THE DISTRIBUTION OF MYCTOPHID FISHES ACROSS THE CENTRAL EQUATORIAL PACIFIC

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ABSTRACT

Analysis of myctophid fishes collected in the upper 50-75 m at night along long. 145°W between lat. 12°N and 3°30'S indicated three faunal groups. Warmwater species ocurred across the entire transect and were most abundant at or just north of the equator. A second group of species occurred only in the North Equatorial Current or the Counter Current, but most are known to be more widely distributed. A third group occurred only at or just north of the equator; all are apparently found within a small latitudinal range between about long. 130° and 170°W. Certain species which are abundant in the central water mass were absent from the present samples. The faunal change within the equatorial water mass is likely a response to the increased primary production and food supply resulting from upwelling near the equator and northward transport of enriched surface waters. Some of the faunal changes observed appear to be replacements of one species by a congener or morphologically similar species.

The geographic ranges of oceanic organisms frequently conform with the boundaries of the major water masses (Johnson and Brinton 1963). The water masses are, however, large-scale, subsurface features defined by the temperature-salinity profiles of the deeper water (Sverdrup et al. 1942). In the surface layers of a given water mass there are variations in temperature and salinity as well as in other biologically relevant factors. Thus it is not surprising that, within major water masses, subpatterns of abundance and distribution have been reported for species which might likely respond to such variations in the upper layers. There are numerous reports of subpatterns in epipelagic zooplankton, e.g., Fager and McGowan (1963) and McGowan (1971); and Ebeling (1962) and Backus et al. (1969) have noted similar changes within water masses for mesopelagic fishes. Backus et al. related these to shallow thermal fronts, and Ebeling suggested that, where species' ranges deviated from water-mass boundaries, they were related to variation in primary productivity in the surface layers.

Within the Pacific equatorial water mass, major and presumably biologically relevant changes are observed in the upper layers. Grandperrin and Rivaton (1966), studying the mesopelagic fishes along the equator, found four longitudinal faunal zones which appeared related to the depth of the Cromwell Current or Equatorial Undercurrent, variations in primary productivity, and concentrations of dissolved oxygen and nutrients in the upper layers. Latitudinally, one encounters four separate current regimes in the upper layers (Cromwell 1951) with associated changes in thermocline depths. Marked changes in primary productivity (Koblentz-Mishke et al. 1970), zooplankton volume (King and Hida 1957), and tuna abundance (Murphy and Shomura 1972) also occur across the water mass.

This study considers the distribution and abundance of myctophid fishes collected by shallow night trawl tows across a latitudinal transect of the Pacific equatorial water mass. It was expected that any patterns observed might be related to available data on differences in surface layer features.

MATERIALS AND METHODS

Most data were collected during cruise 43 of the U.S. Fish and Wildlife Service RV *Townsend Cromwell* (29 April-11 June 1969). Pelagic trawl collections were made along long. 145°W at five latitudes: approximately 12°N, 7°30'N, 3°30'N, 0°, and 3°30'S. Five tows were made with a modified Cobb pelagic trawl (CT) described by Higgins

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(1970) at each latitude except lat. 3°30′S (four tows). Towing speed was about 2 knots (ca. 1 m/s). All tows were made at night; the trawl was at depth for about 6 h each tow (2000-0200 h). Depths of tows were estimated from amount of wire out, wire angle, and depth determinations made on later cruises with a time-depth recorder. Two depth zones were sampled—20-30 m and 50-75 m. These will be referred to as "shallow" and "deep" tows, respectively. Depth of tow was alternated nightly except at the equator where all tows were deep. Station numbers, exact positions, depths, and dates are given in Table 1.

TABLE 1.—Station numbers, positions, towing depths, and dates of mid-water trawl collections taken May-June 1969 on cruise 43 of the RV *Townsend Cromwell*.

Station number	Position Lat.	Position Long.	Depth (m)	Date
8	12°04′ N,	144°54′ W	20-30	7 May
10	12°03′ N,	144°55′ W	50-75	8 May
12	12°11′ N,	145°11′ W	20-30	9 May
14	11°56′ N,	144°54′ W	50-75	10 May
16	11°58′ N,	144°57′ W	20-30	11 May
22	07°41′ N,	145°01′ W	50-75	13 May
24	07°27′ N,	145°05′ W	20-30	14 May
26	07°33′ N,	144°50′ W	50-75	15 May
28	07°33′ N,	144°48′ W	20-30	16 May
30	07°19′ N,	145°09′ W	50-75	17 May
36	03°29′ N,	145°03′ W	20-30	19 May
38	03°30′ N,	145°06′ W	50-75	20 May
40	03°31′ N,	145°00′ W	20-30	21 May
42	03°32′ N,	144°59′ W	50-75	22 May
44	03°40′ N,	144°54′ W	20-30	23 May
46	00°01′ N,	144°50′ W	50-75	25 May
48	00°04′ N,	145°07′ W	50-75	26 May
50	00°03′ N,	145°05′ W	50-75	27 May
52	00°01′ N,	145°03′ W	50-75	28 May
54	00°04′ N,	144°59′ W	50-75	29 May
55	02°59′ S,	144°53′ W	20-30	30 May
57	03°31′ S,	145°11′ W	50-75	31 May
59	03°34′ S,	145°00′ W	20-30	1 June
61	03°35′ S,	145°11′ W	50-75	2 June

Except for very large samples, the entire collection was preserved and counted. When total volume of the sample exceeded ca. 4 gallons (ca. 15 liters), 1-gallon (ca. 4 liters) subsamples were preserved, and counts were adjusted according to the original total volume. Specimens were identified primarily from Nafpaktitis (1968), Nafpaktitis and Nafpaktitis (1969), and an unpublished manuscript kindly provided by R. L. Wisner.[3]

During cruise 43, bathythermograph casts to 300 m were made at approximately 50-km intervals between lat. 14° and 3°N and at approximately 16-km intervals between lat. 3°N and 3°S. Salinity-temperature-depth casts to 500 m were made every degree from lat. 14° to 3°N and every 32 km from lat. 3°N to 3°S.

We have also counted the myctophids from 12 tows with a 10-foot (3 m) Isaacs-Kidd mid-water trawl (IK) taken 5-11 February 1970 at lat. 3°30′N, long. 145°W during cruise 47 of the *Townsend Cromwell*. These tows were all taken at night. Towing depths were 50-500 m; each tow spent about 2 h at depth (Table 2). The data from these tows along with data on vertical distribution of myctophids near Hawaii, somewhat north and west of the sampling area (Clarke 1973), allow us to estimate whether the absence of certain species from Cobb trawl tows in some zones was due to the species' simply occurring deeper than the Cobb trawl sampled.

TABLE 2.—Station numbers, towing depths, and dates of mid-water trawl collections taken near lat. 3°30′N, long. 145°W, February 1970 on cruise 47 of the RV *Townsend Cromwell*.

Station number	Depth (m)	Date
48	50	5 Feb.
49	50	5 Feb.
52	450	6 Feb.
57	200	7 Feb.
58	100	7 Feb.
60	500	7 Feb.
61	300	8 Feb.
67	300	9 Feb.
68	100	10 Feb.
69	200	10 Feb.
76	450	10 Feb.
78	500	11 Feb.

RESULTS AND DISCUSSION

The slope of the isotherms on the temperature profile of the transect (Figure 1) indicate the locations of the major currents of the area. The North Equatorial Current (NEC) extended to about lat. 9°N, the Equatorial Counter Current (ECC) from about lat. 4° to 9°N, and the South Equatorial Current (SEC) southward from about lat. 4°N. The Cromwell Current or Equatorial Undercurrent (EUC) was centered about on the equator. Thus the lat. 12°N samples were taken within the NEC, the lat. 7°30′N samples just south of the boundary between the NEC and the ECC, and the other samples in the SEC, the lat 0° samples actually being in the upper layers of the EUC.

A total of 32 species of myctophids were taken by the CT collections. The catches per tow are given in Table 3. Failure to catch a given species at

[3]Wisner, R. L. Annotated and illustrated key to the identification of fishes of the family Myctophidae of the eastern Pacific Ocean, eastward of 160° West Longitude. Unpubl. manuscr., Scripps Institution of Oceanography, La Jolla, CA 92037.

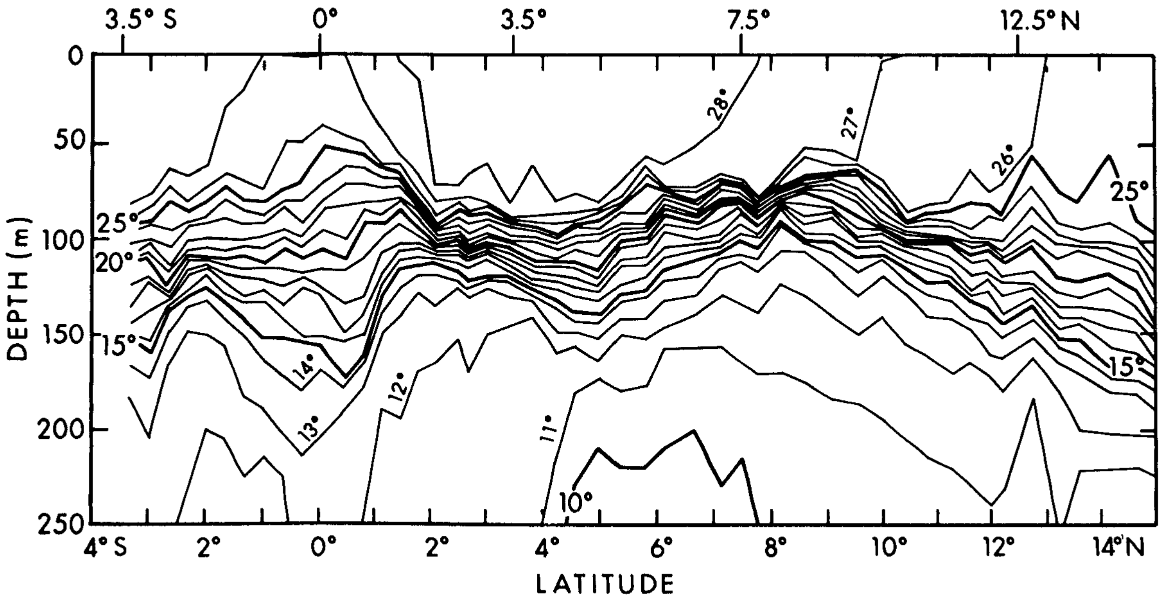

FIGURE 1.—Temperature (in degrees Celsius) profile along long. 145°W. (Compiled by R. A. Barkley from data collected on cruise 43 of the RV *Townsend Cromwell.*)

all stations at a given latitude does not, of course, necessarily mean the species was not present. It may have been present at low abundance and missed by the collections or may have occurred at depths greater than 75 m. With respect to the first possibility, we have ignored zero values in a few cases below, e.g., for very rare species and for the data from lat. 3°30′S where total catches were so much lower than elsewhere that it is likely some fraction of the total species present were not caught. With respect to the second possible source of error, we exclude from further consideration six species for which the upper limit of the depth range is close to the depth of the deep CT tows. Based on vertical distribution data from near Hawaii (Clarke 1973), only slight changes in the depth ranges of *Diaphus brachycephalus*, *Notolychnus valdiviae*, and *Lampanyctus steinbecki* would determine presence or absence in the CT collections. The IK data from lat. 3°30′N (Table 4) indicates that the same may be true for *D. jenseni*, *D. longleyi*, and *D. splendidus*. In the absence of data to the contrary and in some cases with reasonable evidence (see below), we assume that the remaining 26 species have shallow nighttime depth ranges wherever they occur in any abundance and that zero catches were not the result of changes in depth ranges with latitude.

In the presentation below, we attempt to relate patterns of distribution in the study area to other data on the species. Unfortunately, we have felt it necessary to disregard data from certain earlier studies where species identifications are doubtful. We have relied heavily on data from recent studies by Clarke (1973) near Hawaii, by M. A. Barnett (pers. commun.) near the center of the eastern central Pacific gyre (ca. lat. 29°N, long. 155°W), and by Ahlstrom (1971, 1972) in the eastern equatorial Pacific. For convenience, these will not be cited formally each time; unless otherwise cited, "near Hawaii," "gyre center," and "eastern equatorial," respectively, refer to the above three studies.

Eight species occurred across the entire sampling area. These were: *Hygophum proximum*, *Diogenichthys atlanticus*, *Myctophum aurolaternatum*, *M. spinosum*, *Symbolophorus evermanni*, *Diaphus fragilis*, *Triphoturus nigrescens*, and *Ceratoscopelus warmingi*. Other records of these species and of *M. nitidulum* and *Bolinichthys longipes*, which were taken at all latitudes except 3°30′S, indicate that all 10 occur widely throughout central water masses of the Indo-Pacific and, in most cases, the world (Bekker 1965; Nafpaktitis 1968; Nafpaktitis and Nafpaktitis 1969; Gibbs et al. 1971; Wisner footnote 3). All but *M. aurolaternatum* are taken consistently near Hawaii and all have been taken at the gyre center.

TABLE 3.—Species of myctophids and number taken per tow for stations given in Table 1. Stations are grouped by latitude and by depth (Shallow = 20-30 m, Deep = 50-75 m). Species are grouped in roughly the order considered in the text.

Species	Lat. 12°N					Lat 7°30′N					Lat. 3°30′N					Lat. 0°					Lat. 3°30′S			
	Shallow			Deep		Shallow		Deep			Shallow			Deep		Deep					Shallow		Deep	
	Stn. 8	12	16	10	14	24	28	22	26	30	36	40	44	38	42	46	48	50	52	54	55	59	57	61
Diaphus brachycephalus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	21	2	1
Diaphus jenseni	—	—	—	—	—	—	—	—	—	—	—	—	—	53	46	7	5	11	4	60	—	—	—	—
Diaphus longleyi	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—
Diaphus splendidus	—	—	—	—	—	—	—	—	1	106	—	—	11	—	—	—	—	—	—	—	—	—	—	—
Notolychnus valdiviae	—	—	—	—	—	—	—	—	—	—	—	—	—	4	2	312	4	—	12	144	—	—	—	13
Lampanycytus steinbecki	—	—	—	—	20	—	—	—	—	26	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hygophum proximum	8	—	3	170	30	111	51	206	274	98	17	58	52	35	26	91	40	176	64	196	55	117	175	157
Diogenichthys atlanticus	—	—	—	9	1	—	—	5	7	12	1	—	14	60	52	26	4	22	12	32	—	2	27	19
Myctophum aurolaternatum	4	1	1	1	1	3	1	10	18	14	8	5	8	20	16	12	14	20	6	8	1	1	0	0
Myctophum spinosum	1	—	—	—	—	12	1	14	4	10	4	24	6	3	5	5	7	55	48	20	—	1	—	—
Symbolophorus evermanni	1,491	334	270	62	75	446	745	514	359	927	92	141	161	220	92	1,216	819	968	1,984	1,244	43	4	75	62
Diaphus fragilis	—	—	—	—	1	—	—	15	66	259	14	—	—	—	90	13	81	99	20	168	—	—	40	54
Triphoturus nigrescens	—	2	—	—	—	7	7	1	9	18	2	4	3	259	82	1,670	1,526	1,232	1,308	1,824	—	—	—	21
Ceratoscopelus warmingi	—	—	—	—	8	—	—	96	192	2,289	2	—	6	5,103	1,907	1,391	1,764	1,232	2,024	4,016	—	—	71	186
Myctophum nitidulum	6	2	12	4	1	13	3	10	11	3	2	—	3	2	1	2	1	—	24	20	—	—	—	—
Bolinichthys longipes	—	—	—	—	2	—	—	2	15	333	2	—	—	108	11	566	158	99	148	136	—	—	—	—
Diogenichthys laternatus	—	2	—	1,139	173	3	—	214	150	168	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Gonichthys teniculus	2	4	4	1	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diaphus garmani	—	—	—	114	63	—	—	1,085	359	485	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diaphus problematicus	—	—	—	—	—	—	—	1	15	382	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lampanyctus nobilis	—	—	1	193	520	—	2	177	105	126	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lampanyctus omostigma	12	127	17	83	39	2	20	34	17	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notoscopelus resplendens	—	—	—	9	26	—	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Diaphus malayanus	—	—	—	—	—	—	—	—	1	19	—	—	7	1,190	638	156	270	1,694	112	800	—	—	—	—
Diaphus regani	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	65	18	—	32	64	—	—	—	—
Diaphus signatus	—	—	—	—	—	—	—	—	—	—	—	—	—	112	97	604	2,025	2,299	4,400	3,804	—	—	—	—
Diaphus sp. (near *mollis*)	—	—	—	—	—	—	—	—	—	—	—	—	—	46	37	91	495	154	212	280	—	—	—	—
Lampanyctus hubbsi	—	—	—	—	—	—	1	1	1	1	—	—	1	259	43	175	45	33	44	—				
Myctophum asperum	—	—	—	—	—	2	13	13	26	77	3	3	7	1	16	3	43	253	236	26	—	—	2	3
Myctophum obtusirostrum	—	—	—	—	—	—	—	—	—	—	—	2	—	—	3	—	—	11	32	24	—	—	—	—
Diaphus elucens	—	—	—	—	—	—	—	—	—	—	34	—	—	39	32	—	—	—	—	—	—	—	—	—
Centrobranchus choerocephalus	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—
Total	1,524	472	308	1,785	960	599	845	2,403	1,631	5,356	181	237	279	7,515	3,197	6,408	7,319	8,358	10,722	12,866	100	146	392	516
Average, shallow or deep		768		1,372		722			3,130			232		5,356				9,134			123		454	

TABLE 4.—Species of myctophids and number taken per tow for stations given in Table 2.

	50 m		100 m		200 m		300 m		450 m		500 m	
Species	Stn. 48	49	58	68	57	69	61	67	52	76	60	78
Electrona rissoi	—	—	—	—	—	—	—	1	—	—	—	—
Hygophum proximum	1	2	5	3	4	6	3	1	—	1	2	16
Diogenichthys atlanticus	3	3	4	—	—	1	1	—	—	1	—	5
Myctophum aurolaternatum	—	—	—	—	—	1	—	—	—	—	—	—
Myctophum asperum	3	—	—	1	—	—	—	—	—	—	—	—
Myctophum nitidulum	—	2	1	1	1	—	—	—	1	—	—	—
Myctophum obtusirostrum	1	—	—	1	—	—	2	—	—	—	1	—
Myctophum selenoides	—	—	3	—	—	—	1	—	—	—	—	—
Myctophum spinosum	—	2	2	—	1	1	1	—	—	—	—	—
Symbolophorus evermanni	5	8	9	8	3	—	1	2	—	1	—	1
Diaphus drachmani	—	—	—	—	—	—	1	—	—	1	—	—
Diaphus elucens	7	17	1	—	1	—	—	3	1	1	—	—
Diaphus fragilis	5	6	1	2	2	—	2	2	—	—	—	—
Diaphus jenseni	—	—	56	5	2	4	2	1	—	—	—	—
Diaphus longleyi	—	—	31	6	4	10	1	1	4	—	3	2
Diaphus lucidus	—	—	4	4	—	—	—	—	—	—	—	—
Diaphus luetkeni	2	—	4	—	3	4	1	—	2	2	2	1
Diaphus malayanus	67	10	1	2	1	1	—	2	—	—	—	—
Diaphus problematicus	—	—	2	—	—	—	—	—	—	—	—	—
Diaphus regani	—	—	1	—	—	—	—	—	—	—	—	—
Diaphus splendidus	7	—	46	14	6	2	5	3	—	2	5	1
Diaphus termophilus	—	—	—	1	—	7	3	3	6	1	—	1
Diaphus sp. (near *mollis*)	25	—	5	—	2	3	1	1	—	5	2	—
Notolychnus valdiviae	—	—	25	3	4	25	3	1	1	—	8	—
Lampadena luminosa	—	—	7	—	—	2	—	1	—	—	1	—
Triphoturus nigrescens	8	3	14	—	5	27	8	2	3	12	11	7
Lampanyctus hubbsi	78	66	7	4	4	8	—	2	1	4	—	2
Lampanyctus "niger"	—	—	43	23	34	127	13	31	42	11	1	28
Lampanyctus nobilis	—	—	—	—	—	—	1	—	—	1	—	—
Lampanyctus omostigma	—	—	—	—	—	—	—	—	—	1	—	—
Lampanyctus steinbecki	1	—	1	3	1	4	—	—	—	—	—	—
Bolinichthys sp.[1]	—	—	1	—	—	—	1	2	1	—	—	—
Bolinichthys longipes	12	10	1	2	2	1	1	—	3	1	—	1
Bolinichthys photothorax	—	—	2	—	—	—	2	2	1	—	—	—
Ceratoscopelus warmingi	90	123	25	2	10	12	11	14	1	8	5	3

[1]*Bolinichthys* sp. is similar to *B. supralateralis*, but is apparently distinct and undescribed (R. K. Johnson, Field Museum of Natural History, Chicago, Ill., pers. commun.).

Several of these species are truly warmwater cosmopolites (McGowan 1971). *Hygophum proximum*, *M. aurolaternatum*, *M. nitidulum*, and *B. longipes* occur in equatorial waters not only in the study area, but widely throughout the eastern equatorial Pacific. Others, *C. warmingi*, *Diogenichthys atlanticus*, and *Diaphus fragilis*, apparently occur in equatorial waters only west of ca. long. 130°W.

Most of the 10 above species showed similar trends in abundance with latitude; peak abundance was at either lat. 3°30′N or at the equator. The same trend is evident in the total numbers of myctophids taken in deep tows (Table 3). (The total catches of the shallow tows tended to decrease southward. This trend is not marked, and the absence of data from the equator is perhaps critical.) A trend similar to that of the deep catches and of the wide-ranging species has been noted in zooplankton standing crop (King and Hida 1957). The increases in abundance are probably related to the higher primary productivity resulting from the upwelling and subsequent northward transport of enriched waters near the equator (Cromwell 1953; Murphy and Shomura 1972).

Three species of myctophids which are abundant at night in the upper layers near Hawaii and also taken at the gyre center were conspicuously absent from the present samples. *Benthosema suborbitale*, *Diaphus schmidti*, and a *Diaphus* sp. similar to *D. mollis* (called *Diaphus* sp. A by Clarke 1973) are apparently restricted to the central water mass—at least to the east of long. 145°W.

Seven species occurred only or principally at the northern two stations. *Diogenichthys laternatus*, *Gonichthys teniculus*, *Diaphus garmani*, *Lampanyctus omostigma*, *L. nobilis*, and *Notoscopelus resplendens* were taken only at lat. 12°N and 7°30′N. *Diaphus problematicus* was taken only at lat. 7°30′N. Three of these species, *D. problematicus*, *L. omostigma*, and *L. nobilis*, were captured in the IK series at lat. 3°30′N, but in low numbers (Table 4). It is clear that none of these species occurred at lat. 3°30′N in abundance.

Of these seven species, one appears to be widely distributed in the central water masses and four are widely distributed in the eastern equatorial Pacific. *Lampanyctus nobilis* is taken at the gyre center and consistently near Hawaii. Its distribution pattern at long. 145°W is thus intermediate between that of the three strictly central water-mass species mentioned above and that of the species which were taken all the way across the transect. *Diogenichthys laternatus*, *G. teniculus*, *L. omostigma*, and *N. resplendens* occur over a broad latitudinal range in the eastern equatorial Pacific and in a narrower tongue extending into the central equatorial Pacific (Wisner 1963, footnote 3; Bekker 1966). None of these species are taken near Hawaii, and only *G. teniculus* and *N. resplendens* are taken near the gyre center, neither very frequently.

Little is known of the distribution of *Diaphus garmani* and *D. problematicus* in the Pacific. *Diaphus garmani* has been reported from Johnson Island (Nakamura 1970). Wisner (footnote 3) reports it from near Hawaii but it was not taken there by Clarke (1973) nor does it occur at the gyre center. Ahlstrom (1972) recorded *D. garmani* in "an offshore equatorial belt" but mentions neither species as present in the eastern equatorial Pacific. In the Atlantic, both species occur in equatorial waters, but also occupy a broad latitudinal range in the west (Nafpaktitis 1968).

Five species were taken principally at lat. 3°30′N or the equator. *Diaphus signatus* and *D.* sp. (near *mollis* but apparently distinct from either of the *mollis*-like forms recorded from near Hawaii by Clarke) were taken in abundance at both stations, while *D. regani* was taken almost exclusively at the equator. A few *D. malayanus* and *Lampanyctus hubbsi* were taken at lat. 7°30′N, but these species were clearly more common at lat. 3°30′N and the equator. All of these species are found only in the Pacific. There are no reports of any from either the eastern equatorial Pacific or the eastern section of the central water mass. *Lampanyctus hubbsi* is restricted to the offshore equatorial water mass (Wisner 1963). The same is apparently true of the undescribed species of *Diaphus* (Wisner footnote 3). The other three species of *Diaphus* were originally described from farther south or west and near island groups (Gilbert 1908; Weber 1913; Tåning 1932), and a few were collected in the western Pacific by Kulikova (1961). Wisner (footnote 3) indicates that they occur, like *L. hubbsi*, in the narrow offshore equatorial region between ca. long. 130-170°W.

Diaphus elucens was taken only at lat. 3°30′N, and *Myctophum obtusirostrum* at lat. 3°30′N and the equator. Their distributions are however, much broader than the present data indicates (Nafpaktitis 1968, 1973). Both are taken consistently near Hawaii. It seems likely that their capture only at the above latitudes was due more to their greater abundance there as opposed to their absence from the other latitudes sampled. *Centrobranchus choerocephalus* was taken only twice (lat. 7°30′N and 3°30′N). Bekker (1966) suggests it is a central water-mass species, and it is taken regularly near Hawaii. No real significance can be attached to the capture of only two specimens in the equatorial water mass.

The remaining species, *Myctophum asperum*, was taken at all latitudes except lat. 12°N. Its distribution in the Pacific is poorly known. Ahlstrom (1972) records it from lat. 7°N to 2°S between long. 98° and 119°W. It is not taken at the gyre center or near Hawaii. It is apparently, like *Diaphus garmani* and *D. problematicus*, neither a central nor eastern equatorial species, but may have a broader distribution to the west.

Although the data from both the present study and the literature are admittedly fragmentary and we know nearly nothing about distributions south and west of the study area, the evidence indicates that there is no distinct or abrupt change between the shallow-water myctophid faunas of the central and equatorial water masses as defined by Sverdrup et al (1942). While there are at least three abundant central species which did not occur in our equatorial samples, there were more which occurred throughout the sampling area and, in most cases, are also widely distributed in equatorial waters farther east. In between are several central species which occur in the equatorial water mass to a limited extent—both latitudinally (*L. nobilis*) and longitudinally (*Ceratoscopelus warmingi*, *Diogenichthys atlanticus*, and *Diaphus fragilis*).

Within the equatorial water mass, however, there is a distinct and rather abrupt change in fauna. Four species which occur throughout equatorial waters farther east were taken only at the northern two stations, while five other species which do not occur east of ca. long. 120-130°W were taken at lat. 3°30′N and the equator. There is thus little or no overlap between the ranges of the strictly offshore and those of the eastern equatorial species whose ranges extend into the study area.

The change in fauna is close to the northern boundary of the SEC and may be related to the upwelling and northward transport of surface waters near the equator. In Figure 1, the latter are indicated by the shallow 27°C isotherm between about lat. 1°S and 0°30′N—somewhat south of the indicated faunal change. However, King and Hida (1957) and Murphy and Shomura (1972) point out that, while strength of upwelling and extent of northward surface transport vary irregularly over short periods depending on strength and direction of winds, the area between about lat. 1°S and about lat. 4°N can be regarded as a zone of high primary production and high zooplankton standing crop over most of the year.

The central equatorial Pacific is thus somewhat unique in that it is the only major offshore and truly oceanic area in the world where upwelling and high primary production are not strongly seasonal. Other areas of upwelling are either relatively close to land or, e.g., the Antarctic, are light-limited over part of the year. Thus it is not surprising that the fauna of the zone is different from both that of the oceanic, but relative sterile central water mass and that of the highly productive, but less oceanic eastern equatorial Pacific. Nor is it surprising that five of the species which occur in the zone are either endemic or restricted to it at least in the eastern part of the Pacific.

The faunal change observed in the data here could in part be a consequence of the change in primary production and availability of food. Ebeling (1962) has suggested that distributions of even deep-living, nonmigrating fishes are associated with differences in surface primary production, and Backus et al. (1969) have suggested that faunal changes associated with thermal fronts are more directly related to differences in primary production which result from differences in thermal structure on either side of the front. It is not unreasonable to suggest that the five species which were found only near the equator are unable to survive in the less productive waters north of about lat. 4°N.

This is, of course, insufficient to explain other features of the faunal change. It is not clear why some species, many which occur also in sterile central waters, not only occur in the equatorial zone of high production but are markedly more abundant there, while other species, which occur in the highly productive eastern equatorial Pacific, are apparently excluded from the offshore zone near the equator. More knowledge, e.g., the reproductive potential and food requirements, of the species concerned and of environmental characteristics of the areas, e.g., types and rates of predation, is needed before even speculation is warranted.

There are several examples where dominant species are "replaced" by congeners or morphologically similar species. *Lampanyctus omostigma* and *L. hubbsi* are very similar congeners which both occur in the equatorial water mass but with separate distributions. *Diaphus schmidti*, a central water-mass species, is replaced by *D. garmani* and *D. problematicus* in the northern section of the equatorial water mass, and these in turn are replaced by *D. malayanus*, *D. signatus*, and *D. regani* in the zone near the equator. All these *Diaphus* species are similar morphologically. *Diaphus schmidti*, *D. garmani*, and *D. malayanus* are of similar size at maturity while the others are somewhat larger. In addition to differences in placement of body photophores and development of sexually dimorphic head organs, these species are all distinguished by slightly different gill raker counts, suggesting differences in feeding habits. The *Diaphus mollis*-like forms also show a replacement series of sorts. The central water-mass species (*Diaphus* sp. A of Clarke 1973) is very similar in size and morphology to the *Diaphus* sp. taken near the equator; however, no similar form was present in the northern section of the equatorial water mass.

It is not implausible to suggest that *Benthosema suborbitale* and the *Diogenichthys* species form a replacement series. *Benthosema suborbitale* is a diminutive species of *Benthosema* and very similar to the *Diogenichthys*; the two genera are closely related (Moser and Ahlstrom 1970; Paxton 1972). It is apparently replaced by *D. laternatus* in the northern section of the equatorial water mass. *Diogenichthys atlanticus* occurs in all three zones, but is an abundant and dominant species only near the equator—where neither *B. suborbitale* nor *D. laternatus* occur.

Clarke (1973) has shown that, at a single location, closely related species have different nighttime depth ranges. The data here suggest that within a given depth range, closely related species are frequently separated geographically. Investigations of the biology of such closely related, but separated species, particularly near their geographic boundaries, would be a promising approach toward understanding the factors determining zoogeographic distribution in the open ocean.

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