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Winter distribution of cod (*Gadus morhua* L.) off the southwest coast of Newfoundland (ICNAF Div. 4R) in relation to water temperature

by

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Abstract.

The present study shows how the distribution of cod at this time of year off the southwest coast of Newfoundland (ICNAF Division 4 R) may be connected to the water temperature.

In the depths investigated, the cod is distributed from 60 to 300 metres (temperatures from 0 to 6° C) with the greatest concentration between 120 and 250 metres (temperatures from 1 to 5° C). This paper reveals, however, the difference in distribution between the St. George's Bay cod and that of the adjacent sectors.

The size composition and proportion of immatures of this stock are also set out in this publication. In general, the length of males and females increases with depth, except in the Cape Ray - Cape Anguille sector where it decreases. The percentage of immatures varies inversely.

I. - Introduction.

The existence and boundaries of the cod stock off the west coast of Newfoundland (ICNAF Division 4 R) have been clearly defined by TEMPLEMAN (1962), even if migrations of a part of this stock towards the south coast of Newfoundland (3 Pn) were reported (TEMPLEMAN and FLEMING, 1962) as were relations with cod from the North Shore of the Gulf of St. Lawrence (4 S) by JEAN (1963).

For a long time, this cod stock has borne a considerable fishing effort which has increased still further in recent years : 91,146 metric tons caught in 1970 and 66,362 metric tons in 1971 (ICNAF, 1972). But it is important to note that the majority of these catches takes place in the southern part of this sector during the first four months of the year : 76.1 % in 1970 and 78.8 % in 1971.

These heavy concentrations of cod during winter and spring in

the southwest part of the Newfoundland coast which have been observed by TEMPLEMAN (1962) are indeed well-known to commercial fishermen.

In this study, we have tried to show to what degree the distribution and abundance of cod off the southwest coast of Newfoundland could vary, at this time of year, with the depth and temperature of the marine environment.

II. - Material and methods.

The material used for this research was collected during a cruise of the R/V CRYOS from January 22nd to February 2nd in the zone indicated in figure 1.

The trawling was carried out using a bottom trawl with the following specifications : 31.20 m headline mounted on 30.80 m ; 17.70 m groundrope with steel-bobbins ; 140 mm mesh in the wings and body and 50 mm in the codend. The trawl hauls were each of thirty minutes duration.

The total catch of cod was put in baskets and weighed in order to determine the yield per half-hour. When possible, each cod was individually sexed and measured (to the centimetre below). In the case of large catches (greater than 3 metric tons), we had to resort to a random sampling among the full baskets. This method, discussed by POLOHEIMO and DICKIE (1963), was used only seven times out of the 28 stations and we do not consider that it caused any significant inaccuracy in the measurments.

In all, 14,682 cod were sexed and measured for this study ; during the measuring, the reproductive stages of 13,370 cod were noted using the definitions given by POWLES (1958).

For the environmental study, the surface and near-bottom temperatures were taken at each trawling station (28 stations). In addition, 20 hydrographic stations were effected on 3 sections (fig. 1). At each of these stations, the temperature was taken at standard depths using YOSHINO reversing thermometers, protected and non-protected. All the readings (202) were taken twice and corrections made using the CULBERTSON method.

In studying the vertical distribution and the size composition of the cod, we considered three sectors : between 47°30' and 48°00' N, between 48°00' and 48°30' N and between 48°30' and 49°00' N (fig. 1). The data of each sampling have been included under the corresponding hydrographic section - Larkin Point, St. George's Bay, Three Rock Point - according to depth and bottom temperature at each of the hauls.

III. - Results.

1) Cod distribution in relation to water temperature.

a) Horizontal distribution.

In this season, the zone investigated by the R/V CRYOS was restricted by the extent of ice, thus limiting our study of the horizontal distribution of the cod. This ice condition, which was also a limiting factor in the northward progression of the commercial fishery, is shown in fig. 2, in relation to surface temperatures.

In the southern part, between Cape Ray and Cape Anguille, a narrow band of open water extended off shore to about 12 nautical miles and continued to the interior of St. George's Bay. To the east, we encountered a 4 to 5 okta open pack with a few large clearings in the ice. This pack regained the Newfoundland coast at the Port au Port Peninsula and extended to about 48°45' N. North of this latitude, we found a 6 okta close pack whose clearings froze, passing progressively to nilas and then to gray ice. It was impossible to advance north of 49°00' N which therefore bounded our study zone.

In general, the surface temperature diminished from south to north going from 0 and -1° C at Cape Ray and in the south of St. George's Bay to -1.6° C offshore Long Point. These low temperatures (from -1.6° C to less than -1.7° C) corresponded to the freezing point of sea-water.

The relationships between bottom temperatures and the horizontal distribution of the cod in the zone studied are shown in fig. 3. It can be seen that the cod is a little more abundant in the north than in the south and that the maximum concentrations are found between the isotherms 1° C and 5° C. In fact, the yields obtained in water colder than 1° C or warmer than 5° C are clearly less substantial. However the distribution is not equal throughout the zone : in the south (Cape Ray - Cape Anguille) the maximum abundance is between 4 and 5° C (2,000 to 3,000 kg per half-hour) as in the north (Port au Port Peninsula) with 3,000 to 6,700 kg/half-hour, while in the St. George's Bay the heavy concentrations are found between 1 and 2° C (2,000 to 5,000 kg/half-hour).

b) Vertical distribution.

The variations in horizontal distribution of the cod according to the bottom isotherms, as has been noted above, are connected to differences in the depth of the greatest concentrations. The study of the vertical distribution of the cod makes this phenomenon clear.

- Larkin Point section (fig. 4).

Between Cape Ray and Cape Anguille, the greatest concentrations

of cod were found between 220 and 240 metres, where the bottom temperature was close to 4 and 5° C. In fact, a tow effected at 220 m (temperature of 4.28° C) yielded 2,949 kg/half-hour and a catch of 2,641 kg/half-hour was made at 230 m (temperature of 4.84° C). The average yield (2,795 kg/half-hour) is indicated in fig. 4 in C.

Between 150 and 200 m (temperatures from 1 to 2° C inclusive), the cod was still abundant : 1,653 kg/half-hour at 182 m (temperature of 1.47° C), in B.

However, at lesser depths (60-100 m) where the bottom temperature was from 0 to 1° C inclusive, there was a distinct reduction in yield : 633 kg/half-hour at 75 m (temperature of 0.33° C), in A.

Similarly, at depths greater than 250 m, the cod was scarce : catches of 114 kg/half-hour at 290 m (temperature of 6.09° C), in D and of 47 kg/half-hour at 360 m (temperature of 5.70° C), in E.

- Saint-George's Bay section (fig. 5).

In St. George's Bay the cod was most plentiful between 1 and 2° C. Depths between 120 and 180 m where nevertheless the most favourable : average catches of 1,500 kg/half-hour for two hauls made at depths of 120 m (temperatures from 1.22° C to 2.24° C), in C ; of 2,543 kg/half-hour in two hauls at 145 m (temperatures between 1.42° C and 2.00° C), in D; and in particular a catch of 3,951 kg/half-hour at 165 m (1.44° C), in E. Despite favourable temperatures (from 1.57° C to 1.99° C), the catches made between 100 and 105 m were comparatively mediocre : 624 kg/half-hour, in B.

In shallower waters where the temperature is very low (0.5° C or less), the cod was scarce : 117 kg/half-hour for two tows effected between 60 and 70 m (temperatures from -0.34° C to -0.56° C), in A.

Deeper down, the school is seen to deplete as the temperature and depth increase : 519 kg/half-hour at 195 m (temperature of 2 - 3° C), in F, 323 kg/half-hour at 290 m (temperature of 6.28° C), in G, and finally 113 kg/half-hour at 340 m (temperature of 5.20° C), in H.

- Three Rock Point section (fig. 6).

Off the Port au Port Peninsula, the greatest concentrations of cod were found between 4 and 5° C, at 230 - 250 m. In fact, a catch of 6,700 kg/half-hour was made at 250 m (temperature close to 4.80° C) and another of 3,521 kg/half-hour at 230 m (temperature of 4.50° C). The average of these two hauls is indicated in E, in fig. 6.

Attention should also be drawn to concentrations of cod in shallower waters (180-185 m) where the temperature is between 2 and 3° C, since two tows, one at 180 m and the other at 185 m, yielded an average of 1,084 kg/half-hour (in D).

At temperatures close to or greater than 1.5° C at 150-155 m, the cod was still present : an average of 696 kg/half-hour in two tows (in C).

Between 90 and 110 m where the temperatures are less than 1.5° C, the cod is rare : 179 kg/half-hour at 110 m (temperature of 1.40° C) and 216 kg/half-hour at 90 m (temperature of 1.20° C), in A.

Similarly, at depths below the large concentrations indicated above, the cod was much less abuhdant : 273 kg/half-hour at 350 m (temperature of 5.55° C), in F.

2) Size composition of the cod in relation to its bathymetric distribution.

By setting up length-frequency curves of males and females and also by showing the proportion of immatures caught at each bathymetric strata in the three sectors under consideration, we have tried to give a general outline of the size distribution according to depth. We observe that there is a marked contrast between the Larkin Point sector on one hand and the St. George's Bay and Port au Port Peninsula sectors on the other.

a) Larkin Point section (fig. 4).

In this sector, the modal size of males and females decreases slightly as the depth increases (from 51-53 cm at 70 m to 45-47 cm at 225 m). This reduction of size involves an increase in the percentage of immatures (I %) which goes from an average of 41 % at 75 m to 60 % at 220 m.

This involves therefore a greater and greater proportion of cod smaller than commercial size (38 cm).

However, the insufficient number of samples at the deeper stations (220 m - 360 m) - catches of 114 and 47 kg/half-hour - prevents us from ascertaining that this phenomenon is confirmed throughout the vertical distribution of the cod.

b) St. George's Bay section (fig. 5).

On the other hand, in the St. George's Bay, the modal length increases with depth (from 18-20 cm at 60 m to 60-62 cm at 350 m). This therefore entails a progressive decrease in the percentage of immatures i.e. from 85 % at 60 m to 31 % at 350 m.

In shallow waters (60-120 m), a large proportion of the cod do not reach commercial size, although this phenomenon is not evident in the weight data (see W and w). From 150 m and down, the cod of commercial size progressively disappear.

c) Three Rock Point section (fig. 6).

The same phenomenon found in St. George's Bay reoccurs in the Port au Port Peninsula sector : modal sizes of males and females increasing from 39-41 cm at 90 m to 57-59 cm at 350 m) and the percentage of immatures decreasing with depth (72 % at 90 m to 14 % at 350 m).

A similar rarity of non-commercial cod appears at 150 m and deeper.

It is nevertheless worth noting that in this sector, the average percentage of immatures is greater than in St. George's Bay at corresponding depths :

- At 100 m, 76 % as compared to 64 %
- At 150 m, 71 % as compared to 46 %
- At 200 m, 55 % as compared to 26 %
- At 250-300 m, 35 % as compared to 31 %

IV. - Discussion and conclusions.

The general distribution of cod off the Atlantic coast of Canada (JEAN, 1964) shows that in winter this fish is found at depths of 130-180 m (temperatures from 1 to 3° C) in the west of the Gulf of St. Lawrence and at 95-135 m (temperatures from 2 to 4° C) on the Nova-Scotia banks.

Commercial fishermen are familiar with the large winter concentrations of cod off the southwest coast of Newfoundland. The latter have been indicated by Mc CRACKEN and CLARK (1958) who, while observing the French fishery in the gulf of St. Lawrence in 1958, noted the presence of cod between 80 and 300 m, with the heaviest concentration at 200 m. TEMPLEMAN (1962) noted more precisely in his study of the western Newfoundland stock that large concentrations of cod took place principally in winter and spring, at depths between 110 and 240 m.

The present study defines more exactly this winter distribution of cod both by showing the local variations from Cape Ray to the Port au Port Peninsula and also by connecting this distribution to bottom temperatures. In the region as a whole, the outer boundaries of cod distribution lie between 60 and 350 m (temperatures from 0 to 6° C) while the boundaries of its maximum distribution are 120 and 250 m ; i.e. in waters whose temperatures range from 1 to 5° C.

We must, however, connect the results obtained for the Cape Ray - Cape Anguille sector with those of the Port au Port Peninsula sector :

- concentration of cod between 150-250 m at water temperatures ranging from 1 to 5° C, with greater abundance at 220-240 m (temperatures between 4.28° C and 4.80° C),

- reduced frequency of cod at depths of 75-150 m (temperatures of 0 - 1° C),
- scarcity of the cod between 250 and 350 m (temperatures of 5 and 6° C).

The unique situation in St. George's Bay must be brought to attention ; the cod is, in fact, just as abundant in this location, but seems to prefer somewhat shallower waters where the temperatures are lower :

- concentrations between 120 and 180 m at temperatures of 1 to 2° C with greater abundance between 140-165 m (temperatures of 1.42° C and 1.44° C). In still shallower waters, where the temperature is nevertheless between 1 and 2° C (1.57° C), the cod is less abundant.
- further scarcity of cod between 60 and 100 m where temperatures range from -0.8° C to 1° C.
- beneath 180 m, cod is still present as far as 200 m (temperatures between 2 and 3° C) but becomes more and more scarce from 200 m to 350 m (temperatures from 3 to 5° C).

As for the size composition of this stock, it is important to note the opposition between the cod in the southern Cape Ray - Cape Anguille sector and that of the northern region (St. George's Bay and Port au Port Peninsula) :

- In the south, the larger fish are found in shallow waters (80 m) and the size of males and females decreases with depth.
- In the north, the size increases with depth, the small cod being confined to colder shallow waters (60-100 m).

There is evidently a relationship between this phenomenon and the percentage of immatures (I %) which increases with depth in the south of this region while it diminishes progressively in the north. The increase in size and, therefore, in the number of mature fish, with depth can be explained by the fact that the cod seeks higher temperatures more favourable to the maturation of its gonads. It is difficult to explain the opposite trend which, according to our data, seems to occur in the south of the zone. This implies, in any event, that some factor, other than the maturation of the gonads, plays a role in the distribution of mature cod in relation to water temperature.

It is also worth noting that, at all depths investigated, the number of immature females is always greater than that of the males, which can be explained by the larger size of the females at their first sexual maturity.

The examination of the gonads (MINET, 1973) showed that the majority of the mature cod (males and females combined) in this region, at this time of year, were ripening (stage 2 of POWLES, 1958) : 86.8 %, while a minority were ripe (stage 3) : 7.9 %, and a few large fish, which had spawned the previous year, were recovering (stage 6) : 5.3 %. These observations are to be compared with the data of TEMPLEMAN and FLEMING (1962) for the cod of the south coast of Newfoundland (Isle aux Morts) in the winter of 1952.

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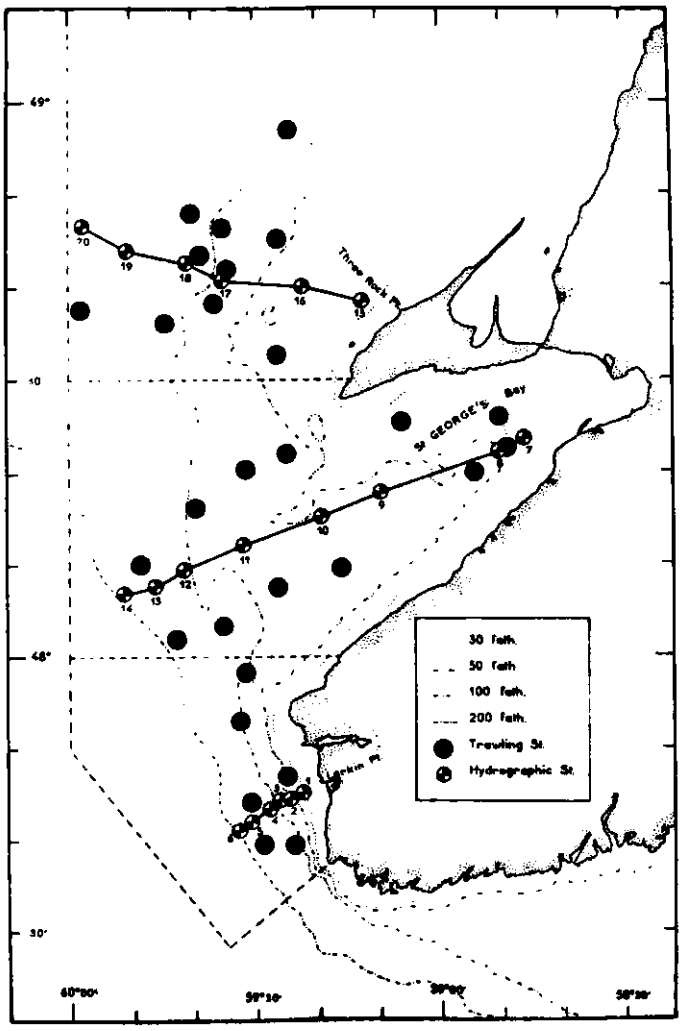

Fig. 1. Positions of trawling and hydrographic stations occupied by the R/V *Cryos*.

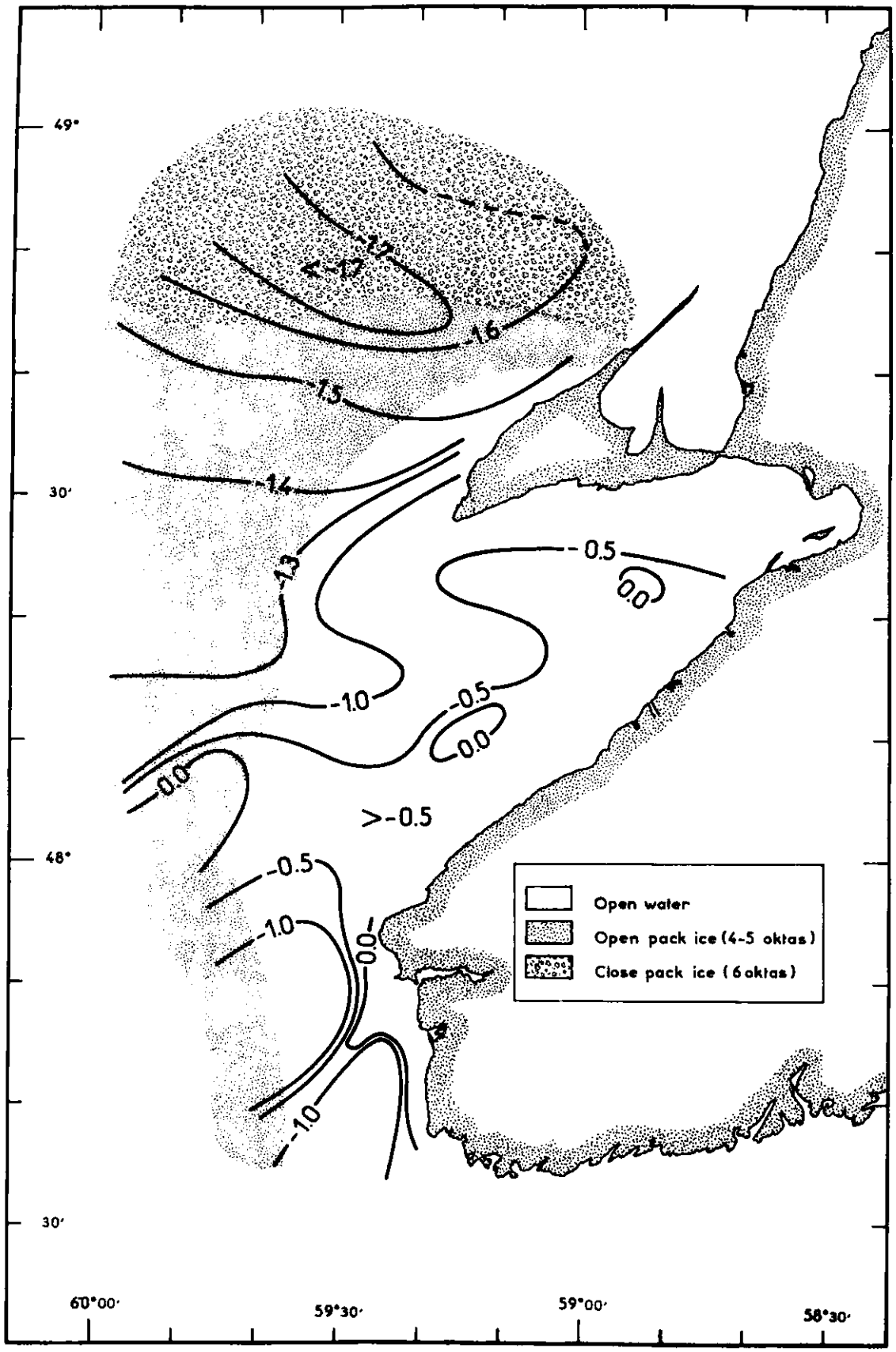

Fig. 2. Ice conditions (23 January-2 February) in relation to surface temperatures.

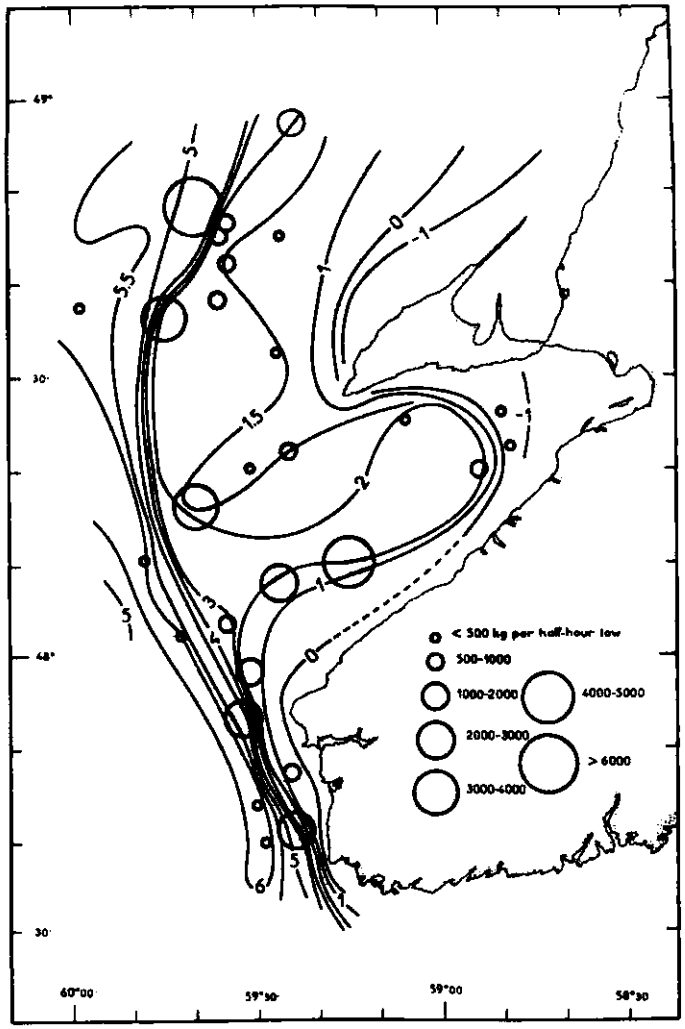

Fig. 3. Horizontal distribution of cod (kg/half-hour) in relation to near-bottom temperatures.

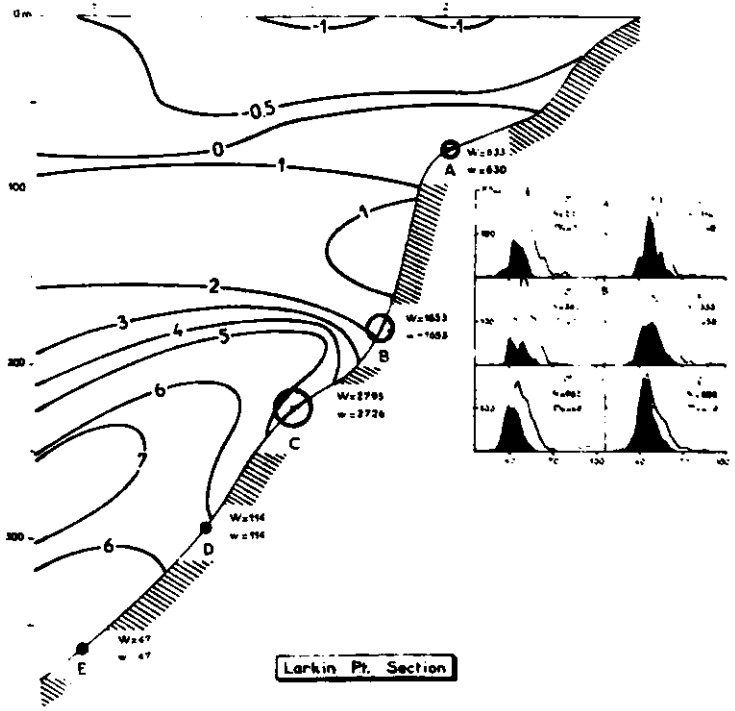

Fig. 4. Vertical distribution of cod in the Cape Ray-Cape Anguille sector in relation to water temperature

W = total catch of cod (kg/half-hour),
w = catch of commercial-size cod (Lt > 38 cm) in kg/half-hour,
N = number of cod measured (total length to the cm below),
I % = percentage of immature cod,
Solid black = size distribution of immature cod.

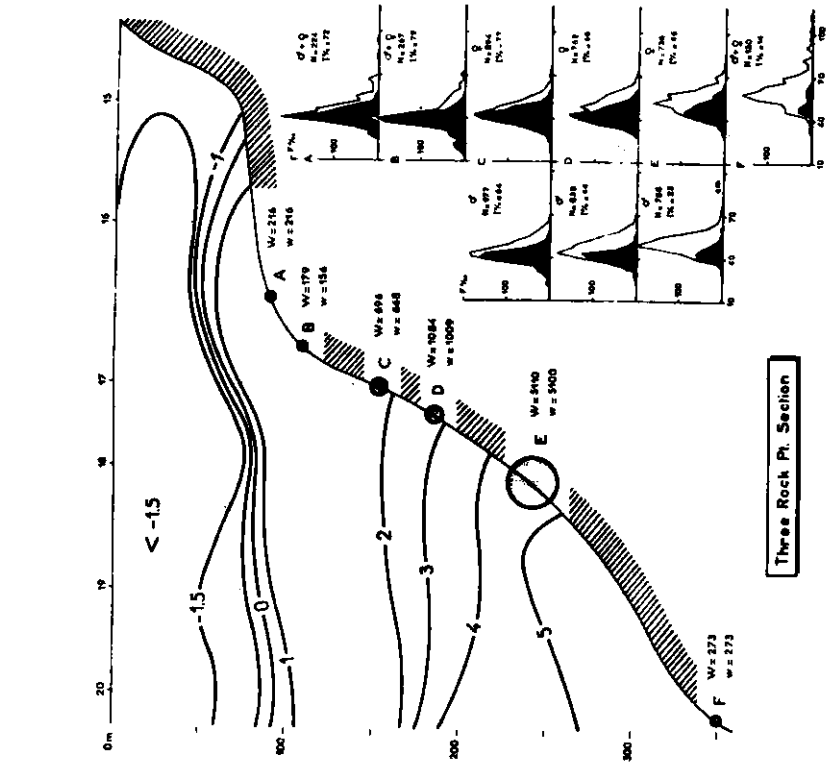

Fig. 6. Vertical distribution of cod in the Port au Port Peninsula sector in relation to water temperature.

For symbols, see Fig. 4.

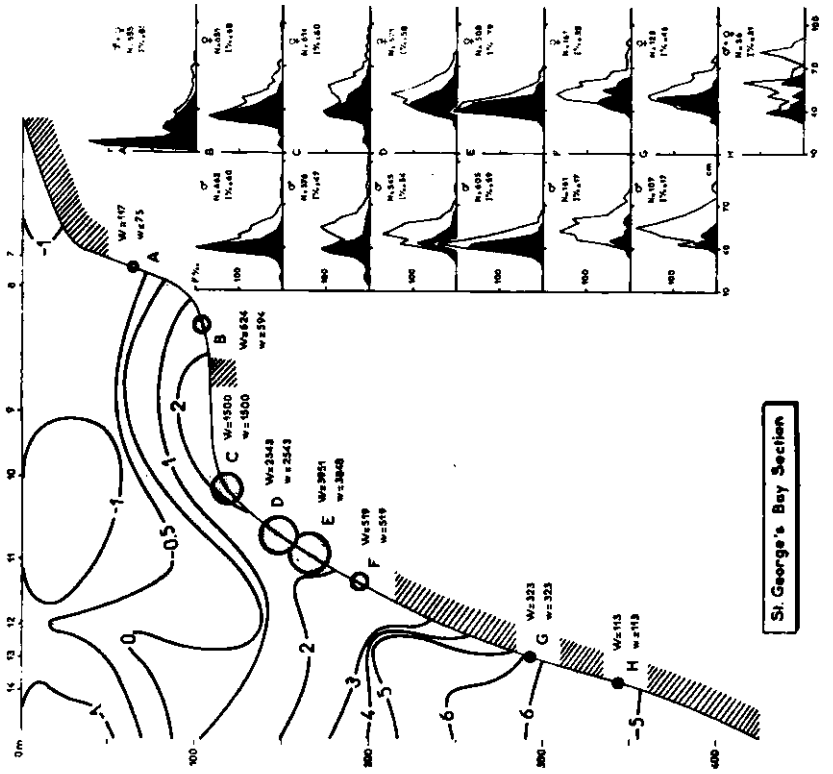

Fig. 5. Vertical distribution of cod in the St. George's Bay sector in relation to water temperature.

For symbols, see Fig. 4.