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THE MESOPELAGIC FISHES COLLECTED DURING CRUISE 17 OF THE R/V CHAIN, WITH A METHOD FOR ANALYZING FAUNAL TRANSECTS¹

RICHARD H. BACKUS,² GILES W. MEAD,² RICHARD L. HAEDRICH,² AND ALFRED W. EBELING³

INTRODUCTION

Cruise 17 of the R/V CHAIN of the Woods Hole Oceanographic Institution was devoted mainly to hydrographic, bathymetric, and geochemical studies in the Atlantic Ocean in the neighborhood of the Romanche Trench, a depression lying on the equator at about 17° West. On the homeward leg of this cruise (April 20–May 15, 1961), 14 collections (800–813) were made by the senior author with a 10-foot Isaacs-Kidd midwater trawl (IKMT) (Fig. 1). Earlier in the cruise, four successful collections (4, 5, 6, and 9) had been made by Mr. Herbert Curl, Jr., with a three-foot IKMT. The fishes taken have been identified, and provide data from which we derive a method for the analysis of such faunal transects. The application of this method, together with ancillary physical observations, permits some tentative remarks on faunal boundaries in the southern North Atlantic Ocean.

Collection data, together with the numbers of species and specimens taken (exclusive of larvae), are given in Table 1. The tows were made at about 3½ knots, and all but one took place at night. Their

depths were computed from measurements of wire angle and amount of wire out and are considered to be accurate to about ±5 per cent. This procedure is justified by the findings of Backus and Hersey (1956) who compared the results of such computations with echo-sounder measurements of the depth of an IKMT made from a following ship. Comparisons of computed depths with measurements made using a time-depth recorder (Benthos Company Depth Recorder) were made on a cruise in early 1963. These again justify the use of triangulation for determining the depth of the IKMT, at least with towing warps a few hundred meters long and towing speeds of about 5 knots or less.

As no closing device was used with the net during CHAIN Cruise 17, we cannot be certain that any specimen came from the depth given for the net. However, the time at depth was made long with respect to the time consumed in setting and hauling the net.

Fishing depths were chosen which promised to yield large amounts of material. Choices were based on inspection of the echo-sounder record (Edo Corporation UQN-1b with the Precision Graphic Recorder; operating frequency, 12 kcps) for the deeper hauls (230–495 m) and the echo-sounder record and a bathythermogram for the shallower hauls (42–90 m). For the deeper hauls the depth of a pronounced sound-scattering maximum was chosen. For

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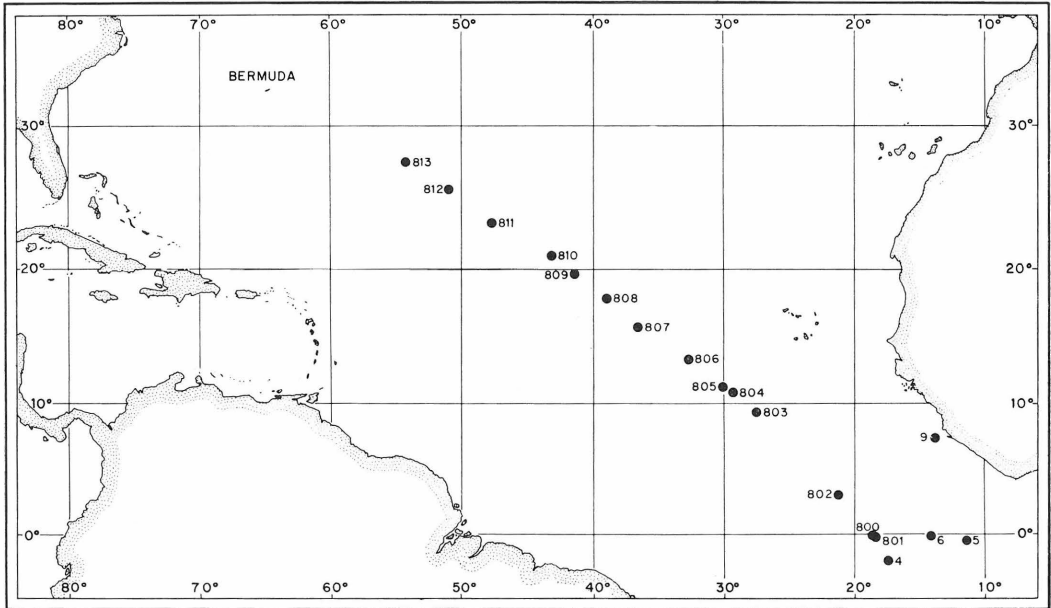


Fig. 1. Location of collections.

the shallower hauls some critical point on the temperature-depth curve that lay within a zone of intense sound-scattering was chosen. The bottom of an isothermal layer, the bottom of a thermocline, and the level of a pronounced temperature inversion all appear to be places where animals tend to concentrate.

It is traditional in oceanography to make the samples comparable in depth when sampling over a long section. The only property of the environment held approximately constant by such a choice is pressure. This property seems of relatively little importance in the lives of pelagic animals, at least when compared with temperature, transparency and probably many other properties. In measuring such a factor as temperature, a successful observation is assured, given a working instrument. Often in collecting pelagic fishes, however, "no catch" results from a haul at an arbitrarily chosen depth. While this may be an interesting ecological observation, it is generally considered unsatisfactory when the purpose is zoogeographical.

The cruise was conducted under Contracts 2196 and 3351 between the Office of Naval Research and the Woods Hole Oceanographic Institution. Other parts of the work have been supported by National Science Foundation Grants G-9579 and GB-543 to the Woods Hole Oceanographic Institution and G-15887 to Harvard University. We are greatly indebted to these organizations for their help, and to Vaughan T. Bowen and W. G. Metcalf, the organizers of the cruise. Metcalf provided the bathythermograph data used. Charles Karnella sorted many of the collections. Robert H. Gibbs, Jr., U. S. National Museum, identified the stomiatoid fishes, except for the sternoptychids and the gonostomatids. The last were identified by the late Marion Grey, Chicago Natural History Museum. Daniel M. Cohen, U. S. Bureau of Commercial Fisheries, identified most of the anacanthine fishes. Loren P. Woods, Chicago Natural History Museum, identified the specimens of *Diretmus*. George S. Myers, Stanford University, identified the *Neocyttus helgae*. N. B. Marshall identified

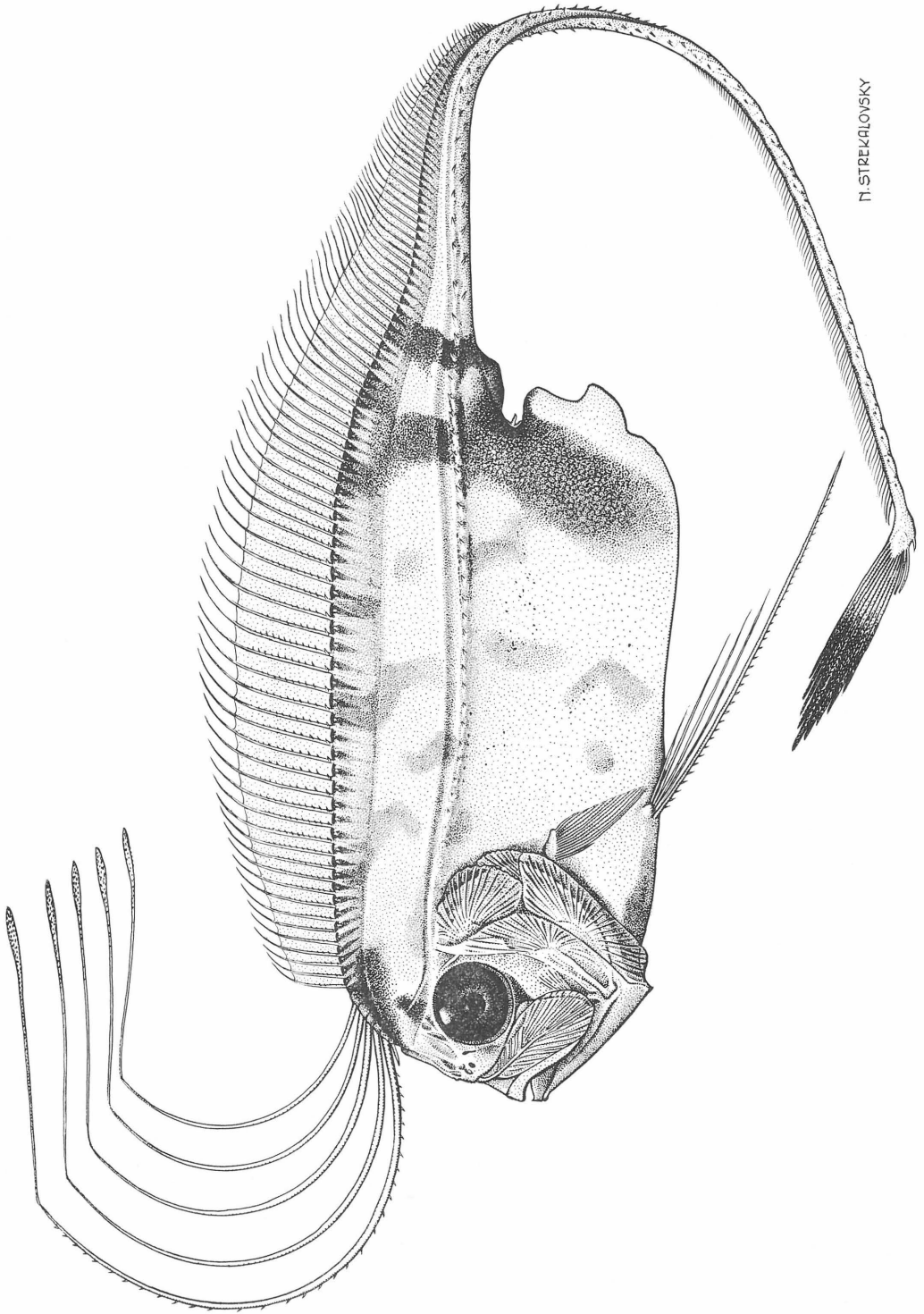


Fig. 2. *Zu cristatus* (Bonelli, 1820). 120 mm S. L.

TABLE 1. COLLECTION DATA ASSOCIATED WITH MIDWATER TRAWL HAULS, CRUISE 17, R/V CHAIN

COLLEC- TION	POSITION	DATE (1961)	TIME (LOCAL)	DEPTH (m)	TEMPERATURE (°C)			NO. OF SPECIES	NO. OF SPECI- MENS
					Surf.	at net ¹	200 m ⁵		
4	02°10'S., 17°25'W.	2 April	0010-0225	- ¹	29.0	-	12+	19	30
5	00°35'S., 11°30'W.	3 April	2145-2230	-	28.5	-	12+	16	32
6	00°05'S., 14°15'W.	4 April	1955-2200	-	29.0	-	12+	14	45
9	07°15'N., 14°00'W.	20 April	2140-2335	- ²	30.0	-	14+	26	43
800 ³	00°12'S., 18°40'W.	24-25 April	2320-0240	85	29.5	18.5	13+	17	47
801	00°15'S., 18°40'W.	26 April	0250-0605	85	29.5	18.5	13+	34	82
802	03°00'N., 21°15'W.	27-28 April	2020-0020	275	29.0	10.5	13+	32	69
803	09°27'N., 27°45'W.	1 May	0340-0725	275	25.0	10.0	11+	24	140
804	10°55'N., 29°30'W.	1-2 May	2200-0110	42	25.0	22.0	11+	24	947
805	11°17'N., 30°00'W.	2-3 May	2015-0045	230	24.5	11.5	11+	35	101
806	13°30'N., 32°55'W.	3-4 May	2030-0040	70	23.5	19.0	11+	31	629
807	16°00'N., 36°20'W.	4-5 May	2125-0250	430	23.5	10.0	15+	13	30
808	18°00'N., 39°00'W.	5-6 May	2010-0115	290	24.0	13.0	16+	15	30
809	19°40'N., 41°20'W.	6 May	1930-2235	70	24.0	23.0	18+	16	62
810	20°55'N., 43°15'W.	7 May	0920-1355	495	24.5	11.0	19+	7	154
811	23°15'N., 47°05'W.	8 May	2035-2340	90	25.0	23.0	19+	15	66
812	25°40'N., 50°50'W.	9-10 May	2115-0040	70	24.0	21.5	18+	18	104
813	27°30'N., 54°05'W.	10-11 May	2110-0220	53	23.5	23.0	18+	13	97

¹ 0-1800 m of wire out.² 0-400 m of wire out.³ Bridle broke part way through tow closing the net.⁴ Numbers in roman type are from bathythermograph observations made at time of collection; numbers in italics are from Fuglister (1960).⁵ From E. Schroeder (1963).

the *Sphagemacrurus*. Basil Nafpaktitis aided greatly in the identification of fishes in the genus *Diaphus*. Otherwise the determinations are those of the authors. The specimens have been deposited in the Museum of Comparative Zoology, Harvard University. We are especially indebted to Gibbs and Mrs. Grey, who not only identified large amounts of material, but also read and improved the manuscript. We are grateful as well to V. T. Bowen, N. B. Marshall, G. G. Simpson, D. W. Bourne and L. V. Worthington for their criticism. James Rohlf advised us in statistical matters. The drawings of fishes were done by N. Strekalovsky.

LIST OF SPECIES

Following the species name are the station numbers at which the species was taken, and, in parentheses, the number of specimens and range of standard lengths. In some cases, determinations were not positive, and we have introduced the use of opposed question marks (following the Spanish

custom) for setting off that part of the scientific name held in doubt.

Selachii (Squaloidea)

Dalatiidae

Isistius brasiliensis (Quoy and Gaimard, 1824). 4 (1, 350 mm t. l.); 5 (1, 425 mm t. l.); 801 (1, 320 mm t. l.); 802 (1, 265 mm t. l.); 805 (1, 265 mm t. l.). This material does not include a new western Atlantic species, *I. plutodus* Garrick and Springer, 1964.

Isospondyli

Clupeoidea

Alepocephalidae

Holtbyrnia sp. 802 (1, 43.2 mm)

Argentinoidea

Bathylagidae

Bathylagus ? *argyroaster* Norman, 1930? 9 (2, 29.0 & 62.0 mm); 801 (2, 30.8 & 79.0 mm)

Opisthoproctidae

Opisthoproctus grimaldii Zugmayer, 1911. 803 (2, 55.0 & 55.5 mm); 805 (1, 20.9 mm)

Opisthoproctus soleatus Vaillant, 1888. 4 (1, 71.0 mm)

Stomiatoidea

Sternoptychidae

Argyropelecus aculeatus Cuvier and Val-

- enciennes, 1849. 805 (14, 9.9–15.6 mm); 808 (2, 11.2 & 53.5 mm); 810 (1, 16.6 mm)
- Argyropelecus affinis* Garman, 1899. 4 (3, 17.8–52.5 mm); 6 (18, 53–55 mm); 802 (1, 15.0 mm); 807 (5, 13.4–24.0 mm)
- Argyropelecus gigas* Norman, 1930. 6 (1, 61.8 mm)
- Argyropelecus hemigymnus* Cocco, 1829. 4 (1, 23.5 mm); 802 (1, ca. 18.0 mm); 807 (1, 20.5 mm)
- Argyropelecus lychnus lychnus* Garman, 1899. 5 (4, 15.3–51.5 mm); 6 (3, 12.6–29.6 mm); 9 (1, 20.4 mm); 802 (1, 10.8 mm); 803 (3, 10.7–30.8 mm); 805 (3, ?–51.3 mm); 807 (3, 11.0–11.5 mm)
- Polyipnus polli* Schultz, 1961. 5 (1, 18.7 mm)
- Sternoptyx diaphana* Hermann, 1781. 802 (6, 16.3–29.0 mm); 805 (1, 15.5 mm)
- Gonostomatidae
- Bonapartia pedaliota* Goode and Bean, 1896. 4 (2, 35.5 & 62.0 mm); 5 (4, 38.5–57.0 mm); 6 (7, 46.5–66.0 mm); 9 (1, ca. 25 mm); 802 (9, 38.5–44.0 mm); 803 (32, 30.0–50.5 mm); 805 (2, 50.0 & 52.5 mm)
- Cyclothone* sp. 4 (5, ca. 14–28 mm); 802 (1, 26.5 mm); 803 (5, ca. 15–20 mm); 805 (1, 24.5 mm); 808 (1, 21.5 mm); 810 (145, less than 20.5 mm); 811 (5, small and damaged)
- Diplophos taenia* Günther, 1873. 805 (3, ca. 28 mm); 806 (2, 69.5 & 106.0 mm)
- Gonostoma atlanticum* Norman, 1930. 802 (6, 22.0–51.0 mm); 803 (18, 38.5–55.0 mm); 805 (4, 38.5–49.0 mm); 807 (3, 44.0–59.5 mm)
- Gonostoma denudatum* Rafinesque, 1810. 802 (1, 90.0 mm)
- Gonostoma elongatum* Günther, 1878. 805 (2, 153.0 & 187.0 mm)
- Gonostoma* sp. 800 (1, ca. 33.5 mm); 805 (1, 22.5 mm); 806 (18, 15.0–26.0 mm)
- Ichthyococcus ovatus* (Cocco, 1840). 802 (3, 34.5–43.5 mm); 803 (6, 18.5–41.5 mm); 805 (1, 22.5 mm); 806 (4, 22.0–35.5 mm); 810 (1, 21.5 mm)
- Margrethia obtusirostra* Jespersen and Tåning, 1919. 808 (1, 37.0 mm)
- Maurolicus muelleri* (Gmelin, 1789). 804 (3, 14.5–26.5 mm); 806 (2, 14.5 & 15.0 mm)
- Pollichthys maui* (Poll, 1953). 9 (2, 39.0 & 47.0 mm); 813 (5, 37.0–40.5 mm)
- Valenciennellus tripunctulatus* (Esmark, 1870). 6 (1, 30.5 mm); 802 (4, ca. 28.0–30.0 mm); 803 (2, 20.0 & 28.0 mm); 805 (1, 25.5 mm); 807 (9, 23.0–30.5 mm); 808 (4, 13.0–18.0 mm); 810 (3, 21.0–22.5 mm)
- Vinciguerria nimbaria* (Jordan and Williams, 1895). 6 (5, 26.0–ca. 36.0 mm); 9 (1, 35.0 mm); 800 (16, ca. 24.0–29.0 mm); 801 (8, 27.0–33.0 mm); 802 (1, 28.0 mm); 803 (31, 15.5–36.5 mm); 804 (159, 15.0–40.0 mm); 806 (100, 15.5–36.0 mm); 809 (7, 19.5–41.5 mm); 811 (1, 40.5 mm)
- Vinciguerria* sp. 9 (1, ca. 13 mm); 804 (245 young, 13.5–18.5 mm); 805 (1, ca. 28 mm); 806 (28, 14.0–18.0 mm); 810 (2, 14.5 & 15.5 mm)
- Astronesthidae
- Astronesthes caulophorus* Regan and Trewavas, 1929. 9 (1, 54.4 mm)
- Astronesthes cyaneus* (Brauer, 1902). 9 (1, 27.3 mm)
- Astronesthes richardsoni* Poey, 1852. 5 (1, 94.5 mm); 9 (1, 27.0 mm); 805 (1, 93.5 mm); 806 (6, 30.7–52.0 mm)
- Heterophotus ophistoma* Regan and Trewavas, 1929. 6 (1, 212.9 mm); 802 (1, 154.4 mm)
- Chauliodontidae
- Chauliodus danae* Regan and Trewavas, 1929. 807 (2, 83.5 & 93.2 mm); 808 (4, 72.1–93.1 mm); 811 (1, 86.4 mm)
- Chauliodus schmidti* Ege, 1948. 804 (2, 32.1–37.5 mm); 805 (1, 135.4 mm)
- Chauliodus sloani* Bloch and Schneider, 1801. 802 (1, 156.7 mm)
- Idiacanthidae
- Idiacanthus fasciola* Peters, 1885. 809 (1, ca. 270 mm); 813 (5, 54.1–96.4 mm)
- Stomiidae
- Stomias affinis* Günther, 1885. 802 (3, 85.9–93.5 mm); 804 (4, 25.4–36.5 mm); 806 (1, 43.4 mm)
- Melanostomiidae
- Bathophilus brevis* Regan and Trewavas, 1930. 804 (2, 17.1 & 35.6 mm)
- Bathophilus nigerrimus* Giglioli, 1884. 6 (1, 83.2 mm)
- Bathophilus pawneeii* Parr, 1927. 801 (1, 58.5 mm); 809 (1, 25.7 mm)
- Echiostoma barbatum* Lowe, 1843. 811 (1, 158.1 mm); 812 (1, 113.5 mm)
- Eustomias melanostigma* Regan and Trewavas, 1930. 9 (1, 85.4 mm)
- Eustomias obscurus* Vaillant, 1888. 804 (1, 68.6 mm); 812 (1, 77.9 mm)
- Leptostomias* (cf. *gracilis* Regan and Trewavas, 1929). 805 (1, 147.6 mm); 806 (1, 72.2 mm)
- Melanostomias biseriatus* Regan and Trewavas, 1930. 9 (1, 181.7 mm)
- Melanostomias tentaculatus* (Regan and Trewavas, 1930). 811 (1, 53.5 mm)
- Photoneustes parvimanus* Regan and Trewavas, 1930. 812 (1, 28.2 mm)

Malacostracidae

Aristostomias zittmanni Welsh, 1923? 801 (1, 102.7 mm); 802 (1, 130.5 mm)

Photostomias guernei Collett, 1889. 9 (1, 35.7 mm); 812 (2, 29.3 & 40.5 mm)

Inioini

Myctophidae

Benthoosema suborbitale (Gilbert, 1913). 801 (1, 11 mm); 804 (5, 13–26 mm); 806 (122, 10–31 mm); 808 (4, 10–26 mm); 809 (4, 21–24 mm); 811 (1, 28 mm); 812 (3, 24–26 mm)

Ceratoscopelus townsendi (Eigenmann & Eigenmann, 1889). 4 (2, 21 & 21 mm); 5 (1, 54 mm); 9 (1, 20 mm); 800 (1, 70 mm); 801 (1, 25 mm); 804 (27, 22–50 mm); 806 (25, 22–59 mm); 808 (1, 62 mm); 809 (5, 17–62 mm); 811 (5, 20–62 mm); 812 (14, 17–62 mm); 813 (12, 18–55 mm)

Diaphus brachycephalus Tåning, 1928. 800 (2, 40 & 41 mm); 801 (13, 21–42 mm); 808 (1, 33 mm)

Diaphus dofleini (Zugmayer, 1911). 4 (1, 45 mm); 5 (1, ca. 50 mm); 801 (1, 34 mm); 803 (3, 25–46 mm); 804 (1, 22 mm)

Diaphus dumerili (Bleeker, 1856). 801 (1, 58 mm)

Diaphus effulgens (Goode and Bean, 1896). 812 (12, 18–31 mm)

Diaphus elucens (Brauer, 1904). 806 (8, 38–55 mm)

Diaphus fragilis Tåning, 1928. 800 (1, 30 mm); 801 (1, 40 mm); 806 (53, 35–76 mm); 809 (4, 49–50 mm)

Diaphus gemellari (Cocco, 1838). 806 (5, 27–31 mm); 808 (5, 37–57 mm); 809 (1, 29 mm); 810 (1, 38 mm); 811 (3, 27–31 mm); 812 (1, 14 mm)

Diaphus zintermedius Borodin, 1930? 807 (1, 65 mm). This specimen closely resembles Borodin's type of *intermedius*, but the status of this species is unresolved. Perhaps it is a synonym of *D. rafinesquei*.

Diaphus lucidus (Goode and Bean, 1896). 5 (1, 70 mm); 800 (1, 51 mm); 801 (1, 51 mm); 802 (1, 59 mm); 805 (1, 56 mm)

Diaphus luetkeni (Brauer, 1904). 4 (1, 50 mm); 9 (2, 33 & 40 mm); 800 (2, 28 & 35 mm); 801 (1, 30 mm); 802 (11, 44–49 mm); 803 (3, 31–53 mm); 804 (5, 17–28 mm); 805 (2, 26 & 48 mm); 806 (10, 10–26 mm); 807 (1, 36 mm)

Diaphus mollis Tåning, 1928. 800 (1, 39 mm); 804 (1, 19 mm); 806 (12, 19–40 mm); 809 (2, 15 & 26 mm); 810 (1, 34 mm); 812 (7, 20–42 mm); 813 (5, 15–29 mm)

Diaphus problematicus Parr, 1928. 800 (1, 60 mm); 808 (1, 56 mm); 811 (1, 65 mm)

Diaphus splendidus (Brauer, 1904). 811 (6, 41–47 mm)

Diaphus termophilus Tåning, 1928. 808 (1, 35 mm)

Diaphus sp. A. 4 (2, 25 & 26 mm); 5 (2, 24 & 26 mm); 9 (3, ca. 15 mm); 801 (1, 21 mm); 803 (3, 18–26 mm); 804 (94, 11–26 mm). The Dn and Vn appear to form a single large antorbital organ. The first and last AOa are elevated, the first markedly so. In 25 specimens counted, the AO were 6 + 5 (11 specimens), 6 + 4 (10), 5 + 5 (2), 7 + 4 (1), and 5 + 6 (1). Related to *D. rafinesquei*.

Diaphus sp. B. 801 (1, 50 mm). Dn roughly circular and mainly directed forward. Vn separate from Dn and larger, extending rearwards to level of anterior edge of lens. AO 6 + 4. AOa₁ not quite above line connecting tops of AOa₂ and AOa₃. AOa₄₋₆ make ascending series. Photophores very large, the AOp being scarcely separated.

Diogenichthys atlanticus (Tåning, 1928). 801 (1, 13 mm); 803 (1, 44 mm); 804 (87, 13–22 mm); 806 (65, 13–21 mm)

Electrona rissoi (Cocco, 1829). 6 (1, ca. 40 mm); 803 (1, 39 mm)

Hygophum macrochir (Günther, 1864). 5 (5, 29–71 ? mm); 9 (3, 11–41 mm); 801 (13, 17–39 mm); 803 (1, 28 mm); 804 (69, 12–49 mm); 805 (1, 46 mm); 806 (3, 16–18 mm); 809 (2, 25 & 44 mm)

Hygophum reinhardti (Lütken, 1892). 803 (1, 42 mm); 804 (1, 41 mm); 806 (1, 43 mm); 808 (1, 40 mm); 812 (2, 17 & 19 mm)

Lampadena nitida Tåning, 1928. 801 (1, 50 mm)

Lampanyctus alatus Goode and Bean, 1896. 9 (1, 20 mm); 800 (4, 40–44 mm); 801 (4, 40–44 mm); 802 (1, 35 mm); 806 (4, 18–36 mm)

Lampanyctus crocodilus (Risso, 1810). 806 (20, 22–59 mm)

Lampanyctus cuprarius Tåning, 1928. 812 (9, 27–35 mm); 813 (2, 27 & 29 mm)

Lampanyctus zlineatus Tåning, 1928? 805 (5, 39–116 mm)

Lampanyctus macropterus (Brauer, 1904). 800 (3, 67–82 mm); 801 (4, 66–79 mm); 802 (3, 52–69 mm); 809 (9, 34–47 mm)

Lampanyctus photonotus Parr, 1928. 802 (1, 55 mm); 809 (13, 22–56 mm); 811 (25, 21–58 mm); 812 (9, 18–43 mm); 813 (21, 19–57 mm)

Lampanyctus tenuiformes (Brauer, 1906)? 813 (3, 18–19 mm)

Lepidophanes gausi (Brauer, 1906). 809 (2, 26 & 35 mm); 811 (12, 30–36 mm);

- 812 (5, 25–35 mm); 813 (10, 17–32 mm)
Lepidophanes guentheri (Goode and Bean, 1896). 4 (1, 30 mm); 5 (6, 20–47? mm); 6 (3, 45–60 mm); 9 (1, 24 mm); 801 (5, 37–47 mm); 802 (2, 39–42 mm); 803 (9, 29–75 mm); 804 (71, 15–57 mm); 806 (4, 45–50 mm); 808 (2, 36 & 61 mm); 811 (1, 66 mm); 813 (2, 45 & 56 mm)
Lepidophanes pyrsobolus (Alcock, 1890). 5 (1, 50 mm); 806 (1, 23 mm); 807 (1, 68 mm); 808 (1, 28 mm); 809 (3, 19–22 mm); 811 (2, 17 & 30 mm); 812 (7, 12–20 mm); 813 (8, 12–22 mm)
¿Loweina? sp. 9 (1, 23 mm)
Myctophum affine (Lütken, 1892). 800 (3, 34–46 mm)
Myctophum asperum Richardson, 1844. 5 (1, 33 mm); 801 (1, 53 mm); 804 (14, 24–59 mm)
Myctophum gasperum Richardson, 1844? 6 (1, 16 mm); 9 (2, 16 & 25 mm)
Myctophum nitidulum Garman, 1899. 800 (2, 49 & 49 mm); 802 (1, 72 mm)
Myctophum sp. 801 (1, 16 mm)
Notolychnus valdiviae (Brauer, 1904). 9 (5, ca. 20 mm); 803 (5, 18–20 mm); 804 (39, 12–22 mm); 806 (94, 11–22 mm); 809 (6, 16–19 mm); 812 (27, 14–20 mm); 813 (21, 15–21 mm)
Notoscopelus caudispinosus (Johnson, 1863). 4 (1, ca. 55 mm); 811 (1, 86 mm)
Notoscopelus resplendens (Richardson, 1844). 4 (1, 69 mm); 801 (1, 64 mm); 803 (1, broken); 804 (101, 22–83 mm); 805 (1, 72 mm); 806 (31, 26–71 mm)
Symbolophorus rufinus (Tåning, 1928). 806 (1, 46 mm)
- Paralepididae
Lestidiops affinis (Ege, 1930). 802 (1, 97.5 mm)
Paralepis atlantica Krøyer, 1891. 801 (1, 97.5 mm)
- Scopelarchidae
Neoscopelarchoides dubius Marshall, 1955. 807 (1, 119.0 mm)
Neoscopelarchoides sp. A. 801 (1, 41.5 mm)
Scopelarchus guentheri Alcock, 1896. 805 (1, 76.1 mm)
Scopelarchus sp. A. 801 (1, 43.0 mm); 803 (1, 37.6 mm)
- Evermannellidae
Evermannella balbo (Risso, 1820). 804 (7, 7.4–16.5 mm)
Evermannella indica Brauer, 1906. 805 (2, 58.8 & 65.8 mm); 812 (1, 23.7 mm); 813 (2, 22.5 & 27.0 mm)
Evermannella sp. A. 6 (1, 37.8 mm); 800 (1, 27.0 mm); 801 (6, 26.3–29.0 mm). These specimens probably represent an undescribed form related to *E. sicaria* Rofen, 1960, but have fewer anal rays (29–32 cf. 35 or 36) and, as postlarvae, lack discrete rows of spots on the sides of the body. As all eight specimens are postlarval, the description and christening of this form are deferred.
- Allotriognathi
 Trachypteridae
Zu cristatus (Bonelli, 1820). 804 (1, 35.3 mm); 809 (1, 120.0 mm, Figure 2)
- Stylephoridae
Stylephorus chordatus Shaw, 1791. 807 (1, 130.0 mm). The specimen has been forwarded, for dissection, to Dr. Werner Meinel, Zoologisches Institut der Justus Liebig—Universität, Giessen.
- Apodes
 Derichthyidae
Derichthys serpentinus Gill, 1887. 807 (1, 219.0 mm)
- Nemichthyidae
Nemichthys scolopaceus Richardson, 1848. 4 (1, 530+ mm); 6 (1, 365.0 mm); 802 (1, 365.0 mm); 805 (1, 545.0 mm); 807 (1, 305.0 mm)
- Nessorhamphidae
Nessorhamphus ingolfianus Schmidt, 1930. 802 (1, 82+ mm)
- Anacanthini
 Gadoidea
 Moridae
Melanonus zugmayeri Norman, 1930. 4 (2, 76.4 & 206.0 mm); 9 (1, 82.7 mm); 802 (1, 81.5 mm); 805 (3, 94.1–114.8 mm)
- Bregmacerotidae
Bregmaceros atlanticus Goode and Bean, 1896. 4 (2, 39.8 & 40.0 mm); 801 (1, 35.0 mm); 812 (1, 20.0 mm)
- Macrouroidea
 Macrouridae
¿Sphagemacrurus? sp. 803 (1, 153.0 mm, Figure 3).
- Xenoberyces
 Melamphaidae
Melamphaes eulepis Ebeling, 1962. 9 (1, 29.4 mm); 803 (1, 19.3 mm)
Melamphaes longivelis Parr, 1933. 803 (1 young)
Melamphaes polylepis Ebeling, 1962. 9 (2, 18.5 & 19 mm)
Melamphaes simus Ebeling, 1962. 9 (5, 16–21 mm); 805 (2, 24.5 & 24.0 mm)
Melamphaes typhlops (Lowe, 1843). 805 (1, ca. 42.0 mm)
Poromitra megalops (Lütken, 1877). 4 (1, 32.2 mm); 5 (1, 20.9 mm)
Scopelogadus beanii (Günther, 1887). 5 (1, 54.9 mm)
Scopelogadus mizolepis mizolepis (Günther,

1878). 4 (1, 67.2 mm); 5 (1, 30.3 mm); 800 (1, 23.0 mm); 801 (1, 30.0 mm); 802 (1, 54.5 mm); 803 (2, 62.0 & 79.0 mm); 805 (16, 39.0–68.5 mm); 808 (1, 57.8 mm)

Berycomorphi

Diretmidae

Diretmus argenteus Johnson, 1863. 4 (1, 22.0 mm); 801 (3, 12.0–16.0 mm); 803 (7, 14.5–26.0 mm); 805 (19, 16.1–28.0 mm)
Diretmus sp. A. 9 (1, 60.0 mm); 800 (1, 14.0 mm)

Zeomorphi

Zeidae

Neocyttus chelgae (Holt and Byrne, 1908)? 805 (1, 72.5 mm, Figure 4).

Percomorphi

Percioidea

Bramidae

Brama dussumieri Cuvier and Valenciennes, 1831. 6 (1, 18.5 mm); 804 (3, 27.8–80.7 mm); 806 (1, 33.1 mm)

Taractes asper Lowe, 1843. 806 (1, 15.6 mm)

Cheilodipteridae

Bathysphyraenops simplex Parr, 1933. 800 (6, 12.5–18.2 mm); 802 (1, 59.6 mm); 806 (1, 33.1 mm)

Chiasmodontidae

Chiasmodon niger Johnson, 1863. 801 (1, 30.2 mm)

Chiasmodon sp. A. 805 (3, 40.3–49.8 mm)

Pseudoscopelus altipinnis Parr, 1933. 802 (1, 90.2 mm); 805 (1, 118.0 mm)

Pseudoscopelus sp. A. 801 (1, 33.8 mm). The specimen has a higher number of dorsal and anal fin rays and a more blunt snout, but is otherwise similar to *Pseudoscopelus stellatus* Beebe, 1932.

Caristiidae

Caristius japonicus Gill and Smith, 1905. 805 (1, 21.3 mm)

Scombroidea

Gempylidae

Gempylus serpens Cuvier and Valenciennes, 1831. 806 (1, 50 mm); 809 (1, ca. 35 mm)

Nealotus tripes Johnson, 1865. 805 (1, 40 mm)

Trichiuridae

Diplospinus multistriatus Maul, 1948. 806 (4, 58–85 mm); 812 (1, ca. 24 mm)

Stromateoidea

Nomeidae

Psenes maculatus Lütken, 1800. 804 (5, 13.5–17.5 mm)

Plectognathi

Molidae

Mola mola (Linnaeus, 1758). 813 (1, 6.4 mm)

The list comprises 2,708 specimens in 369

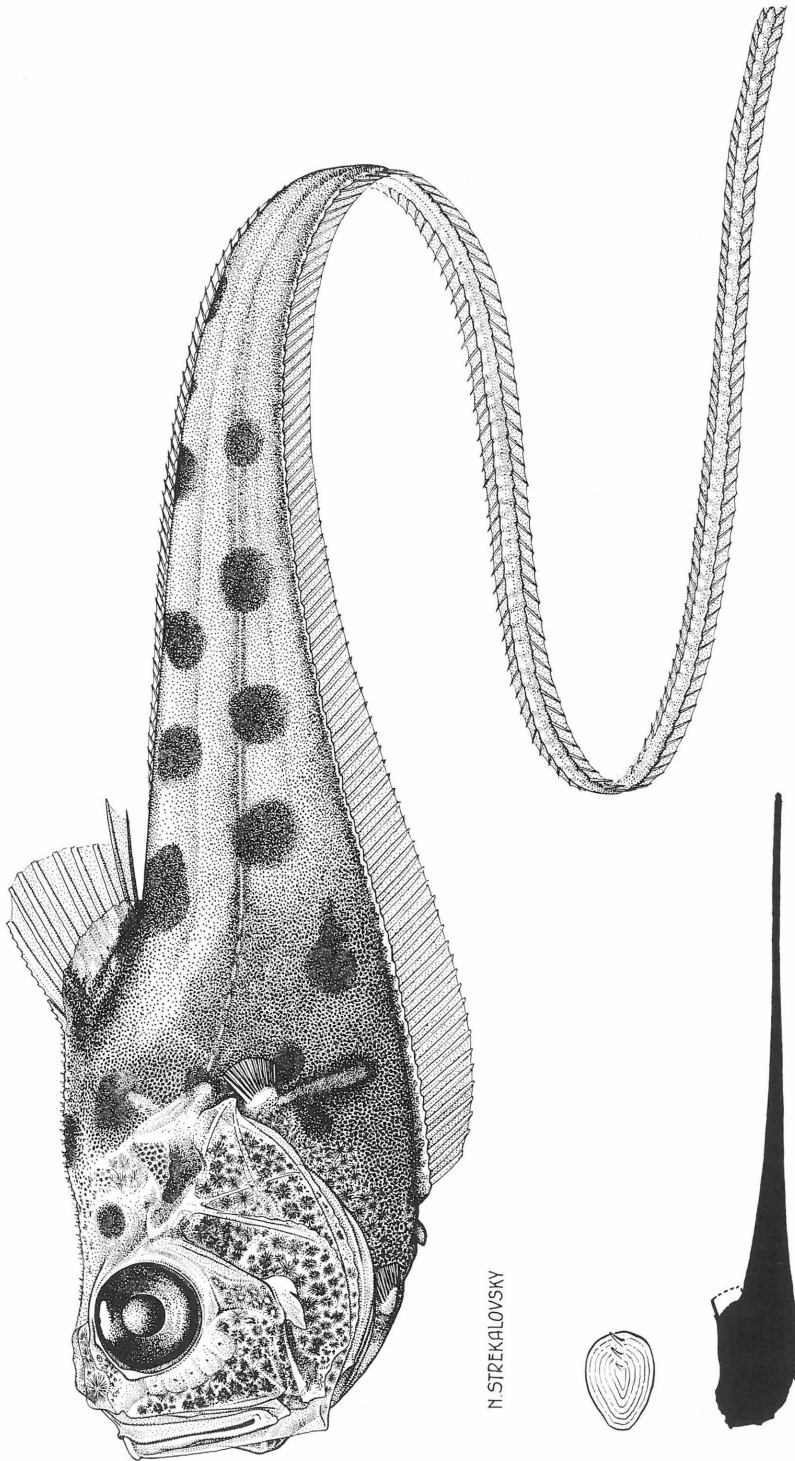
species lots. One-hundred-thirty species, 73 genera, 35 families and 11 orders are represented. Each of 54 species was collected at a single station only; 41 of these were represented by a single specimen. Each of 28 species was collected at two stations, 12 at three, 9 at four, 10 at five, 3 at six, 7 at seven, 3 at eight, 0 at nine, 2 at ten, 0 at eleven, and 2 at twelve. No species was collected at more than 12 of the 18 stations. The myctophid fishes *Ceratoscopelus townsendi* (12 lots, 95 specimens) and *Lepidophanes guentheri* (12 lots, 107 specimens) were the most widespread. The most abundant species was *Vinciguerria nimbaria* (329 specimens, 10 lots).

DISCUSSION

Several recent contributions to pelagic zoogeography have stressed the relationship between the distribution of animal species and oceanic water masses, defined principally by temperature-salinity relationships (e.g., Pickford, 1946; Haffner, 1952; Bieri, 1959; McGowan, 1960; Brinton, 1962; Ebeling, 1962; Fager and McGowan, 1963; and Ebeling and Weed, 1963). While a species may be confined to a part of a water mass, be distributed throughout a water mass, or be found in two or more water masses, the conformance of the boundaries, or parts of the boundaries, of species' ranges with the boundaries of the water masses is often marked.

In proceeding from the Romanche Trench to Bermuda on Cruise 17, CHAIN necessarily crossed the boundary between the South Atlantic Central Water Mass and the North Atlantic Central Water Mass. Sverdrup, Johnson, and Fleming (1942: 669, fig. 183) show this boundary as a belt (presumably of transitional water) near 10°N, somewhat wider in the east than in the west and slightly concave to the north.

On May 3 and 4, 1961, as CHAIN traversed the parallels ca. 11°–15°N, it was recognized that the ship was in a region of transition. Changes were noted in the number and kinds of petrels, in both broad-band



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Fig. 3. ♂ *Sphagemacrurus*? sp. 153 mm S. L.

and 12-kcps mid-water sound-scattering, in numbers of flying fish, in numbers of Portuguese Men-o'-War (*Physalia*), in water color, and in wind direction. With respect to 12-kcps sound-scattering, May 3 was recorded as a "sort of day of transition." After the cruise, measurements that had been made of other ocean properties were inspected for changes which had occurred on or about May 3. Among these, the change in the bathythermograph section was notable (Fig. 5).

For detecting faunal boundaries within the transect from Collection 800 to Collection 813, we have derived a method from the simple device of adding the number of species caught for the first time at a station, a_o , to those caught for the last time at the preceding station, b_o (Table 2, Cols. 2 and 4).⁴ Freed of bias and with due allowance for sampling error, maxima of $a_o + b_o$ should occur at station intervals containing faunal boundaries if there be such.

It is evident, in sampling a homogeneous population, that the number of first-time and last-time captures of species in a collection will vary more or less directly as the total number of species in that collection. (This total number ranges from 7 to 35 in our 14 collections.) To minimize this bias we have divided each a_o and each b_o by the ratio of the number of species in the collection concerned (s) to the average such number ($\bar{s} = 21.0$) (Table 2, Cols. 3 and 5); a_o corr. for a collection is added to b_o corr. of the preceding collection to give a_o corr. + b_o corr. for the interval between collections (Table 2, Col. 6).

In sampling along a homogeneous transect, the chances of taking species for the first time must diminish steadily as the sampling proceeds (for instance, all species taken in the first collection necessarily are

taken for the first time) and, conversely, the chances of taking species for the last time will increase steadily (all species taken in the last collection necessarily are taken for the last time). With this in mind we have constructed an expected distribution of first-time and last-time captures with successive samplings, assuming a homogeneous population along our transect.

These values were computed for a community of species that is most easily described by likening it to a community of numbers in an urn. Each number is represented once. Fourteen drawings (corresponding to the 14 CHAIN-17 collections) are made of 21 numbers each (corresponding to the average number of species in Collections 800-813). The numbers are replaced after each drawing. It is not necessary actually to engage in this drawing for the average result is described by the expression

$$a_e(x) = k - \frac{k}{N} \sum_{n=0}^{x-1} a_e(n),$$

where $a_e(x)$ is the number of first-time captures of numbers in drawing x , k is the number of numbers taken with each drawing, N is the number of numbers in the urn, and $\sum_{n=0}^{x-1} a_e(n)$ is the sum of first-captures from prior drawings. To make such a computation analogous to the capture of species in the CHAIN-17 collections, it was necessary to set $N = 128$ to insure that 118 (the total number of species in Collections 800-813) numbers had been taken after 14 drawings. The 14 successively computed values of a_e (Table 2, Col. 7) are plotted in Figure 6.

This model, in which all species are represented equally, admittedly does not describe realistically any natural community of species. To determine the amount of bias thus introduced, we have compared the distribution of first-captures of species in this simplified model with the distribution of first-captures empirically determined from a complex community of numbers in which all numbers (or species) are not

⁴ We experimented with adapting Simpson's (1960) index of faunal resemblance, $C/N_1 \times 100$, to our needs but were not successful. C is the number of taxa common to two faunas being compared, while N_1 is the total number of taxa in the smaller of the two.

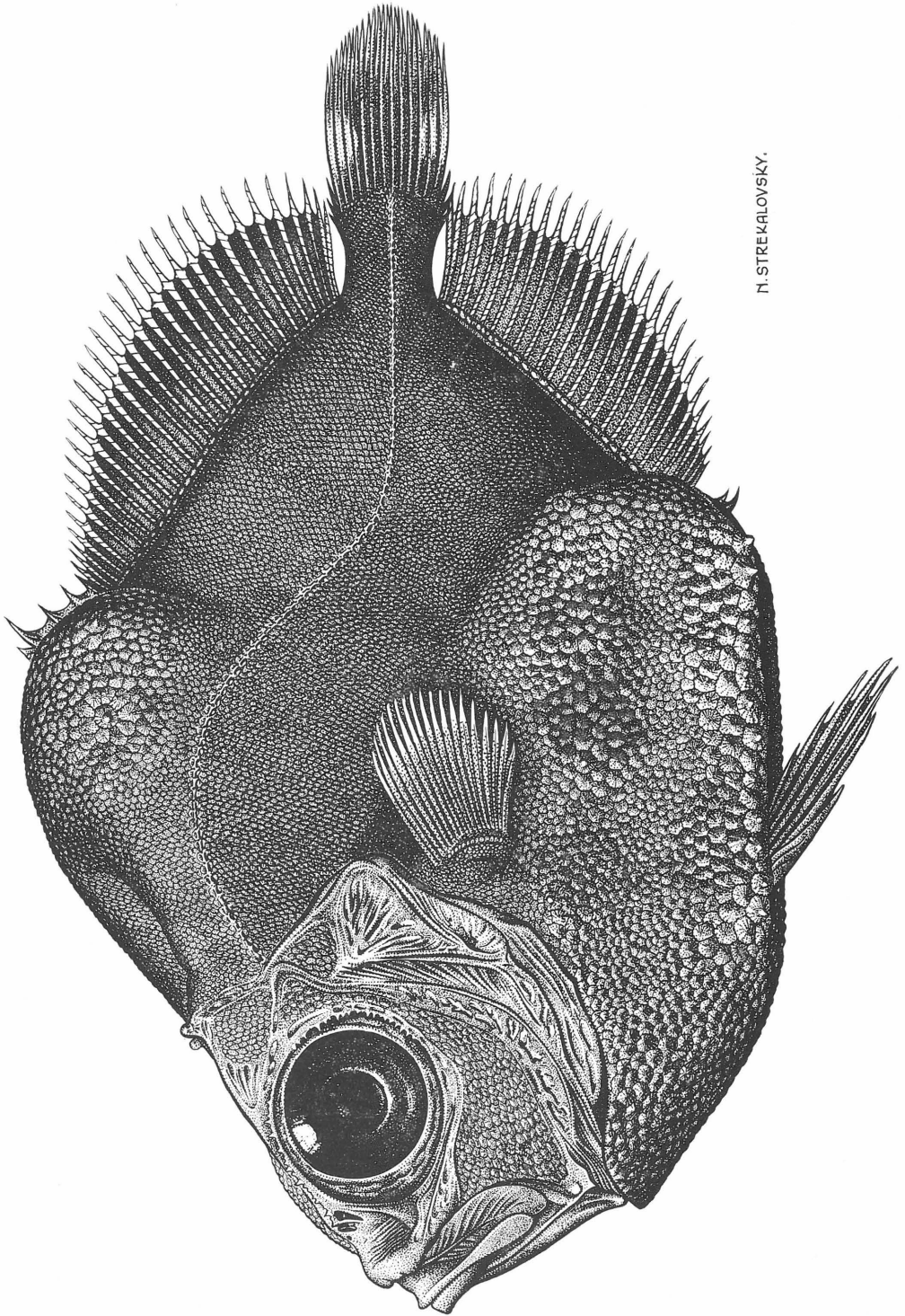


Fig. 4. *Neocyttus rhelgae* (Holt and Byrne, 1908)? 72.5 mm S. L.

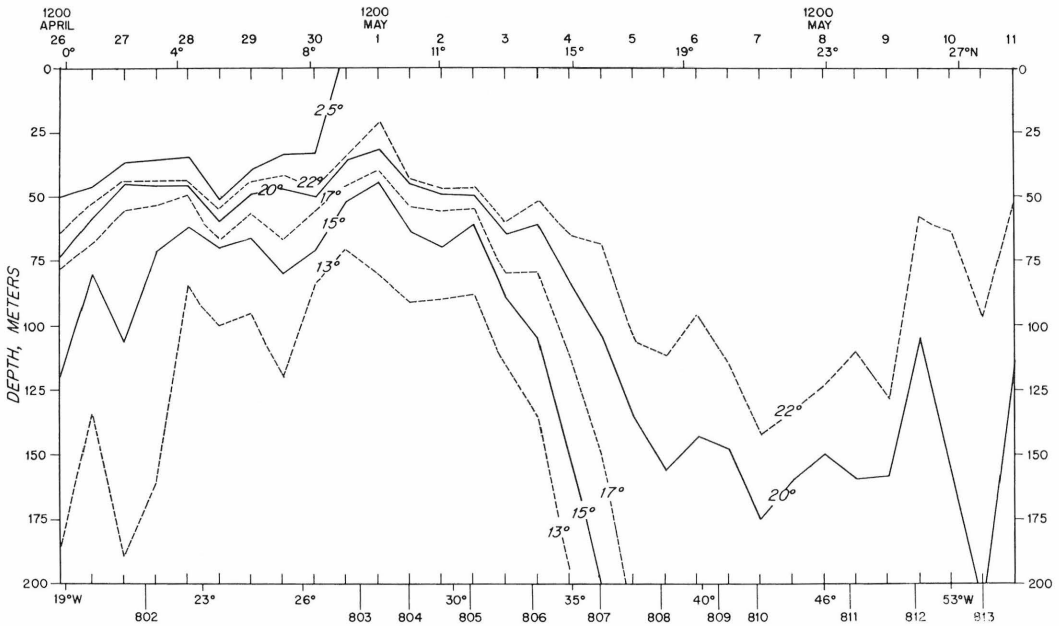


Fig. 5. Temperature vs. depth along the collection transect constructed from bathythermograph observations.

represented equally. The incidence of numbers in this community was made to resemble the incidence (number of collections in which a species occurred) of species in the CHAIN-17 samples. Fourteen consecutive drawings of 23 numbers were made and the numbers of first-time captures noted with each successive drawing. (It was determined that 23 numbers were needed to be drawn to assure that, on the average, about 21 different ones would be drawn on the first sampling.) The whole procedure was repeated six times. Mean values from these six trials were calculated for first-time captures for samplings 1-14. These mean values are plotted in Figure 6 with a curve fitted by eye. Since this distribution of first-time captures does not differ greatly from that for the simpler model, since a number of poor assumptions must be made in the design of the community of numbers in the complex model, and since we have not been able to calculate (but must determine empirically) the distribution of first-time

captures in the complex one, we have contented ourselves with the simple distribution.

When the order of the a_e 's computed from the simple model is reversed, the numbers correspond to 14 successive values of b_e , the expected number of last-time captures with successive samplings (Table 2, Col. 8). From a_e for a collection and b_e for the collection in arrears, the value $a_e + b_e$ was obtained for each collection interval (Table 2, Col. 9). Comparisons were then made *individually* between expected values for collection intervals and those observed, using the chi-square test and obtaining probability levels based on single degrees of freedom. The deviations of the observed from the expected values and the chi-square values are plotted against collection interval in Figure 7. Levels of significance are indicated for a single degree of freedom. The peak in the interval between Collections 807 and 808 ($\chi^2 = 3.79$) implies a faunal boundary, for here the odds are

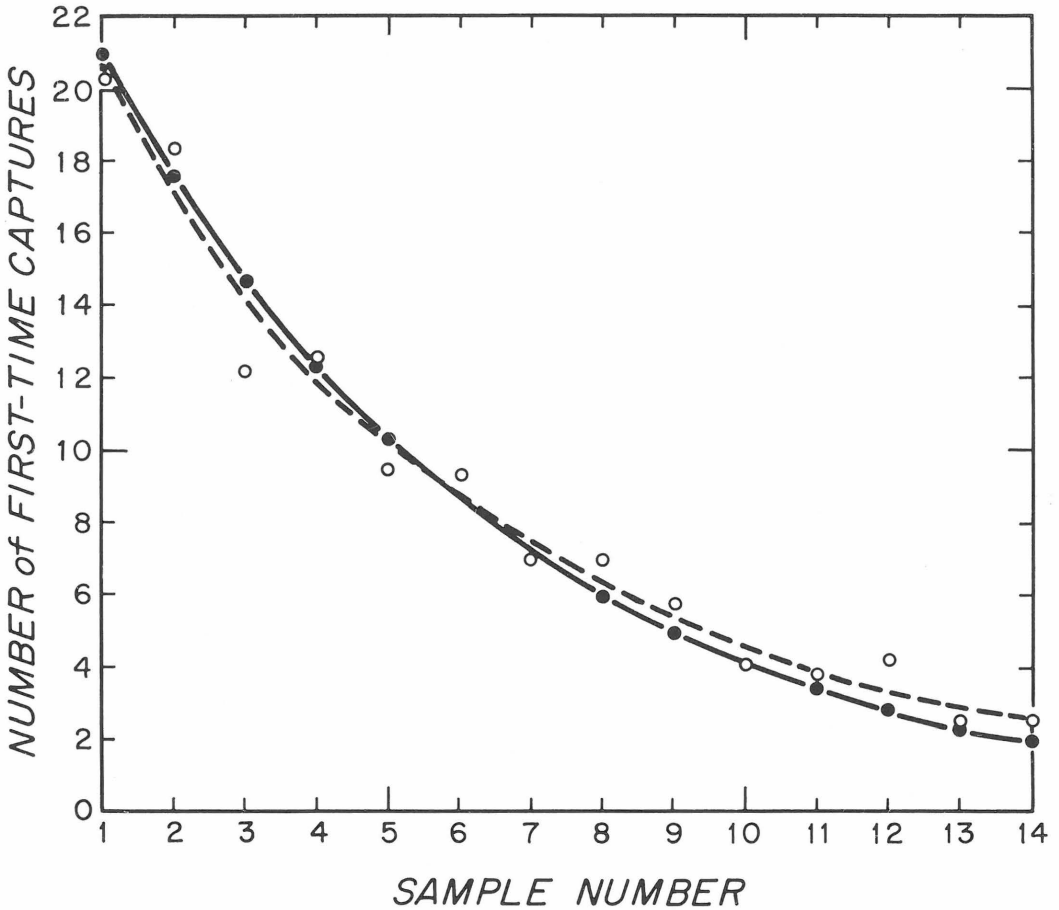


Fig. 6. Frequency of first-time captures with successive samples. Filled circles are values computed from population in which all species are represented once, open circles empirically determined from population with species not represented equally. See text.

about 19 to 1 that the departure of the observed from the expected is not due simply to sampling error. The value for the interval 806–807 is also significant ($P < .10$), suggesting that the boundary is not an abrupt one.

Additional evidence for a faunal boundary near the site of Collection 807 is the difference in faunal diversity in Collections 800–806 and Collections 807–813. Table 1 and Figure 8 show that there is a pronounced break in the number of species per collection between Collections 806 and 807

without a similar pattern in the number of specimens per collection. The fauna south of the boundary is markedly more diverse. For Collections 800–806, $\bar{x} = 28.1$, $s = 6.62$, and $s_{\bar{x}} = 2.50$. For Collections 807–813, $\bar{x} = 13.8$, $s = 3.48$, and $s_{\bar{x}} = 1.31$.

The faunal boundary indicated around Collection 807 occurs just after an abrupt deepening and diverging of the 20° and 15° isotherms (Fig. 5). Previously, the two isotherms had been close to one another in a layer between about 25 and 100 meters. This sudden degradation of the thermocline

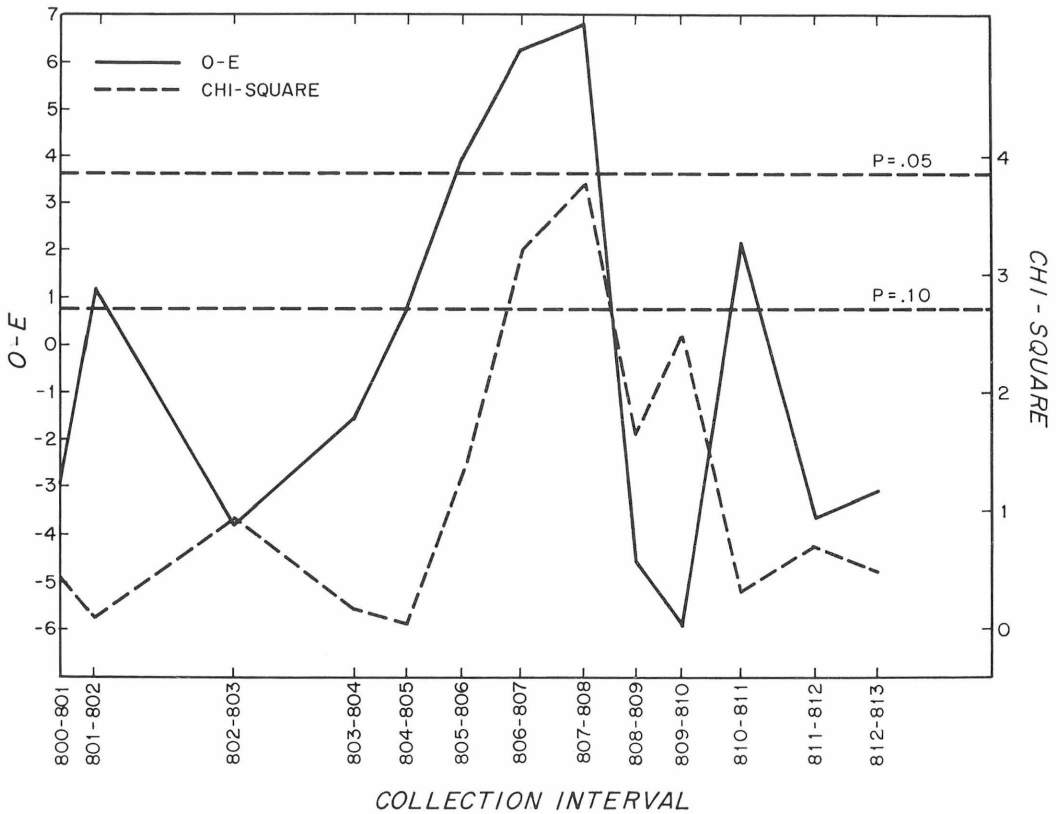


Fig. 7. The deviations of expected first-time captures from the observed first-time captures for the several collections and the chi-square values calculated from them. Probability levels for comparing with the chi-square values are shown also. See text.

and thickening of the surface isothermal (or near-isothermal) layer with increasing latitude can be noted in other corresponding sections, e.g., near 15°N, 50°W in a November-December section of ATLANTIS (Fuglister, 1960); near 12°N, 30°W in an April-May section of MIKHAIL LOMONOSOV (Gamutlov and Gruzinov, 1960); and near 12°N, 41°W in a March section of ATLANTIS (Iselin, 1936), and hence is considered a permanent feature in this part of the ocean.

To better understand this marked phenomenon we have made a temperature-salinity plot of observations at ATLANTIS stations 1177-1165 from the March section noted above (Fig. 9). Stations 1177-1172

(ca. 3°N-12°N) were dominated in their upper levels by South Atlantic Central Water. Temperatures at 200 meters ranged from 9.7°C to 12.5°C (excepting one of 13.9°C at 3°N, far removed from the region of our interest). Stations 1169-1165 (ca. 16°30'N-22°30'N) were dominated in their upper levels by North Atlantic Central Water. Temperatures at 200 meters ranged from 17.2°C to 19.6°C. Stations 1171 (ca. 13°30'N) and 1170 (ca. 15°N) were intermediate in nature and had 200-meter temperatures of 14.2°C and 15.3°C respectively.

Thus, the BT section and T-S diagram together show that the faunal boundary near Collection 807 corresponds to the boundary between the South Atlantic Cen-

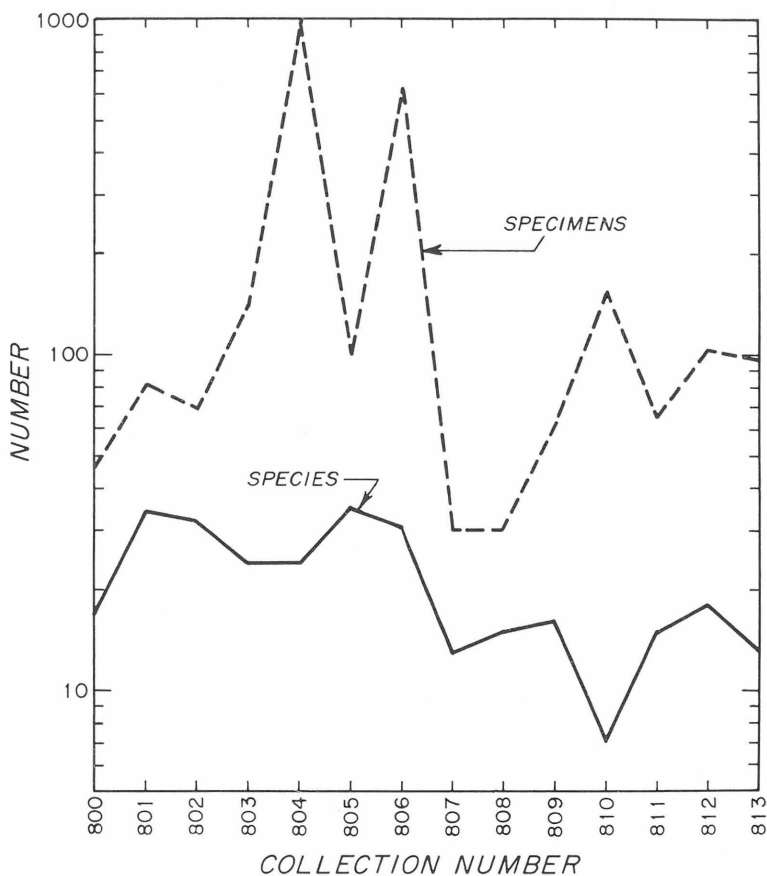


Fig. 8. Numbers of species and specimens per collection for each of Collections 800-813.

tral Water and North Atlantic Central Water Masses. A good working rule would seem to be that when the 200-meter temperature in these latitudes is in excess of about 15°C , the observer is in the North Atlantic Central Water Mass; when the 200-meter temperature is less than about 13°C , the observer is in the South Atlantic Central Water Mass. Isotherms for these temperatures at the 200-meter level are given by Schroeder (1963) and her plate 4 should be of great use to zoogeographers working in this area.

Although the boundary noted marks the meeting of the North and South Atlantic Central Water Masses, it is not, in terms of circulation, the meeting of the central gyres of these two oceans. These gyres are

separated by an equatorial zone defined by the shallow thermocline of steep gradient already noted ("the well-known equatorial discontinuity layer," Voorhis, 1961). The degradation of this layer can be said to mark the poleward limits of the equatorial zone. To the north, the boundary of this zone and the boundary between North and South Atlantic Central Water Masses are thus co-determined. Does this boundary have faunal significance because it marks the northern edge of the equatorial zone or because it marks the meeting of North and South Atlantic Central Water Masses? For the time being we must beg the question. It can be approached by determining, when collections are available, the faunal

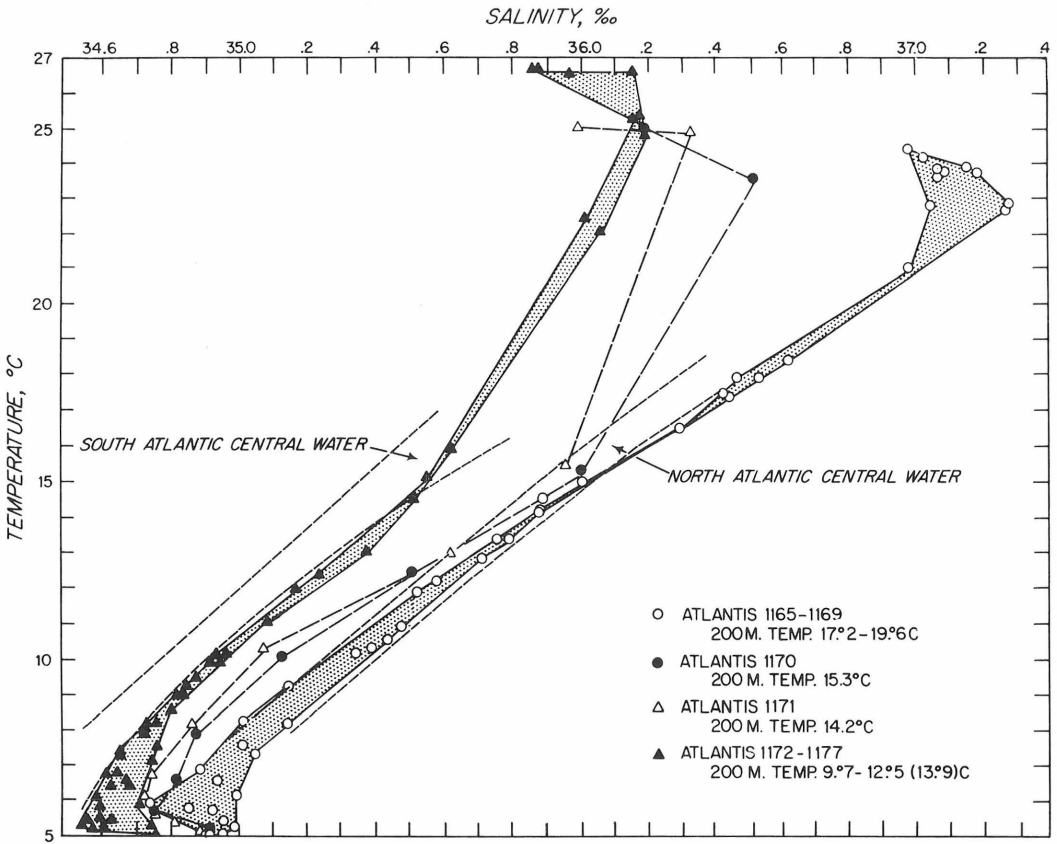


Fig. 9. Temperature-salinity relationships for North Atlantic Central Water and South Atlantic Central Water and the relationship of these to 200-m temperatures in the southern North Atlantic.

significance of the boundary between the equatorial zone and the South Atlantic central gyre.

What is the relation of the boundary noted near Collection 807 (*ca.* 16°N) to the southern edge of the Sargasso Sea? Recent physical definitions of the Sargasso Sea have been based on the distribution of superabundances of 18° water (Worthington, 1959, and Istoshin, 1961). The Sargasso Sea so defined, in general finds its southern edge at about 20°N.⁵ Judging

from Worthington's chart, CHAIN crossed this boundary at about 21°-22°N, 45°W (between Collections 810 and 811). Analysis of our data by the method of first-plus-last captures gives no indication of a boundary here, although the collection lists show that the myctophids *Lampanyctus cuprarius*, *Lampanyctus photonotus*, and *Lepidophanes gaussi* occur primarily in the Sargasso Sea collections (see Table 3). *Melamphaes pumilus* Ebeling is an example of a fish whose range conforms closely to Worthing-

⁵ Worthington's and Istoshin's Sargasso Seas are derived by somewhat different methods, though both are based on the superabundance of 18° water. The geographical limits of their seas conform quite closely. Winge's (1923) Sargasso Sea,

based on the distribution of *Sargassum* and therefore having semantics on its side, fits the others well enough except that it extends much farther to the east (to 30°W or more, while the others reach only to about 40°W).

ton's and Istoshin's Sargasso Sea (Ebeling, 1962). It should be noted that our collections are not sufficient for denying the existence of boundaries (especially weakly developed ones), which is quite a different matter from *establishing* the existence of strong ones.

Table 3 shows the occurrence of all species that were taken three or more times in Collections 800-813, plus certain additional species in *Chauliodus* and *Lampanyctus*. Some species that are confined to the southern end of our transect are known to be widely distributed well to the north of our northernmost collection. An example is *Diaphus dofleini*, which is the commonest mesopelagic myctophid in the slope water off southern New England (Hersey and Backus, 1954) and is widely distributed in the northeastern Atlantic (Bolin, 1959). It appears to be replaced by its sibling, *Diaphus gemellari*, in the central North Atlantic. Perhaps this is an example of a species pair in which one species is found in areas of high productivity, the other in poorer areas (Ebeling, 1962), although such a distribution may prove explainable on the basis of temperature alone, with *D. gemellari* confined to warmer waters. The upper part of the mesopelagial in the North Atlantic does not cool from the equator polewards; rather, it cools both equatorwards and polewards from a line connecting Guatemala in the west (*ca.* 15°N) with the Canary Islands in the east (*ca.* 28°N) (Schroeder, 1963). This fact of the physical environment of the North Atlantic generally has been overlooked in discussing disjunct ranges of mesopelagic animals.

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TABLE 2. VALUES FOR COLLECTIONS AND TRANSECT COLLECTION-INTERVALS USED IN THE ANALYSIS FOR FAUNAL BOUNDARY

1 COLLEC- TION	2 a_o	3 a_o CORR.	4 b_o	5 b_o CORR.	6 a_o CORR. + b_o CORR.	7 a_e	8 b_e	9 $a_e + b_e$	10 $O - E$	11 χ^2
800	17	21.0	2	2.5	16.7	21.0	2.0	19.6	-2.9	0.429
801	23	14.2	10	6.2	19.3	17.6	2.4	18.1	1.2	0.080
802	20	13.1	8	5.3	11.4	14.7	2.9	15.2	-3.8	0.947
803	7	6.1	5	4.4	12.3	12.3	3.5	13.8	-1.5	0.163
804	9	7.9	6	5.2	13.6	10.3	4.2	12.8	0.8	0.050
805	14	8.4	18	10.8	16.2	8.6	5.0	12.2	4.0	1.311
806	8	5.4	15	10.2	18.3	7.2	6.0	12.2	6.3	3.233
807	5	8.1	10	16.2	19.0	6.0	7.2	12.2	6.8	3.787
808	2	2.8	4	5.6	8.2	5.0	8.6	12.8	-4.6	1.656
809	2	2.6	6	7.9	7.9	4.2	10.3	13.8	-5.9	2.522
810	0	0	4	12.0	17.6	3.5	12.3	15.2	2.2	0.318
811	4	5.6	7	9.8	14.5	2.9	14.7	18.1	-3.6	0.718
812	4	4.7	10	11.7	16.5	2.4	17.6	19.6	-3.1	0.490
813	3	4.8	13	21.0		2.0	21.0			

TABLE 3. NUMBER OF SPECIMENS OF CERTAIN SPECIES IN COLLECTIONS 800-813

	800	801	802	803	804	805	806	807	808	809	810	811	812	813
<i>Argyrolepecus aculeatus</i>						14	-	-	2	-	1			
<i>Argyrolepecus lychnus</i>			1	3	-	3	-	3						
<i>Bathysphyraenops simplex</i>	6	-	1	-	-	-	1							
<i>Benthoosema suborbitale</i>					5	-	122	-	4	4	-	1	3	
<i>Bonapartia pedaliota</i>			9	32	-	2								
<i>Ceratoscopelus townsendi</i>	1	1	-	-	27	-	25	-	1	5	-	5	14	12
<i>Chauliodus danae</i>								2	4	-	-	1		
<i>Chauliodus schmidti</i>					2	1								
<i>Chauliodus sloani</i>			1											
<i>Cyclothone</i> sp. A			1	5	-	1	-	-	1	-	145	5		
<i>Diaphus brachycephalus</i>	2	13	-	-	-	-	-	-	1					
<i>Diaphus dofleini</i>		1	-	3	1									
<i>Diaphus fragilis</i>	1	1	-	-	-	-	53	-	-	4				
<i>Diaphus gemellari</i>							5	-	5	1	1	3	1	
<i>Diaphus lucidus</i>	1	1	1	-	-	1								
<i>Diaphus luetkeni</i>	2	1	11	3	5	2	10	1						
<i>Diaphus mollis</i>	1	-	-	-	1	-	12	-	-	2	1	-	7	5
<i>Diaphus problematicus</i>	1	-	-	-	-	-	-	-	1	-	-	1		
<i>Diaphus</i> sp. A		1	-	3	94									
<i>Diogenichthys atlanticus</i>		1	-	1	87	-	65							
<i>Diretmus argenteus</i>		3	-	7	-	19								
<i>Evermannella indica</i>						2	-	-	-	-	-	-	1	2
<i>Gonostoma atlanticum</i>			6	18	-	4								
<i>Gonostoma</i> sp. A	1	-	-	-	-	1	18							
<i>Hygophum macrochir</i>		13	-	1	69	1	3	-	-	2				
<i>Hygophum reinhardtii</i>				1	1	-	1	-	1	-	-	-	2	
<i>Ichthyococcus ovatus</i>			3	6	-	1	4							
<i>Isistius brasiliensis</i>		1	1	-	-	1								
<i>Lampanyctus alatus</i>	4	4	1	-	-	-	4							
<i>Lampanyctus cuprarius</i>													9	2
<i>Lampanyctus lineatus?</i>						5								
<i>Lampanyctus macropterus</i>	3	4	3	-	-	-	-	-	-	9				
<i>Lampanyctus photonotus</i>			1	-	-	-	-	-	-	13	-	25	9	21
<i>Lepidophanes gaussi</i>										2	-	12	5	10
<i>Lepidophanes guentheri</i>		5	2	9	71	-	4	-	2	-	-	1	-	2
<i>Lepidophanes pyrsobolus</i>							1	1	1	3	-	2	7	8
<i>Nemichthys scolopaceus</i>			1	-	-	1	-	1						
<i>Notolychnus valdiviae</i>				5	39	-	94	-	-	6	-	-	27	21
<i>Notoscopelus resplendens</i>		1	-	1	101	1	31							
<i>Scopelogadus mizolepis</i>	1	1	1	2	-	16								
<i>Stomias affinis</i>			3	-	4	-	1							
<i>Valenciennellus tripunctulatus</i>			4	2	-	1	-	9	4	-	3			
<i>Vinciguerria nimbaria</i>	16	8	1	31	159	-	100	-	-	7	-	1		
<i>Vinciguerria</i> sp. A					245	1	28	-	-	-	2			

