Ocean Acre; only 40 specimens were taken, 9 of these from discrete-depth, noncrepuscular samples during the paired cruises.

DEVELOPMENTAL STAGES.—Only one 10-mm postlarva was taken. Juveniles ranged from 15 mm to about 21 mm, subadults were 21–25 mm, and adults 24–28 mm.

VERTICAL DISTRIBUTION.—The postlarva came from an open-net sampling to 680 m at night. Postmetamorphics inhabit depths of 900 to more than 1500 m and do not migrate vertically.

This species appears to be stratified by size. Discrete-depth samples during daytime took 8 specimens: 1 (15 mm) at 925 m, 1 (22 mm) at 1200 m, 1 (21 mm) at 1240 m, and

TABLE 169.—Maximum size, life span, day and night depths inhabited by most of the population, and peak spawning period of the five species of Melamphaidae believed to breed in the Ocean Acre area.

SPECIES	MAXIMUM SIZE (MM)	LIFE SPAN (YEARS)	MAIN-DEPTH (M)		PEAK SPAWNING PERIOD
			DAY	NIGHT	
Melamphaes ebelingi	137	3-4	870-1060	290-520	LATE FALL-WINTER
M. typhlops	73	2	550-1050	150-450	ALL YEAR?
M. pumilus	24	1	550-1350	50-400	SPRING-EARLY SUMMER
Poromitra capito	99	3	800-1100	150-550	NOVEMBER-DECEMBER
Scopeloberyx ophisthopterus	39	2	800-1550	800-1550	SPRING-SUMMER

5 (26–28 mm) at 1525 m; at night a 28-mm specimen was taken at 1535 m. Open-net data confirm these conclusions. Five specimens (18–24 mm) taken during daytime were from maximum depths of 1275–1425 m and 5 (24–28 mm) from 1500–1920 m. At night, 18 specimens were taken at maximum depths of 1025 m (17–21 mm), 1050 m (20 mm), 1330–1400 m (20–24 mm), 1500 m (27 mm), 1690 m (26–27 mm), and 1930 m (25–28 mm); one 20-mm specimen was in a sample from 0–3500 m, and one 26-mm specimen in a 0–700 m sample, the latter probably a contaminant from the preceding 1930 m tow.

Habitat Segregation and Resource Partitioning

Only five species of melamphaids definitely appear to be breeding residents in the Ocean Acre area: *Melamphaes pumilus*, *M. typhlops*, *M. ebelingi*, *Poromitra capito*, and *Scopeloberyx opisthopterus*. Four of these are the most numerous and most abundant species of Melamphaidae in the area; *M. pumilus* and *S. opisthopterus* are abundant, *P. capito* is common, *M. typhlops* is uncommon, and *M. ebelingi* is rare. The three species of *Melamphaes* migrate vertically and have rather similar vertical distributions both night and day, but they have different maximum sizes and life spans, and two of them (perhaps all three) have different peak spawning seasons (Table 169). *Poromitra capito* also migrates vertically, and it has night and day vertical distributions that overlap, but are in the deep portion of, those of the three *Melamphaes* species. It lives longer and grows to be larger than two of the *Melamphaes* and has a spawning peak in late fall, as does only *M. ebelingi* (Table 169). *Scopeloberyx opisthopterus* lives deeper than the other four species, deeper than 800 m, and does not appear to migrate vertically. It is a small species, but larger and living a year longer than the dwarf *M. pumilus*; the two species have a similar time of peak spawning. The five principal species in the Ocean Acre, thus, may avoid competition among themselves for resources through aspects of their life histories and vertical distributions.

Four rare species are represented in the Ocean Acre by one or two postlarvae and by adults, suggesting that they,

too, might spawn in the area. *Melamphaes longivelis* is a relatively large species, while *Melamphaes* sp. is medium size; both appear to be vertical migrators and to have similar vertical distributions both during the day and at night. *Scopeloberyx* sp. is a dwarf species, while *S. robustus* is medium size; both live below about 900 m, at least to 1500 m, and do not appear to migrate vertically. Too little is known of any of these four species to suggest mechanisms of resource partitioning among themselves and other congeneric species.

The remaining six rare or uncommon species probably do not breed in the Ocean Acre area. Two (*M. simus* and *M. polylepis*) are represented by single specimens and three (*M. suborbitalis*, *P. megalops*, and *S. beanii*) only by stages other than postlarvae and adults. All of these except *M. suborbitalis* have their main distributions north or south of Bermuda. We would expect *M. suborbitalis* to be breeding in the area, but the indications are otherwise. *Scopelogadus mizolepis* is the only uncommon (as opposed to rare) species of the six. All stages of *S. mizolepis* except postlarvae were taken, and we have suggested the probability that this species moves into the area, probably from the south, during the warmer part of the year.

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Index

(Page numbers of species accounts are in italics)