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Migrations of cod between the northern Gulf of St. Lawrence and the south-western banks of Newfoundland

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Abstract.

This paper deals with migrations that cod undergoes between the northern Gulf of St. Lawrence (ICNAF Div. 4 R) and the south-western banks of Newfoundland (ICNAF Div. 3 Pns). The results are provided by two tagging experiments carried out during the winters of 1975 and 1976 in the northeast part of the Gulf of St. Lawrence and on the Rose Blanche and Burgeo banks. The 40 returns recorded show that during the winter period (January to April) the cod of the northern Gulf stock migrates towards the south alongside the west coast of Newfoundland, goes out of the Gulf through the Cabot Strait and reaches the Rose Blanche bank and even the Burgeo bank. During the spring-summer period (May to August) an opposite movement is observed which drives the cod tagged on these south-western banks of Newfoundland to come back into the Gulf through the Cabot Strait and to migrate as far north as the Strait of Belle Isle. Simultaneously with the taggings, the thermic environment, the sexual state and the feeding activity of cod were observed during the winter period in the two areas studied. The influence of these three factors on the migratory phenomena is discussed. It is shown that, if the sudden drop of water temperatures can stimulate the winter migration, this factor is not sufficient however to explain a movement of such importance. The sexual factor does not have any influence during the winter period but it is very important during the spring-summer migration. The feeding factor has, on the contrary, much more influence during the winter migration since cod is still in intense period of feeding activity and feeds mainly on fish and specially on capelin.

I - Introduction.

The movements of cod towards the interior and the exterior of the Gulf of St. Lawrence are well known. Some of them occur through the Strait of Belle Isle but the principal take place through the Cabot Strait.

These migrations through the Cabot Strait are known for a long time by the European fishermen including French since during the winter period they start their fishing off the west coast of Newfoundland (Port au Port Peninsula and St. George's Bay) or south of the Magdalen Shallows (Magdalen Islands and Bird Rock) and gradually go south as the fishing season progresses on both sides of the Laurentian Channel, respectively on the south-western banks of Newfoundland or on the Cape Breton Shelf (Mc CRACKEN, 1958 ; Mc CRACKEN and CLARK, 1958 ; MINET, 1973-b).

Also, the Canadian fishermen from the Gulf of St. Lawrence know that cod comes back alongside their coasts at the end of spring and during summer. This is the case in St. George's Bay with the "herring run" of cod as mentioned by TEMPLEMAN and FLEMING (1962) or on the Gaspé Coast and the lowest North Shore (JEAN, 1960 ; MOUSSETTE, Mc CRACKEN and MARCOTTE, 1964).

Many scientific works have dealt with the subject. They all show that in a general way except a few minor cases which represent a very small percentage, two great migratory patterns can be distinguished, one on the west side and the other on the east side of the Laurentian Channel.

On the west side of the Channel, between the Quebec coast (mainly Gaspé Peninsula) and the Cape Breton Shelf, these migrations were mostly pointed out through the works of TREMBLAY (1944), MC KENZIE (1956), Mc CRACKEN (1957, 1959), JEAN (1963), MARTIN AND JEAN (1964) and KOHLER (1975) and by the numerous data held by the Grande Rivière Biological Station after the taggings carried out by MARCOTTE.

We already know the importance that the knowledge of those migrations (HALLIDAY, 1974) had on the cod fishery management in divisions 4 T - 4 Vn by ICNAF.

On the east side of the Channel, the migrations occurring between the northern Gulf and the south-western banks of Newfoundland (Rose Blanche and Burgeo) were revealed early by the studies of THOMPSON (1943) and mainly by those of TEMPLEMAN and FLEMING (1962) and TEMPLEMAN (1974), a part of which deals with this region.

Here again, the knowledge of those phenomena was of great importance to allow the division of the cod stocks in this region of Newfoundland (TEMPLEMAN, 1962) and to know out of which stock the commercial catches are made.

This paper is therefore a contribution to the study of those migrations occurring on the east side of the Laurentian and Esquiman Channels, between the northern part of the Gulf of St. Lawrence (ICNAF Div. 4 R) and the south-western banks of Newfoundland (ICNAF Div. 3 Pns). We try however to better understand those migrations by pointing out the main factors that can induce and/or accompany them such as the environment or the biological cycle of cod.

II - Material and methods.

1. Tagging experiments.

In order to complete the results given by the authors already mentioned, two tagging experiments were carried out during the winters of 1975 and 1976.

In 1975, the tagging operations were made on board the R/V Cryos, from 19 January to 1st February, in the Gulf of St. Lawrence from Pointe Riche to the Port au Port Peninsula, alongside the west coast of Newfoundland (4 R). From 15 to 23 February of the same year, they were carried on the Rose Blanche and Burgeo banks (3 Pns). A total of 870 cods were tagged (465 in 4 R and 405 in 3 P).

To complete this preliminary experiment, more taggings were made in the same regions during the winter of 1976, on board the research vessel. 1500 cods were tagged in the Gulf of St. Lawrence between Pointe Riche and Bonne Bay, from 10 to 17 January, using yellow Petersen disks of 13 mm diameter. Then 1500 more cods were tagged, from 2 to 8 March, using yellow Garlin tags of 33 mm long, principally on the Rose Blanche bank and also on Burgeo bank. So, the 1976 tagging operations were separated by a greater interval of time, two months.

Therefore, 3870 cods were tagged during these two experiments (1965 in 4 R and 1905 in 3 Pns) during the winter period, from January to March 1975-1976.

The technics of catching, handling and tagging were the same in 1976 than those described in a former paper (MINET, 1975). As well, the criteria for judging the condition of fish when tagged and released were those used in 1975.

For these two experiments, the fish used in tagging was caught during bottom-trawl hauls of 30 minutes duration at depths ranging from 100 to 250 meters.

The size composition of the cod tagged in 1975 and 1976 is shown in figure 1. In the Gulf of St. Lawrence, their sizes are roughly the same for the two experiments. The distributions range around the same mode (58 cm Lt) with however a few larger specimens tagged in 1975 (from 100 to 112 cm Lt). On the south-western banks of Newfoundland, the size of the cod tagged is slightly smaller in 1976 than in the previous year. In general, all the cods tagged were larger than 35 cm Lt and most of them were between 50 and 70 cm of total length.

2. Hydrography.

Simultaneously with the tagging operations of winter 1975, 25 hydrographic stations, distributed in 5 sections, were occupied from 27 January to 23 February, at different locations of divisions 4 R and 3 Pns (fig. 2).

During each station, a profile of the water temperatures was recorded from the surface to the bottom using a BT (sections 1, 2 and 4) or an XBT (sections 3 and 5).

3. Sexual maturity.

During the tagging cruises of 1975 and 1976, the samples of cod caught during the trawling stations were studied in divisions 4 R and 3 Pns. The fish sampled was measured (total length to the centimeter below) after the determination of sex and examination of the sexual state using the six reproductive stages defined by POWLES (1958).

So, in the Gulf of St. Lawrence, a sample of 5448 specimens (2782 males and 2666 females) was examined in January 1975 after the catches made during 31 stations distributed from Pointe Riche to Cape Ray. In January 1976, 5230 specimens (2682 males and 2548 females) sampled during the 33 stations occupied in the same area were also examined.

On the south-western banks of Newfoundland, in February 1975, a sample of 1492 fishes (753 males and 739 females) was examined after the 24 trawling stations carried out in the Rose Blanche and Burgeo banks. In March 1976, 4666 specimens (2149 males and 2517 females) were also examined after the 19 stations occupied on these two banks.

4. Feeding.

The material necessary to this study was collected during the winter 1975 tagging cruise on a random sample of 333 male and female fish caught during 26 trawling stations, from 50 to 250 meters of depth, in the divisions 4 R and 3 P;

In the division 4 R, from 25 January to 3 February, 235 cod stomachs were sampled at 18 stations occupied from 50° latitude north to Cape Ray, on fish measuring from 23 to 115 cm of total length. On the other hand, 98 stomachs were taken between 12 and 17 February on a sample of cod measuring from 26 to 78 cm caught at 5 stations on the Rose Blanche bank and at 3 stations on the Burgeo bank.

After the sampling on board, the stomachs were quickly frozen at -40° C then stored at -26° C. For each stomach, the information on sex, size and sexual state of the cod were recorded as well as all the details concerning the sampling station. In the laboratory, the stomachs

were defrost and dissected. Their stage of repletion was estimated using the following criteria : 0 for empty stomachs, 1 for quarter-full stomachs, 2 for half-full stomachs, 3 for three-quarter full stomachs and 4 for completely full stomachs. Then, the organisms found in each stomach were separated by species or by systematic group when they were too far digested to be distinguished.

Each species or group was weighted to the hundredth of gram and this de-frozen weight was converted in fresh weight using the ratio between the total weight of the frozen stomach and the total weight of the de-frozen stomach in order to take into account the loss of water due to the freezing process.

For this study, the fresh weight of each food group found in a stomach was converted in percentage of the total fresh weight of food contained in this stomach, in order to allow the comparison of the results.

III - Results.

A - Migrations.

1. Recaptures.

The results on the migrations of cod in this region are based on 40 recaptures of tagged fish as shown in Table 1.

We notice that after the 1975 experiment, no return was recorded during the September to December period in both areas. All the recaptures were made during the winter period (January to April) of 1975 and 1976 or during the period from May to August, that is to say during the periods when the fishing effort is the most important in this region.

On those 40 recorded recaptures, 22 come from Canadian fishermen (14 caught by trawl and 8 by handline) and 18 from European fishermen (16 from French trawlers and 2 from Spanish trawlers).

In the Gulf of St. Lawrence, the cods recaptured during the winter months following the taggings have covered relatively large distances. The ones recaptured after the 1975 experiment have covered distances ranging from 80 to 210 nautical miles during periods from 20 to 79 days after the tagging which represents an average virtual speed of 3.3 miles per day. Also, those recaptured after the 1976 experiment have covered from 35 to 240 miles during periods from 17 to 70 days, i.e. an average migration speed of 3.5 miles per day.

As for those recaptured during the winter months of 1976, from 363 to 392 days after their tagging, their virtual journeys range between 110 and 180 miles. In fact, it could be supposed that they have accomplished their migrations twice between 4 R and 3 P.

As for the fish recaptured from May to August 1975, i.e. 97 to 229 days after their release, the real distances covered cannot be known precisely since they can have made the journey back and forth.

On the south-western banks of Newfoundland, the cods recaptured during the winter months following the taggings have generally covered smaller distances at lower speeds. Two of them, recaptured after the 1975 experiment had covered 16 and 20 miles in respectively 13 and 60 days. On the other hand, one of the three fishes recaptured on the Sable Island bank would have covered 250 miles in 20 days, i.e. a speed of 12.5 miles per day.

The fishes recaptured after the 1976 experiment had covered from 3 to 60 miles in 1 to 38 days after tagging, i.e. an average speed of 2.1 miles per day.

As for the fishes recaptured during the period from May to August 1975, they apparently had covered from 75 to 200 miles at speeds ranging from 0.9 and 2.6 miles per day.

The cod recaptured are not numerous enough to know if their size is representative of the whole of the tagged fish. However, no cod smaller than 50 cm have been recaptured since the sizes of the returns are ranging from 50 to 95 cm of total length. Also, the size given by the finders are too often inaccurate to take in consideration the differences of size noticed over a year.

The poor recaptures rate can be explained by the small number of cod tagged during the 1975 experiment and by the fact that, when writing this paper, the experiment of 1976 is over only since two months. However, the whole of the returns recorded shows that, except few cases, the global movements are very similar. This tends to prove that the results are representative enough of the general scheme of the cod migrations in this region.

2. Description of the migration patterns.

The results provided by the returns recorded on one hand during the winter months following the taggings and on the other hand after one year during this winter period, show a migration completely opposite to the one observed during the May to August period. The results obtained during the two periods are therefore given separately first for the Gulf of St. Lawrence then for the south-western banks of Newfoundland.

a - Winter period (January-April 1975-1976).

- Gulf of St. Lawrence (4 R).

After the 1975 experiment, the six returns obtained during this period in 1975 and the three ones recorded in 1976, show the same phenomenon and are therefore grouped in figure 3. The movement towards the south made by the cod at this period can be clearly noticed. The northern Gulf stock migrates to the south towards the Cabot Strait and spreads as far as the Rose Blanche bank (3 Pn) and even off Burgeo and Ramea Islands (3 Ps). This migration concerns not only the cod found on the western shelf of Newfoundland but also the cod found on the western slope of the Esquiman Channel. On the other hand, out of these 9 returns only one has crossed the Laurentian Channel since it was caught in winter 1976, south of St. Paul's Island on the Cape Breton Shelf (4 Vn).

The results obtained after the 1976 experiment confirm the migratory pattern towards the south of this northern Gulf stock (fig. 4) although most of the tagged fish were recaptured by the French trawlers - fishing in the Gulf this year, mainly off St. George's Bay - before having accomplished their complete migration through the Cabot Strait.

- South-western banks of Newfoundland (3 Pns).

Two out of the 3 recaptures made in the 1975 winter period (fig. 5) show migrations of minor importance towards the northeast (south coast of Newfoundland) or towards the southeast (from Rose Blanche bank to Burgeo bank). This can be interpreted as an extension of the migration observed from the northern Gulf of St. Lawrence towards the Cabot Strait and Rose Blanche bank. It must be noted here again that one of the 3 cods has crossed the Laurentian Channel since it was recaptured on the southwest part of the Sable Island bank.

The 12 recaptures recorded during the 1976 winter period just after the second tagging experiment (fig. 6) confirm this general pattern of a migration towards the east and towards the south coast of Newfoundland. Indeed, we note once again a movement from Rose Blanche bank to Burgeo bank (3 recaptures). However, the results are not as clear as they should be since many cods were recaptured shortly after their tagging at places very close to the release position.

b - Spring-summer period (May-August 1975).

- Gulf of St. Lawrence (4 R).

Opposite to what happens in winter we note in the Gulf during the period from May to August, migrations occurring towards the north, alongside the west coast of Newfoundland (fig. 7). Indeed, 4 of the five recaptures show this phenomenon and specially one of them caught in the

Strait of Belle Isle. Obviously, this is only a virtual movement as those cods have certainly migrated first towards the south in winter to the Cabot Strait and even on the south-western banks of Newfoundland and then in the opposite direction towards the north of the Gulf as far as the Strait of Belle Isle.

Here again, a specimen which has crossed the Laurentian Channel is recorded since it was tagged off Bay of Islands and recaptured on the Bradelle bank (4 T) at the latitude of Tracadie (N.B.). It is again a virtual movement as this specimen could have first crossed the Channel during its migration towards the south in the previous winter and then migrated to the place of recapture following the mechanism of migration described for the region located west of the Channel.

- South-western banks of Newfoundland (3 Pns).

Opposite to the migration patterns observed in winter on these banks, we note that two cods tagged on the Rose Blanche bank and on the Burgeo bank were recaptured during the period from May to August 1975 in the southeast part of the Gulf of St. Lawrence as north as Bay of Islands (fig. 8).

We also notice that a cod tagged on the Burgeo bank was recaptured in the Fortune Bay.

B - Main factors intervening in the migrations.

The observations made during the tagging cruises permitted the study of three of the main factors intervening in the migrations occurring in the Gulf of St. Lawrence and on the south-western banks of Newfoundland, during the winter period. They are thermic environment, sexual state and feeding activity of cod.

1. Thermic environment.

In the Gulf of St. Lawrence (fig. 9) we observed in the three sections the presence of a cold water lobe when temperatures are less than -1° C. This lobe is located on the surface above the western shelf of Newfoundland at distances ranging from 40 miles (section I) to 25 miles (section II) and then 20 miles (section III) offshore. It results from the cold influence of one of the arms of the Labrador Current entering through the Strait of Belle Isle and becoming stronger at the beginning of the winter period.

It induces a cold water lobe of temperatures lower than 0° C which spreads deeper and more easterly towards the Newfoundland coast. Indeed, these waters of temperature inferior to 0° C penetrate

from the surface to the depths of 100 m (off St. Paul's Bay - section I), and of 130 m (off Cape St. Gregory -section II, and off Port au Port Peninsula - section III). However, they only reach the bottom (at depth from 0 to 70 m) off the Port au Port Peninsula. They spread towards the east at 20 miles from the coast (section I and II) to the coast itself (section III).

Underneath this cold lobe, we observed very compressed isotherms giving a very important thermic gradient. The maximum temperatures on the bottom of the shelf (sections I and II) are around 3 and 4° C at about 200 m depth but they are warmer on the bottom of the Esquiman Channel since off the Port au Port Peninsula, they reach more than 6° C between 200 and 300 m depth.

On the south-western banks of Newfoundland, cold waters with temperatures less than 0° C were also present as a layer which spread from the surface to depths of about 150 m (fig. 10).

In the Rose Blanche and Burgeo banks area (section IV), very compressed isotherms are found under this cold layer ; they are practically horizontal and reach 4 to 5° C on the bottom between 200 and 250 m.

On the northern part of the St. Pierre bank (section V), the cold water layer with temperatures inferior to -1° C totally covers the bottom down to the depth of 100 m. The superior part of the western slope of this bank is covered with water of temperatures less than 0° C from 100 to 150 m depth.

Underneath, a very strong thermic gradient is again found as the horizontal isotherms range from 0° C to more than 6° C between 150 and 250 m depth.

2. Sexual state.

The observation of the sexual state of cod during the winters of 1975 and 1976 in both regions shows that the large majority of fish are either immature or, among mature specimens, mainly ripening with some cases found ripe or recovering.

In the Gulf of St. Lawrence (fig. 11), if we take only in consideration the mature fish (stages II to VI), we note that for the two winters studied the great majority of cod is in a ripening period - stage II (84 % in 1975 and 88 % in 1976, both sexes combined). However, some specimens are found ripe - stage III (8 % in 1975 and 1976) or recovering - stage VI (8 % in 1975 and 4 % in 1976). No fish was observed spawning (stage IV) or spent (stage V) neither in 1975 nor in 1976.

This results correspond well enough with those we already gave (MINET, 1973-b) after examination of the sexual state of 6500 cods in div. 4 R during the winter of 1973, from 22 January to 2 February. Among the mature fish and for both sexes combined, 89 % were ripening (stage II) and only 7 % ripe (stage III) and 4 % recovering (stage VI). This year again, no fish was found spawning or spent (stages IV and V).

On the south-western banks of Newfoundland (fig. 12), the results are slightly the same. Taking only into account the mature fish, we observe here again that, in this winter period, the large majority of cod is ripening (79 % in 1975 and 1976, both sexes combined). Few others are already ripe (7 % in 1975 and 6 % in 1976) while a larger number than in the Gulf is still recovering (14 % in 1975 and 15 % in 1976). Again in this region during this period, no fish was observed ready to spawn, spawning or spent.

3. Feeding activity.

In both divisions 4 R and 3 Pns, most of the cod stomachs examined contained food (fig. 13).

In the Gulf of St. Lawrence, almost half of the 235 stomachs examined were completely full (43 %). An equivalent proportion was either three-quarter full (21 %) or half-full (21 %). Few of them were quarter-full (12 %) and only 9 stomachs (4 %) were found completely empty.

On the south-western banks of Newfoundland, the feeding activity of cod is more intense as the major part of the 98 stomachs examined were completely full (62 %). A little number was found three-quarter full (23 %) and half-full (14 %). Only one stomach was quarter-full (1 %) and none was completely empty.

The whole of these results show that cod is still in active feeding phase during the winter period in the two regions studied with however a more important activity in 3 P than in 4 R. This great activity is expressed mainly by a massive ingestion of fish.

Indeed, during this period, fish represents 72.5 % of the total fresh weight ingested by cod in div. 4 R and 92.6 % of the total fresh weight ingested in div. 3 Pns (fig. 14).

Out of this great quantity of fish consumed, capelin represents the most important weight (46.1 % of the total food weight in 4 R and 71.2 % of the total food weight in 3 P). Then comes the redfish with 17.0 % of the total weight in 4 R and 20.0 % in 3 P.

In the Gulf of St. Lawrence, the diet in fish is more varied since American plaice (4.6 % of the total weight), herring (3.3 %) and cod (0.6 %) were also found here and they were not present in the stomachs sampled in 3 Pns. Herring is always found instead of capelin

in the larger cods examined, measuring between 65 and 115 centimeters of total length. American plaice and cod are always found with a little amount of capelin in the stomachs of the large fish (more than 70 cm Lt) which had not ingested herring. In both sectors, capelin was recorded in cods of all sizes while redfish was not found in the stomach of cods smaller than 50 cm Lt.

The other fish consumed in small quantity are the wolffish Anarhichas lupus (in one stomach) and specimens from the Macrouridae family (in one stomach) which represent 1.4 % of the total weight ingested in division 3 Pns. In division 4 R, Lumperus maculatus, Lycodes sp., Cottunculus microps and Aspidophoroides monopterygius represent 0.9 % of the total weight ingested.

Crustaceans are also ingested in 4 R (16.1 % of the total weight) and in 3 P (6.1 %). The major portion consists of shrimps Pandalus borealis and Sabinea sarsi (8.2 % of the total weight in 4 R and 0.2 % in 3 P), and of krillshrimps Meganyctiphanes norvegica (4.3 % in 4 R and 4.9 % in 3 P). The crabs (Hyas araneus, H. coarctatus and Chionoecetes opilio are also ingested in small quantities (2.3 % in 4 R and 0.1 % in 3 P) as well as the amphipod Anonyx mugax in 4 R (1.3 %) and the isopod Idotea sp. in 3 P (0.9 %).

The other food groups found in the stomachs are mainly echinoderms in 4 R (7.5 %) represented by ophiurids Ophiura sarsi, O. robusta and Ophiopholis aculeata and by the sea-urchin Strongylocentrotus droehbachiensis. Polychaets annelids (1.6 % in 4 R and 0.1 % in 3 P) and the gasteropods and pelecypods molluscs (1.5 % in 4 R and 0.1 % in 3 P) constitute the complement of the cod's diet.

IV - Discussion and conclusions.

- The taggings made in the Gulf of St. Lawrence (4 R) show that, during the winter period (January to April), the cod of the northern Gulf stock undergoes a southward migration, alongside the west coast of Newfoundland. This migration goes down to the Cabot Strait and even as far as the Rose Blanche and Burgeo banks (3 Pns). During the period from May to August, this cod moves in the opposite direction to come back to the northern part of the Gulf as north as the Strait of Belle Isle.

These results confirm those of THOMPSON (1943, p.27 and Chart II) obtained after taggings off the Port au Port Peninsula. They also agree with the observations of TEMPLEMAN and FLEMING (1962, p.461 and fig.12-13) after their experiment off Lark Harbour, and with those of TEMPLEMAN (1974, p.1075 and fig.2) after the taggings carried out in Forçeau Bay, Flowers Cove and Port au Choix.

- The taggings made on Rose Blanche and Burgeo bank (3 Fns) show that, during the winter months, cod migrates generally eastwards. The cod from the Rose Blanche bank moves either towards the Newfoundland south coast (northeast direction) or towards the Burgeo bank (southeast direction). It can be supposed that this migration is the continuation of the one described above, i.e. those cods tagged on the Rose Blanche bank are certainly coming from the Gulf and continue their movement towards the Burgeo region and perhaps the north of the St. Pierre bank.

During the period from May to August, the recaptures show two opposite migratory movements :

- the first one has a northwest direction towards the Gulf of St. Lawrence, through the Cabot Strait, as cod tagged on the Rose Blanche bank and even on the Burgeo bank were recaptured off St. George's Bay and as north as the Bay of Islands. Here again, it can be supposed that these cods belong to the northern Gulf stock, that they were tagged on the south-western banks of Newfoundland during or after their winter migration and that they were going back to their original area when recaptured in May.

- the second one has a northeast direction towards the south coast of Newfoundland as one cod tagged on Burgeo bank was recaptured in the Fortune Bay. On the contrary, it could be supposed here that this cod effectively belongs to the Burgeo bank stock and migrates towards the shore in summer. This could confirm that this offshore stock partly supplies the summer inshore fisheries of the southern Newfoundland and Miquelon Island.

These results correspond to those given by TEMPLEMAN (1974, p.1084 and fig.6) which indicate that cod tagged on the Burgeo bank were recaptured the next winter in the same area close to the Newfoundland south coast or even more south-easternly along the slope of the St. Pierre bank.

As well, this author showed that during the May to August period following the taggings, some of the cods tagged on the Burgeo bank were recaptured in the Gulf of St. Lawrence as north as the Strait of Belle Isle. He was also thinking that, in this case, it was cods of the northern Gulf that were tagged on the Burgeo bank.

In order to explain what brings the cod to migrate, many authors tried to define the factors that can induce and/or accompany the movements. Among the numerous external responsible factors, some as the water currents and temperatures, or light are often mentioned. Among the internal factors, nutrition, reproduction and more complex phenomena where hypophysis and thyroid activity intervene are also taken into account. Using the three factors studied in this paper, we can bring few explanations on the migrations described.

At the beginning of the winter, the cod of the northern Gulf of St. Lawrence is affected by the sudden drop of the temperature of the waters issued from the Labrador Current entering through the Strait of Belle Isle. These waters of temperature less than 0° C have cold influences no suitable for cod which has to move away from them. For this, cod can undertake vertical movements towards the deeper waters where the temperatures are ranging between 3 and 6° C below 200 meters. It is the case for instance in the Esquiman Channel where this fish could find suitable thermic conditions all year long. Even if cod really undergoes those vertical movements towards the greater depths (JEAN, 1964 ; MINET, 1973-a), it however undertakes a more important southward migration as mentioned. This migration drives it to a region (Rose Blanche and Burgeo banks and perhaps the north of St. Pierre bank) where we have shown that the thermic conditions are very similar to those observed in the Gulf at this time of the year. In fact, the cold water layers of temperature less than -1° C are also present and the favourable temperatures for cod (4 to 6° C) are also located between 200 and 250 m.

So, cod leaves a region where it could find favourable thermic conditions for its survival and physiological needs and migrates towards another area where those conditions are very similar. Therefore, if the sudden winter cooling of the waters can have a stimulative action on the behaviour of cod and urge it to move, this factor is not sufficient however to explain such large migrations towards the southern Gulf and the south-western banks of Newfoundland.

On the other hand, we have shown that, among the physiological factors, reproduction was not responsible for the southward winter migration. Indeed, we have observed that in this winter period, the majority of cod (79 to 89 %) is ripening and only a very small percentage (7 to 8 %) is ripe. This is as true for the fishes examined in the Gulf than for those examined on the south-western banks of Newfoundland. Therefore, it is obviously not a factor related to the reproduction that incites cod to migrate southward in winter. However, if the hypothesis of a spawning migration is excluded, we must not forget that it is partly because cod is in a ripening period that it is more sensitive to the winter sudden drop of temperatures and searches warmer waters more favourable to the gonads ripening.

On the contrary, we have shown that cod was still in a very active feeding phase during the winter. This feeding activity, greater on the south-western banks of Newfoundland than in the Gulf, is expressed by a massive consumption of fish among which capelin is of prime importance. We have also seen that capelin is more ingested on the south-western banks of Newfoundland (71.2 % of the total fresh weight of food ingested) than in the Gulf of St. Lawrence (46.1 %). Therefore it appears that this species - associated to other fishes which are permanently present in the whole of this region as the redfish which represents from

17 to 20 % of the ingested food - constitutes a first choice food item responding to the needs of cod in great feeding activity. Then, this feeding factor which incites it to consume food of high calorific level like fish and specially capelin, can partly explain the cod movement towards regions where they are abundant.

As for the spring-summer migration of cod from the southwestern banks of Newfoundland to the northern Gulf, we do not have any direct observations. We can however suppose that -similarly to what happens in winter - this migration is induced by the thermic factor associated to other factors as light for instance ; the breaking up of ice and the general warming up of waters would be then responsible for it. But the important factor which urges cod to migrate towards the northern Gulf at this period of the year is doubtless reproduction. Indeed, at the beginning of this migration, the major part of the cods are ripe and ready to spawn since in the Gulf reproduction occurs during summer and early autumn, from June to September with a peak at the end of June - early July (Mc KENZIE, 1956 ; POWLES, 1958). So, reproduction occurs latter for this stock than for the sedentary stocks and we can suppose that cod waits for the end of its northward migration before reproducing. In autumn, after the reproduction, cod enters into an active feeding period (POWLES, 1958) that can drive it, in its search for food and specially capelin, to undertake movements towards the exterior of the Gulf through the Strait of Belle Isle, as shown by the recaptures recorded until December by TEMPLEMAN (1974) off the south-east coast of Labrador and the east coast of Newfoundland. When the water temperatures become colder at the beginning of winter, the fish goes back in the Gulf and then its biological cycle is completed.

However, even if the few factors studied in this paper have an influence on these movements, they are insufficient to explain the annual migration cycle, undertaken during all its life by cod which obey to hereditary characteristics.

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Table 1. Recaptures by seasonal periods of cod tagged during the two experiments in ICNAF Div. 4R (19 January - 1st February 1975 and 10-17 January 1976) and in ICNAF Div. 3P (15-23 February 1975 and 2-8 March 1976).

Place of tagging Periods of recaptures	4 R		3 P	
	1975 Experiment	1976 Experiment	1975 Experiment	1976 Experiment
January-April 1975	6	-	3	-
January-April 1976	3	8	0	12
May-August 1975	5	-	3	-
September-December 1975	0	-	0	-

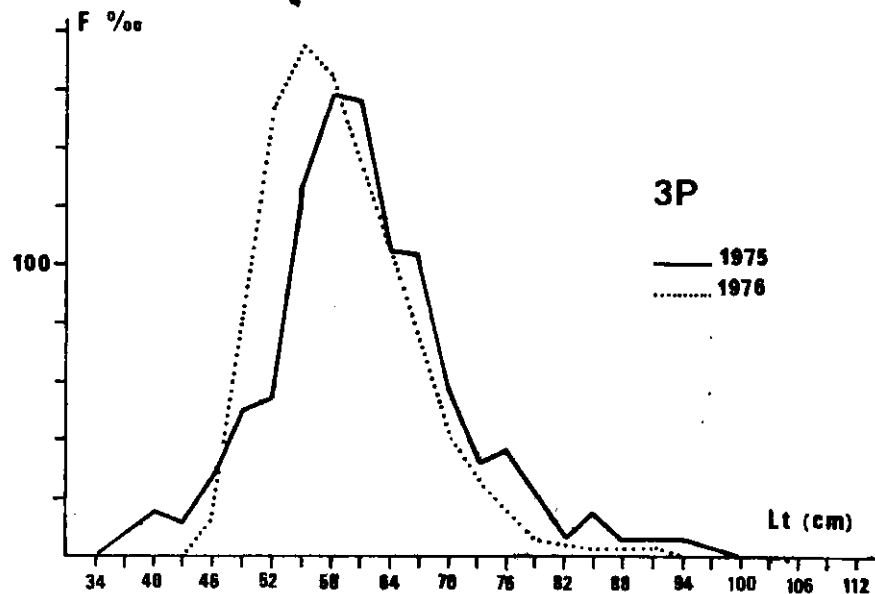
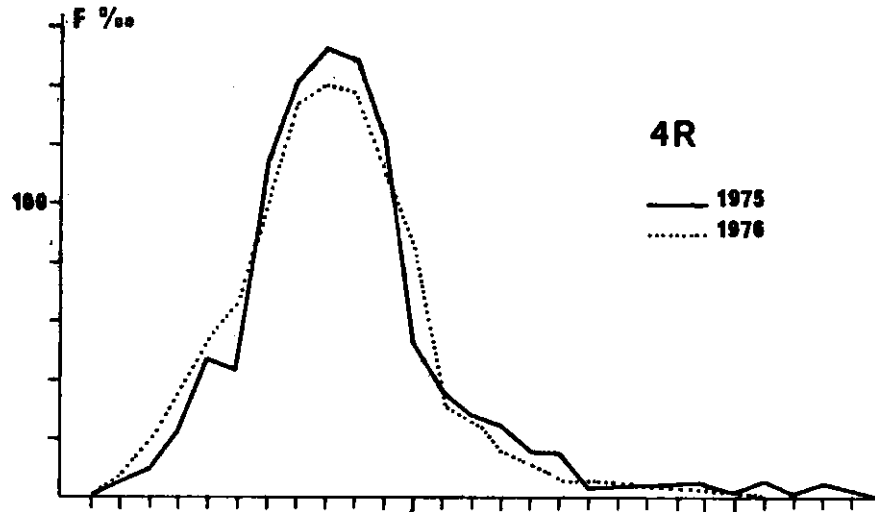


Fig. 1. - Length (Lt) frequencies of cod tagged during the experiments of 1975 and 1976 in ICNAF Divisions 4 R and 3 P.

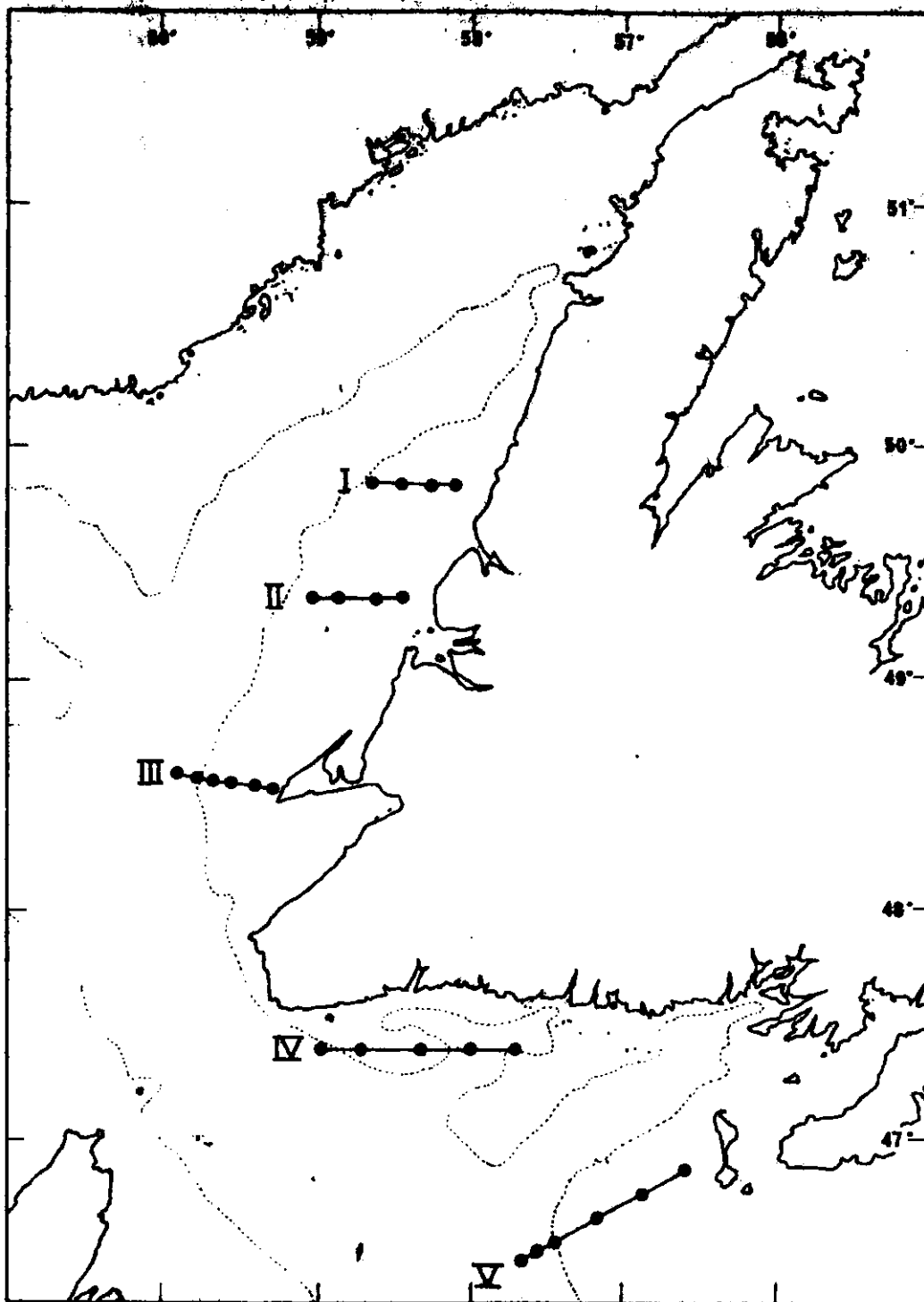


Fig. 2. - Position of the hydrographic sections carried out on board the R/V Cryos in Divisions 4 R and 3 P during the winter of 1975.

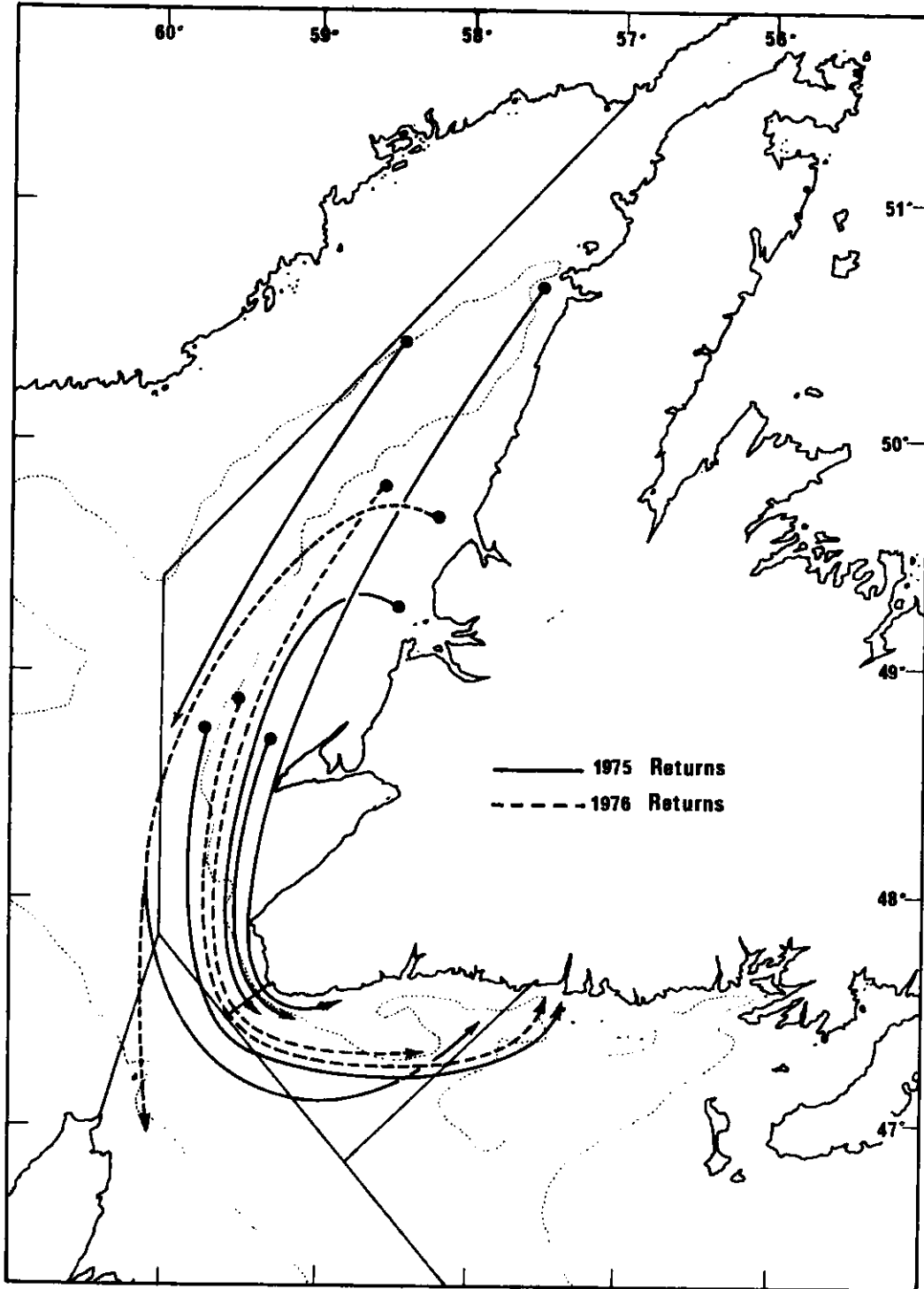


Fig. 3. - God tagged in the Gulf of St. Lawrence (4 R). - Recaptures from January to April 1975-1976 after the 1975 experiment.

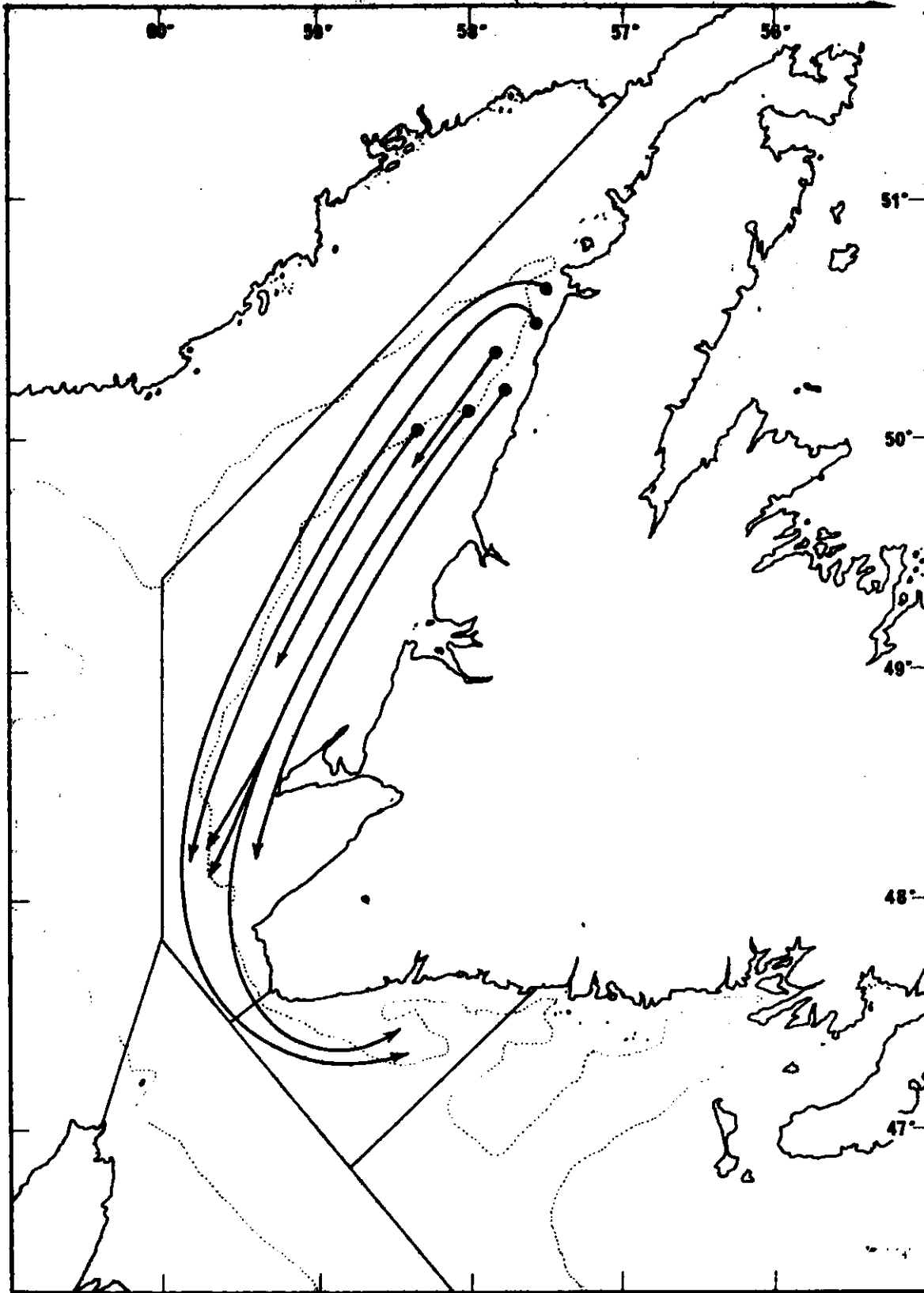


Fig. 4. - Cod tagged in the Gulf of St. Lawrence (4 R). - Recaptures from January to April 1976 after the 1976 experiment.

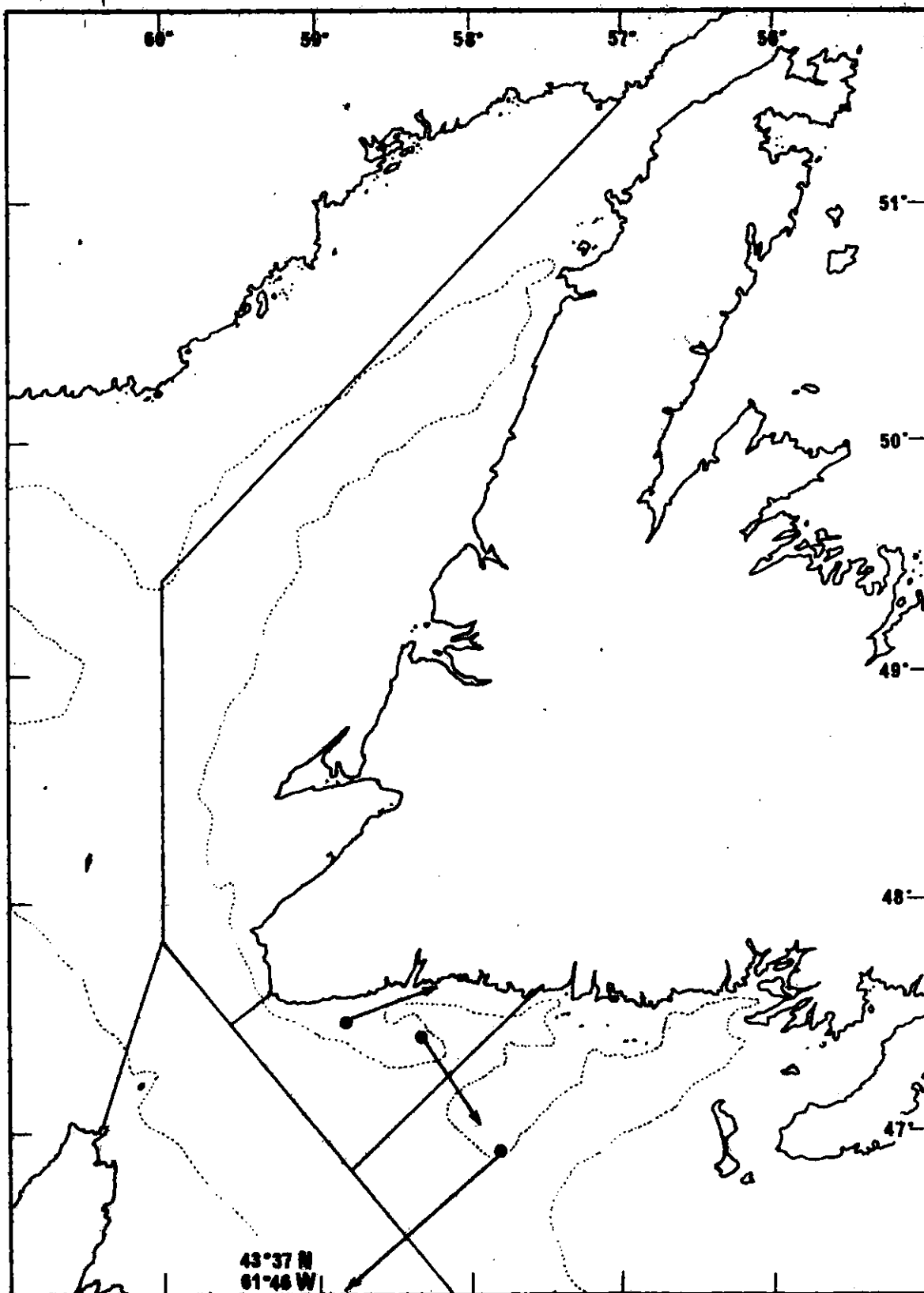


Fig. 5. - Cod tagged on the south-western banks of Newfoundland (3 Pns).-
Recaptures from January to April 1975 after the 1975 experiment.

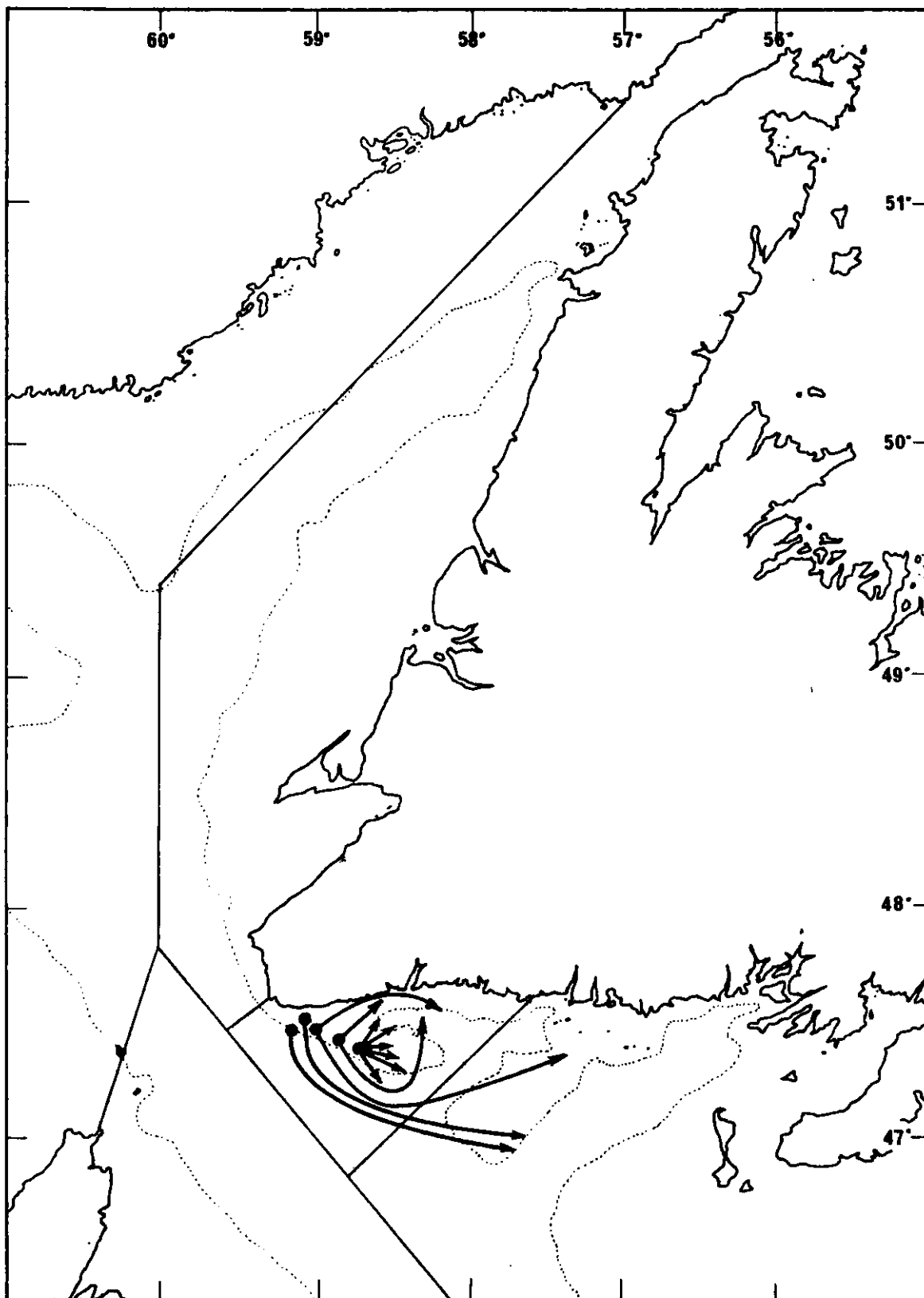


Fig. 6. - Cod tagged on the south-western banks of Newfoundland (3 Pns).-
Recaptures from January to April 1976 after the 1976 experiment.

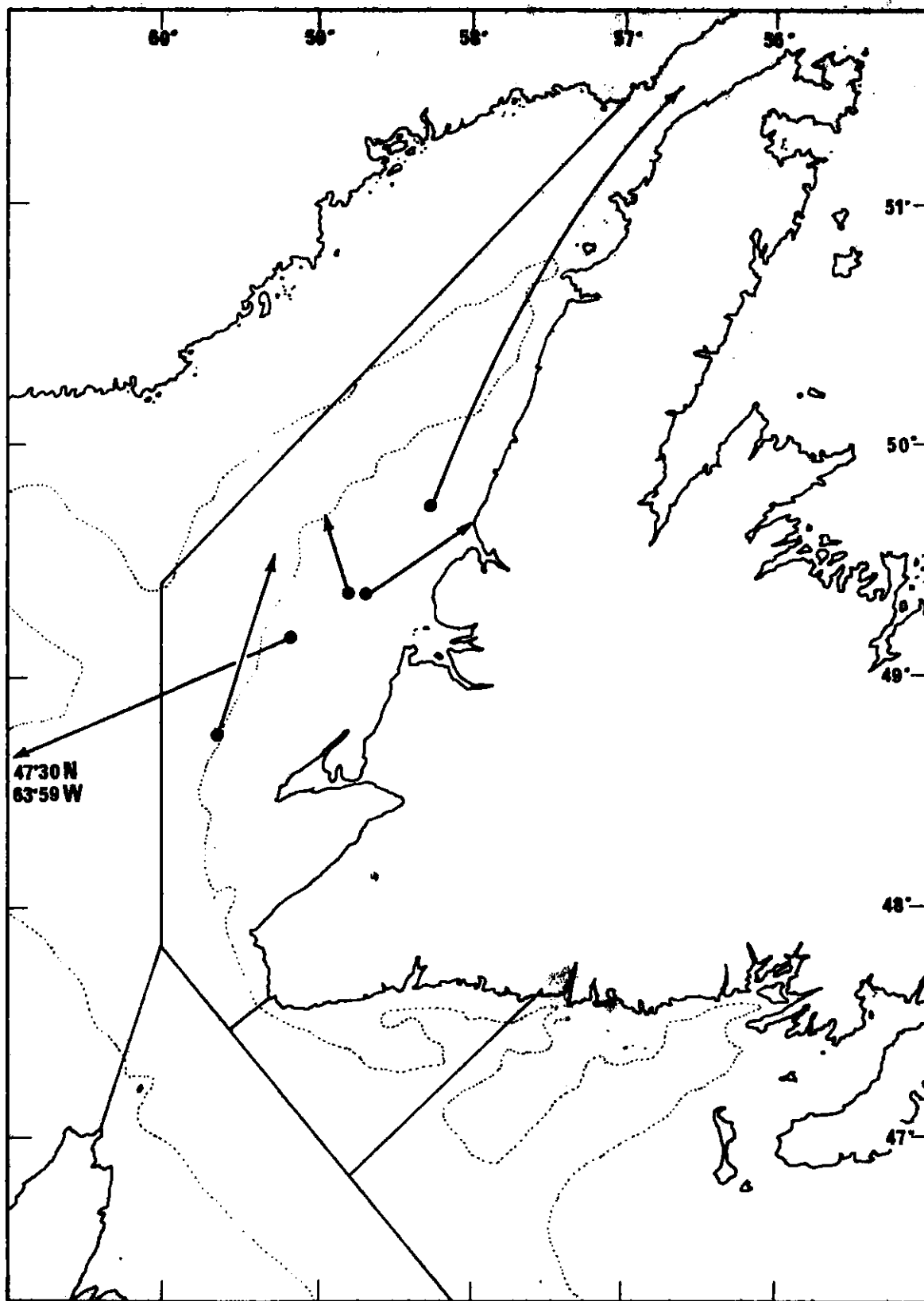


Fig. 7. - Cod tagged in the Gulf of St. Lawrence (4 R). - Recaptures from May to August 1975 after the 1975 experiment.

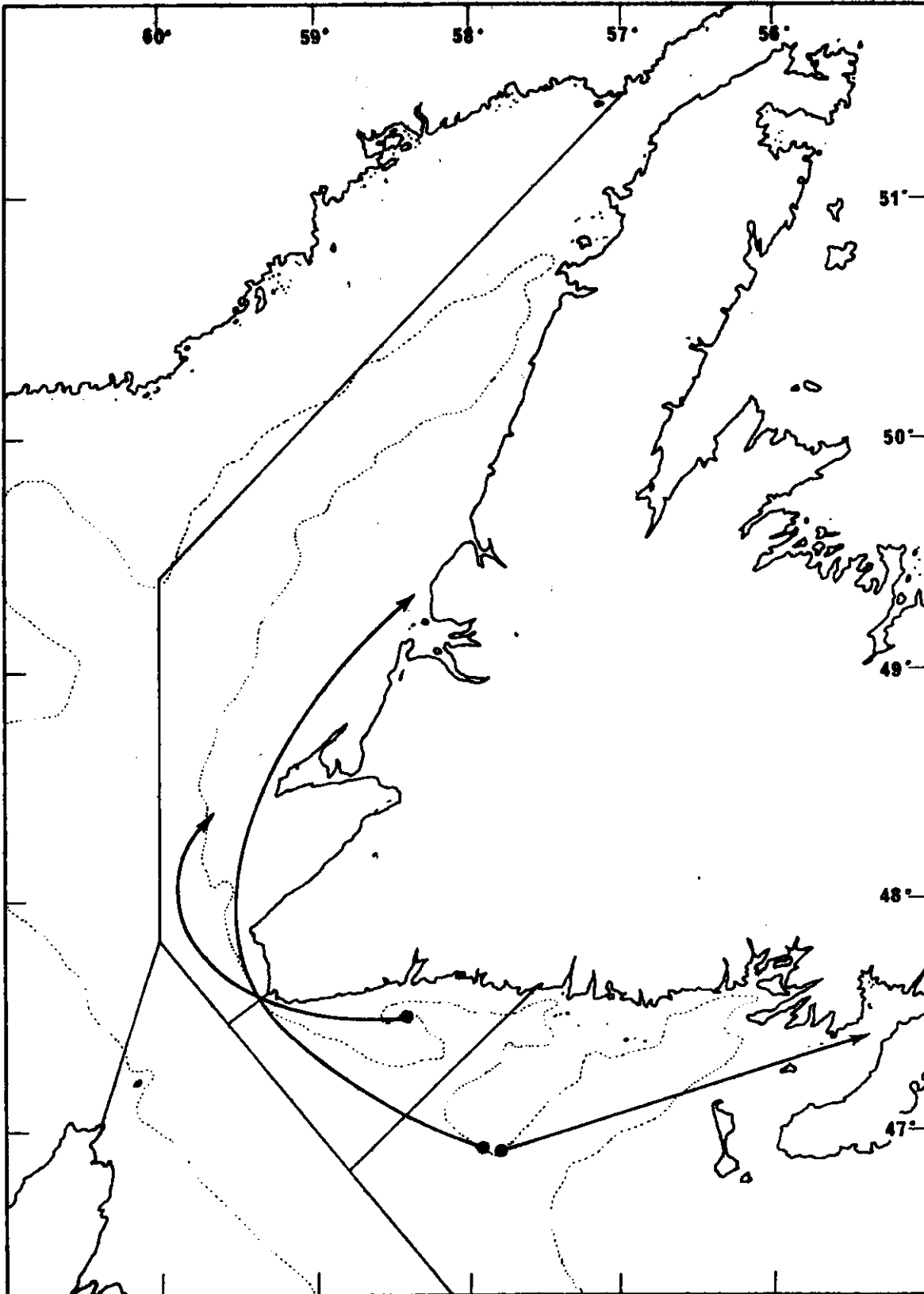


Fig. 8. - Cod tagged on the south-western banks of Newfoundland (3 Pns).-
Recaptures from May to August 1975 after the 1975 experiment.

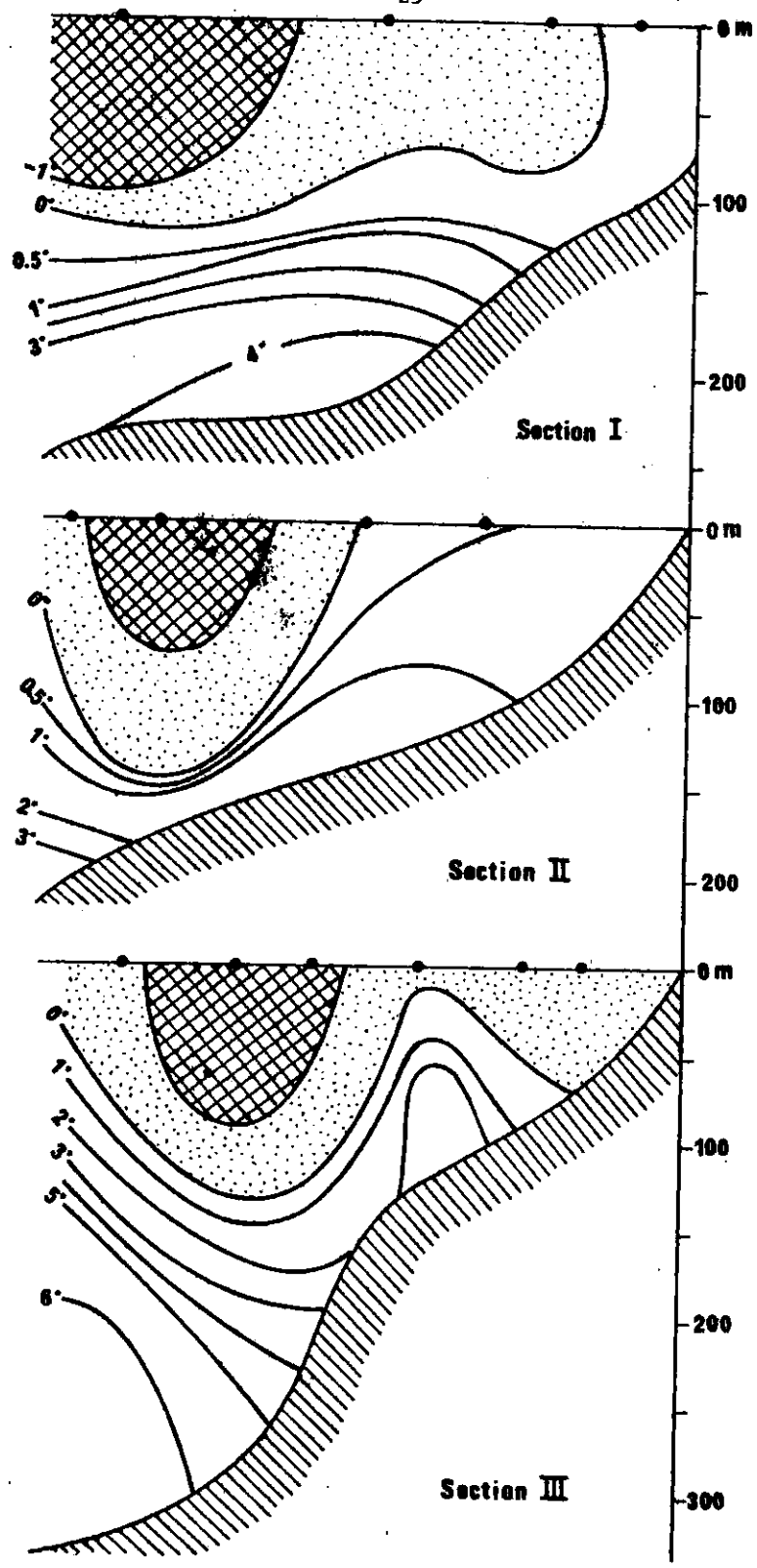


Fig. 9. - Distribution of water temperatures as given by the 3 hydrographic sections in the Gulf of St. Lawrence (4 R). -
Section I - St. Paul's Bay - 29 January 1975
Section II - Cape St. Gregory - 27 January 1975
Section III - Port au Port Peninsula - 1st February 1975.

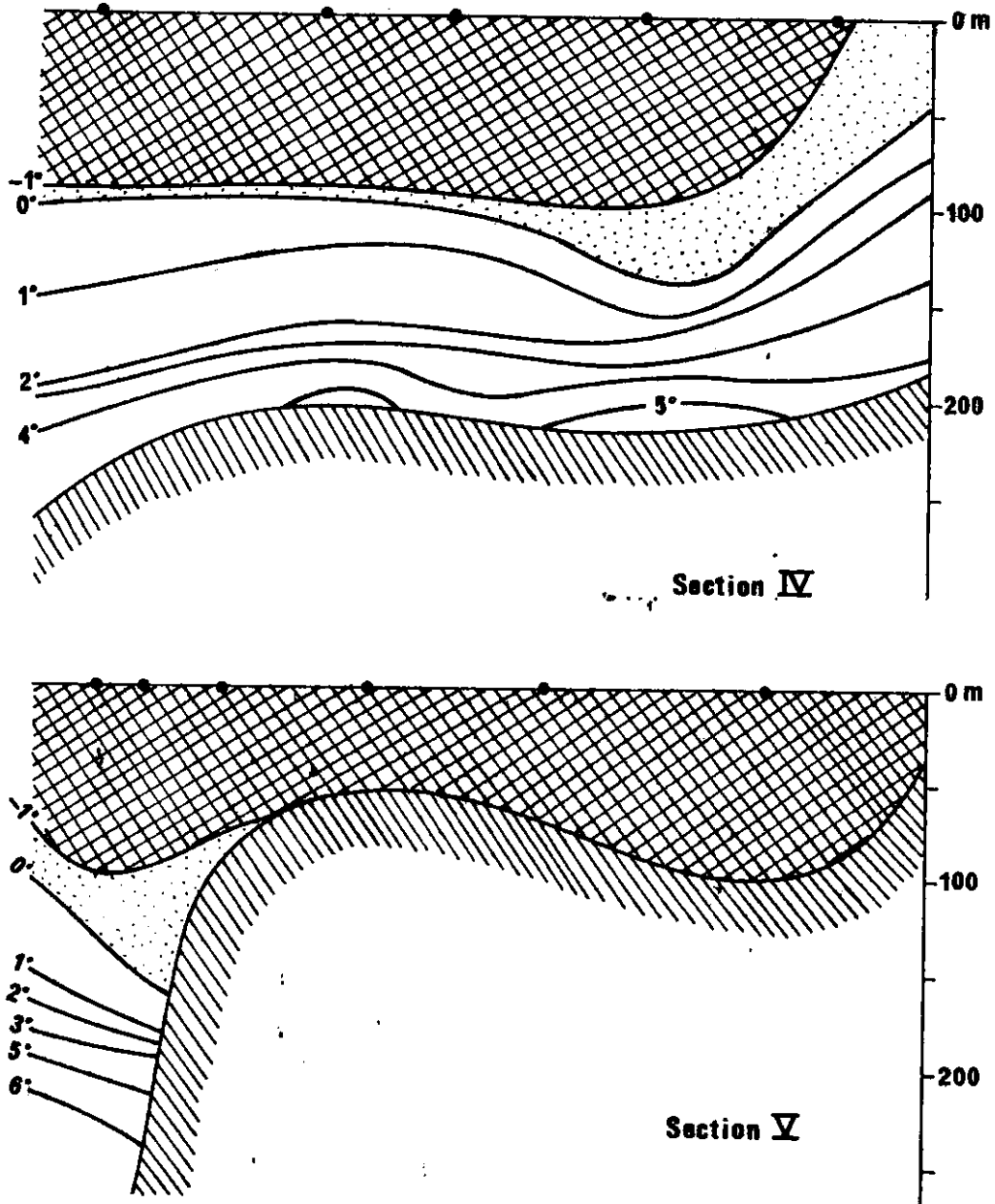


Fig. 10. - Distribution of water temperatures as given by the 2 hydrographic sections on the south-western banks of Newfoundland (3 Pns). -

Section I - Burgeo/Rose Blanche - 13 February 1975

Section II - St. Pierre and Miquelon - 23 February 1975

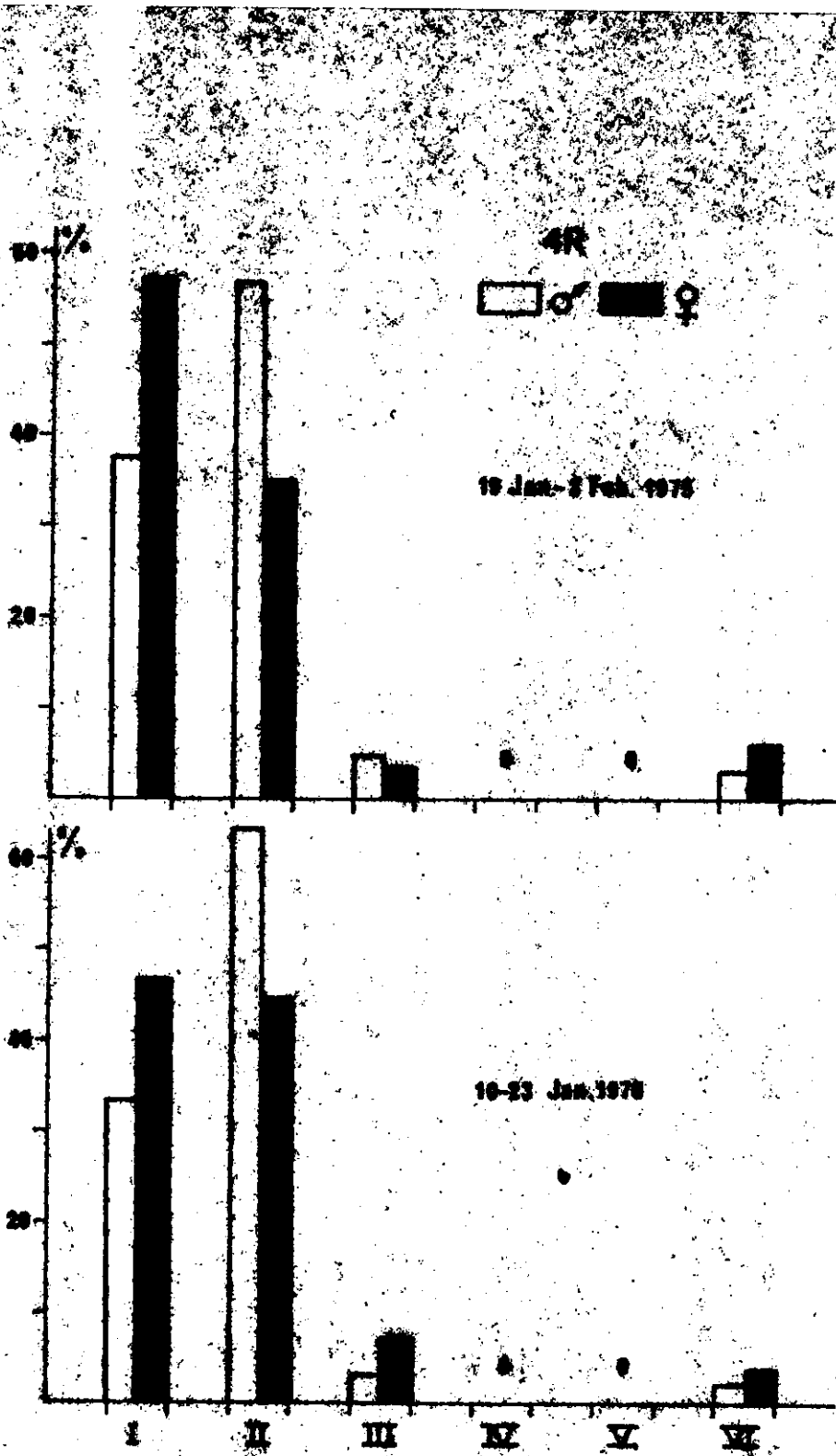


Fig. 11. - Sexual state of cod in the Gulf of St. Lawrence (4 R) during the winters of 1975 and 1976. - Percentages of immature fish (I) and of the different stages of the cod reproductive cycle (II - Ripening, III - Ripe, IV - Spawning, V - Spent and VI - Recovering).

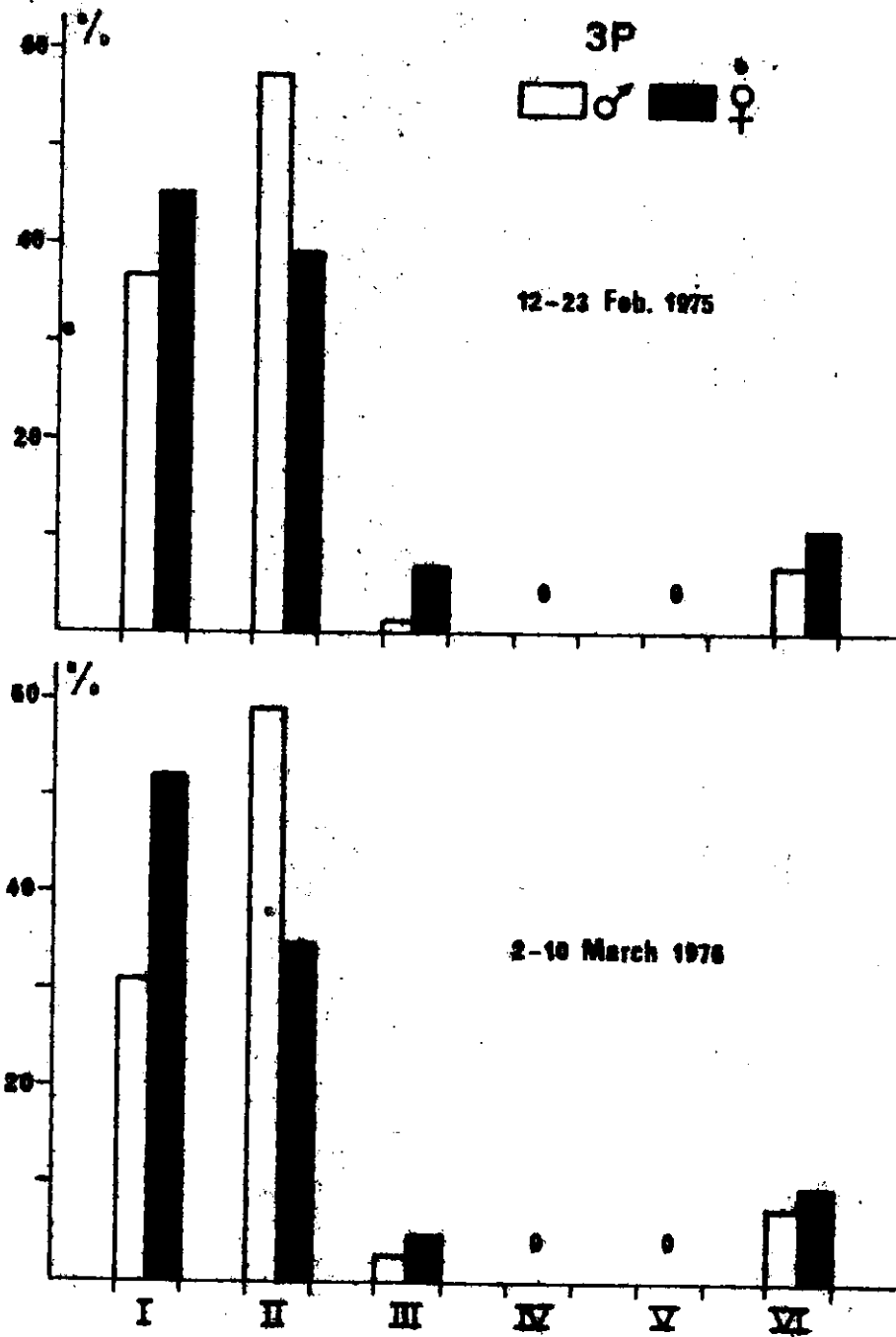


Fig. 12. - Sexual state of cod on the south-western banks of Newfoundland (3 Pns) during the winters of 1975 and 1976. - Percentages of immature fish (I) and of the different stages of the cod reproductive cycle (II - Ripening, III - Ripe, IV - Spawning, V - Spent and VI - Recovering).

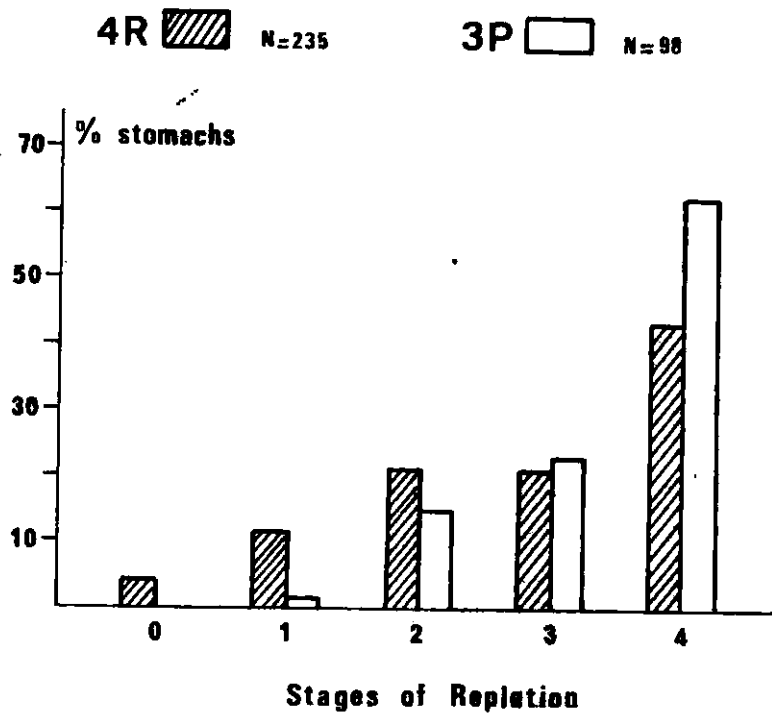


Fig. 13. - Determination of the winter feeding activity of cod in the Gulf of St. Lawrence (4 R) and on the south-western banks of Newfoundland (3 P). - Percentages of cod stomachs examined according to their stages of Repletion :

- 0 - Empty stomachs
 - 1 - One-quarter full
 - 2 - Half-Full
 - 3 - Three-quarter full
 - 4 - Completely full
- (N = Number of stomachs examined).

