

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*

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Summary—No large fish populations were found comparable to those present on our known fishing banks.

The area designated as A, from Long. 63° 17' to Long. 65° 59' W, yielded considerably more fish both in number and pounds than did any of the areas from Long. 66° to Long. 74° 15' W. The 200–400 fathom depth zone, on the overall average, produced the best catches throughout all these areas.

A total of 75 species of bottom dwelling fishes were caught, most of them in numbers so small as to suggest that they are of little economic importance within this region.

Among the dominant species were (a) the redfish, *Sebastes marinus*, which was taken in promising numbers, and large in size, in depths of 220–370 fathoms between Long. 63° 50' and Long. 65° 27' W; (b) the long-finned hake, *Urophycis chesteri*, found chiefly between 200–450 fathoms throughout all the areas fished; (c) the offshore hake, *Merluccius albidus*, taken west of Long. 66° and chiefly in 100–350 fathoms and (d) the grenadier, *Coryphaenoides rupestris*, present in greatest abundance east of Long. 66° and in depths of 300–500 fathoms.

Lobsters were caught in relatively large numbers off southern New England between 70–150 fathoms and as deep as 260 fathoms. A deep water lobster fishery in this region has ensued as a result of the discovery of these grounds.

The red crab, *Geryon quinquidens*, was found to be distributed throughout the range of our exploratory trawling in depths beyond 150–200 fathoms and in quantities that might prove sufficient to support a new fishery for this species which up to the present has been unexploited.

Bottom temperatures in 200–730 fathoms, throughout the region explored, varied but little either up and down the slope or from east to west, indicating a stability in this respect so far as concerns the bottom- and near bottom-dwelling marine life.

INTRODUCTION †

IN THE early 1880's the U.S. Fish Commission Str. *Fish Hawk* made a number of cruises to explore the bottom fauna along the southern New England coast, particularly in depths beyond 50 fathoms. Up until that time very little was known of the bottom dwellers of the outer shelf and the middle and upper slope of this region. However, the *Fish Hawk*, using a beam trawl, made about 100 successful hauls in depths ranging down to about 600 fathoms along a belt some 5 to 15 miles wide and extending about 150 miles from east of Nantucket to the offing of eastern Long Island. Here a rich fish and invertebrate fauna was found including many rare and previously

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† This Introduction is somewhat repetitious to that given in "Deep water elasmobranchs and chimaeroids from the northwestern Atlantic Slope" (BIGELOW and SCHROEDER, 1954, pp. 38–39.

unknown species. In this same period a number of bottom hauls were made still deeper along the slope, beyond 800 fathoms, by the *Blake* and the *Albatross*. It was just before these cruises, in 1879, that the tilefish had been discovered within this region. But, although various published reports appeared subsequently dealing with these catches, no organized deep water exploratory fishing was done along our northeastern Atlantic coast during the following seventy years, except a few stations made by the *Albatross* at widely separated times up until 1920.

The Woods Hole Oceanographic Institution vessel *Caryn*, in 1948 and 1949, made a few short cruises along the slope off southern Nova Scotia and New England and, for the first time, an otter trawl was used here in depths as great as 460 fathoms, all the earlier fishing having been done with relatively small Blake trawls and beam trawls, both of which were attached to rigid frames. The *Caryn*, although not well adapted to this type of fishing, made a total of 20 successful otter trawl hauls between 100 and 460 fathoms, the deepest haul being limited by the capacity of the winch. Many interesting specimens of fish and invertebrates were taken.

It now seemed timely to explore more fully the outer part of the shelf and upper slope, not only to seek rare or little known species and to learn something about them ecologically, but to determine whether or not any fish or invertebrates were to be found there in quantities and of a sort that might be of interest to the commercial fishery; in other words, to locate new fishing grounds. Accordingly, *Cap'n Bill II*, an 83 ft. dragger built in 1952 in Thomaston, Maine, owned and captained by HENRY W. KLIMM, Jr., was chartered by the Woods Hole Oceanographic Institution for three cruises in June–July 1952 and three cruises in June–July 1953.

Up to the present time most of the bottom trawling done by the commercial fishing fleet along the Atlantic coast has been in less than 125 fathoms, although the redfish vessels have recently been operating near the southern part of the Grand Bank in depths approaching 200 fathoms. Beyond this extreme, most of the boats are not equipped to fish much deeper with otter trawls, being limited by the amount of wire that can be wound on the winches which they now carry. In the commercial fishery two wires, or warps, usually $\frac{3}{4}$ or $\frac{15}{16}$ inches in diameter, are used in fishing the trawls which are upwards of 100 feet wide at the mouth with otter boards each weighing from 700 to 2000 pounds or more. In our experimental fishing we used a single wire of $\frac{3}{8}$ inches with a 20-fathom bridle of $\frac{5}{16}$ inches reaching to the otter boards. In making our earlier hauls various types of boards were used, but during most of 1952 and all of 1953 a standardized type was employed, each board having a weight of 160 pounds. The trawls measured, respectively, 35, 50, and 60 feet at the foot rope, and about 18 per cent less at the head rope, with body and wings of 3 inch, 15 thread stretched mesh, and the cod end of $1\frac{1}{2}$ inch, 24 thread. Double $\frac{3}{16}$ inch galvanized chain was attached to the foot rope, and floats in varying number, to the head rope. Glass floats proved the most satisfactory for withstanding the great pressures beyond 300 fathoms, although some of them became partially filled with water and had to be replaced. Aluminium floats of the sort we used, were the least effective as most of them imploded beyond 200 fathoms.

The duration of the tows varied from one-half to one hour depending on depth, roughness of the bottom, and weather conditions. Fishing was done chiefly during daylight hours, but in some instances extended into late evening. In cases where long runs from one area to another were necessary, these were made at night without

loss of fishing time. The towing speed averaged about $2\frac{1}{2}$ knots. Bottom temperatures, recorded by a maximum-minimum thermometer, were obtained in 1953.

Six cruises were made, as follows:

Cruise No. 1: June 20 to June 27, 1952, from Hudson Canyon to the offing of Nantucket (Long. $72^{\circ} 05'$ to Long. $69^{\circ} 37'$ W); 50 hauls in depths ranging from 105 to 500 fathoms. Mr. JAMES BARKER accompanied me.

Cruise No. 2: July 10 to July 17, 1952, from the offing of Nantucket to the offing of Georges Bank (Long. $69^{\circ} 37'$ to Long. $67^{\circ} 45'$ W); 35 hauls in depths ranging from 75 to 530 fathoms. Dr. BENJAMIN LEAVITT accompanied me, as well as Dr. P. SCHOLANDER and DR. L. VAN DAM who took gas and blood samples of various species of fish to supplement their data for shoaler water.

Cruise No. 3: July 23 to July 30, 1952, from the offing of Georges Bank to the offing of southeastern Nova Scotia (Long. $66^{\circ} 55'$ to Long. $63^{\circ} 17'$ W); 32 hauls in depths ranging from 67 to 540 fathoms. Dr. RICHARD H. BACKUS assisted me, and Drs. SCHOLANDER and VAN DAM continued their work on gas and blood samples.

Cruise No. 4: June 25 to July 1, 1953, from the offing of Cape Charles, Virginia to Hudson Canyon (Long. $74^{\circ} 15'$ to Long. $72^{\circ} 04'$ W); 45 hauls in depths ranging from 63 to 720 fathoms. Dr. BENJAMIN LEAVITT participated in this cruise, and Drs. SCHOLANDER and VAN DAM continued their gas and blood studies.

Cruise No. 5: July 10 to July 17, 1953, from the offings of Georges Bank to southeastern Nova Scotia (Long. $65^{\circ} 27'$ to Long. $63^{\circ} 47'$ W); 31 hauls in depths ranging from 68 to 705 fathoms. Mr. ROBERT WOLF of U.S. Fish and Wildlife Service assisted me, while Drs. SCHOLANDER and VAN DAM continued their observations.

Cruise No. 6: July 23 to July 30, 1953, from the offings of Nantucket to Georges Bank (Long. $70^{\circ} 43'$ to Long. $66^{\circ} 39'$ W); 34 hauls in depths ranging from 70 to 730 fathoms. Mr. JAN HAHN accompanied me and made a photographic record of the trip.

Table I

A list of the total hauls, 32 of them by the Caryn and 227 by the Cap'n Bill II, arranged by depths

<i>Fathoms</i>	<i>Number of Hauls: Successful</i>	<i>Number of Hauls: Not Successful</i>
0-50	0	1
51-100	20	2
101-150	18	2
151-200	16	10
201-250	22	5
251-300	18	8
301-350	22	4
351-400	15	8
401-450	21	11
451-500	21	5
501-550	8	2
551-600	4	2
601-650	4	4
651-700	2	0
701-730	2	1
830-890	0	1
Total	193	66

In most cases the trawl fished bottom without apparent mishap, but there were occasions when a haul obviously was not successful for one reason or another, as is to be expected when fishing an unexplored area and in depths where technical difficulties are multiplied. Catch statistics of unsuccessful bottom hauls were segregated from those hauls considered representative.

The causes for the 66 unsuccessful or otherwise unrepresentative hauls were: trawl did not fish bottom at all or for only a small part of the haul (22); net tore so that all or part of the catch was lost (13); drawstring opened before catch was landed (1); net lost (9); gear twisted (13); aluminium floats all imploded (1); fathometer not operating (2); trawling wire snapped (2); cause unknown (3). Catch records of these hauls are not included in this report.

RESULTS

A total of 75 species of fishes that might be classed as dwelling part or all of the time on bottom, or close to it, were caught in the two years combined, of which 7 species were taken in 1952 only and 13 in 1953 only. These figures are subject to slight revision after a number of final indentifications have been established. In addition, some 30–40 species of bathypelagic fishes were captured while the trawl was being payed out and/or hauled in and when an off-bottom haul was made. These species have not yet been critically studied. Accounts of the sharks, skates and chimaeras taken deeper than 200 fathoms have already been published (BIGELOW, SCHROEDER and SPRINGER, 1953; BIGELOW and SCHROEDER, 1954) as well as a paper dealing with two fishes of especial interest, the offshore hake *Merluccius albidus* and the blue whiting *Gadus (Micromesistius) poutassou* (BIGELOW and SCHROEDER, 1955). Also, certain data concerning various fishes taken on these Atlantic slope cruises are included in recently published *Fishes of the Gulf of Maine* (BIGELOW and SCHROEDER, 1953).

Much the greater number of the bottom-dwelling species that were taken deeper than 200 fathoms are at present of little commercial importance, either because of their relative scarcity in deep water or because they have not yet been accepted as food fishes. In fact, only the redfish (*Sebastes marinus*) was found in numbers sufficient to give some promise of supporting a profitable fishery. Others taken that might prove of some value to the fisheries include the gray sole (*Glyptocephalus cynoglossus*), the long-finned hake (*Urophycis chesteri*) and the whittings (*Merluccius bilinearis* and *M. albidus*).

New and prolific lobster grounds were discovered and considerable information was obtained on the distribution and abundance of the deep water red crab (*Geryon quinquidens*), a species that may prove to form the basis of a new crab fishery.

As the area fished, although only about 5 to 20 miles wide, extended some 600 miles from the offing of Nova Scotia to that of Cape Charles, Virginia, it is expedient that it be divided into sectors, as follows: area A—Long. 63° 17' to 65° 59' W, from the offing of southeastern Nova Scotia to the eastern slope of Georges Bank; area B—Long. 66° 00' to 69° 59' W, from the eastern slope of Georges Bank to the offing of Nantucket; area C—Long. 70° 00' to 71° 59' W, from the offing of Nantucket to Hudson Canyon; and area D—Long. 72° 00' to 74° 15' from Hudson Canyon to the offing of Cape Charles, Virginia. The most northerly latitude fished was 42° 48', and the most southerly, 37° 38' (see Fig. 1).

Table II

A list of the fish species taken by the Caryn and the Cap'n Bill II arranged by areas, depths, hauls, and aggregate catches, in which 50 hauls were made in area A, 56 hauls in area B, 49 hauls in area C, and 38 hauls in area D

Species	Fathoms		Caught in		Number of fish: Aggregate catch		
	— 200	+ 200	1-10 Hauls	11+ Hauls	1-10	11-100	101+
<i>Myxine glutinosa</i>	D		X		X		
<i>Petromyzon marinus</i>		A	X		X		
<i>Scyliorhinus retifer</i>	B-C-D		X			X	
<i>Apristurus profundorum</i>		A-B-C-D		X		X	
<i>Mustelus canis</i>	D		X		X		
<i>Centroscymnus coelolepis</i>		B-C-D	X		X		
<i>Centroscyllium fabricii</i>		A-B-C-D		X			X
<i>Etmopterus princeps</i>		A-B-C		X		X	
<i>Raja bathyphila</i>		B	X		X		
<i>erinacea</i>	B		X		X		
<i>fyllae</i>		A-B		X		X	
<i>garmani</i>	B-C-D			X		X	
<i>jensenii</i>		A D	X		X		
<i>laevis</i>	C	A-B-C	X		X		
<i>mollis</i>		A	X		X		
<i>ocellata</i>	B		X		X		
<i>radiata</i>	B-C	A-B-C-D		X		X	
<i>sentia</i>	B-C-D	A-B-C-D		X		X	
<i>spinicauda</i>		A-B	X		X		
<i>Harriotta raleighana</i>		A-B-C-D		X		X	
<i>Rhinochimaera atlantica</i>		A-B D	X		X		
<i>Argentina silus</i>		A		X		X	
<i>striata</i>	A-B-C-D		X			X	
<i>Notacanthus phasganorus</i>		A C	X		X		
<i>Polyacanthonotus rostratus</i>		A	X		X		
<i>Simenichelys parasiticus</i>		A-B-C-D		X		X	
<i>Conger oceanica</i>	D		X		X		
<i>Synaphobranchus pinnatus</i>		A-B-C-D		X			X
<i>Chlorophthalmus</i>							
<i>chalybeius</i>	B-C-D	B-C-D		X			X
<i>truculentus</i>	B-C		X		X		
<i>Merluccius bilinearis</i>	A-B-C-D	A-B-C		X			X
<i>albidus</i>	B-C-D	B-C-D		X			X
<i>Gaidropsarus ensis</i>		A	X		X		
<i>Enchelyopus cimbrius</i>	C		X		X		
<i>Pollachius virens</i>	A		X		X		
<i>Melanogrammus</i>							
<i>aeglefinis</i>	A-B D		X				X
<i>Antimora rostrata</i>		A-B-C-D		X			X
<i>Urophycis regius</i>	B-C-D			X			X
<i>tenuis</i>	B-C-D	A-B-C-D		X			X
<i>chuss</i>	A-B-C-D			X			X
<i>chesteri</i>	B-C-D	A-B-C-D		X			X
<i>Laemonema barbatulum</i>		D	X		X		
<i>Brosme brosme</i>		A	X		X		
<i>Gadus (Micromesistius)</i>							
<i>poutassou</i>		A-B	X		X		
<i>Macrourus bairdii</i>	B-C-D	A-B-C-D		X			X
<i>berglax</i>		A-B		X		X	
<i>Coelorhynchus carminatus</i>	B-C-D	B-C-D		X			X
<i>Coryphaenoides rupestris</i>		A-B-C-D		X			X
<i>Citharichthys arctifrons</i>	B-C-D			X			X
<i>Monolene sessilecaudata</i>	C-D		X			X	
<i>Reinhardtius hippoglossoides</i>		A-B		X		X	
<i>Hippoglossus hippoglossus</i>		A	X		X		

Table II (continued)

Species	Fathoms		Caught in		No. of fish Aggregate catch		
	— 200	200	1-10	11+ Hauls	1-10	11-100	101+
<i>Hippoglossoides platessoides</i>	A	A	X		X		
<i>Paralichthys oblongus</i>	B-C-D	B		X			X
<i>Glyptocephalus cynoglossus</i>	B-C-D	A-B-C-D		X			X
<i>Zenopsis ocellatus</i>	D		X		X		
<i>Polymyxia nobilis</i>	C-D		X			X	
<i>Poronotus triacanthus</i>	B-C-D		X			X	
<i>Lopholatilus chamaeleonticeps</i>	C		X		X		
<i>Sebastes marinus</i>	A	A-B-C		X			X
<i>Helicolenus dactylopterus</i>	B-C-D	B-C-D		X			X
<i>Myoxocephalus octodecemspinosus</i>	A		X		X		
<i>Cottuaculus microps</i>		A-B		X		X	
<i>thompsoni</i>		A-B-C-D		X		X	
<i>Paraliparis copei</i>		A-B	X			X	
<i>Peristedion miniatum</i>	B-C-D			X			X
<i>Tautoglabrus adspersus</i>	B		X		X		
<i>Macrozoarces americanus</i>	B		X		X		
<i>Lycodes esmarkii</i>		B	X		X		
<i>frigidus</i>		A-B-C	X		X		
<i>Lycenchelys paxillus</i>		A	X		X		
<i>Dicrolene intronigra</i>		B-C-D		X		X	
<i>Lepophidium cervinum</i>	C-D		X		X		
<i>Lophius americanus</i>	A-B-C-D	A-B-C-D		X		X	
<i>Dibranchius atlanticus</i>	B-C-D	A-B-C-D		X			X

Thus the 193 hauls yielded only 21 species of which the aggregate catch was greater than 100 individuals, 21 species which ranged from 11 to 100, and 33 species from 1 to 10.

It is not surprising that most of our commercial species, including haddock, pollock and various flounders, were not taken as deep as 200 fathoms, for their known depth range does not extend that far. On the other hand, the total absence of cod in our hauls, and the capture of only 1 cusk and of 1 halibut deeper than 200 fathoms, indicate that they are much too scarce along the northwestern Atlantic slope, within the scope of our exploratory trawling, ever to support or contribute materially to a fishery there. While cod are not taken in substantial numbers deeper than 200 fathoms, in fact about 125 fathoms marks the ordinary limit in our fishery, the cusk descends to 250-300 fathoms (though most plentiful considerably shoaler), and the halibut to 400-500. It is possible that a scarcity of preferential food and type of bottom may be chiefly responsible for this paucity of cusk and halibut along the slope. On the other hand, temperature, *per se*, does not seem to be a limiting factor; for the 38°-42° which exists throughout the year all along the route of our exploratory fishing, in 200-500 fathoms, is a favourable range for both these species.

While the shoaler water fishes (those which we caught above 200 fathoms and no deeper) are included in the preceding table, species other than those listed are known to be present in winter but not in summer within this depth range—notably the spiny dogfish (*Squalus acanthias*), the summer flounder (*Paralichthys dentatus*), the seup

(*Stenotomus versicolor*) and the sea robin (*Prionotus carolinus*), all of which I have seen taken in large numbers by commercial fishermen in mid-winter off southern New England, within the 50–100 fathom zone. On the other hand it is difficult to explain our capture of only one tilefish (*Lopholatilus*) for, while the population appears to be more scattered during the summer, it is a year around resident in about 60–150 fathoms, most abundantly between the offings of Nantucket and Delaware Bay where draggers, from late fall to spring, often take 10–20,000 pounds per trip. Certainly there is evidence here that some species may easily evade the small trawls such as were used in our exploratory fishing.

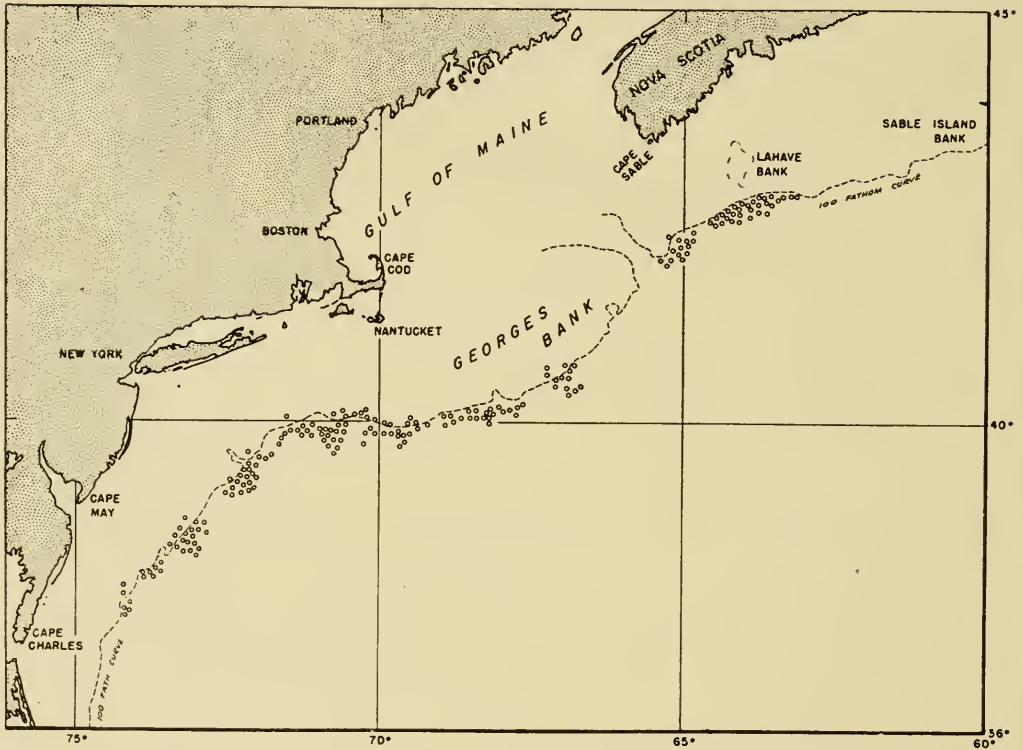


Fig. 1. Distribution of bottom otter-trawling stations along the shelf and slope made during June–July 1952 and 1953 by *Cap'n Bill II*.

In this connection it is of interest to note the difference in yield between our 50 foot and the 60 foot trawls in such cases where they could be reasonably compared for the same depth zone and area. Thus in 53 hauls of the 50 foot trawl, 16,618 fish of all sorts estimated to weigh about 9,500 pounds were caught, or an average of 314 fish and about 180 pounds per haul, while the catch in 33 hauls of the 60 foot trawl was 12,316 fish estimated to weigh about 11,500 pounds, or an average of 373 fish and about 350 pounds per haul. The larger trawl not only caught more fish by number (as might be expected) but also fish that averaged larger in size. Much the same result was obtained in the catch of crabs (*Geryon*), for in 31 hauls of the 50 foot trawl the average catch per haul was 32 crabs weighing about 40 pounds, while

in 21 hauls of the 60 foot trawl the average catch was 41 crabs weighing about 60 pounds, in areas and depths where the catches could be reasonably compared.

These data are presented to emphasize the importance of giving due consideration

Table III
Catch by depth zones and areas giving the total number of hauls and the average number and estimated weight of fish caught per haul of 1 hour, in depths greater than 100 fathoms

Fathoms	Area A		Area B		Area C		Area D		Average	
	Hauls	Pounds	Hauls	Pounds	Hauls	Pounds	Hauls	Pounds	Hauls	Pounds
101-200	(0)		(8)	216	(13)	371	(9)	386	(30)	333
201-300	(10)	1013	(9)	408	(9)	261	(5)	450	(33)	522
301-400	(16)	710	(2)	321	(5)	273	(5)	180	(28)	705
401-500	(9)	480	(2)	200	(0)		(4)	338	(15)	674
501-730	(6)	488	(3)	135	(2)	230	(8)	158	(19)	327
Average	(41)	933	(24)	285	(29)	311	(31)	300		153

to the type of gear used when interpreting results quantitatively and qualitatively. It is a matter for speculation as to what our catches would have been had larger trawls been employed.

In the preceding table the catches of all the fishes taken during 1952–1953, deeper than 100 fathoms (excluding bathypelagic species), are segregated by depths and areas and converted to a standard based on the 60 foot trawl dragged on bottom for 1 hour.

According to this summary the greatest number and poundage of fish, taken together, was found between 200 and 400 fathoms, and the species contributing most to this were the redfish (*Sebastes*) and a macrourid (*Coryphaenoides*) in area A, the offshore hake (*Merluccius albidus*) in areas B, C, D, and the long-finned hake (*Urophycis chesteri*) in areas A, B, C, D.

The upper hundred fathoms of the slope (100–200 fathoms) produced the smallest yield in pounds of fish per haul, while deeper than 400 fathoms the decline was apparent, and here a substantial part of the catch comprised the macrourids (*Macrourus bairdii* and *Coryphaenoides rupestris*), the long-finned hake, and the gray sole (*Glyptocephalus*). Along the outer part of the shelf, in 50–100 fathoms (not included in Table III) the 20 hauls made averaged only about 100 fish weighing 50 pounds.

A 60 foot trawl having a footrope about 50 ft. wide, fishing a swath estimated to be 30 ft. wide in a one-hour drag at 2½ knots, would traverse an area equal to about 10½ acres.

Table IV
Calculated catch of fish in pounds per acre

Fathoms	Area A	Area B	Area C	Area D	Average
	Pounds	Pounds	Pounds	Pounds	Pounds
101–200	(no hauls)	10.2	19.7	17.6	16
201–300	96.5	18.3	17.1	24.6	43
301–400	67.6	17.1	19.4	8.6	45
401–500	45.7	10.8	(no hauls)	14.3	33
501–730	46.5	10.0	15.7	9.0	22
Average*	67	14	18	15	

* Based on the total number of hauls as given in Table III.

Thus Table IV (which presents in another form part of the data in Table III) shows that area A, from Long. 63° 17' W to 65° 59' W, was considerably more productive in pounds of fish per acre than areas B, C, or D, from Long. 66° W to 74° 15', which were rather uniform in yield as compared one with the other.

These figures of yield per acre would be increased considerably by the use of a commercial-size otter trawl. And the amounts would have been substantially greater (regardless of trawl size) if our efforts had been directed chiefly in exploiting the most productive grounds rather than in exploring poor areas as well. From the

standpoint of the food-fish fishery the most promising region is in area A between 200 and 400 fathoms where *Sebastes* was dominant, and for the so called trash-fish fishery areas A to D in this same depth zone, together with areas C-D in 100-200 fathoms and area A in 400-730 fathoms.

So few records are available pertaining to the yield of fish per acre on the ocean bottom that it is of interest to note here data obtained during 1936 for a small area in the Gulf of Maine to the westward of Jeffrey's Ledge where, in 80-100 fathoms, using an 82 foot shrimp trawl calculated to fish a breadth of 52 ft., the catch of fish per acre worked out to about 47 pounds.*

There follows a further discussion of certain of the species listed in Table II (p. 362) arranged by groups.

ELASMOBRANCHS AND CHIMAEROIDS

The species comprising this group, caught deeper than 200 fathoms, have been discussed by BIGELOW and SCHROEDER (1954). Only the black dog-fish (*Centroscyllium fabricii*) was taken in relatively large numbers, chiefly in 300-550 fathoms within area A.

EELS

Of the several species of Apodes caught, the long-nosed eel *Synaphobranchus pinnatus* was the most plentiful, chiefly in area A between 450 and 500 fathoms, where the best 4 hauls averaged about 150 of this species. In areas B, C, and D, where it was found to be much less plentiful, the best catches likewise were made in the 450-500 fathom zone. The shoalest capture was in 220 fathoms, beyond which it was taken at all depths down to our deepest haul at 730 fathoms.

CODS AND HAKES

Both in numbers and poundage this group proved dominant in depths beyond 200 fathoms. Most plentiful is the long-finned hake *Urophycis chesteri*, taken in small numbers as shoal as 125 fathoms and as deep as 730 fathoms, with the best catches between 200 and 450 fathoms. For example, in area A 2 hauls averaged 676 hake in 200-250 fathoms, and 8 hauls averaged 360 hake in 250-300 fathoms; in area B the average of 3 hauls was 267 in 250-300 fathoms, in area C 6 hauls averaged 125 in 200-250 fathoms, and the best hauls in area D were 2 averaging 254 hake in 250-300 fathoms. The general run of fish ran 1-1½ pounds.

Moderate numbers of blue hake, *Antimora rostrata*, were taken in area A between 300-700 fathoms, the average catch per haul ranging from 14 to 29 individuals, while in areas B, C and D a scattering few were caught between 400-730 fathoms. In size the general run ranged from 10 to 14 inches, the extremes from 6 to 21¼ inches.

The red hake, *Urophycis chuss*, important chiefly in the inshore trash-fish fishery, and the white hake, *U. tenuis*, considered of more value as a food fish, were taken in scattering numbers throughout areas A to D, the former down to 200 fathoms and the latter to 550 fathoms.

An account of the first western Atlantic records of the blue whiting *Gadus (Micromesistius) poutassou* is given by BIGELOW and SCHROEDER (1955). One specimen was

* See BIGELOW and SCHROEDER (1939) p. 322, where the catch of shrimp and fish is given as 55 pounds per acre, of which the fish comprised about 85 per cent, or 47 pounds per acre

trawled on the seaward slope of Georges Bank, Lat. 40° 18' N, Long. 68° 01' W at 230–250 fathoms, July 15, 1952 and three others at 240–280 fathoms on the slope of Browns Bank between Lat. 42° 09' N Long. 65° 21' W and Lat. 42° 08' N, Long. 65° 27' W, July 16 1953. They ranged in standard length from 349 to 416 mm.

The offshore hake, *Merluccius albidus*, was next in importance, but none at all was taken in area A. In the other areas a scattering few were caught as shoal as 55–100 fathoms and deeper than 400 fathoms, but the best yields were as follows: area B, an average of 80 to 108 per 5 hauls between 200–350 fathoms; area C, 126 to 400 per 3 hauls between 150–350 fathoms; area D, 140–164 hake per 14 hauls in 100–300 fathoms. The majority of these hake ranged from 1 to 3 pounds, some as large as 4-4½ pounds.

The silver hake, *M. bilinearis*, an important shoal water commercial species, was not found to be an important factor off shore. The best catches were in area B, where in 100–300 fathoms an average of 70 to 125 fish was taken in 6 hauls.

GRENADIERS OR MACROURIDS

More pounds of *Coryphaenoides rupestris* were taken than of any other macrourid, chiefly because of its relatively large size (most of those taken ranged from 1 to 6 pounds) and its abundance within area A where, between 300–550 fathoms, the averages for 36 hauls ranged from 220 to 535 fish of this species. The shoalest capture was in the 200–250 fathom zone, and the deepest around 700 fathoms. To the westward, within areas B, C, and D, relatively few were taken, and these deeper than 350 fathoms, the best catch being an average of 70 fish in 2 hauls made in area D in 450–500 fathoms.

The common grenadier or rat-tail, *Macrourus bairdii*, was found to be very widespread in all depths from 150 fathoms to 730 (our deepest haul) throughout areas A to D. The better catches (between 300–700 fathoms) ran from about 75 to 150 fish per haul. But as this species averages only ¼–½ pound in weight, the poundage taken per haul was insignificant.

THE FLOUNDER TRIBE

The gray sole (*Glyptocephalus cynoglossus*) is the only flounder that was found to be widespread deeper than 200 fathoms. In fact, it was caught in a greater number of hauls than any other species of fish listed in Table II. On the other hand, although it was widespread, no large concentrations were found, and the general range in size was relatively small, only about ¼ to 1 pound, with but few reaching 2 pounds or more. This flounder was taken just about everywhere between 120 and 730 fathoms from areas A to D. Excluding the smallest catches, the results were: Area A, 200–550 fathoms, 23 to 96 fish per haul; area B, 250–600 fathoms, 17 to 45 fish per haul; area C, 150–730 fathoms, 18 to 120 fish per haul; area D, 150–730 fathoms, 12 to 114 fish per haul. The greatest number taken in a single haul was 218, area A, 350–400 fathoms.

It is of interest to note that the gray sole is one of the important food fishes in the northern Atlantic where, off our coast, the best catches are made between about 60 and 150 fathoms.

Only 1 halibut was caught during our exploratory fishing, this a 75 lb. fish taken in 340–360 fathoms in Lat. 42° 41' N, Long. 63° 58' W. The paucity of halibut along the slope is referred to on p. 363.

A few Greenland halibut (*Reinhardtius hippoglossoides*) were taken, 20 of them between Long. 63° 47' and 65° 10' (area A) and 1 at 67° 59' (area B), this latter being the most westerly known record. The depth range was 305-530 fathoms, the size from 13 to 36 inches long.

REDFISH OR OCEAN PERCH

Although the redfish occurs in great abundance in the North Atlantic, especially off New England, Nova Scotia and the Grand Banks, virtually all of our catch was taken within area A. A list follows of those hauls in which more than 100 redfish were caught:

Table V

Catches of Sebastes marinus taken between Long. 63° 17' and Long. 65° 59' W, converted to a 1 hour haul with a 60 ft. otter trawl, arranged by longitude

Station	Date	Lat.	Long.	Fathoms	Redfish Number	Bushels	Bottom* Temp. F.
164	July 12, 1953	42° 43'	63° 50'	310-335	210	6½	39.4
173	July 13, 1953	42° 40'	64° 10'	240-270	450	15	40.3
105	July 27, 1952	42° 41'	64° 13'	260-290	386	9½	
172	July 13, 1953	42° 36'	64° 15'	220-370	744	25	39.6
176	July 14, 1953	42° 33'	64° 17'	280-320	189	6½	40.1
184	July 15, 1953	42° 23'	64° 52'	265-295	728	28	40.1
188	July 15, 1953	42° 17'	65° 01'	270-340	720	24	39
109	July 28, 1952	42° 20'	65° 03'	305-320	510	17	
189	July 15, 1953	42° 18'	65° 05'	220-240	338	11½	40.5
191	July 16, 1953	42° 09'	65° 21'	240-280	1056	32	40
193	July 16, 1953	42° 08'	65° 27'	250-300	298	9	39

* As a maximum-minimum thermometer was used the temperatures given are presumed to be for the deepest part of a haul.

All of these fish ranged in length from 12 to 19 inches with a mean of about 15 to 16 inches, with the exception of one of 8½ inches. The count in most cases ran from 30 to 35 fish to the bushel. Thus the populations sampled proved to contain exclusively very large redfish and, according to present age studies, such fish were probably from 15 to 20 years old.

A ready explanation as to why virtually no small or medium redfish were taken in these hauls is not available at the present time. True, this area had never been fished before with otter trawls, so far as is known, and therefore being a virgin territory might be the answer, at least in part. And it is of interest to note that the Fisheries Research Board of Canada engaged in exploratory dragging for redfish in the Gulf of St. Lawrence during 1953 and 1954, and found areas in 100-175 fathoms where the dominant sizes of the fish likewise were very large, ranging from 35 to 40 cm. (14 to 16 inches).† On the other hand, the newly exploited redfish grounds in the Grand Banks region where trawlers have been operating as deep as 175 fathoms, and perhaps a little more, have from the beginning produced a substantial percentage of small to medium fish.

† MARTIN in *Fish. Res. Bd., Canada, Rept. Atlantic Biol. Sta. for 1953* (1954), pp. 61-64, and STEELE and MARTIN in *Fish. Res. Bd., Canada, Rept. Atlantic Biol. Sta. for 1954* (1955), pp. 63-65.

No hauls were made in 100–200 fathoms in area A, but it appears certain that redfish occur there along the upper slope, perhaps in somewhat the same abundance as they are at present found on the slope of the Grand Banks. But it is not likely that any large bodies of fish are to be found deeper than about 370 fathoms in area A (Long. 63° 17' to Long. 65° 59' W), for only 11 were caught in 27 hauls made there in 400–700 fathoms, the deepest catch being at about 425.

While our best catches of redfish were taken within the narrow temperature range of 39°–40.5° F, they are known to occur in more or less abundance between about 36° and 48°, with the 38°–42° temperature zone probably the most favourable for it.* But factors other than temperature influence the presence and abundance of redfish, of which type of bottom and an adequate supply of preferred food (chiefly euphausiids, shrimps, small mollusks and various other invertebrates) must play an important part, as only a scattering few were taken by us in the many hauls made along the slope to the westward of Long. 66° in temperatures of 38°–42°.†

The black-bellied rosefish (*Helicolenus dactylopterus*), a close relative of the redfish, was taken in small numbers in areas B, C, D, between 70 and 300 fathoms, the best catches being in 150–200 fathoms with averages per haul as follows: area B, 66 fish in 3 hauls; area C, 160 fish in 8 hauls, and area D, 87 fish in 2 hauls. The usual size was 6–8 inches in length, the extreme range 3–13 inches.

MISCELLANEOUS SPECIES

Of the remaining species listed in Table II, and not otherwise mentioned, there follows the depth ranges of those which were captured beyond 200 fathoms in this survey, the deepest haul made being in 730 fathoms.

Table VI
Depth range of fish not otherwise mentioned

Species	Range in Fathoms
<i>Petromyzon marinus</i>	220–470
<i>Argentina silus</i>	200–380
<i>Notacanthus phasganorus</i>	270–570
<i>Polyacanthonotus rostratus</i>	220–370
<i>Simenchelys parasiticus</i>	250–730
<i>Chlorophthalmus chalybeius</i>	50–250
<i>Gaidropsarus ensis</i>	415–545
<i>Antimora rostrata</i>	300–730
<i>Laemonema barbatula</i>	275–650
<i>Macrourus berglax</i>	250–530
<i>Coelorhynchus carminatus</i>	100–460
<i>Hippoglossoides platessoides</i>	265–295
<i>Paralichthys oblongus</i>	50–235
<i>Cottunculus microps</i>	200–500
<i>Cottunculus thompsoni</i>	250–700
<i>Lycodes esmarkii</i>	400–430
<i>Lycodes frigidus</i>	350–520
<i>Lycenchelys paxillus</i>	250–480
<i>Dicrolene intronigra</i>	450–730
<i>Lophius americanus</i>	50–450
<i>Dibranchius atlanticus</i>	150–500

* For a more detailed account see BIGELOW and SCHROEDER 1953, p. 432.

† See STEELE and MARTIN (1955), who trawled large redfish in the Gaspé region in 39.4°–40.9°, and who point out that the presence and abundance of the euphausiid *Meganctiphanes norvegica* appeared to be an important factor determining the distribution and movements of redfish.

It is probable that some of the *Argentina* and *Chlorophthalmus* were taken well off bottom. Most of the species listed above are known from depths beyond those given here. None were taken in large numbers.

LOBSTERS AND RED CRABS

It is planned to present in a separate paper, an account of the lobsters (*Homarus americanus*) and red crabs (*Geryon quinquidens*) taken during this exploratory fishing. It can be said here that lobsters were found in quantities sufficient to support at least a limited amount of commercial fishing in depths of from about 70 to 150 fathoms where we trawled up to 4 bushels or more in a 1 hour drag between Long. 69° 30' and Long. 71°. Catches also were made as deep as 260 fathoms and as far westward and southward as fishing was done (Lat. 37° 38' N, Long. 74° 15' W.)

It has long been known that lobsters, especially very large ones, occur off shore between the offings of Nova Scotia and North Carolina, and in the last few years otter trawlers have been bringing in fair catches from off the coast of New Jersey. But since releasing information concerning their whereabouts and relative abundance off the New England coast, based on our recent investigations, a number of boats have been operating successfully with catches reported as high as 8,000 pounds landed from a 5- or 6-day trip. All sizes of lobsters are present in this offshore area from about 5 inches in total length to those weighing 20 pounds or more. While the average size has been considerably larger than that taken inshore by the trap fishery, in which the size of the trap opening excludes large lobsters, nevertheless a good proportion of very small ones is present also. There is an indication from this that the offshore population, rather than being composed chiefly of large and very old individuals that may have gradually worked into deeper water, is in fact made up substantially of all ages. It would seem therefore that the offshore stock is not too dependent on emigrants from inshore but rather that much of this population owes its existence to lobsters being carried there during their planktonic existence.

The red crabs were found throughout the areas fished, but while they were taken in the deepest hauls their shoalest range was quite sharply defined. Thus in area A they first appeared at about 250 fathoms, in areas B and C at about 200 fathoms, and in area D at about 150 fathoms. The best average catches per 1 hour drag were as follows: area A, 23 to 115 crabs in 300-550 fathoms; area B, 30 to 79 in 200-400 fathoms; area C, 29 to 80 in 200-550 fathoms, and area D, 65 to 203 crabs in 150-450 fathoms. They were well distributed, for catches were made in almost every haul made within these depths.

In size the great majority of the red crabs ranged from 1 to 2 pounds and, as they have proven very good to eat, there is a possibility that a fishery for them may develop.

BOTTOM TEMPERATURES

On the three cruises made in 1953, from June 25 to July 30, temperatures were obtained for most of the hauls with a maximum-minimum thermometer which was attached to an otter board. It may be presumed that these minimum temperatures, in most cases at least, were those prevailing at or very close to the bottom.

It must be admitted that the instruments used were not of a quality or calibration comparable to the precision of the best deep-sea reversing thermometers. However, from time to time the latter were used as a check on the former, and differences in

Table VII

The average temperatures in °F for various depths in the four sub-areas with the number of stations or hauls shown in parentheses

Fathoms	Area A 63° 17'–65° 59'	Area B 66° 00'–69° 59'	Area C 70° 00'–71° 59'	Area D 72° 00'–74° 15'
101–125		(1) 53	(2) 50.8	(2) 47.8
126–150		(1) 45		(4) 46.8
151–200	(3) 42.7		(1) 46	(2) 46
201–250	(1) 40.5	(3) 41.3	(1) 42	(1) 42.4
251–300	(7) 40	(1) 40.5		(3) 40.6
301–350	(5) 39.1	(1) 40		(2) 40.1
351–400	(3) 39.6	(1) 40	(1) 39	(4) 39.7
401–450	(2) 39.6	(2) 38.5		(3) 39
451–500	(3) 39.1	(3) 39		(2) 39.2
501–550	(2) 39.7			(3) 39
551–600		(1) 38	(1) 39.6	(2) 38.8
601–650	(2) 39.7	(2) 39.7		(3) 38.7
651–700				(2) 38.9
701–730	(1) 38	(1) 39	(1) 38.5	(2) 38.8

temperature between the two were seldom greater than 0.5°. It is of interest to note, also, that the results listed above agree very closely with those obtained in the same region, in summer, by the *Blake*, *Fish Hawk* and *Albatross* in the 1880's.

As we are concerned here chiefly with conditions along the Atlantic slope, within the region explored, as it pertains to the bottom-dwelling fishes and other marine life, it seems evident that the temperatures at or near bottom, between 200 and 730 fathoms at least, are very uniform. And while this applies to June–July, the few readings obtained by the *Albatross* in February–March 1920 between Long. 64° and 68° W in 200–700 fathoms are in close agreement.

So far as the role of temperature, *per se*, is concerned with the presence and abundance of these fishes living beyond 200 fathoms, conditions appear to be very stable, and it would not be surprising if the results thus far obtained, with due consideration to the type and efficiency of the gear employed, would be found to be approximately the same for any season or year. Only further exploratory work can reveal whether or not this is so.

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