THE LANTERNFISHES (PISCES: MYCTOPHIDAE) OF THE EASTERN GULF OF MEXICO

JOHN V. GARTNER, JR.,[1] THOMAS L. HOPKINS,[1] RONALD C. BAIRD,[2] AND DEAN M. MILLIKEN[3]

ABSTRACT

Forty-nine species from 17 genera of Myctophidae were taken in midwater trawl samples from the eastern Gulf of Mexico during March through October between 1970 and 1977. Seven abundant species (*Ceratoscopelus warmingii*, *Notolychnus valdiviae*, *Lepidophanes guentheri*, *Lampanyctus alatus*, *Diaphus dumerilii*, *Myctophum affine*, and *Benthosema suborbitale*) comprised 74.4% of the total number (13,369) of myctophids captured. Of the remainder, 10 species were common, 26 were uncommon, and 6 were rarely collected. Diel vertical profiles showed that all species except *Taaningichthys* vertically migrated. Daytime vertical ranges for the entire assemblage were between 300 and 900 m, while at night myctophids were most abundant between the surface and 150 m. A deep group remained below 600 m at night and was composed of mostly juvenile nonmigratory individuals of 19 species and *Taaningichthys bathyphilus*. Five daytime and five nighttime groups of associated species were defined based on vertical ranges, minimum depths of occurrence and zones of abundance. Species of tropical and tropical-subtropical zoogeographic affinities comprised the largest percentage of the total number of specimens and were about equal in their percentage contributions. The presence of many tropical species in the collections may have been due to the transport of the Florida Loop Current. Comparison of the species list with those reported for other myctophid assemblages from tropical-subtropical latitudes shows panoceanic distribution of 10 species.

Myctophid fishes are one of the dominant components of oceanic mesopelagic ecosystems (McGinnis 1974; Maynard et al. 1975; Badcock and Merrett 1976; Nafpaktitis et al. 1977; Hulley 1981; Hopkins and Lancraft 1984; Hulley and Krefft 1985). With the exception of Clarke's (1973) work in Hawaiian waters, there have been no comprehensive studies on faunal structure and ecology of this family in subtropical-tropical oligotrophic regions where myctophids are exceptionally diverse (Backus et al. 1977).

The Gulf of Mexico is one such regime. Backus et al. (1977) noted that although there are no endemic myctophid species in the Gulf of Mexico, it is zoogeographically unique and faunistically separable from other regions of the western North Atlantic. Unlike the adjacent Caribbean Sea, which it hydrographically resembles (Nowlin and McLellan 1967), the Gulf of Mexico undergoes a marked change in surface water temperatures over an annual cycle (Jones 1973). In addition, circulation patterns are strongly influenced by the Florida Loop Current, whose penetration into the Gulf of Mexico is both geographically and seasonally variable. The central Gulf of Mexico, despite seasonal variability, has many characteristics typical of low latitude oligotrophic gyre systems.

This paper details the taxonomic composition, zoogeographic affinities, and vertical structure of the mesopelagic (sensu Marshall 1971) myctophid fauna in the eastern Gulf of Mexico (hereafter as Gulf) during the warm months of late March through early October. The results are based primarily on collections with opening-closing midwater trawls made from 1970 to 1977 in the eastern central Gulf in the vicinity of lat. 27°N, long. 86°W. Additional data from other stations in adjacent northeastern and southeastern Gulf areas are included.

MATERIALS AND METHODS

The data are from 526 stations occupied during 12 cruises made between 1970 and 1977 (Fig. 1). The majority of samples were taken within a 20 nmi diameter circle centered around lat. 27°N, long. 86°W in the eastern central Gulf of Mexico, an area referred to as the "Standard Station". Samples were also taken from the northeastern and south-

[1]Department of Marine Science, University of South Florida, 140 Seventh Avenue, S.E., St. Petersburg, FL 33701.
[2]Director of Corporate Relations, Worcester Polytechnic Institute, Worcester, MA 01609.
[3]Florida Institute of Oceanography, 830 First Street S., St. Petersburg, FL 33701.

Manuscript accepted August 1986.
FISHERY BULLETIN: VOL. 85, NO. 1, 1987.

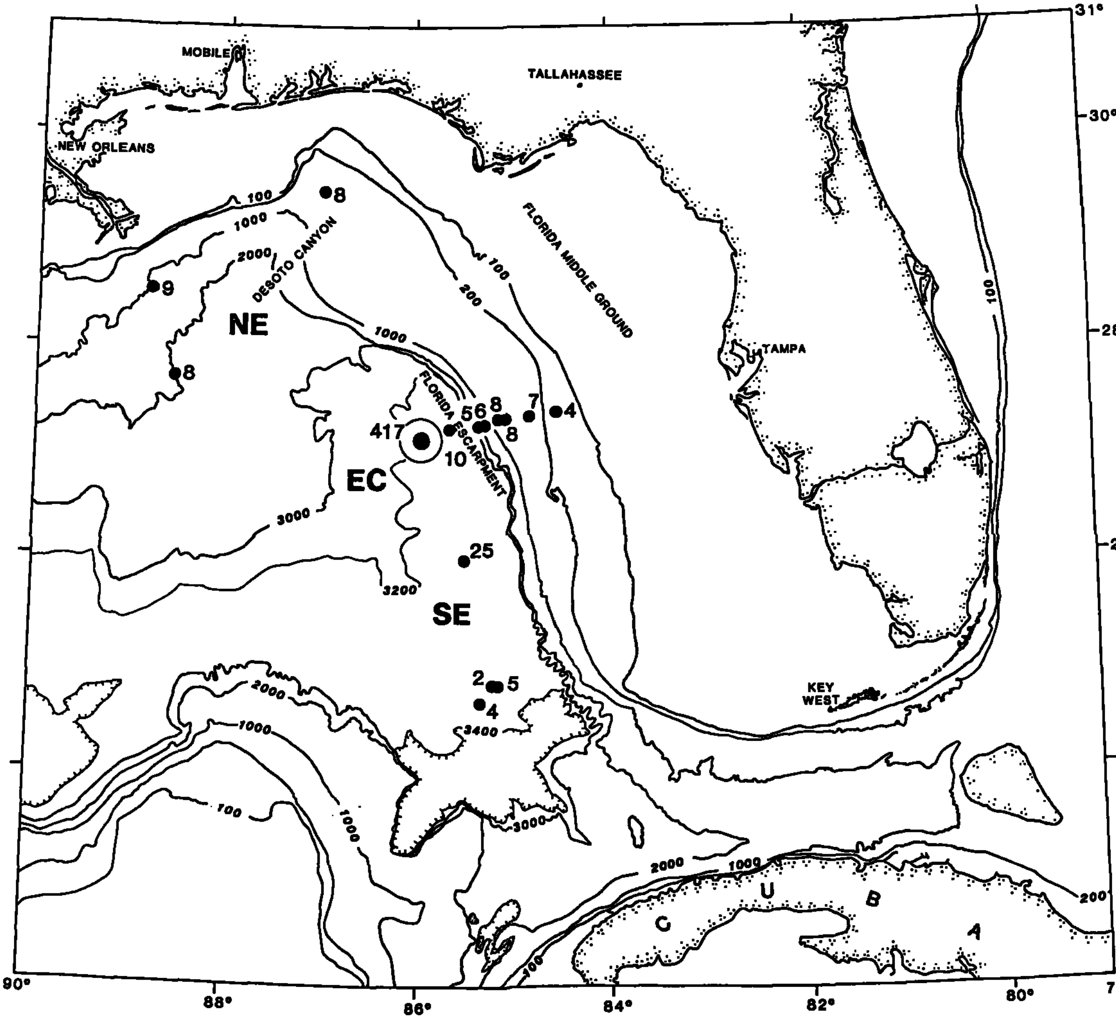

FIGURE 1.—Collection locations and numbers of tows per location in the eastern Gulf of Mexico. Sampling regions: NE - northeast; EC - eastern central; SE - southeast. Circle in EC region delimits 20 nmi diameter sampling area around lat. 27°N, long. 86°W.

eastern Gulf, and although there is a large discrepancy in the relative number of samples taken and in day-night depth coverage, collections were assigned to three latitudinal areas: northeast (NE), eastern central (EC), and southeastern (SE). The northernmost Gulf is known to support populations of cooler water myctophid species (Backus et al. 1977), and our hydrographic data showed that the southeastern stations were the only collections that were directly impacted by the tropical Loop Current waters during sampling, hence this regional partitioning.

Most of the cruises were made during the summer months (June through early September), and although sampling extended from late March through early October, all cruises were made while summer hydrographic conditions prevailed in the study area. With respect to lunar cycles, 9 of the 12 cruises occurred during waxing or full moon period, 2 during first quarter, and 1 during new moon. Table 1 lists general data for the 12 cruises.

Samples were taken primarily in the upper 1,000 m of the water column, although a few extended as deep as 1,500 m. The nets used were 3.2 m^2 or 6.5 m^2 mouth area opening-closing modified Tucker trawls (Hopkins et al. 1973) which incorporated 1.1 cm stretch mesh in the body and 505 μ mesh in the cod end. Opening and closing of the nets were accomplished mechanically using double release mechanisms and messengers. Fishing depth was monitored on all cruises by mechanical time-depth recorders (TDR), meters of wire out and wire angle. Additionally, on three RV *Columbus Iselin* cruises (Table 1) depth was monitored by electronic deck readout via a depth transducer and conducting cable. Volume of water filtered per tow was calculated from flowmeters mounted in the mouth of the plankton net and on the main trawl frame. Inclinometer measurements and underwater observations of the wire angle of nets towed just beneath the surface indicated the mouth of the net fished at an angle of about 30° from the vertical, which was used as a standard angle when filtration volumes were calculated. Trawl speed was 1.5 to 3 kn.

Nets were fished obliquely over a depth range, or, as on *Columbus Iselin* cruises, at specific depth horizons. Vertical depth control during horizontal tows was +/−10 m from 0-300 m (except for the surface and 5 m depth strata), +/−25 m from 300-700 m, +/−50 m from 700-1,000 m.

The trawl catch was initially fixed in 10% v:v seawater Formalin[4] and subsequently transferred to 50% isopropanol. Myctophids were measured to the nearest millimeter standard length (mm SL) and identified to species using Nafpaktitis et al. (1977).

Diel vertical distributions for all species were calculated using data pooled from all cruises. Samples which were taken within 1 hour before or after sunrise and sunset were excluded from analysis, because vertical migration is pronounced at these times. Excluding the sunrise-sunset samples, a total of 155 samples (82 days, 73 nights) collected during the *Columbus Iselin* cruises from 0 to 1,000 m were used to construct vertical profiles for the abundant species (Table 2). Abundance was expressed as individuals per 10^4 m^3.

[4]Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

TABLE 1.—Sampling data. Sampling regions: NE - northeast; EC - eastern central; SE - southeastern.

Research vessel	Date	Location/Region	No. tows (stations)	Lunar Phase[1]/Date	Loop Current impingement?
Joie de Vivre	2-5 Oct. 1970	Standard Station (EC)	12	New - 30 Sept. 1/4X - 8 Oct.	No
Dan Braman	25-31 July 1971	Standard Station (EC)	46	New - 22 July 1/4X - 30 July	No data
Mizar cruise I	7-14 June 1971	25°50'N, 85°30'W (SE)	20	Full - 9 June 3/4W - 16 June	Yes
Mizar cruise II	24-28 Mar. 1972	25°50'N, 85°30'W (SE)	5	3/4X - 22 Mar. Full - 29 Mar.	No
Bellows cruise I	2-9 Aug. 1972	Standard Station (EC)	25	1/4W - 2 Aug. New - 9 Aug.	No
Mizar cruise III	13-23 Aug. 1973	Standard Station (EC) 27°36'N, 88°40'W (NE) 29°19'N, 87°01'W (NE) 28°28'N, 88°56'W (NE)	7 8 8 9	Full - 14 Aug. 3/4W - 21 Aug.	No No No No
Bellows cruise II	9-11 Oct. 1973	24°30'N, 85°20'W (SE) 24°40'N, 85°10'W (SE) 24°38'N, 85°10'W (SE)	4 5 2	Full - 12 Oct.	Yes Yes Yes
Bellows cruise III	28-31 Aug. 1974	Standard Station (EC)	15	Full - 1 Sept.	No
Columbus Iselin cruise I	15-22 June 1975	Standard Station (EC)	79	3/4X - 16 June Full - 23 June	No
Columbus Iselin cruise II	6-17 June 1976	Standard Station (EC)	133	3/4X - 5 June Full - 12 June 3/4W - 19 June	No
Bellows cruise IV	27 May- 2 June 1977	27°11'N, 84°50'W (EC) 27°10'N, 85°07'W (EC) 27°09'N, 85°04'W (EC) 27°07'N, 85°16'W (EC) 27°06'N, 85°19'W (EC) 27°04'N, 85°40'W (EC) 27°14'N, 84°33.5'W (EC) Standard Station (EC)	7 8 8 6 5 10 4 4	3/4X - 27 May Full - 1 June	No No No No No No No No
Columbus Iselin cruise III	19 Sept. - 6 Oct. 1977	Standard Station (EC)	96	3/4X - 20 Sept. Full - 27 Sept. 3/4W - 5 Oct.	No

[1]Lunar phases: X - waxing, W - waning.

TABLE 2.—Depth horizon data for discrete-depth samples collected during *Columbus Iselin* cruises I, II, and III.

Depth (m)	Day: No. of stations sampled	Day: Total volume filtered (10^4 m^3)	Night: No. of stations sampled	Night: Total volume filtered (10^4 m^3)
0-5	16	18.4	20	24.8
10	9	5.9	3	2.0
15	5	3.4	8	2.7
30	4	3.0	3	2.0
50	6	4.5	3	3.7
75	0	—	2	3.0
105	0	—	3	4.9
125	0	—	3	3.9
155	2	2.9	2	2.6
210	1	1.5	3	3.7
300	4	6.8	3	4.6
350	4	5.1	2	2.3
400	2	2.4	2	2.8
450	5	8.0	2	2.5
500	5	4.7	3	3.7
550	3	3.0	4	5.2
600	4	11.9	1	2.5
650	2	2.6	0	—
700	3	6.6	1	2.1
800	4	7.4	0	—
900	2	4.3	2	3.7
1,000	1	2.2	3	5.9
Totals	82	104.6	73	88.6

Groups of associated species were determined for both day and night and were defined based on the minimum depth of occurrence (the shallowest discrete depth capture of a species) and zone of maximum abundance, using the *Columbus Iselin* data. These associations included the abundant and common species, as well as those uncommon species whose sample size was sufficient to determine depth range or which had a very narrow range of capture.

Although our data were limited, effects of lunar phase on vertical distribution of abundant species were examined by comparing the minimum depth of captures between new and full moon phases. Three cruises were defined as new moon (*Joie de Vivre*, *Dan Braman*, *Bellows* cruise I, Table 1); the remainder as full.

RESULTS

Hydrography

The circulation of the eastern Gulf of Mexico is dominated by the Loop Current (Leipper 1970; Nowlin 1971; Jones 1973; Molinari and Mayer 1980). This current, of Caribbean origin, enters the Gulf through the Yucatan Straits and moves anticyclonically, exiting through the Florida Straits. The extent of penetration into the Gulf is latitudinally variable and seasonally unpredictable. The Loop Current can be identified by the depth of the 22°C or 20°C isotherms which occur at 100 m and 150 m, respectively (Leipper 1970; Maul 1977; Sturges and Evans 1983). Meanders of the Loop Current often pinch off to form cold core eddies which spin cyclonically and drift southward along the eastern edge of the Loop Current off the West Florida Shelf (Vukovich and Maul 1985). Some of these cyclonic eddies have been tracked through our eastern sampling areas (EC and SE).

All of the southeastern (SE) collections were in waters covered by the Loop Current at the time of sampling, whereas the more northerly samples (EC and NE) were from what is termed Loop Transition Water. The characteristics of Loop Transition Water during the collection period (summer) were as follows: a mixed layer of variable depth, usually extending 25 to 50 m with surface temperatures of 27° to 30°C; a sharp thermocline from the base of the mixed layer to approximately 150 m depth where the temperature was 15° to 18°C; a gradual temperature decline from 150 m to about 4°C at 1,000 m. Figure 2 illustrates a typical profile of the Loop Transition Water during the summer months.

Productivity measurements within the Loop Current and in Loop Transition Waters indicate an

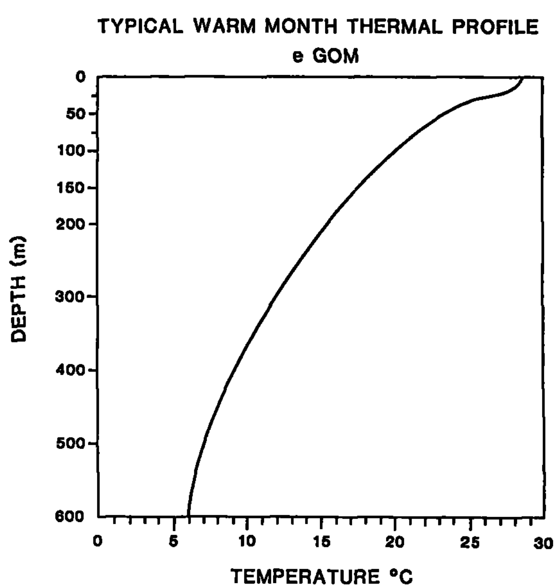

FIGURE 2.—Typical warm month thermal profile for the eastern Gulf of Mexico (eGOM).

oligotrophic regime in the eastern Gulf, with an annual primary production of <50 to 75 g C yr^{-1} (El-Sayed 1972; Hopkins 1982, unpub. data).

Species Data

A total of 13,369 myctophids were examined from all stations, with all but 77 (0.6%) identifiable to species. Table 3 lists all taxa, along with the number of individuals captured from each sampling region, their distribution pattern (from Backus et al. 1977), diel distribution ranges, and overall size ranges. The identified material comprised 17 genera and 49 species.

The distribution ranges and estimates of abundance and standing stock of the abundant species in the following species accounts were limited to data collected during the three *Columbus Iselin* cruises to Standard Station (EC). Too few collections were made in the other two areas (NE, SE) to allow for comparable analyses.

Based on frequency of capture and total number of specimens from EC, seven species were considered abundant, i.e., dominant, (>500 specimens total captured) in the eastern Gulf. In decreasing order of abundance these were *Ceratoscopelus warmingii*, *Notolychnus valdiviae*, *Lepidophanes guentheri*, *Lampanyctus alatus*, *Diaphus dumerilii*, *Benthosema suborbitale*, and *Myctophum affine*. Together they comprised approximately 75% of the total number of specimens collected from EC (74.4%). Table 4 lists the dominant species along with their percentage composition among the dominant species and overall.

From all collections, 42 additional species were divided into the following abundance categories: common (101-500 specimens; 10 species); uncommon (10-100 specimens; 26 species), and rare (<10 specimens; 6 species).

Abundant Species

***Ceratoscopelus warmingii*: N = 2,267, 14-65 mm SL, Juvenile-Mature Adult**

The vertical distribution profile shows this species to be a strong migrator with a broad diel depth range (Fig. 3a). During the day, it occurred from 650 to 1,000 m (recent deep mesopelagic daytime tows in the Gulf of Mexico have taken *C. warmingii* below 1,000 m, J. V. Gartner unpub. data). Night captures were mainly between 75 and 125 m, with a maximum abundance of 95 individuals/10^4 m^3 at 125 m. Abundance was bimodally distributed with some small juveniles apparently remaining near daytime depths at night (Fig. 3a, Table 5).

***Notolychnus valdiviae*: N = 1,780, 9-22 mm SL, Postlarvae-Mature Adult**

Peak daytime distribution was mainly between 400 and 500 m (Fig. 3b). Some night captures were made as shallow as 50 m, but abundance maxima were found at 75 and 155 m, with the peak at 75 m (>72 individuals/10^4 m^3). The distribution pattern was discontinuous, with no specimens taken at 125 m. There was no evidence for a nonmigratory portion of the population as was found for *C. warmingii*.

Analysis of the size vs. depth for *N. valdiviae* showed an increase in mean size with increasing depth at night (Table 5). No trend was apparent during the day because of small sample size.

***Lepidophanes guentheri*: N = 1,610, 13-64 mm SL, Juvenile-Mature Adult**

This species was a moderate to strong vertical migrator. Although daytime captures were recorded as shallow as 400 m, this species was most abundant between 650 and 800 m and recent discrete depth hauls in the Gulf of Mexico have also taken *L. guentheri* from below 1,000 m (J. V. Gartner unpub. data). Nighttime abundance was highest at 75 m (38.1 individuals/10^4 m^3) and sharply decreased below this depth (Fig. 3c). Differences in day-night abundances were not as pronounced as in *Ceratoscopelus* or *Notolychnus*. At 650 m during the day, catch abundance was approximately the same as at 105 and 125 m at night.

Lepidophanes guentheri was the only abundant species for which lunar influence on depth of capture was apparent. During a new moon cruise (*Dan Braman*), *L. guentheri* measuring 27 to 37 mm SL were captured as shallow as 10 m.

Nonmigration of members of the population was noted, mostly among juveniles measuring from 13 to 25 mm SL. Because of sample size, no other clear size-depth patterns were discernible.

***Lampanyctus alatus*: N = 1,418, 15-48 mm SL, Juvenile-Mature Adult**

The daytime vertical profile extended from 350 to 900 m, with a peak at 650 m (Fig. 3d). This species was found between 75 and 155 m at night (maximum 24.2 individuals/10^4 m^3 at 125 m). Some estimated daytime abundances for *L. alatus* were as large as

TABLE 3.—List of species grouped according to abundance. Totals by region, zoogeographic affinity, diel vertical depth and peak abundance ranges and size ranges. Sampling regions: NE - northeast; EC - eastern central; SE - southeastern.

Species	Total	Region			Distribution pattern[1]	Day		Night		Size range (mm SL)	Non-migrators?[2]
		NE	EC	SE		Range (m)	Max. (m)	Range (m)	Max. (m)		
Abundant											
Benthosema suborbitale	687	159	467	61	TST	400-600	—	50-105;500-550	—	10-30	Yes
Ceratoscopelus warmingii	2,267	338	1,872	57	TST	650-1,000	—	75-125;600-700	75,125	14-65	Yes
Diaphus dumerilii	1,279	273	970	36	T	300-600	—	50-155	75,125	12-53	No
Lampanyctus alatus	1,418	240	1,143	35	T	350-900	650	75-155	125	15-48	No
Lepidophanes guentheri	1,610	128	1,305	177	T	400-900	650	75-155;700-1,000	75	13-64	Yes
Myctophum affine	893	20	865	8	T	500	—	Surface-155	Surface	12-58	No
Notolychnus valdiviae	1,780	364	1,213	203	TST	400-500;800	400	50-155	75	9-22	No
Common											
Bolinichthys photothorax	130	16	105	9	TSST	550-700	—	50-250	90-125	12-51	No
Centrobranchus nigroocellatus	104	3	101	—	TST	400-550	—	Surface-150	Surface	13-43	No
Diaphus lucidus	131	14	101	16	T	450-1,000	450-600	60-300	100-150	15-79	No
D. mollis	434	72	340	22	TST	300-1,000	400-550	50-225;450-500	50-100	9-53	Yes
D. problematicus	105	15	78	12	T	325-550	400-500	55-275	80-150	15-73	No
D. splendidus	307	8	288	11	TSST	300-600	400-550	30-250;450-550	50-110	11-64	Yes
Diogenichthys atlanticus	121	24	95	2	TST	350-700	550-600	50-220;650-700	65-125	9-23	Yes
Hygophum benoiti	463	64	388	11	TmpSST	300-700	550-600	0-250;500-700;1,000	50-125	10-43	Yes
H. taaningi	362	34	286	42	ST	350-1,000	500-700	10-300;375-600	75-130	11-47	Yes
Lampanyctus lineatus	171	16	149	6	ST	600-1,000	—	110-600;800-1,000	110-300	25-113	Yes
Uncommon											
Bolinichthys supralateralis	49	15	28	6	TST	250-600	—	60-250;500-700	—	12-44	Yes
Diaphus brachycephalus	56	3	31	22	TSST	350-600	—	50-300	125-200	9-40	No
D. effulgens	14	1	11	2	ST	300-500	—	110-330?	—	10-48	N/D
D. fragilis	14	2	10	2	T	350-550	—	70-200	—	10-69	N/D
D. garmani	17	3	8	6	T	350-550?	—	65-150	—	11-28	N/D
D. luetkeni	72	14	54	4	T	300-600	—	60-300	100-160	10-52	No
D. perspicillatus	36	8	18	10	T	300-600	—	40-140	40-75	11-36	N/D
D. rafinesquii	45	2	43	—	TmpSST	300-600	400-500	100-375;500	100-150	11-80	Yes
D. subtilis	25	2	20	3	TSST	400-600	—	100-325;450-475	—	11-50	Yes
D. taaningi	41	23	15	3	P	400-550?	—	40-300	40-75	15-56	No
D. termophilus	16	2	14	—	T	—	—	75-150	—	10-35	N/D
Gonichthys cocco	34	2	30	2	TST	—	—	Surface;100-150	Surface	20-49	N/D
Hygophum macrochir	34	3	20	11	T	500-650	—	10-250	50-100	13-35	No
H. reinhardtii	82	11	70	1	ST	550-700	—	0-250;600-900	100-150	12-49	Yes
Lampadena luminosa	94	18	71	5	TSST	500->1,000	600-650	65-350;550-600	75-125	17-85	Yes
Lampanyctus ater	35	14	19	2	ST	500?-650	—	100-350;500-700	—	25-95	Yes
L. cuprarius	15	1	13	1	ST	600-900	—	125-220;600-950	—	22-61	Yes
L. nobilis	52	1	46	5	T	800-1,000	—	40-250;600	100-150	19-78	Yes
L. tenuiformis	24	5	19	—	T	—	—	75-250?	100-150	19-53	N/D
Lobianchia gemellarii	76	14	52	10	TST	300-450	—	80-210	70-125	12-48	No
Myctophum asperum	27	2	25	—	T	400	—	Surface-150	Surface	14-35	N/D
M. nitidulum	18	—	18	—	TST	—	—	Surface-50;600	Surface	16-77	Yes
M. obtusirostre	32	6	24	2	T	500-600	—	Surface-150	Surface	11-37	N/D
M. selenops	20	—	19	1	TST	—	—	60-150	—	10-43	N/D
Notoscopelus resplendens	69	1	65	3	TST	—	—	50-225	75-125	19-57	No
Taaningichthys bathyphilus	11	—	10	1	B	600->1,000	—	900	—	18-56	Yes

TABLE 3.—*Continued.*

Species	Region				Distribution pattern[1]	Day		Night		Size range (mm SL)	Nonmigrators?[2]
	Total	NE	EC	SE		Range (m)	Max. (m)	Range (m)	Max. (m)		
Rare											
Diaphus bertelseni	1	—	—	1	TST	—	—	160-190	—	10-46	N/D
Hygophum hygomii	8	—	7	1	TmpSST	—	—	50-100	—	8-44	N/D
Notoscopelus caudispinosus	8	—	7	1	TST	—	—	60-150	—	20-68	N/D
Symbolophorus rufinus	3	1	2	—	TST	—	—	50-250?	—	13-28	N/D
Taaningichthys minimus	1	1	—	—	ST	>600	—	—	—	N/D	N/D
T. paurolychnus	1	—	1	—	B	>1,000	—	—	—	54	N/D

[1]Pattern determined from Backus et al. (1977). Abbreviations are as follows: T - Tropical; TST - Tropical-Subtropical; TSST - Tropical-Semisubtropical; ST - Subtropical; TmpSST - Temperate-Semisubtropical; P - Pseudooceanic; B - Bathypelagic.
[2]Refers to nonmigration of members of the population. N/D indicates insufficient data for determination.

some of those for night, though overall densities were higher for night. No evidence was found for members of the population remaining at depth at night.

***Diaphus dumerilii*: N = 1,279, 12-53 mm SL, Juvenile-Mature Adult**

This species had the shallowest daytime depth of capture (300 m) and was the weakest migrator of all seven abundant species (Fig. 4a); maximum depth during the day was 600 m, with no discernible abundance peak within the daytime range. Nighttime captures were as shallow as 50 m, with peak abundance between 75 and 125 m (maxima 39 and 47 specimens/10^4 m^3, respectively). There was some evidence of nonmigration of juvenile members of the population remaining at depth at night (Table 5).

***Myctophum affine*: N = 893, 12-58 mm SL, Juvenile-Mature Adult**

Our only discrete record of capture for this species during the day was from 500 m. The nighttime vertical profile for *M. affine* was distinctly different from that of the other abundant species. A strongly bimodal pattern was evident, with a 75-155 m component of the population with a small peak at 105 m, and the majority of the population at night (97% of our catch) between the surface and 5 m. Most of these shallow individuals were at the surface (95% of 0-5 m captures), and on calm nights, it was possible to dip net this species. A maximum of 102 specimens/10^4 m^3 was recorded at the surface at night (Fig. 4b), and our data indicated that the entire population vertically migrated.

Analysis of *M. affine* size with depth for night-captured individuals showed that in the 0 to 5 m depth strata, juveniles of 18.5 mm mean SL entered the very surface waters, while specimens approximately twice their size ($\bar{x}$ = 37.2 mm SL) occurred just below them at 5 m depth (Table 5).

***Benthosema suborbitale*: N = 687, 10-30 mm SL, Juvenile-Mature Adult**

The daytime depth range was well defined between 400 and 600 m. Nighttime distribution was bimodal, with a migratory group between 50 and 105 m and a group of nonmigratory juveniles (Table 5) remaining at daytime depths. The diel vertical profile showed that this species was not particularly concentrated at any depth (Fig. 4c) and, in contrast to all other abundant and common species, *B. sub-*

TABLE 4.—Abundance data for dominant myctophid species from the eastern Gulf of Mexico. CI - Columbus Iselin cruises I, II, III; other - all other cruises.

Species	Number captured CI (other)	Dominant species (%)	Total species (%)
Ceratoscopelus warmingii	1,822(445)	22.8	17.0
Notolychnus valdiviae	1,169(611)	17.9	13.4
Lepidophanes guentheri	1,124(486)	16.2	12.1
Lampanyctus alatus	942(476)	14.3	10.7
Diaphus dumerilii	846(433)	12.9	9.6
Myctophum affine	646(247)	9.0	6.7
Benthosema suborbitale	419(268)	6.9	5.2
		Total	74.7

orbitale was somewhat more prevalent in our day than our night catches.

Common Species

Ten species were represented by 101 to 500 specimens (Table 3). With the exception of two species (*Lampanyctus lineatus* and *Diaphus lucidus*), sizes ranged from postmetamorphic through sexually mature adult stages. The maximum sizes for all 10 species, however, were smaller than reported in Nafpaktitis et al. (1977).

Diel distribution patterns showed that all species in this group were migrators (Table 3). During the day, the maximum abundance of all but one species occurred between 400 and 700 m. *Lampanyctus lineatus* was found between 600 and 1,000 m.

At night, three vertical patterns were evident. *Centrobranchus nigroocellatus* entered the surface (0-5 m) waters, while *L. lineatus* remained at lower epipelagic-upper mesopelagic depths (110-300 m). The other eight species primarily concentrated between 50 and 150 m, though *Hygophum benoiti* and *H. taaningi* were often captured as shallow as 0 to 10 m, which suggests that these species may have disjunct night distributions similar to *Myctophum affine*.

The entire populations of *Diaphus lucidus*, *D. problematicus*, *Bolinichthys photothorax*, and *Centrobranchus nigroocellatus* apparently migrated nightly while some individuals of the other six species remained at depth at night (Table 3). Data were insufficient to discern size-depth trends in these species.

Uncommon and Rare Species

Twenty-six uncommon species were represented by 10 to 100 specimens in our collections. Comparison of the sizes captured vs. size at metamorphosis and sexual maturity (where known) indicated that six species (*Lampadena luminosa*, *Lampanyctus ater*, *L. cuprarius*, *L. nobilis*, *L. tenuiformis*, *Notoscopelus resplendens*) were represented only by juveniles. Nine species (*Bolinichthys supralateralis*, *Diaphus effulgens*, *D. perspicillatus*, *D. subtilis*, *D. termophilus*, *Hygophum macrochir*, *Myctophum asperum*, *M. obtusirostre*, *M. selenops*) occurred only

TABLE 5.—Mean size (mm SL) of dominant species with respect to depth.

Depth (m)	*Ceratoscopelus warmingii* Day	*Ceratoscopelus warmingii* Night	*Notolychnus valdiviae* Day	*Notolychnus valdiviae* Night	*Lepidophanes guentheri* Day	*Lepidophanes guentheri* Night	*Lampanyctus alatus* Day	*Lampanyctus alatus* Night	*Diaphus dumerilii* Day	*Diaphus dumerilii* Night	*Myctophum affine* Day	*Myctophum affine* Night	*Benthosema suborbitale* Day	*Benthosema suborbitale* Night
0												18.5		
5												37.2		
10														
15														
30														
50				12.0						15.0		15.0		12.0
75		25.1		16.9		43.2		20.6		24.0		17.0		21.5
105		44.3		17.4		53.4		37.8		35.9		27.8		25.0
125		32.3				51.3		35.4		26.2		23.5		
155				17.4		59.0		41.8		35.0		27.0		
210														
300									14.2					
350														
400			18.0		52.0		23.0		22.5				28.5	
450			18.7						16.0				18.0	
500			16.7				24.0				16.0		19.7	
550					23.0		23.0			18.0			28.0	10.3
600		27.0			59.0		34.0		12.0				30.0	
650	14.0				31.4		37.0							
700	16.5	15.5			44.5	14.0	37.6							
800	36.5		20.0		32.8		30.0							
900	30.5				19.0	54.0	44.0							
1,000						21.3								

as newly metamorphosed through juvenile stages (Table 3). The remaining 11 species showed a relatively complete ontogenetic series. With the exception of *Hygophum reinhardtii*, no individuals of the 26 uncommon species approached the maximum size recorded for these species (Nafpaktitis et al. 1977).

During the day, most species were found between 300 and 700 m, except for *Lampanyctus cuprarius*, *L. nobilis*, *L. tenuiformis*, and *Taaningichthys bathyphilus*, which generally were captured deeper than 600 m. Nocturnal vertical patterns showed that all uncommon species except *Taaningichthys*, a nonmigrator, entered upper mesopelagic or epipelagic depths at night. *Gonichthys cocco*, *Myctophum*

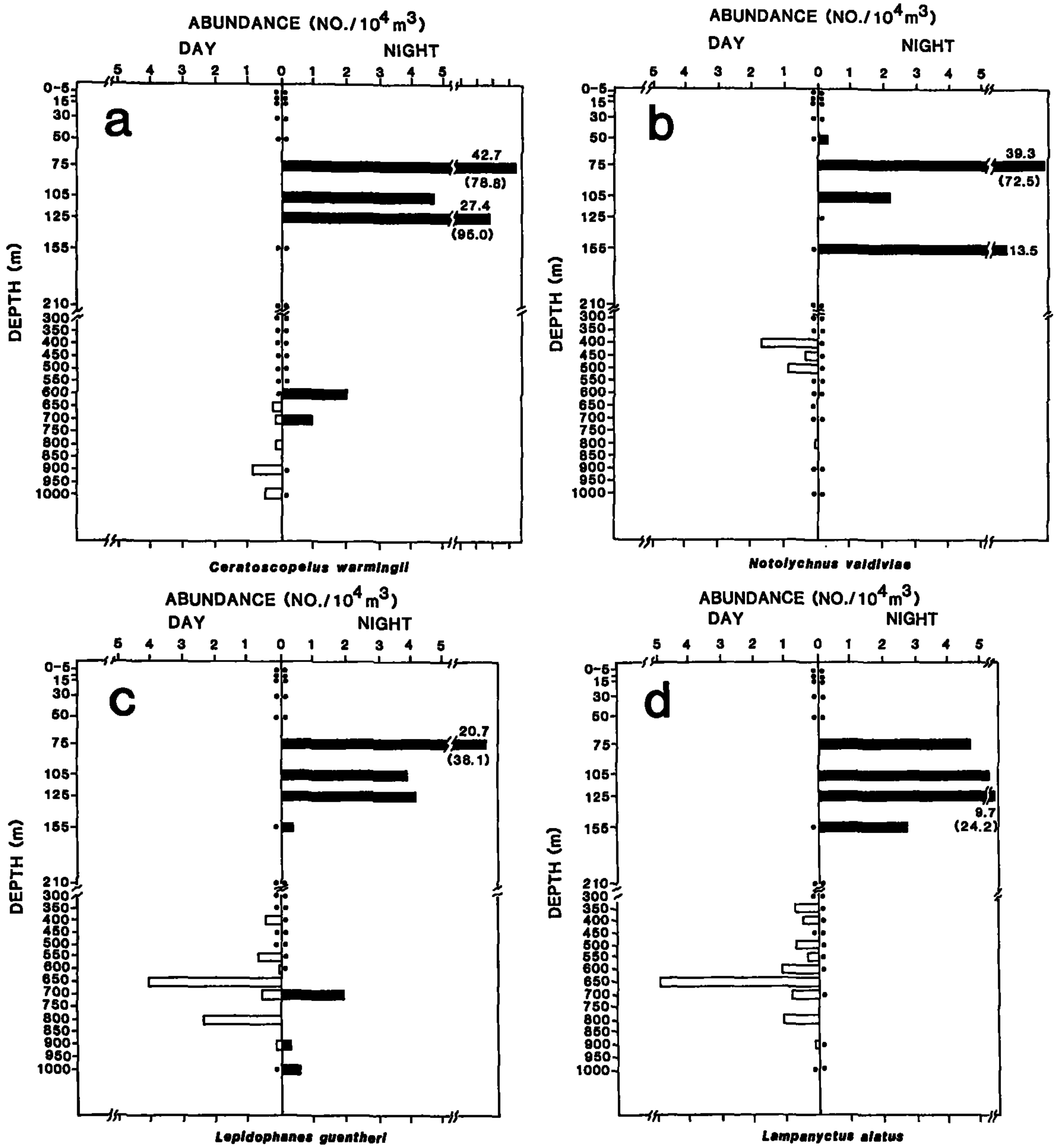

FIGURE 3.—Diel vertical profile of dominant myctophid species in the eastern Gulf of Mexico. a - *Ceratoscopelus warmingii*; b - *Notolychnus valdiviae*; c - *Lepidophanes guentheri*; d - *Lampanyctus alatus*. Numbers above bar indicate average abundance at depth, numbers in parenthesis below bar indicate maximum abundance at depth.

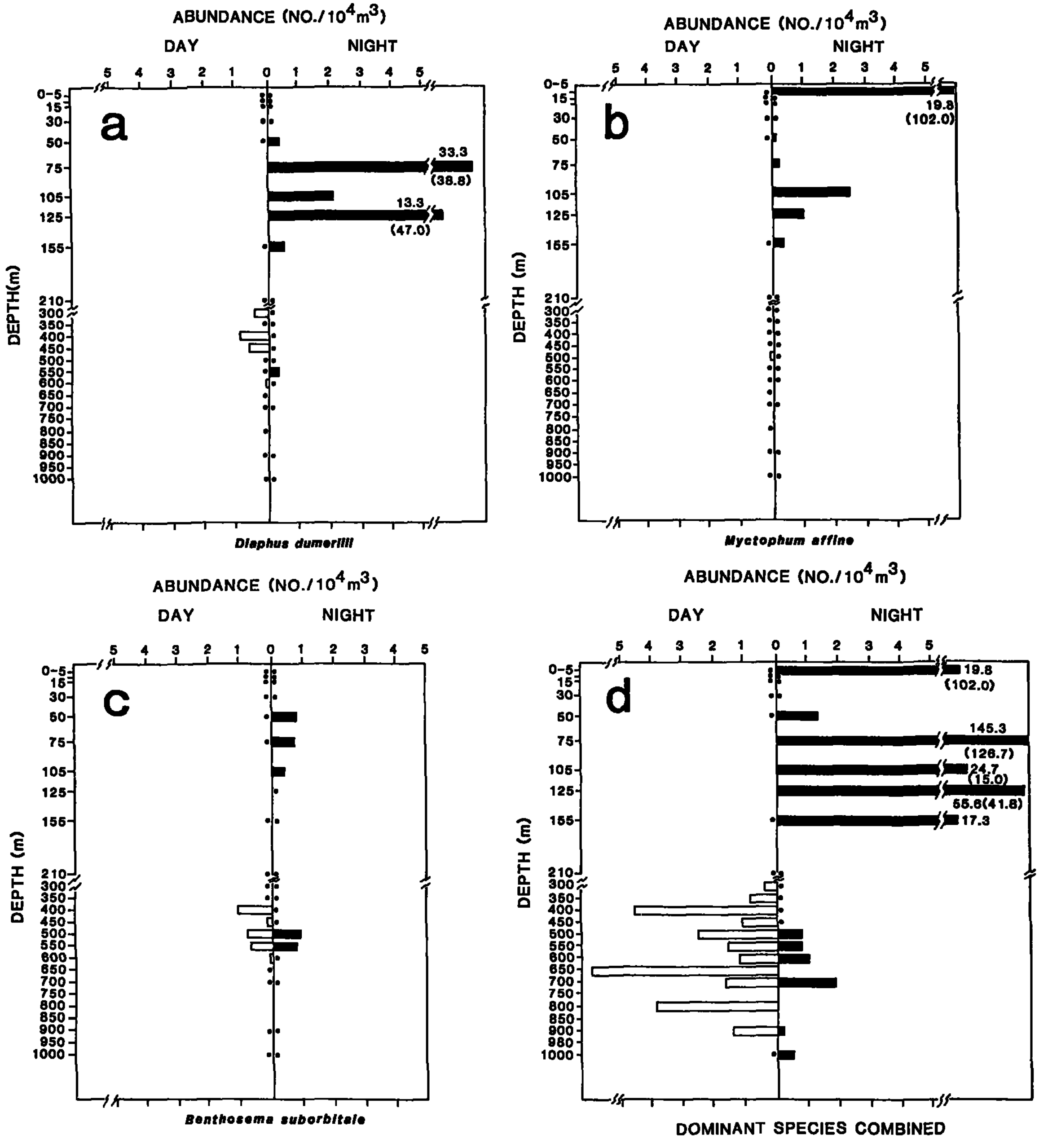

FIGURE 4.—Diel vertical profile of dominant myctophid species in the eastern Gulf of Mexico. a - *Diaphus dumerilii*; b - *Myctophum affine*; c - *Benthosema suborbitale*; d - All dominant species (7) combined. Numbers above bar indicate average abundance at depth, numbers in parenthesis below bar indicate maximum abundance at depth.

asperum, *M. nitidulum*, and *M. obtusirostre* were most abundant in the surface (0-5 m) strata. *Hygophum macrochir*, which also entered near surface waters, *Diaphus perspicillatus*, *D. taaningi*, and *Myctophum selenops* occurred primarily between 50 and 100 m. Seven species (*Bolinichthys supralateralis*, *Diaphus fragilis*, *D. garmani*, *D. termophilus*, *Lampadena luminosa*, *Lobianchia gemellarii*, *Notoscopelus resplendens*) were most abundant between 75 and 150 m. The remaining 11 species usually were found deeper than 100 m, although several (*Diaphus brachycephalus*, *D. luetkeni*, and *Lampanyctus* *nobilis*) were captured as shallow as 50 m, and *Hygophum taaningi* was occasionally taken in surface (0-5 m) waters. Individuals of nine species were taken deep at night, between 450 and 950 m, indicating incomplete migration of the populations (Table 3).

Six species were considered rare (<10 individuals). Both *Taaningichthys* species were taken below 600 m during the day while the other four species came primarily from night samples between 50 and 200 m (Table 3).

NE and SE Sampling Areas

A total of 1,943 specimens from 42 of the 49 eastern Gulf myctophid species were captured in the NE sampling area, while 40 of the 49 species were recorded from SE samples (813 specimens; Table 3). The seven most abundant species in both areas are the same as for EC with the exception of *Myctophum affine*, which was infrequently captured because of a lack of surface night samples. *Diaphus mollis* was in the top seven species in the NE locale; *Hygophum taaningi* in the SE. The top seven species comprised 81.0% of the total number of specimens collected from NE samples and 75.2% from SE.

DISCUSSION

Vertical Distribution

Despite spatial overlapping, the vertical profiles of the eastern Gulf of Mexico myctophids show discrete stacking of species groups, which presumably enhances partitioning of spatial and trophic resources. Based on minimum depths of occurrence (MDO), vertical ranges and zones of abundance, groups of clearly associated species can be defined (Table 6). Five day and five night groups were constructed. Each day group consists of at least one abundant species plus one or more common species. However, because of differential migration ranges, only the three shallowest night groups contain abundant species.

During the day, almost all species have an MDO within their zone of highest abundance. All *Diaphus* species are typically upper mesopelagic inhabitants, while *Lampanyctus* and *Taaningichthys* species primarily dwell in the lower mesopelagic zone. *Hygophum* and *Myctophum* species are divided among upper and middle zones.

The daytime distribution of the abundant species

TABLE 6.—Species groups based on minimum depth of occurrence (MDO) and zones of abundance by day (36 spp.) and night (43 spp.). Underline indicates abundant species. Species in parentheses are outside of zone of maximum abundance; number after name indicates zone.

DAY

MDO (m)	Species	
300	B. supralateralis	D. problematicus
	D. dumerilii	D. rafinesquii
	D. effulgens	D. splendidus
	D. luetkeni	H. benoiti
	D. mollis	L. gemellarii
	D. perspicillatus	
350	D. brachycephalus	D. atlanticus
	D. fragilis	H. taaningi
	D. garmani	(L. alatus; ≥600)
400	B. suborbitale	D. taaningi
	C. nigroocellatus	(L. guentheri; ≥600)
	D. lucidus	N. valdiviae
	D. subtilis	
500	B. photothorax	M. affine[1]
	H. macrochir	M. obtusirostre
	H. reinhardtii	
	L. ater	
	L. luminosa	
≥600	C. warmingii	
	L. cuprarius	
	L. lineatus	
	L. nobilis	
	T. bathyphilus	

NIGHT

MDO (m)	Species	
Surface	C. nigroocellatus	M. affine
	G. cocco	M. asperum
	(H. benoiti; 50-125)	M. nitidulum
	(H. macrochir; 50-100)	M. obtusirostre
	(H. reinhardtii; 100-150)	
	(H. taaningi; 75-130)	
50	(B. photothorax; 90-125)	D. perspicillatus
	B. supralateralis	(D. problematicus; 80-150)
	B. suborbitale	D. splendidus
	(D. brachycephalus; 125-200)	D. taaningi
	D. dumerilii	(L. nobilis; 100-150)
	(D. lucidus; 100-150)	M. selenops
	(D. luetkeni; 100-160)	(N. valdiviae; 75)
	D. mollis	(N. resplendens; 75-125)
75	C. warmingii	L. alatus
	D. garmani	L. tenuiformis
	D. termophilus	L. luminosa
	D. atlanticus	L. gemellarii
	L. guentheri	
≥100	D. effulgens	L. ater
	D. fragilis	L. cuprarius
	D. rafinesquii	L. lineatus
	D. subtilis	
≥600	T. bathyphilus	

[1]Based on single capture; included because of additional unpublished data.

are separated among these zones as well (Table 6; Fig. 4d). *Diaphus dumerilii* (300 m MDO) and *Notolychnus valdiviae* and *Benthosema suborbitale* (400 m MDO) are upper mesopelagic, while *Myctophum affine* appears to be middle mesopelagic (based also on recent unpublished data of J. V. Gartner). *Ceratoscopelus warmingii* inhabits lower mesopelagic depths during the day, and while both *Lampanyctus alatus* and *Lepidophanes guentheri* have upper mesopelagic MDO's, both are most abundant in the lower mesopelagic zone.

Nighttime patterns show that many species frequently range shallower than their zones of maximum abundance (Table 6) and that all but one species (excluding *Taaningichthys minimus* and *T. paurolychnus*) vertically migrate. Species from four genera (*Myctophum*, 4 spp.; *Hygophum*, 4 spp.; *Centrobranchus nigroocellatus*; *Gonichthys cocco*) are regularly found in the surface waters (0-5 m) at night. However, none of the *Hygophum* species have their highest abundances in this stratum.

Diaphus species show several groupings at night though most occur below 100 m. The *Lampanyctus* species are all most abundant below 75 m, although individuals of *L. nobilis* are taken as shallow as 50 m. *Taaningichthys bathyphilus*, the only *Taaningichthys* species for which we have day and night data characteristically shows no evidence of vertical migration (see also Clarke 1973; Backus et al. 1977). This deep night group also includes nonmigratory individuals of many species.

Of the seven abundant species, four have nighttime MDO's at 75 m which coincide with their zones of maximum abundance (Table 6; Fig. 4d). A fifth species, *N. valdiviae*, while also most abundant below 75 m, occurs as shallow as 50 m. *Benthosema suborbitale* is also captured as shallow as 50 m, but shows no particular zones of abundance at night. *Myctophum affine* is most abundant at the surface.

Vertical partitioning and species associations have also been noted by Karnella (1983). Factorial analysis of abundant species collected from the Bermuda "Ocean Acre" project resulted in from five to eight daytime and six to eight nighttime discrete species associations, depending on season. The Ocean Acre location is in a subtropical region (Backus et al. 1977) and 45 of the 63 species reported by Karnella (1983) also occur in the Gulf. Despite differences in species abundances and general faunal structure and the fact that factorial analysis was inapplicable to the present data set, there are similarities in species associations both day and night between our studies. Karnella (1983) also showed generally shallow daytime distributions for *Diaphus* species, *Lobianchia gemellarii* and *Notolychnus valdiviae* (the only species which is abundant for both studies), and deep (>700 m) daytime distributions for most *Lampanyctus* species and *Ceratoscopelus warmingii*. At night, his surface group included *Myctophum* and *Hygophum* species, *Centrobranchus nigroocellatus*, and *Gonichthys cocco*. Middle groups (30 and 50 m MDO) included *Benthosema suborbitale*, *Ceratoscopelus warmingii*, and *Hygophum* species, while most *Lampanyctus* species were in the deeper (>100 or 200 m, depending on season) groups. The abundant species also tended to be divided among several depth groups both day and night. Our findings are also in general agreement with the distribution and abundance ranges reported by other authors for the same species (Clarke 1973; Badcock and Merrett 1976; Nafpaktitis et al. 1977).

Although vertical stacking of species groups is apparent, it is also obvious that the nighttime overlap of peak abundances among most of the abundant species is quite pronounced (Fig. 4d). It may be that vertical partitioning is on a much finer scale than the present data can resolve or that temporal partitioning of the same depth stratum may occur. It does not seem that day-night MDO's are linked to the extent of vertical migration, since some species which live relatively deep by day (e.g., *Ceratoscopelus warmigii*) are found at the same or shallower depths than those species inhabiting relatively shallow daytime depths (e.g., *Diaphus dumerilii*).

A number of factors including light (e.g., Clarke and Backus 1956, 1964; Paxton 1967; Badcock 1970; Marshall 1980), temperature (Paxton 1967; Robison 1972), and feeding migrations (Marshall 1960) have been suggested as control mechanisms limiting the vertical distribution range of myctophids and other mesopelagic animals. The relationships between these factors and myctophid vertical distributions in the eastern Gulf, however, are not readily apparent. Clarke (1973) determined that lunar period at night was an important factor in limiting the upward extent of vertical migration for many species, finding that the upper depth of migration was depressed by 50 to 125 m during a full moon period for a number of myctophid species (although *Hygophum* species apparently did the opposite, migrating shallower during full moon). In the Gulf, only a single species, *Lepidophanes guentheri*, showed a markedly shallower depth of capture during a new moon period (10 m vs. 75 m during new and full moons, respectively). All other species tended to show the same upper depths of capture regardless of the lunar phase. In fact, individuals of the 10 Gulf species with nighttime surface captures were regularly taken at the surface under a full moon with the deck lights turned on. The effect of temperature in the eastern Gulf is also unclear since the night distributions of almost all species extend through the base of the thermocline and many species enter the mixed layer which is generally isothermal (Fig. 2). Thus, many species encounter the highest temperatures found in Gulf surface waters.

If, as Marshall (1960) and later researchers suggested, nighttime vertical migrations of myctophids and other midwater animals are feeding migrations, a third possible control of depth range would be prey density. In this case, it would be reasonable to assume that zones of maximum potential prey and predator densities would be closely correlated. Analysis of zooplankton catches taken concurrently with our fish trawls show that this is not the case in the eastern Gulf (see Hopkins 1982). Rather, maximum zooplankton biomass of potential forage size organisms occurs in the upper 30 m at night in the eastern Gulf (Hopkins 1982), which is well above the MDO's of all species except surface dwelling *Myctophum* species, *C. nigroocellatus*, *G. cocco*, and occasional individuals of *Hygophum* species and *L. guentheri*.

Size Structure

The trend of increasing body size or advancing ontogenetic stage with increasing depth has been demonstrated among myctophids by many workers (Badcock 1970; Gibbs et al. 1971; Clarke 1973; Badcock and Merrett 1976; Willis and Pearcy 1980; Hulley 1981; Robison et al.[5]). Our data, which are confined to the abundant Gulf species, are in general agreement with these earlier findings for all species at night and for most during the day as well.

Many myctophid populations have individuals which do not migrate on a daily basis, and these nonmigrators are usually small juveniles (Gibbs et al. 1971; Clarke 1973; Badcock and Merrett 1976; Willis and Pearcy 1980). Our data also show this in that at least 19 of the 49 Gulf species had individuals captured at or below daytime depths (Table 3). In comparison with published accounts of identical species, our data on nonmigratory individuals supports the findings of Clarke (1973) for *Benthosema suborbitale*, *Bolinichthys supralateralis*, *Ceratoscopelus warmingii*, *Lampadena luminosa*, and *Lampanyctus nobilis* off Hawaii, and of Badcock and Merrett (1976) for *B. suborbitale*, *Diaphus rafinesquii*, and *Hygophum reinhardtii* in the eastern North Atlantic. Badcock and Merrett also captured *C. warmingii* but did not observe nonmigration, possibly because they took no individuals of the deep nonmigratory size range. Both Clarke (1973) and Badcock and Merrett (1976) reported that *Notolychnus valdiviae* had a significant nonmigratory fraction of the population, whereas in the Gulf the entire population apparently migrated.

Comparison of the size ranges of our abundant species with published sizes of the same species from other tropical-subtropical areas (Clarke 1973; Hulley 1981) show distinctly smaller sizes of adult individuals in the Gulf (Table 7). With a few exceptions, none of the Gulf species approaches maximum recorded sizes. This may have to do with sampling mechanics (e.g., net mouth area, towing speed, and net avoidance); however, the fact that we have made many additional net hauls since 1977 (20 cruises, ca. 600 discrete depth and oblique samples from 0 to 1,000 m) with a variety of gear and have not significantly increased the upper size limit of the abundant species suggests that this is not the case. A second possibility, which is supported by research on a variety of inshore and offshore species, is that fish species in the Gulf tend to grow faster, with given developmental stages being smaller, and reach maturity at smaller sizes than the same species found outside the Gulf (e.g., *Cynoscion nebulosus*, Tabb 1961; *Micropogonias cromis*, White and Chittenden 1977; *Mycteroperca microlepis*, Manooch and Haimovici 1978; *Mycteroperca phenax*, Godcharles and Bullock 1984; adult *Sciaenops ocellatus*, Mur-

TABLE 7.—Size range comparisons of dominant eastern Gulf myctophid species with the same species from other tropical-subtropical regions.

Species	This study	Clarke (1973) Hawaii	Hulley (1981) Eastern and South Altantic
Ceratoscopelus warmingii	14-65	11-79	25-80
Notolychnus valdiviae	9-22	9-25	[1]19
Lepidophanes guentheri	13-64		29-76
Lampanyctus alatus	15-48		30-58
Diaphus dumerilii	12-53		25-85
Myctophum affine	12-58		[2]28-47
Benthosema suborbitale	10-30	9-38	20-33

[1]Based on 1 specimen.
[2]Based on 13 specimens.

[5]Robison, B. H., T. L. Hopkins, and J. J. Torres. Ecology, physiology and nutrient energy dynamics of the Southern Ocean myctophid *Electrona antarctica*. Manuscr. in prep. Marine Science Center, University of California at Santa Barbara, Santa Barbara, CA 93106.

phy and Taylor MS in review[6]; larval and juvenile *S. ocellatus*, M. M. Leiby[7]; deep-sea benthic fishes, K. J. Sulak[8]).

Species Composition, Zoogeographic Affinities, Hydrographic Influence

Relatively few accounts have been published on Gulf of Mexico myctophids. Rass (1971) examined material from 5 years of deep otter trawl collections and reported 20 species. Bekker et al. (1975) identified 31 species from 19 stations in the southwestern Gulf, while Backus et al. (1977) collected 38 species from 7 midwater trawl stations extending from the north central to the southwestern Gulf. Nafpaktitis et al. (1977) recorded 52 species based on a variety of collections and earlier accounts from throughout the Gulf. Murdy et al. (1983) listed 39 species of myctophids taken from 35 Isaacs-Kidd Midwater Trawl stations also located throughout the Gulf. Most recently, Hopkins and Lancraft (1984) reported 34 species from 28 oblique hauls taken with an open net between 0 and 1,000 m at Standard Station. With the exception of Backus et al. (1977) and Nafpaktitis et al. (1977), these accounts are mainly annotated species lists.

Of these earlier studies, only Bekker et al. (1975) and Nafpaktitis et al. (1977) reported myctophid species not found in the present study. Bekker et al. captured one specimen each of *Lampadena anomala* and *Lampanyctus festivus*. Nafpaktitis et al. listed five species (*Diaphus adenomus*, *D. anderseni*, *D. metopoclampus*, *D. minax*, *Lepidophanes gaussi*) from the Gulf which we have not collected. The records of *D. anderseni* and *D. minax*, each based on a single specimen from our University of South Florida collections, were found to be misidentifications of *D. brachycephalus* and *D. perspicillatus*, respectively. Of the other five species, *D. adenomus* appears to be epibenthic (Clarke 1973; Hulley 1981) and as such cannot be considered part of the mesopelagic myctophic assemblage. The captures of *Lampadena anomala*, *Lampanyctus festivus*, and *D. metopoclampus* were well to the south and west of our study areas. Because of differences in circulation patterns of western and eastern Gulf waters, these species may never occur as far east as our sampling areas. Thus, the only species that we cannot reconcile is *Lepidophanes gaussi*, which was reported from the eastern Gulf by Nafpaktitis et al. (1977), although at best this species appears to be an exceedingly rare visitor.

Despite these records, we feel that with the data from the present study, the eastern Gulf of Mexico myctophid fauna has been defined. Of our 49 species, 42 were taken on the first three cruises and all 49 were collected by 1976. Despite an additional 20 cruises with approximately 600 mesopelagic trawl samples and over 8×10^6 m^3 water filtered, we have not added a single new species. We also conclude that all 49 species, including the 6 species listed as rare, are typical components of the eastern Gulf myctophid assemblage during the warm months. In other studies of myctophid assemblages (Clarke 1973; Karnella 1983), the term "rare" is used to designate species whose centers of geographic distribution lie outside the study area but which may occasionally be captured as strays, a definition which does not apply in the present study. With the exception of *Hygophum hygomii*, whose low numbers are attributed to geographic exclusion by its congener, *H. benoiti* (Nafpaktitis et al. 1977), the rare species in the eastern Gulf are everywhere rare or extremely uncommon. Data from the upper 1,000 m collected in the eastern Gulf since 1977 show all but the *Taaningichthys* species, which may occur below our normal fishing depth ranges, to be persistent low abundance members of the myctophid assemblage. Additional evidence of this is the capture of the larvae of *Symbolophorus rufinus* and *Notoscopelus caudispinosus* in the eastern Gulf (Houde et al. 1979; W. J. Conley[9]).

The number of myctophid species associated with a particular distribution pattern as defined by Backus et al. (1977) are listed in Table 8. Three of the 49 species captured in the Gulf (*Diaphus taaningi*, *Taaningichthys bathyphilus*, *T. paurolychnus*) are omitted because they have indeterminate geographic distributions. *Diaphus taaningi* is a pseudooceanic species, associated primarily with land, while the two *Taaningichthys* species are bathypelagic and do not appear to conform to shallower mesopelagic zoogeographic patterns.

Representatives of five of the nine Atlantic distribution patterns established by Backus et al. (1977)

[6]Murphy, M. D., and R. G. Taylor. Reproduction, growth and mortality of red drum, *Sciaenops ocellatus* in Florida. Manuscr. in prep. Department of Natural Resources, Bureau of Marine Research, 100 8th Avenue S.E., St. Petersburg, FL 33701.

[7]M. M. Leiby, Florida Department of Natural Resources, Bureau of Marine Research, 100 8th Avenue S.E., St. Petersburg, FL 33701, pers. commun. January 1986.

[8]K. J. Sulak, Atlantic Reference Centre, Huntsman Marine Laboratory, St. Andrews, New Brunswick E0G 2X0, Canada, pers. commun. June 1986.

[9]W. J. Conley, University of South Florida, Department of Marine Science, 140 7th Avenue S.E., St. Petersburg, FL 33701, pers. commun. September 1985.

TABLE 8.—Distribution patterns of eastern Gulf myctophids. NE - northeast, EC - eastern central, SE - southeastern.

	Total no. of species			No. of species by region (percent total no. of specimens)			Percent total no. of specimens	
	Atlantic (Backus et al. 1977)	Gulf (Backus et al. 1977)	Gulf (This study)	NE	EC	SE	Backus et al. 1977[1]	This study
Temperate-Semisubtropical	8	3	3	2(3.4)	3(4.2)	2(1.5)	0.3	3.9
Subtropical	13	5	7	7(4.0)	6(5.2)	6(6.6)	2.1	5.1
Tropical-Subtropical	18	13	15	11(51.1)	14(40.9)	12(45.4)	64.8	42.4
Tropical-Semisubtropical	5	4	5	5(2.4)	5(4.9)	5(6.2)	1.4	4.6
Tropical	18	12	16	16(37.9)	16(44.6)	13(39.8)	31.0	43.5

[1]Collections from shallower than 200 m at night.

are found in our collections. Species with tropical and tropical-subtropical affinities predictably form the largest component of the Gulf myctophid assemblage during the summer, comprising almost 70% of the 46 species. The seven abundant species all belong to one of these two faunal associations: three (*Ceratoscopelus warmingii*, *Notolychnus valdiviae*, *Benthosema suborbitale*) are tropical-subtropical; the other four (*Lepidophanes guentheri*, *Lampanyctus alatus*, *Diaphus dumerilii*, *Myctophum affine*) are tropical. Species with subtropical and temperate-subtropical affinities, however, are poorly represented in our collections. A comparison of species number by sampling locale (NE, EC, SE) within the Gulf reveals no particular pattern (Table 8). Absences from an area are probably due to species rarity or inadequate depth coverage of samples rather than to geographic influence.

Backus et al. (1977) characterized the mesopelagic Gulf of Mexico as a special zoogeographic region because of its unique physical and faunal characteristics. Although our collections captured a larger number of species than did theirs (49 vs. 38), the species composition patterns are very similar (Table 8) and indicate that the Gulf myctophid assemblage is overwhelmingly dominated by tropical-subtropical species. However, comparison of the percentage contribution of species within the two collections shows a much different composition (Table 8). Where the data of Backus et al. (1977) showed a 2:1 numerical predominance of tropical-subtropical myctophids over tropical species, our findings indicate that the two groups are roughly equal. This discrepancy may be due to the fact that Backus et al.'s data were based on collections from the western Gulf which has a different circulation pattern and is less directly influenced by the tropical Loop Current (Jones 1973). Their data were also from collections <200 m at night (J. E. Craddock[10]) which could have affected species number and percentages.

The largely tropical and tropical-subtropical composition of the eastern Gulf, during the warmer months at least, is most probably due to the influence of the Loop Current, which may entrain individuals of many uncommon species from the Caribbean. The size ranges of some of the species taken in our collections support such a hypothesis for transient species. Among the 26 uncommon species, 15 are represented only by either newly metamorphosed through juvenile or juvenile stages (Table 3). This suggests that the large, sexually mature adults may occur and spawn outside the Gulf, with occasional transport of eggs, larvae, and juveniles into the Gulf via the Loop Current. Four of the 15 species, however, are deep-dwelling *Lampanyctus* (*L. ater*, *L. cuprarius*, *L. nobilis*, *L. tenuiformis*) and the sexually mature individuals of these species may be present in the Gulf below our normal fishing depths, i.e., >1,000 m.

Other evidence of Loop Current influence is the relative absence of subtropical species whose geographic distributions usually place them at higher latitudes well to the north or south of the Caribbean Sea and Florida Straits. This is reinforced by the fact that of the six subtropical species we recorded from the Gulf, four (*Hygophum reinhardtii*, *Lampanyctus ater*, *L. lineatus*, *Taaningichthys minimus*) have uncertain zoogeographic affinities, as they seem to occur often in lower latitudes, including the Caribbean and the Gulf (Backus et al. 1977).

Although the Loop Current appears to play an important role in the composition of the eastern Gulf myctophid fauna, the biomass transported appears to be low. Comparison of the 25 northern (NE) non-

[10]J. E. Craddock, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, pers. commun. August 1978 (reconfirmed July 1986).

Loop Current-influenced stations with the 36 southern (SE) Loop Current samples showed that the samples were comparable in diel and vertical depth coverage and that species composition was also similar. However, the number of specimens collected at the NE sites were almost 2.5 times that of the SE total. This apparent impoverishment of myctophids in Loop Current waters is supported by the data of other workers showing low biomass of zooplankton in the Loop Current (Austin 1971; Jones 1973).

Tropical-Subtropical Myctophid Faunal Structure

The only other work which has extensively analyzed the myctophid assemblage in a tropical-subtropical setting is that of Clarke (1973) in the waters off Hawaii (lat. 21°N, long. 158°W). Estimates of micronekton standing stock off Hawaii (Maynard et al. 1975) and in the eastern Gulf (Hopkins and Lancraft 1984) show that both ecosystems are oligotrophic with roughly equivalent micronekton biomass in the upper 1,000 m. Because of these similarities, a direct comparison between the present study and the findings of Clarke (1973) is possible.

High diversity was apparent in both myctophid assemblages, with 18 genera, 47 species off Hawaii (Clarke 1973) and 17 genera, 49 species in the eastern Gulf. Of these taxa, the two systems shared 21 species. Excluding 2 bathypelagic species and 2 species of uncertain affiliation, 10 species are tropical-subtropical, 5 are tropical and 2 are tropical-semisubtropical according to Backus et al. (1977). Of the seven numerically dominant species of both studies, three (*Benthosema suborbitale*, *Ceratoscopelus warmingii*, *Notolychnus valdiviae*) are shared (Table 9). In fact, *C. warmingii* is the top ranked species on both lists. The other dominants on Clarke's list are Pacific congeners of Atlantic-Caribbean species, or are in very closely related genera (Paxton 1972). The percent of the total number of individuals that the top seven species comprise is strikingly similar (75.5%, Hawaii, 74.7% Gulf). Considering the difference in gear types and sampling strategy, estimates of numbers of individuals for the three shared species also agree well. Clarke's (1973) abundance ranges for *B. suborbitale* during warm months was 14 to 23 × 10^3 m^2, compared with 32 to 42 in the Gulf; *C. warmingii*; 55 to 155 vs. 86 to 287; *N. valdiviae*; 23 to 104 vs. 27 to 128. Thus, the contribution of the abundant species in the myctophid faunas appears to remain relatively constant.

Clarke's (1973) data on diel distributions of *B. suborbitale*, *C. warmingii*, and *N. valdiviae* are also similar to our own. Some differences, which may be the result of localized environmental variations, include shallower MDO's, depression of MDO and zones of abundance during full moon and roughly equivalent day-night abundances off Hawaii. Additionally, members of the Hawaiian *N. valdiviae* population were found to have a significant nonmigratory fraction, which has not been observed in the Gulf population. Clarke (1973) did note, however, that during several collection periods (March and June) no evidence of nonmigration was observed in *Notolychnus*.

Comparison of our species list with those compiled from other studies encompassing tropical-subtropical latitudes (Nafpaktitis and Nafpaktitis 1969, Indian Ocean; Hulley 1972, SW Indian Ocean; Clarke 1973, central Pacific; Wisner 1976, eastern Pacific; Hulley 1981, eastern and South Atlantic) showed that 10 myctophid species (8 mesopelagic, 2 bathypelagic) were common to all regions and that three (*Benthosema suborbitale*, *Ceratoscopelus war-*

TABLE 9.—Comparison of the top seven myctophid species and their percentage composition for the tropical-subtropical community off Hawaii (from Clarke, 1973) and the eastern Gulf of Mexico (the present study). Underline indicates shared species.

Hawaii			Eastern Gulf of Mexico		
Species	No.	Percent of total specimens	Species	No.	Percent of total specimens
Ceratoscopelus warmingii	3,911	20.7	*Ceratoscopelus warmingii*	2,267	17.0
Lampanyctus steinbecki	2,362	12.5	*Notolychnus valdiviae*	1,780	13.4
Triphoturus nigrescens	2,120	11.2	*Lepidophanes guentheri*	1,610	12.1
Lampanyctus niger	1,946	10.3	*Lampanyctus alatus*	1,418	10.7
Bolinichthys longipes	1,458	7.7	*Diaphus dumerilii*	1,279	9.6
Notolychnus valdiviae	1,267	7.0	*Myctophum affine*	893	6.7
Benthosema suborbitale	1,157	6.1	*Benthosema suborbitale*	687	5.2
	Total	75.5		Total	74.7

mingii, *Notolychnus valdiviae*) were relatively abundant everywhere. Distributional affinities of six of the eight mesopelagic species (the three preceding species plus *Diogenichthys atlanticus*, *Lampadena luminosa*, and *Myctophum nitidulum*) are tropical-subtropical; the other two (*Lampanyctus nobilis* and *L. tenuiformis*) are tropical (Backus et al. 1977). These species represent 5% to 17% of the total number of species from each region and between 9% and 38% of the total number of specimens examined (Wisner 1976 excluded). Thus, based on our comparison with Clarke's (1973) Hawaiian myctophid assemblage and the species lists from various regions of the world ocean, our findings on the eastern Gulf of Mexico myctophid fauna provide additional support to the idea that oligotrophic low-latitude mesopelagic habitats show considerable structural and ecological uniformity allowing for circumglobal distribution of a number of species, a pattern similar to that demonstrated to an even greater degree by bathypelagic fish species (Marshall 1980).

ACKNOWLEDGMENTS

Shiptime was provided by the Florida Institute of Oceanography and UNOLS (University-National Oceanographic Laboratory System). We thank Donald Wilson of the Office of Naval Research, Naval Research Laboratory for arranging shiptime on the RV *Mizar*. The research was funded by National Science Foundation contracts DES 75-03845, OCE 75-03845, and OCE 84-10787. The senior author especially wishes to thank the Gulf Oceanographic Charitable Trust for providing financial assistance. We are grateful to the following University of South Florida Marine Science (USFMS) personnel: Denise Bombard for typing the tables, Deborah Walton for preparation of the figures, and David Williams for photographic layout. Finally, thanks are extended to Mark Leiby, Florida Department of Natural Resources, Bureau of Marine Research; Jose Torres and Tom Lancraft, USFMS; and the two anonymous reviewers for their critical review of the manuscript.

LITERATURE CITED

AUSTIN, H. M.
1971. The characteristics and relationships between the calculated geostrophic current component and selected indicator organisms in the Gulf of Mexico Loop Current system. Ph.D. Thesis, Florida State University, Tallahasee, 369 p.

BACKUS, R. H., J. E. CRADDOCK, R. L. HAEDRICH, AND B. H. ROBISON.
1977. Atlantic mesopelagic zoogeography. *In* R. H. Gibbs, Jr. (editor), Fishes of the western North Atlantic, p. 266-287. Sears Found. Mar. Res., Yale Univ., Mem. 1, Pt. 7.

BADCOCK, J.
1970. The vertical distribution of mesopelagic fishes collected on the SOND Cruise. J. Mar. Biol. Assoc. U.K. 50:1001-1044.

BADCOCK, J., AND N. R. MERRETT.
1976. Midwater fishes in the eastern North Atlantic-I. Vertical distribution and associated biology in 30°N, 23°W, with developmental notes on certain myctophids. Prog. Oceanogr. 7:3-58.

BEKKER, V. E., Y. N. SHCHERBACHEV, AND V. M. TCHUVASOV.
1975. Deep-sea pelagic fishes of the Caribbean Sea, Gulf of Mexico and Puerto Rican trench. [In Russian] Tr. Inst. Okeanol. Akad. Nauk USSR 100:289-336.

CLARKE, G. L., AND R. H. BACKUS.
1956. Measurements of light penetration in relation to vertical migration and records of luminescence of deep-sea animals. Deep-Sea Res. 4:1-14.
1964. Interrelations between the vertical migration of deep scattering layers, bioluminescence, and changes in daylight in the sea. Bull. Inst. Oceanogr. Monaco 64(1318):1-36.

CLARKE, T. A.
1973. Some aspects of the ecology of lanternfishes (Myctophidae) in the Pacific Ocean near Hawaii. Fish. Bull., U.S. 71:401-434.

EL-SAYED, S. Z.
1972. Primary productivity and standing crop of phytoplankton. *In* V. C. Bushnell (editor), Chemistry, primary productivity and benthic algae of the Gulf of Mexico. Serial Atlas of the Marine Environment, p. 8-13. Am. Geophys. Soc., Folio 22.

GIBBS, R. H., JR., R. J. GOODYEAR, M. J KEENE, AND D. W. BROWN.
1971. Biological studies of the Bermuda Ocean Acre. II. Vertical distribution and ecology of the lanternfishes (family Myctophidae). Report to the U.S. Navy Underwater Systems Center, 141 p.

GODCHARLES, M. F., AND L. H. BULLOCK.
1984. Age, growth, mortality and reproduction of the scamp, *Mycteroperca phenax* (Pisces: Serranidae). FL. Dep. Nat. Res. Bur. Mar. Res. PL88-309 Annu. Rep. FY 82-83 to NMFS Jan. 1984, 30 p.

HOPKINS, T. L.
1982. The vertical distribution of zooplankton in the eastern Gulf of Mexico. Deep-Sea Res. 29:1069-1083.

HOPKINS, T. L., AND T. M. LANCRAFT.
1984. The composition and standing stock of mesopelagic micronekton at 27°N, 86°W in the eastern Gulf of Mexico. Contrib. Mar. Sci. 27:143-158.

HOPKINS, T. L., R. C. BAIRD, AND D. M. MILLIKEN.
1973. A messenger-operated closing trawl. Limnol. Oceanogr. 18:488-490.

HOUDE, E. D., J. C. LEAK, C. E. DOWD, S. A. BERKELEY, AND W. J. RICHARDS.
1979. Ichthyoplankton abundance and diversity in the eastern Gulf of Mexico. Report to the Bureau of Land Management, Contract No. AA550-CT7-28, 546 p. NTIS PB-299 839.

HULLEY, P. A.
1972. A report on the mesopelagic fish collected during the deep-sea cruises of R.S. 'Africana II', 1961-1966. Ann. S. Afr. Mus. 60(6):197-236.
1981. Results of the research cruises of F.R.V. "Walther Her-

wig" to South America. LVIII. Family Myctophidae. (Osteichthyes, Myctophiformes). Arch. Fischereiwiss. 31:1-300.

HULLEY, P. A., AND G. KREFFT.
1985. A zoogeographic analysis of the fishes of the family Myctophidae (Osteichthyes, Myctophiformes) from the 1979-Sargasso Sea expedition of R.V. "Anton Dohrn". Ann. S. Afr. Mus. 96(2):19-53.

JONES,, J. I.
1973. Physical oceanography of the northeast Gulf of Mexico and Florida continental shelf area. *In* State University System of Florida (Coordinator), A summary of knowledge of the eastern Gulf of Mexico. See IIB. FL. Inst. Oceanogr., St. Petersburg, FL, p. 1-11.

KARNELLA, C.
1983. The ecology of lanternfishes (Myctophidae) in the Bermuda Ocean Acre. Ph.D. Thesis, George Washington Univ., Washington, D.C., 499 p.

LEIPPER, D. F.
1970. A sequence of current patterns in the Gulf of Mexico. J. Geophys. Res. 75:637-657.

MANOOCH, C. S., III, AND M. HAIMOVICI.
1978. Age and growth of the gag, *Mycteroperca microlepis*, and size-age composition of the recreational catch off the southeastern United States. Trans. Am. Fish. Soc. 107: 234-240.

MARSHALL, N. B.
1960. Swimbladder structure of deep-sea fishes in relation to their systematics and biology. Discovery Rep. 31:1-122.
1971. Explorations in the lives of fishes. Harvard Univ. Press, Cambr., MA, 204 p.
1980. Deep-sea biology. Developments and perspectives. Garland STPM Press, N.Y., 566 p.

MAUL, G. A.
1977. The annual cycle of the Gulf Loop Current. Part I: Observations during a one-year time series. J. Mar. Res. 35:29-47.

MAYNARD, S. D., F. V. RIGGS, AND J. F. WALTERS.
1975. Mesopelagic micronekton in Hawaiian waters: faunal composition, standing stock and diel vertical migration. Fish. Bull., U.S. 73:726-736.

MCGINNIS, R. F.
1974. Biogeography of lanternfishes (family Myctophidae) south of 30°S. Ph.D. Thesis, Univ. Southern California, Los Angeles.

MOLINARI, R. L., AND D. A. MAYER.
1980. Physical oceanographic conditions at a potential OTEC site in the Gulf of Mexico: 27.5°N, 85.5°W. NOAA Tech. Mem. ERL AOML-42, 82 p.

MURDY, E. O., R. E. MATHESON, JR., J. D. FECHHELM, AND M. J. MCCOID.
1983. Midwater fishes of the Gulf of Mexico collected from the R/V *Alaminos*, 1965-1973. Tex. J. Sci. 35:109-127.

NAFPAKTITIS, B. G.
1974. A new record and a new species of lanternfish, genus *Diaphus* (Family Myctophidae), from the North Atlantic Ocean. Los Ang. Cty. Nat. Hist. Mus. Contrib. Sci. No. 254, 6 p.

NAFPAKTITIS, B. G., R. H. BACKUS, J. E. CRADDOCK, R. L. HAEDRICH, B. H. ROBISON, AND C. KARNELLA.
1977. Family Myctophidae. *In* R. H. Gibbs, Jr. (editor), Fishes of the western North Atlantic, p. 13-265. Sears Found. Mar. Res., Yale Univ., Mem. 1, Pt. 7.

NAFPAKTITIS, B. G., AND M. NAFPAKTITIS.
1969. Lanternfishes (Family Myctophidae) collected during Cruises 3 and 6 of the R/V *Anton Bruun* in the Indian Ocean. Bull. Los Ang. Cty. Nat. Hist. Mus. Sci. No. 5, 79 p.

NOWLIN, W. D., JR.
1971. Water masses and general circulation of the Gulf of Mexico. Oceanol. Int. 6:28-33.

NOWLIN, W. D., JR., AND H. J. MCLELLAN.
1967. A characterization of the Gulf of Mexico waters in winter. J. Mar. Res. 25:29-59.

PAXTON, J. R.
1967. Biological notes on southern California lanternfishes (family Myctophidae). Calif. Fish Game 53:214-217.
1972. Osteology and relationships of the lanternfishes (family Myctophidae). Bull. Los Ang. Cty. Mus. Nat. Hist. Sci. 13:1-81.

RASS, T. S.
1971. Deep-sea fish in the Caribbean Sea and the Gulf of Mexico (The American Mediterranean Region). Symp. Invest. Res. Carib. Sea and Adj. Reg. UNESCO, Paris 1971:509-526.

ROBISON, B. H.
1972. Distribution of the midwater fishes of the Gulf of California. Copeia 1972:448-461.

STURGES, W., AND J. C. EVANS.
1983. On the variability of the Loop Current in the Gulf of Mexico. J. Mar. Res. 41:639-653.

TABB, D. C.
1961. A contribution to the biology of the spotted seatrout, *Cynoscion nebulosus* (Cuvier) of east-central Florida. Fla. Board Conserv., Mar. Res. Lab., Tech. Ser. 35, 22 p.

VUKOVICH, F. M., AND G. A. MAUL.
1985. Cyclonic eddies in the eastern Gulf of Mexico. J. Phys. Oceanogr. 15:105-117.

WHITE, M. L., AND M. E. CHITTENDEN, JR.
1977. Age determination, reproduction and population dynamics of the Atlantic croaker, *Micropogonias undulatus*. Fish. Bull., U.S. 75:109-123.

WILLIS, J. M., AND W. G. PEARCY.
1980. Spatial and temporal variations in the population size structure of three lanternfishes (Myctophidae) off Oregon, USA. Mar. Biol. (Berl.) 57:181-191.

WISNER, R. L.
1976. The taxonomy and distribution of lanternfishes (Family Myctophidae) of the eastern Pacific Ocean. U.S. Gov. Print. Off., Wash., D.C., 229 p.