

**BULLETIN No. 120**

# **Redfish distribution in the North Atlantic**

**BY**

**WILFRED TEMPLEMAN**

*Fisheries Research Board of Canada  
Biological Station, St. John's, Nfld.*

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BOARD OF CANADA UNDER THE CONTROL OF  
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W. E. RICKER  
N. M. CARTER  
*Editors*

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## ABSTRACT

The distribution of *Sebastes marinus* and to a much lesser degree that of *Sebastes viviparus* are described. Although *Sebastes marinus* may be divided into *Sebastes marinus marinus*, the ordinary redfish, and *Sebastes marinus mentella*, the deep-water redfish, these two subspecies have not, as a rule, been differentiated in the available statistical and other data. Therefore, with regard to most of the information, it is possible to consider only the distribution of *Sebastes marinus* including both subspecies. The name redfish in this abstract refers to *Sebastes marinus*.

*Sebastes viviparus* is well differentiated from *S. marinus* by the greater number of scale rows in the latter. *S. marinus mentella* has a sharply projecting beak on the lower jaw and a large eye whereas in *S. marinus marinus* this beak is absent, or present as a rounded protuberance, and the eye is relatively small.

In *S. viviparus* the most anterior preopercular spine is directed backward. In *S. marinus marinus* of the Newfoundland area it is usually directed downward or obliquely downward and backward. In *S. marinus mentella* of the Newfoundland area this anterior preopercular spine is usually directed obliquely downward and forward.

Redfish larvae and young have been found abundantly in the Norwegian Sea, west and south of Iceland (including a great oceanic area south of Iceland and extending almost to Flemish Cap), in southern Greenland waters, and in the Newfoundland, Grand Bank, Gulf of St. Lawrence, Nova Scotian and Gulf of Maine areas. Larval redfish tend to be most numerous above the deeper water bank and channel contours where adult redfish are abundant; they have a pelagic life of at least several months in the upper water layers. Although in northern Greenland waters young redfish up to 45 to 50 mm are numerous in these upper water layers, in the region from Newfoundland to the Gulf of Maine, redfish of 30 mm and over are not commonly caught near the surface in plankton nets but rather in bottom trawls. Some redfish of these sizes have recently been captured, however, in mid-water in the Gulf of Maine by means of a mid-water trawl.

The redfish fishery in the ICNAF area, which began as a special fishery in the Gulf of Maine in 1935, is now carried out in all ICNAF subareas. The greatest catch was 159,000 metric tons in 1957. In the latter year the United States catch was 61,000 metric tons; followed by the USSR, 49,000; Canada, 21,000; Germany, 15,000; and Iceland, 13,000. Almost half the catch was obtained in Subarea 3 of ICNAF (the Newfoundland subarea). The total redfish catch by the European countries of the International Council for the Exploration of the Sea (ICES) and the USSR increased gradually (with some downward variations during wars) from 1,000 metric tons in 1907 to 294,000 in 1955, falling again to 251,000 in 1956. As a rule, before 1955 over half of the catch came from the Icelandic grounds with, until 1954, the Barents Sea, Bear Island and Spitsbergen area usually next in importance. In 1954 the redfish catch in Greenland increased beyond that in the Barents Sea, Bear Island and Spitsbergen area, and in 1955 the catch from Greenland was slightly greater than that from the Icelandic area. In 1956 landings from the Greenland area again fell considerably below those from the Icelandic area. In 1956, 50% of the redfish was caught by Germany, 27% by Iceland and 17% by the USSR. The redfish catch in the West Greenland Subarea (1) of ICNAF amounted to 14,000, 16,000, 32,000 and 14,000 metric tons in the years from 1953 to 1956, respectively, and less than 1,000 in earlier years, and is included both with the ICNAF and the ICES catches; otherwise the ICES and USSR catches up to and including 1955 were from east of the ICNAF area. In 1956 the ICES landings include 13,000 metric tons taken in the Newfoundland subarea almost entirely by the USSR.

Explorations by the research vessel *Investigator II* of the Fisheries Research Board of Canada's Station at St. John's from 1947 to 1954, and the commercial fishing largely resulting

from these otter-trawling explorations, have shown redfish in the various deep channels of the Gulf of St. Lawrence and in deep water around the fringes of the banks in the Newfoundland and Labrador area, as far northward as off the northern tip of Labrador. Commercial fishing possibilities exist at least as far north as east of Hamilton Inlet Bank and as far east as Flemish Cap.

*Sebastes viviparus* lives in considerably shallower water than *Sebastes marinus*. It occurs in numbers from the Finmark coast of Norway southward along the Norwegian coast, in the northern North Sea, off Scotland, Ireland, northern England, the Faroes, and south and west of Iceland.

*Sebastes marinus* is common in the Barents Sea to Spitsbergen, along the Norwegian coast to the Faroes, Iceland, southern Greenland, Labrador, Flemish Cap, the Grand Bank, the Gulf of St. Lawrence, and southward to the Gulf of Maine. Individual captures are reported to the northeast off West Spitsbergen at Lat. 80°06' N and Long. 11°17' E, off West Greenland north to Umanak Fjord in about Lat. 71° N, and the most southerly record along the American continent is at Lat. 39°48'10" N, and Long. 71°48'40" W.

*Sebastes marinus mentella* is distributed in the deep water from south of Bear Island to West Greenland. It is the common form throughout the Labrador, Newfoundland and probably the whole North American area. *Sebastes marinus marinus* is abundant in the shallower parts of the deep-water area from the Barents Sea and the Bear Island grounds to West Greenland. It is moderately abundant in limited portions only of the Newfoundland-Labrador area, but here also it occurs in shallower water than the deep-water *mentella* form. Bottom temperatures and depths suited to the *mentella* form are continuous over the whole redfish range from Georges Bank to the most northeasterly part of its distribution off the Russian coast. The bottom connection between West Greenland and Baffin Island and also the bottom areas in some of the channels to the east are suited in depth only to the *mentella* form. Populations of the *marinus* form may be connected only pelagically, across these channels.

The *marinus* type and probably also *mentella* are plentiful off West Greenland, and both are abundant off East Greenland. On the basis of the available imperfect data, although *mentella* is present, *marinus* is the common form on the Norwegian grounds and in the Barents Sea. *Marinus* is present in the shallower and *mentella* in the deeper water near Iceland, whereas *mentella* is the common form on the Iceland-Faroes Ridge and on the Bear Island deep-water grounds. It must be remembered, for the European area, that *marinus* lives shallower, is larger and is more favoured in the market, and thus when in equal or in slightly lesser abundance will usually be fished for instead of *mentella*. Most of the redfish landed in Iceland and Europe, at least until recent years, have been of the *marinus* type.

The pelagic existence of numerous redfish, over water much too deep for them to descend to the bottom, has been demonstrated for the Norwegian Sea. The presence of great quantities of redfish larvae over a wide area south of Iceland, in the absence of another explanation, makes it plausible to believe that a large pelagic population of redfish may be present in this area, but this belief cannot in any way be regarded as proven. In the area from west of the tail of the Grand Bank southward to Cape Cod, there are no extensive areas, at suitable redfish depths seaward of the bank slopes, with temperatures suitably low for redfish. It is thus extremely unlikely that large pelagic populations of redfish exist seaward of the bank slopes in the southern part of the Northwest Atlantic.

In comparisons of redfish catches by Newfoundland otter-trawlers over the 24-hour period, sets carried out more than an hour before sunrise or after sunset usually had negligible redfish catches compared with the daylight period. However, in some deep-water areas where redfish were abundant, night sets, although considerably smaller than daylight sets, were large enough to make night fishing worth while. Although more data are desirable, there was a tendency in the 50 to 75 fathom depths, and in the May to July catches at most depths, to have morning and afternoon peaks in the catch. Between 76 and 160 fathoms the morning catches were usually greater than the afternoon catches. In the darkest months, November to January, the largest catches in the deeper water were in the late morning or at noon. In the deepest

water, 161 to 190 fathoms, the highest catches were from late morning to the earlier part of the afternoon. Good catches extended over a longer part of the day in the brightest months with the longest period of daylight, May to July.

In the Newfoundland redfish catches from January to April mature females were much less abundant than large males. In May and June mature females were scarce at the shallower depths but plentiful in greater depths. In July and August and in November and December females were more numerous than males. During September and October mature females were scarce at intermediate depths. Corresponding to the lack of availability of mature females, the catch of redfish per hour's dragging was at a minimum in March. In Hermitage Bay, in catches between April and December, mature females were considerably fewer than large males. In April, in fish of mature size 30 cm and over, females formed only 9% of the catch.

European, Icelandic and Greenland commercial redfish are usually larger than those of North America. Redfish from the deep water off Labrador are also large. Close analysis is impossible since usually the *marinus* and *mentella* forms have not been separated in the length-frequencies, but differences in the size at sexual maturity and in temperature and other environmental factors in these areas, with resulting growth differences, are doubtless factors of importance in determining the limits of redfish size.

At depths between 51 and 210 fathoms in the various divisions of the Newfoundland area, greatest redfish catches were obtained in the 131 to 210 fathom range. Most large catches occurred at depths where average temperatures were between 3.4 and 5.0°C, but on the eastern slope of the Grand Bank the greatest catches were at a depth where the average temperature was 2.1°C. When catches at individual depths are considered the larger catches were usually between 1 and 5°C. The tendency to obtain large catches at these moderately low temperatures was particularly evident at the greater depths whereas at the lesser depths (51 to 90 fathoms) where redfish are smaller and fewer the best catch averages were at 5 to 6°C. In the Newfoundland-Labrador region large populations of redfish exist only in or near areas where temperatures at redfish depths are over 3°C.

In many parts of the bank slopes of the Northwest Atlantic from Georges Bank to southern Labrador, redfish investigations in deep water during recent years have demonstrated abundant redfish beyond the 200 fathom depth which until recently was the usual commercial fishing limit. These redfish, usually larger than those of the same sub-species (*mentella*) from shallower water, occur in apparent commercial abundance often to 250 fathoms, sometimes at 300 and occasionally at 350 fathoms. Individual redfish have been captured at 451 to 500 fathoms.

The data available agree with Tåning's conclusion that redfish are not plentiful except in areas where temperatures between 3 to 8°C exist in depths of about 200 to 500 metres (110 to 270 fath). Over most of the Northwest Atlantic the temperatures at these depths in areas of redfish abundance are usually between 3 and 6°C. In the Icelandic area redfish are abundant mainly in the warmer water to the south and west and are usually scarce in the colder water to the north and east. The decreasing quantities of redfish, found in proceeding southward on the seaward slope of Georges Bank, may be explained by the increasingly high temperatures in redfish depths, and the existence of a large population of redfish in the Gulf of Maine is correlated with moderately low sea temperatures over most of the year. Both on the southern Nova Scotian Shelf area and in the Gulf of Maine the greatest amount of redfish is coastward where the lowest temperatures are to be found, or in deep water on the seaward edge of the slope where deep-water temperatures are lower than those in the shallower water.

Within the temperature range suited to redfish, depth is more important than temperature in the vertical distribution of the *marinus* and the *mentella* types of redfish. In the European area *mentella* lives in colder water than *marinus*, but in the Northwest Atlantic *marinus* usually lives in colder water than *mentella*. In the Flemish Cap area both forms live in water of the same temperature. In all three areas *mentella* is in the deeper and *marinus* in the shallower water and the depth relationships of the two forms are approximately the same in all three areas.

Many factors may be responsible for local concentrations of a redfish population. Among these factors are light, food, spawning cycle, temperature, bank slopes and ridges, depressions in the continental shelf, stranding by currents, V-shaped areas, under-water projections of banks, and type of bottom.

The abundance of the *marinus* type in the European area coincides with the presence of a thick upper layer of moderately warm North Atlantic Current water, whereas this shallower water form is relatively scarce in the Northwest Atlantic where the water at the levels inhabited by *marinus* is typically cold. The *mentella* type is abundant in the Northwest Atlantic where the water at the greater depths suited to adults of this form is generally moderately warm, and in the North-Central and Northeast Atlantic the *mentella* type is abundant, also, in areas where the warm North Atlantic water extends deeply into the *mentella* range.

## INTRODUCTION

The preparation of this paper on redfish distribution was begun for a redfish symposium of the International Commission for the Northwest Atlantic Fisheries (ICNAF). The symposium was held in Ottawa under the chairmanship of Dr. H. W. Graham on June 9, 1955, during the Annual Meeting of ICNAF.

The present article deals principally with *Sebastes marinus* (L.) with some references to *Sebastes viviparus* Krøyer.

In European waters the smaller inshore form, *S. viviparus*, can be distinguished from the larger and deeper water form, *S. marinus*, by the greater number of scales possessed by the latter. Ginsburg (1953), who examined 41 specimens of *S. marinus* (38 from the western and 3 from the eastern Atlantic) found 87 to 110 scales in longitudinal counts as compared to 76 to 82 scales in similar counts in 4 specimens of *S. viviparus* from the eastern Atlantic. A further difference has been pointed out by Å. Vedel Tåning (personal communication, May, 1955) who, using the number of scale rows below the lateral line, has found that *S. marinus* of the eastern Atlantic possesses about 57, the American form of *Sebastes* about 60 and *S. viviparus* about 39 of these scale rows. Tåning gives the following figures from his investigations on samples from the three stocks, the "American form" being based on a sample from Lat. 45°50' N, Long. 58°20' W, and a depth of 120-140 fathoms:

	No. in sample	Scale pockets below the lateral line	
		Range	Average
<i>S. viviparus</i> .....	238	34-45	39.27
<i>S. marinus</i> .....	50	52-63	57.38
American form.....	83	56-67	60.47

Although *S. viviparus* is distinct, the range of the number of scale rows in the European *S. marinus* overlaps with that of Tåning's so called "American form".

Saemundsson (1932) says that in *S. marinus* the first preopercular spine is directed downward, while in *S. viviparus* the first preopercular spine is directed backward. Storer (1854) gave a very brief and insufficient description of the redfish of the western Atlantic and called the species *Sebastes fasciatus*. Of recent workers Tåning (1949) inclines to the belief that the western Atlantic

species is not *S. marinus* and, for the present, may as well be called *S. fasciatus*. Ginsburg (1953), on the basis of the comparison of 3 specimens of *S. marinus* from European waters with many specimens of redfish from the western Atlantic, found overlapping meristic characters, and some differences in body proportions, but, from the small number of European specimens, he was unable to draw definite conclusions regarding a species difference. Bigelow and Schroeder (1953), after examining specimens of *S. marinus* from Europe and redfish from the western Atlantic, were unable to find differences sufficient for specific separation either in number of scales, fin-ray number, body proportions or in the cheek spines.

Lundbeck (1940) recorded the name "Tiefenbarsch" for a distinct type of redfish living in the deep water and described the main differences between the "Tiefenbarsch" and the typical *Sebastes marinus* of the shallower deep water. Kotthaus (1950) compares the Tiefenbarsch with the usual European type of redfish and shows the many differences in body form between the two varieties. The two forms of *Sebastes marinus* are often found in the same locality but most often at different depths. The Tiefenbarsch occurs in the deep water in most of the North Atlantic areas of redfish distribution, and Travin (1951) has described this form as a distinct species, *Sebastes mentella*.

Andriiashev (1954) considers *mentella* to be a infraspecies and gives the following key for dividing the three types of *Sebastes*:

*S. viviparus* Krøyer. Lower preopercular spines more pointed and directed rearward. The longest spine of the dorsal fin exceeds the length of the snout (to the anterior edge of the lower jaw with the mouth closed).

*S. marinus marinus* (L.) and *S. marinus mentella* Travin. Lower preopercular spine angular and directed downward. The longest spine of the dorsal fin shorter than the snout.

*S. marinus marinus* (L.). Bony protuberance on the lower jaw usually rounded, blunt, frequently weakly developed. Horizontal diameter of the orbit usually less than 26% of the head length and less than 60% of the interorbital distance of the head. Colour orange-red [actually, in the southern part of the Newfoundland area it is often golden yellow, or possesses a greenish colour in addition to dark and red]. More often in depths not more than 250 to 300 metres (140 to 160 fath).

*S. marinus mentella* Travin. Bony protuberance on the lower jaw projecting, well developed, usually pointed. Horizontal diameter of the orbit is usually more than 26% of the length of the head and more than 60% of the interorbital distance of the head. Colour bright red. More often in depths greater than 300 metres (160 fath).

There is, however, some overlapping of morphological and meristic characters in redfish individuals of the *marinus* and *mentella* types and the key will not serve to allot definitely these individuals of intermediate type to *marinus* or *mentella* groups.

Kotthaus and Krefft (1957) say that at present they cannot agree completely with either of the Russian opinions. Their investigations of redfish from different areas show that, in principle, two separate types of redfish (*Sebastes marinus*) exist, i.e. the common redfish and the Tiefenbarsch or deep-sea redfish (also termed "Schnabelbarsch" by the fishermen); but there are also redfish which cannot be defined as either of these types (for instance on the southwestern and northwestern coasts of Iceland, at the Norwegian coast and other places) and which are intermediate forms. Furthermore Kotthaus and Krefft say that the more or less pure groups of each form differ considerably in vertebral number, shape and size of their otoliths, colour, growth, etc., depending on their origin. They conclude that great efforts still have to be put forth in order to clarify the taxonomy of the redfish, including more biological data than have previously been used. Until the question has been finally settled they prefer the more neutral terminology of *Sebastes marinus* type "marinus" for the common redfish and *Sebastes marinus* type "mentella" for the deep-sea redfish.

Baranenкова (1957), on the basis of investigations into the distribution of redfish in the western part of the Barents Sea and the eastern part of the Norwegian Sea (Fig. 40C, 40D), says that in addition to *Sebastes viviparus*, *Sebastes marinus marinus*, and *Sebastes marinus* infrasp. *mentella*, individuals of intermediate form, *Sebastes* sp., were caught, differing from the typical described forms. Specimens of this intermediate form were found in the trawl catches from the general region of Malang Bank on the northwestern coast of Norway. These redfish had the bony protruding appendage on the lower jaw of smaller size than that of *Sebastes marinus mentella*, but more conspicuous than that of *Sebastes marinus marinus*. Individuals of this intermediate form were readily separated from the *marinus* and the *mentella* forms on the basis of this feature, but from the external appearance and also from the size and colour they more nearly resemble *Sebastes marinus marinus*. The intermediate form reached a larger final size than the *mentella* form but not as large as the *marinus* form.

Klausewitz (1956) mentions that the illustration of the redfish published in Goode and Bean (1895) indicates that the Tiefenbarsch or *Sebastes marinus mentella* exists off the American coast.

At the meeting of the ICNAF Committee on Research and Statistics in Biarritz, March, 1956, Adolf Kotthaus provided specimens of the *mentella* and of the *marinus* types from the eastern Atlantic and also of intermediates between the two. Å. Vedel Tåning demonstrated European specimens of *S. marinus* and of *S. viviparus* and G. F. Kelly specimens of various sizes of the American form of redfish from the Gulf of Maine, Gulf of St. Lawrence, Grand Bank and Nova Scotian Shelf areas. The author had the privilege of examining these specimens.

*S. viviparus* could readily be distinguished superficially from *S. marinus* from the abovementioned differences in the angle of the most anterior preopercular spine. The larger specimens of the American redfish exhibited were usually of the *mentella* type.

In our redfish investigations at the Biological Station at St. John's in 1956 (Templeman and Sandeman, 1957) we have noted that some definite *Sebastes marinus marinus* are present near the upper limits of redfish distribution in some parts of the Newfoundland area, but the typical and by far the most abundant commercial redfish resembles *Sebastes marinus mentella*. Exhaustive comparisons of the European and American *mentella* types have not yet been made and meanwhile for purposes of this paper we shall refer to the typical North American redfish as *Sebastes marinus mentella*. More details are given later. As far as we can tell at present from our investigations, apart from the southern Labrador Subarea 2J (see Addendum), Flemish Cap and probably the Northeast Newfoundland Shelf, there is no significant error in considering the redfish data included in this paper from the Newfoundland and Labrador Subareas, the Gulf of St. Lawrence, the northern Nova Scotian banks and probably for the western Atlantic south of Greenland to refer to *Sebastes marinus mentella*.

Particularly off Labrador, but also off northeastern Newfoundland and on the northern slope of the Grand Bank, some *marinus* specimens are present, but some large redfish of the *mentella* type in general body appearance have a chin beak somewhat of an intermediate type. The chin beak in these forms is pointed but appears to be more broadly based in relation to the length than that of the typical *mentella* such as is encountered among the larger redfish at Flemish Cap, in the Gulf of St. Lawrence, in the general area west of the tail of the Grand Bank, and, also, in the northern Grand Bank and in the Labrador areas. The shape of the chin beak of these intermediate-type redfish off Labrador and from the area north of the Grand Bank, however, seems to us to be similar to that of the younger immature and of the young mature redfish of the southern and western areas of the Newfoundland region where *marinus* is scarce and where larger deep-water forms are typical *mentella*. This form difference is accompanied, especially in the Labrador area, by a much larger size before sexual maturity is reached and a much larger final size than in the Newfoundland areas where the more typical *mentella* exist. It is our opinion at present, therefore, that these so-called intermediates of the *mentella* type from the Newfoundland-Labrador area, at any rate, are *mentella* forms with delayed sexual maturity and we shall refer to them as *Sebastes marinus mentella*. With delayed sexual maturity this intermediate form grows to a larger final size than the typical *mentella* form of the southern and western parts of the Newfoundland area.

Kotthaus and Krefft (1957) say that in a number of localities they have found redfish groups in which the individuals are intermediate between the *marinus* and *mentella* forms. Baranenkova (1957) describes an intermediate type with a general appearance closer to the *marinus* type. The author has also seen redfish from the Labrador and the Flemish Cap regions, which were of the *marinus* type when judged from the whole appearance of the fish, but which had a chin beak longer and more angular than that of the typical *marinus* form.

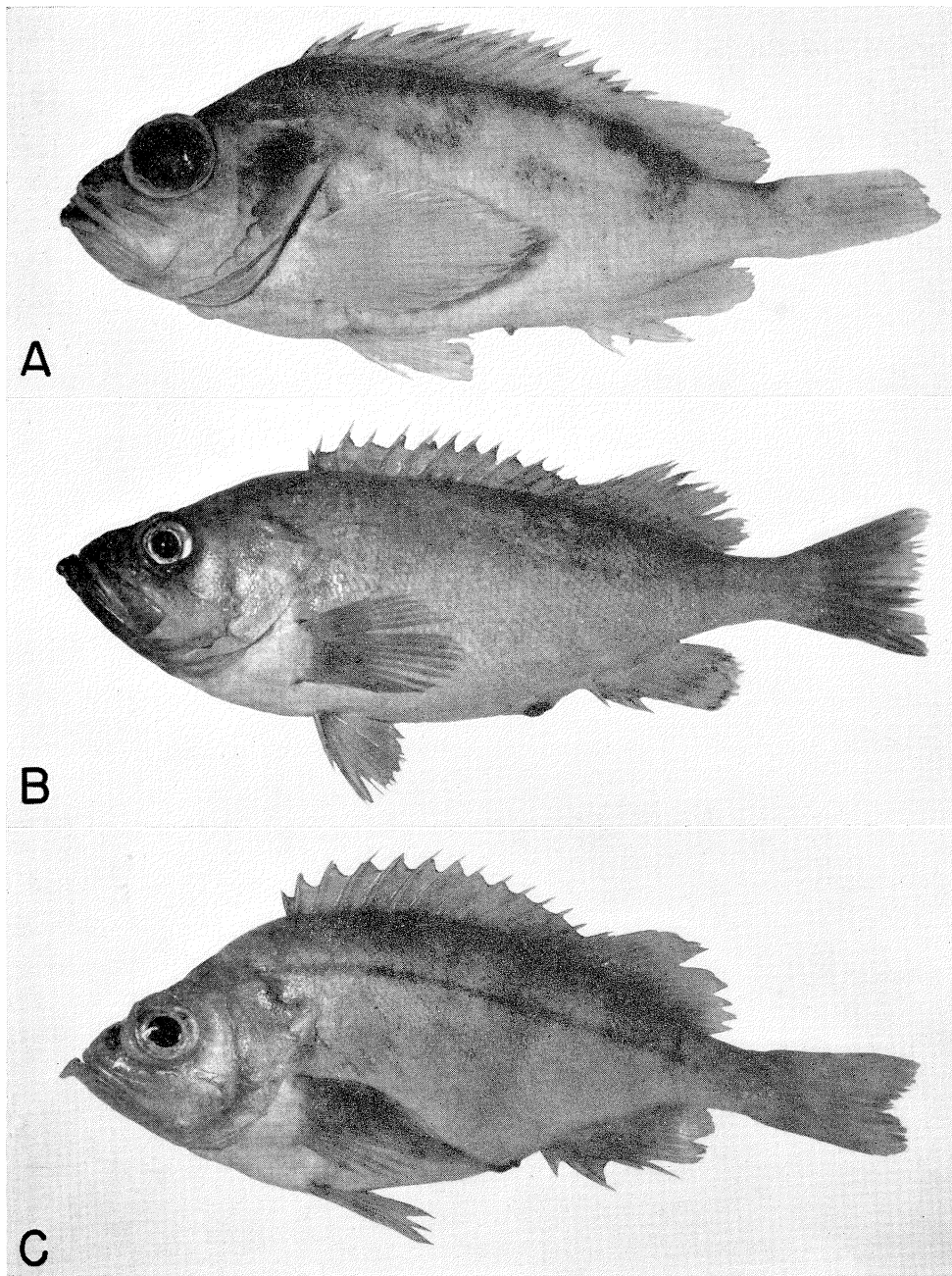


FIGURE 1. **A**, *Sebastes viviparus*, length 22.1 cm, mature male, from east of the Faroe Islands, 1956. Specimen preserved in formalin and supplied by Bennet B. Rae of the Marine Laboratory, Scottish Home Department, Torry, Aberdeen. **B**, *Sebastes marinus marinus*, length 50 cm, female, *Investigator II*, Flemish Cap, 150 fath, July 13 to 16, 1956. **C**, *Sebastes marinus mentella*, length 32 cm, mature female, *Blue Spray*, SW. Grand Bank, 85 fath, Feb. 20, 1958.

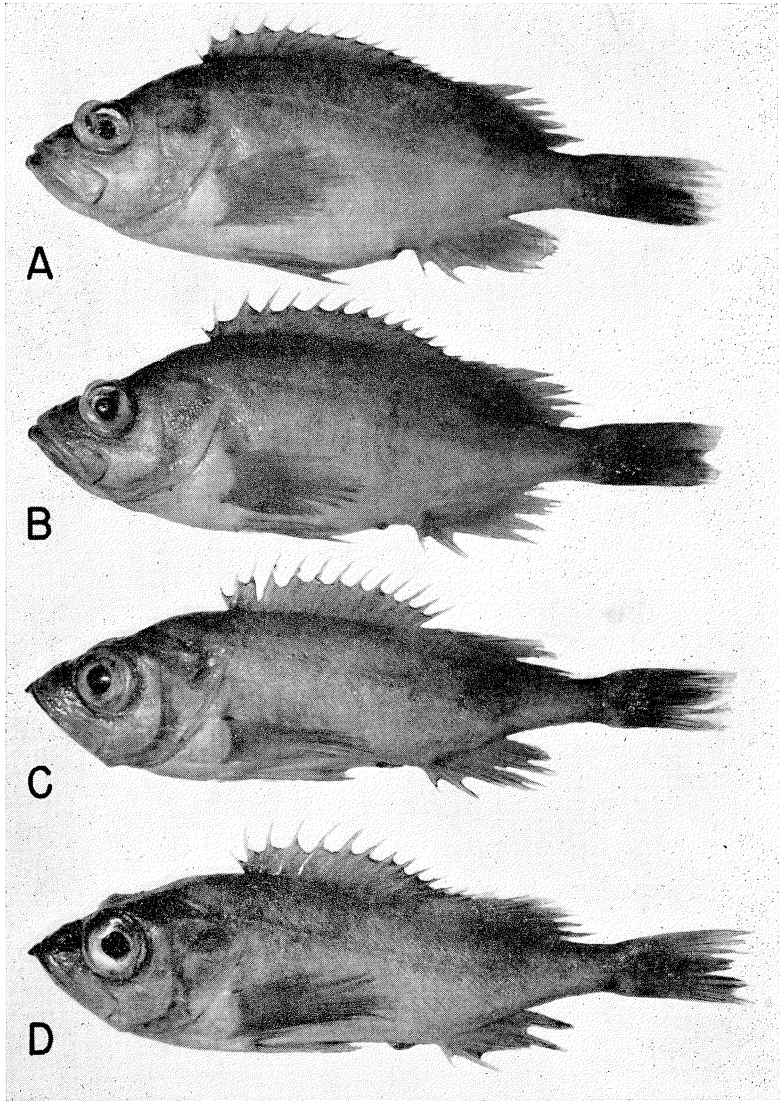


FIGURE 2. **A**, *Sebastes marinus marinus*, length 24 cm, female; **B**, *Sebastes marinus marinus*, length 24 cm, male; both from 150 fath, July 13 to 16; **C**, *Sebastes marinus mentella*, length 25 cm, female; **D**, *Sebastes marinus mentella*, length 25 cm, male; both from 250 fath, July 20. All specimens from *Investigator II* catches at Flemish Cap, 1956.

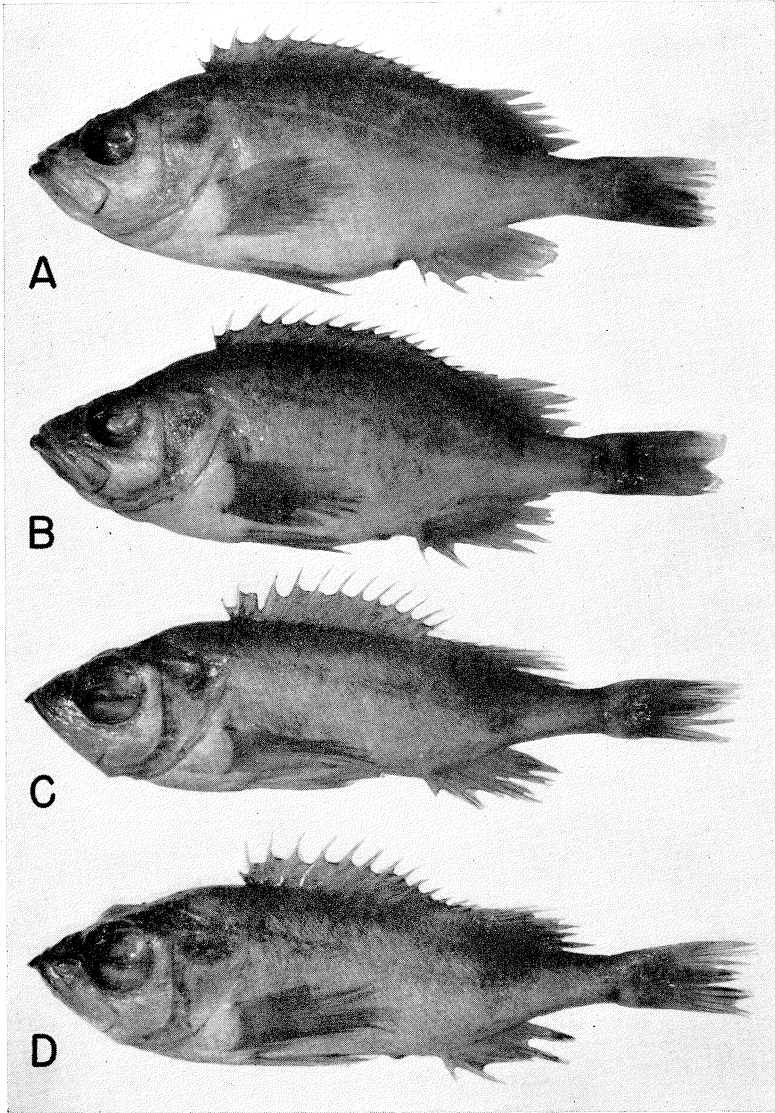


FIGURE 3. A and B, *Sebastes marinus marinus* and C and D, *Sebastes marinus mentella*. These are the same fish and in the same order as those of Fig. 2 but the eyes have been removed before photographing.

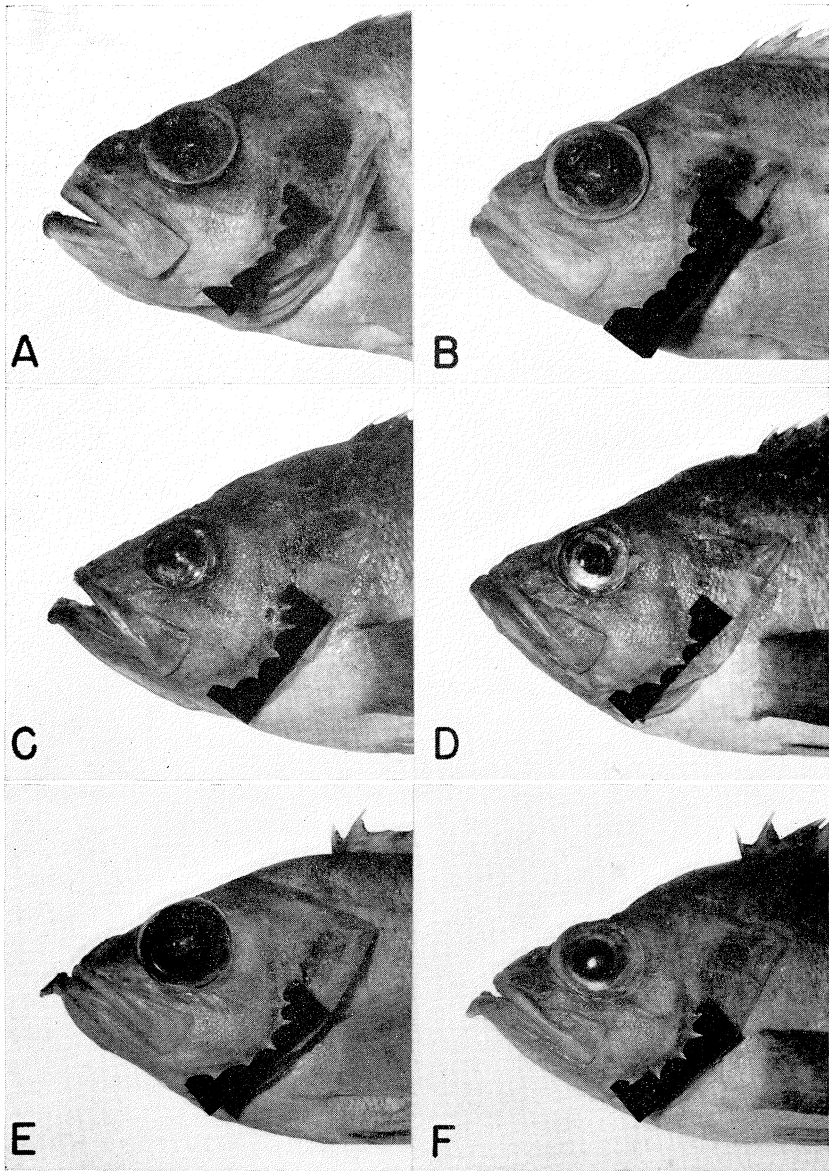


FIGURE 4. A and B, *Sebastes viviparus* from east of the Faroe Islands, 1956, length 25 cm, mature female, and 22 cm, mature male, respectively. C and D, *Sebastes marinus marinus*, from *Investigator II*, Connaigre Bay, 100 to 102 fath, January, 1957, 32 cm and 45 cm respectively, both male. E, *Sebastes marinus mentella*, *Investigator II*, Gulf of St. Lawrence, off Bay of Islands, Nfld., 120 to 160 fath, October, 1953, length 41 cm, female; F, *Sebastes marinus mentella*, M.V. *Marinus*, Hermitage Bay, 128 to 147 fath, Feb. 23, 1956, length 34 cm, male. (In D and E the integument covering the eye has been removed. In E the eye is bloodshot.)

In the cases of these so-called intermediates where a single character, such as the chin beak, is not as distinctive as it usually appears, it is our opinion that the fish should be considered as a whole, and this may usually be sufficient to place almost all large redfish either with the *marinus* or the *mentella* type. Each of these types is certain to have considerable form variation both in a single area and throughout its range. In the Newfoundland-Labrador area, at least, a study of the relative numbers of caudal melanophores in late stage larvae taken from the ovaries of female redfish serves as a very good check on whether the population is in fact *marinus* or *mentella* in type. These larval examinations also indicate the possibility of some interbreeding between the two forms.

Wherever it is not especially indicated otherwise in the text, references to *Sebastes marinus* in this paper are meant to include both *Sebastes marinus marinus* (L.) and *Sebastes marinus mentella* Travin. Except where noted particularly, these two forms of *Sebastes marinus* have not been distinguished in landings of redfish nor in the length-frequencies, larval and other observations discussed in this text. When *Sebastes marinus* is referred to as distinct from *Sebastes marinus mentella*, it will be called *Sebastes marinus marinus* or the *marinus* form of redfish.

Fig. 1 to 4 show specimens of *Sebastes marinus marinus* and of *Sebastes marinus mentella* from various parts of the Newfoundland area and of *Sebastes viviparus* from the Faroes. It is easy to distinguish (1) the small eye and short rounded chin beak of the *marinus*-type redfish, (2) the large eye and sharp chin beak of the smaller *mentella*-type redfish, and (3) the long, sharp chin beak of the larger *mentella*-type redfish.

In *Sebastes viviparus*, as noted by many European investigators, the most anterior preopercular spine is directed backward. In *Sebastes marinus marinus* of the Newfoundland area it is usually directed either downward or obliquely downward and backward and occasionally obliquely downward and forward. With regard to *Sebastes marinus mentella* of the Newfoundland area, we have examined the preopercular spines in several thousand specimens and have noted that the most anterior preopercular spine, especially in the medium-sized and larger individuals from the deeper water, is usually directed obliquely downward and forward (Fig. 4). However, in some specimens it points downward, in others obliquely downward and backward, and occasionally directly forward or directly backward. The anterior two preopercular spines are also usually more pointed in the *mentella* than in the *marinus* form.

It is most likely from a consideration of the general appearance, the chin beak, the direction of the most anterior preopercular spines, and the depth distribution, that an anatomical and physiological gradient exists from *mentella* through *marinus* to *viviparus*, or from *marinus* both to *viviparus* and to *mentella*.

When one considers the great variation in scale number which is produced in the same fish species by differences in temperature during development (Mottley, 1934; Wilder, 1952), it is difficult to maintain that the characters which at present separate *Sebastes viviparus* from *Sebastes marinus marinus* are

much greater than those which separate the average and especially the larger specimens of *Sebastes marinus marinus* from the average and larger specimens of *Sebastes marinus mentella*. Usually, however, the scale count and other form characteristics will separate individuals and small fish of *S. viviparus* and *S. marinus*, whereas it is at present sometimes difficult or impossible to allot some individual *S. marinus* (especially specimens below 25 cm in length) to the *marinus* or *mentella* subspecies.

The spine direction is somewhat plastic in the *marinus* and in the *mentella* forms. Similarly, if the direction of the first preopercular spine in *viviparus* were studied in large numbers of these fish we would expect that the first preopercular spine would sometimes be in some other direction than backward. Hence all redfish with the first preopercular spine projecting backward cannot be assigned to *viviparus* nor, until the matter is studied in more detail, can we be entirely sure that all *viviparus* have the first preopercular spine pointing backward.

The intermediate species in habitat and form and the species with the greatest size and presumably fastest growth is *Sebastes marinus marinus*. (Judging from the 3 specimens of *viviparus* that we have examined, however, the eye is apparently large as in *mentella*.)

In the North Pacific among the very numerous *Sebastodes* relatives of the Atlantic redfishes, the Pacific ocean perch, *Sebastodes alutus* (Gilbert) shows many close resemblances in form and depth distribution to *Sebastes marinus mentella*. (See Phillips, 1957, and Clemens and Wilby, 1946, for a description of *Sebastodes alutus* and other *Sebastodes* species.) Following the argument of Ekman (1953) for other fish groups, the great number of species of *Sebastes* relatives (*Sebastodes*) in the Pacific and the small number of Atlantic species of *Sebastes* indicate a greater period of existence for this group in the Pacific than in the Atlantic, with a considerably greater time in the Pacific for differentiation into species to occur. Thus, although it is possible that the group originated in the Pacific and that the *mentella* form was derived from the Pacific, it is difficult, with our present knowledge, to speculate further regarding the origin of the *marinus* form from *mentella* and of *viviparus* from *marinus* or the separate derivation of one or both of these latter forms from Pacific progenitors. Arguments for the *mentella* form being the original Atlantic species are its much more widespread distribution in the Atlantic than *marinus* and still more than *viviparus*, and its possession of a closely related Pacific relative.

There can be little doubt that there are considerable differences between *Sebastes marinus marinus* and *Sebastes marinus mentella*, especially at their intermediate and larger sizes. Although, hitherto, these forms have not usually been separated in length-frequencies and other observations taken at sea or on shore or in the statistics of landings, there is no question that in future they should be separated. Data for *marinus* and *mentella* types, and the *viviparus* type when present, should always be collected separately. *S. viviparus*, however, is not important commercially. If at some future time the differences between

the *marinus* and *mentella* forms can be explained on other than a different specific or subspecific basis, these data may be combined, but if no separation is made and a species distinction exists, the data collected will be less useful for population studies. A great deal of the redfish material and statistics already collected from many areas will lose considerably in value from the indiscriminate collection of combined information for these two forms. These remarks apply especially to the European data.

Judging from our observations in the Newfoundland area, except for a small number of *Sebastes marinus marinus*, the whole fishery in the western Atlantic (apart from West Greenland) before 1958 (see Addendum) has been for *Sebastes marinus mentella* or a form closely resembling it. In the eastern Atlantic, according to Tåning (1949), the principal form in the fishery is *S. marinus*, while the smaller *S. viviparus* is of little value to the fishery. Although it is generally understood that *Sebastes marinus marinus* has been by far the more abundant form landed in Europe and Iceland, with landings of *Sebastes marinus mentella* increasing in recent years, the actual proportions of these two forms landed both in the past and at present appear to be unknown, except for some information on recent German catches which is presented later.

This paper attempts to present and evaluate available data on redfish distribution. Much of the review is of previously unpublished data. Apart from general statements and raw statistical data, there is indeed only a small amount of published material on redfish distribution. Under the circumstances the paper is to be regarded as an attempt to come to some preliminary conclusions on redfish distribution in the North Atlantic and to provide preliminary explanations for this distribution. Further refining of these conclusions must await additional studies of racial and specific distinctions in *Sebastes*, the separation in scientific and catch-statistics data of *Sebastes marinus marinus* and *Sebastes marinus mentella*, and the gathering of additional information on a North Atlantic scale. Many of the original data presented in this paper are from the files of the Biological Station at St. John's. Although as broad a coverage of the North Atlantic as possible has been made, with the aid of almost all living students of redfish, it is natural that the most detailed information available to me should be from the Newfoundland area.

## LARVAE AND FRY

### GENERAL DISTRIBUTION

#### EASTERN NORTH ATLANTIC AND GREENLAND

NORWEGIAN SEA AND EASTWARD. Collett (1880) reports the capture of 23 small redfish (9.5 to 19 mm long) by the Norwegian North-Atlantic Expeditions, 1876 to 1878. These young redfish were taken at the surface in the Norwegian Sea and up to 250 miles from the nearest land.

Although some records of redfish larvae were available from the Norwegian Sea, due to lack of sufficient larval records the larval distribution off the Norwegian coast shown in Fig. 5 has been largely deduced by Tåning (1949) from a consideration of temperature conditions.

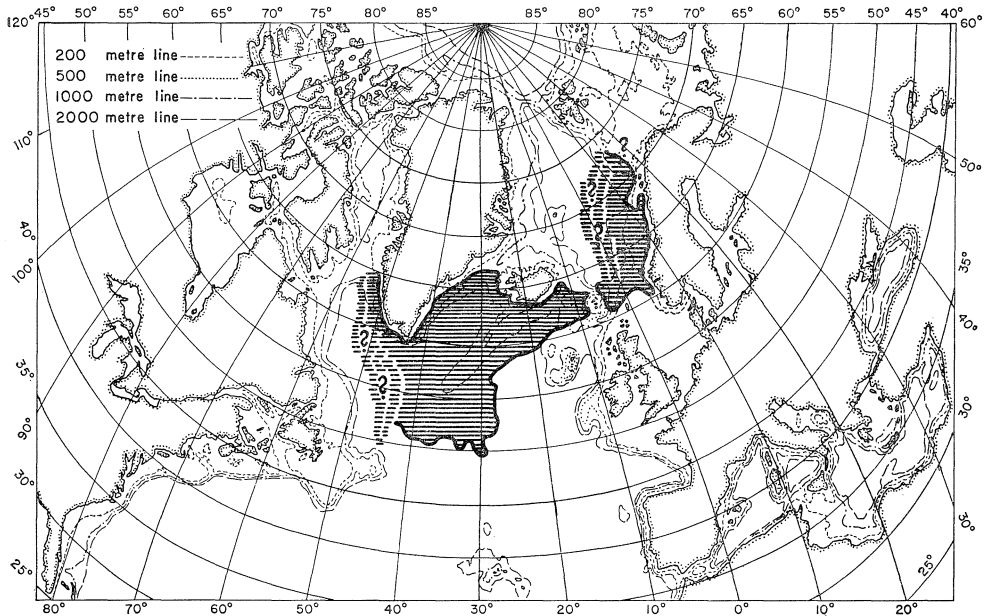


FIGURE 5. Distribution of larvae of *Sebastes marinus* in the central and eastern North Atlantic (after Tåning, 1949, fig. 4).

Veshchezerov (1944b) says that the extrusion of *Sebastes marinus* larvae begins in the second half of April near the Lofoten Islands up to Ringvadsö Island and from here the pelagic distribution divides with the current in two directions—northward along the edge of the continental shelf and eastward along the North Cape branch of the Atlantic Current. In June the centre of the larval extrusion shifts eastward and single catches of larvae occur as far as

Kola Bay. He also reports that the extrusion of the larvae of *Sebastes marinus* in the Barents Sea and in the Iceland coastal waters occurs at moderately high temperatures of about 5 to 7°C.

Baranenkova *et al.* (1956) give an account of investigations by the Arctic Scientific Institute of Marine Fisheries and Oceanography (PINRO) at Murmansk, USSR, during the years 1951 to 1955, on the distribution of larval redfish in the Norwegian Sea. The larvae were caught by towed plankton nets, chiefly with an 80 cm ring and made of No. 140 silk gauze, and sometimes by a net with a 50 cm ring with No. 23 silk gauze. Collections were mostly obtained from May to July. The distribution of larval redfish was similar in 1951-53 (Fig. 6A) and in 1954-55 (Fig. 6B). Redfish larvae were found throughout the eastern part of the Norwegian Sea and were absent in the western and north-western part.

The Russian data confirm Tåning's hypothesis of the distribution of *Sebastes* larvae in the Norwegian Sea (Fig. 5) and extend, in a northeasterly direction, the boundaries of the distribution of larval redfish.

Presumably most of these *Sebastes* larvae are *Sebastes marinus* but whether they are of the *marinus* or of the *mentella* form, or as is probable, a mixture of both, has not yet been decided.

WEST OF ICELAND AND SOUTH OF ICELAND AND GREENLAND. Schmidt (1904) found large numbers of redfish fry in the sea south and west of Iceland in May and June, 1903.

Jensen (1922) reports the capture of numerous specimens of small, 7 to 9 mm, redfish at and near the surface above depths of 800 to 1,600 fathoms in the North Atlantic south of Denmark Strait from May 14 to 26, 1908, during the passage of the *Tjalfe* to Greenland.

Tåning (1949) gives an account of his very important explorations on the distribution of redfish fry with the *Dana*, June 14 to July 8, 1947. Fig. 5, after Tåning (1949), shows the distribution of young *Sebastes marinus* in the area south of Iceland and Greenland, chiefly from *Dana* cruises in 1947, supplemented with some observations from earlier cruises by the *Dana* in 1931 and 1938 and from earlier cruises by other research vessels. Tåning's important finding in the area south of Iceland and Greenland was that the post-larvae of *Sebastes marinus* were abundant only above areas where the temperatures of the water in depths of about 200 to 500 metres (110 to 270 fath) lay between 3-4° and 8-8.5°C. (See temperature distribution in Fig. 60 in relation to larval distribution in Fig. 5. The post-larvae were apparently most abundant in the upper 50 metres or 27 fathoms.) The southern boundary of the redfish fry, therefore, coincided with the region where within a few miles there was a rapid change to water warmer than 8°C at 200 to 500 metres (110 to 270 fath). Large numbers of fry of *Sebastes marinus* were found south of Iceland and Greenland. These fry were abundant, they had an average length of 12 to 14 mm (range 7 to 22 mm), and over the area of about 970,000 square miles an average catch of 200 specimens in an hour's haul with a 2-metre net was obtained (see Fig. 7, which is Tåning's

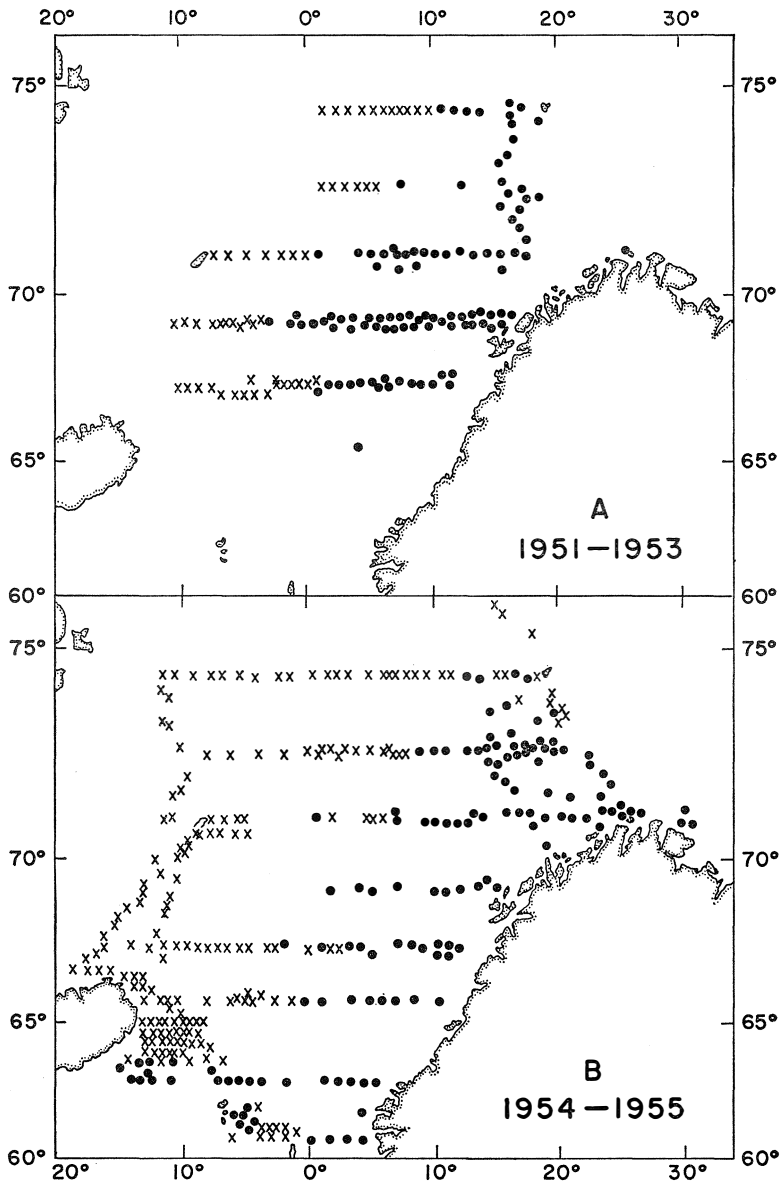


FIGURE 6. Occurrences of larvae of the redfish, *Sebastes*, from Russian investigations: A, 1951 to 1953, and B, 1954 to 1955. (Black dots indicate where *Sebastes* larvae were captured and station positions X show where successful plankton tows were made but where no larvae of *Sebastes* were found. After figure 1 of Baranenkova *et al.*, 1956.)

fig. 6, for one good haul; also Fig. 8, 9 and 10B for larvae, ready for extrusion, of *mentella*-type redfish, and Fig. 10A for redfish fry, from the Newfoundland area.) Tåning's catches and estimates indicated, in only the upper 50 metres (27 fath) of the area investigated, a minimum number of considerably more than



FIGURE 7. Fry of redfish, *Sebastes marinus*, from  $\frac{1}{2}$  hour's haul with the 2-metre stramin net about 300 miles southeast of Cape Farewell; 1,072 specimens, length 9 to 21 mm, average 14.7 mm. (This figure is from Tåning, 1949, fig. 6.)

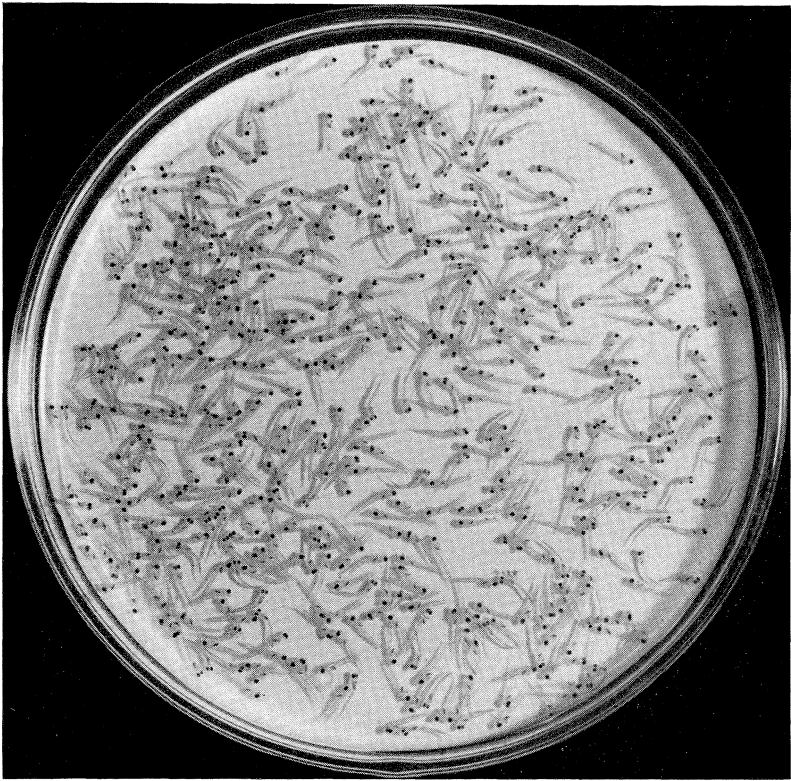


FIGURE 8. Redfish larvae, natural size, from ovary of *mentella*-type redfish, 36 cm long, Hermitage Bay, Newfoundland, 127 to 152 fath, June 23, 1956. Larvae approximately ready for extrusion to sea. Larval length (20 larvae at random after preservation in 7% formalin) 7.4 to 8.0 mm, mean 7.7 mm.

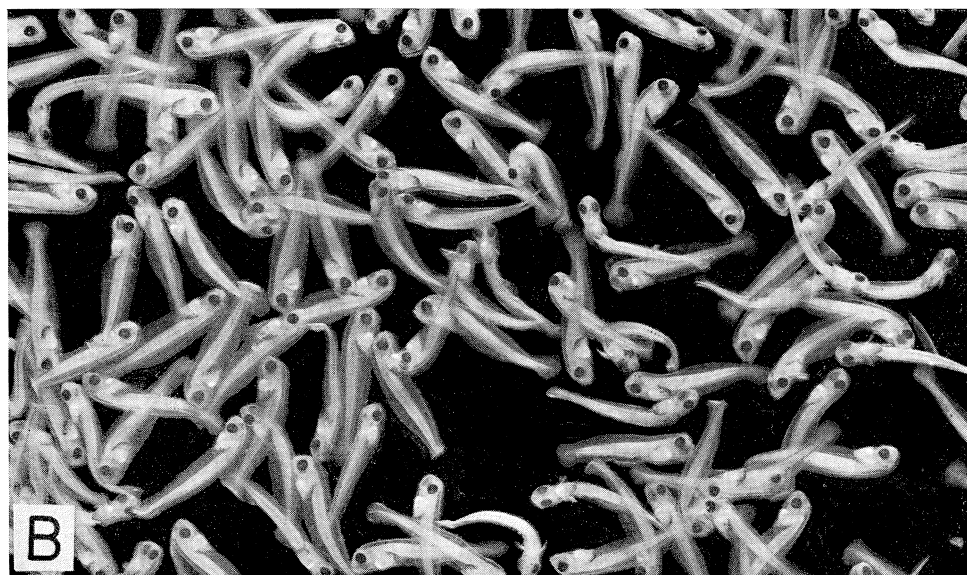
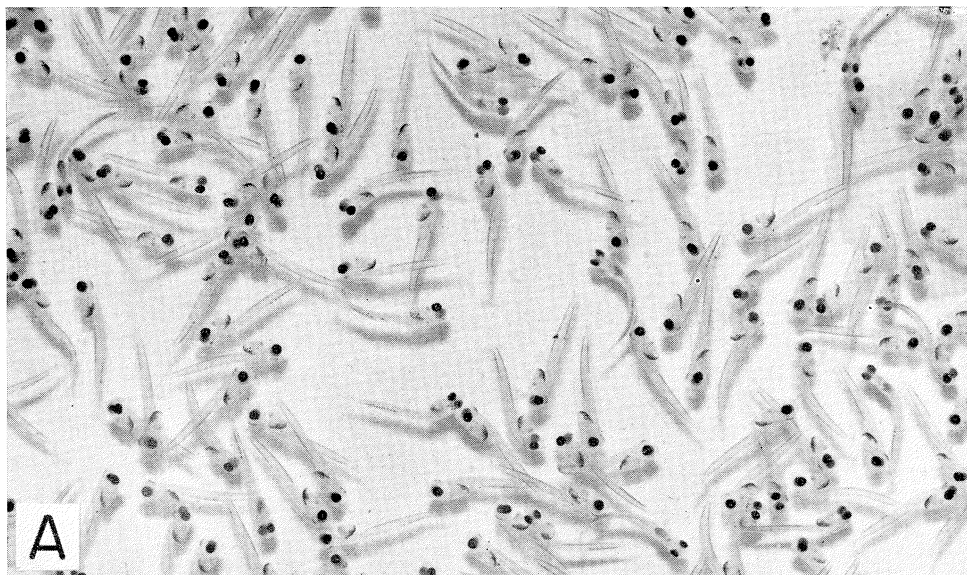


FIGURE 9. A, redfish larvae, *mentella* type, just before extrusion. (Same larvae shown in Fig. 8, average size 7.7 mm.) B, larvae from same female parent as for A but under different lighting conditions.

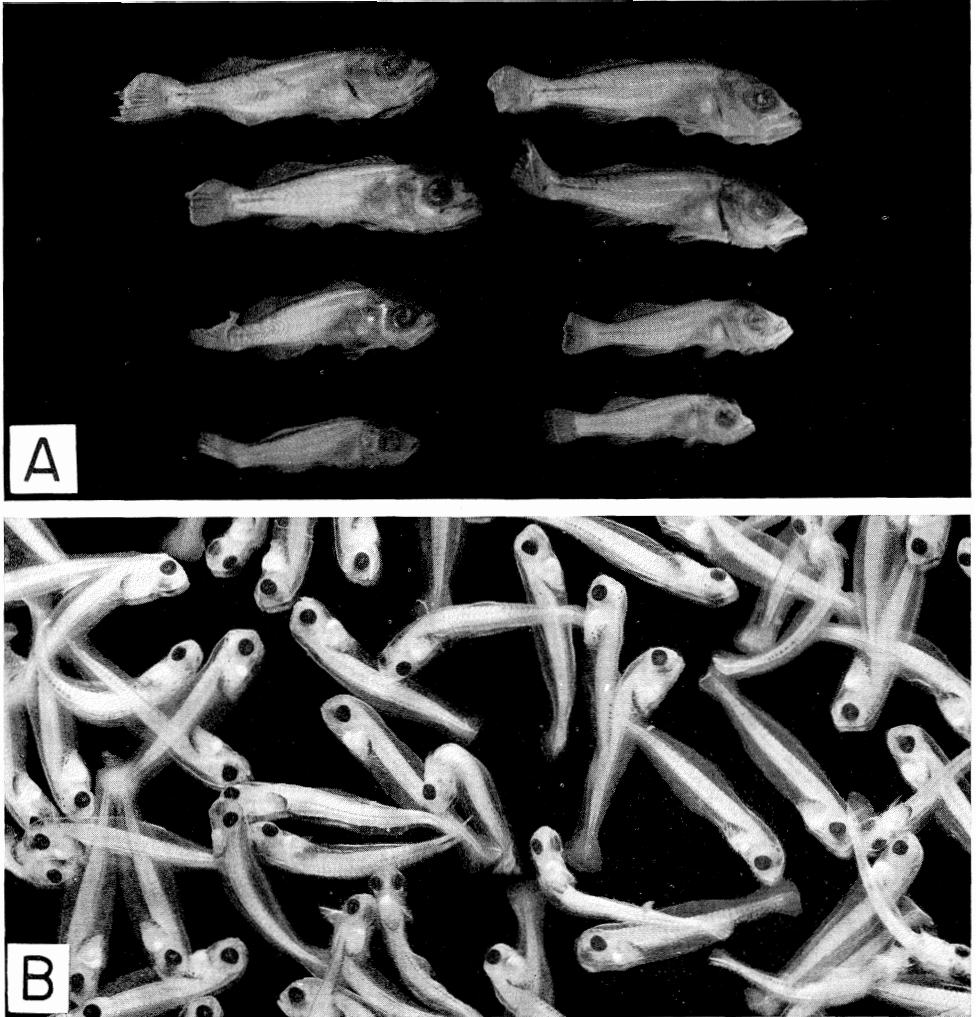


FIGURE 10. **A**, young redfish taken at the surface of Englee Harbour, Newfoundland, Sept. 4, 1947. Lengths after preservation in formalin 14.5-21 mm, average 18.5 mm. **B**, redfish larvae, *mentella* type, 7.4-8.0 mm, average 7.7 mm, just before extrusion. (Same larvae shown in Fig. 8 and 9, but enlarged for comparison of larval shape with later shape.)

1,250,000,000,000 fry which had already grown considerably from the approximately 6 mm hatching size, in an area of about 970,000 square miles. This is approximately 1 larva per 20 square feet ( $2m^2$ ).

The importance of these oceanic larvae to the redfish stocks is unknown. If redfish, like haddock, have to approach the sea bed toward the end of a pelagic phase in order to survive, these are merely lost larvae which will perish. If they can live for many years pelagically, and this is more likely for redfish than for haddock, some of them will doubtless add to redfish stocks on the fishing grounds. The magnitude of the addition to the stocks on the shallower grounds depends on the migratory habits of the redfish and on the extent to which redfish are moved by currents. It will be shown later that very large populations of redfish exist in the area from West and South Iceland to East Greenland and from southern Labrador to Flemish Cap. It is possible that this great offshore larval (possibly also adult) population of redfish south of Iceland-Greenland is partly responsible for maintaining the great redfish populations and redfish fisheries of the Iceland-Greenland and possibly, also, of the southern Labrador-Flemish Cap areas. If the larvae noted by Tåning south of Iceland-Greenland represent merely wasted larvae it is difficult to imagine how the Iceland-East Greenland redfish population is maintained at such a high level.

GREENLAND. Jensen (1922) comments on the collection by Holm (1888) from Angmagssalik, Lat.  $65^{\circ}40'$  N, in East Greenland, of a great many young redfish, about 22 to 26 mm, and reports that young redfish of this size and even somewhat larger, 25 to 30 mm, in another collection, are abundant at Angmagssalik in the last half of May and in June when the capelin come in to spawn. Jensen states that a similar collection (127 small redfish, 29 to 45 mm) was obtained Oct. 24, 1913, in the same locality.

The same author gives an account of 10 redfish, 47 to 66 mm, collected about 1900 at Godthaab in West Greenland. This small group was a sample of an "enormous quantity" of these small redfish which were frozen in the ice in the fjord at Godthaab.

Jensen also reports the capture on Sept. 25, 1909, by the *Tjalfe* of 9 young *Sebastes marinus* 27 to 43 mm in length. These were caught near the southern tip of Greenland at  $60^{\circ}05'$  N,  $46^{\circ}35'$  W, from the surface to about 50 metres (27 fath) below the surface above a depth of 1,347 metres (737 fath). Also 7 young redfish, 38 to 49 mm, were obtained in September, 1915 to 1916, at Sydprøven in Southwest Greenland when a strong west wind was blowing into the fjord. Similarly two young redfish, 65 and 69 mm, were thrown on the beach in a storm at Sukkertoppen Mar. 3, 1916.

From the absence of young redfish in the many plankton net tows in West Greenland waters, and from their abundance south of Iceland and in the North Atlantic south of Denmark Strait, Jensen concluded that, although the redfish was widely distributed in West Greenland waters, it did not breed there and that the young reached West Greenland by the currents from Denmark Strait.

Jensen (1926), discussing the *Dana* investigations in West Greenland waters in 1925, reports that pelagic young of *Sebastes marinus* were found from June 7 to July 9 at 19 stations, situated between Lat. 61°47' and 66°38' N, in some cases over great depths in Davis Strait down to more than 3,000 metres (1,640 fath) but also over shallower water on the various banks. By far the greatest numbers (42 and 65) were taken at two stations on Lille Hellefiskebanke at 130 and 150 metres (71 and 82 fath). At none of the other stations were as many as 10 larvae obtained. The young redfish were 7 to 17 mm long, and those from 13 to 17 mm were taken only in the latter part of the period. In this paper Jensen is not so firmly of the opinion expressed previously (Jensen, 1922) that the pelagic fry which he found in West Greenland waters in the autumns of 1908 and 1909 must have been carried there by the current from Denmark Strait, and expresses the belief that the redfish fry which he found in West Greenland in 1925 were spawned in West Greenland waters.

Å. V. Tåning, by personal letter, May, 1955, confirms Jensen's observation and says that, in the cold period before about 1920, no breeding was observed in West Greenland in the warmer water north to the Walsingham-Holsteinsborg Ridge. Tåning says that he found the first very young *Sebastes marinus* fry in West Greenland in 1924; since then richer collections have been obtained. He thinks, however, that the greater part of the redfish fry in West Greenland waters even now drifts into the area from the Denmark Strait where richer spawning occurs.

Paul Hansen (personal communication, February, 1956) says that in West Greenland pelagic redfish fry have been taken very seldom in the fjords. In the southern part of Davis Strait fry are abundant, but near the northern limit, about Lat. 64° N, only very few larvae have been taken. Hansen (1957) says that in August, 1930, large numbers of small redfish were found in the Julianehåb District drifting dead and dying on the surface. Thirty-eight of these small redfish were measured and the mean length was 35.6 mm. On Sept. 18, 1951, small redfish were collected in the Julianehåb District from cod stomachs. The mean total length was 43.6 mm.

#### WESTERN NORTH ATLANTIC, APART FROM GREENLAND

CANADIAN AREA. Murray and Hjort (1912) in the *Michael Sars* found larvae of the redfish, *Sebastes*, on the slope of the Grand Bank just west of the southern tip, at Lat. 43°18' N and Long. 51°17' W over a depth of 138 to 147 metres (75 to 80 fath) on June 30, 1910.

Dannevig (1919) has given an account of the captures of redfish larvae in the Gulf of St. Lawrence and on the Nova Scotian and Newfoundland banks in 1915 during the Canadian Fisheries Expedition under Dr. Johan Hjort. Fig. 11 and 12 have been adapted and redrawn from the figures and tables of Dannevig's paper. These figures show that there was a considerably greater and more widespread abundance of redfish larvae in the offshore areas outside the Gulf in the period July 21 to 29 than in the period May 29 to June 4, and a much more widespread distribution in the northern Gulf of St. Lawrence from Aug. 3 to 12

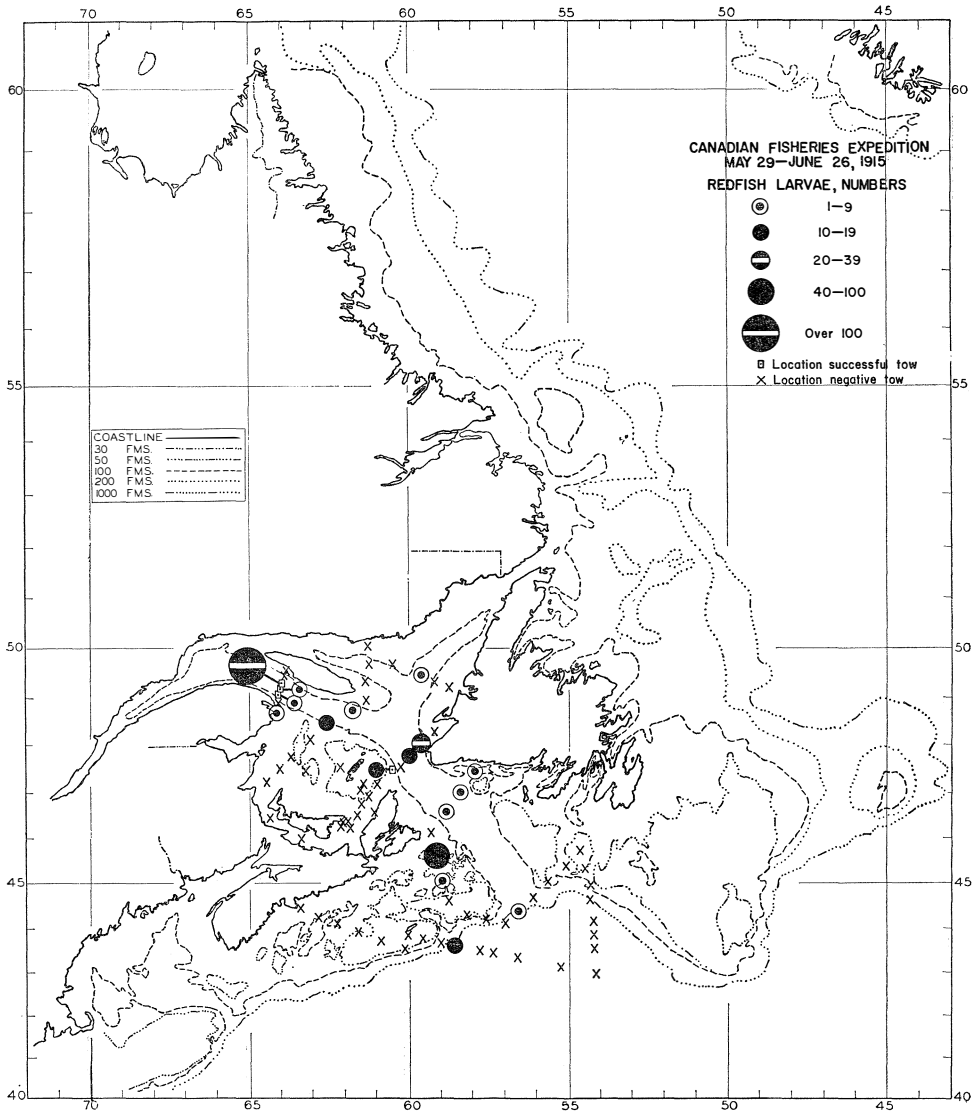


FIGURE 11. Captures of larvae of the redfish, *Sebastes marinus*, by the Canadian Fisheries Expedition, between May 29 and June 26, 1915. (The Anticosti-Gaspé section by *Steam Drifter No. 33*, June 1 to 26. Remaining Gulf of St. Lawrence stations mainly by the *Princess*, June 9 to 15. Stations outside Gulf by the *Acadia*, May 29 to June 4.)

than from June 9 to 15. A large amount of spawning probably occurred in these areas after the earlier cruises. The greatest catch of larvae, 325, was taken at the surface over the deep Laurentian Channel south of Anticosti on June 26. Other than this the largest catch was 43.

It is noteworthy that in the Gulf of St. Lawrence the larval distribution, particularly in the earlier cruise, June 9 to 15, followed the deep-water channels. By Aug. 3 to 12, however, there was some dispersion of the larvae over the

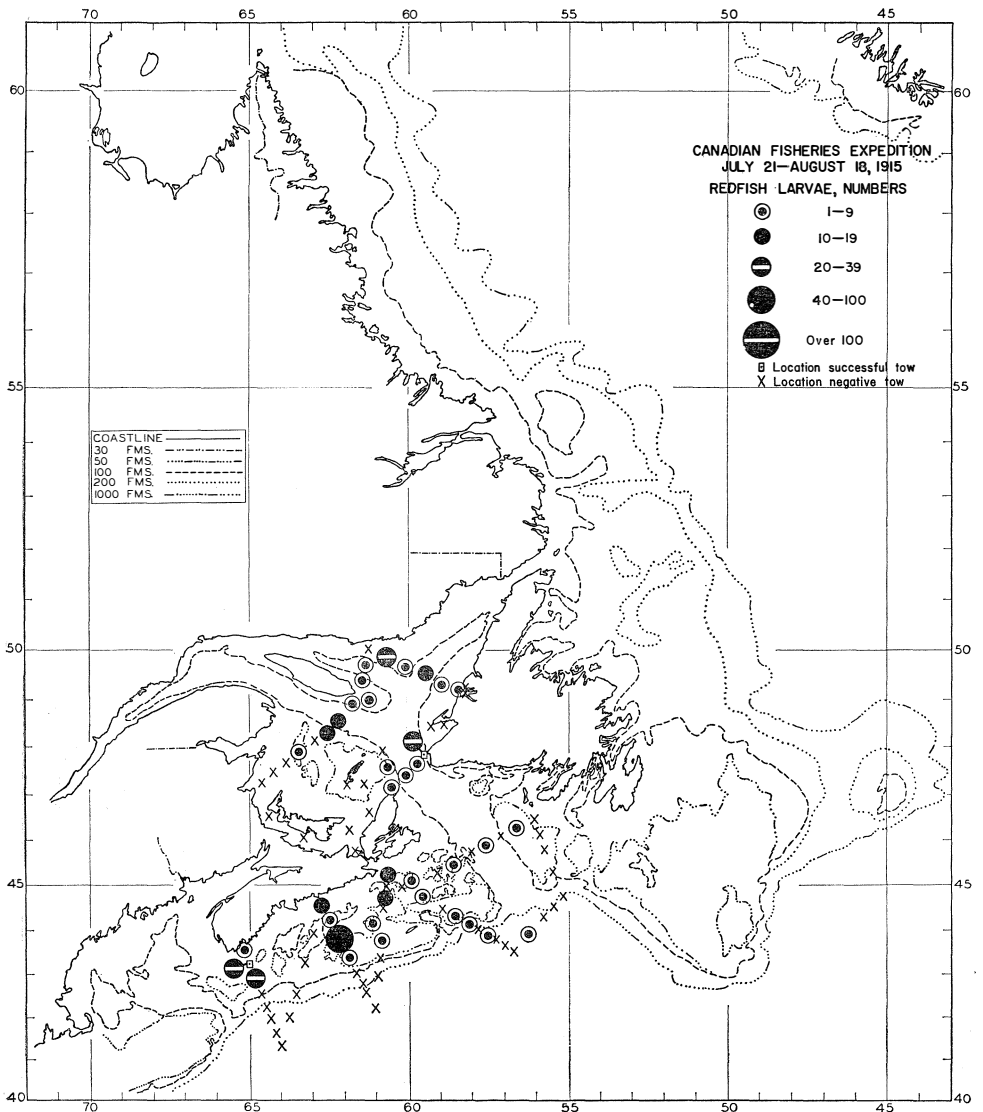


FIGURE 12. Captures of redfish larvae by the Canadian Fisheries Expedition, between July 21 and Aug. 18, 1915. (A few Gulf of St. Lawrence stations with catches only of 3 redfish larvae at one station and 1 redfish larva at another station by the *Steam Drifter No 33*, July 26 to Aug. 18. Remaining Gulf of St. Lawrence stations by the *Princess*, Aug. 3 to 12. Stations outside Gulf by the *Acadia*, July 21 to 29.)

shallower water immediately adjacent to the deep channels. (In August, 1938, from plankton tows at the surface for larval lobsters near shore in St. George's Bay on the west coast of Newfoundland, the author often obtained redfish fry of the year.)

In the area outside the Gulf, redfish larvae were scarce in the May 29 to June 4 period but common in the July 21 to 29 tows, indicating considerable

spawning after the earlier period. Redfish commonly inhabit the deeper waters between the banks as well as between the banks and the shore on the Nova Scotian Shelf, and redfish larvae, also, were commonly found over the shelf. There was some indication of larval distribution outside the slope areas near the mouth of the Laurentian Channel between St. Pierre Bank and Banquereau, but, in view of Tåning's captures of numerous redfish larvae over deep water south of Iceland and the recent discovery of large numbers of redfish in the deep water at the outer edge of the Nova Scotian Shelf, it may be thought surprising that no fry were taken outside the 100-fathom line in the southern Nova Scotian area. As we shall see later, however, although there is a deep-water redfish population at the continental slope in the southern Nova Scotian area, there is little water of suitably low temperatures for redfish at redfish depths seaward of this shelf. There was a pronounced trend for most larvae to be taken centrally and shoreward on the Nova Scotian Shelf and this was particularly true on the southern half of this shelf. As will be seen later the distribution of redfish fry in this shelf area is approximately similar to that of adult redfish. While some of the redfish fry in the Nova Scotian Shelf area may have drifted from the Gulf of St. Lawrence there are such quantities of redfish on the shelf area that most of the fry caught there were probably spawned locally. In the Gulf itself, neglecting the one very large catch in the Gaspé area, there is no evidence that between May and August the Gulf has been depleted of fry by an outward drift. There is considerable evidence, however, from measurements of small and adult redfish, that good larval settlement occurs only occasionally in the Gulf; an outward drift of larvae is very likely although not necessarily demonstrated by Fig. 11 and 12.

The information given on the sizes of these larvae is very incomplete, consisting only of the "middle length" (possibly the average length or the median length for the young redfish caught in each set). This "middle length" ranged from 7.0 to 8.7 mm in the offshore catches, May 29 to June 4, and from 7.8 to 9.0 mm in the Gulf of St. Lawrence catches, June 9 to 15. The "middle length" had a range of 5.3 to 10.5 mm in the offshore catches July 21 to 29, and 7.0 to 13.3 mm in the Gulf catches, Aug. 3 to 12.

Fig. 13 and 14 show the catches of redfish larvae by the research trawler *Cape Agulhas* in half-hour tows with a 2-metre ring stramin net in the Newfoundland area and vicinity from 1931 to 1935. (These figures are adapted from Frost, 1938, and the annual reports of the Newfoundland Fishery Research Commission and of the Newfoundland Department of Natural Resources, 1932 to 1936.)

In 1931 there was no spring cruise, in 1932 the spring cruise was from May 21 to June 16, and in 1933, 1934 and 1935 the so-called spring cruise was between June 5 and July 26. The so-called fall cruises were from Aug. 5 to Sept. 12 in 1931 and were within the period Aug. 23 to Sept. 30 in each of the years from 1932 to 1935.

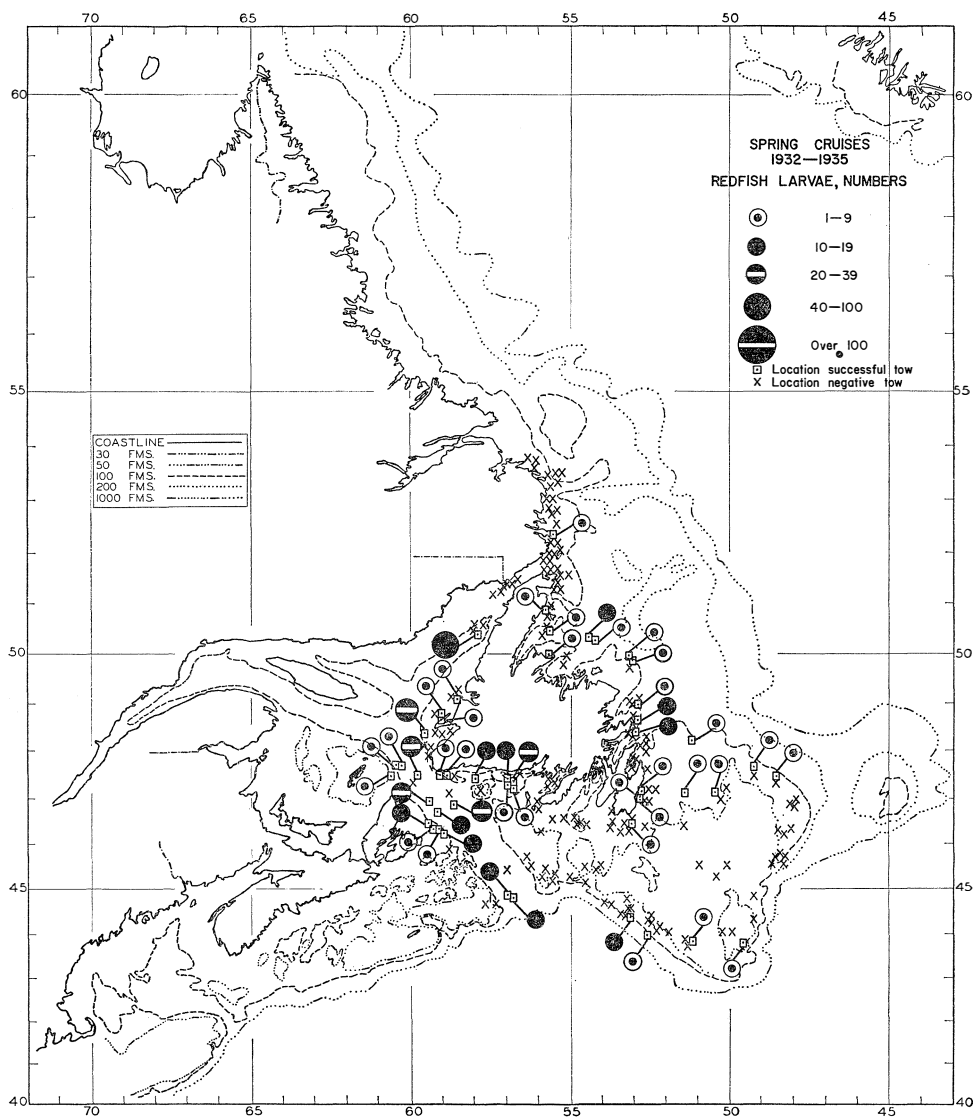


FIGURE 13. Redfish larvae caught during Newfoundland research cruises. Spring cruises, 1932 to 1935.

Most of the 2-metre net tows were taken at 25 to 50 metres (14 to 27 fath) with a few shallower tows from surface to 25 metres (14 fath), some from 50 to 100 metres (27 to 55 fath), but only a small percentage deeper than 100 metres (55 fath). The tows were oblique, the nets being raised by 10 metres (5.5 fath) at a time, towed for a regular proportion of the towing time and then raised again with the last period being at the surface.

More larvae were obtained in the June to July than in the August to September cruises, although the largest catch was obtained in 1931 in the autumn

cruise just west of the southern tip of the Grand Bank. Larvae were relatively scarce in the earlier cruise, May 21 to June 16, in 1932, compared with succeeding years when the first cruise was a little later (see Frost, 1938, chart 7, for this and for the distribution in the individual cruises).

The larvae were most abundant over and at the edge of the deep water of the Gulf of St. Lawrence, the southwest coast of Newfoundland, the northern edge of the Nova Scotian banks and the western edge of the Newfoundland banks. They were scarce or absent in the shallow water areas.

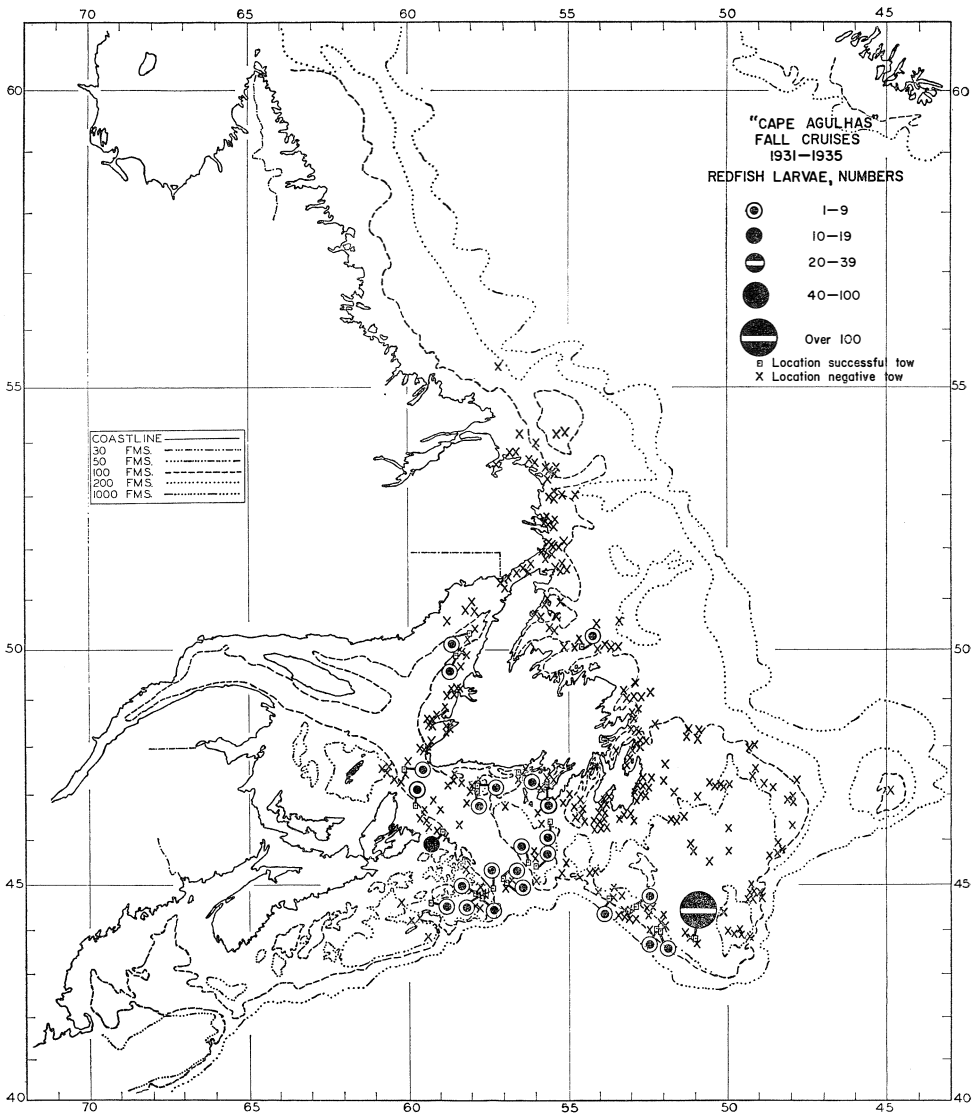


FIGURE 14. Redfish larvae caught during Newfoundland research cruises. Fall cruises, 1931 to 1935.

Huntsman *et al.* (1954), in researches from July to early September, 1923, obtained *Sebastes marinus* larvae in the Strait of Belle Isle and in the area between Anticosti Island and Cape Whittle, Labrador. In this latter area, over the deep water, the larvae were taken in much greater numbers than in the shallower water of the Strait where adult redfish do not live. *Sebastes* larvae were taken at the surface and at 25 metres (14 fath) and these larvae were usually more abundant during sunlight in the surface tows than in the tows at 25 metres. They were present along the west coast of Newfoundland to the northern entrance to the Strait but were absent in the cold Labrador Current water passing inward to the Gulf along the Labrador side of the Strait.

Jean (1955) reports on collections of *Sebastes marinus* larvae taken mostly in surface tows from May to September, 1952 to 1954, at Grand River at the mouth of Chaleur Bay in the Gulf of St. Lawrence. Larvae of *Sebastes marinus* were captured between May 24 and Aug. 25. The mean length of the larvae for each tow ranged from 6.0 to 9.5 mm and did not increase significantly during the period of the experiment.

Steele (1957) collected redfish larvae from June to August, 1954, in surface and oblique hauls with plankton nets in 4 sections off the Gaspé Coast and interprets his results, showing increasing sizes in the southerly stations, to indicate a southeasterly drift of redfish larvae out of the Gulf of St. Lawrence. Almost all the larvae were between 6 and 9 mm in total length. The greatest numbers of larvae were captured in June, and larvae were more abundant in surface than in oblique tows, indicating that the young larvae live near the surface.

GULF OF MAINE. Figure 15 indicates the approximate number and location of net tows in the general Gulf of Maine area in July and August, 1912, 1913, 1914, 1916 and 1922 and from May to October, 1915. Late fall and winter tows have been omitted as being unlikely to have produced many of the redfish larvae shown in the figure. This figure has been adapted from Bigelow (1926, fig. 1, 2, 3, 4, 5 and 8) for set stations and from Bigelow and Welsh (1925, fig. 142) for captures of redfish larvae. Bigelow (1914) found the range of sizes between July 22 and Aug. 31 for specimens of redfish larvae from the Gulf of Maine to be 6.5 to 21 mm.

Bigelow and Welsh (1925), in Gulf of Maine cruises from 1912 to 1922, found redfish larvae well distributed in the Gulf of Maine over the deep water and to a great degree on or near the 50-fathom contour. Only rarely were catches to be found in shallower water. Sometimes several hundred larvae were taken in a tow. The records as shown in Fig. 15 are mostly for the area west of the line from Cape Cod to Cape Sable with few records outside this area except near Cape Sable. Most tows were taken near the coast. On Georges Bank only one redfish larva was obtained, and the absence of other seaward captures indicates a comparative lack of spawning female redfish in the offshore area east of the western 50-fathom contour of Georges Bank.

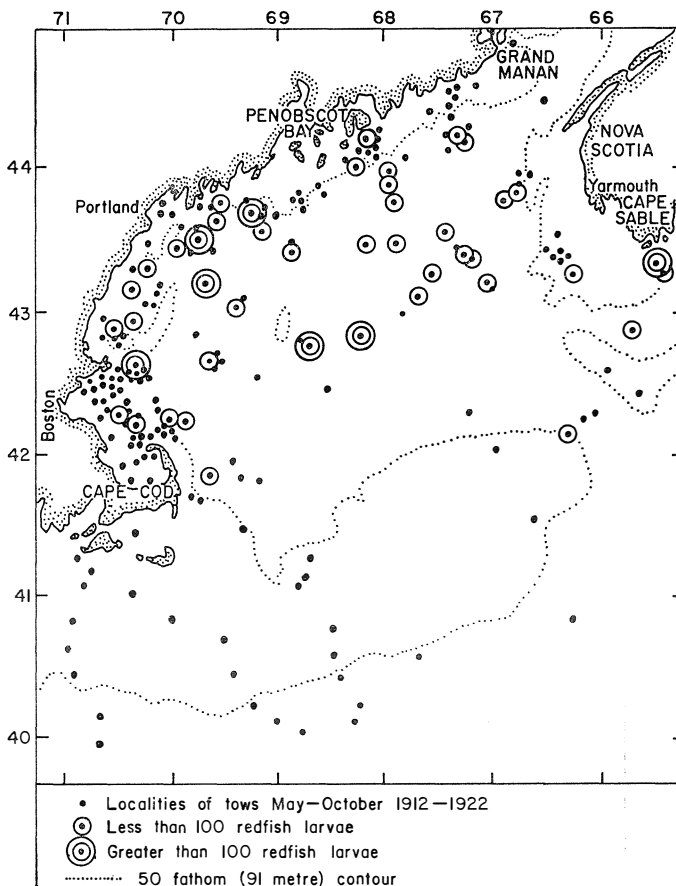


FIGURE 15. Captures of redfish larvae in the Gulf of Maine (adapted from Bigelow, 1926, and Bigelow and Welsh, 1925).

### CONCLUSIONS

Young redfish apparently have a long pelagic life near the surface. It is thus surprising, in view of the possibility of distribution far and wide by currents, that larval redfish at the surface follow so well the deeper contours. This adds weight to Tåning's argument that the widespread distribution of very large numbers of redfish fry south of Iceland represents production of larvae in the vicinity from a large redfish spawning population.

It is evident also, however, from the abundance of 15-21 mm larvae in the harbour at Englee on the northeastern coast of Newfoundland in early September, 1947 (discussed later in this section), that there can be considerable larval drifts from their place of origin over the deep water.

The 15-21 mm larvae at Englee in September and the 22-30 mm larvae reported by Jensen to be abundant at Angmagssalik, Greenland, in May and June, are evidently 0-group and 1-group redfish, respectively.

## LARVAL LENGTH AT TIME OF LIBERATION

In a consideration of the distribution of redfish larvae and of the time that has elapsed since liberation, the size of the larvae is important. Larval measurements mentioned in the literature are typically of preserved specimens, presumably in formalin. Bigelow and Schroeder (1953) refer to redfish larvae as being about 6 mm at birth.

At the St. John's Station, measurements of random samples of fresh redfish larvae from females in which all the larvae were hatched and close to liberation, were carried out in 1950 to 1951. From some of these parent females (in 1951) large numbers of larvae were preserved in 5% formalin and random samples were again measured in 1955 (Table I). In both cases the total over-all lengths were measured using an eyepiece micrometer calibrated against a stage micrometer. Both fresh and preserved larvae were relatively straight and easy to measure accurately.

TABLE I.—Sizes of random samples of redfish larvae ready or nearly ready for liberation, and shrinkage of redfish larvae in 5% formalin.

*Larval condition:* Fish No. 1 and 2, all larvae hatched, nearly ready for liberation and no definite external indication of yolk. No. 3 to 5, all larvae hatched.

*Locality:* No. 1 and 2, 48°05'N 48°30'W, 182 to 184 fath (333 to 337 m), June 26, 1950.  
No. 3 to 5, 45°05'N 48°55'W, 172 to 180 fath (315 to 329 m), July 12, 1951.

Length ranges	No. of larvae— fresh condition					No. of larvae— 5% formalin			Totals with each larval frequency from an individual female recalculated to equal a total of 33		
	Fish number					Fish number			Fresh 1-5	Fresh 3-5	Preserved 3-5
	1	2	3	4	5	3	4	5			
<i>mm</i>											
5.61-5.80.....							1				1
5.81-6.00.....							0				0
6.01-6.20.....							2	5			8
6.21-6.40.....						2	2	7			12
6.41-6.60.....						13	13	9			37
6.61-6.80.....						9	5	5			20
6.81-7.00.....					1	9	8	4	1	1	22
7.01-7.20.....			17		5				24	24	
7.21-7.40.....	4		1		5				12	8	
7.41-7.60.....	14		4		3				22	8	
7.61-7.80.....	9	7	3	1	3				24	8	
7.81-8.00.....	2	5	7	12	5				34	27	
8.01-8.20.....	2	2	0	7	2				14	10	
8.21-8.40.....	3	7	1	8					20	10	
8.41-8.60.....		1		2					3	2	
8.61-8.80.....		5		1					6	1	
8.81-9.00.....		3							3		
9.01-9.20.....		0							0		
9.21-9.40.....		1							1		
Total.....	34	31	33	31	24	33	31	30	164	99	100
Av. size, <i>mm</i> .....	7.66	8.25	7.42	8.11	7.51	6.66	6.58	6.48	7.79	7.68	6.57
Shrinkage, <i>mm</i> .....						0.76	1.53	1.03			1.11
% shrinkage.....						10.2	18.9	13.7			14.5
Length female parent, <i>cm</i> .....	38	37	39	37	36						

The fresh redfish larvae ranged in length from 7.01–7.20 mm to 9.21–9.40 mm with averages from the individual parent females between 7.42 and 8.25 mm. Shrinkages ranged from 0.76 to 1.53 mm (10.2–18.9%) or 14.5 % over-all.

The parent females were large for the southern Newfoundland area—between 36 and 39 cm total length—and their larvae would probably be larger than those of smaller fish which had been mature for fewer years.

The shrinkage shown here is only an indication of what the actual shrinkage may be. The strength of the formalin used was approximately 5% and a good deal of this had probably evaporated from the corked vials over the four-year period of storage. Also the larvae were from iced fish and, although apparently in good condition, would not have had the same ability to shrink as the live larvae obtained in the plankton and preserved immediately. Templeman (1948) found that adult capelin placed in 10% formalin, 4 hours after capture, after being measured fresh  $2\frac{1}{2}$  hours after capture, shrank more than twice as much (0.52 cm compared with 0.22 cm) as capelin placed in 10% formalin immediately after being measured 11 hours after capture.

#### VERTICAL DISTRIBUTION OF LARVAE AND FRY

The data on plankton-net captures of redfish larvae, in the literature and in our records, come almost entirely from oblique hauls, vertical hauls, and hauls without closing mechanisms or adequate records or controls of the depth of the net. Moreover, because the larval collections were usually made in the course of general plankton surveys, only one or a very few tows were carried out in each locality. Hence it is impossible to compare the quantities of pelagic larvae at different depths.

Fig. 16 and Table II show measurements of redfish larvae caught in 1931 to 1954 and of redfish fry and young redfish up to 100 mm caught in 1931 to 1953 by the St. John's Station in plankton and bottom nets. Also included are some records of captures of young redfish in Passamaquoddy Bay, N.B. by the St. Andrews Station and kindly supplied by W. R. Martin. Some of the Newfoundland captures of larvae have been given by Perlmutter and Clarke (1949). The Passamaquoddy Bay specimens were measured fresh. The other measurements in Table II are of preserved specimens, and for these the fresh lengths are somewhat greater than those recorded in the table. Since almost all the plankton towing recorded in the table and figure ended in September the absence of larvae in December has little significance. The Newfoundland catches of young redfish in December were in Hermitage Bay in 1953 at 120–140 fathoms, and the Passamaquoddy Bay catches were in 15–20 fathoms in August and in 30–50 fathoms just outside the mouth of the bay in December. While a few of the larvae below 26 mm were caught by bottom trawls with the cod-end covered by stramin, almost all larvae of these sizes were caught by plankton net, mostly the 2-metre (6.6-foot) stramin net and a 1-metre (3.3-foot) cheesecloth or silk net, between the surface and 100 metres (55 fath).

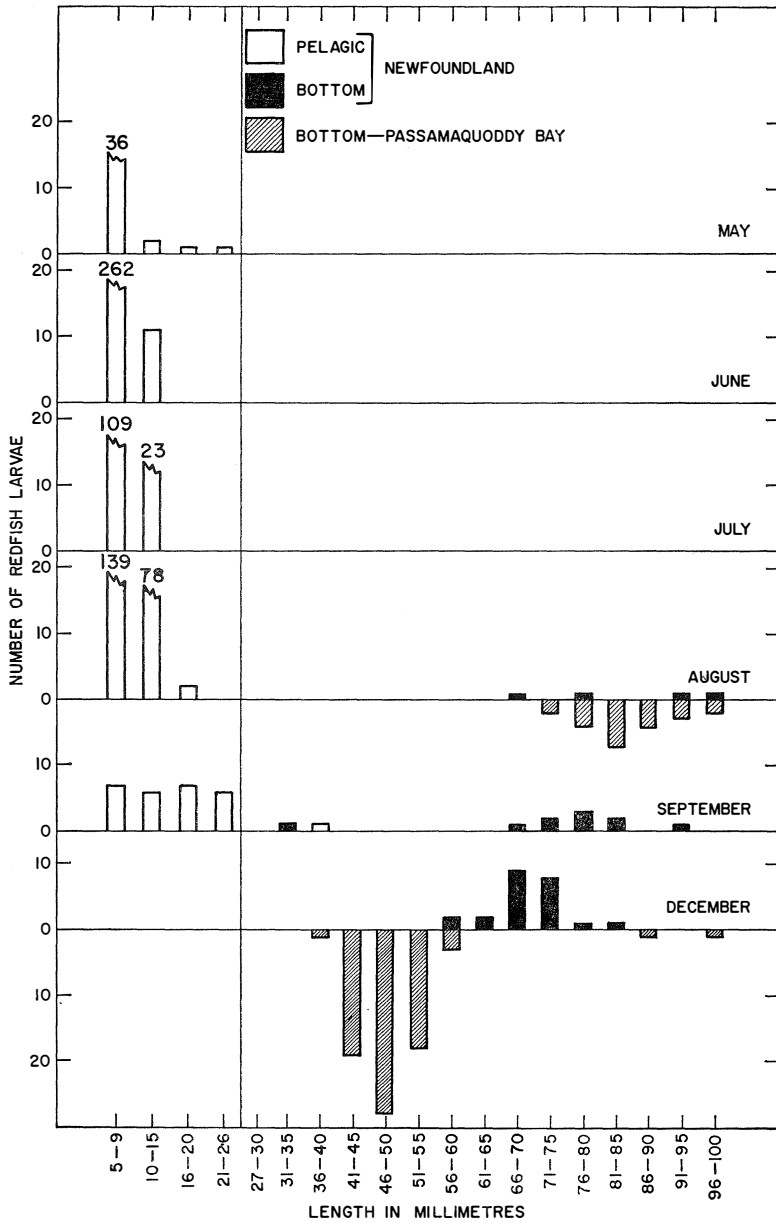


TABLE II.—Length-frequencies of larval and young redfish from the Canadian area.

Length range	Newfoundland area, 1931-1954						Passamaquoddy Bay, N.B., 1953	
	May	June	July	Aug.	Sept.	Dec.	Aug.	Dec.
<i>mm</i>								
5-9.....	36	262	109	139	7			
10-15.....	2	11	23	78	6			
16-20.....	1			2	7			
21-26.....	1				6			
27-30.....								
31-35.....					1			
36-40.....					1			1
41-45.....								19
46-50.....								28
51-55.....								18
56-60.....						2		3
61-65.....						2		
66-70.....				2	1	9	1	
71-75.....					2	8	2	
76-80.....				1	3	1	4	
81-85.....					2	1	7	
86-90.....							4	1
91-95.....				1	1		3	
96-100.....				1			2	1

A. M. Fleming, biologist at the St. John's Station, reports that on Sept. 4, 1947, in the harbour of Englee on the northeast coast of Newfoundland, redfish fry were abundant at the surface. They swam singly, not in schools, and were rather scattered. They were actively pursued by small cod. Many others were seen swimming farther down below the surface. Twelve redfish fry (15 to 21 mm in length, on later examination by the author at the station) were scooped up in a pail, and very much greater numbers could have been captured. They were caught at the surface in the daytime in sunny weather. In this general area the nearest grounds where redfish occur in moderate numbers are almost 100 nautical miles eastward.

Although the greatest amount of towing resulting in the capture of the larvae shown in Fig. 16 was by 2-metre plankton nets, only one redfish larva above 26 mm (37 mm) was captured pelagically in a plankton net or young-fish trawl. Above this size all young redfish captures were by bottom otter trawl with a shrimp-net or stramin cover on the cod-end or by the Agassiz trawl dragged on the bottom. Actually the smallest redfish above 26 mm captured by covered bottom trawl measured 35 mm. It is likely of course that fry of 30 mm in length can evade the plankton net or a small young-fish trawl unless these are towed rapidly. It is evident, however, from the literature already quoted (from Jensen, 1922) and from later experiences related to us by Å. Vedel

Tåning and by P. M. Hansen, that in more northern waters, such as those of Greenland, young redfish up to about 45-50 mm in length are commonly captured in the plankton nets or shown by other records to be pelagic. For example, Tåning (personal communication, March, 1956) says that in the cold water (about 3°C) along the west side of Denmark Strait, using a 2-metre stramin net at a speed of 2 knots in horizontal-oblique hauls in the upper water layers, he has obtained in July to August thousands of 20-45 mm redfish fry. He has never obtained quantities of fry of these large sizes in the warmer water (about 5-6°C) on the east side of Denmark Strait near Iceland, where, however, smaller fry are found in enormous quantities during spring. Considerable numbers of these larger redfish fry are stranded in Southwest Greenland in autumn. Tåning says that in Greenland fjords large quantities of these little redfish drift ashore and Greenlanders often gather large numbers.

In the Canadian area, however, it is likely, on the basis of what evidence is available, that the little redfish of 30 mm and over, although they must be at least intermittently pelagic in deeper water layers, have in the main deserted the surface layers of the sea.

The experience of Bigelow and Schroeder (1953) in the Gulf of Maine is similar to that recorded here in that they have not taken redfish fry larger than 27 mm in their plankton nets, while fry of about 38 mm and upwards are plentiful on the bottom, both in the Bay of Fundy and off southern New England.

Thus, either the fry in the colder areas remain in the surface layers until they reach a larger size, or the chilling in the colder water makes them much less able to evade the plankton nets. Possibly both factors are responsible.

By using a larger net, or by towing faster, larger larvae may, however, be captured in more southern areas. During a cruise of the *Albatross III*, July 25 to Aug. 2, 1957, in the western part of the Gulf of Maine, with G. F. Kelly in charge, 84 tows were made at various depths with an Isaacs-Kidd mid-water trawl rigged as an opening-closing net. Collections of more than 1,000 redfish fry ranging from 12 to 40 mm in length were made at several stations (Anon., 1957a). The greatest numbers were apparently taken at 20 metres (11 fath) during both day and night and very few were taken below 40 metres (22 fath).

Again on a cruise of the *Albatross III*, Sept. 5 to 11, 1957, in the western and central parts of the Gulf of Maine (Anon., 1957b) it was noted that these "young of the year" redfish had settled into deeper water and had grown about 5 mm since the previous cruise.

In the records available to us at present the smallest redfish to be caught in numbers on the bottom are the 36-40 to 56-60 mm group from Passamaquoddy Bay in December, 1953 (Table II).

Goode and Bean (1895) say that redfish fry were caught by the bushel in the trawl net and were eaten on the *Fish Hawk*, cooked after the manner of "whitebait". Bigelow and Schroeder (1953) say that this *Fish Hawk* station was presumably off Cape Cod in 55 fathoms. This record presumably refers to

very small bottom stages since the young redfish were apparently caught at the bottom by beam trawl. If they were not very small, the spines would have interfered with their being eaten whole.

The following information on redfish larvae has been kindly sent by H. Aurich giving a partial report on some of the redfish larval collections by the *Anton Dohrn* in the Iceland-Greenland area in 1955: Vertical hauls were taken; only at a few stations were hauls made at more than one depth range; the number of redfish larvae in a water column of  $\frac{2}{3}$  sq metre (7.2 sq feet) area is given in the following table:

Depth	Number of larvae at stations		
	139	141	168
<i>metres</i>			
25 to 0.....	15	1	...
50 to 0.....	51	1	18
120 to 0.....	38	1	...
700 to 0.....	...	3	2

There is no evidence in this small number of tows that significant numbers of redfish larvae, relative to the numbers above 50 metres, occur in the depths below 50 metres (27 fath).

## COMMERCIAL LANDINGS

### ICNAF AREA

The total landings of redfish by all countries from each subarea of the International Commission for the Northwest Atlantic Fisheries (ICNAF) and the total catch by each country in the whole ICNAF area are shown in Table III for 1916 to 1956 and in Fig. 17 for 1932 to 1956.

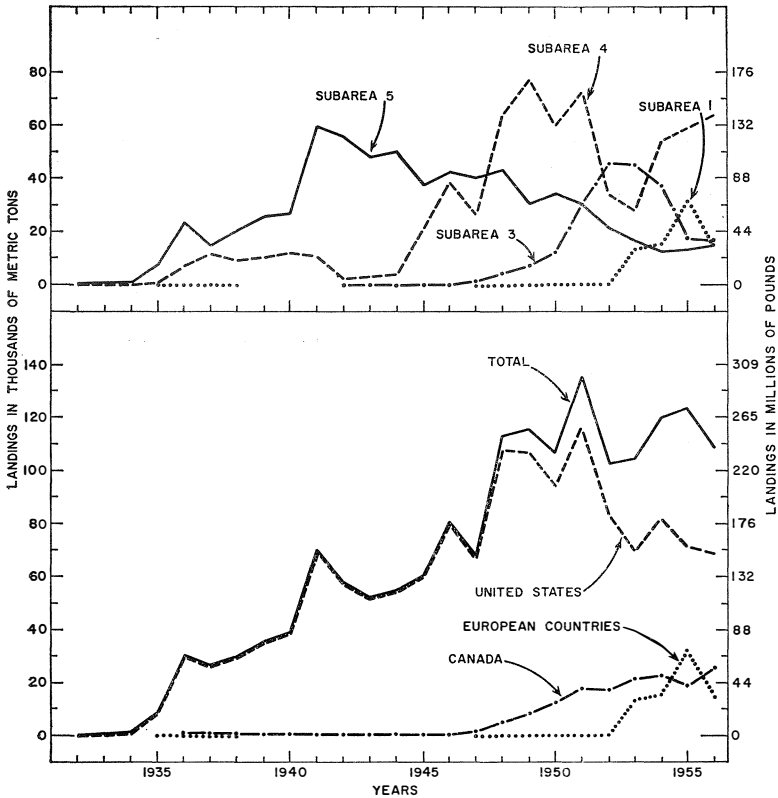


FIGURE 17. Redfish landings from the ICNAF area. (One metric ton = 2204.6 lb.)

Fig. 18 shows the total subarea catch and the percentage of this catch landed by each country in the years 1952 to 1956. For Subareas 3, 4 and 5 the catch is available by subdivision of the subareas in 1954 and 1955, and part of the catch of Subarea 1 has been allotted to subdivisions in 1955 (Fig. 19).

The statistics for Table III and for Fig. 17, 18 and 19 have been taken from ICNAF publications (ICNAF, 1952, 1954-1958).



TABLE III.—Redfish landings (metric tons round fish) from the ICNAF area.—*Cont.*

Year	Total redfish by subarea					Total redfish by country							Total landings	
	1	2	3	4	5	Canada	Denmark	Germany	Iceland	France and Norway	United Kingdom	United States		
1924.....					35								35	35
1923.....					7								7	7
1922.....					14								14	14
1921.....					13								13	13
1920.....					31								31	31
1919.....					25								25	25
1918.....					41								41	41
1917.....					82								82	82
1916.....					53								53	53

Metric ton = 2204.622 lb.

The small disagreement in the total and the sum of sub-totals in 1951 is due to rounding off.

The United States catch for 1951 in the various subareas was supplied by H. W. Graham (personal letter, April, 1955). These are final figures and are somewhat different from the provisional statistics of U.S. catch for 1951 in the ICNAF Statistical Bulletin for 1951 but are similar to the data included in figure 3 of the ICNAF Statistical Bulletin for 1952.

The 300 metric tons for Germany in 1952 are gutted fish and consequently this figure and the corresponding totals are slightly too low.

In the totals for France and Norway the landings in 1953 were entirely by Norway; in 1954 landings were 32 metric tons by France and 3 metric tons by Norway; in 1955 the whole landings of 128 metric tons were by France (St. Pierre and Miquelon) and in 1956 the whole landings of 27 metric tons were by Norway. In 1956 an additional 88 metric tons (not included above or in the text) were taken in Subarea 3 by St. Pierre and Miquelon.

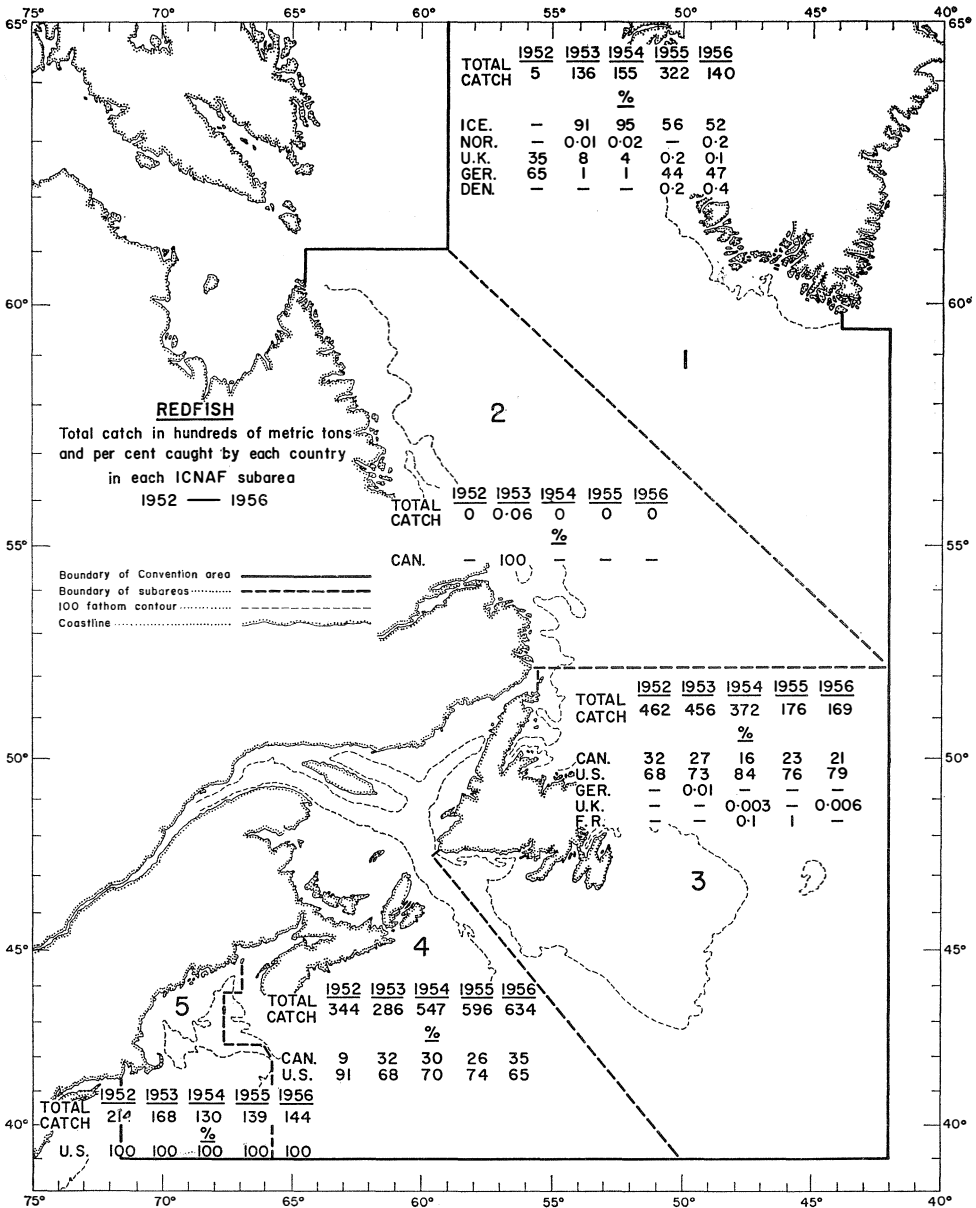


FIGURE 18. Redfish landings from the ICNAF area, by subarea. (One metric ton = 2204.6 lb.)

The redfish fishery in the ICNAF area began as a special fishery in 1935, and until 1948 the United States obtained almost the whole catch. The United States still lands the greatest part of the redfish catch in the area, but since 1948 Canada has taken a significant share.

The redfish fishery began to expand in the New England Subarea (5) in 1935 and the catch was mainly from this subarea until 1945. The whole redfish

catch in Subarea 5 has always been taken by United States vessels. The redfish landings for this subarea reached a maximum of 60,000 metric tons in 1941 and have since shown a gradual decline to 13,000 metric tons in 1954 and to 14,000 metric tons in 1955 and in 1956. In Subarea 5 most of the catch, 89% in 1954 and 80% in 1955, comes from Subarea 5Y, the western section of the Gulf of Maine (Fig. 19).

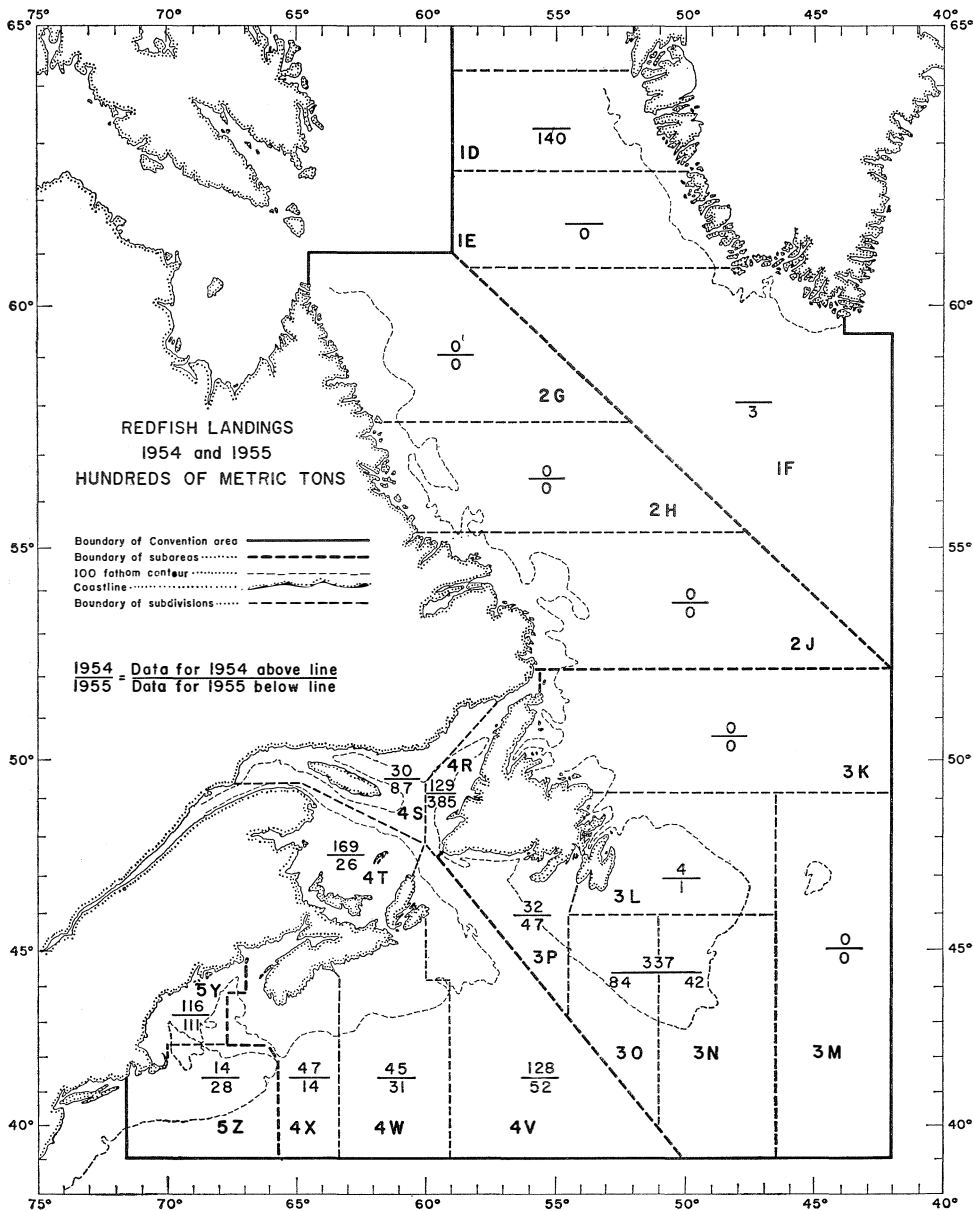


FIGURE 19. Redfish landings from the ICNAF area, by subdivision. (Differences between Fig. 19 and 18 are due to some of the redfish classified by subarea in Fig. 18 not being available by subdivision for representation in Fig. 19. One metric ton = 2204.6 lb.)

By 1936 United States vessels were obtaining significant redfish catches in the Nova Scotian Shelf part of Subarea 4. The redfish catch in this subarea, for a long time almost entirely by United States vessels, gradually increased and since 1948 has invariably exceeded that in Subarea 5. The peak catch in Subarea 4 was 78,000 metric tons in 1949. Although a new commercial redfish fishery began in the Gulf of St. Lawrence part of Subarea 4 late in 1951 the diversion of fishing effort to the rich new Grand Bank grounds of Subarea 3 resulted in a fall in production for Subarea 4. From 1954 to 1956 fishing effort was again diverted from the Grand Bank to the Gulf of St. Lawrence portion of Subarea 4, with the result that the Subarea 4 catch rose to 63,000 metric tons in 1956. By 1954, 60%, and by 1955, 84% of the redfish catch in Subarea 4 was from the Gulf of St. Lawrence. In 1954 important catches were made in Subdivision 4T and 4R of the Gulf of St. Lawrence and in the northern Subdivision 4V of the Nova Scotian Shelf area. In 1955, 65% of the Subarea 4 catch came from Subdivision 4R.

During the past few years, from a beginning in 1947 and 1948, the landings from the Newfoundland Subarea (3) increased rapidly until 1952 to 46,000 metric tons, levelling off in 1953, decreasing in 1954 and falling sharply to 18,000 metric tons in 1955 and to 17,000 metric tons in 1956 as fishing effort was diverted to the Gulf of St. Lawrence. Apart from a catch of 50 metric tons from St. Pierre Bank by the United States in 1948 (Fishery Statistics of the United States for 1948 (1951)), the landings from this area were entirely by Canada until 1950, while more recently the major landings have been by the United States trawlers. In 1954, 90% of the Subarea 3 catch was in Subdivisions 3N and 3O, the southeastern and southwestern portions of the Grand Bank.

In the Labrador Subarea (2) there has been no commercial redfish fishing, apart from 6 metric tons obtained by Canada in 1953. The explorations of the *Investigator II* have shown, however, as early as 1950, that commercial quantities of redfish exist in this subarea, at least on the eastern and southern slopes of Hamilton Inlet Bank.

In the West Greenland Subarea (1) the catch was negligible until 1953 when Iceland caught 12,000 metric tons out of a total catch of 14,000 metric tons. The redfish catch in Subarea 1 in 1955 was 32,000 metric tons, shared almost equally between Iceland and Germany. By 1956 it had fallen again to 14,000 metric tons, due to a diversion of fishing effort to the newly discovered East Greenland grounds.

DETAIL OF UNITED STATES LANDINGS FROM NOVA SCOTIAN AND NEW ENGLAND AREAS. The New England area is fished exclusively and the Nova Scotian Shelf chiefly by the United States. United States data are available on the locations of capture of redfish in small statistical areas adopted in 1939 by the North American Council on Fishery Investigations. These data are redfish landings at certain Massachusetts ports in 1950 to 1954, in the Fishery Statistics of the United States for 1950 to 1954 (1953 to 1956), and the whole United

States landings for 1953 from data supplied by G. F. Kelly (Fig. 20-23). The Massachusetts catches are well distributed and represent 62, 71, 68, 61 and 56% of the United States landings in the years 1950 to 1954 respectively. Almost all the remainder is landed in Maine, and, judging from the Massachusetts and United States redfish distributions in 1953 (Fig. 22), the addition of the Maine catch does not change significantly the distribution of the catch, apart from increasing the proportion obtained from the coastal Maine sections.

In the Gulf of Maine the greatest catches are in the central portion, and, according to Kelly, are in the western or coastward part of the central area in the vicinity of Cashes Ledge where depths are mostly 70 to 120 fathoms. Additionally, good catches are made in the South Channel area (Subareas XXIIG and XXIIH), the deeper water between the shallow water of western Georges Bank and the shoals of Cape Cod. There are significant catches also in the Maine coastal sections, but on Georges Bank and on the northeastern, eastern and southeastern slopes of this bank the redfish catches are insignificant.

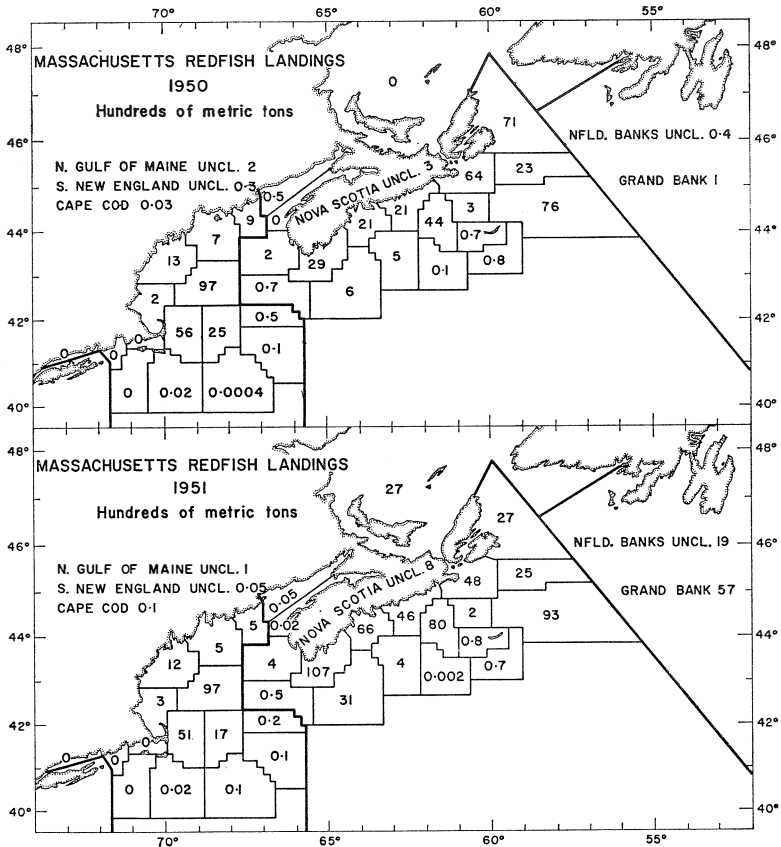


FIGURE 20. Redfish landings at certain Massachusetts ports from the ICNAF area, 1950 and 1951, by small statistical areas. (Uncl. = unclassified.)

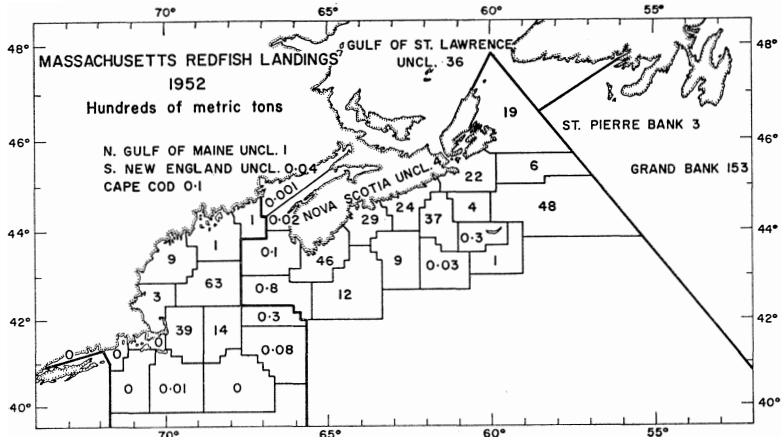


FIGURE 21. Redfish landings at certain Massachusetts ports from the ICNAF area, 1952, by small statistical areas. (Uncl. = unclassified.)

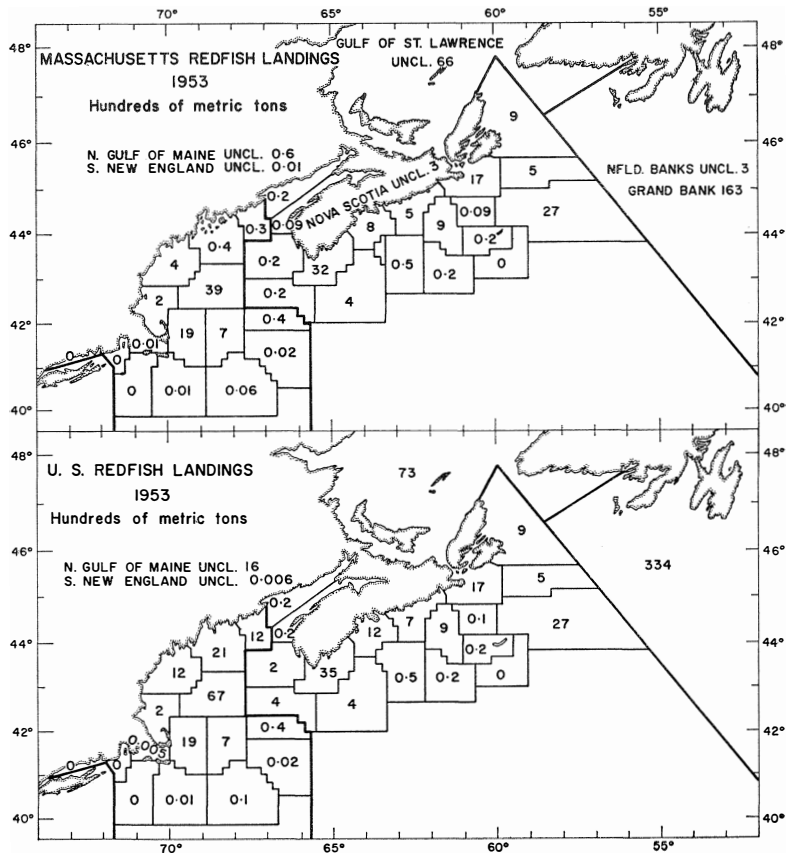


FIGURE 22. Redfish landings at certain Massachusetts ports and in the whole United States from the ICNAF area in 1953 by small statistical areas. (Uncl. = unclassified.)

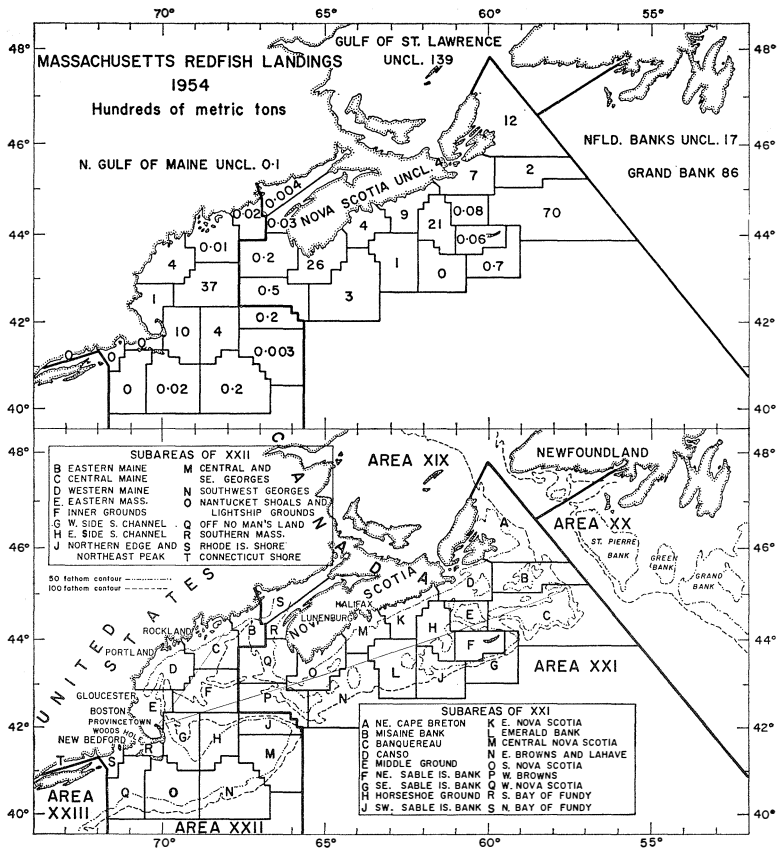


FIGURE 23. Redfish landings at certain Massachusetts ports from the ICNAF area in 1954 by small statistical areas. (Uncl. = unclassified. In the lower section of the figure the statistical areas used for Fig. 20 to 23 are outlined.)

In the Nova Scotian Shelf area, apart from good catches on the northern edge of Banquereau including a small part of the northern edge fringing the Laurentian Channel, and in "The Gully" between Banquereau and Sable Island Bank, the significant catches are generally distributed very much more coastward, where, according to Kelly, most of the redfish are taken in depths between 50 and less than 100 fathoms, rather than seaward near the outer edge of the shelf. For instance, the occasional moderate catch in XXIN (Fig. 20, 1951) is chiefly made near the fringes of the coastward Subarea XXIO, and there has been almost no commercial fishery near the seaward edge of the shelf which in the shallower redfish depths is not at all a good redfish fishing area. Similarly the small catches in XXII are coastward in the depressions and not on the seaward edge of the shelf. In the depressions deeper than 100 fathoms which occur in the shelf the fishing takes place around the edges of the depressions and shoreward rather than seaward. Most of the fishing is not in the depressions but

shoreward and in depths as shallow as 50 fathoms on some trips. On Banquereau, Subarea XXIC, except for the catches in "The Gully", there is very little fishing on the southeast seaward slope of the bank.

LOCATION OF NEWFOUNDLAND REDFISH CATCHES. Figures 24 and 25 show the locations of the redfish catches by Newfoundland commercial trawlers from 1953 to 1956. Redfish landings in Newfoundland were assigned to  $1^{\circ}$ -longitude,  $\frac{1}{2}^{\circ}$ -latitude areas of capture and totalled by 500,000-pound lots. As far as possible the catch symbols are located in the appropriate rectangles, close to the actual depth contours and positions where fishing was carried out.

The 1953 picture is very similar to the general picture of the redfish catches in the southern part of the Newfoundland area by the *Investigator II* in exploratory fishing during 1947 to 1954. Comparatively small landings of redfish were made from the Grand Bank area in 1954 and very small landings in 1955 and 1956, whereas a considerable increase in landings occurred from the northern portion of the deep Esquiman Channel along the west coast of Newfoundland. In 1955 and 1956 the Esquiman Channel provided large catches, with increasing catches in the eastern part of the Mingan Channel north of Anticosti Island, but very little of the catch came from the Laurentian Channel. In all years there was a significant catch in the deep water off the western part of the south coast of Newfoundland.

MONTHLY REDFISH LANDINGS FROM ICNAF AREA. For the whole ICNAF area data on catch per month are not available before 1955. The 1955 data (Fig. 26) indicate that in the area as a whole most of the redfish catch is obtained between June and October. The greatest catch, 27,000 metric tons, was in August and the lowest catch, 3,000 metric tons, in January. In the Greenland area (Subarea 1), presumably because of weather conditions, almost all the catch is taken from July to September. In the Newfoundland region (Subarea 3) and the New England region (Subarea 5) there is a reduction in the catch in the summer months (extending to October in Subarea 3). This is largely due to diversion of a large part of the redfish fleet to Subarea 4 and especially of the Subarea 3 fleet to the Gulf of St. Lawrence part of Subarea 4 during the months from June to October.

Although the shortened period of daylight in winter reduces the fishing hours per day, most of the lowered catch during the winter months in the ICNAF area is due to lack of effort specifically for redfish. In some of the areas such as Greenland and the Gulf of St. Lawrence conditions are not suitable for fishing at this time.

#### ICES AREA

The statistics of redfish catches by the countries of the International Council for the Exploration of the Sea (ICES), for the years 1906 to 1955, have been taken from the *Bulletin Statistique* (ICES), 1909 to 1957.

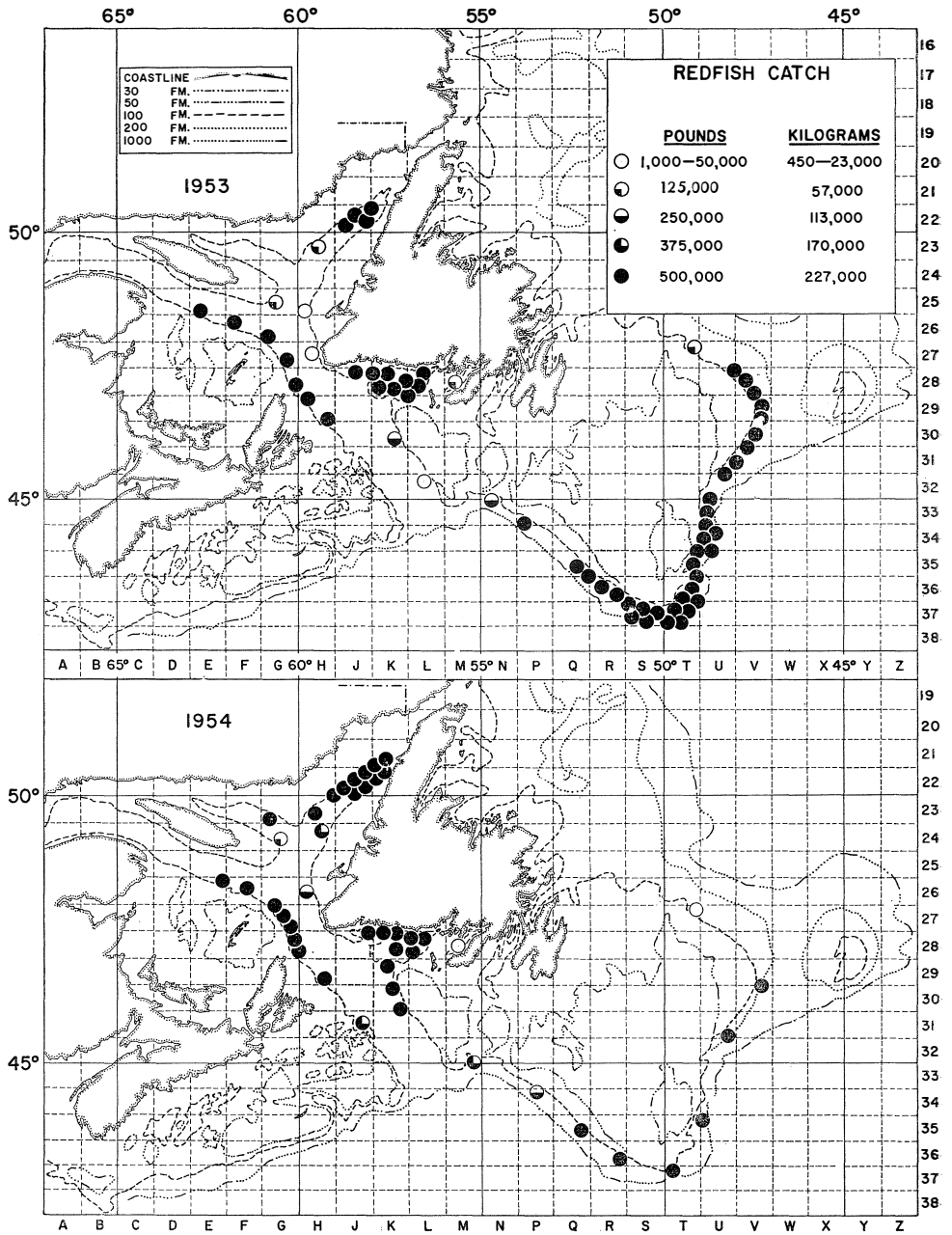


FIGURE 24. Newfoundland redfish catch, 1953 and 1954, by rectangles of 1 degree longitude,  $\frac{1}{2}$  degree latitude.

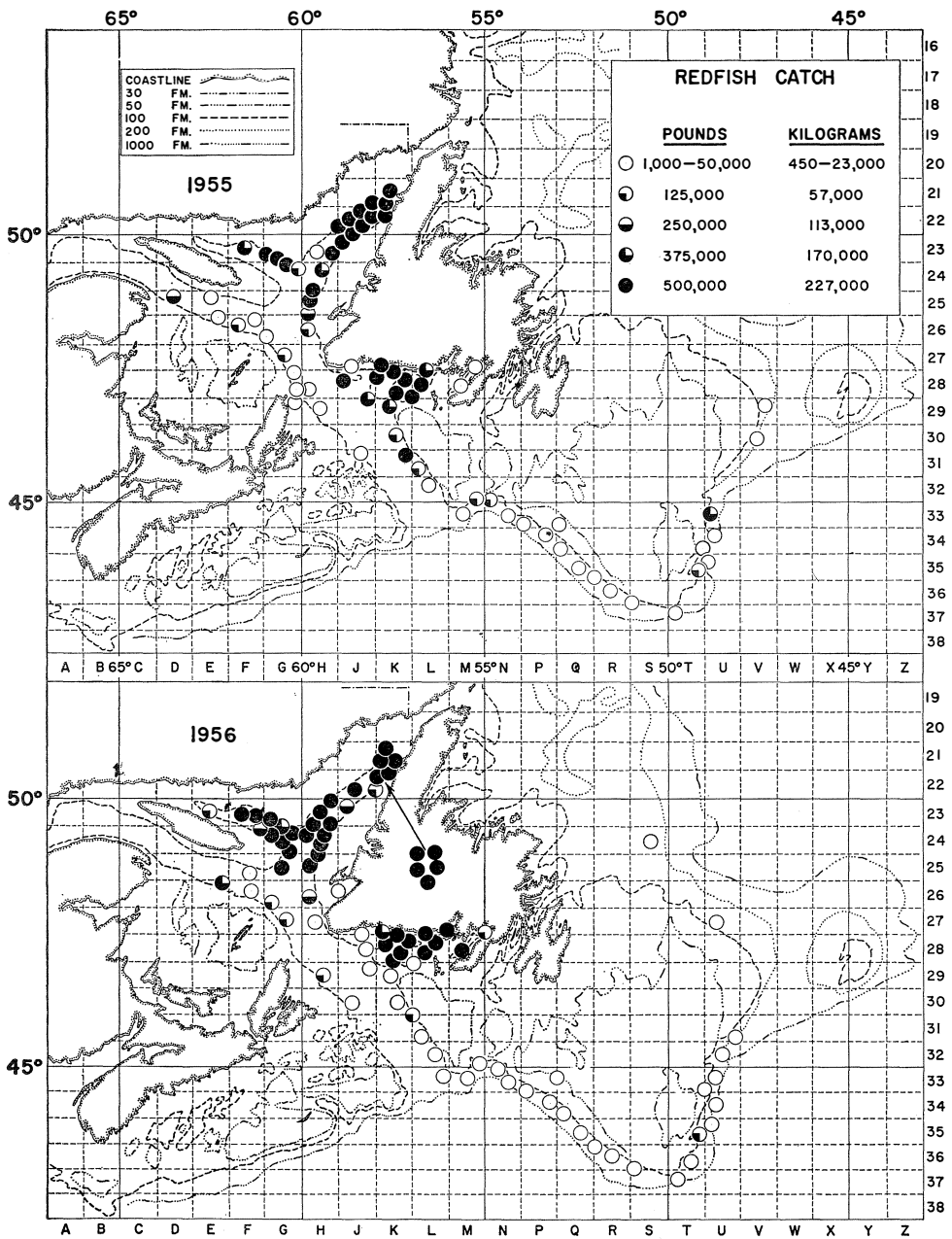


FIGURE 25. Newfoundland redfish catch, 1955 and 1956, by rectangles of 1 degree longitude,  $\frac{1}{2}$  degree latitude.

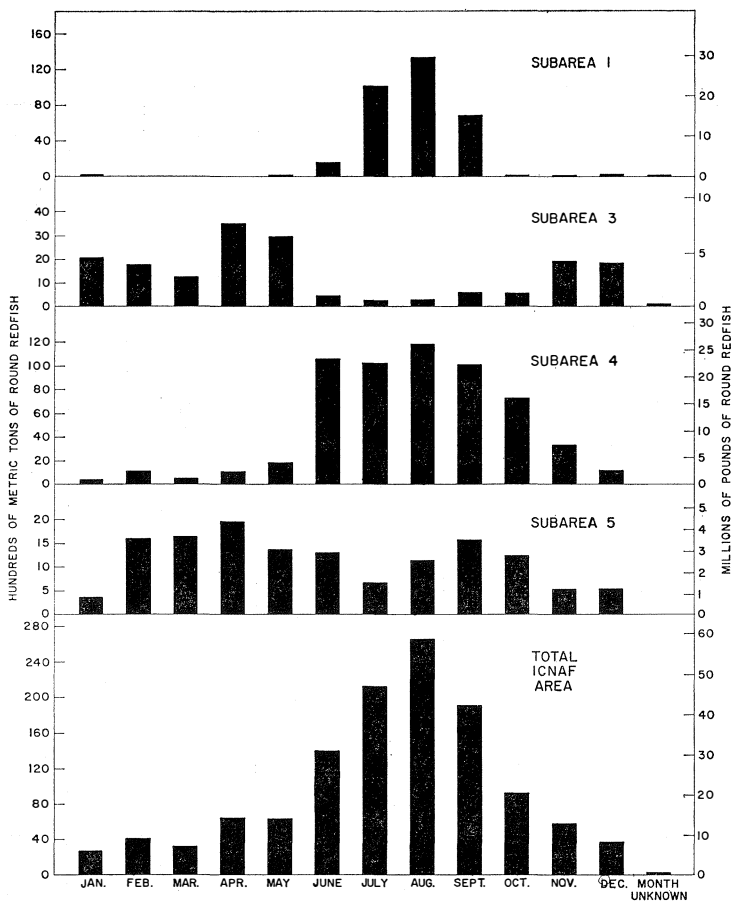


FIGURE 26. Monthly landings of redfish from the ICNAF area and its subareas in 1955.

Fig. 27 and Tables IV and V show the total landings of redfish and the catch in different statistical areas and by various member nations of ICES from 1906 to 1955. The West Greenland and the Newfoundland redfish landings by European vessels are approximately duplicated in both ICNAF and ICES statistics but the amounts are usually too small to affect appreciably the graphs of Fig. 27. (In the years 1953 to 1955 (Table III) the redfish catch in West Greenland was 14,000, 16,000 and 32,000 metric tons respectively; in earlier years catches in West Greenland did not reach 1,000 metric tons in any year.) Statistics of redfish catches by Russian vessels are not included in Tables IV and V but are given later; they are, however, included in Fig. 27. In this figure the Russian catch has been added to the total yearly catch for the ICES area. The Russian redfish catch was reported to ICES for the first time in 1955 and is attributed in the *Bulletin Statistique* entirely to the Barents Sea, Subarea I of ICES. From the Russian description of the redfish fishing areas, given later, it is probable that some of the Russian catches have come from a wider part of

the Barents Sea than is included in ICES Subarea I. Some of these Russian catches may have come from the Spitsbergen—Bear Island Subarea (IIb) or even from the northern part of the Norwegian Subarea (IIa). Since most of the Russian catch doubtless comes from Subareas I and IIb and since the division between these two subareas in relation to redfish in deep water is somewhat artificial, we have combined the catches from the Bear Island and Spitsbergen and Barents Sea subareas in Fig. 27.

Fig. 28 shows the European (ICES) redfish catch by subareas for 1953 to 1955, apart from 5 metric tons in 1953, 1 metric ton in 1954 and 2 metric tons in 1955 reported from the Newfoundland Subarea (XX). In this figure the Russian catches have been attributed to the Barents Sea although as discussed above they may have come in part from neighbouring Subareas IIb and possibly IIa.

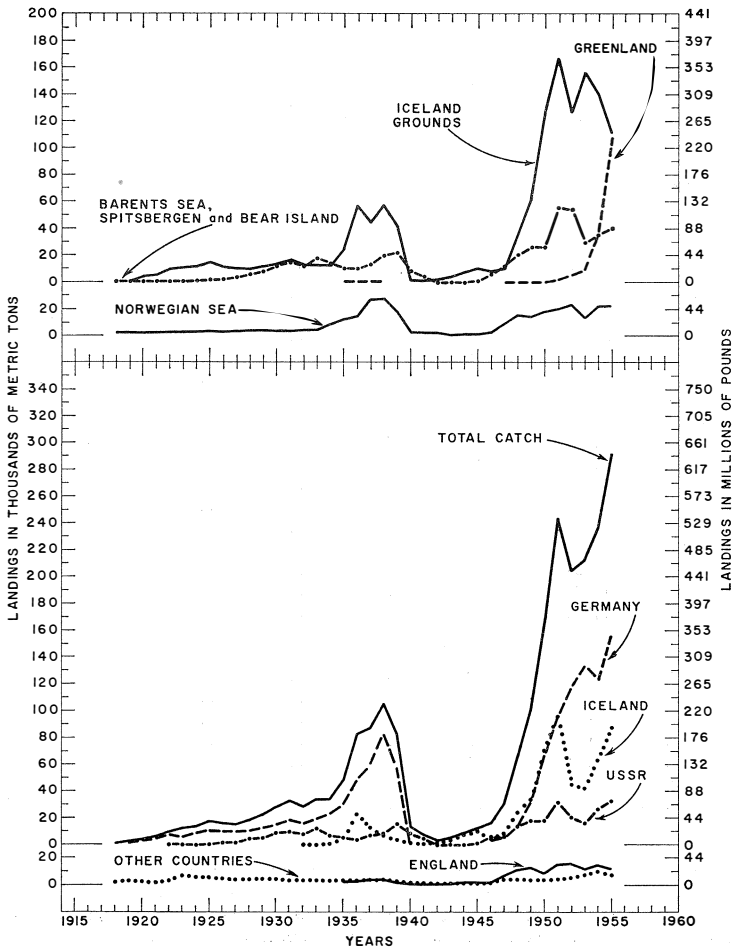


FIGURE 27. Redfish landings by European countries from the ICES area. (One metric ton = 2204.6 lb.)

TABLE IV.—Redfish landings (metric tons

Year	Barents Sea I	Norwegian Sea II a	Spits- bergen Bear Island II b	Kattegat Skagerak III a	Baltic III b	North Sea			Iceland grounds	
						IV a	IV b	IV c	V a1	V a2
1955.....	4,449	22,545	3,473	..	..	41	..	..	110,269	
1954.....	4,611	22,422	4,148	..	..	25	..	..	141,124	
1953.....	7,355	13,440	6,639	..	..	51	..	..	157,488	
1952.....	29,205	23,823	3,142	..	..	32	..	..	126,607	
1951.....	21,852	19,692	3,757	..	..	29	..	..	166,501	
1950.....	6,535	18,140	880	..	..	136	..	..	125,907	
1949.....	6,669	14,286	1,407	..	..	104	..	..	61,108	
1948.....	4,122	14,675	1,198	..	..	83	..	..	4,704	29,198
1947.....	2,008	9,014	3,740	1	..	1	135	..	10,215	
1946.....	560	2,188	825	1	96	..	101	..	8,234	
1945.....	..	552	..	3	..	..	3	..	10,286	
1944.....	9	906	..	2	..	..	5	..	7,283	
1943.....	21	998	..	1	..	..	4	..	3,703	
1942.....	66	1,364	..	..	..	..	7	..	974	
1941.....	85	1,590	..	..	..	..	12	..	662	
1940.....	379	1,879	32	..	..	..	15	..	1,543	
1939.....	1,809	16,488	3,575	..	..	..	236	..	41,210	
1938.....	2,778	26,661	9,734	..	..	..	190	..	57,124	
1937.....	3,974	26,904	3,716	..	..	..	131	..	45,386	
1936.....	2,132	14,369	4,530	..	..	..	137	..	57,634	
1935.....	2,987	11,992	2,713	..	..	..	282	..	24,315	
1934.....	4,512	8,023	3,323	..	..	..	116	..	11,621	
1933.....	3,629	2,693	3,267	1	..	..	82	..	12,630	
1932.....	1,439	2,868	1,797	..	..	..	175	..	13,721	
1931.....	2,191	2,769	1,279	..	..	..	75	..	16,233	
1930.....	2,201	2,868	773	..	..	..	98	..	13,678	
1929.....	1,937	3,346	200	..	..	..	101	..	11,432	
1928.....	1,336	3,241	377	..	..	..	266	..	8,823	
1927.....	1,810	2,522	134	..	..	..	153	..	9,103	
1926.....	1,017	2,077	97	..	..	..	212	..	10,491	
1925.....	114	2,497	105	..	..	..	134	..	14,222	
1924.....	..	2,114	94	..	..	..	109	..	11,677	
1923.....	..	1,777	160	7	..	..	134	..	10,284	
1922.....	..	1,390	78	7	..	..	145	..	8,955	
1921.....	..	1,742	91	6	..	..	74	..	4,170	
1920.....	..	1,129	36	7	..	..	54	..	3,252	
1919.....	..	1,370	137	4	..	..	39	..	625	
1918.....	..	888	222	..	..	..	4	..	..	
1917.....	..	1,024	131	..	..	..	4	..	..	
1916.....	..	1,134	325	..	..	..	5	..	12	
1915.....	..	1,251	61	2	..	..	8	..	8	
1914.....	..	1,083	59	19	..	..	45	..	1,331	
1913.....	20	735	79	32	..	..	66	..	2,156	
1912.....	8	941	70	20	..	..	260	..	1,833	
1911.....	..	927	78	19	..	..	156	..	2,924	
1910.....	..	933	92	23	..	..	104	..	2,729	
1909.....	..	978	25	18	..	..	..	..	1,584	
1908.....	..	584	68	..	..	..	..	..	925	
1907.....	..	..	..	..	..	..	..	..	1,190	
1906.....	..	..	..	..	..	..	..	..	412	

From 1908 to 1928 small amounts of redfish were recorded from the Polar Sea. These amounts have been transferred to the Spitsbergen, Bear Island column for which there were no records in these years. Eight metric tons recorded for the White Sea in 1912 have been transferred to the Barents Sea Column.

1 metric ton = 2204.622 pounds.

round fish) by ICES countries by subareas.

Faroese grounds V b	NW coast Scotland N. Ireland VI a	Irish Sea Br. Channel VII a,f	W. coast Ireland VII b,c	English Channel VII d,e	S. coast Ireland VII g,k	Green- land XIV- XV	Nfld. XX	Not accounted for by area	Total
10,173	..	..	..	..	..	111,122	2	..	262,074
2,203	2	1	..	..	..	36,409	1	..	210,946
155	..	..	..	..	..	10,970	5	..	196,103
30	4	5	..	..	..	595	..	..	183,443
93	3	..	..	..	1	246	..	22	212,196
4	..	..	..	..	..	3	..	1,901	153,506
5	3	..	..	..	..	71	..	682	84,335
5	19	..	..	..	..	101	2	7	54,114
19	10	..	..	..	..	1	..	..	25,144
4	..	..	..	..	..	..	..	1	12,010
..	..	..	..	..	..	..	..	1,018	11,862
..	..	..	..	..	..	..	..	1,261	9,466
..	..	..	..	..	..	..	..	621	5,348
..	..	..	..	..	..	..	..	490	2,901
..	..	..	..	..	..	..	..	413	2,762
..	..	..	..	..	..	..	..	624	4,472
..	..	..	..	..	..	..	..	2,570	65,888
27	8	..	4	3	6	23	..	478	97,036
41	7	..	3	..	1	50	..	770	80,983
40	13	..	4	..	4	16	..	141	79,020
46	22	..	8	..	2	31	..	8	42,406
..	..	..	..	1	..	..	..	1	27,597
..	9	..	..	..	..	..	..	7	22,318
..	..	..	..	3	1	..	..	..	20,004
..	..	..	..	..	..	..	..	8	22,555
..	..	..	..	..	..	..	..	8	19,626
..	..	..	..	..	..	..	..	5	17,021
..	..	..	..	..	..	..	..	6	14,049
..	..	..	..	..	..	..	..	6	13,728
..	..	..	..	..	..	..	..	13	13,907
..	..	..	..	..	..	..	..	9	17,081
..	..	..	..	..	..	..	..	40	14,034
..	..	..	..	..	..	..	..	17	12,379
..	..	..	..	..	..	..	..	53	10,628
..	..	..	..	..	..	..	..	9	6,092
..	..	..	..	..	..	..	..	13	4,491
..	..	..	..	..	..	..	..	1	2,176
..	..	..	..	..	..	..	..	1	1,115
..	..	..	..	..	..	..	..	..	1,159
..	..	..	..	..	..	..	..	1	1,477
1	..	..	..	..	..	..	..	..	1,331
..	..	..	..	..	..	..	..	1	2,538
..	..	..	..	..	..	..	..	2	3,090
..	..	..	..	..	..	..	..	..	3,132
..	..	..	..	..	..	..	..	4	4,108
..	..	..	..	..	..	..	..	28	3,909
..	..	..	..	..	..	..	..	191	2,796
..	..	..	..	..	..	..	..	339	1,916
..	..	..	..	..	..	..	..	13	1,203
..	..	..	..	..	..	..	..	246	658

TABLE V.—Redfish landings (metric tons round fish) by country for the ICES area.

Year	Belgium	Denmark	England	Finland	Germany	Holland	Iceland	Norway	Poland	Scotland	Sweden	Total
1955	850	66	12,003		155,091	2	87,183	6,836		43		262,074
1954	826		14,203		122,809	30	64,476	8,530		72		210,946
1953	845		11,804		133,924		42,645	6,787		98		196,103
1952	782		15,874		117,906	18	44,337	4,381		145		183,443
1951	940	9	15,108		95,001	91	97,277	3,411		359		212,196
1950	606		8,994		67,088	29	72,897	3,892				153,506
1949	502		12,499		34,544	51	33,514	3,225				84,335
1948	521		10,599		14,388	15	25,120	3,471				54,114
1947	191		6,015		7,361	1	8,226	3,350				25,144
1946	40		1,900		3,751	4	4,245	2,070				12,010
1945			1,018				10,286	558				11,862
1944			1,261				7,283	922				9,466
1943			621				3,703	1,024				5,348
1942			490				974	1,437				2,901
1941			413				662	1,687				2,762
1940			624		388	3	1,543	1,914				4,472
1939	469		1,843		57,434	15	3,519	2,608				65,888
1938	564		3,763		83,824	61	6,120	2,704				97,036
1937	446		3,931	38	61,561	23	12,150	2,831	3			80,983
1936	299		2,774		49,554	29	23,053	3,311				79,020
1935	275		2,851		31,732	80	4,002	3,466				42,406
1934	234				23,401	49	607	3,306				27,597
1933	270				19,146	7	15	2,880				22,318
1932	346				16,162	66	357	3,073				20,004
1931	336				18,703	22		3,489			5	22,555
1930	388				15,245	12		3,978			3	19,626
1929	381				12,902	12		3,726				17,021
1928					10,404	13		3,632				14,049
1927					9,641	49		2,687		1,351		13,728
1926					9,730	68		2,189		1,920		13,907
1925					10,997	33		2,618		3,433		17,081
1924					8,510	21		2,217		3,286		14,034
1923					5,533	48		1,949		4,849		12,379
1922					7,604	40		1,490		1,494		10,628
1921					4,172	66		1,851		3		6,092
1920					3,303	9		1,179				4,491

1919.....					657			1,519			2,176
1918.....								1,115			1,115
1917.....								1,159			1,159
1916.....						11		1,465	1		1,477
1915.....					2	4		1,319	6		1,331
1914.....					975	8		1,157	398		2,538
1913.....					1,816	11		833	430		3,090
1912.....					1,666	1		1,249	216		3,132
1911.....					2,680	6		1,144	278		4,108
1910.....					2,778			1,131			3,909
1909.....					1,618			1,178			2,796
1908.....					1,125			791			1,916
1907.....					1,200	3					1,203
1906.....					658						658

A few minor differences in the original totals for Tables IV and V in the original ICES figures in Bulletin Statistique were resolved by accepting the totals in Bulletin Statistique by country by area for use in both tables. Statistics estimated for Iceland and Poland for 1938 were corrected in Bulletin Statistique for 1939. In Bulletin Statistique for 1932 the Norwegian statistics for 1929, 1930 and 1931 were corrected. Denmark, 1955 = Greenland.

1 metric ton = 2204.622 pounds.



Year	Redfish landings USSR	Year	Redfish landings USSR
	<i>metric tons</i>		<i>metric tons</i>
1922.....	100	1939.....	15,890
1923.....	50	1940.....	8,460
1924.....	130	1941.....	4,730
1925.....	720	1942.....	10
1926.....	1,810	1943.....	10
1927.....	990	1944.....	60
1928.....	4,530	1945.....	1,160
1929.....	5,570	1946.....	4,980
1930.....	8,750	1947.....	6,880
1931.....	10,230	1948.....	14,460
1932.....	8,030	1949.....	17,840
1933.....	11,680	1950.....	18,390
1934.....	6,640	1951.....	31,070
1935.....	5,090	1952.....	21,240
1936.....	4,150	1953.....	16,340
1937.....	6,990	1954.....	26,380
1938.....	8,310	1955.....	31,566

of the redfish were taken in the southwestern part of the Barents Sea, mainly off the north coast of Norway. The years 1928 to 1933 are exceptions; in these years a significant part of the catch was taken from Bear Island. From 1953 onward, catches of redfish in the southern part of the Barents Sea fell off sharply and the principal redfish region became the relatively deep channel ("Bear" or "Western") which falls off to the westward in the Barents Sea. This region can be considered as belonging to the Bear Island-Spitsbergen region. Travin says that the Russian landings of redfish are not the result of a special fishery but that redfish are taken as an incidental species in the fishery for gadoid fishes.

*Bulletin Statistique* (1957) attributes the whole Russian catch of redfish for 1955 to the Barents Sea statistical Subarea (I).

Information from FAO indicates that since the war, as in the pre-war period, redfish catches by Poland have been negligible.

In the following description of redfish landings from the ICES area the Russian catches are included. Only small amounts of redfish were landed before 1920, and the catch increased gradually from 2,000 metric tons in 1919 to 33,000 metric tons in 1931. The redfish landings increased rapidly to a peak of 105,000 metric tons in 1938. By this time almost all the catch was taken by Germany, and when World War II began the landings dropped precipitously to 13,000 metric tons in 1940, 7,000 metric tons in 1941 and to a low point of 3,000 metric tons in 1942. After the war the total catch rose rapidly to a new peak of 243,000 metric tons in 1951. There was a small decline to 205,000 metric tons in 1952 due to a decrease in the Icelandic catch, but in 1954 the catch rose to 237,000 metric tons and in 1955 to 294,000 metric tons.

Since the second world war the Icelandic redfish landings, which were of some importance in the immediate pre-war period, increased rapidly, and remained slightly above the German catch until 1951. After 1951 the German catch rose rapidly as new trawlers came into use, and the Icelandic catch declined temporarily as the effort of the Icelandic trawlers was apparently directed toward other groundfish. The redfish catches by the USSR and to a lesser extent those by England and Norway have also shown some increases in recent years.

The Icelandic grounds and more particularly those to the south and west of Iceland have been by far the most important redfish area, with a peak catch of 167,000 metric tons in 1951. Next in importance have been the Barents Sea, Spitsbergen and Bear Island area and the Norwegian Sea. In recent years, with the increase in the Russian fishery, the Barents Sea, Spitsbergen and Bear Island area has increased in importance. The most phenomenal increase, however, has occurred in redfish landings from the Greenland area and particularly from East Greenland following the explorations of the German research vessel, the *Anton Dohrn*, in 1955. Up to and including 1952 the yearly redfish landings from Greenland had always been less than 1,000 metric tons. After 1952 an increasing effort was directed toward the redfish grounds in this area. Consequently, the redfish landings from the Icelandic grounds were somewhat less in 1955, 110,000 metric tons compared with 111,000 metric tons from the Greenland area.

Redfish landings from other ICES areas are negligible.

## INVESTIGATOR II EXPLORATIONS IN NEWFOUNDLAND AND NEIGHBOURING AREAS

### INTRODUCTION

From 1946 until the present time the Fisheries Research Board of Canada's vessel *Investigator II* (Fig. 29) has carried out exploratory and experimental fishing with the St. John's Station as a base. Since 1947 some of the effort has been in deep water, specifically for redfish. The fishing method has been otter-trawling. The ship is 82 feet in overall length, 22 feet wide, 10 feet deep and 124 gross-tons. She is a Pacific Coast purse-seine type vessel with the house forward. She was built at the Clarenville shipyards, Newfoundland, in 1946, and made her first cruise on April 27, 1946. The engine is a 250 h.p. heavy-duty Atlas. The winch is a Pacific Coast "Northern Dragger" type, mechanically operated from the main engine. The ship is equipped with a Marconi radar and radio telephone, a direction finder and a Sperry Loran, the Loran being in operation since the first trip of 1950. The Loran positions are often checked by Station personnel in addition to the captain. The positions can be regarded as very accurate since 1950 and fairly accurate before that time. The net since 1947 has been a No. 36 manila otter trawl with a 60-foot head-rope and an 80-foot foot-rope. Otter doors are 800 pounds each and  $7\frac{1}{2} \times 3\frac{3}{4}$  feet. The wire warp on each drum is  $\frac{5}{8}$  inch in diameter and 450 fathoms long. Bridles between

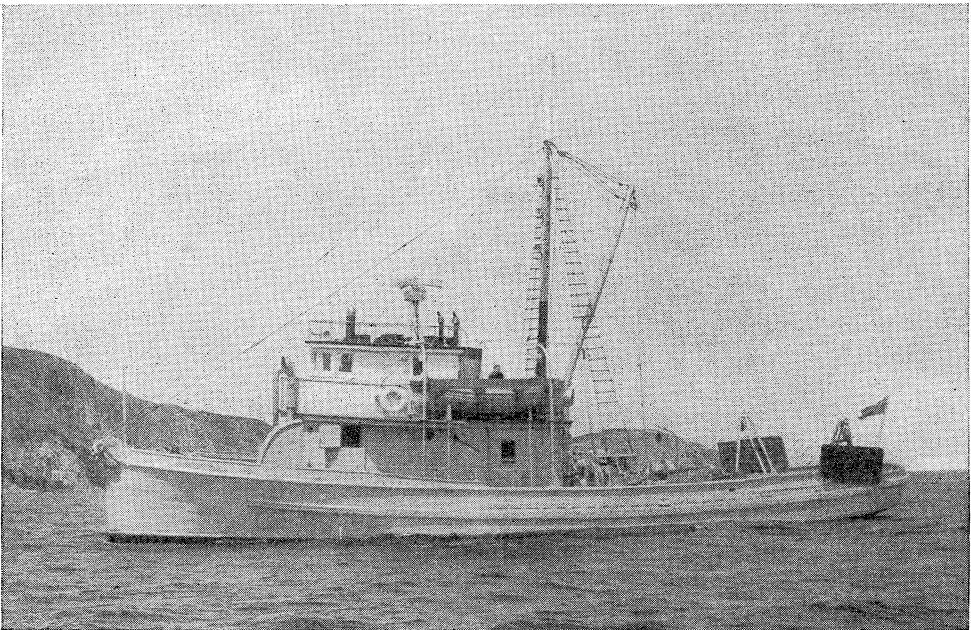


FIGURE 29. The *Investigator II* (just outside the entrance to St. John's Harbour).

the doors and net are 30 fathoms in length. The net is operated over the stern from two stern gallows. The speed when dragging is approximately 4 knots.

The net operates efficiently to a depth of about 180 fathoms. It often fishes effectively at 200 fathoms but sometimes, when there is considerable wind or current, it does not operate efficiently at this depth.

Fig. 30 to 34 show, for all successful drags of the *Investigator II* with the No. 36 net, to a depth of 200 fathoms, 1947 to 1954, the amount of dragging and the resulting redfish catches per hour's drag. A few trips using smaller nets and fishing down to 400 fathoms are not included here but are discussed elsewhere in this paper. Sets not included are those in which the net or the cod-end was lost, sets in which the cod-end was ripped, those in which the warps were twisted or the net was not on bottom, or other sets in which the fishing operation was so seriously interfered with that normal results could not be expected. All drags included were bottom drags for groundfish.

From 1947-49 the time dragging on bottom was usually one hour but in 1950-54 the dragging time on bottom has been a half-hour and in these cases the amounts caught have been doubled for use in Fig. 30 to 34 and in the tables of *Investigator II* catches. Redfish catches for each set were measured in tubs of standard size and a conversion factor to pounds was developed by a large number of test weighings.

All successful drags have been included in the figures, whether resulting from random explorations or from effort specifically directed either toward redfish or toward other groundfishes.

Although in Fig. 32 all data have been included so as to show the fringe or bank areas where redfish are lacking, it is realized that, by using the method of averaging by rectangles, the quantities of redfish evident in the slope areas are reduced by the absence or scarcity of redfish in the shallower parts of the same rectangle. Thus in Fig. 33 data have been included only from drags of 110 fathoms and deeper from Long. 50°W at the southern tip of the Grand Bank westward toward the Laurentian Channel and into the Gulf of St. Lawrence, and of 160 fathoms and deeper from Long. 50°W eastward, and northward along the eastern slope of the Grand Bank, Flemish Cap, the east coast of Newfoundland and off Labrador. As will be seen by Table XVII these depths correspond approximately with the usual occurrence of quantities of redfish in the two areas.

#### REDFISH DISTRIBUTION FROM INVESTIGATOR II CATCHES, 1947 TO 1954

Figure 32 indicates that redfish are absent on Hamilton Inlet Bank, the true bank areas of the Grand Bank and St. Pierre Bank, in the coastal areas between these banks and the Avalon and Burin Peninsulas, and in the Magdalen Shallows in the southern part of the Gulf of St. Lawrence. On the east coast of Newfoundland they are present in small numbers in Trinity Bay and in some of the deep-water arms of Notre Dame Bay. They are present in the depressions greater than a hundred fathoms in the Nova Scotian Shelf area and also in

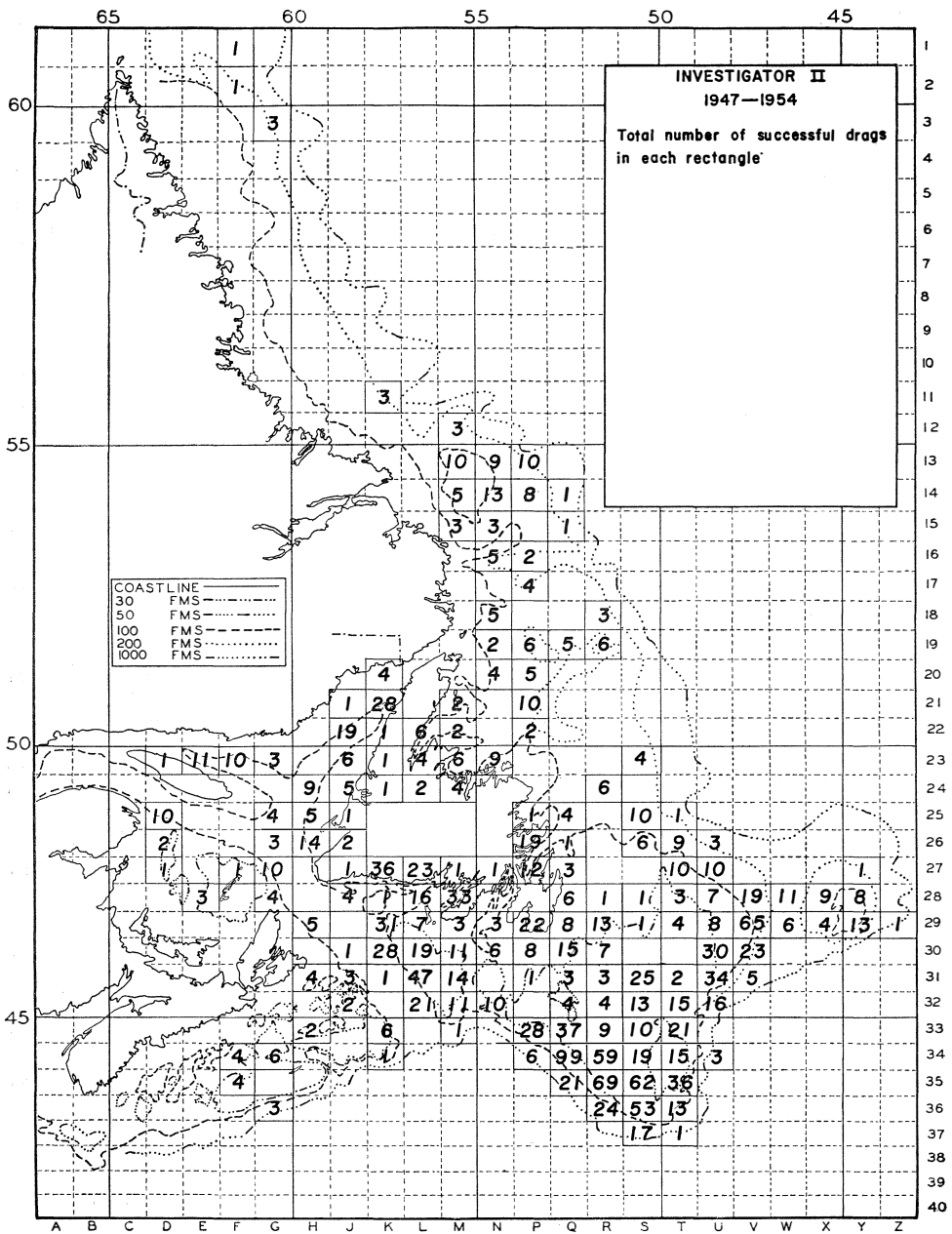


FIGURE 30. Total number of successful drags by the *Investigator II* in each rectangle during 1947 to 1954.

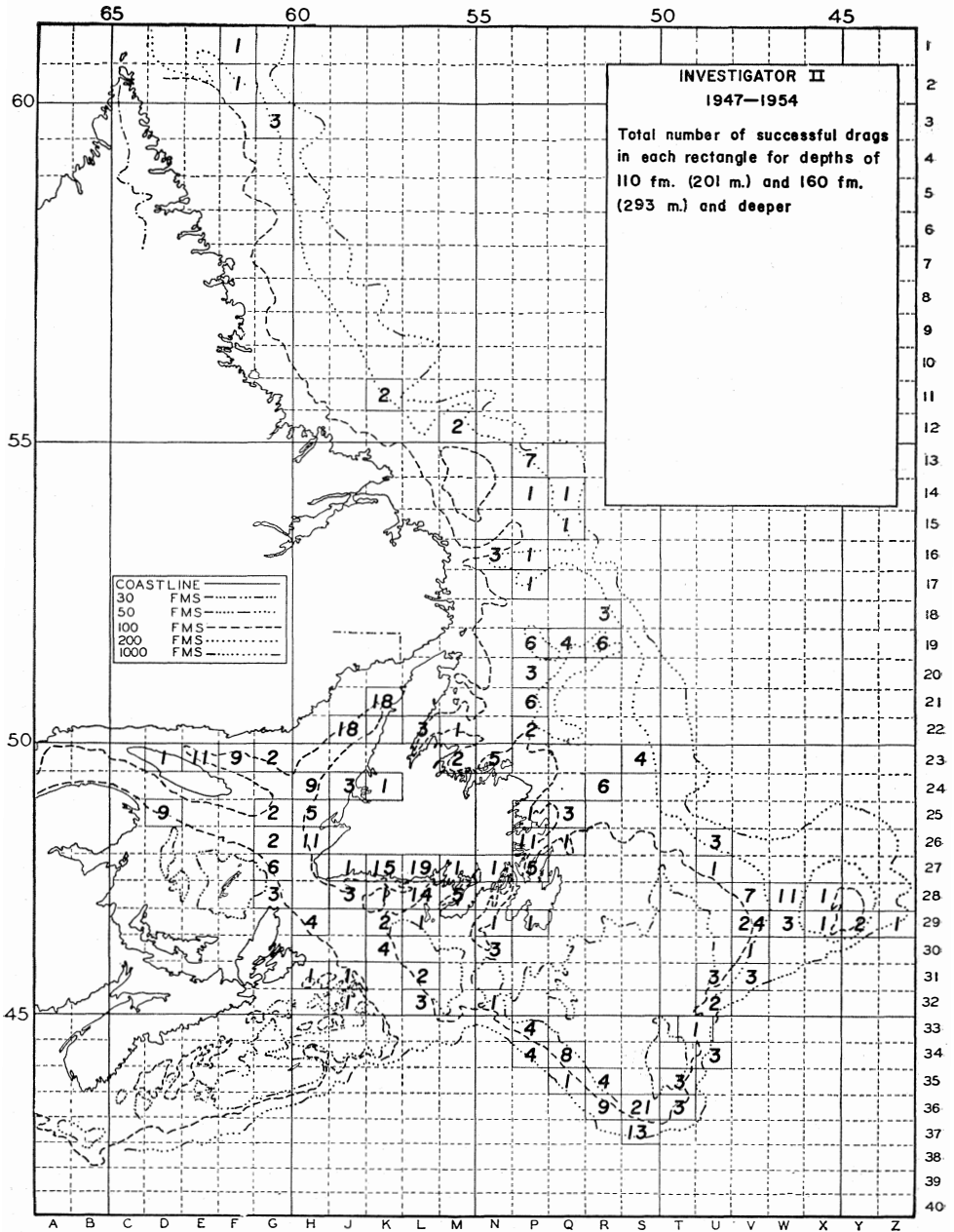


FIGURE 31. Number of successful drags by the *Investigator II* in each rectangle during 1947 to 1954, in 160 to 200 fathoms east of longitude 50°W along the eastern Grand Bank and north of the Grand Bank and east of Newfoundland and Labrador; and in 110 to 200 fathoms west of longitude 50°W along the southern and western slopes of the Grand Bank and St. Pierre Bank, the western part of the south coast of Newfoundland, the Gulf of St. Lawrence and the Nova Scotian banks.

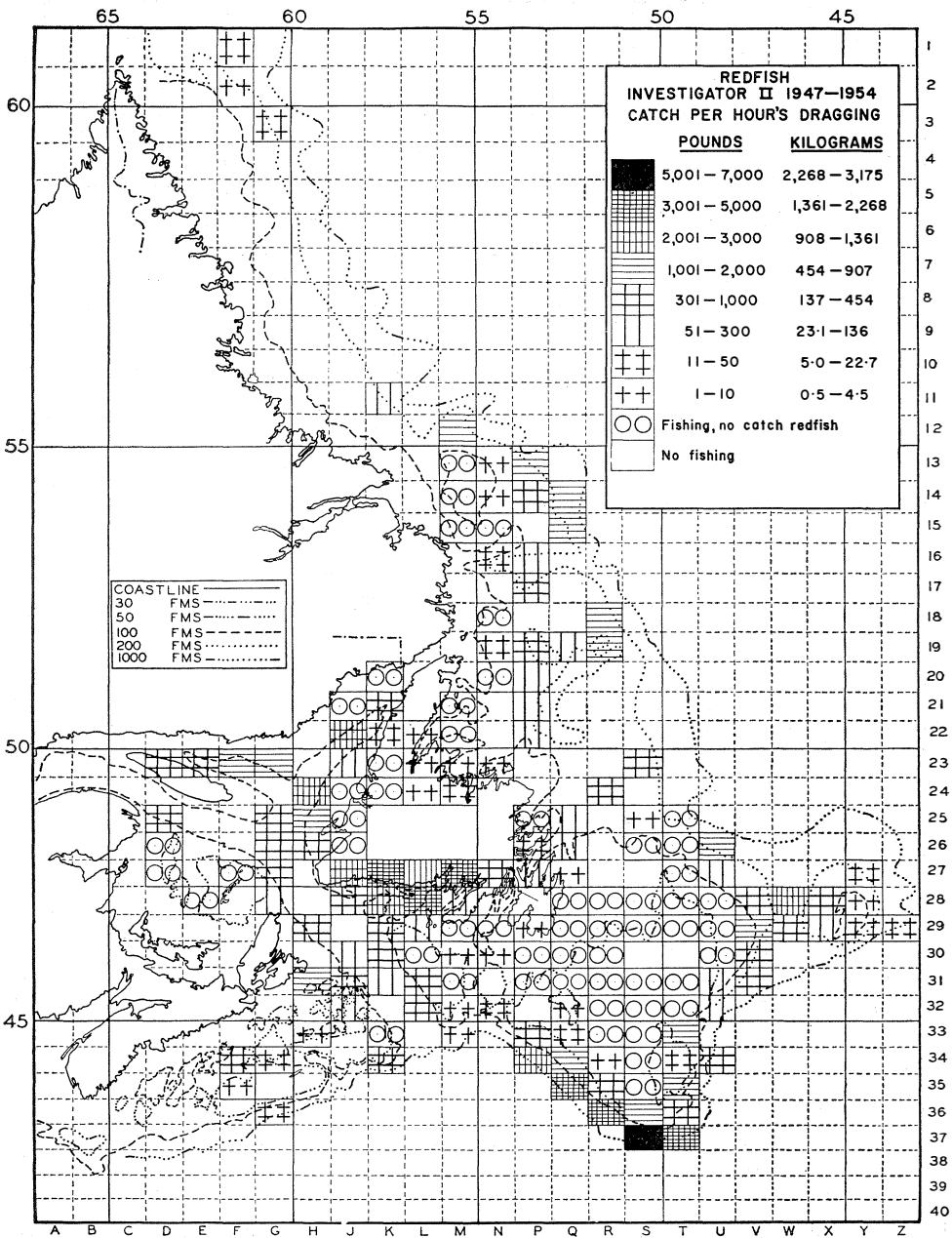


FIGURE 32. Average redfish catches, per hour's dragging in each rectangle, by the *Investigator II*, 1947 to 1954.

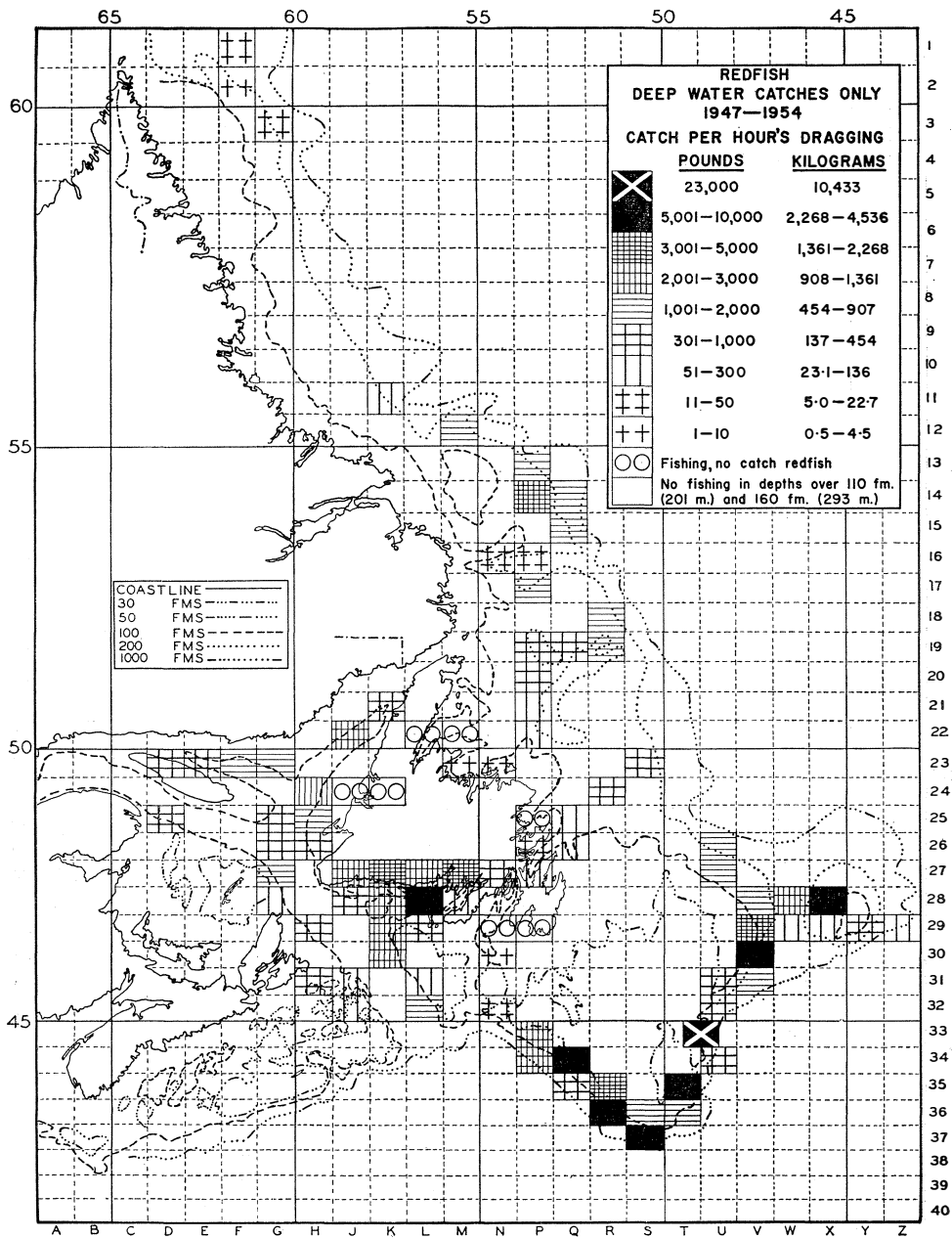


FIGURE 33. Average redfish catches, per hour's dragging in each rectangle by the *Investigator II* during 1947 to 1954, in 160 to 200 fathoms east of longitude 50°W along the eastern Grand Bank, and north of the Grand Bank and east of Newfoundland and Labrador; and in 110 to 200 fathoms west of longitude 50°W along the southern and western slopes of the Grand Bank and St. Pierre Bank, the western part of the south coast of Newfoundland, the Gulf of St. Lawrence and the Nova Scotian banks.

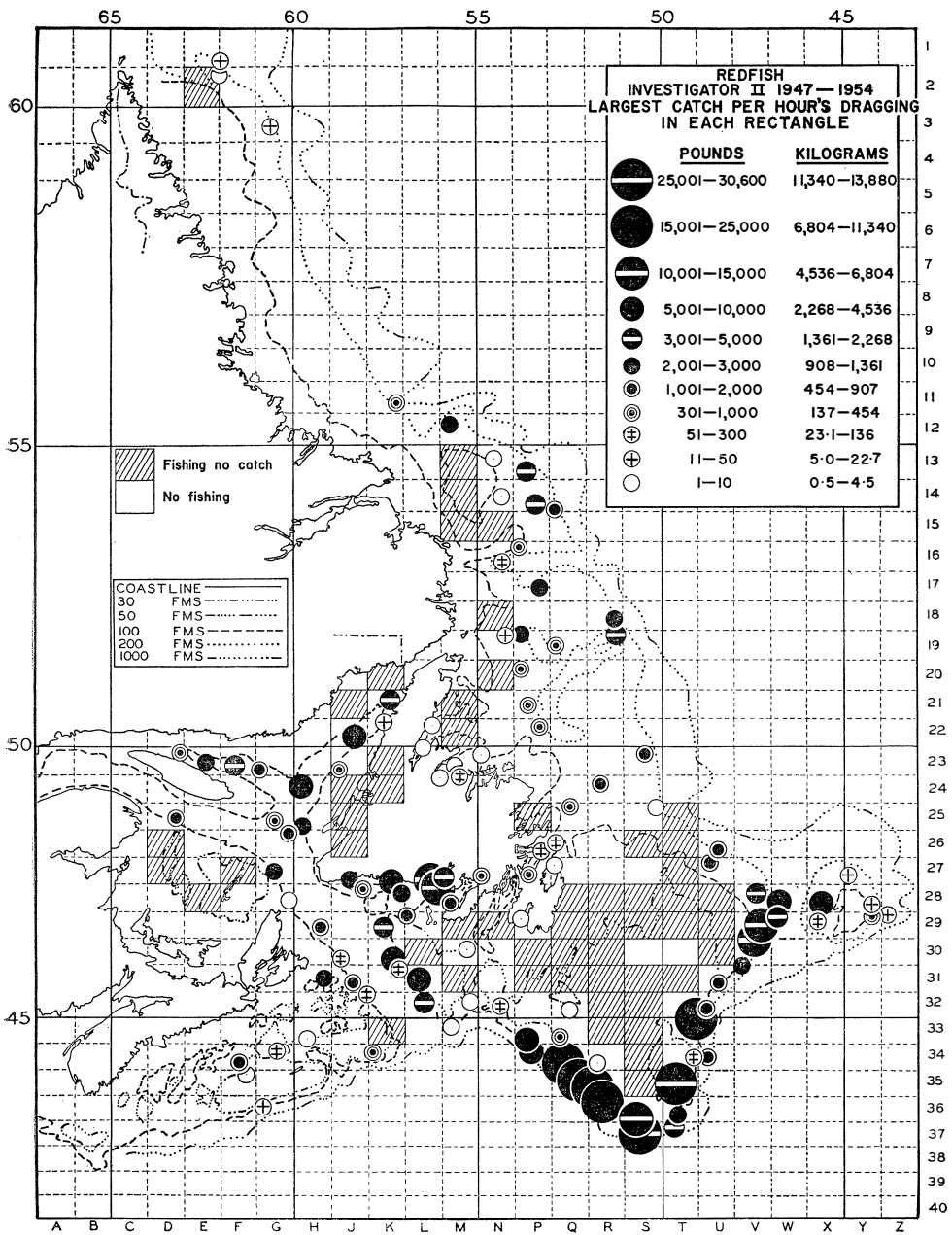


FIGURE 34. Greatest catch of redfish per rectangle, per hour's dragging by the *Investigator II*, 1947 to 1954.

water less than a hundred fathoms deep between the banks and the coast in this area. A few redfish were obtained as far north as off Cape Chidley in Labrador.

Since the results in Fig. 32 are diluted by many tows at depths where redfish are not to be expected, the relative quantities of redfish in the various areas can be seen best from Fig. 33 in which shallower depths, that usually have few redfish, are omitted. While in many of the areas shown in this figure the number of drags is low, it is obvious that the greatest catches per hour's dragging were taken around the southwestern and eastern slopes of the Grand Bank and on the western part of the south coast of Newfoundland. Good catches were also obtained in the deep Esquiman Channel along the west coast of Newfoundland, on the northwest slope of St. Pierre Bank and east of Hamilton Inlet Bank in Labrador. An excellent catch in one drag was taken west of Flemish Cap. There were also moderately good catches north of Anticosti, north of Hamilton Inlet Bank, on the western edge of St. Pierre Bank, and also considering the small net and moderate power of the vessel, in the Laurentian Channel north of the Magdalen Islands in the Gulf of St. Lawrence, north of the Grand Bank and east of the Strait of Belle Isle.

Fig. 34 shows the largest *Investigator II* catches per hour's dragging of redfish in each rectangle in which dragging has been carried out. This map indicates, within the limited amount of dragging experience available, the maximum catches at the best depths and locations. These catches are centred at the exact point of capture in each rectangle. While the largest catches follow the largest averages as described for Fig. 33, in addition a moderately good catch will be noted at the edge of the continental shelf east of Belle Isle Strait.

The *Investigator II* made a few redfish catches in 1946, and from 1947 onward a good share of the exploratory work of this ship was devoted to redfish. In 1947 when the *Investigator II* began these redfish explorations, except for the results of larval catches in plankton nets, almost nothing definite was known about the distribution and numbers of redfish in the Newfoundland and Labrador areas and in the Gulf of St. Lawrence. In 1947 the *Investigator II* discovered the Hermitage Bay area and between 1947 and 1950 found large redfish over the whole Gulf of St. Lawrence deep-water area with an especial abundance northward in this area. Between 1947 and 1950, also, large concentrations of redfish were discovered by the *Investigator II* on the southwestern slope of the Grand Bank, on the northeastern and eastern slopes of the Grand Bank, west of Flemish Cap, and east of Hamilton Inlet Bank. Smaller concentrations were found west of St. Pierre Bank and small numbers even off Cape Chidley at the extreme northern part of Labrador. The area between the Grand Bank and Hamilton Inlet Bank was surveyed in 1951 and 1952 and moderate numbers of redfish found all along the deep-water slope. All the major redfish areas now fished by American and Canadian trawlers in the Gulf of St. Lawrence, St. Pierre Bank, Southwest Grand Bank, Northeast Grand Bank, and the south coast of Newfoundland with the exception of the area near Ramea were first found and fished successfully by the *Investigator II*.

Some of the significant results of the redfish catches and the approximate sizes of redfish caught by the *Investigator II* in 1950 on the southwestern Grand Bank, the northeastern Grand Bank, Flemish Cap, east of the Strait of Belle Isle and off Hamilton Inlet Bank, Labrador were given in the Annual Report of the Fisheries Research Board of Canada for 1950 (Biological Station, St. John's, 1951). An account of the success of the earliest deeper-water (200-400 fathoms) fishing by the *Investigator II* for redfish east of Hamilton Inlet Bank, Labrador in September, 1954 is to be found in Templeman (1955). General accounts of redfish explorations by the *Investigator II* in the Gulf of St. Lawrence from 1947 to 1951 were given in the Annual Reports of the Fisheries Research Board of Canada for 1949 and 1951 (Biological Station, St. John's, 1950; 1952). A more detailed account was given by Templeman and Handrigan (MS, 1949), and a detailed list of the dates, positions, bottom temperatures and depths of all redfish catches of 1,000 lb and over obtained in the Gulf of St. Lawrence by the *Investigator II* between 1947 and 1950 was recorded by Templeman and Knapp-Fisher (MS, 1951). Twenty-three hauls with between 1,000 and 6,000 lb of redfish and averaging 2,300 lb per hour's dragging were listed.

On the south coast of Newfoundland, on the southwestern Grand Bank and on the western edge of St. Pierre Bank, exploitation by Newfoundland trawlers followed rapidly in 1947 to 1949 the discovery of redfish populations by the *Investigator II*. On the southern part of the eastern slope of the Grand Bank local trawlers found new fishing grounds. The new fishing grounds found in the Gulf of St. Lawrence by the *Investigator II* between 1947 and 1950 were first exploited commercially by the United States trawlers late in 1951. (We have, however, one record (Templeman and Handrigan, MS, 1949) of a catch of 100,000 pounds of redfish in one day's trawling by a Newfoundland commercial trawler in late autumn, 1949, in the Gulf of St. Lawrence off Port Saunders, Newfoundland. This rich redfish area had been previously discovered by the *Investigator II* and the skipper of the trawler had been advised of the success of the fishing by the *Investigator II*.) This fishing by United States trawlers began in the Bird Rocks area (of the Magdalen Islands) on the southern side of the Laurentian Channel, expanded to Gaspé in 1952, and finally in 1953 to the deep Esquiman Channel on the west coast of Newfoundland and in this channel as far northward as Port Saunders. In 1950 United States vessels first entered the fishery on the Grand Bank with a catch of 282 metric tons. In 1951 and succeeding years this United States redfish fishery both on the southwestern and southeastern slopes of the Grand Bank has increased greatly. The large redfish population on the northeast corner of the Grand Bank, found by the *Investigator II* in 1950, was first successfully exploited commercially by the Newfoundland redfish vessels led by Captain Blackwood of the *Blue Spray* in July, 1953. The Flemish Cap redfish population has been fished commercially by USSR trawlers beginning in the latter part of 1956.

Apart from a Canadian catch of 6 metric tons off southern Labrador in 1953, the redfish area from the north of the Grand Bank to Labrador was not commercially fished until 1957-58 (see Addendum).

## GENERAL DISTRIBUTION

### NORTHEAST AND CENTRAL NORTH ATLANTIC

#### *Sebastes viviparus*

Saemundsson (1949) says that *S. viviparus* is less numerous than *S. marinus* and that it is common in the warm water along the south and west coasts of Iceland in relatively shallow water between 10 and 100 metres (5 to 55 fath), but extends down to 300 metres (160 fath). It is rare along the north coast of Iceland and is not found on the east coast.

Lundbeck (MS, 1955) states that in parts of the European area a small separate species of redfish, *Sebastes viviparus*, lives near the coast and that this small species is the most common one around the Faroes; in the North Sea, disregarding rare visitors of *S. marinus*, it is the only species.

B. Rasmussen (private communication, October, 1956) says that *Sebastes viviparus* does not seem to occur as far north as the common redfish. Although in earlier publications *S. viviparus* has been mentioned as a coastal form only, trawl catches have proven that it is common in the open sea off the coast, for instance, in the northern part of the North Sea. Along the Norwegian coast *S. viviparus* is quite numerous, especially along the south and southwest coasts. Earlier publications on the fish fauna of Norway give Trondheim's Fjord as the northern limit for *S. viviparus* but, in reality, it can be found much farther north, being often caught by shrimp trawlers in waters adjacent to the Vestfjord in northern Norway. *S. viviparus* has been proven, however, to occur still farther north. In trawl hauls made in the Tanafjord in Finmark (70°50' N, 28°30' E) on January 10, 1933, 58 specimens of *S. viviparus* were found. This was 18% of the total catch of redfish at that particular time. All the redfishes in the catch were rather small, the *S. marinus* measuring 13 to 23 cm and the *S. viviparus* 9 to 18 cm. It is not improbable that *S. viviparus* can intermingle with younger groups of *S. marinus*. Such a mixture of identical size categories of the two species has also been found on various shrimping grounds in Norway. Catches made by shrimp trawlers indicate that *S. viviparus* can be found both in shallow and in deep waters in the fjords and off the coast. At the Faroes *S. viviparus* is one of the most common fishes, more numerous than *S. marinus*. Here *S. viviparus* is found from the shallows of Thorshavn Harbour to depths of 300 to 400 metres (160-220 fath) along the slopes of the banks. Although *S. viviparus* is common south and west of Iceland, in his various researches in West Greenland Rasmussen has not found evidence of the occurrence of this species in Greenland waters.

Travin (1951) states that *Sebastes viviparus*, which lives on the northwestern part of the outer Norwegian coast, only rarely reaches the Barents Sea and is an insignificant member of its fish fauna.

Andriiashev (1954) says that M. B. Zborovska reports that the young of both *S. viviparus* and *S. marinus*, weighing up to 150 grams (0.3 lb), were repeatedly taken in the White Sea in the region of Gridin in 1949.

Fig. 35, provided mainly by Å. V. Tåning (personal communication, April, 1955), indicates the distribution of the shallow-water *Sebastes viviparus*. (Using the data provided by Rasmussen we have extended the distribution of *S. viviparus* in the figure originally provided by Tåning, northeastward from the Tromsø area to Tanafjord near the eastern part of the Finmark coast of Norway.) According to Tåning this diagram does not include stray records of the species but only the main distribution. Referring to both *viviparus* and *marinus*, Tåning states that records of single specimens of redfish are available outside the distribution shown, e.g. in the southern North Sea; in some cases these stray specimens are, however, not determined as to species with sufficient exactness. Tåning says that in the Faroes the distribution of *S. viviparus* extends from depths of 1 metre (0.5 fath) close to shore out to depths of 300 metres (160 fath).

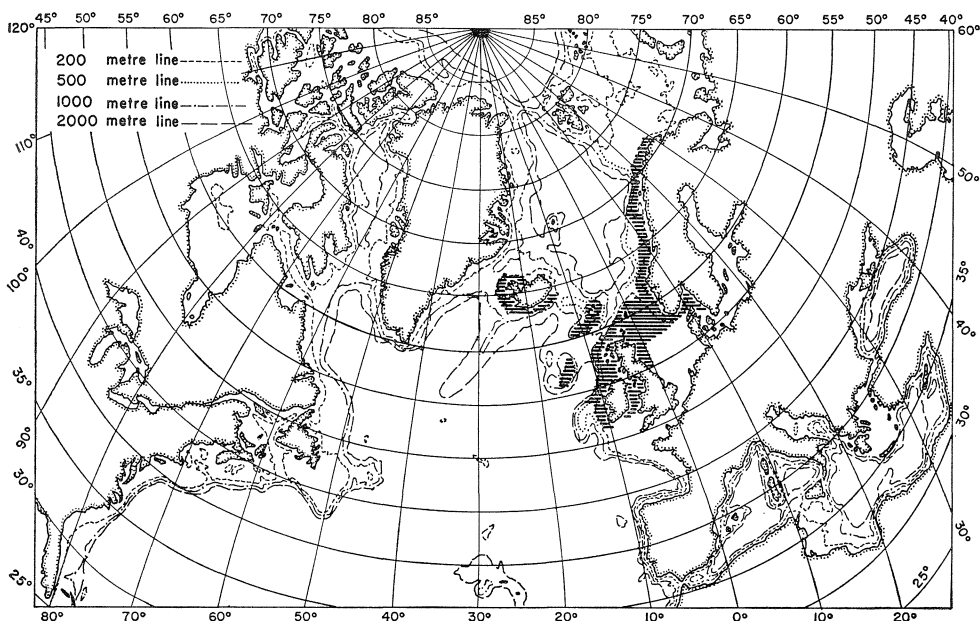


FIGURE 35. Distribution of *Sebastes viviparus*. (Mainly from Å. V. Tåning, personal communication, April, 1955).

Fig. 36, from data by Kotthaus and Krefft (1957), shows a general Icelandic distribution for *S. viviparus* similar to that indicated by Tåning and in addition adds a record from East Greenland. It will be noted from Table VI and Fig. 36 that, although the greatest catch of *viviparus* occurred at 150 metres (80 fath), this species was also caught in small numbers in deeper water, with 26 specimens in one set from a depth of 470 to 500 metres (255 to 275 fath). Although the deep records are significant, the very shallow depths west and south of Iceland, where this species may be still more plentiful than at 150 metres (80 fath), were

not fished on these cruises. The length of *viviparus* from these cruises ranged from 8 to 30 cm. Kotthaus says that in the "Rosengarten" area between Iceland and the Faroes, *viviparus* has been caught regularly in the German research cruises.

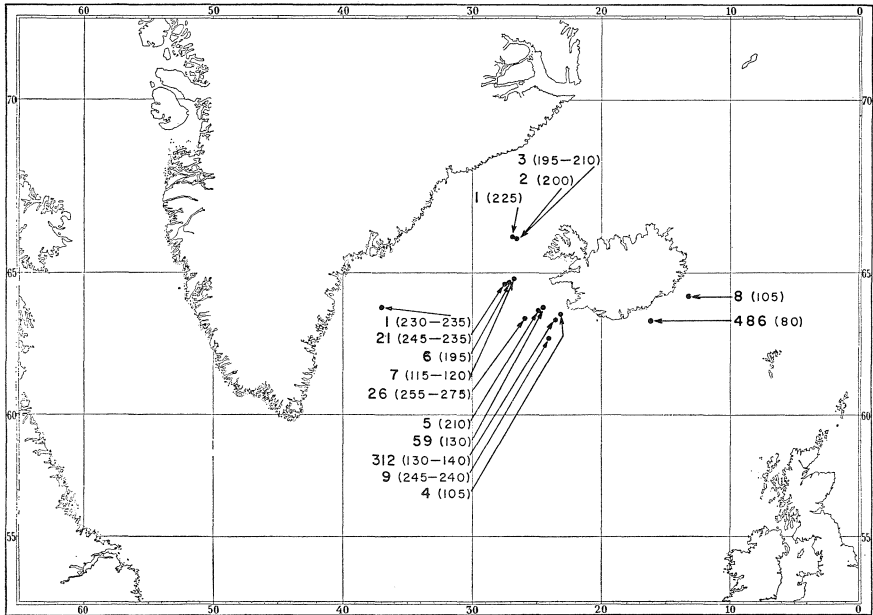


FIGURE 36. Distribution of the shallow-water redfish, *Sebastes viviparus*, in the Iceland-Greenland area. (Data from *Anton Dohrn* otter-trawling cruises, May to July and September to October, 1955, Kotthaus and Krefft, 1957. Each dot indicates position of one set in which the species was captured; the figure to left of bracket indicates the number of individuals of this species caught in the set and the figures in brackets indicate the depth-range in fathoms. 100 fath = 183 m.)

### *Sebastes marinus*

The following description of the distribution of *Sebastes marinus* usually does not differentiate between the distribution of the true *marinus* form and that of the deep-water *mentella* type.

NORTHEAST ATLANTIC. R. W. Blacker, of the Fisheries Laboratory, Lowestoft, has sent us (January, 1955) the following records of redfish captures by the *Ernest Holt* (Fig. 37):

SPITSBERGEN: Have been taken as far north as 77°24'N on the west side, but only a few specimens at a time.

BEAR ISLAND: In the deep water (150 to 200 fathoms) from due west around to southeast of the island, redfish are often caught in large quantities—up to 150 baskets (84 pounds or 38 kg per basket). Commercial trawlers have reported up to 10 bags (400 baskets) from west of Bear Island.

HOPE ISLAND: Have been taken in position 76°44'N, 30°50'E—the most northerly record we have, from east of Spitsbergen. South of Hope Island it has been taken in moderate quantities (up to 25 baskets per hour) in positions around 75°11'N, 27°17'E. Odd specimens have been found along the western side of the Central Bank.

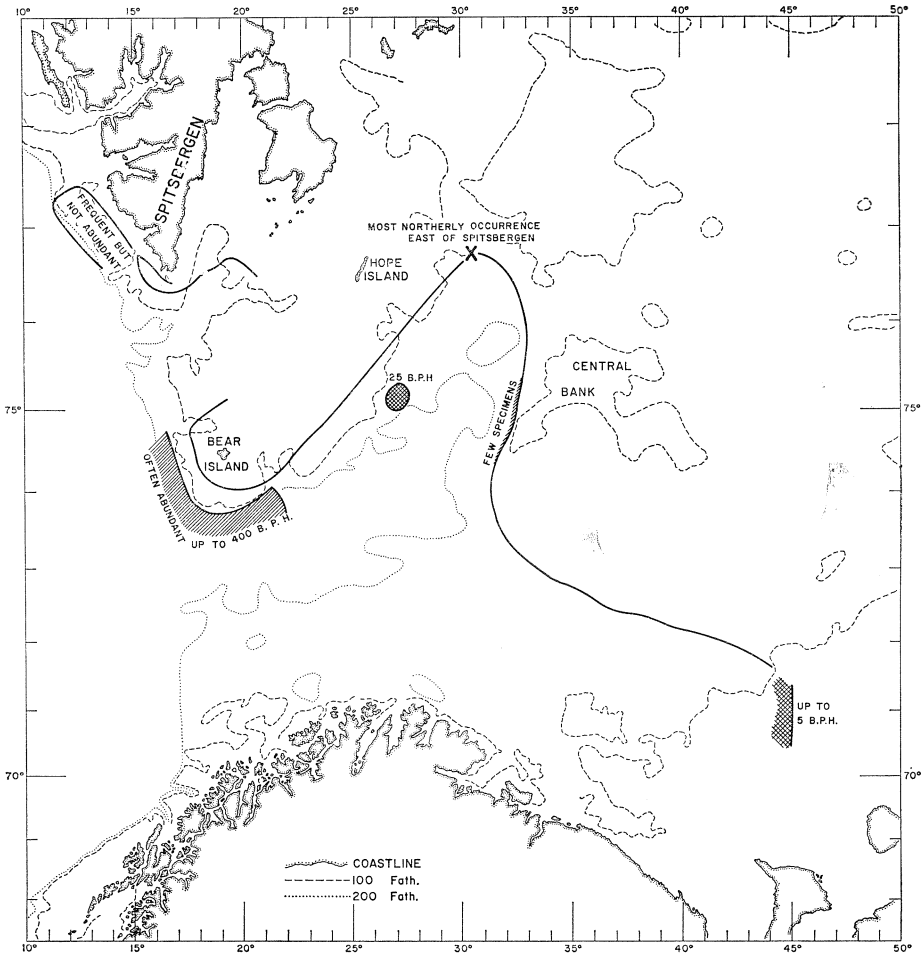


FIGURE 37. Some redfish catches in the North Atlantic by the *Ernest Holt*. (B.P.H. = baskets of 84 lb or 38 kg per hour's dragging. The black line indicates the northern and eastern limits of redfish distribution in the explorations of the *Ernest Holt*, which was mainly for cod rather than redfish.)

SOUTHERN BARENTS SEA: We have done very little work here but *Sebastes* has been caught in quantities up to 5 baskets per hour as far as 45°E.

SHETLAND: Some *Sebastes marinus* were caught in a haul at 61°30'N, 01°02'W.

Except for the very shallow water on the bank between Bear and Hope Islands, redfish are taken sporadically throughout the area between the limits mentioned.

Andriiashev (1954) says that this species is found in important quantities in the southern part of the Barents Sea, in the east to the Kanin Banks and Novaya Zemlya Shoals, in the north to the Bear Island Shoals and southwestern Spitsbergen and individuals to Nadezhda (Hope) Island. It is scarce in the White Sea and great numbers occur along the northwestern shores of Norway; to the south it reaches the Skagerrak.

According to Birger Rasmussen (private communication, October, 1956) Thor Iversen has made some observations on the northward distribution of *Sebastes marinus*. Using a fine meshed trawl off the west coast of Spitsbergen in 1923 to 1939 Iversen captured great numbers of both large and small redfish. The majority of the redfish caught by the trawl were found in bottom temperatures of 1.0 to 2.9°C. In the same area large redfish have been caught in temperatures of 2 to 4°C. Thor Iversen has also caught redfish on longlines east and west of Bear Island and in the northern part of the Barents Sea. In the latter locality redfish were very scarce and Iversen captured, in the period 1923 to 1939, only 10 specimens in bottom temperatures of 1 to 2°C. Iversen noted that redfish numbers were low and their occurrence incidental in waters with low bottom temperatures. The most northerly position for the capture of redfish at West Spitsbergen was Lat. 80°06' N and Long. 11°17' E.

ICELAND. Saemundsson (1949) says that in Icelandic waters *Sebastes marinus* is essentially a deep-water species which is rather scarce along the northeast coast of Iceland, but otherwise is very common from 30 to about 1,000 metres (16 to 550 fath).

Árni Fridriksson (personal communication, February, 1955) says that this species is abundant around Iceland, especially in the warm water area (SE, S, SW, and NW), down to the greatest depths fished at 500 to 600 metres (270 to 330 fath), and that it certainly also occurs in deeper waters.

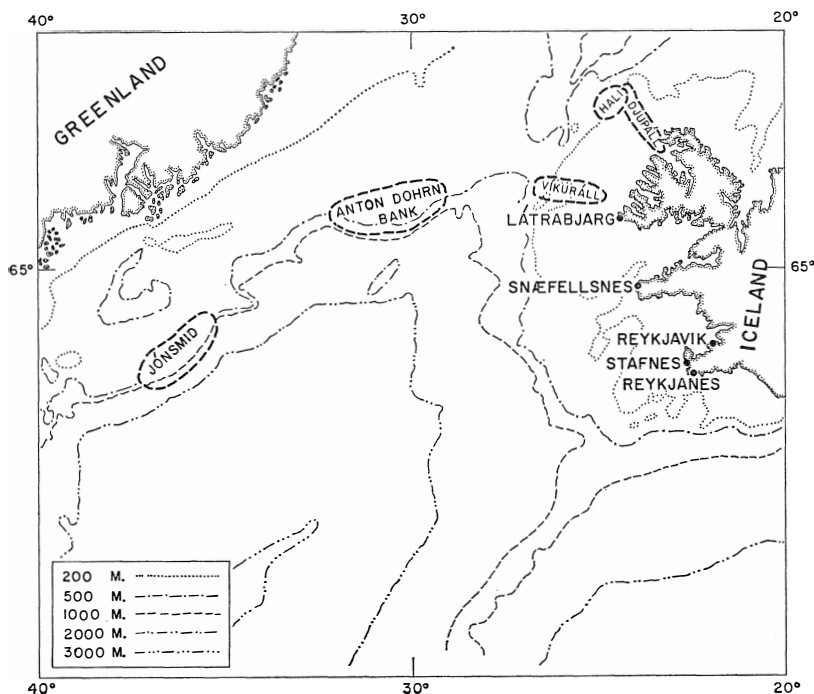


FIGURE 38. Some redfish fishing grounds west of Iceland and east of Greenland.

Jakob Magnússon (personal communication, November, 1955) states that redfish are abundant on the top of the Iceland-Faroe Ridge and on its western slope. Large catches of redfish are generally made in the area (Fig. 38) southwest, west-southwest and south by west of Reykjanes mainly in depths between 190 and 200 fathoms; about 100 nautical miles northwest of Stafnes in depths of 160 to 170 fathoms; about 80 nautical miles northwest of Snaefellsnes in depths of 115 to 200 fathoms; in the Víkuráll area (NW of Látrabjarg) in depths of 140 to 200 fathoms and on the Hali (on the south side of Djúpáll) in depths of 140 to 200 fathoms; on the newly found Anton Dohrn Bank about 130 nautical miles west-northwest and northwest of Látrabjarg in depths of 165 to 210 fathoms and in 240 to 250 fathoms also (but there the fish are smaller); and on the Jónsmid (about 64°20' N, 30°00' W) in depths of 190 to 210 fathoms. On the north side of the Iceland-Greenland Ridge and north of Iceland redfish are generally scarce and have only been caught at times during the summer season after these waters have been warmed up by the Atlantic influx.

GREENLAND. Birger Rasmussen (private communication, October, 1956) says that fishing experiments by Thor Iversen in 1931 to 1933 showed that redfish could be quite numerous along the east coast of Greenland from the latitude of Iceland to Cape Farewell.

Adolf Kotthaus (personal communication, February, 1956, with reference to the redfish investigations of the *Anton Dohrn* in May to July and September to October, 1955, in the area between West Iceland and West Greenland) says that redfish were found everywhere the ship fished on the east coast of Greenland and on the slope of the Iceland-Greenland Ridge (approximately between 62°45' N, 41°00' W and 65°45' N, 30°00' W) preferably in depths between 300 and 350 metres (160 to 190 fath), and also on the Icelandic Coast. The catch was sometimes large enough to indicate that commercial quantities of redfish were present. On the second trip to this region redfish occurrence in still greater quantities was detected somewhat further to the east; and there was developed in this area (Anton Dohrn Bank, Fig. 38) the extraordinarily productive redfish fishery which at present still continues. On the Anton Dohrn Bank the unusual daily yields of more than 50,000 kg (110,000 lb) continued from the discovery on Sept. 14 up to Oct. 20, 1955. The catch on the bank then decreased, with fluctuating daily yields between 10,000 and 40,000 kg (20,000 to 90,000 lb), continuing up to Dec. 1 when bad weather put a temporary end to the fishery. Again from Dec. 17 to the time of the communication Feb. 6, very good yields, with some up to 60,000 kg (130,000 lb) per day, continued to be obtained on this bank. Between Oct. 20 and 26, 1955, when redfish catches on the bank itself had decreased, there were landed at Bremerhaven and doubtless at other harbours redfish almost exclusively of the deep-water (*mentella*) type which were caught on the slope of the bank in depths below 380 metres (210 fath).

Kotthaus says that the German commercial trawlers fishing in the various areas of redfish abundance in the North Atlantic usually fish in 350 to 550 metres (190 to 300 fath).

Another rich redfish fishing area was found by a German trawler fishing in East Greenland waters in March, 1956. This new fishing ground is 80 miles west of the Anton Dohrn Bank in the same latitude as Angmagssalik (O'Brien, 1956).

R. W. Blacker (personal communication, January, 1955) has sent the following account of redfish captures by the *Ernest Holt* at Greenland: Fifteen baskets per hour were caught off Cape Desolation, Southwest Greenland and 10 baskets off Cape Bille, East Greenland (38 kg per basket). In both cases the trawl hooked bottom and was badly damaged. Redfish are also found around Cape Farewell. Forty baskets per hour were caught off East Greenland 100 miles east of Angmagssalik at 240 to 182 fathoms.

Paul Hansen (personal communication, February, 1956) says that, in his fishing experiments with shrimp trawl from the *Adolf Jensen*, redfish were taken in many of the West Greenland fjords at depths between 200 to 400 metres (110 to 220 fath). In two cases, only, were spawning redfish caught, namely in Godthaab Fjord in 270 metres (150 fath) depth, June 2, 1947, and June 23, 1953. The smallest spawning female redfish was 43 cm in total length. Redfish taken with shrimp trawl are mostly small specimens measuring from 10 to 30 cm. In Godthaab Fjord he has sometimes taken between 1,000 to 2,000 redfish in one hour's drag with a shrimp trawl.

In one of the branches of the Godthaab Fjord redfish have been taken at 20 metres (11 fath) depth. On May 24, 1954, nineteen redfish were taken in this locality. The Greenlanders fish for redfish with longlines in many of the fjords and in the coastal waters and get the best catches in late summer and in the fall.

On the shrimp beds of Disko Bay (about Lat. 69°N) redfish are common in the trawl catches. North of Lat. 70°N redfish occur very seldom. It is a rare fish in Umanak Fjord (about Lat. 71°N).

In Davis Strait Hansen has obtained redfish on the inner and outer slope of Fyllas Bank and he has seen Portuguese fishermen take redfish off Fiskenaes Bank. The depths were about 200 to 400 metres (110 to 220 fath). He says that undoubtedly redfish are distributed in depths of 200 to 400 metres (110 to 220 fath) in Davis Strait at least to about Lat. 68°N.

GENERAL NORTHEAST AND CENTRAL NORTH ATLANTIC. Figure 39 provided by Å. V. Tåning (personal communication, April, 1955) indicates what in Tåning's opinion is the principal distribution of *Sebastes marinus* known at present. (Tåning is of the opinion that the American form may not be *marinus*.) There has been no attempt to include the areas where very small numbers or stray specimens of *Sebastes marinus* occur. We have changed Tåning's distribution map very slightly in the northeastern region to agree with new data in the text.

In Fig. 39 Tåning has extended the limits of *Sebastes marinus* pelagically over the Norwegian Sea on the basis of suitable temperatures in redfish depths,

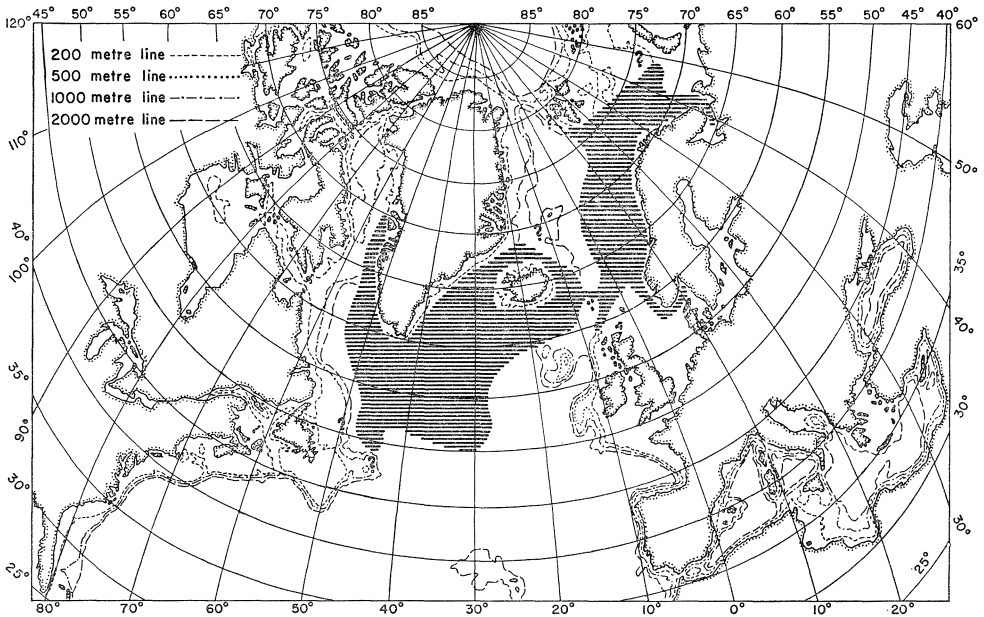


FIGURE 39. Distribution of redfish, *Sebastes marinus*, in the Northeast Atlantic, Iceland and Greenland. (Mainly from Å. V. Tåning, personal communication, April, 1955).

captures of redfish larvae and the pelagic longline catches of redfish in the Norwegian Sea. Similarly, the limits of the distribution of the species have been extended far to the southwest of Iceland and south of Greenland almost entirely because of the capture of very large numbers of redfish larvae over this whole area.

Fig. 40A, provided by V. I. Travin (private communication, February, 1957) shows the eastern limit of redfish distribution according to Russian data. This figure, Fig. 40C, 40D, and Fig. 37 showing the catches of the *Ernest Holt* will serve to further refine the eastern limit shown in Fig. 39. Travin says that the eastern limit of redfish distribution touches the contour of distribution in the Barents Sea of the warm and saline water of the North Atlantic Current. In this connection note the Norwegian data in Fig. 40B which indicate temperature conditions in the Barents Sea in March. Later in the year the water of 3°C and above moves farther to the east.

#### *Sebastes marinus marinus* AND *Sebastes marinus mentella*

Travin (1951) states that the *mentella* form of *Sebastes* lives at depths of 300 metres (160 fath) and more, that at depths shallower than 300 metres (160 fath) only individual specimens of *S. marinus mentella* can be found, and that it has not been found at depths less than 200 metres (110 fath). *S. marinus marinus*, according to Travin, is met with most commonly at 150 to 300 metres (80 to 160 fath) depth.

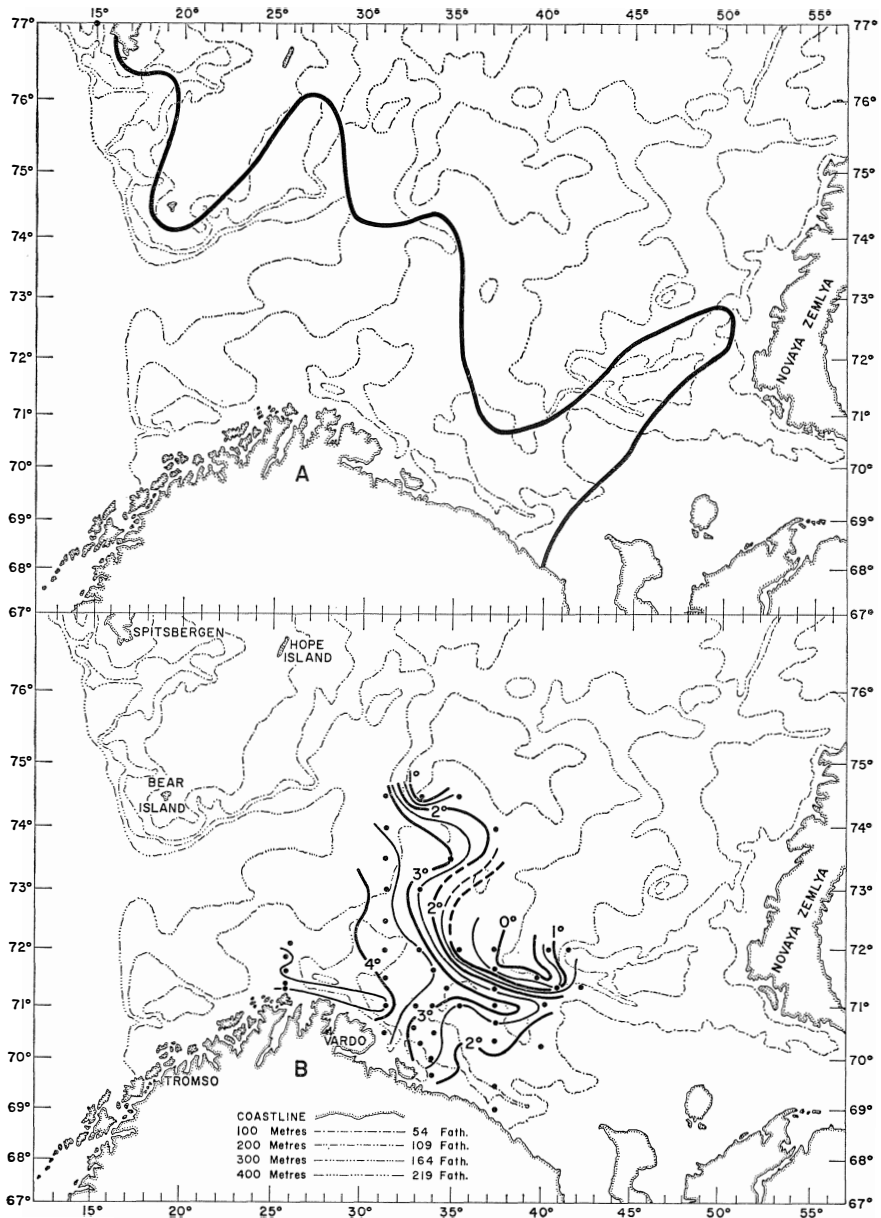


FIGURE 40. A, line marking the eastern distribution of redfish according to Russian data. B, temperature in °C at 150 metres (82 fath) in the southeast Barents Sea, March, 1957. (B is after fig. 3 of the report of a cruise of the *G. O. Sars*, in Fiskets Gang, Middtun, Saetersdal and Vestnes, 1957.)

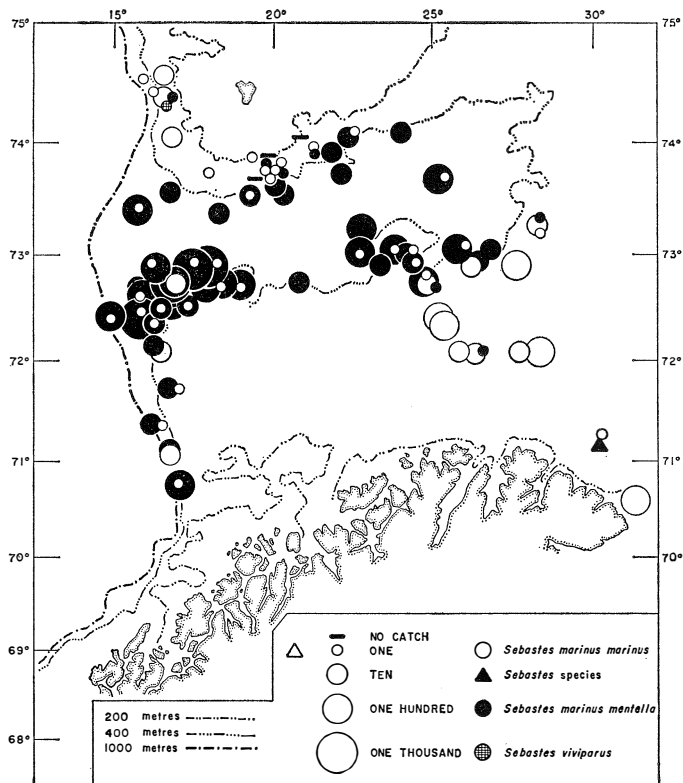


FIGURE 40C. Catch of redfish per hour's trawling by the trawler *Rossiya*, in March, 1956, in the eastern part of the Norwegian Sea and in the western part of the Barents Sea. (After Baranenkova, 1957, fig. 1).

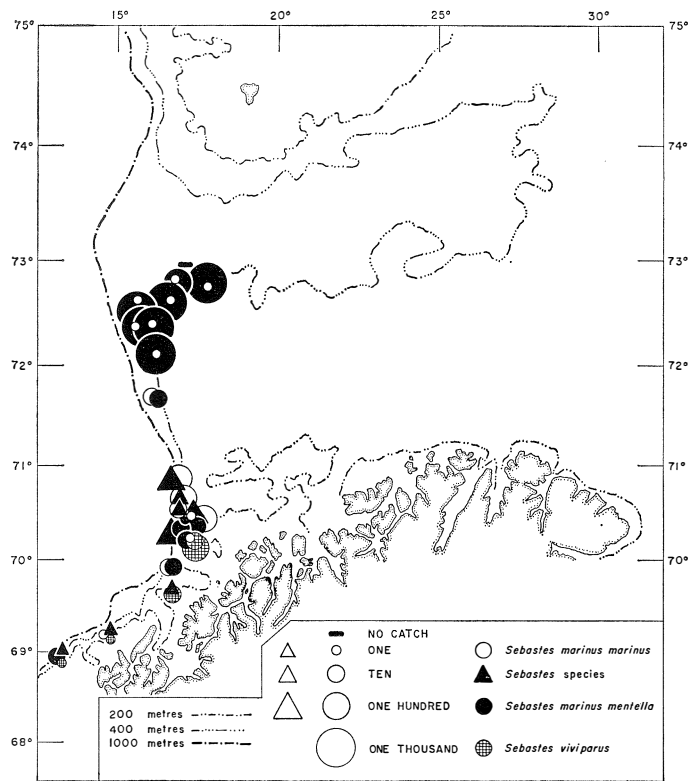


FIGURE 40D. Catch of redfish per hour's trawling by the trawler *Rossiya*, in April, 1956, in the eastern part of the Norwegian Sea and in the western part of the Barents Sea. (After Baranenkova, 1957, fig. 2).

Travin (1951) describes the range of *mentella* as limited on the east by a line running from Spitsbergen to Bear Island and from there down to the European Coast at the 30° meridian. He says that it becomes scarcer going from west to east.

Lundbeck (MS, 1955) says that the *mentella* deep-sea form or species has up to the present been found in the deep water to the south of Bear Island, on the northwestern Norwegian Shelf, on the eastern slope of the Faroe Shelf, and on the ridge between the Faroes and Iceland.

In March and April, 1956, the USSR Arctic Research Institute for Marine Fisheries and Oceanography at Murmansk, using the trawler *Rossiya*, carried out investigations of the distribution of redfish and other fishes in the western part of the Barents Sea and in the eastern part of the Norwegian Sea (Baranenkova, 1957). Most attention was paid to the region of "Kopytova" located between 71°20' and 73°30'N and 15° and 22°E. Special attention was given to the region where *Sebastes marinus mentella* concentrates in great numbers in April-May. As many as 142 drags were made with a commercial type 35-metre (115-foot) ground trawl. In some sections, for example in the eastern part of the Western Channel, trawling was carried out for the first time.

Trawling in various depths on Malang Bank on April 8 to 9 by the trawler *Rossiya* showed a predominance of *Sebastes marinus mentella* in the greater depths. In the lesser depths more *Sebastes viviparus* were found, and *Sebastes marinus marinus* and *Sebastes* sp., an intermediate form between the *marinus* and *mentella* varieties, occupied intermediate depths (Fig. 40 C and 40D, after Baranenkova, 1957, fig. 1 and 2). It had previously been observed in the same area during exploratory trawling by the research vessel *Saratov*, April 9, 1947, that in depths of 240 to 260 metres (130 to 140 fath) *Sebastes marinus marinus* predominated in the catches, whereas in depths of 330 metres (180 fath) *Sebastes marinus mentella* predominated. The greatest catches were at the southern entrance to the Western Channel where *Sebastes marinus mentella* predominated in the catches. Trawling was, however, chiefly carried out in depths greater than 400 metres (220 fath) so that the predominance of the *mentella* form was to be expected. Usually only single specimens of *Sebastes marinus marinus* were found at these greater depths especially in the Western Channel and in the Kopytova region. When trawling was carried out in lesser depths the *marinus* form increased in number.

Lundbeck (1956) supplies the information, from the 1955 explorations of the *Anton Dohrn* and from investigations in the market, that in the whole distribution area as far west as West Greenland the deep-sea *mentella* form is always associated with the normal *marinus* form but inhabits greater depths; also in the western area there may be more intermediate forms than farther to the east.

Adolf Kotthaus (personal communication, March, 1956), largely from information obtained during the cruises of the *Anton Dohrn* in 1955, says that *mentella* occurs on the southwest, west and northwest coasts of Iceland and

that it is found up to 200 metres (110 fath) but mainly at 400 metres (220 fath) and deeper. *S. marinus marinus* does not go much deeper than 400 metres (220 fath) but *mentella* is much more abundant deeper than 400 metres (220 fath). On the Iceland-Greenland Ridge and on the east coast of Greenland *mentella* is found somewhat shallower, up to 380 metres (210 fath). A sharp boundary is not found because the deep-water fish (*mentella* type) are also to be found in lesser depths but in lesser numbers. In the range of the deep-water redfish (below 380 to 400 metres, 210 to 220 fath) the true redfish (*marinus* type) is to be found only rarely and then at lengths of more than 55 cm. *Mentella* also occurs at Lofoten and on the Iceland-Faroe Ridge.

Kotthaus and Krefft (1957) (referring to the May to July and September to October, 1955, cruises of the *Anton Dohrn* to Iceland and Greenland) report *Sebastes marinus marinus* around most of Iceland, on the Iceland-Greenland Ridge and in East and West Greenland (Fig. 41). Thus *marinus*-type redfish extend at least as far north in West Greenland as Lat. 68°48' N.

During the same cruises *Sebastes marinus mentella* were caught mainly west of Iceland and in West Greenland, with one catch in East Greenland (Fig. 42).

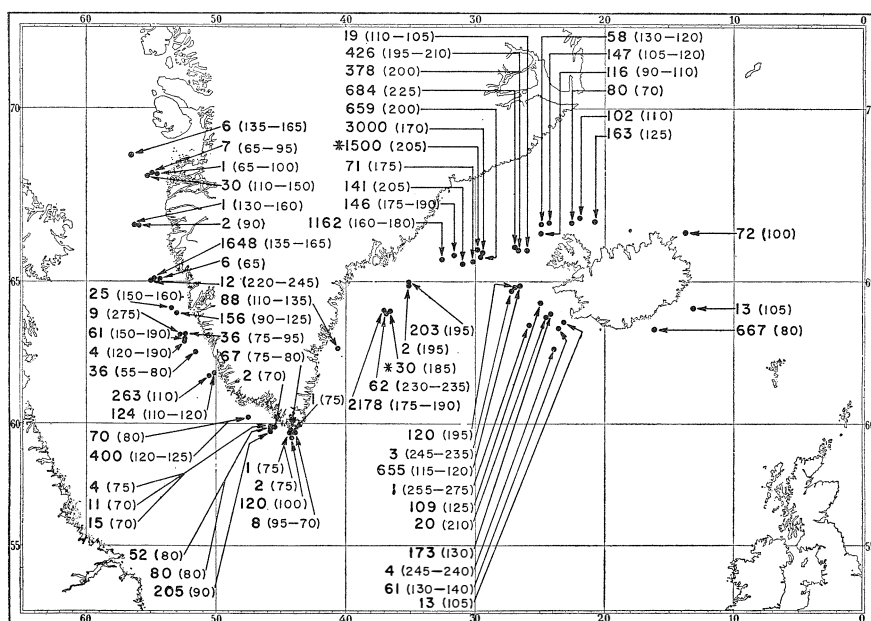


FIGURE 41. Distribution of the common redfish, *Sebastes marinus marinus*, in the Iceland-Greenland area. (Data from *Anton Dohrn* otter-trawling cruises, May to July and September to October, 1955, Kotthaus and Krefft, 1957. Each dot indicates position of one set in which *marinus*-type redfish were caught; the figure to left of bracket indicates the number of *marinus*-type individuals caught in the set and the figures in brackets indicate the depth range in fathoms. 100 fath = 183 m. Asterisk indicates where catch given by Kotthaus and Krefft in baskets has been converted in this figure to number of individuals by estimating 1 basket = 30 redfish. Kotthaus in a letter, September, 1957, says 1 basket = approximately 30 to 35 redfish in the area under investigation.)

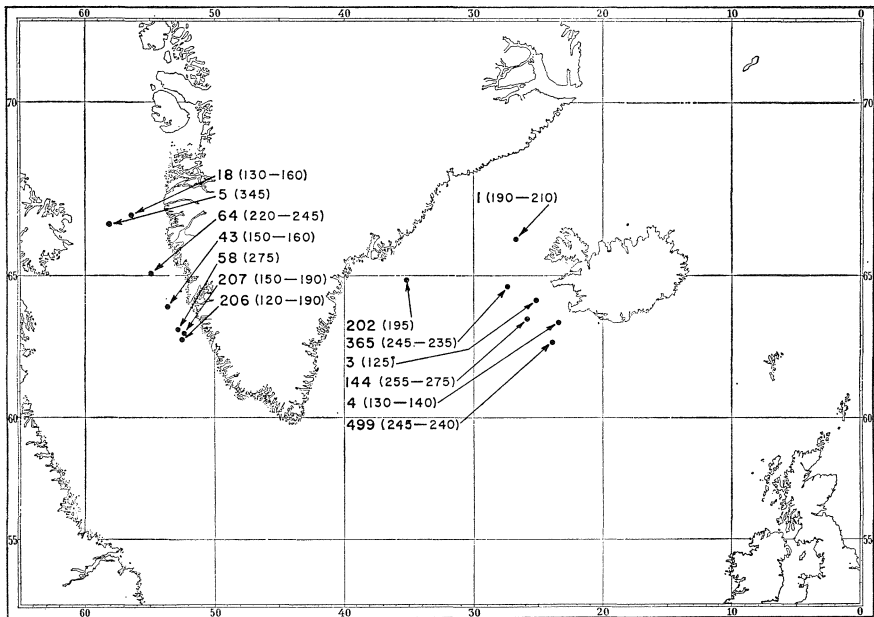


FIGURE 42. Distribution of the deep-water redfish, *Sebastes marinus mentella*, in the Iceland-Greenland area. (Data from *Anton Dohrn* otter-trawling cruises, May to July and September to October, 1955, Kotthaus and Krefft, 1957. Each dot indicates position of one set in which *mentella*-type redfish were caught; the figure to left of bracket indicates the number of *mentella*-type individuals caught in the set and the figures in brackets indicate the depth range in fathoms. 100 fath = 183 m.)

The *marinus* form was much more plentiful than the *mentella* but this result is probably without significance because most of the sets were at depths more suited to *marinus* than to *mentella*.

The greatest numbers of *marinus*-type redfish were found at 301 to 350 metres (165 to 190 fath) and the greatest numbers of the *mentella* type at 401 to 450 metres (220 to 245 fath) (Table VI). There were very few sets, however, in water of greater depth than 450 metres (245 fath).

Lengths of over 15,000 *marinus*-type redfish ranged from 7 to 78 cm and of 1,850 *mentella*-type from 24 to 66 cm.

Sixty-one redfish 7 to 33 cm long were obtained from Tunugdliarfik in West Greenland, 60°56' N, 45°47' W, in 295 metres (160 fath) by shrimp trawl on Sept. 29 and Oct. 20, 1956, through Paul Hansen and S. A. Horsted. These were examined by the author at the St. John's Station and all were *mentella*-type redfish, apparently similar to those of the Newfoundland area.

Adolf Kotthaus (personal communication, Aug. 30, 1957) has very kindly sent information on the efforts now being made to separate the *marinus* and *mentella* forms of redfish in the German landings. He says that beginning in the summer of 1957 the German authorities have made arrangements for the determination of type composition of all future redfish landings in Bremerhaven where most of the German redfish catches are landed. Kotthaus has also sent us data

TABLE VI.—Depth distribution in the Iceland-Greenland area of *Sebastes viviparus*, *Sebastes marinus marinus* and *Sebastes marinus mentella*. (Data from Anton Dohrn cruises, May to July and September to October, 1955, Kotthaus and Krefft, 1957. 100 m = 55 fath.)

Depth range	No. of sets in which the species was recorded	No. of sets where temp. recorded	Range of No. individuals caught in any one set	Av. No. individuals per set	Av. No. individuals in sets where temp. recorded	Range of bottom temperature	Av. bottom temperature
<i>m</i>						°C	°C
<i>Sebastes viviparus</i>							
150.....	1	0	486	486	.....	.....	.....
151-200.....	2	2	4-8	6	6	7.5-7.6	7.6
201-250.....	3	3	7-312	126	126	6.0-7.2	6.8
351-400.....	4	4	2-6	4	4	1.0-6.5	3.7
401-450.....	4	4	1-21	8	8	1.0-6.5	4.3
451-500.....	1	1	26	26	26	6.8	6.8
<i>Sebastes marinus marinus</i>							
120-150.....	18	6	1-667	58	21	1.3-5.8	3.1
151-200.....	12	10	2-23	93	93	1.6-7.6	4.7
201-250.....	11	10	30-6556	183	188	1.1-7.2	4.8
251-300.....	5	1	1-1,648	337	6	2.7	2.7
301-350.....	7	6	30-3,000	951	1,099	0.4-5.9	3.8
351-400.....	9	8	2-1,500	383	414	1.0-6.5	3.9
401-450.....	5	5	3-684	153	153	1.0-6.5	4.3
451-500.....	2	2	1-9	5	5	4.3-6.8	5.6
<i>Sebastes marinus mentella</i>							
201-250.....	2	2	3-4	4	4	6.0-7.2	6.6
251-300.....	3	0	18-206	89	.....	.....	.....
301-350.....	1	0	207	207	.....	.....	.....
351-400.....	2	2	1-202	102	102	1.3-4.2	2.8
401-450.....	3	2	64-499	309	432	6.2-6.5	6.4
451-500.....	2	2	58-144	101	101	4.3-6.2	5.3
601-635.....	1	1	5	5	5	1.9	1.9

showing the type composition of some redfish catches which have been sampled by scientific personnel for age and length in 1956 and 1957 (Table VII). The *marinus* type predominated greatly in the commercial landings from East Greenland, all coasts of Iceland, the Norwegian coast at Lofoten, and the Barents Sea, and made up the whole of the samples from West Greenland. The *mentella* type was slightly greater in the landings from the Iceland-Greenland Ridge and was the sole form in samples from the Iceland-Faroes Ridge and the Bear Island Deep. Kotthaus has also noted large numbers of redfish on the Iceland-Greenland Ridge and small numbers on the southwest coast of Iceland of a type intermediate between *marinus* and *mentella*.

Kotthaus, however, states that these scanty data are in no way sufficient to delineate the areas of distribution of the two types. Records of the depths are not always available; generally the vessels change their fishing position very frequently; sometimes they fish in deep waters and shortly afterwards in shallow

TABLE VII.—Relative quantities of *marinus* and *mentella* types, in redfish examined by investigators, from landings in Bremerhaven from summer, 1956, to summer, 1957.

West Greenland				West coast Iceland			
9 landings				Date	<i>marinus</i>	<i>mentella</i>	
100% <i>marinus</i> type				15.10.56	60%	40%	
				18.10.56	90%	10%	
				29.10.56	90%	10%	
East Greenland				Southwest coast Iceland			
Date	<i>marinus</i>	<i>mentella</i>		Date	<i>marinus</i>	<i>mentella</i>	Inter- mediate types
25.8.56	100%	.....		14.8.56	.....	.....	100%
4.9.56	100%	.....		18.9.56	80%	20%	.....
12.9.56	100%	.....		25.10.56	90%	10%	.....
1.11.56	100%	.....		6.11.56	100%	.....	.....
19.3.57	.....	100%		28.11.56	80%	20%	.....
26.3.57	.....	100%		1.2.57	80%	20%	.....
1.4.57	100%	.....		7.2.57	100%	.....	.....
Iceland-Greenland Ridge				11.2.57	95%	5%	.....
Date	<i>marinus</i>	<i>mentella</i>	Inter- mediate types	18.2.57	90%	10%	.....
15.8.56	.....	.....	100%	7.3.57	90%	10%	.....
5.9.56	.....	.....	100%	21.3.57	95%	5%	.....
13.9.56	.....	100%	.....	23.3.57	100%	.....	.....
26.9.56	75%	25%	.....	23.3.57	95%	5%	.....
9.10.56	.....	100%	.....	25.3.57	95%	5%	.....
25.2.57	100%	.....	.....	27.3.57	95%	5%	.....
8.4.57	90%	10%	.....	28.3.57	95%	5%	.....
11.5.57	95%	5%	.....	2.4.57	100%	.....	.....
24.5.57	.....	.....	100%	29.4.57	100%	.....	.....
29.5.57	.....	.....	100%	31.5.57	95%	5%	.....
8.8.57	.....	100%	.....	26.6.57	5%	95%	.....
12.8.57	5%	95%	.....				
16.8.57	.....	100%	.....				
Northwest coast Iceland				South coast Iceland			
Date	<i>marinus</i>	<i>mentella</i>		2 catches			
7.8.56	90%	10%		100% <i>marinus</i> type			
22.8.56	100%	.....					
27.8.56	100%	.....		Southeast coast Iceland			
31.8.56	70%	30%		3 catches			
3.9.56	95%	5%		100% <i>marinus</i> type			
6.9.56	95%	5%					
22.9.56	90%	10%		Iceland-Faroes Ridge			
24.1.57	100%	.....		11 catches			
8.2.57	100%	.....		100% <i>mentella</i> type			
17.7.57	100%	.....					
23.7.57	100%	.....					
1.8.57	100%	.....					

TABLE VII.—Relative quantities of *marinus* and *mentella* types, in redfish examined by investigators, from landings in Bremerhaven from summer, 1956, to summer, 1957—*Cont.*

Norwegian coast (Lofoten)			Norwegian coast (Lofoten)—( <i>cont.</i> )		
Date	<i>marinus</i>	<i>mentella</i>	Date	<i>marinus</i>	<i>mentella</i>
20.9.56	90%	10%	29.4.57	100%	.....
12.10.56	100%	.....	22.5.57	95%	5%
17.10.56	100%	.....	Barents Sea		
24.10.56	90%	10%	Date	<i>marinus</i>	<i>mentella</i>
22.1.57	100%	.....	20.12.56	100%	.....
2.2.57	100%	.....	28.5.57	90%	10%
14.2.57	100%	.....	5.6.57	100%	.....
22.2.57	90%	10%	Bear Island grounds (Bear Island Deep)		
8.3.57	100%	.....	27 catches		
20.3.57	100%	.....	100% <i>mentella</i> type		
25.3.57	100%	.....			
3.4.57	100%	.....			
10.4.57	100%	.....			
26.4.57	100%	.....			

waters; hence on landing it is not possible to state where any individual fish was caught. It is of course almost certain that, where the more favoured and shallower *marinus* type can be found in comparable abundance, the less desired and deeper *mentella* type will not be fished. Since so much of the German fishery is off Iceland and Greenland most of the redfish landed are evidently of the *marinus* type.

Jakob Magnússon (private communication, Nov. 28, 1957) says that in recent years the Icelandic trawlers are mainly fishing for redfish in the West and East Greenland waters. From these areas, in his observations, the redfish catch consists mainly of the *marinus* type, but some *mentella*-type redfish are present. In the Icelandic waters the situation differs markedly from one fishing ground to another and no estimation of the amount of each type landed is possible. The *mentella* and *marinus* types are not distinguished on the market nor in the Icelandic fish industry.

In the redfish investigations by the St. John's Station in 1956 a special attempt was made to distinguish between the *marinus* and *mentella* types. In fishing carried out between 150 and 300 fathoms northeast of Hamilton Inlet Bank, Labrador, in August, out of 21 redfish at 154 to 156 fathoms, 82 at 198 fathoms, 42 at 246 to 252 fathoms and 8 redfish at 300 fathoms examined at the St. John's Station, only 2 large specimens, one of 45 cm at 246 to 252 fathoms and one of 67 cm at 300 fathoms, were of the *marinus* type; the remainder belonged to the *mentella* variety. The actual proportion of *marinus*- to *mentella*-type redfish was much less than that indicated above because some large specimens were especially selected for examination.

North of Flemish Cap, in July, 1956 (Templeman and Sandeman, 1957), at 150 fathoms the *marinus* form was more abundant than the *mentella* in the

small numbers of redfish secured. At 200 fathoms most of the redfish were *mentella* and a few, consisting of all the largest specimens, 43 to 53 cm, were *marinus*. At 250 fathoms, where good catches were obtained, all redfish were of the *mentella* type and at 300 fathoms all were very definitely typical *mentella* forms.

Near the southern end of the southwest slope of the Grand Bank *marinus* forms were not noted in many redfish sets from 110 to 310 fathoms nor in 102 redfish from these depths examined more closely at the Biological Station; all were *mentella*. From a small commercial catch of 3,000 lb of redfish during a cod-fishing trip by the otter trawler *Blue Spray* in January, 1958, in the southern part of the Halibut Channel between St. Pierre Bank and Green Bank in 88 to 90 fathoms, 543 redfish were examined of which 14% were of the *marinus* type and the remainder of the *mentella* type. In Hermitage Bay on the south coast of Newfoundland, where redfish fishing is usually carried out in 120 to 160 fathoms, occasional *marinus*-type redfish are present. Many of these are larger than 45 cm, but the common *mentella*-type redfish present are below this length. Here there are only a few *marinus*-type redfish, often only 10 to 20 specimens in a whole trip in which 30,000 or more *mentella*-type redfish are caught. Even these few are in the shallower water and they are typically golden yellow or with a combination of green, dark brown, and red colours rather than the bright red of the *mentella* type. In Hermitage Bay the *marinus*-type redfish are caught near the 120 rather than the 160 fathom depth, and in the neighbouring Connaigre Bay at 92 to 112 fathoms they may be plentiful enough to obtain several large *marinus*-type fish in a set among the very much more numerous smaller *mentella*-type redfish.

#### NORTHWEST ATLANTIC

Figure 43 represents a synthesis of present knowledge on the main distribution of the redfish, apparently mainly *Sebastes marinus mentella*, in the Northwest Atlantic. No attempt has been made to include areas represented by few or individual records. In the Labrador area the indicated redfish distribution north of about Lat. 60°N and south of approximately Lat. 55°30'N is based on catches of the *Investigator II* (Fig. 32 to 34). Redfish existence in the intervening slope area has been assumed. Doubtless the redfish extends farther northward on the continental slope east of Baffin Island than is shown here, but the area north of Labrador is yet to be explored for redfish. In the western part of the Laurentian Channel, Steele (1957) says that redfish are abundant in the deep water to the southeast of Seven Islands (Long. 66°23'W), but are scarce west of this area. Most of the remaining redfish area shown in Fig. 43 has been explored either by research ships or by commercial ships or both. In the Gulf of St. Lawrence and in the part of the Laurentian Channel between St. Pierre Bank and Banquereau, the *Investigator II* has commonly obtained redfish down to 180 to 200 fathoms. On the one occasion when trawling was carried out beyond this depth in November, 1956, off Cape Anguille in Cabot Strait at the entrance to the Gulf, *mentella*-type redfish were still present

but scarce at 280 to 287 fathoms, the greatest depth fished. Ten redfish (18 lb) were obtained at this depth in a half-hour's fishing with a No.  $\frac{3}{4}$ -35 otter-trawl. In the Gulf of Maine redfish are scarce in the deepest water. Since, from lack of information, it is impossible to be precise regarding redfish distribution in these deep-water areas, the distribution in Fig. 43 has been extended across the deep channels of both Gulfs to indicate the probability either of some redfish on the bottom or temporarily living pelagically in the channels.

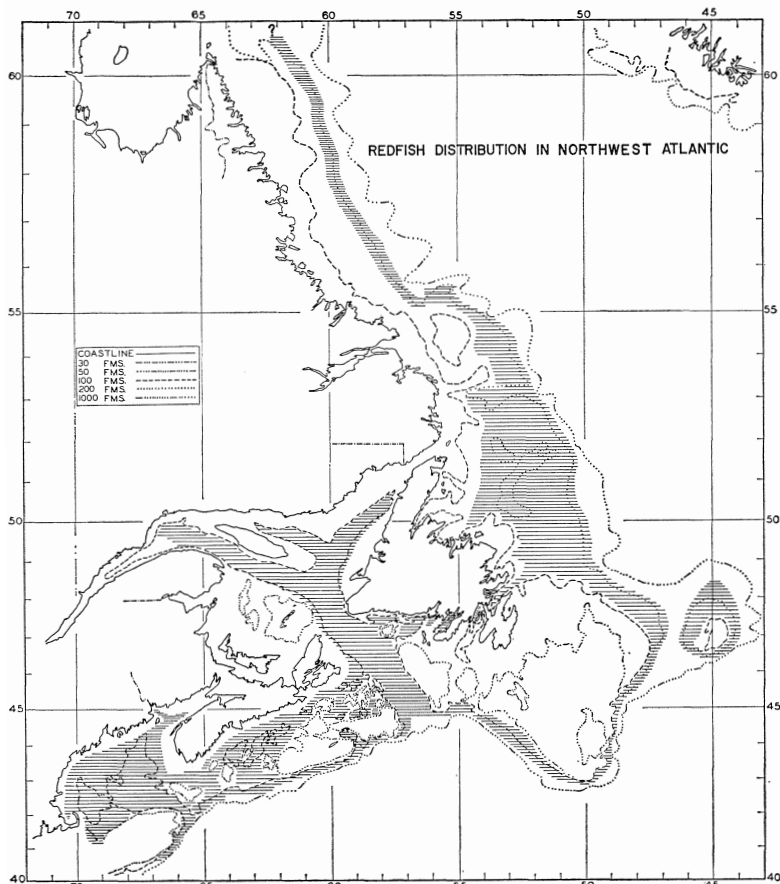


FIGURE 43. Distribution of redfish, *Sebastes marinus*, in the Northwest Atlantic.

#### DEPTH DISTRIBUTION

On the Grand Bank east of Long. 49° to 50° W and to the north of the Grand Bank, off East Newfoundland and Labrador and around Flemish Cap, redfish are typically deeper than 120 fathoms, and are generally below 140 fathoms. On the southwest slope of the Grand Bank, especially in the middle and warmer portion of the slope, redfish can be found as shallow as 50 fathoms and often in quantity at 80 fathoms or less. In the Gulf of St. Lawrence redfish

may be common as shallow as 100 fathoms. Huntsman (1918), while presenting no details, refers to the presence of redfish in the deep warmer water below the cold layer of the Gulf of St. Lawrence but not in the cold layer itself nor in the warmer surface waters above the cold layer. The above general statements are given here for continuity with the detailed statements on the Nova Scotian and New England areas. The depth distribution of redfish in the above area, as revealed by the exploratory dragging of the *Investigator II*, is discussed in detail later in this paper.

G. F. Kelly (personal communication, October, 1955) has given us the following statement regarding redfish distribution in the eastern Nova Scotian Shelf area:

On the Nova Scotian coast the redfish is distributed in two areas of quite different nature, the broad areas inside the offshore banks and the narrow strip of deep water outside the banks. Most of the commercial catch has come from the areas inside the banks where the depths range from 60 to 120 fathoms, the greater portion of the catch coming from depths less than 100 fathoms. Outside the shoal areas of the offshore banks the bottom drops off very quickly. The strip of bottom between 100 and 300 fathoms is narrow and not well suited to trawling. This area has been explored by research vessels and good quantities of redfish have been found in most of the areas fished.

Huntsman (1922) says that *Sebastes marinus* of all sizes, and including females with eyed eggs, are quite common in the Bay of Fundy, Passamaquoddy Bay and the St. Croix River Estuary at depths of 5 fathoms or more.

Bigelow and Schroeder (1953) state that redfish are taken in numbers all along the northern shores of the Gulf of Maine in depths of 25 fathoms or more, and that they range down to a depth of at least 260 fathoms on the southern slope of Georges Bank. Although redfish are found only deeper than 15 or 20 fathoms during the warm half of the year in the southwestern part of the Gulf of Maine, they have been known to run into Gloucester Harbour in numbers in winter. Bigelow and Schroeder report redfish as shallow as 10 fathoms in summer off Mount Desert Island, Maine. Verrill (1871) mentions the redfish as feeding around the wharves in Eastport, Maine, probably in late summer and early autumn since, according to Bigelow and Schroeder (1953), this was the season when Verrill made his studies of the Eastport fauna.

During 1956, in July, hundreds of redfish were noted in Eastport Harbour, Maine, feeding at or near the surface on the euphausiid *Meganctiphanes*. They remained in this area at least until November. A check in February, 1957, showed that redfish were no longer present. Some of these redfish were caught by hook and line fishing and 3,385 were tagged by G. F. Kelly and his associates during the July to November period. The fish were 13 to 35 cm in length (Anon., 1956c; Kelly, 1957).

G. F. Kelly (personal communication, October, 1955) says that, in the Gulf of Maine in each year since the fishery began, about 50% of the Gulf of Maine redfish catch has been taken in the central portion around Cashes Ledge. Most of the bottom in this area consists of 70 to 90 fathom ridges with 100 to

120 fathom gullies between them. In the areas to the northeast, southeast and southwest of the Cashes Ledge region, the waters deepen to 130 to 160 fathoms, yet the redfish are exceedingly scarce in these depths.

It is evident that there are some discrepancies between the data from the northeastern and north-central Atlantic regarding the depth distribution of *Sebastes marinus mentella*, and some of the data on depth distribution of the American form which for the present we have identified with *Sebastes marinus mentella*. On the American side these redfish are reported in numbers in much shallower water as well as being abundant in many areas in approximately the same depth distribution as the European *mentella* form. In the central and southern portions of the American side, where except for a few *marinus* stragglers the redfish are apparently of one form, it can be reasonably argued that almost all the young immature redfish must be the young of the more usual *mentella* type. In these young immatures the chin beak is usually pointed but to visual observation is broad-based in relation to its length and not the long slender chin beak of the typical adult *mentella*. In the European area it is possible that the young redfish of the *mentella* form are not being recognized. It is also possible that in many European areas the shallower water may have too high a temperature for the *mentella* form.

#### NORTHERN AND NORTHWESTERN LIMITS OF DISTRIBUTION

Redfish are present, at least in modest numbers, in deep water east of Cape Chidley at the northern tip of Newfoundland Labrador, but the northern limits on the Baffin Island side are still to be explored. To the northwest, 3 small redfish have been recorded from Ungava Bay, 2 from Port Burwell (Dunbar and Hildebrand, 1952) and one from Akpatok Island (Tuck and Squires, 1955).

#### SOUTHERN LIMIT OF DISTRIBUTION

Bigelow and Schroeder (1953) give the southern limits of *Sebastes marinus* as being in deep water as far south as the offing of New Jersey. They mention a catch by the *Albatross III* of 63 large redfish in one trawl haul in 175 to 195 fathoms on May 16, 1950, on the southern slope of Georges Bank at Lat. 40°29'N, Long. 67°10'W.

W. C. Schroeder (personal communications, May and October, 1955) has given us some details of his deep-water explorations by otter trawl off the east coast of the United States between 1948 and 1953, but principally with the *Cap'n Bill II* in 1952 and 1953. Schroeder's most southerly good catches of redfish were in Lat. 42°09'N, Long. 65°21'W at 240 to 280 fathoms at 4.4°C on July 16, 1953, where 528 redfish, 12 to 18 inches long, were taken in a 30-minute drag; also in Lat. 42°08'N, Long. 65°27'W in 250 to 300 fathoms at 3.9°C, on July 16, 1953, 192 redfish, 12 to 18 inches long, were taken in a 40- to 45-minute drag, in both cases with a 60-foot otter trawl.

South of Lat. 42°08'N Schroeder had two otter-trawl hauls in which redfish were caught, in 210 to 250 fathoms and 5.0°C at Lat. 40°37'N and Long. 66°59'W on July 16, 1953, and in 230 to 250 fathoms at Lat. 40°18'N and Long. 68°01'W

on July 15, 1952. In these two hauls of 40 to 45 minutes dragging time the redfish captures were respectively 2 redfish, 11 and 16 inches, and 3 redfish, 15½ to 16½ inches.

One 8-inch redfish was caught by Schroeder on Oct. 16, 1948, in Lat. 39°54'N and Long. 70°39'W in 250 fathoms. This is Schroeder's most southerly individual record.

South of Lat. 42°N to Lat. 37°28'N there were 54 successful hauls of an average of 40 minutes duration, deeper than 200 fathoms and down to 730 fathoms (usually 200 to 400 fathoms), well scattered along the slope to the offing of Cape Charles, Virginia. No redfish were taken in these hauls other than the above-mentioned 1 redfish in Lat. 39°54'N, 3 redfish at Lat. 40°18'N and 2 redfish at Lat. 40°37'N. One other redfish, 10 inches long, was captured on July 29, 1952, in 155 to 165 fathoms in Lat. 40°49' N, Long. 66°39'W.

H. W. Graham (personal communication, May, 1955) says that along the southern edges of Georges Bank and Nantucket Shoals the redfish is only a straggler. The most southerly concentration of breeding redfish is in the South Channel between Nantucket Shoals and Georges Bank.

During 1955 the United States Fish and Wildlife Service research trawler *Delaware* carried out 12 successful drags for redfish along the southeastern fringe of Georges Bank between Lat. 40°19' and 40°57'N. In 4 of these drags at 185 to 320 fathoms between Lat. 40°19' and 40°30'N the largest catch per hour's dragging was 20 redfish and the average catch was 8 redfish with an average weight of 2½ pounds. In the 8 drags between Lat. 40°36' and 40°57'N the average catch was 106 redfish with an average weight of 2 pounds. Catches were similarly low east of Georges Bank between Lat. 41° and 42°N. Proceeding farther northward along the eastern edge of the continental shelf, the quantities of redfish taken increased to very large catches off Sable Island Bank and Banquereau in deep water at about 175 to 300 fathoms (personal communication, Robert C. Wilson, November, 1955; Fig. 59, Table XXIII).

Apparently the most southerly redfish location off the American continent is still that reported by Goode and Bean (1895) for the research vessel *Albatross* at Lat. 39°48'10"N, Long. 71°48'40"W at a depth of 114 fathoms. Goode and Bean also report two other redfish captures by the *Albatross* in Lat. 39°59'10"N in 140 fathoms and in Lat. 39°59'15"N in 143 fathoms.

#### GENERAL CONCLUSIONS ON REDFISH DISTRIBUTION

Depths of about 350 fathoms and temperatures of between 3 and 4°C on the southern side of the Baffin Bay-Labrador Sea ridge between West Greenland and Baffin Island (see Sverdrup, Johnson and Fleming, 1942, fig. 181; and Hachey, Lauzier and Bailey, 1956) provide the necessary temperature and depth conditions suitable for *Sebastes marinus mentella*. Thus, apart from a possible pelagic connection for both *marinus* and *mentella* varieties of redfish, there is a direct bottom connection between West Greenland and Baffin Island suitable for small numbers of the *mentella* but generally too deep for the *marinus* form.

Although our captures of redfish extend only to Latitude 61°N it is reasonably certain that the *mentella* variety of redfish occurs northward to southern Baffin Island and continuously westward to West Greenland following the southern side of the Labrador Sea-Baffin Bay Ridge.

From this area of West Greenland depths and temperatures suitable for redfish extend around South, West and East Greenland across the southern side of the Iceland-Greenland Ridge to Iceland, south of Iceland to the Faroes and from thence continuously to the northeast extremity of the redfish range. Although the whole interconnecting area possesses depths suited to the *mentella* form, the channels between many of the land masses are often too deep for *marinus* to occur in numbers, and for *marinus* the cross-channel connections must often be pelagic.

The *marinus* type and probably also the *mentella* are plentiful off West Greenland, and both are abundant off East Greenland. On present data, although *mentella* is present, *marinus* is the common form on the Icelandic and the Norwegian grounds and in the Barents Sea, whereas *mentella* is the common form on the Iceland-Faroes Ridge and on the Bear Island grounds. It must be remembered, for the European area, that *marinus* is shallower, larger, and more favoured in the market and thus, when in equal or in slightly lesser abundance, will usually be caught instead of *mentella*. Most of the redfish landed in the European area, especially until recent years, have been of the *marinus* type.

Also from Baffin Island and Labrador southwards suitable temperatures and depths provide the necessary suitable environment for a direct bottom connection for redfish populations to their most southward extension south of Georges Bank. Furthermore, water with temperatures suitable for redfish, and possibly a continuous distribution of redfish larvae, extend above the very deep water between southern Iceland and Greenland and the continental shelf off northeast Newfoundland and Labrador, the northern slope of the Grand Bank and Flemish Cap. Very likely many of the *marinus*-type redfish, which we have found more abundantly at Flemish Cap than elsewhere in the Newfoundland area, come from the southern fringe of the great pelagic community of redfish larvae south of Iceland and Greenland (Fig. 5), described by Tåning (1949).

## PELAGIC DISTRIBUTION OF ADULT REDFISH

Under pelagic distribution we are not discussing daily up and down movements, but rather the existence of large pelagic populations of redfish over areas where the water is too deep for them to be near the bottom at any time during the 24 hours. The species discussed is *Sebastes marinus*, without distinction between the *marinus* and *mentella* forms.

### EASTERN AND CENTRAL NORTH ATLANTIC

According to Jensen (1922), although Collett (1880) had found redfish larvae in the middle of the Norwegian Sea over very deep water, Nansen (1886) was the first to demonstrate that the adult redfish lived not only in relation to the bottom but also pelagically over great depths. Nansen obtained fresh specimens of *Sebastes marinus* from the stomachs of hood seals in the central part of the Arctic Ocean area between Jan Mayen and Spitsbergen over depths of more than 1,500 fathoms. Because these redfish captured by the seals must have been in the upper layers of water, Nansen suggested that *S. marinus* possibly occurred pelagically all over the Norwegian Sea.

Hjort (Murray and Hjort, 1912) found *Sebastes marinus*, both larvae and old, living pelagically over the very deep waters of the Norwegian Sea. Fig. 44 (from Murray and Hjort, 1912) shows the areas of the Norwegian Sea where pelagic *Sebastes marinus* were captured. Over the deep parts of the Norwegian Sea far from the coastal banks, *Sebastes* was the most numerous of the larger fishes. Hjort reports that these *Sebastes* were captured chiefly at depths of 100 to 200 metres (55 to 110 fath) by means of floating longlines. In one experiment (Hjort, 1909; Murray and Hjort, 1912) 65 *Sebastes marinus* were captured pelagically on 600 hooks using salted bait. This catch was in 100 fathoms in Lat. 71°10'N, Long. 12°30'E on Sept. 7, 1900. The bottom depth here was 1,387 fathoms. Hjort also found thousands of *Sebastes* fry all over the Norwegian Sea and was of the opinion that *Sebastes marinus* must live and spawn pelagically over the deep water of the Norwegian Sea.

Tåning (1949, and private communication Dec. 21, 1956) reports the capture by pelagic trawl, July 1, 1931, during a cruise of the *Dana*, of an adult male *S. marinus*, 48 cm in length, at 300 metres (160 fath) and a temperature of 5.6°C in the central North Atlantic over a depth of 3,300 metres (1,800 fath) at Lat. 53°38'N and Long. 29°41'W. Also, on June 27, 1948, a female of 49 cm was captured by the *Dana* using pelagic trawl in 300 metres (160 fath), 6.2°C, over a depth of 800 metres (440 fath) south of Iceland in Lat. 62°00'N and Long. 26°20'W. Tåning's discoveries of great quantities of redfish fry south of Iceland and Greenland to a latitude of about 50°N led him to postulate that here in the open ocean were immense quantities of pelagic adult redfish far exceeding

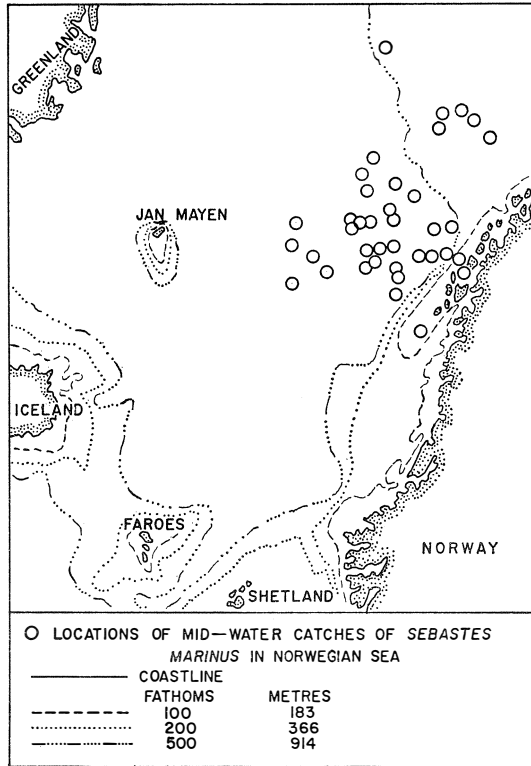


FIGURE 44. Areas of the Norwegian Sea where redfish, *Sebastes marinus*, were captured pelagically (after Murray and Hjort, 1912, fig. 482).

in quantity even the herring and the cod, and to believe that these very great redfish resources would some day be utilized.

Fridriksson (1953) gives a table showing a decline in the Icelandic redfish catch per trawler from 55 or 60 metric tons per day for the first trips in May to 22 metric tons per day at the beginning of August. He thinks that fishing has a depleting effect on the redfish stocks at the fishing grounds, which are near the cold water areas, and that "resting the banks" allows a new accumulation of redfish. The replenishment, however, may come from adjacent grounds not so heavily fished rather than from a truly pelagic population.

Adolf Kotthaus (private communication, February, 1956) says that during the redfish investigations of the *Anton Dohrn* in May to July and September to October, 1955, systematic observations on the echo-sounder at depths of 0 to 600 metres (0 to 330 fath) were carried out to check whether redfish, as Tåning presumes, appear pelagically everywhere in the North Atlantic where conditions for life are suitable. In the trans-Atlantic section from Scotland to Cape Farewell, Greenland, indications of fish (according to Kotthaus probably redfish) were observed easterly to the Reykjanes Ridge, but not in the remaining area, namely

in the Irminger Sea. The indications were in depths of 50 to 450 metres (27 to 250 fath) and were favourable in 100 to 200 metres (55 to 110 fath). No proof is available that these were redfish indications. Tåning's view was not confirmed by these findings but also not refuted. Kotthaus believes that the findings may be in agreement with his own view that redfish live to a great extent pelagically only at times, namely during the spawning season.

#### WESTERN NORTH ATLANTIC

In the Western North Atlantic there have been no positive results, showing large pelagic populations, from the small amount of mid-water towing incidental to the return of the trawl from deep-water—400 fathoms—where very few redfish were found. It is very likely, however, that, away from the bottom barrier, the net must move much faster to catch the pelagic redfish.

In a series of tows of the Isaacs-Kidd mid-water trawl by the *Albatross III* in the Gulf of Maine, July 25 to Aug. 2, 1957, a redfish 29 cm long was caught during the night at 22 fathoms in a locality where the water was 110 fathoms deep (Anon., 1957a).

The lack of captures of redfish larvae beyond the continental shelf, shown in Fig. 11, 12 and 15, in the southern Nova Scotian and New England areas argues against the existence of large pelagic spawning redfish populations over very deep water beyond the continental shelf in these regions.

Also the catch per unit effort from virgin redfish populations in the western Atlantic, even from those Grand Bank areas facing the open Atlantic, declined rapidly year by year after exploitation began. Thus, there is no evidence that these fringe populations, related generally during the daytime to the bottom, receive quick replacement from enormous pelagic populations which would not be expected to be radically changed by a relatively small extraction of fish. On the other hand there are many lines of evidence indicating lack of rapid and extensive migrations in the redfish and, if large pelagic populations are present, replenishment of fringe areas from the main pelagic body may be slow, and the ground may require a rest period during which a new fringe of the pelagic population may move or be moved by currents to the edge of the bank. Some of our recent work in the Labrador area has indicated that vertical replacement may also be difficult.

It is evident, from the temperature relationships of redfish discussed later in this paper, that the existence of large redfish populations depends on the presence of temperatures from 3° up to 6° or 7°, or possibly to 8°C, in depths of about 200 to 500 metres (110 to 270 fath).

In the Norwegian Sea and, as indicated in Fig. 60 and 62, south of Iceland and Greenland, and between Iceland and the southern part of East Greenland, there is a great body of ocean water with temperatures at depths of 200 to 500 metres (110 to 270 fath) between 3° and 8°C.

In the Northwest Atlantic temperatures at depths of 200 to 500 metres (110 to 270 fath) are mostly between 5° and 3°C in the area between the

continental shelves off Southwest Greenland, Southeast Baffin Island, Labrador and Northeast Newfoundland. The lower temperatures at the same depths are off Labrador and Northeast Newfoundland (Fig. 45A, and Smith *et al.*, 1937). This band of deep water, the temperatures of which at depths of 200 to 500 metres (110 to 270 fath) are suited to the pelagic existence of redfish in numbers, extends to the northern slopes of the Grand Bank and Flemish Cap.

From the southern part of the eastern slope of the Grand Bank, and particularly in the continental slope area west of the tail of the bank, and southward to Cape Cod there is nowhere any extensive area seaward of the bank slopes where over a great part of the depth between 200 and 500 metres (110 to 270 fath) the temperatures are fairly constantly as low as 3° to 6°C, or even 3° to 7° or 8°C (Smith *et al.*, 1937; Iselin, 1936; Fig. 64, 66, 67, 71). Nowhere

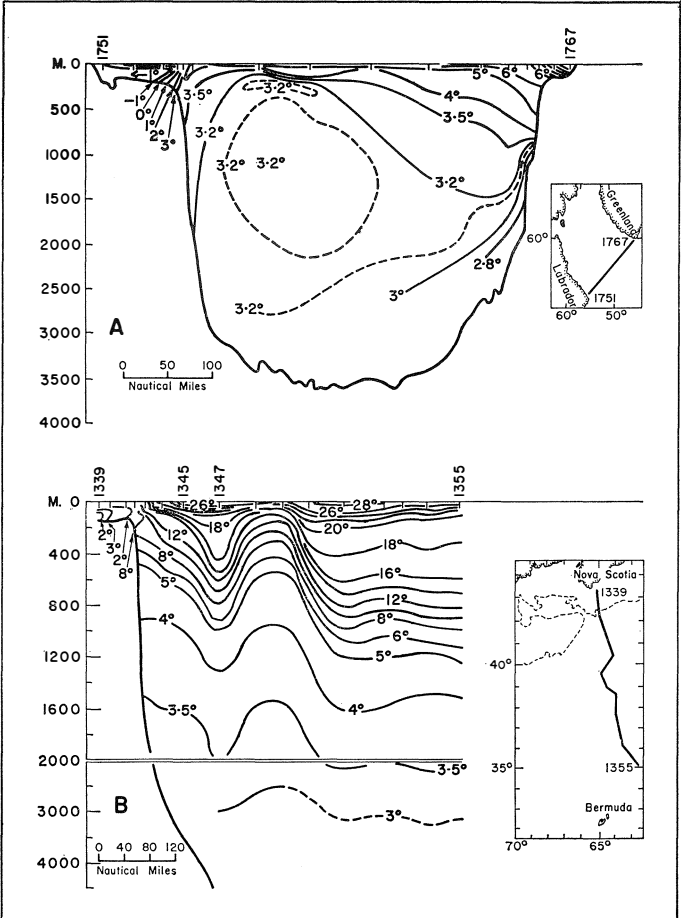


FIGURE 45. Temperature sections: A, through Labrador Sea, South Wolf I., Labrador, to Cape Farewell, Greenland, July 10 to 13, 1934 (after Smith *et al.*, 1937); B, southern tip of southeastern Nova Scotia (at left) to Bermuda, Aug. 14 to 20, 1932 (after Iselin, 1936). (100 m = 54.7 fath.)

in this southern area, therefore, would one expect to find large populations of redfish living pelagically over large areas of water too deep for them to settle to the bottom. The difference is well illustrated by Fig. 45A from Smith *et al.* (1937), a temperature section from Cape Farewell to Labrador, and Fig. 45B from Iselin (1936), showing a temperature section from southern Nova Scotia to Bermuda. [As an exception to the above statement, water of suitable temperatures for redfish at 200 to 500 metres (110 to 270 fath) often extends southward a considerable distance from the tail of the Grand Bank (McLellan, 1956, fig. 2).]

## DAY AND NIGHT VERTICAL MIGRATIONS

### INTRODUCTION

Commercial fishing for redfish in North American waters began in the Gulf of Maine and in the southern Nova Scotia area. As is quite feasible in these areas, much of the dragging was carried out in water of 100 fathoms or less. It became a tradition with redfish fishermen that redfish were not available at night to bottom-fishing otter trawls. Consequently fishing for redfish became a daylight operation which ceased at night.

During the past few years, with the extension of the fishery into the deeper water (140 to 200 fath) to the northward, more variable results have been reported. Here, although the daylight hours are still by far the more productive for this fishery, some commercial night fishing for redfish has been carried out.

Steele (1957) carried out a series of day and night drags for redfish and redfish food in 110 fathoms near Gaspé from June to September, 1954. Somewhat smaller catches of redfish (almost all sexually mature) were obtained in the night than in the daylight periods. Males were most plentiful in the afternoon catches and almost as plentiful in the morning catches but scarce after sunset and before sunrise. Females were most plentiful in the morning catches, slightly less plentiful in the before-sunrise catches and progressively less plentiful in the afternoon and after sunset catches. The diurnal vertical migrations of the female redfish, which were feeding during the course of the experiment, were correlated with the vertical migrations of the euphausiid *Meganyciophanes norvegica*, which was the main food of the redfish at the depth fished. The movements of the male redfish, which were not feeding during most of the experiment, may have resulted from reactions to changes in light intensity.

### INVESTIGATOR II EXPERIMENTS

Figure 46 shows the results of some day and night drags taken by the *Investigator II* on the southwest slope of the Grand Bank at about 150 fathoms in June, 1954, and on the northeastern corner of the Grand Bank in about 160 fathoms in July, 1954. On the southwest slope of the Grand Bank, in the first group of sets at 150 fathoms (Fig. 46A) the night catches were negligible, but two of the catches near midday were negligible also. In the second series (Fig. 46B) the lowest catch in darkness at 12.40 to 1.10 a.m. was only 13% of the average daylight catch. The two other catches in darkness, one at 8.55 p.m. just after sunset and the other at 3.45 a.m. approximately at sunrise, were 39% and 45% respectively of the average daylight catch of 1,520 pounds. Of two night drags taken to the northeast of the Grand Bank, one in moonlight at 11.25 p.m. produced 68% and one in darkness with thick fog at 2.50 a.m. produced 36% of the average daylight catch of 2,180 pounds (Fig. 46C).

Within each group of sets shown in Fig. 46 there did not appear to be any regular difference in relative distribution of males and females on bottom in daylight and darkness, nor, considering all sets, was there any definite indication of a size difference between redfish in day and in night drags. There was, however, only a small number of drags.

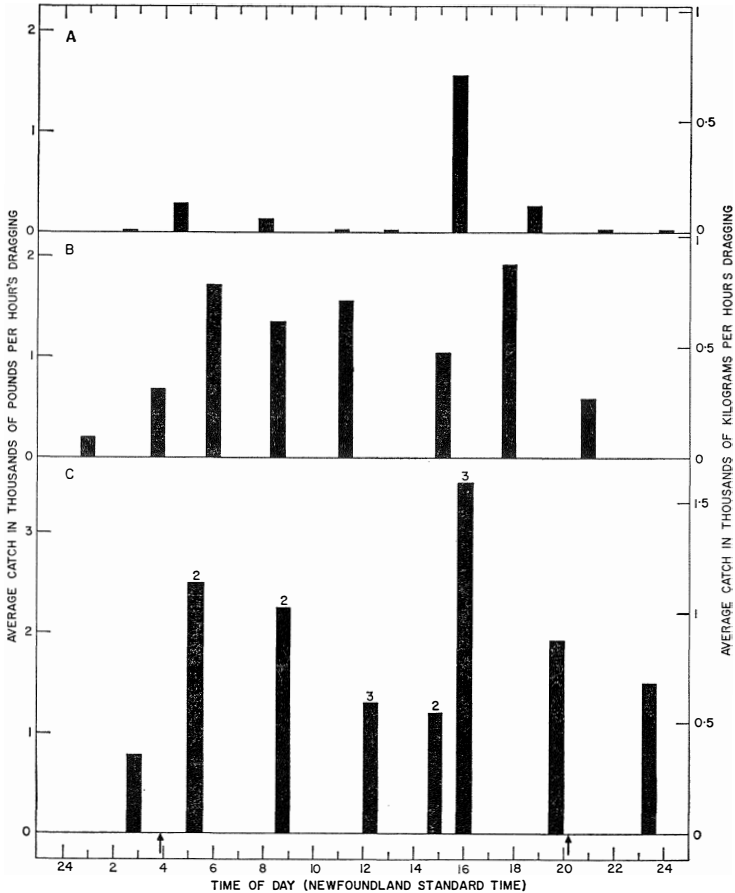


FIGURE 46. Redfish catches by the *Investigator II* over the 24-hour period in 1954: A, SW Grand Bank, 150 fath, June 22 to 23; B, SW Grand Bank, 150 fath, June 28 to 29; C, NE Grand Bank, 160 fath, July 11 to 19. (Arrows at base indicate approximate time of sunrise and sunset. Figures above bars are numbers of sets in averages for which the number of sets is greater than one.)

#### HOURLY CATCHES BY COMMERCIAL VESSELS

Two otter-trawlers fishing for the Northlantic Trawling Company of St. John's have (since the spring of 1948, on special forms and under the supervision of the Biological Station's staff) kept complete records of catch per drag of all fishes. The depth, position, time, length of drag and other relevant data have also been recorded. These two ships are the *Blue Spray* and the *Blue Foam*.

The trawlers are sister ships, each 133 feet in registered length, having an 800 h.p. engine, and typically drag an Iceland trawl with a 78-foot headrope and a 116-foot footrope.

Captain B. Blackwood of the *Blue Spray* was formerly chief field technician on the *Cape Agulhas*, the research vessel of the Newfoundland Fisheries Research Station during the period 1931 to 1935, and continued as technician at the Station, apart from several years in the fishing industry, until 1947. He was captain of the *Investigator II* during her first two years' operation. Captain Thornhill of the *Blue Foam* and also the mate, Angus Pope, have taken a great interest in these records. The records were collected and checked at the end of each trip. There have been many cruises on these trawlers by Station personnel who have checked the methods of collecting the records.

Dragging on bottom usually lasts an hour but there are a few longer drags, up to an hour and a half, and a few shorter down to a half-hour. Each drag has been converted to catch per hour's dragging. The catches were estimates, but the number of bags of fish and the number of deck pounds filled are aids in estimation. A check has been made, from random samples of redfish trips for each boat, of the totals of the estimates against the turnout, and there was an excellent agreement between the two. For 21 redfish trips of the *Blue Spray* on sea estimates per drag totalling 4,715,000 pounds of redfish the total landings were 4.5% below the sea estimates. For 20 redfish trips of the *Blue Foam* on sea estimates per drag totalling 4,464,000 pounds of redfish the total landings were 1.5% above the sea estimates.

The data on catch per hour's dragging from the two ships have been combined in 2-hourly periods and are shown in Fig. 47 and 48 and Tables VIII and IX.

To place a drag in a particular two-hourly period the middle point of the drag was used. Similarly the average depth was used, but results from sets with widely varying depths covering several depth ranges were discarded.

As a general statement on the data, whenever the fishing continued more than an hour after sunset or began more than an hour before sunrise, redfish catches were small or negligible compared with the daylight period. Although the curves for the deeper levels are weak from lack of data during these hours, the November to January 131 to 160 fathom, the May to July 161 to 190 fathom and the August to October 131 to 160 fathom curves show the possibility of modest catches of 3,000 to 5,000 pounds per hour at the deeper levels after sunset, in the pre-midnight hours. With the large daytime catches at these deep levels recorded here, however, judging by the small number of night sets, it apparently did not pay the ships to keep fishing for redfish during the hours of darkness, and it may have been more profitable to have had the whole crew available to handle the large daytime catches. The catches under consideration are of virgin stock, and the catches from 131 fathoms and deeper are mainly from the eastern slope of the Grand Bank. The level of possible catch at present undoubtedly is lower.

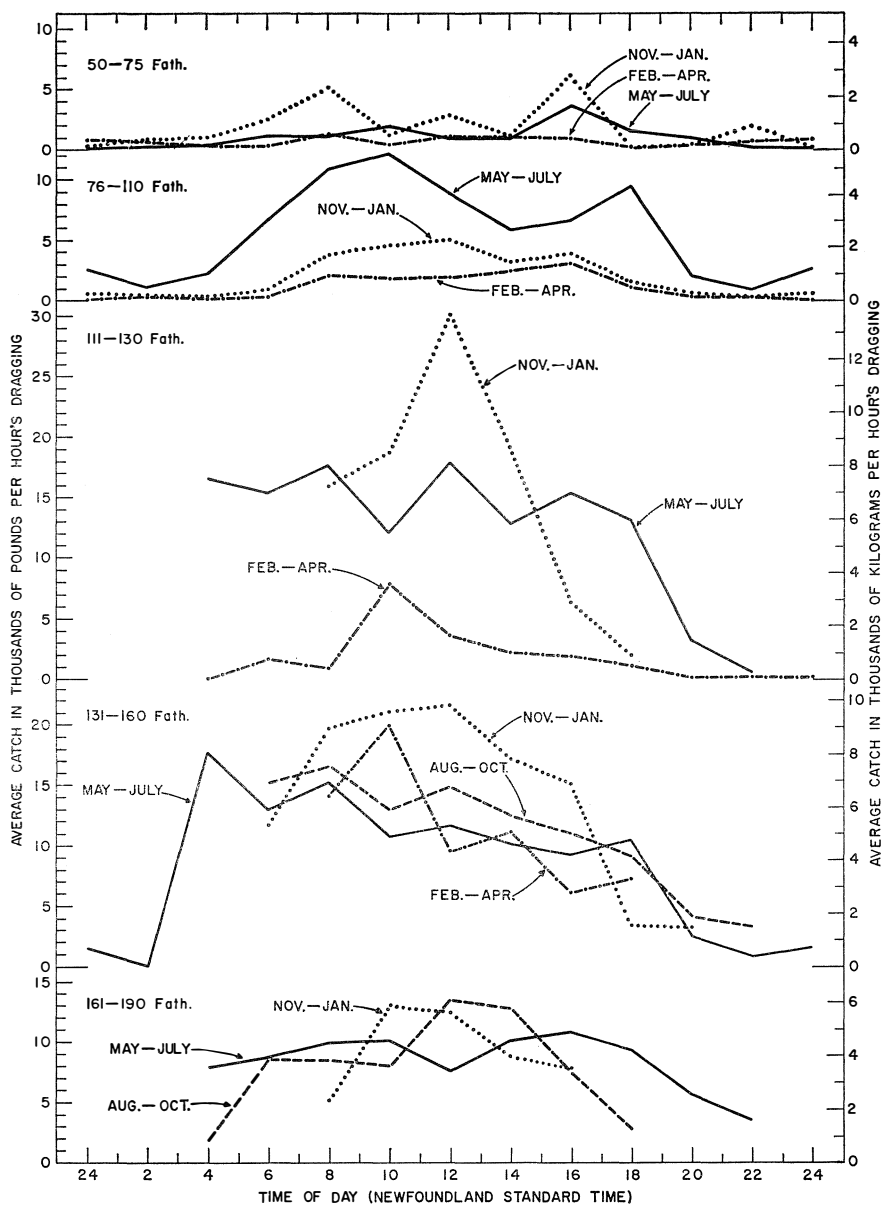


FIGURE 47. Average redfish catches per hour's dragging, 1948 to 1954, by the commercial trawlers *Blue Spray* and *Blue Foam* over the 24-hour period, in various seasons at the same depth.

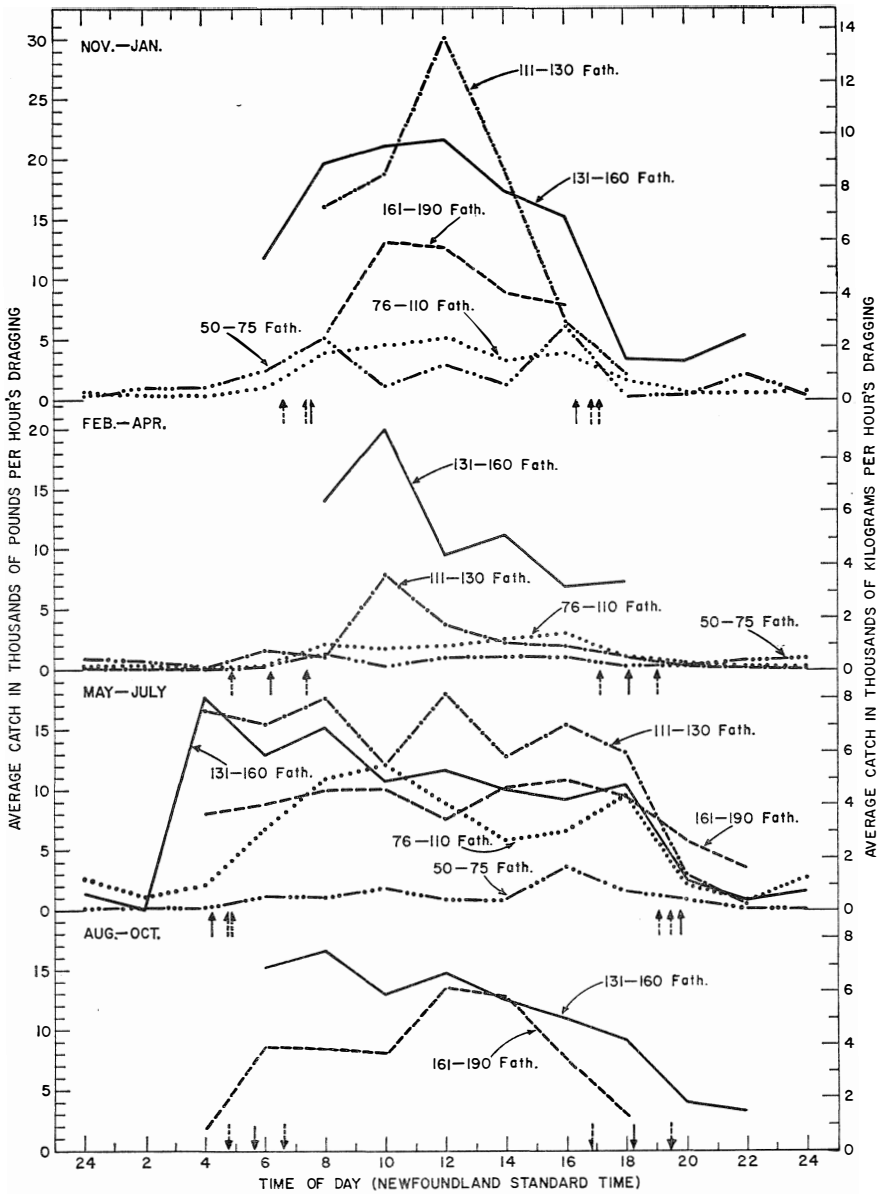


FIGURE 48. Average redfish catches per hour's dragging, 1948 to 1954, by the commercial trawlers *Blue Spray* and *Blue Foam* over the 24-hour period, at various depths during the same season. (Solid arrows at base lines indicate time of sunrise and sunset at mid-season and broken arrows at base lines indicate time of sunrise and sunset at the beginning and end of the season.)

TABLE VIII.—Redfish catch estimates, average catch in pounds per hour's dragging of the otter-trawlers *Blue Spray* and *Blue Foam*, November to April, 1948 to 1954. (The figures in parentheses indicate the number of drags.)

Time of day. Nfld. standard time	50-75 fath (91-128 m)	76-110 fath (139-201 m)	111-130 fath (203-238 m)	131-160 fath (240-293 m)	161-190 fath (294-348 m)
hours	lb	lb	lb	lb	lb
November to January					
23.01-1.00.....	240 (3)	589 (14)	.....	.....	.....
1.01-3.00.....	834 (5)	420 (13)	.....	.....	.....
3.01-5.00.....	993 (5)	303 (15)	.....	.....	.....
5.01-7.00.....	2,438 (6)	955 (37)	.....	11,676 (21)	.....
7.01-9.00.....	5,005 (6)	3,791 (38)	15,900 (3)	19,696 (77)	5,200 (2)
9.01-11.00.....	1,194 (5)	4,529 (45)	18,667 (3)	21,000 (80)	13,000 (1)
11.01-13.00.....	2,867 (7)	5,162 (48)	30,000 (1)	21,594 (70)	12,567 (3)
13.01-15.00.....	1,168 (4)	3,236 (46)	19,000 (2)	17,215 (86)	8,800 (2)
15.01-17.00.....	5,989 (7)	3,894 (36)	6,333 (3)	15,129 (60)	7,800 (1)
17.01-19.00.....	226 (5)	1,603 (33)	2,000 (1)	3,376 (18)	.....
19.01-21.00.....	310 (6)	625 (28)	.....	3,160 (6)	.....
21.01-23.00.....	1,938 (4)	416 (22)	.....	5,200 (1)	.....
February to April					
23.01-1.00.....	860 (5)	108 (17)	118 (2)	.....	.....
1.01-3.00.....	698 (4)	349 (17)	90 (2)	.....	.....
3.01-5.00.....	159 (7)	224 (23)	0 (1)	.....	.....
5.01-7.00.....	309 (16)	398 (33)	1,657 (3)	.....	.....
7.01-9.00.....	1,282 (17)	2,021 (40)	990 (3)	14,086 (7)	.....
9.01-11.00.....	337 (17)	1,787 (32)	7,800 (4)	19,950 (6)	.....
11.01-13.00.....	1,011 (14)	1,982 (30)	3,735 (4)	9,547 (7)	.....
13.01-15.00.....	1,004 (20)	2,504 (30)	2,218 (4)	11,070 (7)	.....
15.01-17.00.....	947 (20)	3,085 (30)	1,965 (8)	6,800 (4)	.....
17.01-19.00.....	241 (19)	1,122 (27)	1,050 (3)	7,200 (1)	.....
19.01-21.00.....	308 (11)	471 (25)	100 (1)	.....	.....
21.01-23.00.....	720 (11)	306 (23)	170 (2)	.....	.....

Considerably more data on the night period are available for the shallower depths. On the southern part of the eastern slope of the Grand Bank the effort in 131 to 190 fathoms was specifically for redfish, and catches of other fish were negligible. The redfish catches from 50 to 110 fathoms, typically, and from 111 to 130 fathoms, occasionally, came from fishing primarily for haddock, which was often continued as a routine throughout the 24-hour period. In this fishing, redfish was usually only an incidental part of the catch. The redfish catches recorded from 50 to 75 fathoms came, as a rule, from the southwest slope of the Grand Bank, and the 76 to 110 and the 111 to 130 fathom catches were usually from the southwest slope of the Grand Bank and the western and southern slopes of St. Pierre Bank.

Redfish catches at the 50 to 75 fathom level are small and sporadic and doubtless depend on unusually dull light conditions which bring the fish up from below. It is consequently in the darkest months of November to January that the best of the small catches have been made at these depths. For the same reason, at these shallow depths and during the darker months there are occasional catches near the midnight period which may equal the daylight catches. In

TABLE IX.—Redfish catch estimates, average catch in pounds per hour's dragging of the otter-trawlers *Blue Spray* and *Blue Foam*, May to October, 1948 to 1954. (The figures in parentheses indicate the number of drags.)

Time of day. Nfld. standard time	50-75 fath (91-128 m)	76-110 fath (139-201 m)	111-130 fath (203-238 m)	131-160 fath (240-293 m)	161-190 fath (294-348 m)
hours	lb	lb	lb	lb	lb
May to July					
23.00-1.00.....	38 (2)	2,613 (4)	.....	1,500 (1)	.....
1.01-3.00.....	173 (2)	1,018 (4)	.....	50 (1)	.....
3.01-5.00.....	204 (10)	2,122 (6)	16,653 (6)	17,683 (6)	7,944 (33)
5.01-7.00.....	1,125 (11)	6,675 (6)	15,398 (14)	12,942 (12)	8,777 (33)
7.01-9.00.....	1,080 (10)	10,930 (6)	17,600 (16)	15,081 (16)	9,957 (39)
9.01-11.00.....	1,793 (8)	12,180 (5)	12,153 (11)	10,735 (11)	10,074 (38)
11.01-13.00.....	844 (7)	8,877 (7)	17,960 (9)	11,514 (12)	7,627 (40)
13.01-15.00.....	820 (6)	5,800 (6)	12,804 (11)	10,071 (17)	10,208 (35)
15.01-17.00.....	3,611 (4)	6,561 (7)	15,348 (6)	9,114 (14)	10,889 (36)
17.01-19.00.....	1,448 (6)	9,478 (6)	13,122 (11)	10,335 (11)	9,415 (34)
19.01-21.00.....	836 (6)	2,084 (5)	3,080 (5)	2,350 (4)	5,707 (21)
21.01-23.00.....	89 (4)	867 (3)	500 (1)	750 (1)	3,500 (3)
August to October					
23.00-1.00.....	.....	.....	.....	.....	.....
1.01-3.00.....	.....	.....	.....	.....	.....
3.01-5.00.....	.....	.....	.....	.....	1,950 (2)
5.01-7.00.....	.....	.....	.....	15,204 (23)	8,676 (15)
7.01-9.00.....	.....	.....	.....	16,570 (33)	8,544 (14)
9.01-11.00.....	.....	.....	.....	12,987 (37)	8,121 (15)
11.01-13.00.....	.....	.....	.....	14,783 (35)	13,547 (17)
13.01-15.00.....	.....	.....	.....	12,484 (37)	12,849 (15)
15.01-17.00.....	.....	.....	.....	10,986 (37)	7,508 (12)
17.01-19.00.....	.....	.....	.....	9,166 (17)	2,829 (7)
19.01-21.00.....	.....	.....	.....	4,000 (8)	.....
21.01-23.00.....	.....	.....	.....	3,250 (2)	.....

this regard note the catches at 21 to 23 hours at 50 to 75 fathoms in the November to January period. At 50 to 75 fathoms the catches may have both a morning and an afternoon maximum with a depression near midday, but in any case the data indicate that the afternoon catch per hour's dragging may often reach equal or higher peak levels than the morning catches. More data are needed here in order that definite conclusions may be reached.

From 76 to 160 fathoms the morning catches are greater than the afternoon catches. The morning catches reach a higher peak level and in general are sustained at a high level over a longer period. The exception is 76 to 110 fathoms February to April, where the small catches show some of the afternoon superiority characteristics of the data for the 50 to 75 fathom level. A probable explanation for the morning superiority is that the pelagic redfish, with eyes sensitized by the dim light at night, quickly retreat to the bottom under the influence of the early morning light. After becoming accustomed to the daylight intensities some of the redfish leave the bottom under light intensities which in the early morning would have forced them to the bottom.

At 161 to 190 fathoms in the brighter May to July period the afternoon catches are slightly higher, although this may not be significant. In a duller period with less daylight, August to October, greater catches are indicated at noon and in the early afternoon than in the morning.

The appearance of some of the deeper-water catch curves indicates that the vessels could profitably have begun dragging somewhat earlier in the morning than was their actual practice.

It is obvious that at all depths the fishing begins earlier and continues at a high level later in May to July when daylight is longest than in any other period of the year. Also, in the many hours of fishing possible in May to July, there is a greater tendency for the catch curves to have morning and late afternoon peaks with a midday or post-midday depression.

It might be expected that not only would the period of longest daylight in May to July show the fish available over a longer period of the day, but that in greater depths in the same months the daily fishing period would be shorter. The only place where this is clearly indicated is in the August to October curves for 131 to 160 and 161 to 190 fathoms. Otherwise, in Fig. 48, it is surprising how little difference there is on the average between the times of the early morning build-up and of the sunset to after-sunset decline of the catch at the various depths.

#### PORT SAUNDERS AREA, 1955

Subsequent to the analysis of the data from the *Blue Spray* and the *Blue Foam* for 1948 to 1954, these trawlers carried out redfish fishing in a very small area of the Gulf of St. Lawrence near Port Saunders on the west coast of Newfoundland, between Aug. 13 and Sept. 18, 1955. During these trips there was a good deal of dragging for redfish, usually in one-hour sets, over the whole 24-hour period. The methods used in summarizing the data were similar to those described previously for these two ships.

All these sets were in a narrow horizontal range (Lat.  $50^{\circ}15'$  to  $50^{\circ}31'30''$ N, Long.  $57^{\circ}41'$  to  $58^{\circ}00'$ W) and, apart from one set at 170 fathoms, all sets were between 124 and 153 fathoms with 60% between 138 and 143 fathoms. The depths fished were on the average the same at night as in the daytime. Catches rose rapidly after sunrise to a peak of 8,660 pounds per hour's dragging at 9 to 11 a.m. and declined gradually to 3,750 pounds per hour's dragging at sunset (Fig. 49). The average catch per hour's dragging in 98 daytime sets between 7 a.m. and 7 p.m. was 6,150 pounds, and in 73 sets at night or near sunrise and sunset, between 7 p.m. and 7 a.m. it was 2,150 pounds. In 55 sets between 7 p.m. and 5 a.m. the average catch was 1,900 pounds. Catches at night were large enough to make fishing at this time worthwhile.

#### RELEVANT EXPERIMENTAL DATA

Scholander *et al.* (1951) on the basis of observations and experiments off the New England coast found that the nitrogen content in the swim-bladders of

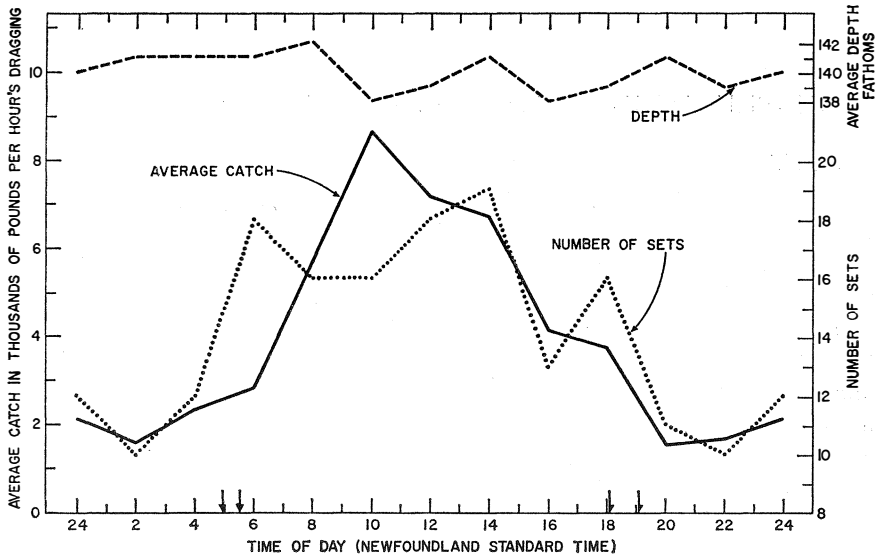


FIGURE 49. Average redfish catches per hour's dragging by the commercial trawlers *Blue Spray* and *Blue Foam*, Aug. 13 to Sept. 18, 1955, in 124 to 153 fathoms (one set at 170 fathoms) near Port Saunders in the Gulf of St. Lawrence. (Arrows at base line indicate sunrise and sunset at the beginning and the end of the fishing period. 1000 lb = 454 kg.)

redfish caught at about 200 metres (110 fath) indicated that the redfish in the area migrated up to at least 80 metres (44 fath) depth during the night. Also, the statement is made that in the area under observation the redfish is caught at the bottom in many places in great abundance, but when trawled for on the bottom at night it is hardly ever caught.

Scholander and Van Dam (1953), however, show that the higher-than-expected nitrogen tension in the swim-bladder of *Sebastes*, which led to the above conclusion regarding *Sebastes* vertical range, is also found in some bottom-living species such as *Cottunculus*. Thus the extent of the redfish nightly range in the area as calculated from nitrogen tension is open to question.

Jones (1952), reasoning from experimental work and field observations on the perch, *Perca fluviatilis*, says that, although the applicability of these researches to marine teleosts with closed swim-bladders is largely guesswork, assuming that they can adapt themselves as quickly as the perch, they would not be expected to make a diurnal migration that involved a reduction of more than 50% in the total pressure to which they were originally adapted.

## DISTRIBUTION OF MALE AND OF FEMALE REDFISH

### SEASONAL VARIATIONS IN SEX-RATIO

Figure 50 and Table X show in different bi-monthly periods and for various depths the percentage of female redbfish in the catch. Most of the sex-determinations were made at sea by biologists and technicians in the course of obtaining length-frequencies of redbfish. Some were obtained, mostly by technicians, on shore at fish plants, and over 6,000 specimens were sexed at the Biological Station at St. John's. The latter were usually checked by the author. The data are made up entirely from random samples usually of 200 to 400 fish measured from each set at sea or from each landing on shore, and the Station samples usually consisted of 120 fish. At sea, with the fish in good condition, the sex-examination was usually external and the penis, often with milt emerging, served as a sufficient distinction. In several months near the spawning season, also, the eggs or larvae emerging from the female provide a distinction. Many internal check examinations were made and the results recorded against previous external examinations. At first most specimens were cut open for examination, later all below 30 cm, more recently all below 25 cm, and doubtful specimens have always been cut open and examined. In most of the area under examination, the majority of male redbfish 20 cm long are mature. Very few errors were noted in the original sexing, by external examination of fresh recently-caught redbfish, on checking by internal examination. The checks indicate a very high standard of accuracy. On shore at the fish plants and at the Station all fish were cut open for examination. Random samples totalling over 160,000 redbfish from the

TABLE X.—Depth distribution of male and female redbfish. (The values in parentheses are the number of fish sexed.)

Depth range <i>fath</i>	Percentage female and total number of fish sexed at each depth range					
	Jan.-Feb.	Mar.-Apr.	May-June	July-Aug.	Sept.-Oct.	Nov.-Dec.
	%	%	%	%	%	%
51-70.....	37 (697)	35 (533)	32 (960)	52 (246)	75 (154)	.....
71-90.....	43 (980)	40 (1,709)	42 (3,233)	60 (208)	.....	53 (1,197)
91-110.....	40 (509)	46 (2,803)	44 (5,376)	50 (2,897)	58 (1,605)	53 (7,646)
111-130.....	43 (656)	41 (2,419)	55 (1,763)	54 (3,218)	35 (3,900)	49 (4,795)
131-150.....	48 (273)	23 (2,139)	46 (12,603)	48 (3,387)	44 (10,125)	55 (6,948)
151-170.....	47 (806)	30 (1,178)	54 (11,892)	56 (14,517)	48 (10,401)	52 (5,593)
171-190.....	.....	24 (204)	57 (8,850)	50 (9,708)	57 (2,715)	57 (1,620)
191-210.....	.....	26 (301)	65 (4,822)	60 (2,189)	65 (1,402)	59 (323)
211-230.....	.....	.....	91 (441)	.....	.....	61 (59)
231-275.....	.....	.....	.....	52 (58)	.....	.....
276-325.....	.....	.....	.....	35 (62)	54 (63)	.....
326-375.....	.....	.....	.....	.....	52 (105)	.....
Shore, fish plant.....	45 (2,871)	32 (1,809)	37 (3,267)	50 (6,376)	56 (3,569)	51 (2,215)
Sea.....	37 (1,050)	38 (9,309)	52 (45,812)	54 (28,235)	46 (25,212)	53 (23,264)
Shore, Biol. Station.....	.....	30 (168)	67 (861)	46 (1,879)	47 (1,689)	54 (2,702)

Newfoundland-Labrador-Gulf of St. Lawrence area were sexed. Allowing for differences due to chance, there was essential agreement between the results from the three methods for the same depth ranges in the same months. Thus, in view of the good agreement and because individual tables were not representative of all times and depths, all the data have been added together to produce Fig. 50 and Table X. Apart from the very small part of occasional commercial landings which was taken at night, all were daytime catches.

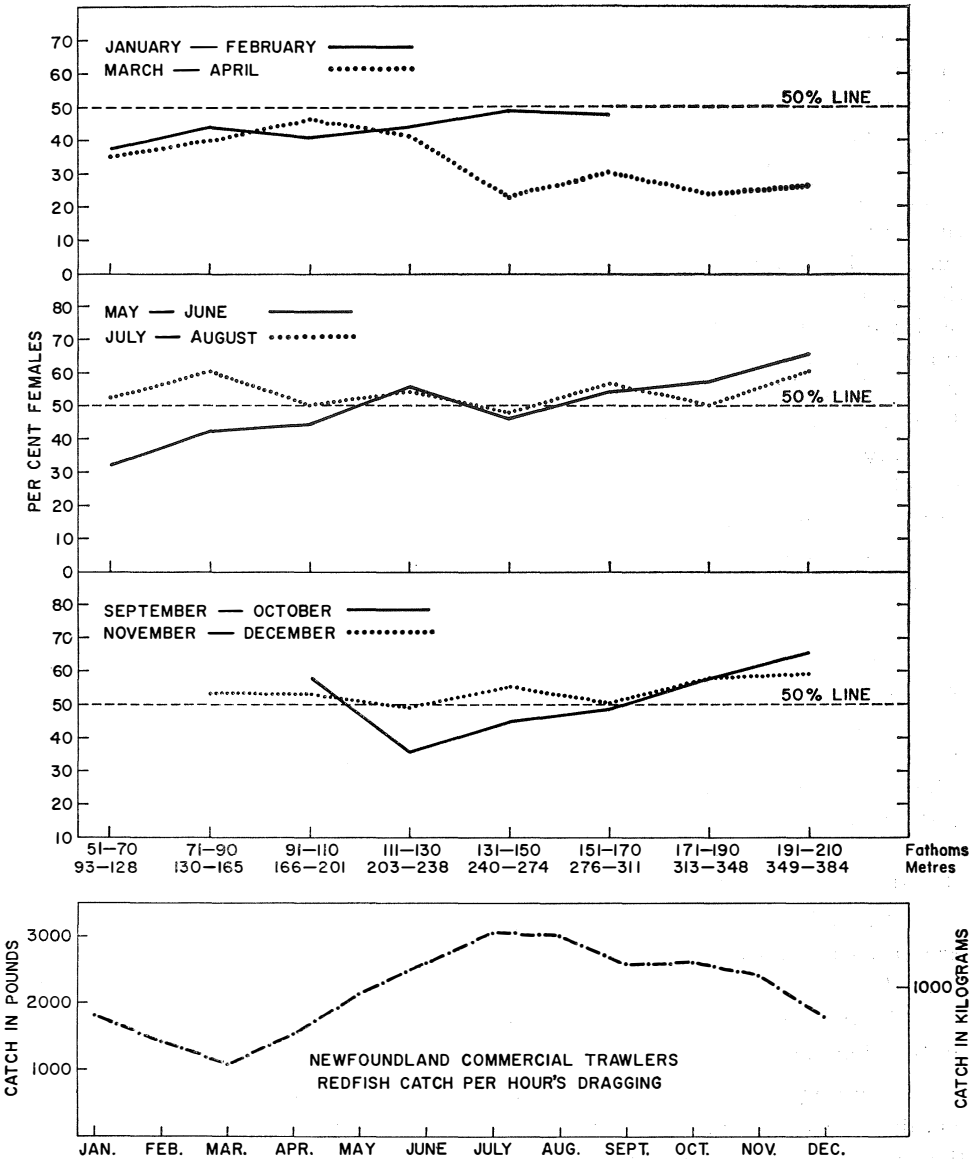


FIGURE 50. Percentage of females in redfish random samples (of Table X), and also redfish catch per unit effort by four 150- to 500-gross-ton Newfoundland trawlers in 1954.

In January-February and March-April the catches at all depths contained fewer females than males. In the latter months the percentage of females was on the average below 30% at the greater depths. In May-June females were less abundant than males at the shallower depths, but the numbers of females gradually increased beyond 50% at greater depths. In July-August and in November-December the percentage of females at most depths was on the average somewhat greater than that of males. In September-October there was a lack of females at the intermediate depths.

The percentages of females in the samples examined from all depths, considering the variation in depths, were fairly similar in the catches examined at sea, on shore and at the Station (Table X). An exception is the May-June period when the sampling of the commercial catch still indicated a low percentage of females comparable with that of the March-April period, whereas the sea and Station samples from the same depths showed higher percentages of females. In May and June the sea and Station samples came entirely from ICNAF Subarea 3 (Grand Bank, St. Pierre Bank and northwest of St. Pierre Bank) but the commercial samples came almost entirely from ICNAF Subarea 4 (Gulf of St. Lawrence). The few commercial samples obtained from Subarea 3 contained more females than males. These differences between areas and the occurrence of a deficiency of large females in Hermitage Bay throughout the year, as discussed later, indicate that as more data become available it will be profitable to study the year-round distribution of mature male and female redfish from considerably smaller areas than have been used in this paper where all the data have been combined.

The average redfish catch per hour's dragging by four Newfoundland trawlers of 151 to 500 gross tons, concentrating on redfish in 1954 (Fig. 50 and Table XI), shows a depression in the catch in March corresponding to the period when the females are least available and peak catches in July-August when females are fully available. In the deeper water, among the large sizes of redfish usually fished by Newfoundland commercial redfish fishermen, the mature females make up a large share of the catch. There are, however, many other variable factors, such as light, which may cause differences in catch per unit effort.

#### DISCUSSION AND CONCLUSIONS

Although the matter cannot be fully discussed here, pending a study of size at sexual maturity over the area, it seems obvious from a general consideration of relative length-frequencies of males and females in different months, that the differences in sex-ratio are largely due to differences in availability of mature females. Fig. 51 and 52 indicate the great differences that may occur.

Hermitage Bay, where the fishery takes place usually in 120 to 160 fathoms, has more large mature males than females generally throughout the year, but in the spring and early summer the shortage of large females is pronounced. Fig. 51 and Table XII illustrate a typical difference in the frequency distribution of

TABLE XI.—Redfish catch and effort in 1954 by 4 Newfoundland trawlers of 151 to 500 gross tons.

Month	Total catch	Total hours dragging by all 4 trawlers	Catch per trawler per hour's dragging
	<i>lb</i>	<i>hr</i>	<i>lb</i>
January.....	467,680	235	1,990
February.....	347,253	228	1,523
March.....	165,014	149	1,107
April.....	120,998	80	1,512
May.....	1,017,524	477	2,133
June.....	3,443,130	1,324	2,601
July.....	1,691,837	558	3,032
August.....	2,397,637	786	3,050
September.....	1,793,143	670	2,676
October.....	1,712,084	629	2,722
November.....	640,337	266	2,408
December.....	95,155	53	1,795
Total.....	13,891,792	5,455	2,547

male and female redfish in Hermitage Bay in December and April. In this area females less than 30 cm in length are almost all immature. Most of the males over 20 cm and almost all the females over 30 cm are mature. Usually in the catch at all seasons of the year in this and in other areas there are approximately equal numbers of immature females and of males of corresponding size, but mostly mature. The upper portions (above 30 cm) of the frequencies in Fig. 51 consist of mature males and females. Less than 10% of the expected numbers of large mature females were present in April.

For the two small redfish fishing areas of Hermitage Bay and the neighbouring Connaigre Bay on the south coast of Newfoundland there is information over a longer period than for other areas of limited extent (Table XIII). This information is from the experimental fishing of the research vessels *Marinus* and *Investigator II*. It is evident that, in Hermitage Bay at depths of 116 to 170 fathoms in the months for which information is available, mature female redfish are relatively scarcest in April, when, for sizes of 30 cm and over, at which almost all females are sexually mature and even the smallest males have been mature for many years, only 9% of the catch consisted of females. The percentage of large females at these sizes was low in June, 21% to 25%, and in August to December, 26% to 37%. For some reason at present unknown, in this inshore deep-water area of Hermitage Bay, but for one exception, large males in all months have been considerably more numerous than large females. Sometimes, as in April, the picture with regard to mature females is much obscured if the data for all females, including the immature sizes also, are combined.

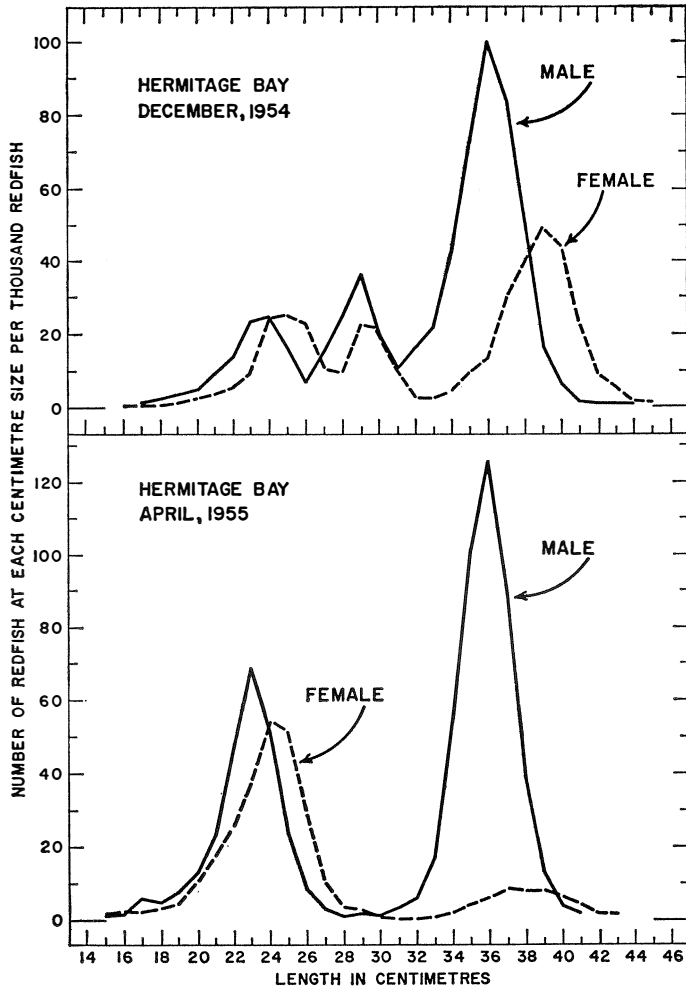


FIGURE 51. Length-frequencies of male and female redfish in otter-trawl catches by the research vessel *Marinus* in Hermitage Bay, Newfoundland, December, 1954 and April, 1955.

In the neighbouring Connaigre Bay area, where dragging was always carried on in the same small area at 92 to 112 fathoms, considerably smaller catches than in Hermitage Bay were obtained, but the percentages of mature females in the small numbers measured were notably higher in April and in June than during the same periods in Hermitage Bay. Similarly, the one catch in Hermitage Bay in which above 50% of the large fish consisted of mature females was in 115 fathoms. This catch was obtained in August.

Whereas the Hermitage Bay data show the changes in numbers of females occurring in approximately the same place and depth, Fig. 52 and Table XIV indicate the changes in redfish sex-ratio which may occur in the same area but at different bottom depths. The length-frequencies used are from the same

TABLE XII.—Length-frequencies of male (M) and female (F) redfish, per thousand fish, in daylight drags by the *Marinus* in Hermitage Bay, Newfoundland (15 cm and over).

Length	Hermitage Bay (No. per 1000)			
	December 1954		April 1955	
	M	F	M	F
<i>cm</i>				
15.....			0.3	0.3
16.....		0.3	1	1
17.....	1	0.3	6	2
18.....	2	0.3	4	2
19.....	3	1	7	4
20.....	5	2	12	10
21.....	8	4	23	18
22.....	14	6	47	26
23.....	23	9	69	38
24.....	25	24	51	55
25.....	17	25	24	52
26.....	6	23	8	28
27.....	14	10	2	10
28.....	23	9	0.3	3
29.....	36	23	1	2
30.....	22	21	1	0.3
31.....	9	9	2	0.3
32.....	15	2	5	0.3
33.....	21	1	17	0.3
34.....	41	4	53	2
35.....	69	8	100	4
36.....	100	13	126	6
37.....	83	28	89	8
38.....	51	39	39	7
39.....	15	48	12	7
40.....	6	43	3	5
41.....	1	24	0.3	3
42.....	0.3	9		1
43.....		5		1
44.....	1	1		
45.....		0.3		
Total.....	611	392	703	297
Total measured.....	2,374	1,523	2,126	894
Depth, <i>fath.</i> .....	124-167		116-16	
Redfish catch per hour's dragging, <i>lb.</i> ....	1,310		480	

TABLE XIII.—Sex-ratios of redfish in Hermitage Bay and Connaigre Bay, Newfoundland.

Date	Year	Ship	Depth range	Number of redfish measured and sexed		Percentage females			Catch per hour's dragging
				15 cm and over	30 cm and over	15 cm and over	15-29 cm	30 cm and over	
HERMITAGE BAY			<i>fath</i>						<i>lb</i>
April 1-5.....	1955	<i>Marinus</i>	116-164	3,020	1,487	30	49	9	480
June 11-14.....	1955	<i>Marinus</i>	116-164	7,872	4,832	33	45	25	2,230
June 23-26.....	1954	<i>Marinus</i>	130-162	3,000	1,830	31	47	21	2,880
Aug. 6.....	1947	<i>Investigator II</i>	115	321	275	58	59	58	3,480
Aug. 20.....	1948	<i>Investigator II</i>	130-155	554	492	29	47	26	590
Sept. 8-13.....	1954	<i>Marinus</i>	123-170	2,704	1,757	37	41	35	3,650
Oct. 2-3.....	1947	<i>Investigator II</i>	90-135	1,015	949	33	44	32	4,420
Oct. 20-22.....	1947	<i>Investigator II</i>	120-140	3,551	3,351	30	39	29	6,980
Dec. 1.....	1947	<i>Investigator II</i>	120-138	236	164	41	58	33	1,700
Dec. 3-11.....	1954	<i>Marinus</i>	124-167	3,897	2,675	39	44	37	1,310
Dec. 4-17.....	1953	<i>Marinus</i>	122-160	1,421	234	45	47	36	130
CONNAIGRE BAY									
April 3.....	1955	<i>Marinus</i>	98-112	95	67	31	50	22	100
June 17.....	1955	<i>Marinus</i>	92-100	632	235	50	48	52	590
Sept. 9.....	1954	<i>Marinus</i>	102-110	632	384	40	39	41	2,020
Dec. 3-12.....	1954	<i>Marinus</i>	100-104	321	195	41	44	40	380

general area between Lat.  $43^{\circ}06'$  to  $43^{\circ}07'N$  and Long.  $49^{\circ}59'$  to  $51^{\circ}05'W$  on the southwest slope of the Grand Bank, June 17 to 18, 1952. In June in this area many of the females possess larvae in a fairly late stage and many females are completely spent. Others are liberating larvae and many have larvae not yet ready for liberation. (There is a variation of at least several weeks in time of larval liberation from locality to locality in the Newfoundland area, also at different depths and probably from year to year.) Almost all females above

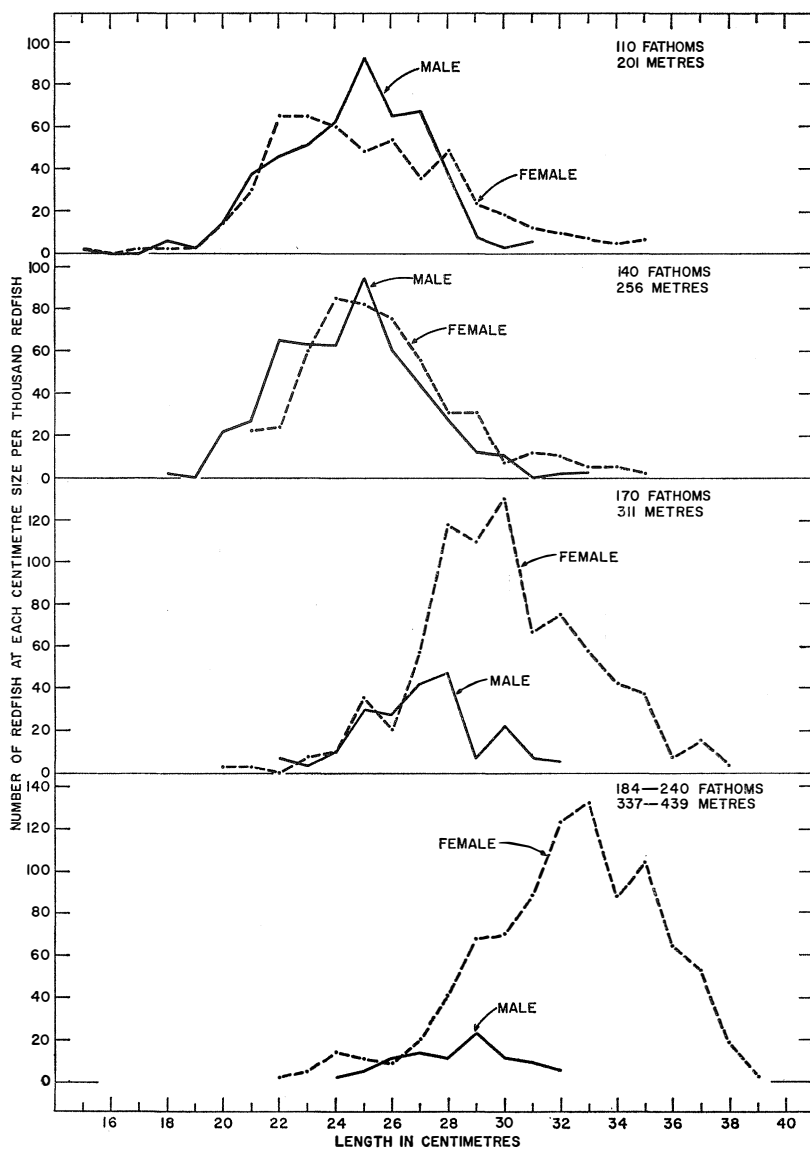


FIGURE 52. Length-frequencies of male and female redfish caught on the southwest slope of the Grand Bank by the *Investigator II*, June 17 to 18, 1952.

TABLE XIV.—Length-frequencies of male (M) and female (F) redfish per thousand fish in daylight drags by the *Investigator II*, southwest slope of the Grand Bank, June 17 to 18, 1952 (15 cm and over).

Length <i>cm</i>	110 fath (201 m)		140 fath (256 m)		170 fath (311 m)		184-240 fath (337-439 m)	
	M	F	M	F	M	F	M	F
15.....	2	2						
16.....								
17.....		2						
18.....	5	2	2					
19.....	2	2						
20.....	14	14	22			3		
21.....	37	30	27	22		3		
22.....	46	65	65	24	7			2
23.....	51	65	63	60	3	7		5
24.....	62	60	63	85	10	10	2	14
25.....	92	48	94	82	30	35	5	11
26.....	65	53	60	75	27	20	11	9
27.....	67	35	44	56	42	55	14	20
28.....	37	48	27	31	47	117	11	41
29.....	7	23	12	31	7	110	23	68
30.....	2	18	10	7	22	129	11	70
31.....	5	12		12	7	67	9	88
32.....		9	2	10	5	75	5	123
33.....		7	2	5		57		132
34.....		5		5		42		86
35.....		7		2		37		104
36.....						7		64
37.....						15		52
38.....						3		18
39.....								2
Total.....	494	507	493	507	207	792	91	909
Total measured....	214	220	204	210	84	318	40	401
Latitude.....	43°07'00"N		43°07'00"N		43°06'00"N		43°07'00"N	
Longitude.....	49°59'00"W		51°00'00"W		51°04'00"W		51°05'00"W	
Catch per hour's dragging, lb.....	2,860		5,200		7,280		2,860	

27-30 cm are sexually mature and nearly all below 27-30 cm are immature. Within the 27-30 cm range some females are immature and some are mature. Most of the males above 20 cm are sexually mature. At 110 fathoms and at 140 fathoms, where almost all the females were of immature sizes, the numbers of males and females were approximately equal. At increasing depths to 170 fathoms mature females became important in the catch, and at 184-240 fathoms

the mature females completely dominated the catch. The number of males was very small at this latter depth range and the total weight of males insignificant compared with that of females.

Steele (1957), in experimental bottom otter trawling for redfish in the western part of the Gulf of St. Lawrence, near Gaspé in 1953 and 1954, found that males outnumbered females in the redfish catches in May, June and July, whereas females were more plentiful than males in the August, September and October catches. Mature females had the greatest relative increase in the increasing catches of redfish per unit effort, from a low level in June to a high in October.

In European waters, also, it is apparently a common experience that schools of male and female redfish are often separate. Kotthaus (1949) says that in the region of the Norwegian coast, where the spawning season occurs from April to the middle of May, it is interesting that in April almost without exception the catch consists of female fish.

Lüling (1951) says that, in an examination of mostly mature redfish from the very large landings in May (and apparently also in June) from the far north-east fishing ground (Sletnes) and from the waters a good 3-hours' steam southeast of North Cape Bank (position 72°N, 28°E), the majority of redfish (70–80%) consisted of male animals, an exactly reverse sex-ratio from that observed in February to March on the fishing grounds of the northwest coast of Norway—Langenes, Andenes and Melangen. On these Norwegian grounds, even toward the end of the brood period in May, the females were still more numerous than males.

Lundbeck (1955) says that the frequently observed schooling of the two sexes separately seems to be connected with the mode of propagation, especially the mating at least one month before the young are born.

Baranenkova (1957) supplies information on the distribution of sexually mature males and females of *Sebastes marinus mentella* (Fig. 52A). Females predominated in numbers in the greater depths, keeping themselves south of the concentrations of males. Commercial fishing in the Kopytova region (see discussion re Fig. 40C and 40D) at present chiefly removes females.

In the Canadian area in March–April, when the females, apparently the spawning females, appear to be scarcest in the catch, spawning (liberation of young) has only barely begun toward the end of April. In May and June during the spawning season, when spawning females are scarce in shallow water (Fig. 50) and scarce in certain areas such as at 110 to 130 fathoms off Gaspe, at 115 to 165 fathoms in Hermitage Bay, and at approximately the same depths in the eastern part of the Gulf of St. Lawrence, they may often be very plentiful in deep water on the southwest slope of the Grand Bank.

When females are absent from the bottom catches in an area they may, as some European redfish workers believe, have migrated to another area more suitable for spawning activities and for the dispersal of their young, and in some areas the movement may possibly be a pelagic one to produce such large

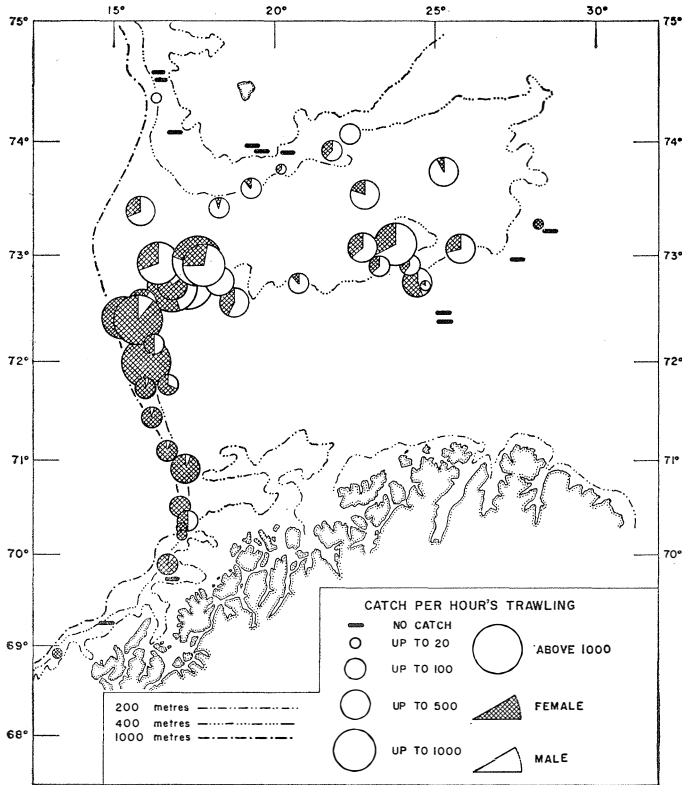


FIGURE 52A. Distribution and sex-ratio of sexually mature redfish, *Sebastes marinus* infrasp. *mentella*, above 34 cm in length, obtained in daylight catches in March-April, 1956. (After Baranenkova, 1957, fig. 3).

concentrations of pelagic redfish larvae as occur south of Iceland and Greenland. On the other hand, the great abundance of large females reported on the Norwegian coast in spring and available near bottom to the fishery are evidently there during or immediately before the spawning season.

Since in the Canadian area most of the female redfish leave their usual bottom abode several months before spawning, there would be time for some pelagic movement. It is apparent from Fig. 50 and Table X that the redfish before and at spawning time do not move into relation with shallower bottom areas, nor in the pre-spawning period are they in the deeper areas. Thus in March and April the present evidence from the Canadian area indicates a pelagic existence for the mature females. During the actual May-June spawning period, however, the spawning females may be generally or locally abundant in the deeper water down to at least 200 fathoms, and we have found them abundantly at these greater depths on the southwest slope of the Grand Bank in June of 1951 and 1952 (Fig. 52). On the other hand, the Hermitage Bay and the neighbouring Connaigre Bay data indicate higher percentages but small numbers of mature female redfish in April and June in the 92-112 fathom

Connaigre Bay area than in the deeper 116–170 fathom Hermitage Bay area. Even in the shallow-water Connaigre Bay area, however, the proportion of females among the larger redfish in April was only 22%.

As with other groundfish populations, the redfish population of each area, or even each school of redfish of a certain size typically living at a certain depth, probably has a pre-spawning movement pattern of its own. In the absence of successful tagging this movement will be very difficult to determine.

It is becoming evident, from the work of Magnússon (1955) and from researches at the St. John's Biological Station since 1947, that the impregnation of the female by the male may occur a number of months before the eggs are ready to be fertilized. The variations in abundance of males and females at different levels in September and October may have some relation to impregnation of the females, but only speculation is possible at the present time.

With the development and production of living young and the apparent lack of impregnation at this time, there is no need for the males and females to be in the same place during March to June, and separation of the mature animals into different schools may readily occur. This separation may be aided mechanically by the greater average size of the mature females than of the mature males, the smallest mature females being often 10 cm or more longer than the larger immature males and still longer than the smallest mature males. In the largest size groups females are several centimetres larger than males (Fig. 51).

So many fishes have a contra-natant movement before spawning that one might be inclined to speculate that such a movement occurs here during the pre-spawning period. However, the lack of general migration and intermingling of populations of redfish indicated for the Northwest Atlantic and the abundance of redfish near the bottom in deep water at spawning time are factors arguing against great horizontal spawning migrations of *mentella*-type redfish in the redfish areas of the Northwest Atlantic.

## SIZES OF REDFISH

Redfish distribution by size is a very large study in itself and cannot be fully discussed here. For the various parts of the European and West Greenland areas the following have published information on redfish length distribution: Veshchezerov (1944a), Kotthaus (1952), Fridriksson (1952, 1953, 1954), Lundbeck (1953a, 1953b), Meyer (1956), Magnússon (1957a, 1957b) and McIntyre (1957). Length-frequencies of redfish from the Gulf of St. Lawrence have been recorded by Steele (1957).

We shall present some typical redfish length-frequencies for various parts of the eastern, central and western North Atlantic (Fig. 53). The Icelandic frequencies are from Árni Fridriksson (personal letter, May 16, 1955) and represent a total of 17 Icelandic redfish random sample measurements taken from November, 1950, to August, 1952. All the material came from catches taken by Icelandic trawlers off the southwest coast of Iceland (Látrabjarg-Reykjanes) at 50 to 100 nautical miles from the coast and at 110 to 230 fathoms depth.

The Bear Island, Norwegian coast, Faroes and West Greenland length-frequencies are from measurements by German scientists and have been provided by Johannes Lundbeck (personal letter, May 5, 1955). The frequencies for the Northwest Atlantic are from the records of the Biological Station at St. John's, 1948 to 1955.

The Canadian measurements were taken on measuring boards with the lines on the half-centimetre positions and the first space  $1\frac{1}{2}$  cm. long, so that successive centimetre lengths are in the middle of the centimetre spaces. The lengths are, therefore, approximately correct. The Icelandic and European measurements are reduced to the nearest whole centimetre below the actual length, and the lengths given are thus  $\frac{1}{2}$  cm. below the true lengths, on the average.

Canadian measurements are from the anterior tip of the projection of the lower jaw with the mouth closed, to the end of the mid-fork of the caudal fin. The German measurements, according to Dr. Lundbeck (personal letter, October, 1955), are from the anterior tip of the projection of the lower jaw with the mouth closed, to the end of the longest part of the caudal fin. (For redfish between 30 and 40 cm in length this measurement is about 1 to  $1\frac{1}{2}$  cm longer than that to the mid-fork.) The Icelandic measurements, according to Fridriksson (private communication, October, 1955), are taken in the same manner as the Canadian.

In order to make direct comparisons possible between samples, each of the centimetre frequencies has been converted to frequencies per 10,000 fish and the 5-cm frequencies to frequencies per 2,000 fish (Fig. 53 and Tables XV, XVI).

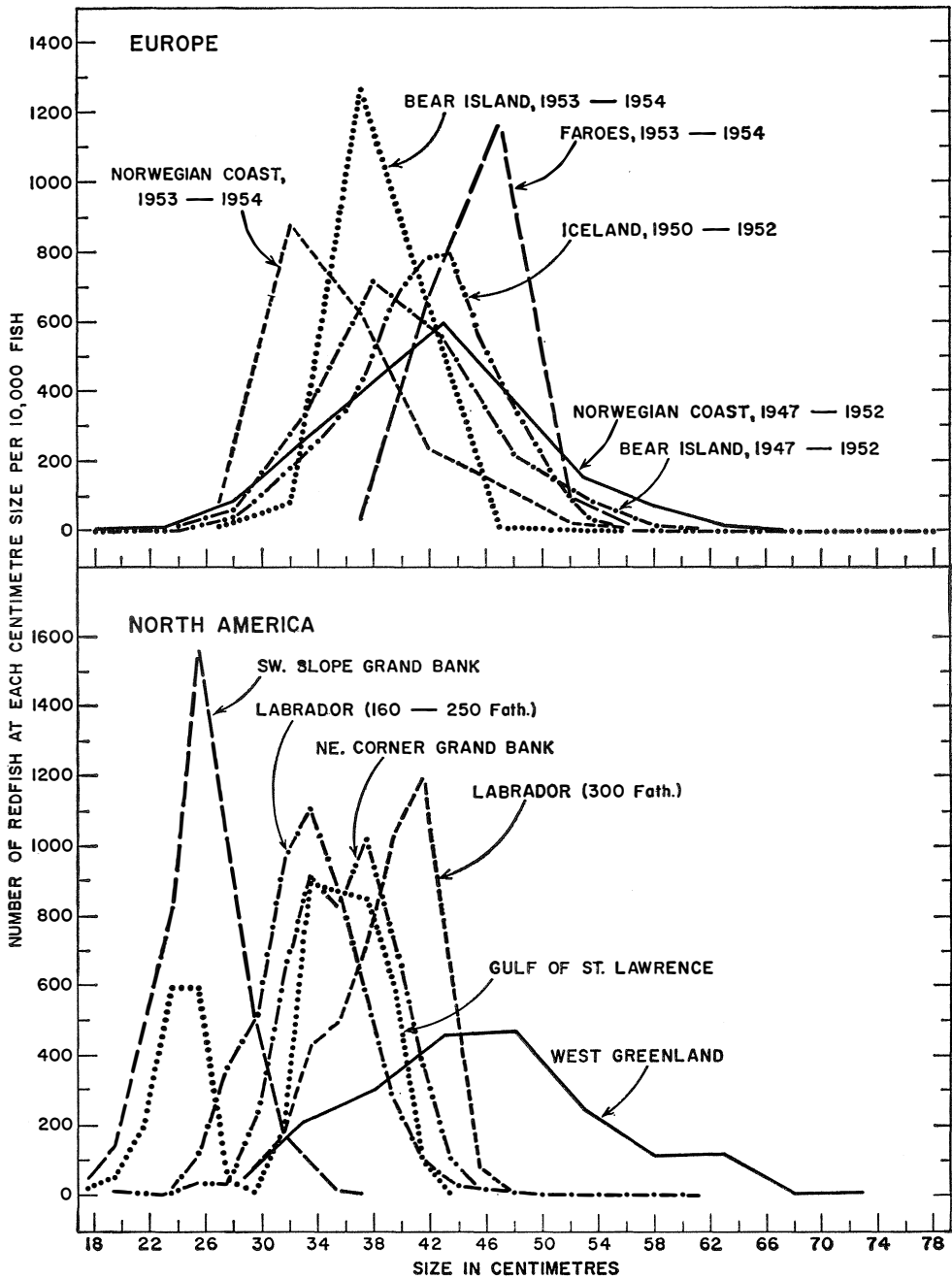


FIGURE 53. Some typical redfish frequencies from the Northeast Atlantic, the central North Atlantic and the Northwest Atlantic.

TABLE XV.—Redfish length-frequencies (median or fork length). (Number per 10,000 fish.)

Length	SW slope Grand Bank, May, 1952, 82-200 <i>fath</i> (150-366 <i>m</i> )	Gulf of St. Lawrence, Port Saunders, 1953, 120-160 <i>fath</i> (220-293 <i>m</i> )	NE corner Grand Bank, July, 1951, 160-200 <i>fath</i> (293-366 <i>m</i> )	E of Hamilton Inlet Bank, Labrador, Sept., 1954		Southern part W coast Iceland, 1950-1952
				160-250 <i>fath</i> (293-457 <i>m</i> )	300 <i>fath</i> (549 <i>m</i> )	
<i>cm</i>						
11-14.....	39		12			2
15.....	74					
16.....	93	7				
17.....	54	13				1
18.....	34	26				
19.....	74	49	25			
20.....	202	56				1
21.....	354	157	12			2
22.....	536	223				1
23.....	748	403		5		5
24.....	900	780	12	28		3
25.....	1,643	804	37	61		6
26.....	1,481	370	37	164		22
27.....	1,235	75	37	327	26	24
28.....	895	10	25	397	13	40
29.....	639	3	198	470	65	64
30.....	413	16	260	535	90	102
31.....	212	56	433	916	129	128
32.....	172	344	841	986	232	196
33.....	93	695	915	1,056	297	218
34.....	74	1,082	939	1,150	581	261
35.....	25	944	779	923	400	300
36.....	5	800	902	846	594	360
37.....	5	780	1,026	699	581	416
38.....		911	1,026	502	890	500
39.....		757	803	346	981	581
40.....		426	655	201	1,135	762
41.....		141	371	124	1,239	755
42.....		59	383	79	1,174	794
43.....		10	124	47	890	812
44.....		3	99	21	439	780
45.....			37	21	129	661
46.....			12	30	39	475
47.....				16	13	449
48.....				7	39	341
49.....				7		299
50.....						221
51.....				5		143
52.....				2		96
53.....				5		55
54.....				5		24

TABLE XV.—Redfish length-frequencies (median or fork length). (Number per 10,000 fish.)  
—Concluded

Length	SW slope Grand Bank, May, 1952, 82-200 fath (150-366 m)	Gulf of St. Lawrence, Port Saunders, 1953, 120-160 fath (220-293 m)	NE corner Grand Bank, July, 1951, 160-200 fath (293-366m)	E of Hamilton Inlet Bank, Labrador, Sept., 1954		Southern part W coast Iceland, 1950-1952
				160-250 fath (293-457 m)	300 fath (549 m)	
<i>cm</i>						
55.....				5	13	16
56-60.....				13		20
61-65.....				2		21
66-70.....						13
71-75.....					13	9
76-80.....						13
81-83.....						2
Total.....	10,000	10,000	10,000	10,001	10,002	9,994
Number measured....	2,033	3,051	809	4,280	775	16,054

TABLE XVI.—Redfish length-frequencies (total length less  $\frac{1}{2}$  cm) in European and West Greenland areas. (Number per 2000 fish.)

Length range	West Greenland, June-July 1952	Norwegian coast, 1947-1952	Bear Island, 1947-1952	Length range	Faroes, Nov., 1954	Norwegian coast, 1953-1954	Bear Island, 1953-1954
<i>cm</i>				<i>cm</i>			
16-20.....		2		15-19.....			
21-25.....		4	2	20-24.....			
26-30.....	36	83	61	25-29.....	2	84	15
31-35.....	214	264	334	30-34.....		883	83
36-40.....	304	428	721	35-39.....	30	629	1,258
41-45.....	464	599	544	40-44.....	686	235	625
46-50.....	476	374	219	45-49.....	1,164	137	11
51-55.....	246	152	99	50-54.....	108	23	5
56-60.....	118	75	18	55-59.....	10	9	3
61-65.....	124	17	2	60-64.....			
66-70.....	8	2		65-69.....			
71-75.....	10		0.3	70-74.....			
Total.....	2,000	2,000	2,000		2,000	2,000	2,000

It is evident from our redfish measurements in the Newfoundland area that the sizes of redfish will vary with locality, depth, season (especially with regard to the availability of large females), probably with time of day, depending on the bottom relations of smaller and of larger male and female redfish with regard to light, and doubtless with many other factors. Consequently it would not be wise to attempt a detailed analysis of these frequencies without much more information on the environment than is available for the frequencies under consideration.

It is evident that the Faroes, Norwegian coast 1947-1952, and the West Greenland length-frequencies contain larger redfish than most of the North American frequencies, although the length-frequency for Labrador (300 fathoms) is very similar to many of the European frequencies. There is no reason to suppose a species difference in the eastern and western areas from size alone, but very likely many of these frequencies from the eastern and central North Atlantic are purely *Sebastes marinus marinus* or contain both *Sebastes marinus marinus* and *Sebastes marinus mentella*, whereas as far as we can tell at present most of the redfish in the western North Atlantic are *Sebastes marinus mentella*. The Labrador redfish are large, West Greenland has very large redfish, and many of the natural size differences in different areas will undoubtedly be related to growth differences due to differences in water temperatures, size at maturity, and availability and quality of food. It is also necessary to separate the *marinus* and *mentella* forms in future measurements. In the Newfoundland area the redfish populations with the smallest average sizes, those from the southwest slope of the Grand Bank, mature at a small size and live in the shallowest water, the highest temperatures and presumably the most light available in redfish depths in the whole area. By contrast, the largest redfish, those in the deeper water off Labrador, have the greatest size at sexual maturity and live in colder and deeper water. In the Gulf of St. Lawrence there have been in recent years two independent groupings in typical redfish frequencies, an older group of fish which has remained at essentially the same size for 8 years or more and a group of lesser length and many years younger. Evidently the year-classes between these two groups have been failures in the Gulf area.

Baranenkova (1957) presents a table of frequencies of redfish from the eastern Norwegian Sea and the western Barents Sea. The largest *Sebastes viviparus* were in the 22.6-26.5 cm length category, the largest *Sebastes marinus mentella* in the 62.6-66.5 cm range and the largest *Sebastes marinus marinus* in the 78.6-82.5 cm category. The largest of the intermediate form between *marinus* and *mentella*, *Sebastes* sp. were in the 58.6-62.5 cm range. In the intermediate form, on the average, the females were larger and the males smaller than those of the *mentella* type.

## DISTRIBUTION OF REDFISH IN THE NEWFOUNDLAND AREA IN RELATION TO DEPTH AND TEMPERATURE

Figures 54 to 56 and Tables XVII to XX show the depth and temperature distribution of redfish in the daylight catches of the *Investigator II* during her ordinary fishing with a No. 36 otter-trawl in depths down to 191 to 210 fathoms during the years 1947 to 1954.

Bottom temperatures were taken using two Negretti and Zambra reversing thermometers. A 5/32-inch diameter wire and an 80-pound lead weight were used. Depths were estimated from metre-wheel and echo-sounder. Thermometers were attached 1.5 metres (0.8 fath) or, in rough weather, 2.5 metres (1.4) fath above the lead. The lead was lowered until it touched bottom and, depending on the size of the waves and the slope of the bottom, was then raised 1 to 3 metres (0.5-1.6 fath) from the bottom to allow clearance on the roll of the ship. The thermometers were, therefore, about 2.5 to 5.5 metres (1.4-3.0 fath) from the bottom. The thermometers were left in this position for 6 minutes before sending down the messenger. Bottom temperatures were typically taken at the beginning and sometimes again at the end of a set.

The *Investigator II* could not fish in very stormy weather; she has a low freeboard and a good draft; also a very heavy lead weight was used. As a result, thermometer wire angles were small, usually less than 10°. There is thus good reason to believe that the bottom temperatures obtained were real, although, when working close under the Labrador Current cover, the temperatures would sometimes be slightly lower than the actual temperature of the bottom water where the redfish were at the moment when they were caught by the net. On the other hand, the redfish, a pelagic feeder, would not be exactly on the bottom. Captain Blackwood of the trawler *Blue Spray* has remarked that on the "Fischlupe" the redfish are somewhat higher off the bottom than the cod.

### AVERAGE CATCHES AND AVERAGE TEMPERATURES AT DIFFERENT DEPTHS

In Labrador waters and on the southwestern slope of the Grand Bank (Fig. 54 and 55, Table XVII) greatest catches were made at the 191 to 210 fathom range; east of Newfoundland and of the Grand Bank, on Flemish Cap (although here, with the small number of drags taken, the catches are approximately as great at 171 to 190 fathoms) and in the Gulf of St. Lawrence catches were greatest at 151 to 170 fathoms; in ICNAF Subdivision 3P including St. Pierre Bank and the western part of the south coast of Newfoundland the greatest catches were in 131 to 150 fathoms.

In all areas, apart from those east of Newfoundland and on the eastern slope of the Grand Bank, all large average catches were obtained in average bottom temperatures at some point between 3.4 and 5.0°C. On the eastern slope of the Grand Bank, as will be discussed later, the largest catches were

usually taken in areas with very irregular bottom. In this area, although it was attempted, it was often impossible to keep to the planned depth contour during the whole of the drag, and it was difficult to know whether the level at which the temperature was taken corresponded exactly with that at which the redfish were taken. There is also a ceiling of cold Labrador Current water and the slope is very steep. The indicated temperatures for this eastern Grand Bank area in Fig. 54 may thus be a fraction of a degree lower than the true bottom temperatures, but it is also probable that the redfish are being concentrated close to a low temperature ceiling, where a few fathoms may be important, and the thermometer, sometimes several fathoms above the fish, would indicate a lower temperature than where the fish are located. The greatest difference in

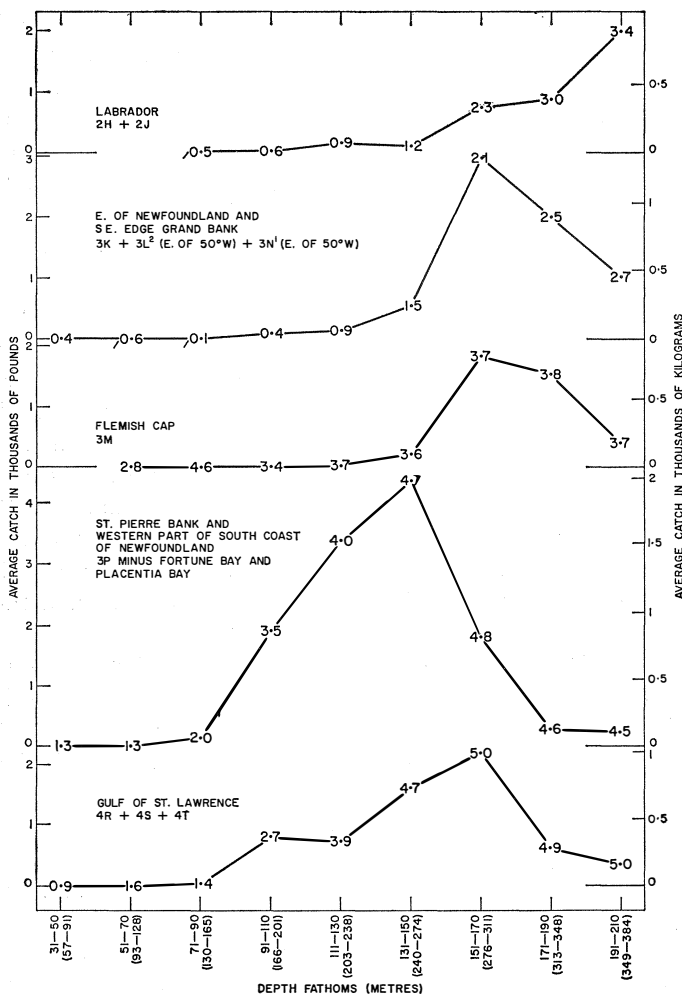


FIGURE 54. Average redfish catches per hour's dragging, in various depths and ICNAF subdivisions, by the *Investigator II*, 1947 to 1954, and average temperatures ( $^{\circ}\text{C}$ ) at these depths.

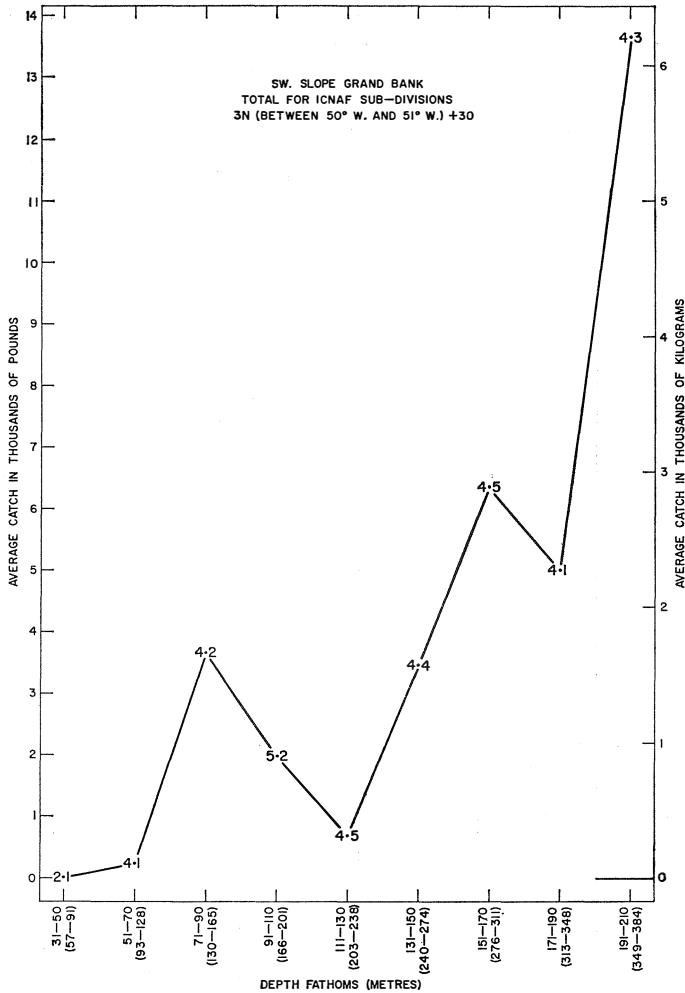


FIGURE 55. Average redfish catches per hour's dragging by the *Investigator II*, and average temperatures ( $^{\circ}\text{C}$ ) at various depths, on the southwest slope of the Grand Bank, 1947 to 1954.

temperature between the fish depth and the thermometer depth is unlikely, however, to be as great as half a degree. The largest catches in this eastern area are at  $2.1^{\circ}\text{C}$ .

It is difficult, from temperature data alone, to explain the fact that on Flemish Cap, where all average temperatures from 71-210 fathoms were between  $3.4$  and  $4.6^{\circ}\text{C}$ , and where in fact the highest average temperature was at 71-90 fathoms, no good catches of redfish were obtained shallower than 151-170 fathoms. On the southwest slope of the Grand Bank, on the other hand, where average temperatures from 51-210 fathoms were similar,  $4.1$ - $5.2^{\circ}\text{C}$ , and where the average temperature at 71-90 fathoms was  $4.2^{\circ}\text{C}$ , catches at 71-90 fathoms averaged 3,660 pounds per hour compared with 6,350 pounds at 151-170 fathoms.

TABLE XVII.—Relation of redfish catches by the *Investigator II*, 1947 to 1954, in various ICNAF subdivisions, to depth and temperature. (Only catches for which bottom temperatures are available are used here. The number of drags is shown in parentheses to the right of the average catch.)

A = Labrador: 2J, 2H. B = E of Nfld. and SE edge of Grand Bank: 3K; 3L, E of 50°W Long.; 3N, E of 50°W Long. C = Flemish Cap: 3M. D = SW slope Grand Bank: 3N, W of 50°W Long.; 3O. E = W part of south coast of Nfld. and St. Pierre Bank: 3P (minus Fortune and Placentia Bays). F = Gulf of St. Lawrence: 4R, 4S, 4T.

Depth range	A	B	C	D	E	F
<i>fath</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>
	Average catch redfish per hour's dragging					
1-20.....						0(1)
21-30.....		0(32)		0(14)	0(57)	0(5)
31-50.....		0(41)		0(277)	0(43)	0(10)
51-70.....		0(41)	0(1)	240(98)	0(14)	0(6)
71-90.....	0(4)	2(42)	1(8)	3,660(36)	140(24)	40(6)
91-110.....	10(25)	80(37)	0(8)	1,930(45)	1,890(46)	800(18)
111-130.....	150(14)	130(39)	20(11)	680(14)	3,370(34)	730(24)
131-150.....	100(15)	540(26)	200(4)	3,470(21)	4,350(11)	1,610(41)
151-170.....	740(7)	2,980(56)	1,810(5)	6,350(11)	1,790(5)	2,180(21)
171-190.....	870(9)	2,000(38)	1,530(6)	5,000(7)	280(1)	620(4)
191-210.....	2,010(5)	1,020(22)	410(4)	13,650(7)	240(3)	360(4)
	Average bottom temperature					
	°C	°C	°C	°C	°C	°C
1-20.....						1.1
21-30.....		2.6		2.4	3.8	3.8
31-50.....		0.4		2.1	1.3	0.9
51-70.....		-0.6	2.8	4.1	1.3	1.6
71-90.....	-0.5	-0.1	4.6	4.2	2.0	1.4
91-110.....	0.6	0.4	3.4	5.2	3.5	2.7
111-130.....	0.9	0.9	3.7	4.5	4.0	3.9
131-150.....	1.2	1.5	3.6	4.4	4.7	4.7
151-170.....	2.3	2.1	3.7	4.5	4.8	5.0
171-190.....	3.0	2.5	3.8	4.1	4.6	4.9
191-210.....	3.4	2.7	3.7	4.3	4.5	5.0

In ICNAF Subdivision 3P, also, including the western part of the south coast of Newfoundland, and in the Gulf of St. Lawrence area as well, the catch pattern followed that on the southwest slope of the Grand Bank in rising significantly when temperatures approaching 3 to 4°C were attained.

The Flemish Cap is a higher temperature area immediately to the east of a lower temperature area; the latter extends from Labrador to the southern tip of the eastern slope of the Grand Bank and is influenced by the Labrador Current.

In spite of its higher temperatures at shallower levels the Flemish Cap redfish depth abundance picture has almost exactly the same pattern as that of the neighbouring area east of Newfoundland and east of the Grand Bank, where the overlying Labrador Current does appear to keep the redfish in deep water. The Flemish Cap redfish, therefore, are apparently kept in deep water by light and habit rather than by temperature.

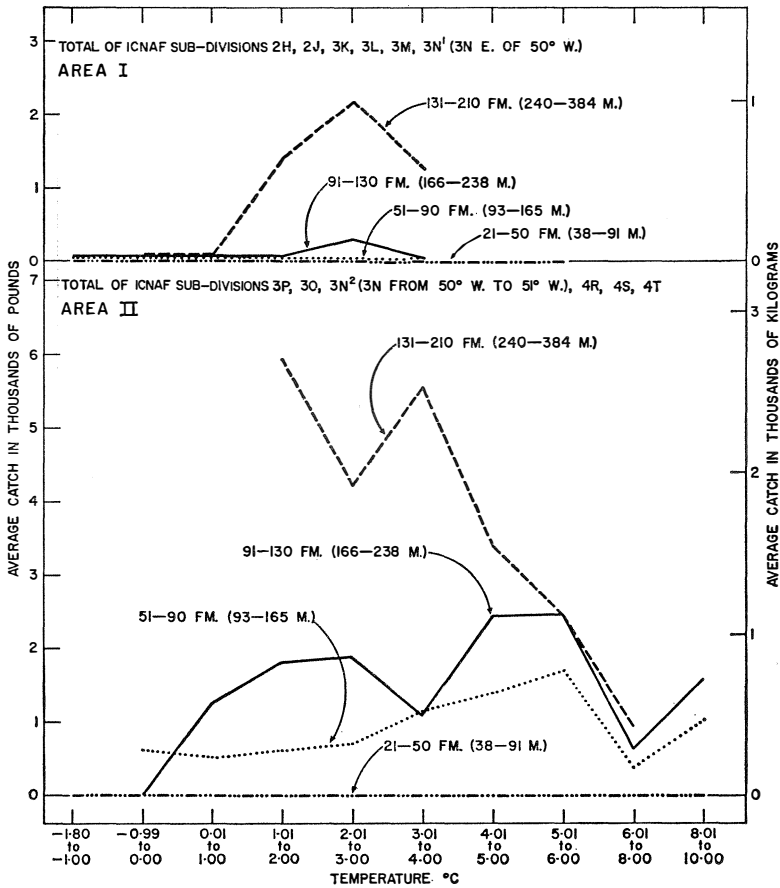


FIGURE 56. Variation in average redfish catches per hour's dragging by the *Investigator II*, with variation in temperatures ( $^{\circ}\text{C}$ ) at the same depth ranges.

#### CATCHES AT DIFFERENT TEMPERATURE RANGES IN THE SAME DEPTH RANGE

For purposes of studying the effect of different temperatures in the same depth range on the redfish catch per unit effort, the area has been divided into two: (I) Labrador, continental shelf and slope off the east coast of Newfoundland, Flemish Cap and northern and eastern Grand Bank as far west as Long.  $50^{\circ}\text{W}$ ; (II) the Southwest Grand Bank west of Long.  $50^{\circ}\text{W}$ , St. Pierre Bank, the south coast of Newfoundland and the Gulf of St. Lawrence (Fig. 56 and Tables XVIII, XIX).

TABLE XVIII.—Redfish catches per hour's dragging by the *Investigator II*, 1947 to 1954, at various temperatures and depth ranges in ICNAF subdivisions of Area "I": 2H, 2J, 3K, 3L, 3M, and 3N, E of Long. 50°W. (The number of drags is shown in parentheses to the right of the average catch.)

Bottom temperature range	Average catch redfish per hour's dragging at various depth ranges			
	21-50 fath (38-91 m)	51-90 fath (93-165 m)	91-130 fath (166-238 m)	131-210 fath (240-384 m)
°C	lb	lb	lb	lb
-1.80 to -1.00.....	0(5)	0(13)	0(2)	.....
-0.99 to 0.00.....	0(27)	1(80)	0(25)	0(3)
0.01 to 1.00.....	0(28)	0(26)	60(60)	30(10)
1.01 to 2.00.....	0(17)	0(10)	60(26)	1,410(60)
2.01 to 3.00.....	0(7)	0(3)	290(18)	2,190(90)
3.01 to 4.00.....	0(2)	1(6)	10(19)	1,280(50)
4.01 to 5.00.....	0(11)	.....	.....	.....
5.01 to 6.00.....	0(4)	.....	.....	.....

TABLE XIX.—Redfish catches per hour's dragging by the *Investigator II*, 1947 to 1954, at various temperatures and depth ranges in ICNAF subdivisions of Area "II": 3P, including Hermitage Bay; 3O; 3N, W of Long. 50°W; 4R, including St. George's Bay; 4S, 4T. (The number of drags is shown in parentheses to the right of the average catch.)

Bottom temperature range	Average catch redfish per hour's dragging at various depth ranges			
	21-50 fath (38-91 m)	51-90 fath (93-165 m)	91-130 fath (166-238 m)	131-210 fath (240-384 m)
°C	lb	lb	lb	lb
-1.80 to -1.00.....	0(2)	.....	.....	.....
-0.99 to 0.00.....	0(20)	610(15)	2(3)	.....
0.01 to 1.00.....	0(77)	520(26)	1,270(6)	.....
1.01 to 2.00.....	0(108)	610(28)	1,820(10)	5,930(1)
2.01 to 3.00.....	0(94)	710(24)	1,890(35)	4,220(5)
3.01 to 4.00.....	0(43)	1,160(13)	1,090(24)	5,570(5)
4.01 to 5.00.....	0(27)	1,400(26)	2,450(64)	3,400(90)
5.01 to 6.00.....	0(16)	1,700(16)	2,460(14)	2,430(30)
6.01 to 8.00.....	0(17)	400(24)	650(22)	950(2)
8.01 to 10.00.....	1(2)	1,010(12)	1,590(2)	.....

"I" is an Area that, apart from Flemish Cap, is under the influence of the Labrador Current. Temperatures over 4°C are not as a rule to be found even in the deeper water down to 210 fathoms. The redfish are distributed deeply, with only small catches above 150 fathoms. (Flemish Cap has been included since there were relatively few catches there and the depth pattern of the redfish follows that of the neighbouring eastern Grand Bank.)

In Area "II" the effect of the Labrador Current is not so great as in Area "I". The overlying low water-temperatures are on the average not so low as in Area "I" and in some parts of the area, such as on the southwest slope of the Grand Bank, no water with a temperature as low as 0°C is usually present at redfish depths. Redfish may be relatively numerous as shallow as 80 fathoms or less on the southwest slope of the Grand Bank.

In Area "I" significant catches were obtained only at the 131-210 fathom range where the greatest catches were in the 2 to 3°C range, but there were significant catches, also, in the 1 to 2°C and in the 3 to 4°C ranges. The data here were greatly influenced by large catches on the eastern slope of the Grand Bank which overshadowed the lesser catches to the northward.

In Area "II", although on the average the greatest catches were from the deep water, 131-210 fathoms, there were significant catches at the 91-130 fathom range and even at 51-90 fathoms. At 51-90 fathoms the best of the small average catches were in 3 to 6°C with the peak at 5-6°C. At 91-130 fathoms there were moderate catches in a very wide temperature range from 0 to 10°C with peak catches at 4-6°C. In the deeper water, 131-210 fathoms, peak catches were at 1-4°C, but there was only a small number of drags at these temperatures. There were good catches at 4-6°C, in which range there were many drags. At 6-8°C only two drags were taken and the catches were low.

Undoubtedly in combining such wide regions as are included in Areas "I" and "II" we have combined too widely, for even in one such area, and particularly in "II", there is considerable variation in the depths inhabited by redfish. When more data become available it will be possible to use smaller areas and more precise conclusions may be drawn regarding the local relationships between redfish abundance and depth and temperature.

Additional data will also allow a study of the effect of size of the redfish on differing abundance at the various depths and temperatures. Redfish of the same sub-species at the shallower levels, especially in Area "II", are smaller than at the greater depths. Thus, part of the apparent greater tendency for the catch level, characteristic of lower temperatures, to be maintained at higher levels of temperature in the lesser than in greater depths in Area "II" may be due to different relationships of smaller and of larger redfish to temperature.

#### COASTAL FRINGE AREAS

Redfish in the Newfoundland area are abundant only at the seaward fringes of the continental shelf, in the deep channel areas of the Gulf of St. Lawrence and of the western part of the south coast, and to the northeast in deep holes at

some distance from the coast. Water comparable in depth with that inhabited by redfish in the warm and open channels of the Gulf of St. Lawrence and on the warmer continental edge, is present in many fjord-like bays and eastern coastal areas of Newfoundland. These inshore areas are, however, under the influence of the cold water of the Labrador Current to a much greater depth than are the Gulf or continental shelf slope areas.

The results of dragging by the *Investigator II* in some of these coastal cold-water areas are shown in Table XX. As a rule, temperatures even at 170-200 fathoms or deeper are below 1°C, and even in the shoreward part of ICNAF area 3L, west of Long. 50°W, temperatures reach only about 2°C at 150-170 fathoms. In the very cold water of the typical coastal bay or of the isolated deep holes in such a bay (Table XX, A) water temperatures are very low, -0.2°C, at 151-170 fathoms and redfish are typically scarce or absent. (The status of each of these bays and areas with regard to redfish captures can be seen in Fig. 32 to 34.) In Trinity Bay with temperatures above 0°C from 111-130 fathoms downward, but with no average temperatures above 0.5°C, the largest average catch of redfish was 120 pounds at 171-190 fathoms.

In the shoreward part of ICNAF area 3L and in Fortune Bay, where deep-water temperatures are up to 1 to 2°C but not as high as 3°C, redfish catches were similarly low. Thus, although redfish may be caught in numbers at temperatures

TABLE XX.—Redfish catches and corresponding bottom temperatures at various depths in exploratory fishing by the *Investigator II*, 1947 to 1954, in various Newfoundland coastal areas. (Only catches for which bottom temperatures are available are used here. The number of drags is shown in parentheses to the right of the average catch.)

A = Total of Lake Melville, White Bay, Notre Dame Bay, Conception Bay, Placentia Bay, Bonne Bay, Bay of Islands. B = Trinity Bay. C = ICNAF Subdivision 3L, W of 50°W Long., excluding all bays except St. Mary's Bay. D = Fortune Bay.

Depth range	Average catch redfish per hour's dragging				Average bottom temperature			
	A	B	C	D	A	B	C	D
<i>fath</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	°C	°C	°C	°C
1-20.....	0(1)				1.0			
21-30.....			0(3)				6.7	
31-50.....	0(2)		0(30)		-0.1		0.9	
51-70.....	0(5)		0.2(27)		-0.5		0.4	
71-90.....	0(6)		0(15)		-0.5		-0.6	
91-110.....	0.2(5)	0(1)	0(5)	250(13)	-0.8	-0.3	-0.1	0.9
111-130.....	0(11)	5(1)	1(10)	240(4)	-0.5	0.3	1.7	1.1
131-150.....	1(8)	2(5)			-0.8	0.4		
151-170.....	20(10)	30(6)	100(2)	10(2)	-0.2	0.4	2.1	0.8
171-190.....	2(3)	120(7)	140(3)		0.6	0.5	1.4	
191-210.....	1(2)	40(3)			0.8	0.5		
211-230.....		40(2)				0.5		

below 3°C in areas where there are also higher temperatures in the deeper water, they are not numerous in areas where temperatures of 3°C or higher are absent in the deeper water. (Recently a few good commercial catches of small redfish, however, have been obtained in the low temperatures of Fortune Bay which is close to Hermitage Bay and neighbouring areas of higher deep-water temperatures.)

In spite of the usual absence of redfish in the shallow warmer water in such areas as the east coast of Newfoundland where an intermediate or a bottom layer of below 0°C exists, a few redfish are rarely to be found here in the inshore shallow-water area. We have heard of several instances of redfish occurring in summer in traps set at less than 20 fathoms depth in Bull Arm, Trinity Bay; and in August, 1952, occasional redfish were taken in traps in similar depths at Little Bay Islands, Notre Dame Bay. In the latter instance this was so unusual that the local people did not know what they were.

Fishermen report that between Harbour Mille and Terrenceville at the head of Fortune Bay on the south coast of Newfoundland, small, dark redfish about 25 cm (10 inches) long are handlined for lobster bait during the early summer in depths of 15 to 18 fathoms.

## DEEP-WATER DISTRIBUTION

### WESTERN ATLANTIC

In July, 1952 and 1953, William C. Schroeder carried out exploratory fishing in deep water off the east coast of the United States (Anon., 1952; Schroeder, 1955). Redfish were found to be numerous in deep water down to over 300 fathoms in an area on the continental slope off southeastern Nova Scotia. The location of the fishing area is shown in Fig. 57. Schroeder has kindly sent us a list of his catches from each of these sets. Catches were given in

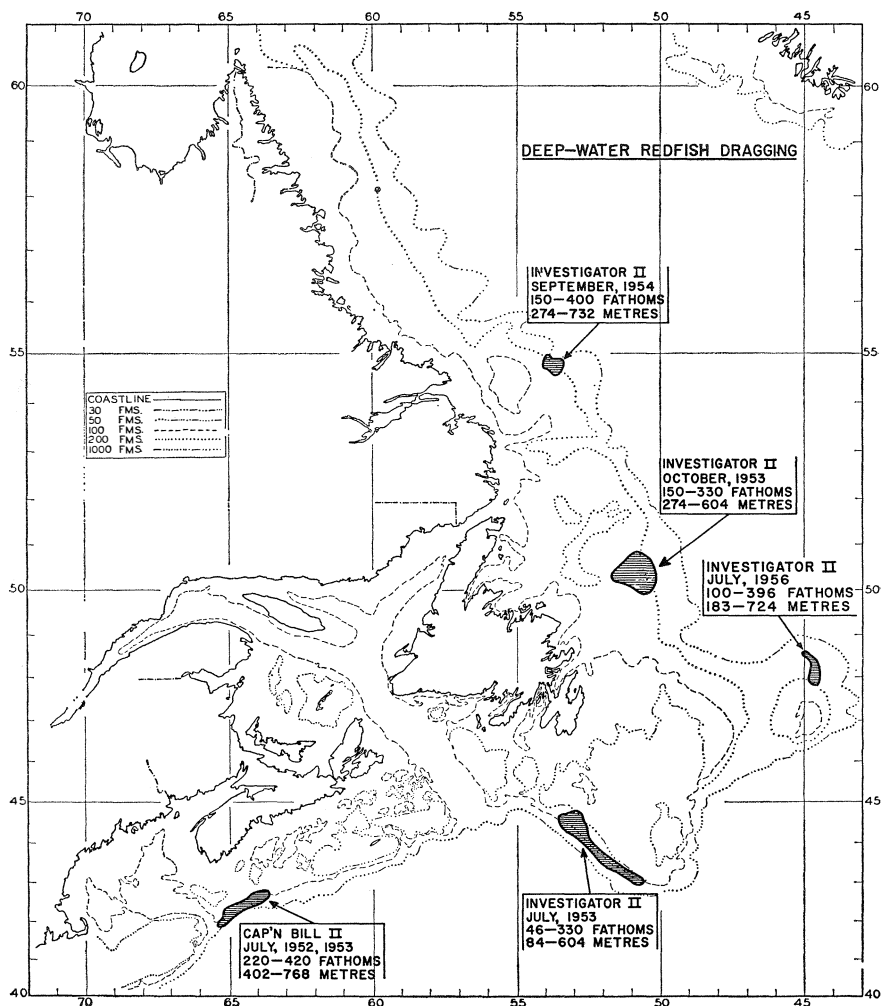


FIGURE 57. Location of deep-water fishing by the *Investigator II* and the *Cap'n Bill II*.

bushels, and we estimate the weight on shore of a bushel of redfish measured at sea to be 52 pounds. From these data Table XXII has been prepared.

Schroeder used the *Cap'n Bill II*, an 83-foot dragger, and at various times 35-, 50- and 60-foot shrimp trawls, each on a single wire. The period of dragging ranged from 30 to 50 minutes. Fishing was done in the daylight hours. The cod-end of the trawl was 1½-inch and the body and wings 3-inch stretched mesh.

In July and October, 1953, and in September, 1954, the Fisheries Research Board of Canada's ship *Investigator II* carried out deep-water fishing in the Newfoundland area (Fig. 57). In 1953 a No. 35A research trawl designed at the St. John's Station was used. This trawl had a 50-foot headrope, a 70-foot footrope, 6-inch wings and square, belly declining gradually from 6 to 3½ inches and 3½-inch cod-end. (All mesh measurements are overall, between knot-centres, new dry.) This net was used with two otter-boards, each 500 pounds, on a single 900-fathom, ⅝-inch diameter wire. In 1954 a No. 3/4-35 trawl was used with a 39-foot headrope, 50-foot footrope, wings and square 5 inches, belly reducing from 4½ to 3½ inches and cod-end 3½ inches. This was used with two otter-boards each 400 pounds on a single 900-fathom, ⅝-inch diameter wire. In both years the length of each drag on bottom was 30 minutes, and the cod-end was lined with 1¾-inch manila shrimp netting. All sets were in daylight hours.

During 1955 the North Atlantic Fisheries Exploration and Gear Research Group of the United States Fish and Wildlife Service, using the research trawler *Delaware*, carried out deep-water explorations of the continental slope at the eastern edge of the New England and Nova Scotian banks from Lat. 40°19'N, Long. 67°37'W to Lat. 44°46'N, Long. 56°22'W. Apart from two sets in January, all sets were between May 11 and Sept. 12. All sets were made either with a standard No. 41 trawl or with a No. 41 balloon trawl and were daylight sets. Some of the information resulting from these explorations has been kindly supplied by R. C. Wilson, chief of the North Atlantic Fisheries Exploration and Gear Research Group.

CATCHES. Allowing for the very small net on a single warp, catches east of Hamilton Inlet Bank in the Labrador area were of good commercial amounts at 160, 200 and 250 fathoms. The best average catch per hour of 2,280 pounds was at 200 fathoms and at 300 fathoms the catch was still 770 pounds per hour, but at 390-400 fathoms the catch was only 10 pounds of redfish per hour's dragging (Fig. 58, Table XXI). In the latter depth, moreover, the net was still fishing well and near the bottom since quantities of grenadiers (*Macrourus*) were caught in each set and usually one or more skates (*Raja*) and Greenland halibut (*Reinhardtius*).

To the north of the Grand Bank and to the southwest of the Grand Bank the largest catches were respectively at 200 and at 180 fathoms. However, there were few sets in these particular experiments. In these two areas no catches of commercial quantities were obtained below 200 fathoms, the deepest significant catches of redfish per hour's dragging being 230 pounds at 311-350 fathoms to the north of the Grand Bank and 150 pounds at 230-360 fathoms on the south-

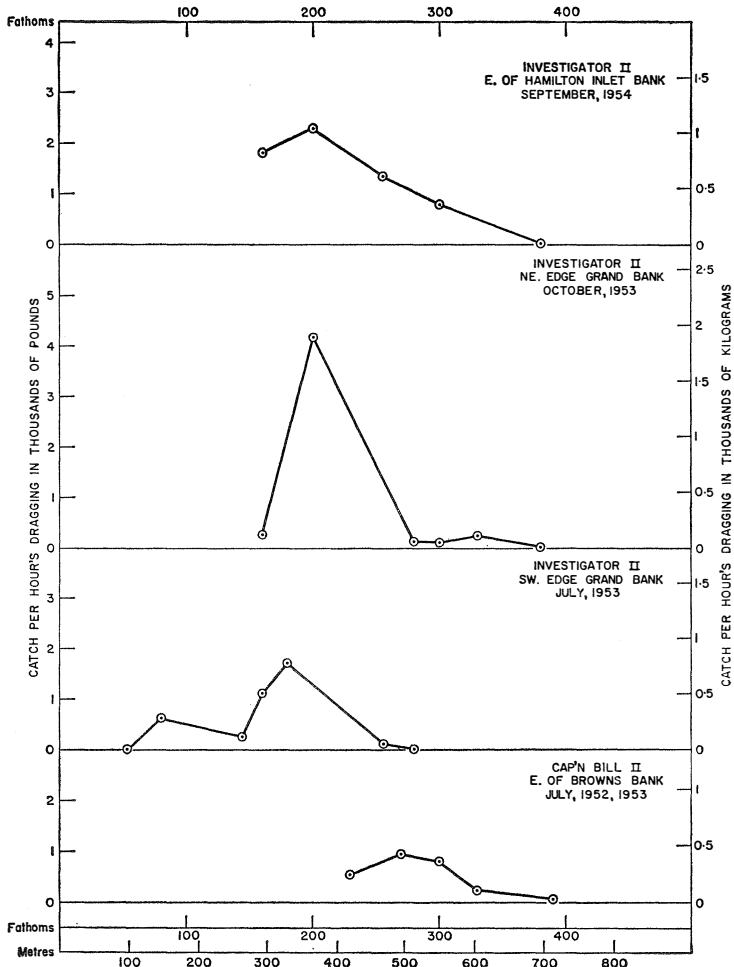


FIGURE 58. Average number of pounds of redfish caught, per hour's dragging in deep water, by the *Investigator II* and the *Cap'n Bill II*.

west slope of the Grand Bank. In these two latter areas, where the larger net was used, there was no indication (from catches of bottom-living fish or invertebrates) that the net was on bottom below 330 fathoms. The absence of redfish in 2 sets at 351-410 fathoms and the capture of 5 pounds of redfish in a set at 290-350 fathoms may indicate one of two things. Either there are no large pelagic schools of redfish during the daytime in these areas, or if there are, a slow-moving net will have great difficulty in catching them.

Schroeder's investigations indicated good catches, averaging between 800 and 960 pounds per hour's dragging, from about 250 to over 300 fathoms (Fig. 58, Table XXII). One set at 220-240 fathoms produced a smaller catch. Catches were rapidly reduced to an average of only 14 pounds per hour's dragging at 361-420 fathoms.

TABLE XXI.—Redfish catches by *Investigator II* in deep-water fishing experiments. (Values in parentheses are numbers of normal drags.)

A.—Southwest slope Grand Bank, July, 1953, No. 35A research trawl; B.—North of Grand Bank, October, 1953, No. 35A research trawl; C.—East of Hamilton Inlet Bank, Labrador, September, 1954, No.  $\frac{3}{4}$ -35 trawl.

Depth range	Average catch of redfish per hour's dragging			Average bottom temperature		
	A	B	C	A	B	C
<i>fath</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	°C	°C	°C
46-60.....	0(2)			3.4		
75-86.....	590(2)			3.5		
138-150.....	260(1)			4.8		
151-170.....	1,130(3)	260(1)	1,820(5)	4.2	2.6	2.1
171-190.....	1,690(2)			3.4		
191-210.....		4,160(1)	2,280(5)	4.6	3.4	3.1
211-240.....						
241-270.....	120(1)		1,330(4)	3.8		3.9
271-290.....	5(1)	120(1)			3.5	
291-310.....		80(1)	770(5)		3.6	3.9
311-350.....		230(1)			3.6	
351-410.....		0(2)	10(4)			3.9
230-360.....	150(1)					
290-350.....	5(1)			3.8		

TABLE XXII.—Redfish catches on the continental slope east of Browns Bank (all sets between Lat. 42°08'N-42°43'N and Long. 63°47'W-65°27'W, July 12 to 28, 1952 and July 13 to 16, 1953, William C. Schroeder, *Cap'n Bill II*).

Depth range	No. of sets	Catch per hour's dragging	Length range of redfish	Average bottom temperature
<i>fath</i>		<i>lb</i>	<i>inches</i>	°C
220-240.....	1	550	12-18	4.7
241-280.....	5	960	12-18	4.4
281-320.....	5	800	12-19	4.2
321-360.....	3	200	13-18	4.1
361-420.....	2	14	15-18	4.1

In the same general area in which the redfish catches shown in Table XXII were taken, at the edge of the continental shelf and between Long. 63°17' and 65°59'W, during 1952 and 1953 Schroeder made 7 successful hauls below 420 fathoms, as follows: 400-460, 420-500, 425-470, 460-475, 460-470, 465-480 and 465-480 fathoms. No redfish were taken in these hauls. Similarly, in the same area he took no redfish in 6 successful hauls between 501 and 730 fathoms. In these deep hauls the net was dragging on bottom for an average time of 40 minutes. Here again it is indicated either that pelagic schools of redfish are absent or not concentrated, or that a fast-moving net is required to catch them.

The redfish catches from the deep-water fishing by the *Delaware* have been summarized in Fig. 59 and Table XXIII. The locations fished and general accounts of the success of fishing have been published (Anon., 1955a, b, c). In Table XXIII only sets on the eastern slope areas of the banks have been included and sets within the Gulf of Maine have been omitted.

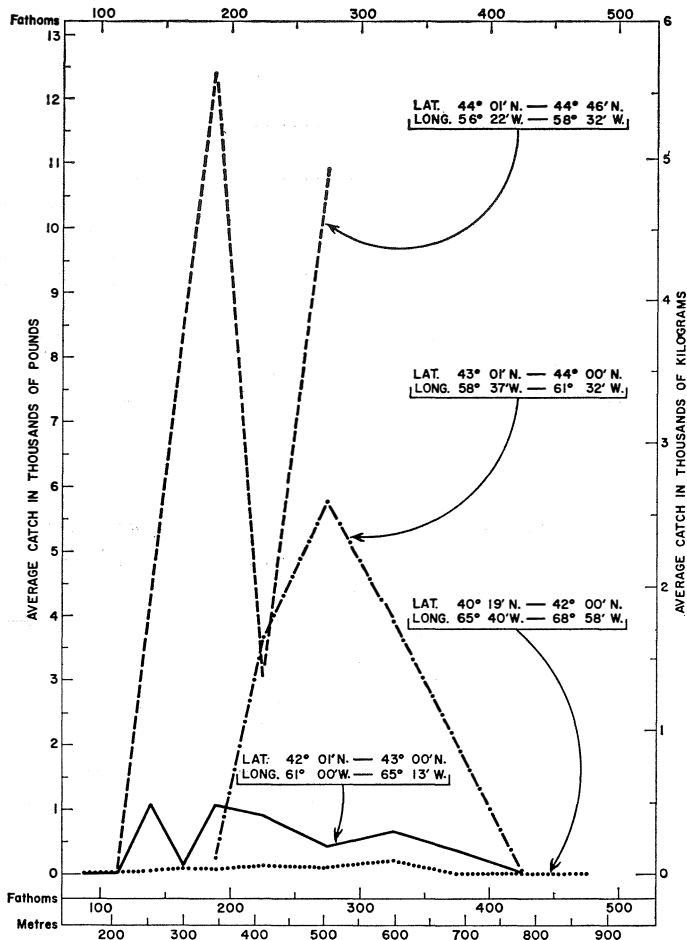


FIGURE 59. Redfish catches per hour's dragging in deep water by the *Delaware*.

TABLE XXIII.—Average redfish catches per hour's dragging and average weights of redfish caught by the *Delaware* in 1955. (Numbers of drags are shown in parentheses.)

Depth range	Lat. 40°19'-41°00' Long. 66°25'-67°37'	Lat. 41°01'-42°00' Long. 65°40'-68°58'	Lat. 42°01'-43°00' Long. 61°00'-65°13'	Lat. 43°01'-44°00' Long. 58°37'-61°32'	Lat. 44°01'-44°46' Long. 56°22'-58°32'
<i>fath</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>	<i>lb</i>
Average catches of redfish per hour's dragging					
74-100.....		2 (1)	2 (5)	3 (2)	
101-125.....		22 (1)	3 (1)		140 (1)
126-150.....			1,080 (1)		
151-175.....	200 (1)	6 (1)	125 (2)		
176-200.....	40 (2)	157 (1)	1,056 (4)	266 (2)	12,456 (1)
201-250.....	141 (5)	130 (1)	907 (6)	3,656 (3)	3,090 (5)
251-300.....	200 (1)	6 (1)	420 (1)	5,764 (3)	10,968 (2)
301-350.....	200 (3)		650 (4)	3,978 (2)	
351-400.....		8 (1)	368 (1)		
401-450.....			21 (2)	95 (1)	
451-500.....		6 (1)			
Average weight of one redfish					
74-100.....			0.9	0.4	
101-125.....		2.0	1.0		0.7
126-150.....			0.9		
151-175.....	2.0		1.3		
176-200.....	1.9	1.8	1.1	0.9	1.2
201-250.....	1.6	1.0	1.5	1.0	1.1
251-300.....	2.0		1.7	1.1	1.5
301-350.....	3.2		2.2	1.3	
351-400.....			2.3		
401-450.....			2.5	1.7	
451-500.....					

Throughout the area investigated the best catches were between the ranges of 176-200 and 301-350 fathoms. In most areas, however, comparatively few tows were made at the shallow depths, between 74 and 175 fathoms. Small non-commercial catches of redfish were obtained down to 401-450 fathoms and in one set at 451-500 fathoms 4 redfish were caught. Catches were very low at all depths between Lat. 40°19' and 42°00'N, southeast and east of Georges Bank, and were a little higher, but not of commercial quantity, between Lat. 42°01' and 43°00'N, off Browns Bank and the southern part of the Nova Scotian Shelf. Catches were high and of commercial quantity between Lat. 43°17' and 44°00'N southeast of Sable Island Bank and between Lat. 44°01' and 44°29'N southeast of Banquereau.

In early December, 1955, the *Delaware* carried out a deep-water cruise for redfish off the southern end of St. Pierre Bank. In 8 one-hour drags the largest catch was 2,000 pounds of medium-sized redfish taken in 225 fathoms (Anon., 1956a).

Again in 1956, from May 21 to June 2 the *Delaware* had 30 one-hour drags in depths from 150 to 350 fathoms on the edge of the continental shelf mainly south of Sable Island Bank but including 7 drags south of Banquereau (Anon., 1956b). Five drags, all south of Sable Island Bank, ranged from 5,000 to 8,000 lb per drag. A No. 41 trawl was used and the greatest catches were on the 240-fathom contour.

In July, 1956 (Templeman, 1957), the *Investigator II* carried out three half-hour drags, north of Flemish Cap, at each of 7 depths from 100-108 down to 386-396 fathoms using a No. 3/4-35 otter-trawl on a single warp. The average catches per half-hour's dragging were 0; 150; 691; 1,343; 627; 98 and 0 lb at 100-108, 150, 200, 250, 300, 350 and 386-396 fathoms respectively. Temperatures at these depths were respectively 3.6, 3.8, 3.7, 3.6, 3.5, 3.5 and 3.4°C. These differences in temperature are not great enough to produce the observed differences in amounts of redfish at the various depths, and, where limiting temperature barriers are not present so that other factors may have full play, the fundamental redfish depth distribution is apparently the result of a reaction to light or food.

Although in this experiment (Fig. 54) the greatest catches were at 250 fathoms (where all redfish were of the *mentella* type), in other experiments, where the *Investigator II* used a larger No. 36 net with 2 warps and thus had to use a smaller warp-length/depth ratio, the largest quantities of redfish in the Flemish Cap area were taken at 151-170 and at 171-190 fathoms. With the larger net it was necessary for the *Investigator II* to slow down at 191-210 fathoms in order to keep the net on bottom. Thus fishing was relatively inefficient at this depth and probably to some degree also at 171-190 fathoms. Hence the depths of greatest catch shown in Fig. 54 and 55 are sometimes minimal.

**SIZE.** In the Labrador and southwestern Grand Bank areas sizes of redfish increased significantly with depth. At depths greater than 200 fathoms in all cases the redfish averaged over 33 cm (13 in) in length, and in Labrador redfish were extremely large (Table XXIV).

Schroeder's deep-water redfish were also large (Table XXII) especially when compared with the redfish prevalent in the commercial catches in shallower waters in the same general area. Schroeder states in a personal note that the respective size ranges (12 to 19 inches inclusive, listed in Table XXII) are believed to include at least 95% of the catch. In some hauls there were a very few fish that ran 1 to 2 inches smaller than the lengths given but only one specimen less than 10 inches long (8½ inches) was noticed.

In the *Delaware* catches redfish sizes usually increased considerably with increasing depths (Table XXIII).

TABLE XXIV.—Size and sex ratio of redfish, male (M) and female (F), in deep water in the Newfoundland area.

Depth range	SW slope Grand Bank, July, 1953				N of Grand Bank, Oct., 1953				E of Hamilton Inlet Bank, Sept., 1954			
	No. fish measured	Percent F	Average length		No. fish measured	Percent F	Average length		No. fish measured	Percent F	Average length	
			M	F			M	F			M	F
<i>fath</i>		%	<i>cm</i>	<i>cm</i>		%	<i>cm</i>	<i>cm</i>		%	<i>cm</i>	<i>cm</i>
75-76.....	208	60	20.6	21.2								
138-150.....	232	53	22.7	23.1								
151-170.....	833	50	23.4	25.3	79	67	30.4	33.4	1,583	62	32.8	32.3
171-190.....	387	51	24.9	27.4								
191-210.....	356	52	25.0	27.4	282	58	32.4	33.8	1,608	52	33.6	33.7
211-240.....												
241-270.....	58	52	33.1	33.3					1,089	55	34.9	35.7
271-290.....					36	69	35.4	33.1				
291-310.....					27	33	32.2	36.9	775	52	38.4	39.7
311-350.....					105	52	32.8	33.7				
351-410.....									15	47	40.1	39.4

In the Flemish Cap experiments between 150 and 350 fathoms in July, 1956, the sizes of the *mentella* type increased with increasing depth (Templeman, 1957), but the largest individuals were *marinus*-type redfish at 150 fathoms.

#### NORTHEAST ATLANTIC AND CENTRAL NORTH ATLANTIC

For the Northeast Atlantic and central North Atlantic, apart from Kotthaus and Krefft (1957), only general references regarding the depth distribution are available. Saemundsson (1949) says that *Sebastes marinus* is common in Icelandic waters from 30 metres (16 fath) to about 1,000 metres (550 fath). Fridriksson (personal communication, 1955) states that *Sebastes marinus* in Icelandic waters is abundant down to the greatest depths fished (500-600 metres, 270-330 fath) and that it is certainly present also in deeper waters. Lundbeck (MS, 1955) says that the depths in which the redfish live in greater quantities vary from 300 metres (160 fath) to over 500 metres (270 fath).

Kotthaus and Krefft (1957) give some information on depth distribution of redfish in the Iceland-Greenland area (Table VI, Fig. 41, 42). Nine large *marinus*-type redfish were caught in a set at 500 metres (275 fath) off Fiskenaes Bank and 5 *mentella*-type redfish at 635 metres (345 fath) on the Baffin Island-Greenland Ridge. The centre of abundance of the *marinus* form was at 300 to 350 metres (165 to 190 fath) and of the *mentella* form 400 to 450 metres (220 to 245 fath). The voyages of the *Anton Dohrn* in which these observations were obtained extended over a wide area, and no attempt was made to explore redfish depth ranges extensively in any one locality. Thus the results are indicative, only, of the depth distribution, especially of the *mentella* form, as only a few sets were taken in the areas and depths where the *mentella* form was abundant.

## TEMPERATURE CHARACTERISTICS OF AREAS OF ABUNDANCE AND SCARCITY OF REDFISH

### INTRODUCTION

Tåning (1949), as a result of researches to the south of Iceland and Greenland, north of Iceland and off East and West Greenland, found that redfish fry were not captured over deep water except where temperatures more than about 3°C were present in depths of about 200 to 500 metres (110-270 fath). They were absent, also, where temperatures of 8 to 9°C extended below the favoured 200 to 500 metre (110-270 fath) range of the redfish. They were most common where the 8 to 9°C water did not lie below a depth of about 200 metres (110 fath), leaving the favoured redfish 200 to 500 metre (110-270 fath) area with temperatures below about 8°C and in the main above 3 or 4°C. Whenever these conditions were fulfilled the fry of *Sebastes marinus* were present and usually abundant in the surface layers. Fig. 60 (Tåning's fig. 1 and 2) shows sections passing northward from the North-Atlantic Current water, where temperatures over 8°C extended to 600 metres (330 fath), to the colder boreal waters where the 8°C isotherm rose to near the 100 metre (55 fath) line near Iceland (Fig. 60A), and the 5°C isotherm rose to near the 100 metre (55 fath) line near Greenland (Fig. 60B). In both sections lower temperatures more suited to redfish occupy the favoured redfish area between 200 and 500 metres (110-270 fath). The change from the warmer condition to the cooler occurred within only a few miles. From this and other hydrographic sections Tåning has delimited with a dotted line in Fig. 60 the location of the quick change from the southern and eastern high-temperature to the northern and western more temperate boreal conditions. The redfish larvae were abundant in the boreal water to the north and west of this line (Fig. 5) but were not to be found in the warmer water to the south and east. Tåning interprets these findings to mean that spawning female redfish are present in numbers between 200 and 500 metres (110-270 fath) in the area where temperature conditions are favourable at these depths but not otherwise. These favourable temperature conditions, according to Tåning, were approximately 3 to 8°C.

Veshchezerov (1944a) says that in the Barents Sea the greatest schools of redfish are to be found in the central part at a temperature of 3°C and above.

As indicated by the distribution of redfish and the relationships between temperature and redfish abundance, discussed elsewhere in this paper, redfish are also abundant in the Newfoundland region only in areas where temperatures of 3°C and over are present in the deeper water. When temperatures above 3°C, suitable for the year-round life cycle of the species, are present in redfish depths in an area, some excellent redfish catches can sometimes be made in still colder water on the upper fringes of the warmer deep-water area (Table XVII). When

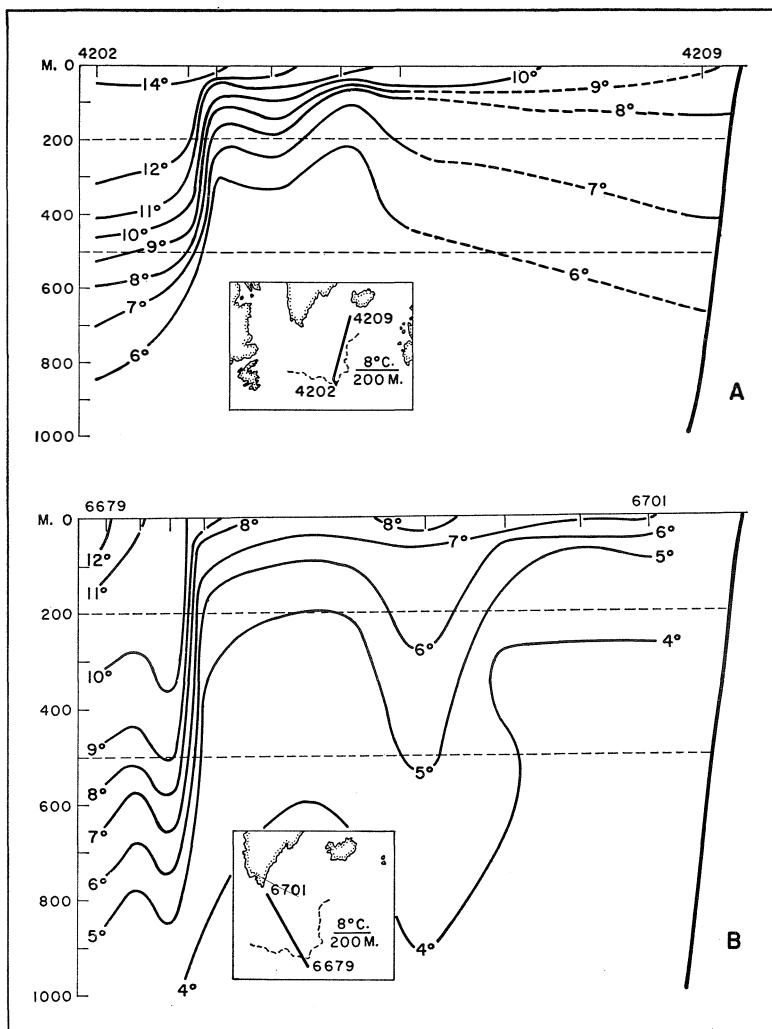


FIGURE 60. A, hydrographic section across the northern border of the North Atlantic Current from about  $47^{\circ}30'N$ ,  $28^{\circ}30'W$  to Iceland, *Dana*, June 27 to July 2, 1931 (after Tåning, 1949); B, hydrographic section across the northern border of the North Atlantic Current from about  $49^{\circ}N$ ,  $31^{\circ}W$  to Cape Farewell, Greenland, *Dana*, June 22 to 30, 1947 (after Tåning, 1949). In both A and B, temperatures are in  $^{\circ}C$  and the dotted line in the inset shows the position of the  $8^{\circ}C$  isotherm at a depth of 200 metres (110 fath).

temperatures of less than  $3^{\circ}C$  are present in the deep water of an area, redfish are scarce or absent (depending on the temperature) in spite of favourable depths (Table XX). When temperatures of  $8^{\circ}C$  and higher are present in the deeper water inhabited by redfish they are again much less plentiful. Our records of abundance at such high temperatures, however, are few and there are no areas near Newfoundland, on the slopes of the banks, where the 200 to 500 metre (110-270 fath) area is filled for a large part of the year with water the temperature

of which is higher than 8°C; although in the warmest area, the southwest slope of the Grand Bank, this high temperature water is sometimes present and is usually not far away.

#### DISTRIBUTION OF TEMPERATURE AND REDFISH

The area discussed will be from Iceland to south of Cape Cod. Only representative sections and broad general principles will be considered.

##### ICELAND AND EAST GREENLAND

Redfish are very abundant south and west of Iceland and scarce to the north and east (Fig. 28A; Saemundsson, 1949; Fridriksson, personal communication, February, 1955; Magnússon, personal communication, December, 1955; and Table XXV).

Table XXV. Redfish catches in experimental trawling cruises undertaken on behalf of the Fisheries Research Institute of Iceland.

Date	Position		Depth	Weight of redfish per hour's drag	Temperature near bottom
	Lat.	Long.			
	West of Iceland		<i>fath</i>	<i>lb</i>	°C
July 10, 1955.....	62°22'N	40°W	196-200	2,600	4.7
July 16-24, 1955.....	63°36'N	37°48'W	115-150	from very poor up to 22,000 lbs.	about 4.0
July 8, 1955.....	64°00'N	38°32'W	190-210	370	4.4
July 9, 1955.....	64°10'N	36°45'W	185-190	12,700	4.6
July 9, 1955.....	64°24'N	36°35'W	170	660	5.0
July 15, 1955.....	65°10'N	34°10'W	154-160	13,200	3.7
July 15, 1955.....	65°30'N	32°30'W	130-135	3,300	4.3
Aug. 28, 1954.....	Jónsmid		160	up to 32,000	6.1 <sup>a</sup>
	North of Iceland				
Sept. 12, 1955.....	67°07'N	22°00'W	110-120	350	0.8
Sept. 12, 1955.....	66°44'N	20°00'W	104	a few	5.0
June 2, 1955.....	67°29'N	19°55'W	186	0	0.9
June 2, 1955.....	67°02'N	18°54'W	120	a few	2.8
Sept. 11, 1955.....	67°00'N	18°14'W	88	0	4.2
Sept. 11, 1955.....	66°59'N	17°24'W	120-131	280	3.8
June 6, 1955.....	66°55'N	17°14'W	120	4,000	2.3
	Northeast of Iceland				
Sept. 9, 1955.....	67°02'N	15°04'W	98-109	190	5.5
June 7, 1955.....	67°00'N	15°58'W	101	70	2.0
June 7, 1955.....	66°56'N	13°55'W	153	a few small	0.4
Sept. 9, 1955.....	66°48'N	13°42'W	109-126	60	3.8
Sept. 8, 1955.....	66°18'N	12°32'W	109-120	0	0.5
Sept. 8, 1955.....	65°47'N	12°00'W	101-104	0	1.6
June 8, 1955.....	65°26'N	11°55'W	137	0	1.0
	Southeast of Iceland				
Sept. 7, 1955.....	64°59'N	11°38'W	126-153	6,600	b
June 8, 1955.....	64°34'N	10°40'W	224	0	0.2
June 8, 1955.....	64°18'N	11°06'W	186	710	0.1
June 9, 1955.....	64°11'N	11°36'W	180-202	570	4.0
Sept. 6, 1955.....	63°56'N	11°00'W	208	7,700	b

<sup>a</sup> trawlers were taking very good catches; <sup>b</sup> no reliable temperature measurements because of bad weather, but other information indicates that bottom temperature was about 7°C in each case.

Figures 61 and 62 show the contrasts in temperature conditions between the northeast coast of Iceland where redfish are scarce, the northwest coast where they are generally scarce, and the middle part of the west coast where they are abundant. The Langanes section to the northeast shows a thin layer of warm Atlantic water above the cold Norwegian Sea water. Temperatures above 3°C occupy the shallow depths only. In the Kögur section to the northwest the same conditions exist but temperatures of 3°C and higher extend deeper. This section is on the north side of the Iceland-Greenland Ridge where, according to Magnússon (personal communication, December, 1955), the temperature

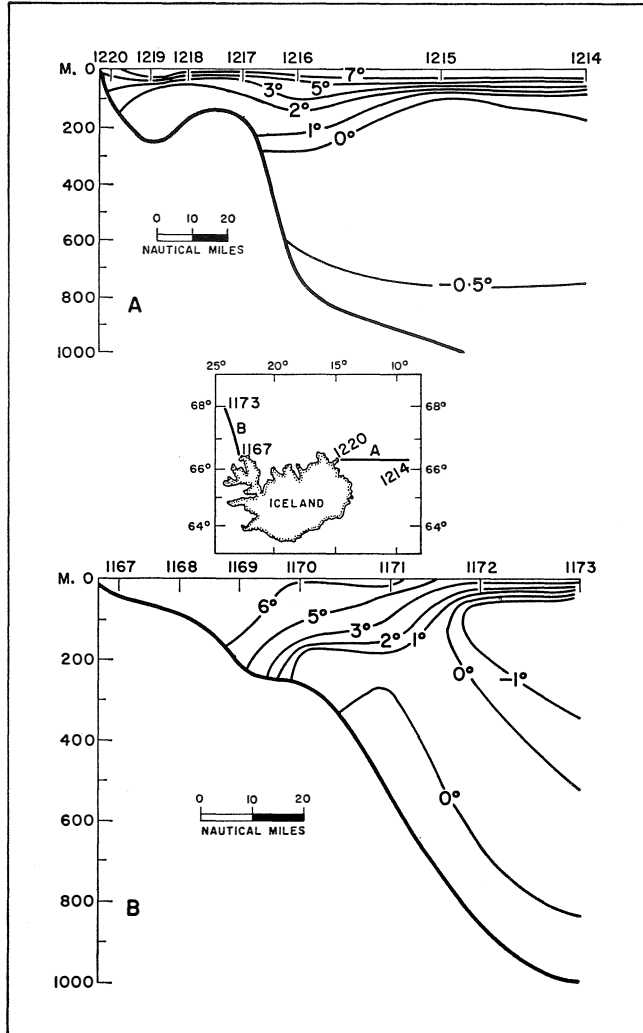


FIGURE 61. Temperature sections in the Icelandic area: A, Langanes section, Aug. 28 to 29, 1949 (after Stefánsson, 1950, fig. 6b); B, Kögur section, Aug. 18 to 19, 1949 (after Stefánsson, 1950, fig. 8b). (100 m = 54.7 fath.)

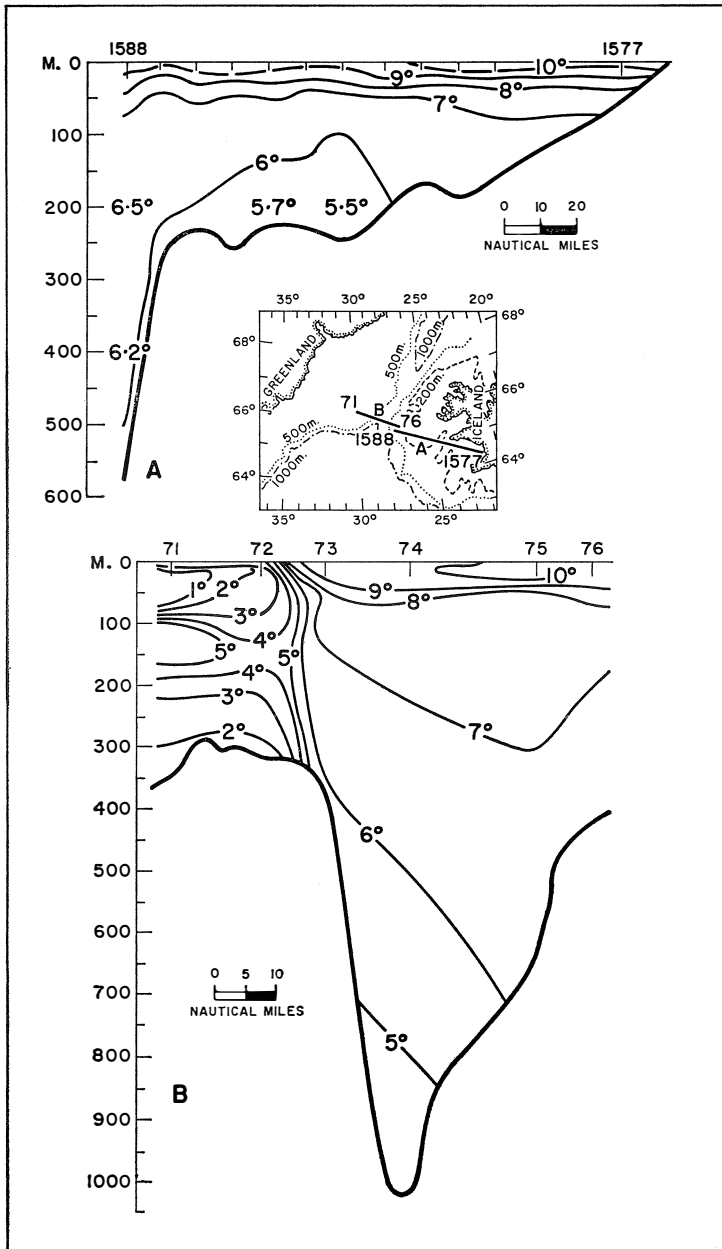


FIGURE 62. Temperature sections in the Icelandic area: **A**, Reykjavik section, June 26 to 28, 1951 (information from Unsteinn Stefánsson, October, 1955); **B**, Denmark Strait section (after Helland-Hansen, 1936, fig. 70). (100 m = 54.7 fath.)

conditions (in depths favoured by redfish) are not generally favourable for these fish, as the Atlantic water is limited to a thin upper layer and the cold Norwegian Sea water is generally found at the bottom. The west-coast Reykjavik section, through an area where redfish are generally abundant, shows the warmer Atlantic water extending to greater depths with temperatures as high as 6°C covering the depths favoured by *Sebastes marinus*.

Table XXV, supplied by Magnússon, gives the results of some experimental trawling cruises in the Icelandic area. Excellent catches of redfish were taken west of Iceland in drags from 115-150 to 185-190 fathoms and temperatures from 3.7 to 6.1°C. Generally poor catches were taken north of Iceland where temperatures were very low at the depths usually frequented by redfish in quantity; the single moderate catch of 4,000 pounds was taken in shallow water (120 fath) in 2.3°C near the bottom of the upper, warm-water layer. To the northeast of Iceland temperatures were generally low in the typical redfish depths (0.4°C at 153 fath) and redfish catches were negligible. Southeast of Iceland redfish catches were low at the lower temperatures and two catches of 7,000 to 8,000 pounds per hour's dragging were made at higher temperatures, possibly approaching 7°C, but this was not certain as no reliable temperature measurements were taken on these two occasions.

Adolf Kotthaus (personal communication, February, 1956, in relation to the redfish investigations of the *Anton Dohrn* in East Greenland and on the Iceland-Greenland Ridge, May to October, 1955) says that according to experience redfish are found everywhere on the continental slope of the North Atlantic, namely in the boundary area of the cold and warm ocean currents, and, following out this idea in explorations in 1955 using the *Anton Dohrn*, great quantities of redfish were discovered in East Greenland and on the Iceland-Greenland Ridge, especially on the Anton Dohrn Bank (see Fig. 38 and the section on general distribution).

Kotthaus and Krefft (1957) list the catches of redfish and the corresponding temperatures in individual sets of the *Anton Dohrn* in the Iceland-Greenland area. These are summarized in Table VI for all three forms, and for *Sebastes marinus marinus* in Table XXVI.

There were 5 sets yielding 21 to 486 *Sebastes viviparus*. In four of these sets, 21 to 312 specimens, bottom temperatures ranged from 6.2 to 7.2°C. For the largest catch—off the south coast of Iceland in 150 metres (80 fath)—no temperature was taken but judging from temperatures in neighbouring sets the bottom temperature should be over 7°C. (The *Anton Dohrn* did not fish the shallow water off the coasts of South and West Iceland where *viviparus* is also abundant. Å. V. Tåning in a verbal communication at the ICNAF redfish symposium at St. Andrews, New Brunswick, in June, 1952, said that in the *viviparus* range of from 1 to 200 metres (0.5 to 110 fath) temperatures of 12 to 6°C were often encountered.)

The greatest catches of *Sebastes marinus marinus* in individual sets were 3,000 in 310 metres (170 fath) at 0.4°C and 2,187 in 320-350 metres (175-190

TABLE XXVI.—Numbers of redfish, *Sebastes marinus marinus*, caught per otter-trawling set in the Iceland-Greenland area. (Data from *Anton Dohrn* cruises, May to July and September to October, 1955, Kotthaus and Krefft, 1957. The number of sets is in parentheses to the right of the average catch. \*Catch of 1 set converted, 1 basket = about 45 kg = 30 redfish. 100 m = 55 fath.)

Bottom temperature range	Average catch of <i>S. marinus marinus</i>				
	120-175 m	176-250 m	251-325 m	326-400 m	401-500 m
°C	no.	no.	no.	no.	no.
0.4-1.0.....			3,000 (1)	378 (1)	684 (1)
1.1-2.0.....	15 (3)	53 (3)		426 (1)	
2.1-3.0.....	1 (2)	263 (1)	6 (1)	*1,500 (1)	
3.1-4.0.....		169 (3)		*788 (3)	62 (1)
4.1-5.0.....	4 (1)	120 (1)		288 (3)	11 (2)
5.1-6.0.....	143 (2)	235 (5)	617 (2)	20 (1)	
6.1-7.0.....		116 (1)		120 (1)	3 (3)
7.1-7.6.....		65 (4)			

fath) at 3.7°C. Table XXVI indicates moderate catches in various depth ranges at temperatures ranging from 0.4-1.0 to 5.1-6.0°C, with small catches of this form in temperatures of 7.1-7.6°C.

The catches of *Sebastes marinus mentella* were: 499 (6.5°C), 365 (6.2°), 202 (4.2°), 144 (6.2°), 58 (4.3°), 5 (1.9°), 4 (7.2°), 3 (6.0°), and 1 (1.3°), at depths ranging from 225 metres (125 fath) to 635 metres (345 fath).

In this survey the area covered was too great, the temperatures at the same depths in different parts of the area were too varied, and the number of sets made was too few, to give more than indications of the temperature relationships of the three varieties of redfish.

#### LABRADOR

Here the redfish do not live in the warm surface water nor yet in the intermediate cold water of the Labrador Current, but are deeper, mostly between 140 and 400 fathoms, with the greatest abundance approximately at 160 to 250 fathoms in temperatures of 2°C to a little over 3°C (Fig. 54, 58; Tables XVII, XXI). In this area no deep-water temperatures higher than a fraction of a degree over 3°C are usually available to the redfish (Fig. 63, 45A).

#### NORTHEAST AND EAST GRAND BANK AND FLEMISH CAP

Apart from a very occasional stray, redfish do not exist in the deep and usually below -0°C water of the Avalon Channel between the Grand Bank and the Avalon Peninsula of Newfoundland, which is about 80-100 fathoms maximum depth. To the east of the Grand Bank they are abundant in the 160-200 fathom water, mostly between 2 and 3°C. West and north of Flemish Cap redfish are

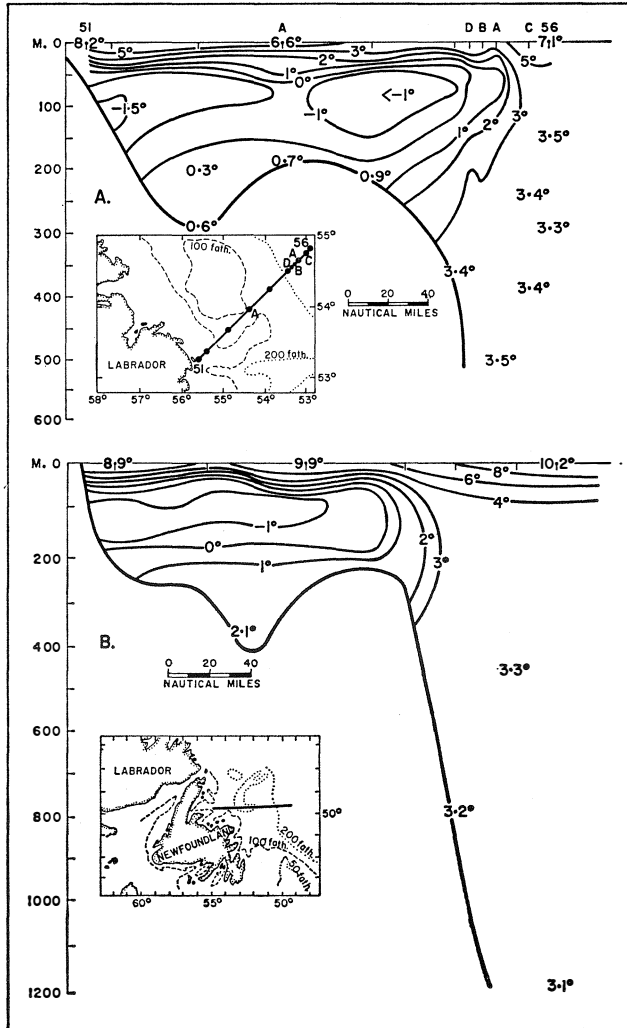


FIGURE 63. Temperature sections in the Labrador-Newfoundland area: A, off Seal Islands, Labrador, July 31 to Aug. 1, 1955; B, continental shelf off northeast coast of Newfoundland, Sept. 8 to 10, 1928 (after Smith *et al.*, 1937, fig. 64P). (100 m = 54.7 fath.)

abundant in 160-180 to 300 fathoms in temperatures between 3 and 4°C (Fig. 54, Table XVII, and the account of deep-water distribution of redfish.) In the redfish depths on the eastern slope of the Grand Bank and on Flemish Cap the temperatures of the deep water, although slightly higher than in Labrador, are typically below 4°C (Fig. 64A).

#### SOUTHWEST GRAND BANK

Here are the highest deep-water temperatures in the redfish depths of the Newfoundland area (Fig. 64B). Redfish are abundant between 80 and 200

fathoms and extend both shallower and deeper (Fig. 55, 58; Table XVII). There is so much action in this area between the mixed slope and colder bank water that the temperature pattern is not in any way as stable as that in the deep redfish environment to the northward. Temperatures at the 200-500 metre (110-270 fath) level are typically between 4 and 8°C, but sometimes warmer southern or colder northern water may temporarily move into the favoured redfish depths of this southwestern Grand Bank area.

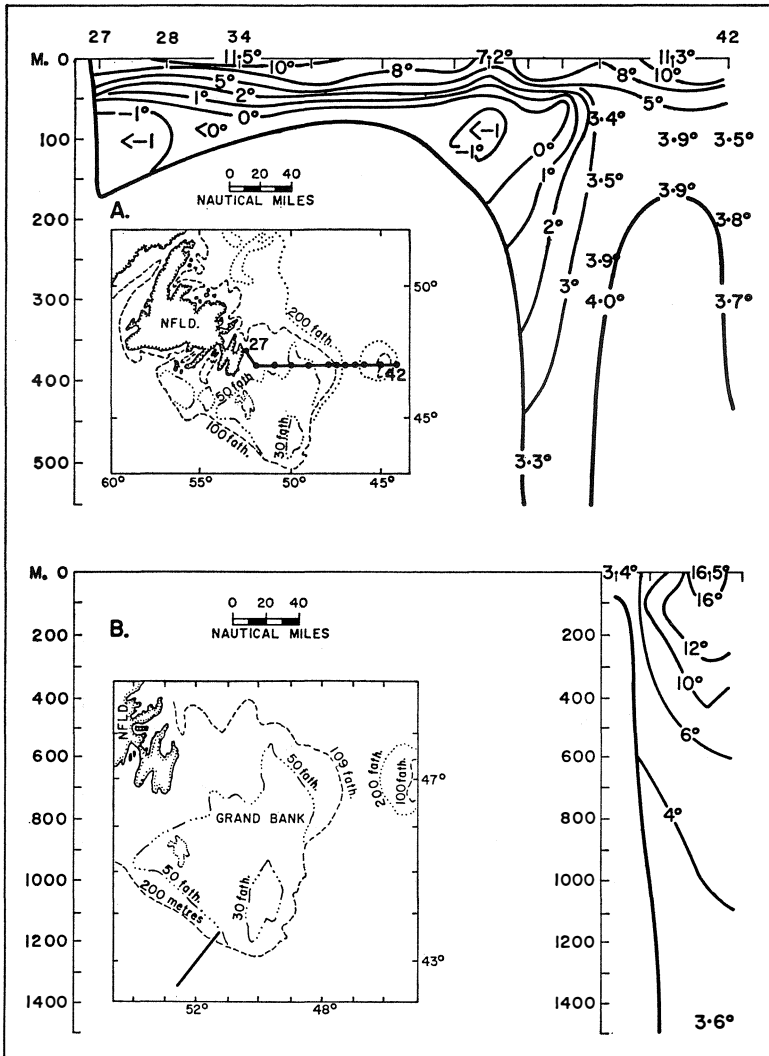


FIGURE 64. Temperature sections in the Newfoundland-Grand Bank area: **A**, St. John's to 47° latitude line and across Grand Bank and Flemish Cap, July 20 to 25, 1955; **B**, southwest slope of Grand Bank, Apr. 19 to 20, 1934 (after Smith *et al.*, 1937, fig. 98x). (100 m = 54.7 fath.)

## GULF OF ST. LAWRENCE

In the Gulf of St. Lawrence redfish are plentiful in the deep-water channels and, according to the catches of the *Investigator II*, are most abundant at 140 to 160 fathoms (Fig. 54, Table XVII).

Temperatures in these areas of redfish abundance in the Gulf are usually between 3 and 5°C, and the highest deep-water temperatures in these deep channels of the Gulf are usually not above 5.5°C (Fig. 65). The channels are deep enough so that below approximately a hundred fathoms the water can remain warm all winter.

Although the adults apparently remain in the Gulf, it appears that in most years the greater numbers of redfish larvae produced in the Gulf probably drift with the Gaspé and Cape Breton Currents and pass through Cabot Strait and also pass with the current outward on the Newfoundland side of the Strait of Belle Isle, since the Gulf redfish frequencies indicate only very occasional good year-classes. On the Newfoundland side of Cabot Strait some redfish larvae from the south coast of Newfoundland will drift into the Gulf.

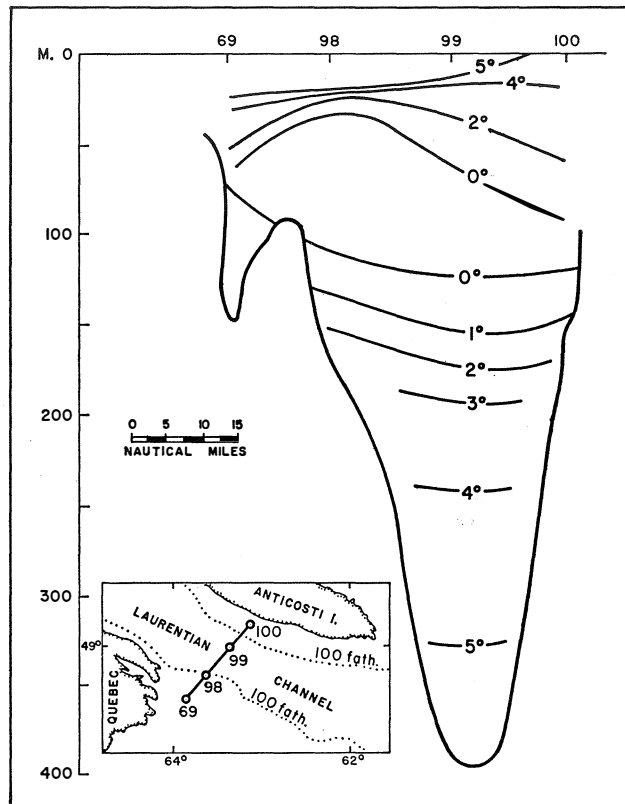


FIGURE 65. Temperature section in the Gulf of St. Lawrence: Laurentian Channel, Gaspé-Anticosti I., spring, 1948 (after Lauzier and Bailey, 1957, fig. 3). (100 m = 54.7 fath.)

## NOVA SCOTIAN SHELF

In the Nova Scotian Shelf area most of the redfish catch (apart from the catches on the northern part of the Banquereau slope and in "The Gully" between Banquereau and Sable Island Bank) is taken near the coast in depths between 50 and less than 100 fathoms, and it is in this coastal area that the greater part of the population of redfish in the southern Nova Scotian Shelf area apparently exists. Fig. 66 to 68 and McLellan (1954, 1955) show that, in this southern Nova Scotian Shelf area, temperatures between 3 and 6°C or 4 and 6°C are typically present at some level in the 50-100 fathom depth range near the coast and on the landward fringes of the depressions in the coastal shelf where redfish are abundant.

Apart from the Banquereau area and the adjacent area known as "The Gully", only very small amounts of redfish are at present caught near the seaward edge of the Nova Scotian Shelf. At the seaward edge of the continental shelf off Southeast Nova Scotia higher temperatures, 6 to 8°C and in recent years often

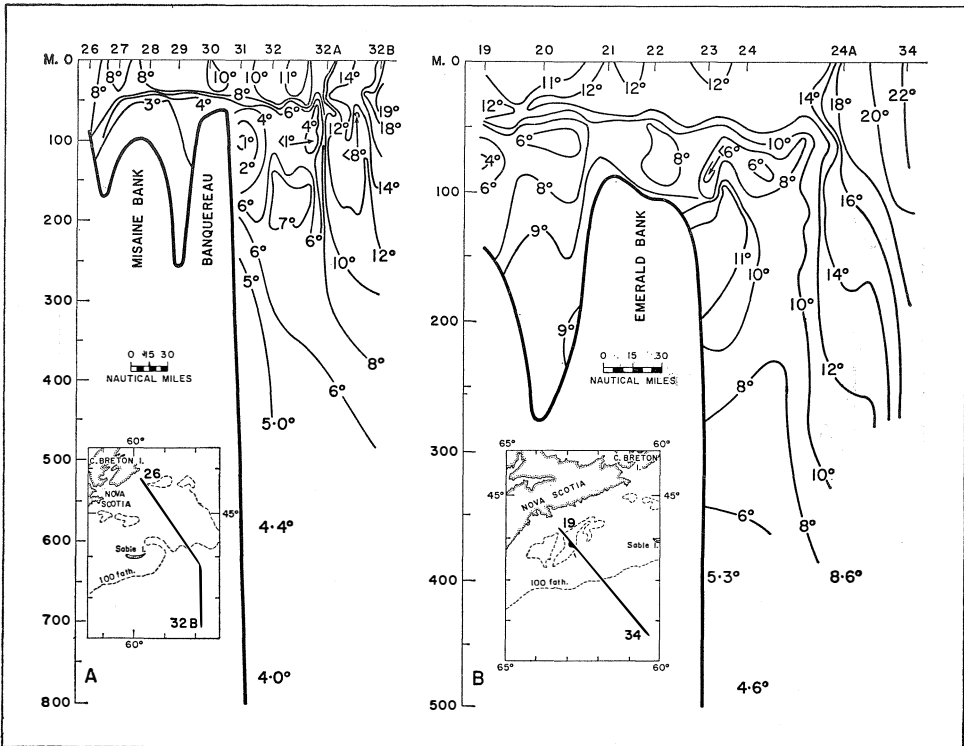


FIGURE 66. Temperature sections through the Nova Scotian Shelf and neighbouring slope areas: **A**, Banquereau, Nov. 7 to 8, 1952 (after Fisheries Research Board of Canada, Atlantic Oceanographic Group, 1953, and additional temperatures 250 to 500 metres for Nov. 7 to 8, 1952, and below 460 metres, for Nov. 25 to 26, 1955, supplied by the Atlantic Oceanographic Group); **B**, Emerald Bank, Nov. 12 to 13, 1951 (after McLellan *et al.*, 1953, fig. 6, with additional data, 300 to 400 metres for the same dates, and other data, 485 metres, for Oct. 19, 1954, supplied by the Atlantic Oceanographic Group). (100 m = 54.7 fath.)

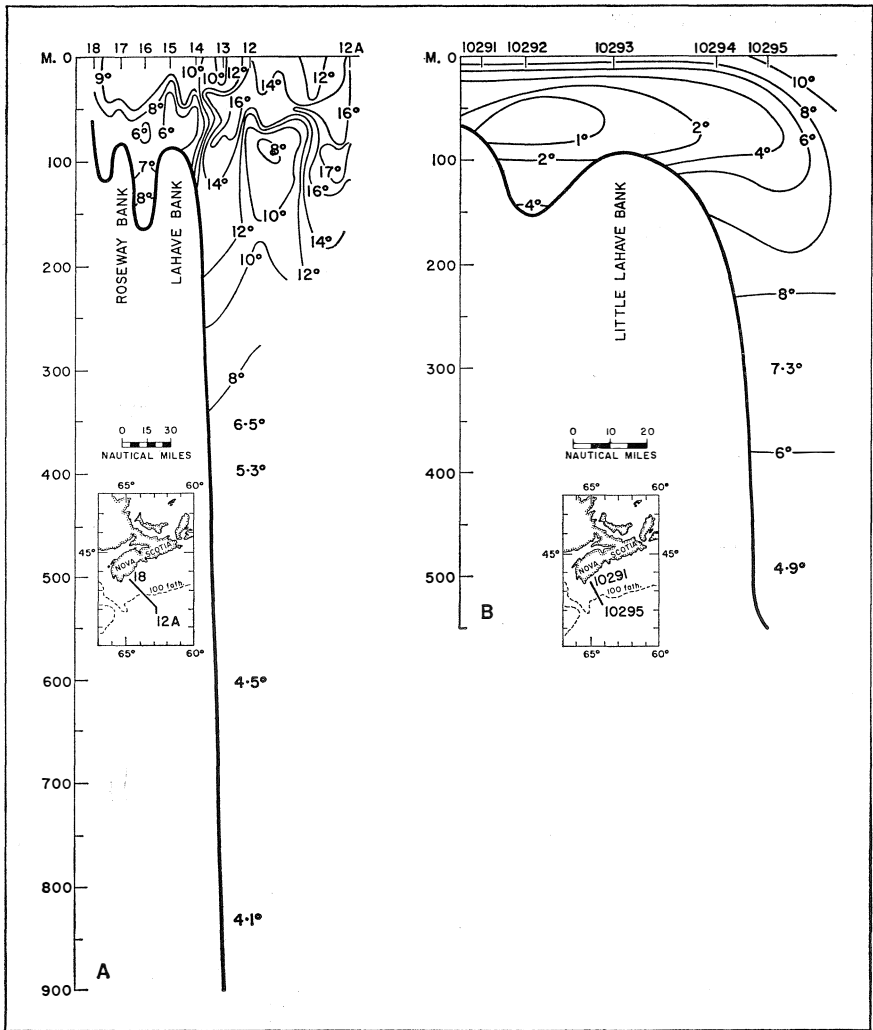


FIGURE 67. Temperature sections through the southern part of the Nova Scotian Shelf: **A**, in the Lahave Bank area, Nov. 29, 1951 (after McLellan *et al.*, 1953, fig. 5, with additional data, 250 to 350 metres for the same date and other data, 400 to 835 metres, for Nov. 17, 1955, supplied by the Atlantic Oceanographic Group); and **B**, in the Little Lahave (Baccaro) Bank area between Lahave and Browns Banks, June 23 to 24, 1915 (after Bigelow, 1927, fig. 41). (100 m = 54.7 fath.)

as high as 8 to 13°C (Fig. 67A; see also Hachey, 1953) exist at typical redfish depths from about 60 down to 350 metres (33-190 fath). From both Schroeder's and the *Delaware* catches and judging also by the lack of commercial exploitation, redfish are apparently scarce in the high temperatures of these typical shallower redfish depths at the edge of the continental shelf off Southeast Nova Scotia. In the same area deeper down, at 250-300 fathoms in temperatures between 4 and 5°C (Table XXII), Schroeder's good catches in a small net on a single wire

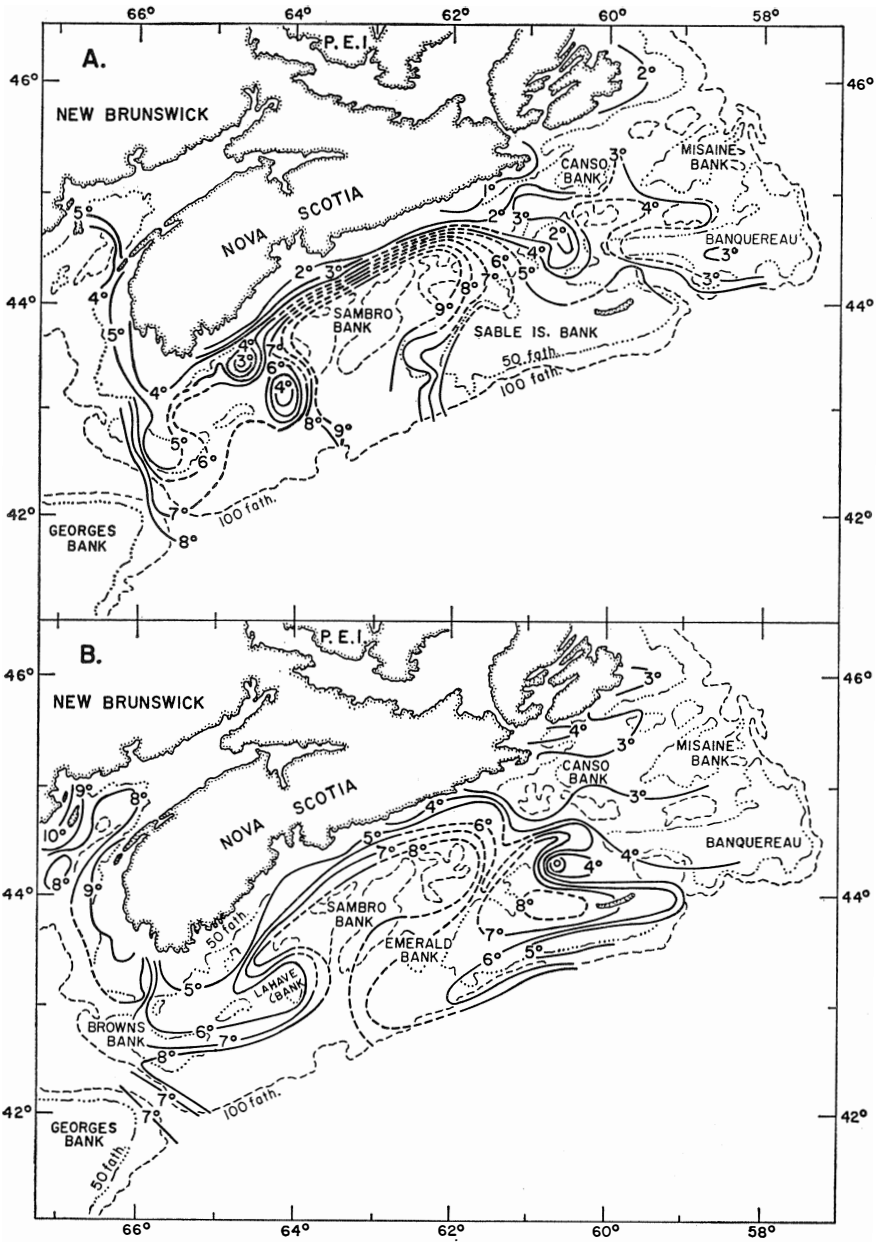


FIGURE 68. Bottom temperatures on the Nova Scotian Shelf (after McLellan, 1955, fig. 4 and fig. 6): A, Apr. 29 to May 11, 1952; B, Aug. 14 to Sept. 5, 1952.

indicated fairly numerous populations of large redfish. Schroeder's temperatures for individual sets between 250 and 300 fathoms in this area ranged between 3.9 and 4.7°C.

It is thus apparent in the southern Nova Scotian Shelf area, where high temperatures, above 6°C and often over 8°C, exist over much of the area, that the bulk of the redfish population follows the distribution of the fringe of the colder coastal waters, with a secondary abundance of large fish in deeper water having again lower temperatures, between 4 and 5°C, near the seaward edge of the shelf. The *Delaware* catches (Fig. 59, Table XXIII, Lat. 42° to 43°N), in the same general area fished by Schroeder, did not, however, show as good catches at any level, considering that a large commercial trawler with a large No. 41 net was used in the experiment.

In the northern part of the Nova Scotian Shelf the *Delaware* obtained excellent catches on the seaward slope southeast of Banquereau: 12,000, 10,000, 10,000 and 20,000 pounds of redfish per hour's dragging from sets in 180, 215, 260 and 275 fathoms between Lat. 43°56' and 44°29'N in September, 1955. Shallower water was tested by only one set, with a catch of 140 pounds at 115 fathoms. In this northern part of the Nova Scotian Shelf where redfish are abundant in the moderately deep water, temperatures on the upper slope of the shelf are lower (Fig. 66A) than off the southern part of the shelf (Fig. 67). No bottom temperatures were taken by the *Delaware* but it is probable that the above large catches were taken in water between 4 and 5°C. (See Fig. 66A in which, in the Banquereau area, water temperatures below 250 metres (140 fath) were below 5°C, but in which even at 450 metres (250 fath) temperatures were probably not much below 5°C.) Similarly the Canadian Fisheries Expedition section through the slope waters off Banquereau in July, 1915, showed temperatures of 6.3°C at 200 metres (110 fath), 4.3°C at 300 metres (160 fath) and 4.15°C at 400 metres (220 fath) (Bjerkas, 1919).

In the *Delaware* catches (Table XXIII) along the seaward edge of the continental shelf there were no good catches in depths from 74 to 175 fathoms in areas where temperatures may be supposed to be higher than 6°C. Apart from one small catch off Southeast Nova Scotia of 1,100 pounds at 132 fathoms, no single catch between these shallower depths exceeded 210 pounds per hour's dragging.

#### GULF OF MAINE

The Gulf of Maine is the most southerly area of great abundance of redfish (Fig. 20-23). In an area such as this, at the southern extremity of the redfish range and experiencing heavy exploitation, the population might be expected to undergo a rapid decline. Although the redfish population of the Gulf has declined considerably under intensive fishing, the cyclic character of the circulation (Bigelow, 1927) and the location of the largest quantities of adult redfish (Fig. 20-23) and also of redfish larvae (Fig. 15) in the inner part of the Gulf must be very favourable to the retention of the young redfish and thus help to provide good recruitment. In this area redfish are abundant on the western or coastward

borders of the deep basin of the Gulf, and to a less (but still considerable) degree in the South Channel area between Georges Bank and Cape Cod. The South Channel is also in the coastward part of the Gulf. Depths of 70 to 120 fathoms provide good fishing, but in the areas to the northeast, southeast and southwest of the Cashes Ledge region the waters deepen to 130 to 160 fathoms, yet the redfish become exceedingly scarce in these depths. As on the Nova Scotian Shelf, the distribution of the redfish in the Gulf of Maine is, therefore, much more a coastward than a seaward one.

The hydrographic information given here regarding the Gulf of Maine (Fig. 69, 70) is from Bigelow (1927). We are somewhat handicapped by a lack of hydrographic sections for recent years when temperatures have probably been a little higher, at least at the shallower and intermediate depths.

Taylor, Bigelow and Graham (1957) say that hydrographic data for the Gulf of Maine in 1953 and 1954 indicate an increase of from  $\frac{1}{2}^{\circ}$  to  $3^{\circ}\text{C}$  throughout the water column, since the period 1912-1926, for most parts of the Gulf.

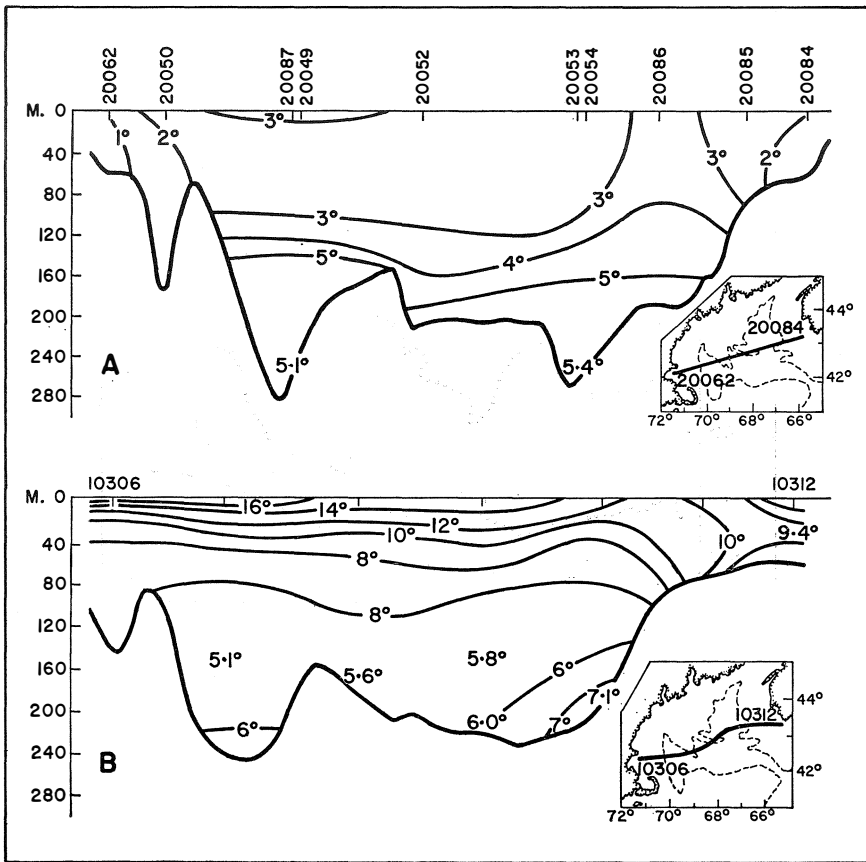


FIGURE 69. Temperature sections in the Gulf of Maine (after Bigelow, 1927, fig. 14 and 62): A, Mar. 5 to 23, 1920; B, Aug. 31 to Sept. 2, 1915. (100 m = 54.7 fath.)

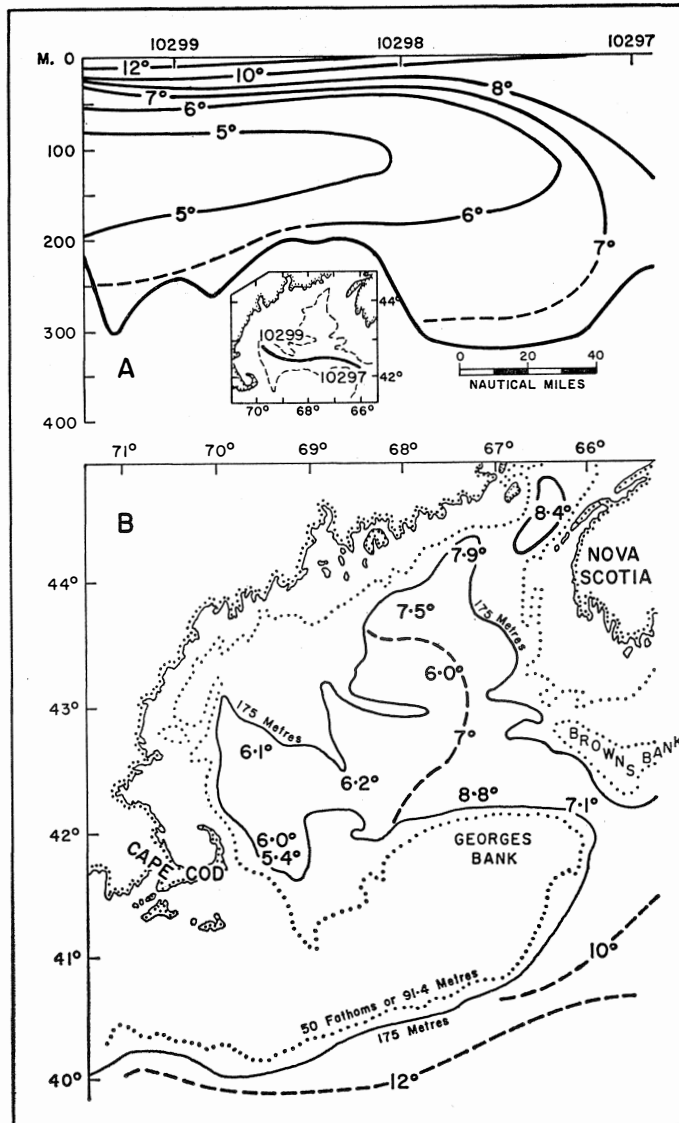


FIGURE 70. Temperature sections in the Gulf of Maine (after Bigelow, 1927, fig. 44 and 57): A, easterly from the basin off Cape Ann along the trough of the Gulf to the Eastern Channel, June 25 to 26, 1915; B, at a depth of 175 metres (96 fath) for August, 1914, within the Gulf and for July to August along the Continental slope. (100 m = 54.7 fath.)

Redfish have considerable ability to adjust their temperature relationships by vertical migration. For the redfish depths below 180 metres (100 fath) only scanty information from 1953 is available to compare with the data from the earlier years 1912-1926. For 3 areas of the Gulf of Maine from 180 to 274 metres (100-150 fath) temperatures in 1953 ranged from 0.7°C less than those of the

earlier years to 1.1°C greater. The average increase was only 0.2°C. We must conclude that, for the deeper water below 100 fathoms in the Gulf, the very small amount of information available indicates that temperatures have changed but little in recent years.

Taylor, Bigelow and Graham (1957) present the following table showing, for a total of 71 readings, mean temperatures recorded in the Gulf of Maine at depths of 160 to 330 metres (90 to 165 fath) in various years between 1912 and 1926 (number of observations is given in brackets):

Month	Mean temperature	
	W. part Gulf of Maine basin	E. part Gulf of Maine basin
	°C no.	°C no.
Feb.-Mar.....	5.1 (11)	5.0 ( 9)
Apr.-May.....	5.4 ( 9)	5.2 ( 6)
June-July.....	5.5 ( 3)	7.7 ( 7)
Aug.-Sept.....	6.2 (10)	6.5 (11)
Nov.-Jan.....	5.2 ( 4)	6.9 ( 1)

They conclude that there is nothing in the record to suggest that the temperature of the deep bottom water within the basin of the Gulf of Maine has fallen appreciably below these limits, or risen above them, in any year since Gulf temperatures have been recorded.

Judging from Bigelow's (1927) data and the tabular matter from Taylor *et al.* (1957) given above, temperatures in the Gulf of Maine may be between 2° or 3° and 6°C (average 5.0 to 5.1°C) at redfish depths in the western part of the Gulf at the end of winter; and they may be typically between 5° and 7°C sometimes 6 and 8°C (average 5.5-6.2°C in the western and 6.5-7.7°C in the eastern basin) at redfish levels in this area by summer and autumn. (We have, however, no actual information on redfish catches at various temperatures in the Gulf of Maine, and thus cannot state at what particular temperatures redfish of commercial size are most abundant.) The lower temperatures in the deep water are toward the coast, and temperatures gradually increase to a degree or two higher seaward near the Eastern Channel entrance to the Gulf of Maine between Georges and Browns Banks. Through this channel, which is about 140 fathoms deep, slope water, usually between 6 and 8°C, penetrates intermittently into the Gulf as a bottom current, rendering the deeper layers warmer, particularly in winter, than they would otherwise be.

In the deeper trough of the Gulf a greater volume of the warmer slope water passes along the eastern and northern sides. This usually allows somewhat lower temperatures to occur in the western part of the trough where more cold water forms due to lower air temperatures near the coast. There is evidence also of an

outflowing deep drift of somewhat colder water than the inflowing slope water, via the western or Georges Bank side of the Eastern Channel entrance to the Gulf. The outflowing current gives colder water than would be expected in the deep water on the northern part of the seaward slope of Georges Bank. This may favour the existence of the modest numbers of redfish that have been found on this part of the continental slope.

Although more knowledge of temperatures during recent years in the actual places of most abundant redfish supply in the Gulf of Maine would enable us to discuss the matter more precisely, it is evident, on the basis of the general information given here, that as in the southern part of the Nova Scotian Shelf area the greatest abundance of redfish in the Gulf of Maine is coastward toward the central and the western parts of the Gulf, where temperatures in the redfish depths tend to be lowest—generally over much of the year between 3 and 6°C, sometimes as high as 7 or 8°C.

The supply of cool water formed locally during the winter, with the inflow from the Nova Scotian area in the spring and sometimes early summer, the inflow of slope water of moderate temperature along the trough of the Eastern Channel and the protection offered by Georges Bank to the penetration of too abundant a supply of too warm water from the southeast allow the Gulf of Maine to keep cool enough for redfish. It may be suspected, however, that a general temperature rise of several degrees Centigrade in the depths suited to redfish in the Gulf of Maine would render the Gulf area much less favourable for these fish.

#### SEAWARD SLOPE OF GEORGES BANK

The summer temperatures on the northern part of the seaward slope of Georges Bank (Fig. 71A) are not very different from those on the continental shelf area of Southeast Nova Scotia (Fig. 67). In this northeastern Georges Bank area, from Bigelow's July 22-23, 1914, profile referred to above, temperatures on the seaward slope of the bank between 100 and 220 metres (55 to 120 fath) were between 8 and 11°C. The temperature gradually declined from 8°C at 220 metres (120 fath) to 6°C at 360 metres (200 fath) and to 5°C at 500 metres (270 fath). On the other hand relatively low temperatures sometimes occur, as in Bigelow's (1927) figure 16, when the water in this area on Mar. 3-12, 1920, probably influenced by the outflow from the Gulf of Maine through the Eastern Channel, was only 4.3°C to a fraction over 5°C from 140 to 500 metres (75-270 fath).

The *Delaware* redfish catches on the seaward slope of the northern half of Georges Bank in May, 1955, were very low at all depths. The greatest redfish catches for the whole area from Lat. 40°19'N on Georges Bank to 42°00'N at the southern tip of the Nova Scotian Shelf, in 20 drags well distributed between 90 and 470 fathoms, averaged only 200 pounds at about 325 fathoms and 139 pounds at about 225 fathoms (Table XXIII). No bottom temperatures were taken during the experimental fishing by the *Delaware*, but reference to a section in the middle of the above area (Fig. 71A) indicates that temperatures at 325 fathoms

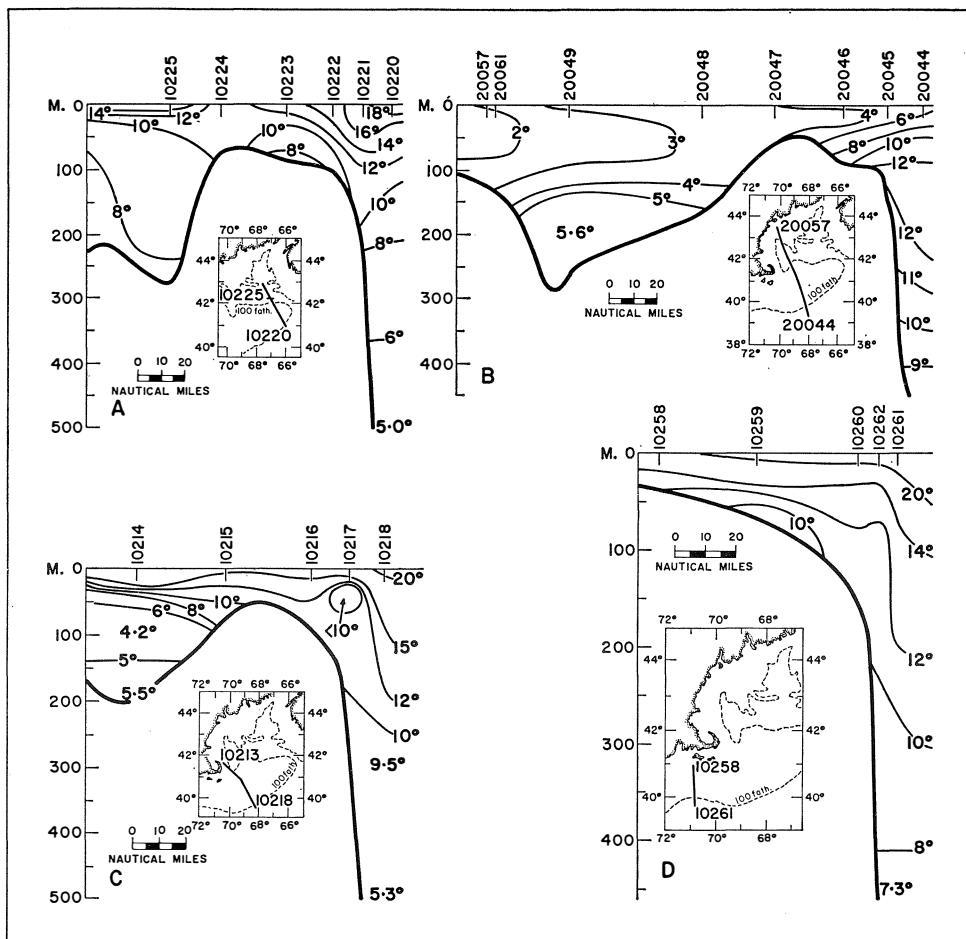


FIGURE 71. Temperature sections on the seaward slope of Georges Bank and adjacent Gulf of Maine and coastal areas (after Bigelow, 1927, fig. 59, 15, 58 and 60): A, July 22 to 23, 1914; B, Feb. 22 to Mar. 4, 1920; C, July 19 to 21, 1914; D, southward from Marthas Vineyard, Aug. 25 to 26, 1914. (100 m = 54.7 fath.)

would be below 5°C and at 225 fathoms between 5 and 6°C. In all this discussion it should be remembered that temperatures, particularly at the upper and intermediate levels, may have been higher in recent years.

In the southern part of the seaward slope of Georges Bank south of Cape Cod and off Martha's Vineyard (Fig. 71D) temperatures at the continental shelf area are still higher with temperatures of 8 to 12°C often extending down to below 400 metres (220 fath). Here, even in the deep water, there are apparently no redfish apart from the occasional specimen.

#### DEATH OF REDFISH AT LOW TEMPERATURES

Jensen (1922) gives an account from R. Müller of great quantities of dead or dying redfish rising to the surface at Sukkertoppen in Greenland on Feb. 11,

1889. An area of the fjord, 4,000 feet long and about 1,000 feet broad, was almost covered with dead redfish. Müller stated further that the Greenlanders informed him that it was not uncommon every year or every few years for greater or lesser numbers of dead redfish to rise to the surface in this manner, but that there was no evidence that the other varieties of fish in the area were killed. The redfish deaths occurred always in the period January to April and mostly in February and March. About 12 years previously the redfish had been killed so extensively that the fjord surface was red with them. In other places in the area redfish have died in the same way but less frequently and in small numbers.

Paul Hansen (personal communication February, 1956) says that during the cold winter of 1948 to 1949 thousands of redfish were killed by the icy water in the deep fjords at Holsteinsborg, West Greenland; and the surface of the fjord and the entrance to the fjord were quite red with dead and dying redfish.

Considering the time of year when the deaths occurred it is most likely that the deaths of redfish described above were due to the chilling of the water.

#### DISCUSSION AND CONCLUSIONS

In Norway and the Northeast Atlantic the redfish-hydrography relationships are essentially similar to those at Iceland, the redfish abundance being related to the inflowing Atlantic water. (For hydrography in the Norwegian area see Helland-Hansen and Nansen, 1909.) Bigelow and Schroeder (1953) say that in the Norwegian Sea *Sebastes marinus* is caught only in the overlying layer of Atlantic influence at temperatures of 3-4°C or higher, never deeper in the icy-cold Polar water.

In the central area, near Iceland, the occurrence of large quantities of redfish (*Sebastes marinus*) is restricted to the deeper parts of a layer of warm Atlantic water. When this Irminger Current layer passes northward, with a suitable depth, above the more northern Arctic water, the redfish live in the warm water above the cold layer. Magnússon's limited data (Table XXV) show good redfish catches west of Iceland at temperatures between 3.7 and 6.1°C, one moderate catch northward at 2.3°C and negligible catches to the northeast of Iceland where temperatures in typical redfish depths below 140 fathoms were lower than 1°C.

In the Iceland-Greenland area Kotthaus and Krefft (1957) found mostly moderately good and occasionally good catches of *marinus*-type redfish at bottom temperatures between 0.4 and 6.0°C. There were no good catches of the *mentella* form, but the best catches of this form were at 6.2 to 6.5°C. This may not be representative as few tows were taken in the depths most favoured by *mentella*.

It is evident from the data presented earlier in this paper that in the Northwest Atlantic, from Labrador southwards, large redfish populations are often to be found on the continental slopes and in deep holes and channels where the temperatures in the redfish depths are usually between 3 and 6°C. On the fringes of such areas there may often be abundant redfish at temperatures

as low as 1 or 2°C or lower and possibly also at temperatures of at least 7°C. Off Labrador, to the east of Newfoundland and east of the Grand Bank the redfish live mainly in water with temperatures from 2°C to less than 4°C lying below the colder part of the Labrador Current. Similarly, in the Gulf of St. Lawrence they usually live in temperatures of 3 to 5°C below the cold-water layer. In the warm water on the southwest slope of the Grand Bank the upper fringe of the redfish population comes into shallower water but most redfish are still to be found between 2 and 5°C. In the coastal deep water of the Newfoundland area, where water of depths suitable for redfish may be found, but where the temperatures in the deep water are less than 3°C, redfish are not plentiful unless these areas are close to typical redfish areas with temperatures of 3°C or higher in the deep water.

Farther southward off southern Nova Scotia and in the Gulf of Maine (apart from Schroeder's fishing experiments at the edge of the continental shelf off Southeast Nova Scotia) we have no information, from experimental fishing, on the relationship of redfish abundance and temperature. From the commercial statistics we have shown that redfish are to be found in both of these areas on the coastward side where, over most of the year, the waters at redfish depths are coldest, and where temperatures of 2 or 3 to 6°C (sometimes approaching 7 or 8°C) are available over a large part of the year. Most of the redfish in these shoreward areas are in shallow water of 50 to 100 or 120 fathoms.

In southern Nova Scotian waters and the seaward side of Georges Bank, however, redfish are scarce on the continental slopes at depths in which they are abundant near the coast, and in which depths the temperatures at the continental slope are usually 6 to 8°C or higher. Here, in the southern Nova Scotian Shelf area at least, large redfish may be common in very deep water below 200 fathoms where water temperatures again approach 4 or 5°C. Still farther south where temperatures as high as 6 to 8°C extend down to approximately 400 to 500 metres (220 to 270 fath), with increasingly higher temperatures from these depths up to 200 metres (110 fath), only occasional redfish are present.

It is apparent that, in the Northwest Atlantic, redfish, *Sebastes marinus mentella*, are not abundant at temperatures lower than 3°C except in the vicinity of areas where water of 3°C or higher occurs at redfish depths. It is equally apparent that they are also not in great abundance at higher temperatures than about 6°C excepting near areas where, for a large part of the year in redfish depths, temperatures between 6 and 3°C, are present.

Our studies of groundfishes generally show that the exact temperature at which a particular species may be abundant, locally and temporarily, is variable and to a great degree dependent on acclimatization, abundance of food, size of fish, and many other factors. However, when species exist in massive abundance, the year-round average temperature and the temperature range for each are attuned to a very narrow cycle.

The redfish, living in a deep and stable environment, apparently has only a narrow range of temperatures within which the essential yearly cycle of living

activities can be maintained. In addition to the immediate environment of the parent, other factors are important. The larvae apparently live for a number of months in the surface layers and, apart from current systems which may sweep the larvae away from the area, in the southern part of the redfish range below the Gulf of Maine there would doubtless be a point beyond which too-high surface temperatures would limit the abundance of larvae of a low-temperature species which liberates its young in late spring and early summer. In most of the redfish areas of the Northwest Atlantic large numbers of redfish larvae must settle near the bottom in adjacent areas below 2°C and even below 0°C, and this may reduce considerably the survival rate of these larvae.

We have observed in our Labrador deep-water exploratory fishing that, when redfish live in very deep water, the onset of sexual maturity may be very much delayed. This factor may limit the numbers of the species in some areas where suitable water temperatures lie too deeply.

Thus, possibly for these and doubtless for many other reasons, redfish numbers are adversely affected by too low or too high temperatures in their normal depth range. Over most of the Northwest Atlantic the usual temperature range for abundant redfish populations is 3° to 5° or 6°C. The great differences in the depths at which redfish are abundant in the various environmental areas, related as they are to the location of suitable temperatures between 3° and 6°C, indicate that, when temperatures above or below this range are present in some part of the usual redfish depth range, the depths at which redfish are located are usually determined to a large degree by temperature. Where, as we have discussed previously for Flemish Cap, approximately the same suitable temperatures for redfish (at Flemish Cap in our deep-water dragging experiment, 3.4 to 3.8°C) exist throughout the possible redfish range, the redfish distribution is probably determined chiefly by other factors such as light and food.

The Gulf of Maine area has for redfish many of the advantages of a northern area, in having moderately cold water from local cooling, cold water in the spring from the Nova Scotian area, and the protection which Georges Bank offers to the penetration of deep warm water from the east. There are also the advantages of its southern position in that the water layer of below 3°C, which is generally too cold for redfish, is thin and disappears quickly in the summer; for this reason redfish in these areas are commonly to be found in shallower water than in many other parts of the Northwest Atlantic. The only areas of the Northwest Atlantic approaching the Gulf of Maine in shallowness of redfish habitat are the southwest slope of the Grand Bank and the coastal areas of the Nova Scotian Shelf.

Because the *marinus* and *mentella* forms of redfish have different depth ranges they will be affected somewhat independently by temperatures at different levels in the redfish range. There are not enough data available at present for the whole North Atlantic but the features are evident from even the present scanty knowledge.

Travin (1951) says that in the Northeast Atlantic *mentella* is a colder water species than *marinus*, optimal temperatures for large concentrations being

generally about 2°C compared with about 4°C for large schools of *marinus*. In the Newfoundland area, however, the very small number of the *marinus* form present are found mainly in the shallower deep water with temperatures usually 2 to 3°C or lower, whereas the more usual *mentella*-type redfish are in the deeper and warmer water, usually 3 to 5°C. On the Flemish Cap both species are in water of the same temperature, about 3½ to 4°C. In the Northeast Atlantic the colder Arctic water lies deeper and the warmer Atlantic water above. Thus the shallower *marinus* is in warmer water than the deeper *mentella*. In most of the North American redfish area the colder water lies above the warmer water and the species temperature relationships are reversed. On the Flemish Cap temperatures are approximately the same over the whole redfish range and the usual depth relationship between the *marinus* and *mentella* varieties still continues to exist. Thus, within a limited range of temperatures, in these two varieties the depth differences are more constant and more fundamental than the temperature differences which are variable according to the locality. In the Northwest Atlantic, apart from West Greenland, almost all the commercial fishery is based on *Sebastes marinus mentella*. In the North-central and Northeast Atlantic the fishery has depended chiefly on the *Sebastes marinus marinus* form which is extremely abundant, larger, heavier, and easier to catch (because it is shallower), and which in Europe is considered to be a more marketable fish than the deep-water form. More recently, since trawlers have begun to fish more deeply, large quantities of the *mentella* form have appeared in the European markets, but as yet, apart from a beginning in Germany, the attempt to provide separate catch statistics for the two subspecies has not been made.

Because in the Northeast Atlantic and at Iceland the presence of redfish is associated with an upper water layer of warm Atlantic water, conditions are suitable for the development of large populations of the *marinus* type which prefers waters only moderately deep and in the European area, where it is abundant, lives in higher temperatures than the deeper *mentella* form. In a great part of this northeastern area, also, the warm Atlantic water goes deep enough to allow large populations of the *mentella* form to exist. By analogy with the lack of the *marinus* form in the eastern Canadian area where it lacks suitable living space, we should expect that, wherever in the Northeast and North-central Atlantic the overlying warm Atlantic layer is shallow over a large area, temperatures will not be high enough at typical *mentella* depths to allow the development of large populations of the *mentella* form. Also, where the warm Atlantic layer moves over banks too shallow for *mentella*, this form should be scarce or absent.

In the regions of the Northwest Atlantic which are nearest to the large *marinus*-type redfish populations of West and East Greenland and Iceland (namely: the Labrador continental slope, the eastern Newfoundland continental shelf and continental slope, and the eastern slope of the Grand Bank), the overlying water layer is a cold one, water with a temperature of 0°C or lower typically extending downward to 120 to 140 fathoms, and most redfish usually live below 140 fathoms. Thus, because almost all *marinus*-type redfish live shallower than

400 metres (220 fath) and the centre of abundance is considerably shallower than this, there is little suitable environment available for large populations of the *marinus* form to exist. The lack of warm water in the upper 150 fathoms may be especially critical for the younger redfish of the *marinus* type. The small number of *marinus*-type redfish found off the eastern Newfoundland and Labrador areas have been most abundant at about 140 to 160 fathoms. The bottom water temperatures in the Labrador and eastern Newfoundland region in the vicinity of 140 to 160 fathoms and shallower are lower than in the deeper water and, since the maximum deep-water temperatures in this area in any case are usually less than 4°C, the temperatures at 140 to 160 fathoms and shallower are even less suited to redfish than the deeper water. Also, the *marinus* form, judging from its European environment, may quite well require a higher temperature for its abundance than does the *mentella* type. Thus, in this Northwest Atlantic area, temperature conditions at depths respectively suited to the existence of these two forms very much favour the development of large populations of *mentella* rather than large populations of *marinus*.

In the area of the Northwest Atlantic where the *marinus* form may be moderately plentiful—Flemish Cap—temperatures are usually between 3½ to 4°C at all redfish depths and no overlying cold layer is usually present.

In the Gulf of St. Lawrence, the western part of the south coast of Newfoundland and in the northern part of the Nova Scotian Shelf area temperature conditions are similar in type but less extreme than off eastern Newfoundland and Labrador. The few *marinus* type present are mainly at 90 to 120 fathoms and the centre of abundance of the *mentella* type is deeper than that of the *marinus* type. The scarcer *marinus*-type redfish occupy a zone near the upper cold water layer and the plentiful *mentella*-type redfish have their centre of abundance in the deeper water zone where the water is warmer.

In the Labrador to Flemish Cap area *marinus*-type larvae or adults may arrive from the large pelagic populations of larvae (and possibly also adults) discovered by Tåning extending from Iceland and South Greenland almost to Flemish Cap.

*Sebastes viviparus*, which is common in shallower inshore areas of the warm North Atlantic Current than are inhabited by the *marinus* form, is both in habitat and in form much more closely related to *marinus* than to *mentella*. Since it lives in shallow water, its maximum temperature requirements may also be higher. This species has not been noted in the Northwest Atlantic and conditions for its existence in most of this region (where inshore water temperatures usually fall as low as -1 to -1.5°C in winter and where during the winter the water in the northern section is chilled below 0°C for over 100 fathoms) are doubtless relatively even more unfavourable than for the *marinus* form.

In a general way the effect of the presence of boreal waters of intermediate temperature on the distribution of the redfish can be seen from Fig. 39, 41 and 42. On the American side, where the Labrador Current, the Gaspé and Cape Breton Currents, local cooling and the deflection seaward of the Gulf Stream

bring the influence of low temperatures far southward, abundant redfish and low temperatures suited to redfish are to be found as far south as approximately Lat. 42°45'N at the tip of the Grand Bank and about Lat. 41°N in the Gulf of Maine. In the central North Atlantic, abundant redfish larvae and at least occasional adult redfish can be found in the southward extension of the boreal waters almost to Lat. 50°N. On the European side the extensions of the North Atlantic Current carry the influence of moderately warm water far to the northeast. Here the southern border of redfish abundance is north of Lat. 60°N and the northern border is near Lat. 75°N. This is well northward of the probable northern limits of abundance of redfish on the American side, off Labrador or Baffin Island.

## LOCAL CONCENTRATIONS AND THE ENVIRONMENT

The general environmental temperatures at suitable depths, larval survival and retention, food supply and other factors in an area allow the development of large populations of redfish. Within each general area which has a large redfish population, however, there are some special conditions which may bring together in one place an unusual abundance of redfish. Since the evidence, such as it is, comes entirely from near-bottom fishing by otter trawls, the concentrations of redfish discussed here are bottom concentrations which make redfish available in quantity for bottom otter trawling.

### LIGHT

Redfish are concentrated near the bottom by sunlight, and this apparently occurs over the whole range of redfish depths from less than 50 to at least 200 fathoms and probably to 350 fathoms or more. It is possible that, with increase in depth of the redfish population, there is less variation in abundance at the bottom between night and day. However, our evidence of modestly successful night fishing, discussed previously, extends only to about 140 to 160 fathoms. Even at these depths it is only where redfish are extremely abundant that night tows are worth while. Captain Blackwood of the commercial trawler *Blue Spray* (personal communication, April, 1956) says that, when redfish are being followed on the "Fischlupe", they can readily be seen, during the daytime near the bottom, but farther off bottom than the cod, and that when they come up off the bottom at night they can be followed for a short time but they then disperse and cannot be followed as a group. If this type of pelagic vertical dispersion is the usual procedure, there is little hope of catching redfish commercially at night by mid-water trawls.

### FOOD

It is obvious from food studies at the St. John's station and from those by Boldovsky (1944) that the redfish is a pelagic feeder.

Steele (1957), from researches near Gaspé in the Gulf of St. Lawrence, reports that the diurnal variation in the distribution of redfish is correlated with diurnal changes in the distribution of the euphausiid *Meganctiphanes norvegica*. This euphausiid was the chief food of the redfish in this area.

It is probable that any current, nutritional or other factors, which bring together at redfish depths a large supply of euphausiid or other redfish food, will also favour the gathering and retention of redfish.

### SPAWNING CYCLE

In most fish whose eggs are fertilized outside the body of the female there are very definite pre-spawning and spawning concentrations, often with a post-

spawning feeding dispersal. In the viviparous redfish ripening of the testis of the male occurs a number of months earlier than that of the ovary of the female and is still earlier than the liberation of young by the female (Magnússon, 1955). In this fish, therefore, the massing of the sexes is likely to occur long before the actual liberation of the young and there is no necessity for male and female to be together at the time of the liberation of young. The redfish also is a pelagic feeder and thus its relations with the bottom and its availability to bottom trawls may well vary with the sexual cycle and with its related feeding cycle. Females grow larger and heavier than males and thus the size of the commercial catch depends a great deal on the availability of mature females on the bottom. In the redfish catches in the Newfoundland area mature females are very scarce from January to April and particularly in March when the availability of mature females on the bottom is at or near its lowest level. The commercial catch per unit effort is also low in this pre-spawning period, and at the shallower depths it is also low during the spawning period. Steele (1957) has found mature females scarce in the Gaspé area of the Gulf of St. Lawrence during the spawning period. At the same time, in June, we have found mature females very plentiful in deeper water on the Southwest Grand Bank. The greater catches per unit effort in the late summer and early autumn may be related, as Steele (1957) believes, to the females and males accumulating near the bottom preliminary to and during their period of copulatory activity.

#### DEPRESSIONS AND TEMPERATURES

From a statement by G. F. Kelly (personal letter, 1955), from our own conversations with Gloucester fishermen, and from the explorations of the *Investigator II* coastward of Banquereau, it is obvious that some of the redfish concentrations on the Nova Scotian Shelf are associated with depressions in this shelf. There are a number of these, the largest and deepest being to the east of Halifax. At least one large depression below the 200-fathom line exists in the continental shelf off the northeast coast of Newfoundland and, through the experimental fishing of the *Investigator II*, we have found these Newfoundland Shelf depressions to contain redfish concentrations.

Fig. 66B shows a section through one of the large depressions in the Nova Scotian Shelf off Halifax. By a consideration of this and other hydrographic sections in this area for various seasons of the year (McLellan *et al.*, 1953; Atlantic Oceanographic Group, 1953), and knowing that redfish are typically common between 2° and 6°C or more often 3° and 5°C, it is apparent that there is a band of favourable temperature at depths suited to redfish on the landward side of the depression. The closeness of the contour lines of the favourable temperature range landward in winter and spring should concentrate the redfish within a narrow range of depths. (This is one of the favourable features of a depression or of a steep slope in comparison with a flat area or an area with slight slope.) The low temperatures of the superficial layer in winter and spring are likely to restrict the vertical movement and produce some trapping effect, as in the cases of the deep-water cod off the east coast of Newfoundland (Templeman and

Fleming, 1956), and the cod in the Bear Island area (Lee, 1952). Seaward, the rising slope of the isotherms to levels not commonly associated with abundance of redfish restricts movement of redfish out of the depression. Thus, both landward and seaward, such a depression as is described here would tend to retain its redfish and concentrate them on its landward side where there is more water of favourable temperature.

It is possible in this depression off Halifax for the seaward slope of the banks to have temperatures between 8° and 11°C in the upper part of the typical redfish range, and for the depression to be filled, especially seaward, with 8° or 9°C water, while the lower temperatures favourable to redfish are restricted to the landward lip of the depression (McLellan *et al.*, 1953, fig. 6 for November, 1951). Experienced Gloucester redfish fishermen have told the author that in these depressions one of the favourite places for redfish fishing is around the upper rim; very excellent fishing also can often be found around elevations which rise in the depressions; these apparently act as leaders and redfish gather around them as they do around a slope.

Farther northward, where temperatures are lower, we have also found redfish in depressions off the northeast coast of Newfoundland, such as that shown in Fig. 63B. Here the water in the bottom of the depression may be over 2°C and thus be moderately favourable for redfish, while temperatures close to 1°C or lower, depending on the year and season, may cover the rim of the depression and thus theoretically help to prevent escape of redfish which may occasionally enter from the seaward continental slope or settle as fry. In contrast with the high and unfavourable temperatures farther south at the continental slope, off southern Nova Scotia and New England, seaward from the depressions in this northern area the temperatures at redfish depths on the continental slope range from 3°C to a little less than 3½°C. In this area redfish may be more common at the continental slope than in the slightly cooler water of the depressions.

#### BANK SLOPES AND RIDGES, AND BOTTOM TEMPERATURES

Where temperatures are not too high, redfish are concentrated on the seaward slopes of the continental shelf (Fig. 24, 25, 32-34). Here they are very available for fishing during the day-time and to a much lesser extent at night. Similar concentrations are found along the slopes of the deep channels. In such situations in the Denmark Strait (Fig. 62B) the redfish are often found to be concentrated on the bottom at the "cold wall" where the warmer, more superficial water of the Irminger Current meets the colder water of the East Greenland Current.

Saemundsson (1949), quoting Á. Fridriksson, says that in the Iceland area redfish, *S. marinus*, are most common where warm currents meet cold ones at depths of 100 to 200 metres (55 to 110 fath) at the edges of the different banks on the continental shelf, for instance on the Hali Bank off the northwest coast and on the Iceland-Faroe Ridge off the southeast coast.

Jakob Magnússon (personal communication, February, 1956) says that it is rather difficult to say definitely that redfish in the Icelandic area (Fig. 38) are most common where warm currents meet cold ones. It is true enough that Jónsmid, Anton Dohrn Bank and Hali, for example, are located where warm and cold currents meet. Doubtless some accumulation of redfish takes place in such areas, where also good catches have been made during recent years. On the other hand, good catches of redfish have also been made in recent years in areas such as southwest of Reykjanes, northwest of Snaefellsnes and in the Víkuráll area, which are all located within the warm-water area. It would perhaps be more appropriate to say that the northern boundary of the redfish distribution is where the warm and the cold water meet, and further that an accumulation of redfish may be expected along this front.

In the Newfoundland area, along the continental slope from Labrador to the southern tip of the eastern edge of the Grand Bank (Fig. 63, 64A), the overlying cold water of the Labrador Current apparently provides a limit to vertical movements of redfish and near the coast or on the slope of the banks a limit to horizontal movements. This should have the effect of concentrating the redfish population, especially if there is some tendency for the redfish to follow the dim light upward or a tendency on the part of the deep-water redfish to attempt to move toward shallower depths.

Farther south off the coast of southern Nova Scotia and New England, similar concentrating conditions, but in this case apparently due to too warm water lying above, may cause concentrations of the redfish living in deeper water (Fig. 67, 71).

A steep slope often causes the favourable temperature isotherms to be concentrated within a short space (Fig. 62B, East Greenland side) and doubtless the redfish are often concentrated correspondingly. On the other hand, off the northeast coast of Newfoundland where there is a moderately favourable temperature, 2 to 3°C, over a very wide area landward from the continental shelf, redfish catches may occur over much of the area, but, without the concentrating effect of the steeper slopes, these catches may not be large (Fig. 32 to 34, 63B).

#### CURRENTS AND STRANDINGS

Because most redfish are pelagic feeders and move upward from the bottom at night, the daylight bottom concentrations of redfish are actually strandings presumably caused either directly or indirectly by light.

Whether or not there are pelagic redfish schools of great extent over very deep water or only schools fringing the slopes and over areas of moderate depths, it is apparent that currents in the deep water inhabited by redfish can have a stranding effect where these currents set toward the slopes or deep ridges. Too little is known of the speed, direction and other characteristics of these movements of the deep water to allow very precise statements to be made.

Lundbeck (1955) says that the ridge 400 to 500 metres (220—270 fath) deep between Iceland and the Faroes was named the "Rose Garden" because

of the rich occurrence of redfish there. Tåning (1949) considers that the accumulations of redfish, revealed by the successful commercial redfish fishing on the Iceland-Faroe Ridge and on the shallower base of the Reykjanes Ridge south of Iceland, are caused by the prevailing currents stranding part of the great pelagic redfish populations which, on the basis of larval distribution, he believes to exist in the area.

The deep slope water entering the northern side of the deep channel of the Gulf of Maine (Bigelow, 1927) should take some redfish with it into the Gulf, and the water movement outward in the deep water on the south side of the channel should take some redfish out of the Gulf. However, at and above the depth of the entrance to the Eastern Channel (140 fath) there are apparently only small numbers of redfish in the immediate neighbourhood to be carried either in or out.

The Gulf of St. Lawrence with its deep Laurentian Channel to the southwest, the Esquiman Channel to the northeast and its deep channel entrance through Cabot Strait is essentially similar to the Gulf of Maine, except that the entrance and the inner channels are deeper. As indicated by MacGregor (1956), a slow inward flow of dense water occurs in the deep water of Cabot Strait including the 400 metre (220 fath) level. This inward flow may have an effect in transporting redfish into the Gulf of St. Lawrence and along the deep channels.

Along the continental shelf and slope east of Labrador, Newfoundland and the Grand Bank, the Labrador Current between 200 and 500 metres (110-270 fath) is generally weak inshore and may be strong on the edge of the continental slope. In general it follows the shape of the bottom contours, flowing parallel to them. There is obviously a weak tendency for the deeper more saline waters inhabited by redfish to underrun the coastal waters (Smith *et al.*, 1937). The southward-flowing Labrador Current at the edge of the continental shelf is evidently strong enough to carry with it any redfish swimming at random in the current and, if redfish are being thus carried, considerable stranding should occur on corners and other projections of banks and lesser stranding from the weaker tendency of the slope waters to move coastward beneath the less saline coastal waters. The evidence at present, however, of the strong localization of a group of redfish which are off Hamilton Inlet Bank parasitized by the copepod *Sphyrion lumpi*, is opposed to the idea that there is a mass transfer of redfish for long distances in the slope band of the Labrador Current.

In the Icelandic area it is evident that redfish are carried in the warm water of the Irminger Current as it passes northward and then eastward around the west coast of Iceland, passing above the cold Arctic water on the northwest and north coasts.

When redfish are carried in currents, these currents will cause their accumulation where the current passes over a bank, meets a slope or meets a wall of water too low or too high in temperature for the redfish to proceed onward.

## V-SHAPED AREAS

The explorations of the *Investigator II* and the subsequent commercial fishing have indicated that, in the virgin condition of the fishery, there were apparently considerably greater redfish catches in V-shaped deep-water areas at the ends of deep channels than in adjacent areas of comparable depth.

One of these V-shaped areas is Hermitage Bay on the south coast of Newfoundland where large redfish populations, discovered by the *Investigator II* in August, 1947, were subsequently fished by several commercial trawlers in 1947 and 1948. These vessels caught over 6 million pounds of redfish in this small fishing area of about 20 square miles where redfish were plentiful between about 120 and 160 fathoms. Hermitage Bay is at the end of a long deep-water channel connected with the deep water of the Laurentian Channel around the northern portion of St. Pierre Bank and around Burgeo Bank. The redfish were certainly more available in this bay than in many other locations in this long channel which were tested by experimental and commercial fishing. The sides of the channel of the large deep-water area reached too shallow depths and possessed too low temperatures for the redfish to escape vertically. The favourable feature seemed to be merely the gradual narrowing of the channel into the V-shaped Hermitage Bay with the resulting concentration of the redfish which over a period of time moved or were moved toward the bay.

A similar V-shaped area, where, when the fishery began in 1946, redfish were concentrated in great quantity in the deep water, lies to the west of Ramea Islands (Fig. 32-34). In this area large quantities of redfish were caught for several years before they were reduced in numbers.

In the Gulf of St. Lawrence a similar concentration of redfish existed, and even up to 1956, after several years' commercial fishing, such a concentration of redfish still existed at the V-shaped northern end of the deep-water channel along the west coast of Newfoundland (Fig. 24, 25, 32-34).

Another concentrating effect of V-shaped areas is the gradual shallowing which usually occurs toward the apex. Because, in the Newfoundland area, this shallowing reduces the depth of the warmer water layer below the intermediate cold layer, the vertical range of the redfish is thereby reduced, and the redfish should become progressively more concentrated near the bottom as the deeper warm water layer becomes gradually thinner toward the shallowing apex of the V.

There are also areas such as that north of Anticosti Island where the two sides of a channel lead downward in a V to the bottom of the channel. Where the bottom of the V is deep enough for large numbers of redfish to occur and yet is not deeper than the zone of maximum abundance of the redfish these fish are often abundant at the bottom of the V. This was the case in our exploratory fishing in the channel north of Anticosti.

## UNDERWATER PROJECTIONS

In contrast to the accumulations at the V-shaped ends of channels, some of the best redfish commercial and experimental fishing has been obtained at the

corners of banks such as the northeast and southeast corners of the Grand Bank (Fig. 24, 25, 32-34). At these places there is usually some evidence of a seaward projecting ridge and this is bound to be important in the "stranding" of redfish. Sometimes also, as at the southeast corner of the Grand Bank, opposing currents with highly different water temperatures meet and form a barrier at certain levels. Even slight underwater projections beyond those of the neighbouring shelf may be of importance in "stranding" redfish. On the eastern slope of the Grand Bank there are many short seaward-projecting ridges, and some of the best catches of the *Investigator II* have been obtained in transverse hauls extending across several of these ridges with their intervening valleys. Here there may be a combination of the concentrating effects of V-shaped valleys and of the temperature, shade, leading, food and other concentrating effects of slope areas. If the redfish also is attracted to irregular rocky areas, there is likely to be more of this type of bottom projecting from the angles of banks than elsewhere.

#### BOTTOM TYPE

Concentrations of many bottom-feeding fishes are usually related to certain bottom types. Many flatfishes and the haddock, for example, are more likely than not to be on relatively smooth bottom, whereas the large cod, when bottom-feeding, prefers a rougher bottom and the halibut is reported to be more common on gravelly bottom.

Bigelow and Schroeder (1953) say that the redfish of the Gulf of Maine, and those of outer Nova Scotian waters as well, are much more plentiful in the deeper basins and depressions and on soft bottom than they are on the grounds that are the chief centres of abundance for cod and haddock. These authors also say, however, that considerable numbers of redfish are sometimes taken on lines or trawls in 20 to 35 fathoms in the Massachusetts Bay region, especially on or near rocky bottom; also that, when they are on bottom, redfish are chiefly on rocky or hard grounds or on mud, but seldom, if ever, on sand.

G. F. Kelly (personal communication, October, 1955) says that in the Gulf of Maine the redfish are mainly concentrated around the rocky areas. Approximately 50% of the redfish catch in the Gulf of Maine is taken in the central part around Cashes Ledge. Most of this area consists of rocky ridges whose tops are at 70 to 90 fathoms, with rough-bottomed gullies, 100 to 120 fathoms in depth, between them. In neighbouring deeper waters of the Gulf of Maine, in depths of 130 to 160 fathoms with suitable temperatures for redfish but with muddy and softer bottoms, the redfish are very scarce.

The redfish is a pelagic feeder and there would seem to be no inherent reason why it should prefer one type of bottom more than another, unless food, temperature, light or chemical relations over this type of bottom are different from those over some other type of bottom in the neighbourhood.

In most of the Newfoundland area, where redfish are in deep water, they can certainly be caught in areas where the bottom is of a hard muddy type often interspersed with boulders. In many of the deep channels of the Gulf of St. Lawrence good redfish catches are obtained on a muddy bottom.

From our work in the Newfoundland area and from that of Hjort and Ruud (1938) in the Gulf of Maine, it was found that redfish are often abundant in the areas of hard or soft mud where the shrimp *Pandalus borealis* is common. It is true, however, that very large populations of redfish are usually to be found on or near slopes which are rocky and ridgy but which may often be near muddy bottom areas. Although in the Newfoundland area our research trawlers have found the usual *mentella* form on both smooth and rough bottom, it has been our experience that the less common *marinus* type, which has been most plentiful in about 90–120 fathoms southward and 140–160 fathoms northward, is generally on bottom so rough that nets are frequently lost. This may indicate an actual preference for rough bottom or possibly only a preference for a depth where the bottom happens to be rough and rocky.

Redfish belong to the rockfish family, which are often found in rocky areas. It is possible that the redfish does not prefer a rocky bottom but that the conditions necessary for the accumulation of redfish in numbers are commonly found on or near a slope. Some of these concentrating conditions are the considerable changes in temperature, salinity, depth, light and shade conditions in a short horizontal distance and the concentrating effect of currents. The same factors also will very likely concentrate the food of the redfish near the slopes. These slopes would usually be ridgy and rocky but often rising from a muddy gully or a flat area. Although little investigation into these matters has been carried out in the Northwest Atlantic, there may possibly be unfavourable oxygen or sulphuretted hydrogen conditions in some deep areas of muddy bottom, where these are partially shut off seaward by shallower thresholds. Such conditions occur in some Norwegian fjords (Hjort and Ruud, 1938) and, as a result, shrimp (*Pandalus borealis*) are found at higher levels along ledges or ridges above the bottom of the fjords.

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## ADDENDUM

Since the foregoing was prepared for publication important new published and other data on redfish distribution have become available.

### REDFISH LENGTH-FREQUENCIES

Within a very short period of time great progress has been made in publishing redfish length-frequencies. Kotthaus (1958) has provided an excellent series of length-frequencies from market measurements at Bremerhaven of samples of redfish obtained in many months of the year from all major redfish areas from West Greenland to the Barents Sea. The sexes were usually separated and sometimes the redfish were recorded as either *marinus* or *mentella* type. Similarly Magnússon (1958) gives length-frequencies of *marinus*- and *mentella*-type redfish obtained from research cruises in the Icelandic area and Hansen (1958) redfish length-frequencies obtained by shrimp trawl in West Greenland Fjords. Meyer (1958) records redfish length-frequencies for two subdivisions of the West Greenland area and Magnússon (1958a) redfish length-frequencies presumably from West Greenland but the area is actually not noted. Kelly and Clarke (1958) give redfish length-frequencies for ICNAF Subareas 3, 4 and 5. These are separated by sex and by month. Marti (1958) records length-frequencies from the Soviet operations in 1957 in ICNAF Subareas 2 and 3.

Unfortunately most of these frequencies do little more than record what the trawlers are catching. To be useful for more than gross study the frequency localities must be of restricted size, the redfish recorded by months, sexes and length. The type, whether *marinus* or *mentella*, should be noted at least for all sizes at which these types can be distinguished, and the frequencies separated by depth ranges. Sizes of the cod-end mesh should be noted, at least approximately. For all these length-frequencies at least two and usually three or more of these vital elements of knowledge are not available. These publications do, however, add considerably to published knowledge. They show that the redfish caught commercially in the central and southern ICNAF Subareas 3, 4 and 5 are much smaller than those taken for commercial purposes in all areas of the Greenland to Barents Sea area.

In the United States length-frequencies provided by Kelly out of about 13,000 redfish measured from Subareas 3, 4 and 5 only 2 female redfish of 51-52 cm from Subarea 3 were over 44 cm in length. These 2 specimens were probably *marinus*-type redfish but the frequencies indicate that large *marinus*-type redfish must be exceedingly scarce in the United States commercial catch from the area from the southern part of Subarea 3 to Subarea 5.

Similarly redfish from the West Greenland banks, although large compared with those from the southern part of ICNAF Subarea 3 and from Subareas 4 and 5 are considerably smaller than those from East Greenland (Kotthaus, 1958).

The redfish caught by Hansen in the West Greenland fjords were small. This was very likely partly because they were caught by shrimp trawl, but also the sample from a West Greenland fjord which was examined at the St. John's Station consisted entirely of the smaller *mentella* form. Kotthaus' length-frequencies from the Icelandic area were quite variable, some were very large on the average and some smaller. Some of these frequencies are possibly *mentella*, some *marinus* and some mixed.

Kotthaus' length-frequencies of *mentella*-type redfish from the deep water of the Iceland-Faroes Ridge are large, and resemble in size the redfish from West Greenland to Iceland many of which are doubtless of the *marinus* type. The deep-water *mentella* form, in Kotthaus' frequencies, has a much more restricted range of lengths and thus more sharply-peaked frequency curves. The length-frequencies of the *mentella*-type redfish from Kotthaus' Bear Island data are considerably smaller and even more sharply peaked than those from the Iceland-Faroes Ridge but are larger than those provided by Kelly from the southern half of the ICNAF area. They are approximately the same size, however, as the *mentella*-type redfish in the redfish length-frequency from 300-fathom depth in the Labrador region, ICNAF Subarea 2 (Fig. 53). Magnússon's (1958) length-frequency for the *mentella* form for all Icelandic areas is very sharply peaked at 43-45 cm, several centimetres below the peak of the grouped frequency for the *marinus* type and several centimetres larger than that from the 300-fathom depth off Labrador (Fig. 53).

#### ADDITIONAL REDFISH LANDINGS

Additional to the landings for 1956 recorded in the foregoing paper new information (ICNAF, 1958a) shows that the Soviet redfish landings from the ICNAF area, which began in 1956, amounted to 12,908 metric tons for that year, all caught in Subdivision 3M (Flemish Cap). Thus the total redfish landings from Subarea 3 of ICNAF in 1956 were 29,759 metric tons and the total landings from the ICNAF area 121,591 metric tons. The provisional data for redfish landings from the ICNAF area in 1957 (ICNAF, 1958, 1958a) are shown below by subarea and country:

Country	ICNAF Subarea					Total
	1	2	3	4	5	
Canada.....			3,848	17,214		21,062
Denmark (Greenland).....	55					55
France (St. P. & M.).....			273			273
Germany.....	14,874		2			14,876
Iceland.....	13,095					13,095
Norway.....	10					10
United Kingdom.....	103		33			136
United States.....			22,265	19,974	18,476	60,715
USSR.....			48,805			48,805
Total.....	28,137		75,226	37,188	18,476	159,027

The USSR landings were 17,232 metric tons from Subdivision 3L (northern Grand Bank) and 31,573 metric tons from Subdivision 3M (Flemish Cap). The total landings of 159,027 metric tons from the ICNAF area in 1957 were the peak landings from the area. The previous highest total landings were 135,382 metric tons landed in 1951.

The redfish landings for 1956 by European countries of the ICES group are now available (*Bulletin Statistique*, 1958). These are in metric tons:

By country		By Subarea	
Belgium.....	1,379	Barents Sea (I).....	11,769
England.....	10,835	Norwegian Sea (IIa).....	20,211
Germany.....	125,470	Spitsbergen and Bear Island (IIb).....	30,522
Greenland.....	60	North Sea (IV).....	43
Iceland.....	66,863	Iceland grounds (Va).....	92,899
Norway.....	4,730	Faroes grounds (Vb).....	5,050
Scotland.....	51	NW coast Scotland and N Ireland (VIa).....	9
USSR.....	41,383	Greenland (XIV-XV).....	75,772
		Newfoundland (XX).....	13,089
		Not accounted for by subarea.....	1,407
Total.....	250,771		250,771

These total landings represent a decline of about 43,000 metric tons below the 1955 landings. The German and Icelandic catches declined and the USSR catches increased. The landings from the Newfoundland area increased considerably and this was due almost entirely to USSR catches. Landings from the combined Spitsbergen-Bear Island-Barents Sea area were slightly greater in 1956 than in 1955, whereas landings from the Faroes grounds were only half and those from the Iceland and particularly from the Greenland area were considerably reduced—by 17,000 and 35,000 tons respectively.

#### NEW COMMERCIAL REDFISH AREA IN LABRADOR (ICNAF SUBDIVISION 2J)

In 1958 commercial fishing began in the Labrador Subarea (2) in an area off Hawke Harbour which was first fished by the *Investigator II* in September, 1951. The part of this new commercial fishing area fished by Newfoundland trawlers is about 80 to 120 nautical miles south of the area east of Hamilton Inlet Bank which has been fished successfully for redfish by the *Investigator II* usually in August or September, from about 140 fathoms down to about 200 fathoms in each year from 1950 to 1953 and down to 300 to 400 fathoms in 1954, 1956, 1957 and 1958 (Fig. 33, 34; Biol. Sta. St. John's, 1951; Templeman, 1955).

Redfish fishing in this new commercial area off Hawke Harbour has been very successful and has been participated in by Canadian, United States, and apparently by Icelandic and USSR trawlers. The only details available at the present time are for the Newfoundland fishery which occurred mainly between 150 and 180 fathoms (occasionally 125-200 fath) in late August, 1958, resulting

in a catch of several million pounds of redfish. The Newfoundland catch was all from ICNAF Subdivision 2J mainly between Lat. 52°45' and 53°00'N and Long. 52°10' and 52°40'W and with good catches also about 40 nautical miles north of this area. The northern part of the Newfoundland fishing area was on the southeastern part of the Hamilton Inlet Bank area and the more southern fishery which was much greater was on the fringes of Hawke Channel, a below-200-fathom indentation in the continental shelf leading toward Hawke Bay. This deep channel, while smaller, is an indentation of the type seen on the western part of the south coast of Newfoundland, in the Gulf of St. Lawrence and in the Gulf of Maine. In the general area of redfish abundance these deep channel indentations from the seaward edge of the continental shelf, when the depths and temperatures are suitable (and this Hawke Channel is deep enough for temperatures above 3°C to be present), always have quantities of redfish. Other favourable characteristics of the Hawke Channel and its fringes are the rapidly rising slopes of the channel which concentrate the fish. Redfish deeper than 200 fathoms in the Hawke Channel are in the lee of the southern slopes of Hamilton Inlet Bank and thus to some degree sheltered from directly southward flowing currents. Such a location is favourable to the accumulation of redfish which may pass over the shallower slope or through the channel inlet into the deep water of the channel.

#### DISTRIBUTION OF MALE AND FEMALE REDFISH

Kotthaus (1958) records that in East Greenland (Angmagssalik) the larger mature females were scarce while the males remained relatively constant in numbers in April, May and June. Off the East Greenland coast (Dohrn Bank) females declined from January 25% to February 14% to April 4% rising to 20% in May and 32% in June. Large mature females were even scarcer than these percentages. Off the northwest coast of Iceland females were very scarce (13%) in January and records from February to May are lacking. The mature females are, therefore, scarce on these fishing grounds before and during the spawning season and Kotthaus believes that the females but not the males migrate into the open ocean for spawning.

On the other hand on the southwest coast of Iceland females made up 71-92% of the catches from April to May and large mature females containing well developed embryos with iridescent eyes were especially numerous. Kotthaus thinks that this area is the main place where mature females from the Icelandic area assemble in spring before migrating to the open ocean for spawning. After May no further considerable catches were made in the southwestern Icelandic area before September and from September to November males and females were on the average approximately equal in number.

Again in the *mentella*-type redfish from the Bear Island region females were scarce, 30% and 15% in April but rose to 78-80% during the last week of July. In the western Barents Sea in May the proportion of females was 15 to 33%; these were mainly small females and large mature females were exceedingly scarce. On the Norwegian coast (Lofoten area) females, especially the large mature ones,

were plentiful (61-81%) in March and April declining to 43% in early May. The larger redfish were nearly all females. Apparently this is an area comparable, for redfish behaviour at spawning time, with the southwest coast of Iceland. Kotthaus says that in spring the mature females (which, from other writings of Kotthaus, are evidently mainly *marinus* type) assemble in the Lofoten area. They then move away and after the first half of May no redfish remain except a few males and some immature females so that fishing is not profitable again until the spent females return in June.

#### *Marinus* AND *Mentella* TYPES OF REDFISH

Travin (1957) records the landings by Soviet trawlers from the Barents Sea and neighbouring areas, and provides a figure showing the eastern boundaries of the occurrence of *marinus*- and *mentella*-type redfish in the Barents Sea.

Magnússon (1958) describes the distribution of the *marinus* and *mentella* forms obtained from research cruises made with a commercial otter trawler in Icelandic waters in July and September, 1956. At 225-265 metres (125-145 fath) on the west coast and at about 400 metres (220 fath) on the northwest coast of Iceland all redfish were *marinus*. At 430-460 metres (235-250 fath) on the northwest and at 450-500 metres (245-275 fath) on the southwest coasts of Iceland the catches were mainly *mentella* with a few *marinus*. On the west and on the southeast coasts of Iceland at 430 metres (235 fath) and 490-540 metres (270-295 fath) respectively the redfish were exclusively *mentella*.

The data now available on the relative percentages of *marinus*- and *mentella*-type redfish taken by Newfoundland trawlers during Aug. 25 to Sept. 25, 1958, in the new commercial redfish area in ICNAF Subdivision 2J are shown below:

Trawler	Fishing dates	Depth range	Redfish examined	Redfish landings			Redfish examined	
				Weight	<i>marinus</i>	<i>mentella</i>	<i>marinus</i>	<i>mentella</i>
				lb	%	%	no.	no.
		<i>fath</i>	<i>lb</i>					
A	Aug. 25-30	150-170	1,329	221,900	59.6	40.4	319	216
B	Aug. 26-31	160	3,343	252,600	18.2	81.8	339	1,528
C	Aug. 30-Sept. 2	150-155	443	110,000	0.8	99.2	3	375
D	Sept. 4-6	160	1,775	122,000	2.2	97.8	30	1,309
A	Sept. 6-11	150-200	2,214	220,500	1.7	98.3	28	1,657
B	Sept. 8-14	160-170	2,206	277,800	7.0	93.0	94	1,256
E	Sept. 22-23	150	1,773	68,700	2.5	97.5	29	1,126
A	Sept. 19-25	125-190	1,780	217,950	3.8	96.2	44	1,103
Total	Aug. 25-Sept. 25	125-200	14,863	1,491,450	10.9	89.1	886	8,570

In a total catch of 1,491,450 lb of redfish of which 1.0% was examined, the percentages of redfish types by number were *marinus* form 11%, *mentella* 89%. Since specimens of *marinus* were on the average more than twice as heavy as the average specimen of *mentella*, the *marinus* form was considerably more important by weight than by relative number.

Although most of the catches were between 150 and 170 fathoms only two late August catches showed a high percentage of *marinus* (60% and 18%) while the remaining 6 catches, almost entirely in September, had the percentages of *marinus* in the catch ranging between 1 and 7%.

Thus in the Labrador (ICNAF) Subarea 2J in depths from about 140 to 180 fathoms there are small numbers of *marinus*-type redfish and occasionally, as for trawler A on Aug. 25-30, a very high percentage of the catch may be *marinus*. The two skippers of trawlers A and C, when landing their Aug. 25-31 catches, were of the opinion that large (*marinus*-type) redfish were more common on rough bottom.

In a cruise of the research vessel *Marinus*, May 5-22, 1958, just east of Hermitage Bay at the northern entrance to Connaigre Bay at 112-116 fathoms 146 *marinus*-type redfish were found in an hour's towing during which 4,500 lb of redfish were caught. The remaining approximately 4,000 redfish were of the usual *mentella* type. Also on the east side of Connaigre Bay just below the edge of the 100-fathom contour and at the same time of the year one dragger caught 7,000 lb of redfish in a 2-hour drag and the captain said that over half of these (probably by weight) were of the *marinus* type. Another dragger also fishing in the same area reported over half its catch to be *marinus* type. These *marinus*-type fish which are typically golden yellow in colour in this area, are on the average considerably larger than the *mentella* type, and are readily recognized by the trawler skippers.

As in Labrador these *marinus*-type fish were on rough bottom. Deeper, on smooth bottom at about 140 fathoms in Hermitage Bay, *marinus*-type fish were very rare as usual. Planned fishing in these areas to collect samples of *marinus*-type fish was also carried out in Hermitage Bay and in this Connaigre Bay area in each of the months from July to October. In these months *marinus*-type redfish again became very scarce while the *mentella* type retained their usual abundance. Again in early November, in Hermitage Bay, *marinus*-type redfish became as abundant as they were in May.

Kotthaus (1958a) says that the *marinus* type is chiefly caught in spring and that this may be because of the heavy pre-spawning concentrations of the females in areas such as Lofoten and the southwest coast of Iceland.

While we have shown that *mentella*-type female redfish may be locally scarce before and during the spawning months and yet during the spawning period may sometimes be found greatly concentrated as in our deep-water catches on the southwest Grand Bank it is apparent that *marinus*-type female redfish may in certain localities be more abundant shortly before spawning.

Although definite evidence is lacking it is quite possible that *marinus* is a more migratory type of redfish than *mentella* and this may apply to its vertical as well as to its horizontal movements.

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