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Benthic Fish Associations on the Continental Slope of the Middle Atlantic Bight

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Benthic Fish Associations on the Continental Slope of the Middle Atlantic Bight

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Master of Arts

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Douglas Frank Markle

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APPROVAL SHEET

This thesis is submitted in partial fulfillment of
the requirements for the degree of

Master of Arts

Douglas Frank Markle

Approved, May 1972

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George C. Grant

John V. Merriner

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ABSTRACT

The species composition of the benthic slope fishes of the Middle Atlantic Bight is described from eleven trawl catches taken from a depth of about 900 m in August, 1969. Analyses of seven samples show two species associations and a transitional area. The difference between the two associations is partially attributable to differences in species composition but primarily to differences in species dominance. The small number of samples precludes geographic and bathymetric delineation of these associations, as well as conclusions about their temporal nature. Diversity values (H') are relatively high in comparison with estuarine and coastal fish associations. Some aspects of the biology and morphology of certain species are included in an appendix.

Benthic Fish Associations on the Continental Slope of the Middle Atlantic Bight

INTRODUCTION

Existing information on the slope fishes of the Middle Atlantic Bight is derived mostly from the work of Goode and Bean (1896). Taxonomic work on particular groups of slope fishes has added to this basic groundwork (Burke, 1930, Parr, 1932, 1946, Bigelow and Schroeder, 1954, Castle, 1964, and others) and some distributional information has been compiled (Schroeder, 1955 and Grey, 1956). However, very little is known about other aspects of the biology or ecological relationships of slope fishes.

The purpose of this study is to describe the species composition of the benthic and engybenthic (Mead, 1970 = "benthopelagic" Marshall, 1967) fish fauna at 400 to 500 fathoms (730 to 915 meters) along the Middle Atlantic Bight from collections made in August, 1969. The distribution and abundance of species is presented and the community ecology is examined using several numerical techniques. A list of the mesopelagic fishes is included. Gonadal condition and other aspects of the biology and morphology of certain species are discussed in an appendix.

MATERIALS AND METHODS

Eleven benthic trawls were made in August, 1969 on the continental slope between Cape Hatteras, North Carolina and Block Canyon aboard the "Albatross IV" (Figure 1 and Table 1) using a 40 foot Gulf of Mexico shrimp trawl with a one-half inch (13 mm) stretch mesh liner. An attempt was made to trawl in the vicinity of the 500 fathom (915 meter) contour.

Seven of the eleven stations were considered successful. Failure occurred either because the trawl did not fish on the bottom at all or for only a short period (stations 3, 5, and 10) or the net ripped resulting in loss of part of the catch (station 7). An account is given of these stations, but they are not included in the ecological analyses.

All stations were made on the steep, irregular upper slope, which extends down to about 1460 meters in the Middle Atlantic Bight (Pratt, 1968). North of Hudson Canyon, the upper slope has an average declivity of 1°, whereas, from Hudson Canyon to Cape Henry, Virginia the upper slope is more irregular and has an average declivity of 4° (Uchupi, 1968).

The dominant sediment is pale-olive to grayish-olive, but tonguelike extensions of shelf sediment are also found in the vicinity of the canyons (Stanley, 1969). The stations in this study were probably made over both types of sediments.

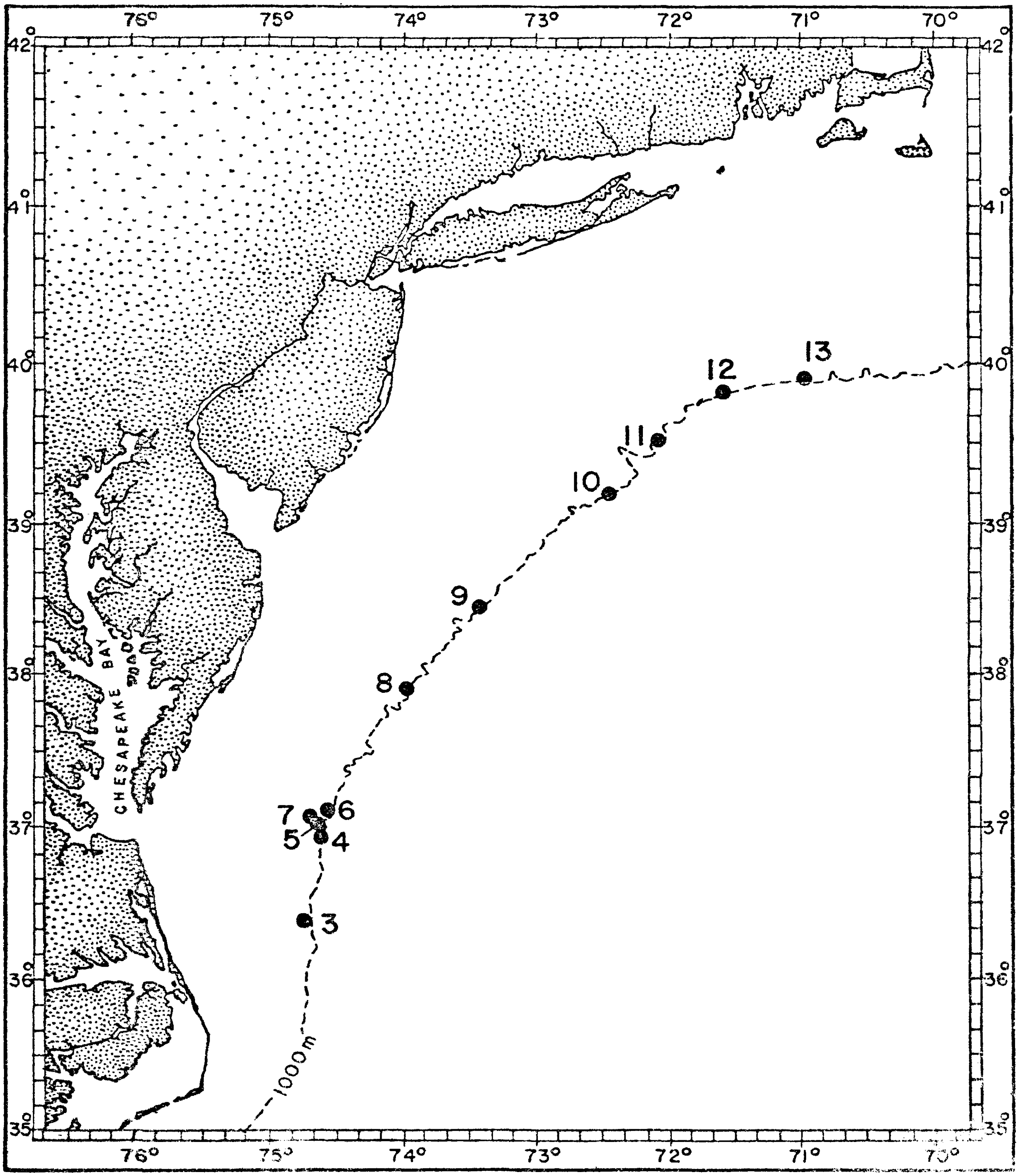
In most instances, specimens were preserved in 10% formalin at sea, transferred to 40% isopropyl alcohol, identified, and measured in the laboratory. However, a shortage of storage containers prevented saving some of the Synaphobranchids at stations 12 and 13, some of the *Nezumia* at stations 6 through 13, and the two specimens of *Lophius americanus*. The discarded Synaphobranchids were most probably *Synaphobranchus kaupi*, and are treated as such for the ecological analyses. The discarded *Nezumia* probably included two species, *N. bairdii* and *N. aequalis*. Consequently, all of the *N. bairdii* and *N. aequalis* which were saved plus those which were discarded are grouped as *Nezumia* spp. for the ecological analyses.

Two methods were used to describe faunal similarity between stations: 1) Sander's (1960) dominance-affinity index; and 2) Horn's (1966) "overlap" analysis, R_o, using numerical abundance of each species.

R_o ranges from 0 when the samples contain no species in common to 1 when the proportional species composition of the samples is identical (Horn, 1966). Thus, when samples are identical with respect to proportional species composition,

$$R_o = 2a/X + Y,$$

a ratio of the species in common between sample pairs to the total number of species, where a is the number of species common to both samples and X and Y are the total number of species in each sample.



76°
75°
74°
73°
72°
71°
70°
42°
41°
40°
39°
38°
37°
36°
35°
CHESAPEAKE BAY
ROAD
1000m
3
4
5
6
7
8
9
10
11
12
13

Table 1

Station data for the eleven slope stations of R. V. "Albatross IV" cruise 69-8 (II).

Station Number	Date	Towing Time (EDT)	Latitude	Longitude	Depth Range (in fathoms)
3	13VIII69	0719-0749	36°24'N	74°42'42"W	440-450
4	13VIII69	1245-1325	36°54'12"N	74°34'30"W	480-500
5	13VIII69	1956-2056	37°02'30"N	74°31'30"W	450-700+
6	14VIII69	0150-0220	37°06'30"N	74°31'30"W	460-470
7	14VIII69	0720-0750	37°03'N	74°35'W	300-550
8	14VIII69	1735-1815	37°53'N	73°54'30"W	400-700
9	14VIII69	2250-2330	38°26'N	73°18'30"W	410-550
10	15VIII69	0557-0627	39°08'30"N	72°18'30"W	490-500
11	15VIII69	1100-1130	39°30'N	71°53'W	450-510
12	15VIII69	1443-1513	39°47'30"N	71°24'W	460-480
13	15VIII69	1804-1834	39°50'N	70°54'W	500-520

Because R_o is derived from information measures of diversity (Horn, 1966), it contains components measuring both the number of species in common between sample pairs and the number of individuals per species in common between sample pairs. An empirical measure of dominance affinity, herein called "T", can then be generated,

$$T = R_o - 2a/X + Y.$$

Values of "T" near 0 ($\pm$ 0.10) are somewhat ambiguous and do not necessarily indicate a lack of dominance affinity. Values greater than + 0.10 indicate that dominant species are held in common between sample pairs whereas values less than - 0.10 indicate that dominant species are not held in common between sample pairs. For example:

Sample Species	X	Y	X	Y	X	Y
A	10	10	25	20	25	0
B	20	0	10	0	0	30
C	0	20	0	10	15	10
D	10	10	15	10	5	5
E	10	10	0	10	5	5
	50	50	50	50	50	50
R_o	0.60		0.69		0.44	
T	0.00		+0.29		-0.16	

Diversity (H'), in bits of information per individual, was calculated using Shannon's equation with tables from Lloyd, Zar, and Karr (1968). The "species richness" (D) component of diversity was measured using $D = S-1/ \ln N$, where S is the number of species and N is the number of individuals (Margalef, 1968). The "equitability" or evenness component (E) was measured using $E = S'/S$, where S is the number of species and S' is the hypothetical number of species required to achieve the observed H' if the species conformed to a particular distribution model, in this case MacArthur's (1957) "broken-stick" model (Lloyd and Ghelardi, 1964).

Stations with high faunal similarity were assumed to represent a natural unit. Their data were pooled to obtain H'_{pop}, a better estimate of the parametric diversity than any one station's H' (Pielou, 1966). D and E were also calculated for the pooled samples.

The relative importance of the dominant species, both overall and within areas of high faunal similarity, was determined by ranking them according to their biological index values (Sanders, 1960).

RESULTS

Seventeen families, 29 species and 990 individual benthic and engybenthic fishes were captured in the seven successful trawls. The benthic and engybenthic species composition, and the mesopelagic species composition are summarized for all stations in Tables 2 and 3, respectively. An annotated list of the benthic and engybenthic species is included in an appendix.

Values of Sander's (1960) dominance-affinity index (Fig. 2) reveal two blocks of high affinity (>60.00), stations 4, 6 and 8 and stations 11, 12 and 13. The mean affinities within each block are 69.09 and 75.82, respectively. Station 9 is intermediate, having a mean affinity with stations 4, 6 and 8 of 55.70 and with stations 11, 12 and 13 of 47.89. The mean affinity of all stations is 45.91.

After eliminating Synaphobranchus kaupi from the data, the range of values for the dominance-affinity index is reduced (Fig. 3). The sharp separation of two blocks of high affinity (Fig. 2) is now obliterated. The mean affinity of all stations is 53.46.

Horn's (1966) "overlap" analysis (Fig. 4) provides a second measure of faunal similarity and shows two blocks of high affinity separated by station 9 (Fig. 2). This station has a mean affinity

Table 2

Species composition of benthic and engybenthic slope fishes

Species	Station Numbers 3	4	5	6	7	8	9	10	11	12	13	Total
Centroscyllium fabricii									5	1		6
Harriotta raleighana									1			1
Ariosoma perturbator									1			1
Ilyophis brunneus		1							2	1		4
Synaphobranchus kaupi	1	6			1	1	17		116	201	57	400
Simenchelys parasiticus						1	2		3	4	3	13
Halosaurus guntheri						1	1					2
Aldrovandia phalacra	1	5					7		1	11		25
Alepocephalus convexifrons									1			1
Bajacalifornia drakei									1			1
Bathypterois viridensis		1										1
Lophius americanus				1	1							2
Dibranchus atlanticus							1					1
Antimora rostrata							5		4	4	2	15

Table 2. Continued.

Species	3	4	5	6	7	8	9	10	11	12	13	Total
Phycis chesteri	4	50		31	40	6	16		5	19	2	173
Dicrolene intronigra		1				2	4		9		4	20
Monomitopus agassizi						1						1
Melanostigma atlanticum	1	1	1	1	3		1		12	6	1	27
Lycodonus mirabilis									1			1
Lycenchelys verrilli	2											2
Lycenchelys paxillus							2		1	1	2	6
Lycodes atlanticus		4									1	5
Trachonurus sulcatus		1										1
Coryphaenoides colon (ms)		1										1
Coryphaenoides rupestris						1			26	4	1	32
Nezumia cyranoi (ms)						1						1
Nezumia aequalis	1	13		2								16
Nezumia bairdii	3	72		1		3	3				1	83

Table 2. Continued.

Species	3	4	5	6	7	8	9	10	11	12	13	Total
Nezumia spp.				13	2		8		19	22	18	82
Paraliparis copei							1		1			2
Glyptocephalus cynoglossus	1	60		22			14		10	10	2	126
Total	14	216	1	71	47	24	82	0	219	284	94	1052

Table 3

Species composition of mesopelagic slope fishes.

Species	3	4	5	6		8	9	10	11	12	13	Total
Nessorhamphus ingolfianus									1	1		2
Derichthys serpentinus	1											1
Serrivomer beanii		1							1	3	4	9
Nemichthys scolopaceus	2		3	1					1	1	1	9
Bathylagus compsus									1			1
Bathylagus sp.										2		2
Scopelogadus beanii		1							1		2	4
Maurolicus muelleri				2								2
Cyclothone spp.	6		2	1	3	2		17	8	1	15	55
Argyropelecus aculeatus								2	2	1		5
Sternoptyx diaphana		1								1	1	3
Bathophilus brevis								1				1
Malacosteus niger			1									1

Table 3. Continued.

Species	3	4	5	6	8	9	10	11	12	13	Total
Chauliodus sloani								1	1	1	3
Stomias boa ferox	1	1	1	2			3	1		1	10
Paralepis atlantica			1								1
Gonichthys coccoi								1			1
Lampanyctus alatus			1						1		2
Lampanyctus crocodilus		2						4	4		10
Ceratoscopelus maderensis	3								3		6
Myctophum affine			1	4							5
Diaphus effulgens									1		1
Diaphus lutkeni									1		1
Lobianchia gemellari								3	1	2	6
Hygophum hygomi				4			2				6
Benthosema glaciale	6	3	11	2		2	5	2	16	22	69
Melanonus zugmayeri								1			1

Table 3. Continued.

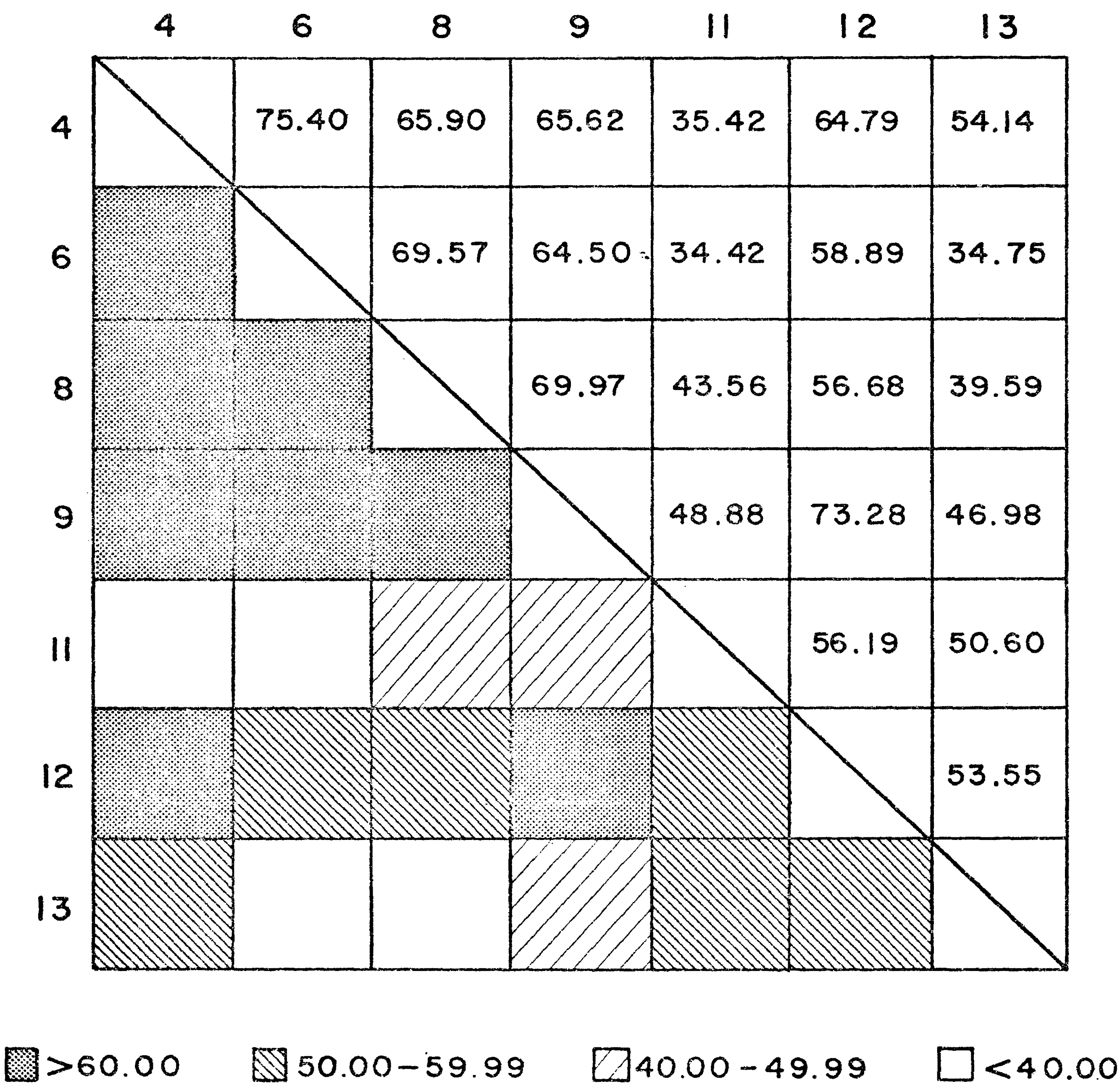
Species	3						9	10	11	12	13	Total
Poromitra sp.								1				
Caulolepis longidens		1										
Nealotus tripes				1								
Total	19	10	21	17		2	2	31	26	38	49	218

Figure 2. Trellis diagram of Sanders' (1960) dominance-affinity index values for all combinations of station pairs.

	4	6	8	9	11	12	13
4		73.93	66.67	55.39	20.06	23.86	29.23
6			66.67	50.61	16.86	19.37	25.53
8				61.11	29.24	24.95	29.44
9					46.02	47.22	50.43
11						74.06	75.47
12							77.94
13							

>60.00 50.00–59.99 40.00–49.99 <40.00

Figure 3. Trellis diagram of Sanders' (1960) dominance-affinity index values calculated after eliminating *Synaphobranchus kaupi* from all combinations of station pairs.



4
6
8
9
11
12
13
75.40
65.90
65.62
35.42
64.79
54.14
69.57
64.50
34.42
58.89
34.75
69.97
43.56
56.68
39.59
48.88
73.28
46.98
56.19
50.60
53.55
>60.00
50.00–59.99
40.00–49.99
<40.00

Figure 4. Trellis diagram of the values of Horn's (1966) "overlap" analysis for all combinations of station pairs.

	4	6	8	9	11	12	13
4		.92	.76	.75	.43	.48	.49
6			.76	.70	.38	.46	.35
8				.78	.58	.54	.51
9					.71	.76	.73
11						.89	.90
12							.91
13							

>.80   .70 - .79   .60 - .69   <.60

of 0.74 with stations 4, 6 and 8 and 0.74 with stations 11, 12 and 13. The mean affinity of stations 4, 6 and 8 is 0.81 and the mean affinity of stations 11, 12 and 13 is 0.90. The mean affinity of all stations is 0.66.

The elimination of Synaphobranchus kaupi from the calculation of R_o values again obliterates the two blocks of high affinity (Fig. 5). The mean affinity of all stations is 0.73.

The values for the ratio of species in common between sample pairs show no sharp separation of blocks of stations and are surprisingly low between stations 4, 6 and 8 (Fig. 6). However, the T values do show strong grouping into two blocks (Fig. 7) represented by stations 4, 6, 8 and 9 and stations 11, 12 and 13.

Species ranking by biological index values (Sanders, 1960) is given in Table 4 for the two blocks of high faunal affinity and for all stations combined. Glyptocephalus cynoglossus and Phycis chesteri ranked highest at stations 4, 6 and 8, whereas Synaphobranchus kaupi ranked highest at stations 11, 12 and 13 and overall. The two Nezumia species were relatively important throughout and ranked second overall.

The change in dominance suggested by Table 4 is graphically illustrated in Figure 8, which also shows the transitory nature of station 9. At this station the three most abundant species were represented by 17, 16 and 14 individuals.

Rare species, as well as dominant species, contributed to the faunal transition. Many species were either wholly restricted to or mainly found in one association or the other (Table 5).

The numbers of species and individuals, and the values of diversity (H'), equitability (E) and species richness (D) are given for each station in Table 6. All three values are lowest at the two most southerly (4 and 6) and northerly (12 and 13) stations, because of the predominance of one or two species at these stations.

Values of diversity, equitability and species richness are also given for pooled samples from the two areas of high faunal affinity (Table 7). Pooled values of species richness are higher and those of equitability are lower than are those values for individual stations. Thus, pooled samples had both more species (higher species richness values) and larger numbers of dominant species (lower equitability is more prominent at stations 11, 12 and 13 because of the large numbers of *Synaphobranchus kaupi*, which also contributed to the lower diversity in this group of stations.

Figure 5. Trellis diagram of the values of Horn's (1966) "overlap" analysis calculated after eliminating *Synaphobranchus kaupi* from all combinations of station pairs.

	4	6	8	9	11	12	13
4		.93	.75	.79	.54	.79	.70
6			.78	.78	.53	.77	.58
8				.80	.66	.71	.64
9					.67	.87	.74
11						.76	.76
12							.76
13							

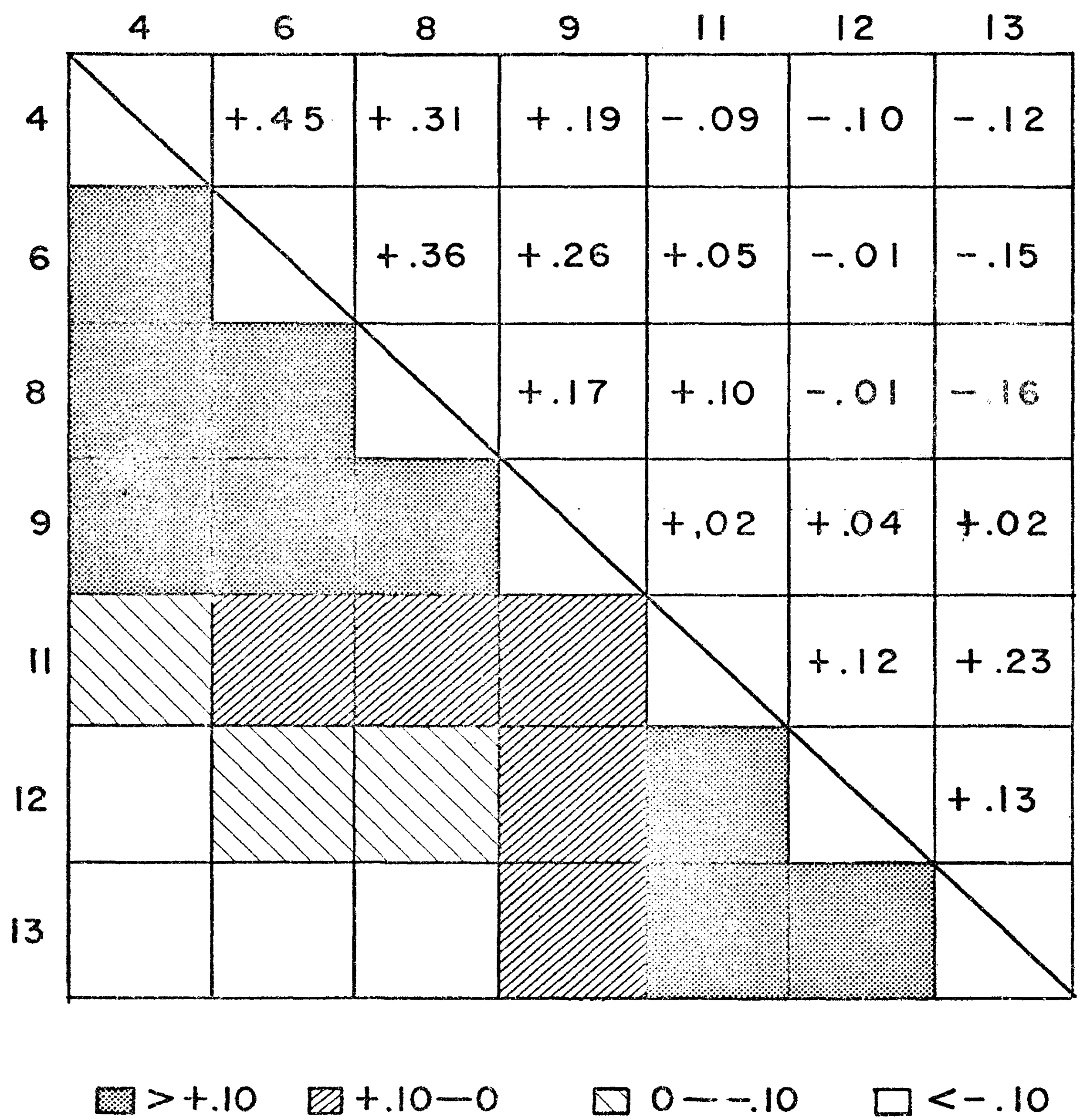
>.80 .70 – .79 .60 – .69 <.60

Figure 6. Trellis diagram of the values for the ratio of species in common between sample pairs.

	4	6	8	9	11	12	13
4		.47	.45	.56	.52	.58	.61
6			.40	.44	.33	.47	.50
8				.61	.48	.55	.67
9					.69	.72	.75
11						.77	.67
12							.78
13							

> .70   .60 - .69   .50 - .59   < .50

Figure 7. Trellis diagram of the values of T (see text for explanation) for all combinations of station pairs.



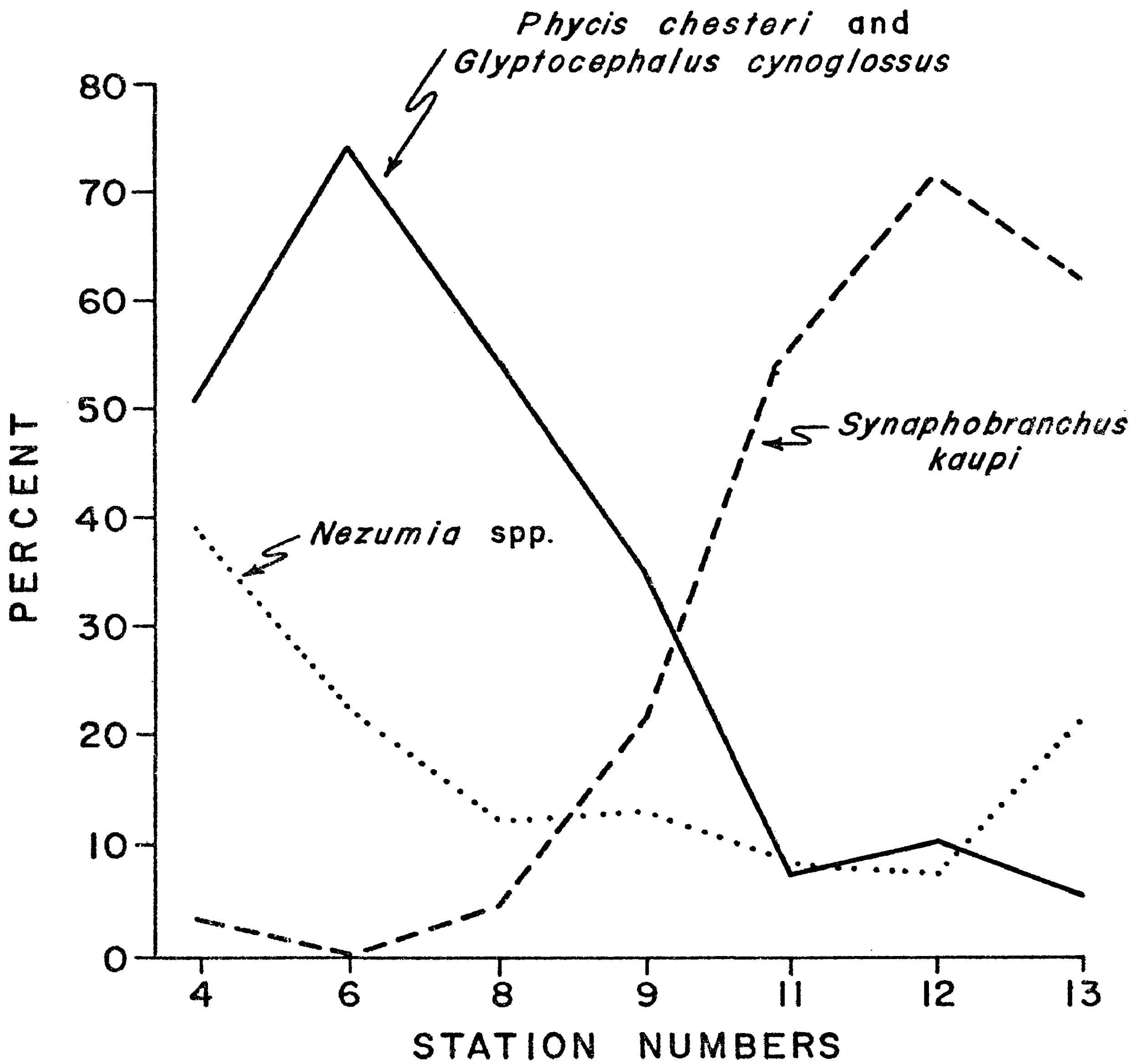
4 6 8 9 11 12 13
4 +.45 +.31 +.19 -.09 -.10 -.12
6 +.36 +.26 +.05 -.01 -.15
8 +.17 +.10 -.01 -.16
9 +,02 +.04 +.02
11 +.12 +.23
12 +.13
13
>+.10
+.10—0
0—-.10
<-.10

Table 4

Species ranking, as determined by Sanders' (1960) biological index, for each station, for each block of stations of high affinity and for all stations

Species	Station Number									
	4	6	8	9	11	12	13	4-8	11-13	4-13
Synaphobranchus kaupi	-	-	-	3	3	3	3	-	9	12
Nezumia spp.	3	1	1	-	1	2	2	5	5	10
Phycis chesteri	1	3	2	2		1	0.5	6	1.5	9.5
Glyptocephalus cynoglossus	2	2	3	1			0.5	7	0.5	8.5
Coryphaenoides rupestris					2				2	2

Figure 8. Percent composition of the dominant species at each station.



Phycis chesteri and
Glyptocephalus cynoglossus
Synaphobranchus
kaupi
Nezumia spp.
PERCENT
80
70
60
50
40
30
20
10
0
4
6
8
9
11
12
13
STATION NUMBERS

Table 5

Percent occurrence of benthic and engybenthic species north and south of station 9

Species	Percent occuring at stations 4 through 8	Percent occuring at stations 11 through 13	Percent occuring at station 9
Centroscyllium fabricii	0	100	0
Harriotta raleighana	0	100	0
Ariosoma perturbator	0	100	0
Alepocephalus convexifrons	0	100	0
Bajacalifornia drakei	0	100	0
Lycodonus mirabilis	0	100	0
Coryphaenoides rupestris	3.1	96.9	0
Synaphobranchus kaupi	2.2	93.5	4.3
Simenchelys parasiticus	717	76.9	15.4
Ilyophis brunneus	25	75	0
Melanostigma atlanticum	25.9	70.4	3.7
Antimora rostrata	0	66.7	33.3
Lycenchelys paxillus	0	66.7	33.3
Dicrolene intronigra	15	65	20
Paraliparis copei	0	50	50
Halosaurus guntheri	50	0	50
Aldrovandia phalacra	24	48	28
Glyptocephalus cynoglossus	71.4	17.5	11.1
Phycis chesteri	75.7	15	9.3
Lycodes atlanticus	80	20	0

Table 5. Continued.

Species	Percent occuring at stations 4 through 8	Percent occuring at stations 11 through 13	Percent occuring at station 9
Bathypterois viridensis	100	0	0
Lophius americanus	100	0	0
Monomitopus agassizi	100	0	0
Trachonurus sulcatus	100	0	0
Coryphaenoides colon (MS)	100	0	0
Nezumia cyranoi (MS)	100	0	0

Table 6

The number of species and individuals and the values of diversity, equitability and species richness for the benthic and engybenthic species.

Station Number	4	6	8	9	11	12	13
Number of species	13	6	10	13	19	12	12
Number of Individuals	216	71	24	81	219	284	94
Diversity (bits/individual)	2.36	1.83	2.84	3.09	2.56	1.72	2.00
Equitability (E)	0.54	0.67	1.00	0.92	0.42	0.33	0.42
Species Richness (D)	2.23	1.17	2.83	2.73	3.34	1.95	2.42

Table 7

Diversity, equitability, and species richness values obtained after pooling stations of high faunal similarity.

Station Group	Diversity (bits/individual)	Equitability (E)	Species richness (D)
4, 6, 8	2.44	0.37	3.14
11, 12, 13	2.21	0.29	3.13

DISCUSSION

Species associations

The benthic and engybenthic fishes of the upper slope (around 900 m) of the Middle Atlantic Bight appear to be an homogenous group. The dominant species are Synaphobranchus kaupi, Nezumia bairdii, Phycis chesteri, and Glyptocephalus cynoglossus. However, in the vicinity of Hudson Canyon, there is a transition from an association dominated by Glyptocephalus cynoglossus and Phycis chesteri to the southwest, to one dominated by Synaphobranchus kaupi to the northeast. All three species are present throughout the area studied, but marked differences can be seen in their relative abundances. Whether these differences are temporally stable or subject to seasonal or other variations is unknown.

The effect of a dominant species on both species association indices (Figs. 2 and 4) is significant (Figs. 3 and 5). Within the association represented by stations 4, 6, and 8, the number of species held in common is low (Fig. 6) and the high values for these indices are due to dominant species (Fig. 7). The association represented by stations 11, 12 and 13 has both a large number of species held in common (Fig. 6) as well as a large number of dominant species held in common (Fig. 7).

Station 9 represents an ecocline or transitory area and is unique in several respects. It has both the largest and smallest specimens of Glyptocephalus cynoglossus and Lycenchelys paxillus, the largest specimen of *Synaphobranchus kaupi*, *Simenchelys parasiticus*, *Halosaurus guntheri*, and *Aldrovandia affinis*, the only specimen of *Dibranchus atlanticus*, the highest diversity value (H'), an intermediate position between two species associations and an almost equal abundance of the three dominant species.

Bathymetric and further geographic delineation of these species associations is not possible because the sampling was restricted to a few stations within a narrow depth zone.

Diversity

At present, there are few published accounts using mathematical indices as measures of fish diversity. Reported values are from 0.6 to 1.8 natural bels (0.9 to 2.6 bits per individual) in a Georgia estuary (Dahlberg and Odum, 1970); from 0.02 to 2.2 natural bels (0.03 to 3.2 bits per individual) in Galveston Bay, Texas (Bechtel and Copeland, 1970); from 1.4 to 3.5 bits per individual for demersal fishes along the Mediterranean Spanish coast (Margalef, 1968); 2.06 natural bels (3.0 bits per individual) in Hudson Canyon (Haedrich and Horn, 1970); and from 1.7 to 3.1 bits per individual in the present study. Apparent differences among these values may be manifestations of gear selectivity or of the degree of difficulty involved in sampling the different environments.

The values of these indices based on catches of fish can not be considered adequate estimates of parametric diversity because of the mobility of fishes, their tendency to form aggregations, and the difficulty in adequately sampling fish populations.

However, the estuarine and bay values were taken seasonally from a large number of samples and are, in most instances, much lower than the values for slope fishes, which suggests that these differences may approximate actual differences in the parametric diversities.

Some workers (Grassle, 1967, Sanders, 1968) attribute high diversity in benthic slope invertebrates to environmental stability. They propose that a stable environment allows for narrower niches or niche specialization and, therefore, more species than in an unstable environment. Relatively high diversity in slope fishes may also be attributable to environmental stability. However, values for fish diversity may vary greatly even on the continental slope because of the mobility of fishes and ontogenetic changes in their habitats. For example, the abundance of deep-demersal Glyptocephalus cynoglossus is most probably dependent on the spawning success of the adult populations on the continental shelf and on the mortality of the epipelagic larvae, rather than on the environmental stability of the slope nursery ground Also, apparent spawning aggregations, such as those represented by Synaphobranchus kaupi in the present study (see appendix), also effect diversity values (Tables 6 and 7). From this limited data, it appears that species-dependent factors contribute significantly to benthic slope fish diversity.

Inherent limitations in the present study do not allow for further interpretation of the results, and the literature on slope fishes does not include station or area species abundance lists, so that comparison with other work is not presently possible.

CONCLUSIONS

Species association indices, computed from a limited number of stations, indicate two associations among the benthic and engybenthic fishes found around 900 m in the Middle Atlantic Bight. A change in the dominant species composition was responsible for the two associations.

Diversity values appear to be relatively high for the benthic fishes of the upper slope, but comparison with values for temporate estuarine and coastal fishes indicates a narrow range for all of these values and considerable overlap in values from among the different environments. Compared to benthic invertebrates, environmental stability may be of less importance in determining diversity in different fish faunas because of the mobility and ontogenetic changes in the habitats of fishes.

Whether or not these ontogenetic changes are significant and whether the above species associations are real or artifacts of sampling cannot be determined without extensive seasonal sampling and more life history data on species in the bathypelagic as well as the benthic realm.

APPENDIX

Annotated species list

In the following list, the teleostean families are listed according to Greenwood, *et al.* (1966). Below the name of each species is the museum collection number, followed in parentheses by the number of specimens and their standard length (SL) range in millimeters and the station number. Total length (TL) is used for the following groups: Chondrichthys, Elopomorpha, Lophiidae, Zoarcidae, Macrouridae, Cyclopteridae, and Pleuronectidae. Sex, distribution and other comments are also included for each species. Museum abbreviations are: VIMS - Virginia Institute of Marine Science and USNM - National Museum of Natural History (formerly United States National Museum).

Family Squalidae

Centroscyllium fabricii (Reinhardt 1825)

VIMS 00917, (5, 285-480), st. 11

VIMS 00916, (1, 460), st. 12

Sex: The five specimens from station 11 are males and the specimen from station 12 is an immature female.

Distribution: All specimens are from the area north of Hudson Canyon.

Comments: Monosexual schools as indicated here, are unusual in Basinobranchs, but apparently not in *C. fabricii* (Templeman, 1963).

Family Rhinochimaeridae

<u>Harriotta</u> <u>raleighana</u> Goode and Bean 1896

VIMS 00915, (1, 413), st. 11

Sex: The specimen is an immature male with claspers 5 mm in length.

Distribution: The station is in the area north of Hudson Canyon.

Family Congridae

<u>Ariosoma</u> <u>perturbator</u> Parr 1932

USNM 206213, (1, 279), st. 11

Sex: The specimen is a mature male.

Distribution: The station is in the area north of Hudson Canyon.

Comments: Parr (1932) gives the type locality as 23° 54' 20" N, 77° 09' W at 710-720 fathoms (1300 m) and Staiger (1970) reports six specimens from the Straits of Florida. The specimen on hand represents a considerable extension of the range of this species.

Morphometrics, expressed as percent standard length, and meristics are in close agreement with the type, which follow in parentheses: length of head, soft snout included 13.2 (14.5); length of snout, soft parts excluded 3.7 (3.7); length of snout, soft parts included 4.4 (4.7); length of gape 3.3 (3.2); length of lower jaw 2.6 (4.0?); diameter of eye 1.1 (1.4); external interorbital width 2 2 (2.3); depth of head 4.0 (3.4);

greatest depth of body 5.5 (4.7); vertical width of gill opening 1.1 (2.0); snout (soft parts included) to dorsal fin 18.0 (18.1); snout (soft parts included) to anal fin 36 8 (35.9); length of pectorals 3.3 (3.8); length of caudal fin rays 2.6 (2.6); and number of vertebrae 158 (159).

Family Synaphobranchidae

Ilyophis brunneus Gilbert 1891

VIMS 00803, (1, 204), st. 4

VIMS 00805, (2, 256, 315), st. 11

VIMS 00804, (1, 266), st. 12

Sex: Undetermined.

Distribution: Station localities are in the vicinity of Norfolk Canyon and in the area north of Hudson Canyon.

Comments: Five specimens from the East Pacific, North and South Atlantic are all that were known to Castle (1964). The specimens on hand plus those reported by Robins (1968) from the Straits of Florida suggest that this species is not as rare as previously believed.

Vertebral counts of 144 (1), 145 (1), and 146 (2) are within the range of the type (146) and another specimen (141) reported by Castle (1964). Robins (1968) reported a range of 144-151 for eleven specimens. Thus, the vertebral range for *I. brunneus* is at least 141 to 151.

<u>Synaphobranchus</u> <u>kaupi</u> Johnson 1862

VIMS 00811, (1, 443), st. 3

VIMS 00808, (6, 200-348), st. 4

VIMS 00806, (1, 187), st. 7

VIMS 00812, (1, 432), st. 8

VIMS 00809, (17, 2080565), st. 9

VIMS 00813, (116, 254-529), st. 11

VIMS 00807 (in part), (201, 229-550), st. 12

VIMS 00810 (in part), (57, 228-540), st. 13

Sex: The sex of 112 specimens over 300 mm TL from station 11 is presented in Table 4. The sex ratio is 3:1, females to males. The mean total length is 373 mm for males and 410 mm for females.

Distribution: Station localities include the entire area sampled, but the distribution is very contagious, 93.5% of the specimens being caught in three of the seven successful tows.

Comments: Many specimens appear to be in spawning condition. Ten eggs from a female (470 mm TL) from station 13 have a mean diameter of 0.99 mm (0.92-1.11). The body cavities of most of the females are full of eggs, and some of the largest ones from station 11 appear spent. Four males from station 13 released milt at the time of capture.

Family Simenchelyidae

<u>Simenchelys</u> <u>parasiticus</u> Gill 1879

VIMS 00816, (1, 363), st. 8

Table 8

Sex ratio of male to female *Synaphobranchus kaupi* at station 11.

Total length (in mm)	Ratio ♂/♀
300-309	1/1
310-319	1/1
320-329	1/3
330-339	1/2
340-349	3/4
350-359	4/1
360-369	3/6
370-379	2/8
380-389	3/4
390-399	3/6
400-409	1/7
410-419	2/6
420-429	1/8
430-439	2/4
440-529	0/23
Total	28/84

VIMS 00818, (2, 320, 408), st. 9

VIMS 00817, (3, 225-375), st. 11

VIMS 00814, (4, 260-395), st. 12

VIMS 00815, (3, 290-355), st. 13

Sex: One female (355 mm TL) from station 13 has eggs up to 0.32 mm in diameter.

Distribution: Station localities are all north of Norfolk Canyon.

Comments: The stomachs of six specimens are empty.

Family Halosauridae

Halosaurus guntheri Goode and Bean 1896

VIMS 00826, (1, 393), st. 8

VIMS 00825, (1, 395), st. 9

Sex: Undetermined.

Distribution: The station localities are in the area between Norfolk Canyon and Hudson Canyon.

Aldrovandia phalacra Vaillant 1888)

VIMS 00828, (1, 368), st. 3

VIMS 00831, (5, 333-387), st. 4

VIMS 00830, (7, 188+-398), st. 9

VIMS 00827, (1, 284), st 11

VIMS 00829, (11, 150-389), st. 12

Sex: A female (389 mm TL) from station 12 has eggs up to 0.72 mm in diameter. No other specimens were examined.

Distribution: The station localities are throughout most of the area sampled.

Family Alepocephalidae

Alepocephalus convexifrons Garman 1899

VIMS 01282, (1, 221), st. 11

Sex: Undetermined

Distribution: The station is in the area north of Hudson Canyon.

Comments: There are no known records of this species in the Western North Atlantic; the type locality is off Acupulco (Garman, 1899).

Bajacalifornia drakei (Beebe 1929)

VIMS 01283, (1, 268), st. 11

Sex: Undetermined.

Distribution: The station is in the area north of Hudson Canyon.

Comments: The stomach contained a large caridean shrimp, _Acanthephyra purpurea_.

Family Bathypteroidae

Bathypterois viridensis (Roule 1916)

VIMS 00846, (1, 121), st. 4

Sex: Undetermined.

Distribution: The station locality is in Norfolk Canyon.

Family Lophiidae

Lophius americanus Valenciennes 1873

uncatalogued, (1, 620), st. 6

uncatalogued, (1, 560), st. 7

Sex: Undetermined.

Distribution: The station localities are in the area between Norfolk Canyon and Hudson Canyon.

Comments: The captures are at the lower limit of this species' bathymetric range.

Family Ogcocephalidae

Dibranchus atlanticus Peters 1875

VIMS 00869, (1, 92), st. 9

Sex: The specimen is a male.

Distribution: The station is to the southwest of Hudson Canyon.

Comments: Although only one specimen is in the present collections, this species is reported as common on both sides of the Atlantic (Bradbury, 1967).

Family Moridae

Antimora rostrata Gunther 1878

VIMS 00870, (5, 120-169), st. 9

VIMS 00871, (4, 276-342), st. 11

VIMS 00872, (4, 161-337), st. 12

VIMS 00873, (2, 303-315), st. 13

Sex: Undetermined.

Distribution: Station 9 is to the southwest of Hudson Canyon and the other stations are to the north of Hudson canyon.

Comments: Although Bigelow and Schroeder (1953) believe this species is one of the more plentiful of fishes on the upper slope between Nova Scotia and Cape Hatteras, it was not pelntiful in the present study.

Family Gadidae

Phycis chesteri Goode and Bean 1878

uncatalogued, (4, 210-265), st. 3

VIMS 00875, (50, 182-332), st. 4

uncatalogued, (31, 230-360), st. 6

uncatalogued, (40, 220-410), st. 7

uncatalogued, (6, 330-380), st. 8

uncatalogued, (16, 230-370), st. 9

uncatalogued, (5, 248-330), st. 11

uncatalogued, (19, 220-380), st 12

uncatalogued, (2, 270, 450), st. 13

Sex: Undetermined

Distribution: Station localities include the entire area sampled.

Comments: A female (330 mm SL) from station 11 has eggs up to 0.16 mm in diameter. Eggs of species in the closely related genus *Urophycis* mature at about 0.70 mm (Musick, MS 1969) which suggests that the eggs in the above specimen are not yet mature, although Bigelow and Schroeder (1953) and Svetovidov (1948) report summer and fall spawning for this species.

The mean standard length of 50 specimens from station 4 (Norfolk Canyon) is 261 mm whereas Fritz (1961) reports a mean length (TL?) of 343 mm for 101 specimens caught in 400 to 500 fathoms off Block Island in August, 1959.

Family Ophidiidae

Dicrolene intronigra Goode and Bean 1883

VIMS 00879, (1, 169), st. 4

VIMS 00878, (2, 122, 145), st. 8

VIMS 00877, (4, 121-162), st. 9

VIMS 00876, (9, 139-342), st. 11

VIMS 01290, (4, 136-158), st. 13

Sex: Undetermined.

Distribution: Station localities range over the entire area sampled.

Comments: Eight of the nine specimens from station 11 are larger than 225 mm, which suggests that larger individuals may be segregated from smaller individuals.

Monomitopus agassizi (Goode and Bean 1896)

VIMS 00881, (1, 174), st. 8

Sex: Undetermined.

Distribution: The station is located in the area between Norfolk Canyon and Hudson Canyon.

Family Zoarcidae

Lycodes atlanticus Jensen 1902

VIMS 00892, (4, 134-209), st. 4

VIMS 01295, (1, 101), st. 13

Sex: Undetermined.

Distribution: The stations are near Norfolk Canyon and Block Canyon, respectively.

Comments: *Lycodes atlanticus* is found in deep water off North America and is closely related to *L. frigidus* of the Eastern North Atlantic (Andriyashev, 1954). The systematics of this species is in a state of confusion (Leim and Scott, 1966) so that the above identification is tentative

Lycenchelys paxillus (Goode and Bean 1879)

VIMS 00891, (2, 194, 231), st. 9

VIMS 01299, (1, 221), st. 11

VIMS 00890, (1, 229), st 12

VIMS 01294, (2, 200, 203), st. 13

Sex: Undetermined.

Distribution: Station 9 is to the southwest of Hudson Canyon and the other stations are to the north of Hudson Canyon.

Lycenchelys verrillii (Goode and Bean 1877)

VIMS 00889, (2, 117, 126), st. 3

Sex: Undetermined.

Distribution: The station is in Norfolk Canyon.

Lycdonus _mirabilis_ Goode and Bean 1883

VIMS 00888, (1, 177), st. 11

Sex: Undetermined.

Distribution: The station is north of Hudson Canyon.

Comments: The specimen agrees with the description by Goode and Bean (1896), except in having fifteen dorsal scutes free of rays instead of ten or eleven as in their description.

Melanostigma _atlanticum_ Koefoed 1952

VIMS 00887, (1, 141), st. 3

Uncatalogued, (1, damaged), st 4

VIMS 00882, (1, 121), st. 5

VIMS 00886, (1, 151), st. 6

VIMS 00883, (3, 41-69), st. 7

Uncatalogued, (1, damaged), st. 9

VIMS 00885, (12, 119-159), st. 11

VIMS 00884, (6, 106-146), st 12

VIMS 01293, (1, 134), st 13

Sex: Undetermined.

Distribution: Station localities include the entire area sampled.

Comments: Many of the specimens, especially those from stations 11 and 12 are mature adults. Sixty-nine eggs from a 133 mm female have a mean diameter of 3.2 mm. Such large eggs and low fecundity suggest benthic eggs. _Melanostigma_ _atlanticum_ may be bathypelagic for most of its life (Mead, Bertelsen and Cohen, 1964), but probably returns to the bottom to spawn and perhaps care for the young.

Family Macrouridae

Coryphaenoides rupestris Gunnerus 1765

VIMS 00896, (1, 164), st. 8

VIMS 00899, (26, 300-510), st. 11

VIMS 00898, (4, 308-340), st 12

VIMS 00897, (1, 280), st. 13

Sex: Undetermined.

Distribution: Station 8 is between Norfolk Canyon and Hudson Canyon and the other statkons are in the area north of Hudson Canyon.

Coryphaenoides colon Marshall, MS

VIMS 00900, (1, 246), st. 4

Sex: Undetermined.

Distribution: The station is in the vicinity of Norfolk Canyon.

Nezumia spp.

Uncatalogued, (13, 150-340), st. 6

Uncatalogued, (2, 180, 240), st. 7

Uncatalogued, (8, 200-260), st. 9

Uncatalogued, (19, 170-310), st. 11

Uncatalogued, (22, 140-350), st. 12

Uncatalogued, (18, 220-360), st. 13

Comments: The above specimens were identified on board as *N. bairdii*, and were measured and discarded. In addition to *N. bairdii*, these specimens may also have been *N. aequalis*.

Nezumia bairdii (Goode and Bean 1877)

VIMS 00907, (3, 256-293), st. 3

VIMS 00908, (72, 128-310), st. 4

VIMS 00905, (1, 299), st. 6

VIMS 00906, (3, 235-325), st. 8

VIMS 00909, (3, 100-167), st 9

VIMS 00895, (1, 266), st. 13

Sex: Undetermined.

Distribution: The stations are throughout the area sampled.

Nezumia aequalis (Gunther 1878)

VIMS 00902, (1, 192), st. 3

VIMS 00901, (13, 132-218), st. 4

VIMS 00903, (2, 147, 170), st. 6

Sex: Undetermined.

Distribution: The stations are in Norfolk Canyon, but *N. aequalis* may have been distributed throughout the area sampled (see comments under *Nezumia* spp.).

Comments: *Nezumia aequalis* is a common eastern Atlantic species with only one reported capture in the Western North Atlantic (Iwamoto, 1970). The stomachs of six specimens contained amphipods, small shrimps, polycahetes, and other crustacean remains.

Nezumia cyranoi Marshall, MS

VIMS 00894, (1, 225), st. 8

Sex: Undetermined.

Distribution: The station is in the area between Norfolk Canyon and Hudson Canyon.

Trachonurus sulcatus (Goode and Bean 1886)

VIMS 00893, (1, 196), st. 4

Sex: Undetermined.

Distribution: The station is in the vicinity of Norfolk Canyon.

Family Cyclopteridae

Paraliparis copei Goode and Bean 1896

VIMS 01285, (1, 140), st. 9

VIMS 01284, (1, 164), st. 11

Sex: Undetermined.

Distribution: Station 9 is to the southwest of Hudson Canyon and station 11 is to the north of Hudson Canyon.

Family Pleuronectidae

Glyptocephalus cynoglossus (Linnaeus 1758)

VIMS 01306, (1, 208), st. 3

VIMS 01307, (60, 87-258), st. 4

VIMS 01308, (22, 110-226), st. 6

VIMS 01309, (7, 190-285), st. 8

VIMS 01310, (14, 76-350), st. 9

VIMS 01311, (10, 209-277), st. 11

VIMS 01312, (10, 157-298), st. 12

Uncatalogued, (2, 270, 330), st. 13

Sex: Undetermined.

Distribution: Station localities include the entire area sampled.

Comments: Glyptocephalus cynoglossus is found on both sides of the North Atlantic over a wide depth range (10 to 858 fathoms) (Leim and Scott, 1966). On the Nova Scotia banks, juveniles up to 300 mm are taken deeper (100-160 fathoms) than adults (20 to 150 fathoms) in the summer (Powles and Kohler, 1970). Table 9 shows the size distribution at each station for the present data and illustrates that the "deep demersal" juveniles are plentiful as deep as 500 fathoms in the Middle Atlantic Bight.

This species is unique among demersal shelf fishes in that it uses the continental slope as a nursery area. Powles and Kohler (1970) suggest that the "deep demersal" phase is a safeguard against direct feeding competition with more abundant shelf species, but lower predation pressure on the slope is probably a more significant selection pressure. The stomach contents of 15 specimens, 87 to 258 mm in length, contain the following frequencies of food organisms: crustaceans, mostly amphipods, 60%; polychaetes, 47%; bivalves, 40%; gastropods, 13%; and holothurians, 6%.

The pelagic larvae of this species metamorphose and migrate to the bottom when 40 to 50 mm large (Beebe, 1929, Bigelow and Schroeder, 1953). The smallest individuals caught were 76 and 87 mm.

Table 9

Size distribution, by station, of *Glyptocephalus cynoglossus* in August, 1969

Station Number:	3	4	6	8	9	11	12	13
Total Length (in mm)								
70-79					1			
80-89		1						
90-99								
100-109								
110-119			1					
120-129					1			
130-139		1						
140-149		3						
150-159		1					1	
160-169		11	1					
170-179		7	3					
180-189		4	3					
190-199		13	3	2				
200-209	1	10	5			1		
210-219		3	5	2	1		1	
220-229		2	1	1		2		
230-239		2		1	4	3	2	
240-249		1					2	
250-259		1			1	2		
260-269					2	1	1	1

Table 9. Continued.

Station Number:	3	4	6	8	9	11	12	13
Total Length (in mm)								
270-279					1	1	2	
280-289				1	1			
290-299							1	
300-309					1			
310-319								
320-329								
330-339								1
340-349								
350-359					1			
	—	—	—	—	—	—	—	—
Total:	1	60	22	7	14	10	10	2
Mean Length	208	187	193	223	238	242	244	300

Their spotty coloration (Bigelow and Schroeder, 1953:287) was not observed on a 110 mm specimen, nor is it found on 40 mm larvae (Beebe, 1929). Apparently, the spotty coloration is typical only of metamorphosed individuals, 50 to 100 mm TL, and reflects the commencement of melanophore activity in an otherwise colorless larva.

LITERATURE CITED

Andriyashev, A. P. 1964. Fishes of the northern seas of the U. S. S. R. 617 pp. (translation by Israel Program for Scientific Translation).

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contr. Mar. Sci. Univ. Tex. 15:103-132.

Beebe, W. 1929. Deep sea fish of the Hudson Gorge. Zoologica 12(1):1-19.

Bigelow, H. B. and W. C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Fish and Wildlife Serv., Fish. Bull., 74, Vo. 53:1-577.

Bigelow, H. B. and W. C. Schroeder. 1954. Deep water Elasmobranchs and Chimaeroids from the Northwestern Atlantic slope. Bull. Mus. Comp. Zool. 112(2):38-87.

Bradbury, M. G. 1967. The genera of batfishes (Family Ogcocephalidae). Copeia No. 2:399-421.

Burke, V. 1930. Revision of the fishes of the family Liparidae. Bull. U. S. Nat. Mus., No. 150, 204 pp.

Castle, P. H. J. 1964. Deep-sea eels: Family Synaphobranchidae. Galathea Report, vol. 7, 29-42.

Dahlberg, M. D. and E. P. Odum. 1970. Annual cycles of species occurrence, abundance, and diversity in Georgia estuarine fish populations. Am. Midl. Nat. 83(2):382-392.

Fritz, R. L. 1961. Size distribution by depth of the longfin hake, Phycis chesteri. Copeia. No. 2:229-230.

Garman, S. 1899. The fishes. Mem. Mus. Comp. Zool. Vol. XXIV. 431 pp. 97 pl. Cambridge.

Goode, G. B. and T. H. Bean. 1896. Oceanic Ichthyology. Deep-sea and pelagic fishes of the world. Spec. Bull., U. S. Nat. Mus., No. 2:1-553, 417 fig.

Grassle, J. F. 1967. Influence of environmental variation of species diversity in benthic communities of the continental shelf and slope. Ph.D. dissertation, Duke University, Durham. 194 pp.

Greenwood, P. H., D. E. Rosen, S. H. Weitzman, and G. S. Myers. 1966. Phyletic studies of teleostean fishes, with a provisional classification of living forms. Bull. Am. Mus. Nat. Hist. 131(4):339-456.

Grey, M. 1956. The distribution of fishes found below a depth of 2000 meters. Fieldiana: Zoology 36(2):73-337.

Haedrich, R. L. and M. H. Horn. 1970. The morid fish Halargyreus johnsonii from the New York Bight. Fish. Res. Bd. Canada 27(2):391-393.

Horn, H. S. 1966. Measurement of "overlap" in comparative ecological studies. Amer. Natur. 100(914):419-424.

Iwamoto, T. 1970. Macrourid fishes of the Gulf of Guinea. Stud. Trap. Oceanogr. 4(2):316-431.

Leim, A. H. and W. B. Scott. 1966. Fishes of the Atlantic Coast of Canada. Bull. Fish. Res. Bd. Canada No. 155. 485 pp.

Lloyd, M. and R. J. Ghelardi. 1964. A table for calculating the equitability component of species diversity. J. Anim. Eco. 33:217-225.

Lloyd, M., J. H. Zar, and J. R. Karr. 1968. On the calculation of information-theoretical measures of diversity. Am. Midl. Nat. 79:257-272.

MacArthur, R. H. 1957. On the relative abundance of bird species. Proc. Natn. Acad. Sci. U. S. A. 43:293-295.

Margalef, R. 1968. Perspectives in ecological theory. The University of Chicago Press. Chicago. 111 pp.

Marshall, N. B. 1967. The organization of deep-sea fishes. Stud. Trop. Oceanogr, Miami. 5:473-479.

Mead, G. W. 1970. A history of South Pacific fishes In Scientific exploration of the South Pacific, W. S. Wooster (ed.), Natl. Acad. Sci., Washington, D. C., 257 pp.

Mead, G. W., E. Bertelsen, and D. M. Cohen. 1964. Reproduction among deep-sea fishes. Deep Sea Research. 11:569-596.

Musick, J. A. 1969. The comparative biology of two American Atlantic hakes, Urophycis chuss and U. tenuis (Pisces, Gadidae). Ph.D. dissertation Harvard University, Cambridge. 150 pp.

Parr, A. E. 1932. Deep sea eels, exclusive of larval forms. Bull. Bingham Ocean. Coll. 3(5):1-41.

Parr, A. E. 1946. The Macrouridae of the western North Atlantic and Central American seas. Bull. Bing. Oceanogr. Coll. 10(1):1-99.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13:131-144.

Powles, P. M. and A. C. Kohler. 1970. Depth distributions of various stages of witch flounder (Glyptocephalus cynoglossus) off Nova Scotia and in the Gulf of St. Lawrence. J. Fish. Res. Bd. Canada. 27:2053-2062.

Pratt, R. M. 1968. Atlantic continental shelf and slope of the United States-Physiography and sediments of the deep-sea basin. U. S. Geol. Survey Prof. Paper 529-B, 44 pp.

Robins, C. H. 1968. The comparative osteology and ecology of the synaphobranchid eels of the Straits of Florida. Ph.D. dissertation, University of Miami, Coral Gables. 149 pp.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay III. The structure of the soft-bottom community. Limnol. Ocean. 5(2):138-153.

Sanders, H. L. 1968. Marine benthic diversity: a comparative study. Am. Nat., 102(925):243-282.

Schroeder, W. C. 1955. Report on the results of exploratory otter-trawling along the continental shelf and slope between Nova Scotia and Virginia during the summers of 1952 and 1953. Papers Mar. Biol. and Ocean. Deep Sea. Res., suppl. to Vol. 3:358-372.

Stanley, D. J. 1969. Atlantic continental shelf and slope of the United States-Color of marine sediments. U. S. Geol. Survey Prof. Paper 529-D, 15 pp.

Svetovidov, A. N. 1962. Gadiformes in "Fauna of the U. S. S. R. Fishes", Vol. IX, No. 4, 304 pp. (translation by Israel Program for Scientific Translations).

Templeman, W. 1963. Distribution of sharks in the Canadian Atlantic (with specieal reference to Newfoundland waters. Bull. Fish. Res. Bd. Canada, No. 140, 77 pp.

Uchupi, E. 1968. Atlantic continental shelf and slope of the United States-Physiography. U. S. Geol. Survey Prof. Paper 529-C, 30 pp.

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