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W. Templeman

Committee on Biological Investigations
Fisheries Research Board of Canada

Symposium on the Migrations of Marine Fishes
Ottawa, January 2, 1951.

Some Migrations of Cod on the Atlantic Coast of Canada
by
W. Templeman*

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*Newfoundland Fisheries Research Station, St. John's, Nfld.

Committee on Biological Investigations, Fisheries Research Board of Canada.

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INTRODUCTION

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In the period 1925-1950, cod were tagged on the Atlantic coast of Canada. The tagging was carried out by the Maritimes and Newfoundland divisions of the Fisheries Research Board of Canada. In the latter part of this period, mostly in the latter part of the 1940's, over eight thousand cod were tagged in the latter part, over ten thousand fish, by the Maritimes division. The direction largely between 1934 and 1940, and between 1940 and 1946 over 300 cod were tagged near St. John's, Newfoundland. The Maritime results discussed in this paper are those of the later tagging under McKenzie. The results of the earlier tagging in 1938-39 by Trebley in Quebec and the results of Thompson in Newfoundland between 1947 and 1950 are also discussed. We are aware recent tagging in the Maritimes and Newfoundland is being carried on only on the Newfoundland coast. The tagging was done by Templeman.

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Most of these data are under McKenzie, some of tagging are as yet unpublished.

Earlier cod vertebral studies under McKenzie in the Maritime area and staff in the Newfoundland area. There is an immense mass of data - counts of fish from the Maritime area and Newfoundland area, all at present unpublished. The published data is available on vertebral studies of McKenzie and Thompson.

Studies on Parrotosaurus are noted as a natural tag, are being done by staff of the St. Andrews Station and Newfoundland Station. In Newfoundland

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INTRODUCTION

In the period 1925 to 1950 about thirty-nine thousand cod were tagged on the Atlantic Coast of Canada. In the Maritime Provinces tagging was carried out between 1925 and 1940, in the earlier part of this period, mostly 1925-27, by Calder directed by Huntsman, over eight thousand cod being tagged, and in the latter part, over ten thousand fish, by various people under McKenzie's direction largely between 1934 and 1938. Between 1930 and 1936 over 300 cod were tagged near Ellerslie P.E.I. by Needler. The Maritime results discussed in this paper are almost all from the later tagging under McKenzie. About three thousand cod were tagged in 1938-39 by Tremblay in Quebec and over eight thousand by Thompson in Newfoundland between 1933 and 1937. In so far as we are aware recent tagging in the area under consideration has been carried on only on the Newfoundland and Labrador fishing grounds by Templeman and staff, about eight thousand cod being tagged in 1947-50.

Most of these data apart from the results of the tagging under Huntsman, some of Tremblay's tagging and all of Thompson's tagging are as yet unpublished.

Earlier cod vertebral studies have been mostly carried out under McKenzie in the Maritime area and more recently by Templeman and staff in the Newfoundland and Labrador areas. This represents an immense mass of data - counts of forty thousand vertebral columns from the Maritime area and nearly ten thousand from the Newfoundland area, all at present unpublished. A small amount of published data is available on vertebral counts in the area by Schmidt and Thompson.

Studies on Porrocaecum, the cod nematode, which to some degree acts as a natural tag, are being carried out by Scott and the staff of the St. Andrews Station and also by the staff of the Newfoundland Station. In Newfoundland also we have kept an account of the occurrence of Lernaeocera branchialis, the large copepod parasite on the branchial arches of the cod. All this work is unpublished. Studies of growth and of variation in year class abundance are of some aid and we have found also that the weight of the

*Newfoundland Fisheries Research Station, St. John's, Nfld.

Otolith offers a good character for distinguishing populations. Doubtless also measurements of body proportions, variations in size at maturity and other factors, such as the number of sclerites in the first year as used by Thompson, or in all years could be used but from lack of time none of these will be considered here.

Huntsman and McKenzie used a monel metal strap tag which was usually attached dorsally during Huntsman's tagging and ventrally by McKenzie at the base of the caudal fin as far onto the scales as possible. A trial was made of the dorsal opercular position for this tag as against the ventral tail position and there was a thirteen per cent advantage for the opercular tag.

In Newfoundland Thompson used a celluloid and aluminum bachelor button tag developed by Herrington for haddock and placed on the operculum by special pliers. In the present tagging in Newfoundland we are comparing the opercular tag inserted through the opercular bone with external celluloid tags attached by nickel wire anterior to the first dorsal fin, around the maxilla and around the pre-opercular and with two, three, four and five inch celluloid belly tags. McKenzie obtained good results from Canadian landings with the monel metal strap tag by wide advertising of the tagging and by frequent contacts with fishermen and fishing vessels. In McKenzie's offshore tagging however only 6 tags out of 285 were returned from the U.S. in spite of catches of U.S. vessels in the Maritime area being one third greater than those of Canadian vessels. This illustrates the failure of the monel metal strap tag unless the collection of the tags is undertaken as a special effort. In the Newfoundland area with most of the fishing on the banks being done by European vessels and with the isolation of the fishing villages, we have considered that not enough information can be placed on the monel metal tag and hence we are using celluloid tags all with an address and a request for information and of course promise of a reward. The reward is one dollar but we frequently have requests for a dollar for each man on the boat and even at times for a new engine as a reward. The Norwegian type hydrostatic tag has not yet been tried for cod in comparison with the other tags used in the north-west Atlantic area. In our tagging the belly tag has been proven to give six times as many recoveries as the opercular bachelor button tag in the third year after tagging while being approximately as good as the opercular tag in the year of tagging and over one and a half times as good in the second year.

The mass of unpublished and published data is so great and the time so short that no attempt will be made to deal with the material in detail and consideration will be given to a few of the main results which are interesting from the point of view of migration or theories of migration. Figures prepared by McKenzie and occasionally by Thompson have been used where necessary, usually without change. Most of the Newfoundland tagging accounts, however, are from our more recent results.

MIGRATION INTO AND OUT OF THE GULF OF ST. LAWRENCE

Southern Entrance around Cape Breton

March-April. Tagging, March 5-26, 1937, on Emerald Bank showed relatively little migration into the Gulf of St. Lawrence - one out of 14 recaptures, while tagging on the nearer Misaine Bank on March 1, in the same year gave considerable migration into the Gulf, 4 out of 6 recaptures.

Tagging near the north-eastern part of Sable Island Bank (south-east peak region) in 1937 during the last week in March and the first week in April showed some migration into the Gulf, 4 out of 46 recaptures, with 2 additional recaptures on the eastern Cape Breton Coast. Tagging of very large steak cod averaging 25 pounds on the western part of Sable Island Bank on April 24, 1938 gave no recaptures in the Gulf out of a total of 21 recaptures.

Cod tagged on eastern Banquereau, April 19 and 20, 1937 showed good penetration of the Gulf - 11 out of 59 recaptures, with 7 others being caught near Cape North at the eastern entrance to the Gulf and 5 additional recaptures being made near the eastern Cape Breton Coast.

It is noticeable that a very great part of the migration into the Gulf continued as far as Gaspé where there is a large summer cod fishery.

May. Cod tagged on Sable Island Bank, just north of the western tip of Sable Island on May 30, 1937, showed no movement into the Gulf - none out of 18 recaptures. Cod tagged on the southern edge of Banquereau in early May, 1937 did not penetrate deeply into the Gulf, one only out of 16 recaptures being in the Gulf in western Cape Breton.

Tagging on eastern Banquereau on May 28 and 29, 1937 in essentially the same area as the April 19 to 20 tagging gave no recaptures in the Gulf out of a total of 58 recaptures.

There was no migration into the Gulf from cod tagged at Chebucto Head, Halifax, in May, 1935 and very little migration into the Gulf, 2 to Gaspé and one to Cheticamp out of 372 recaptures from cod tagged in late May, 1934 in the Jeddore Rock to Egg Island area just north of Halifax.

June-August. There was no migration into the Gulf from cod tagged at Chebucto Head, Halifax in June, 1934. Also none of 55 recaptures from tagging at Canso, July 31 and August 1, 1934 were taken in the Gulf. In all these inshore areas tagging was later and usually considerably later than the March-April dates showing good migration into the Gulf from the offshore banks. Earlier March and April tagging in the inshore areas may give some migration into the Gulf.

Tagging at Cheticamp, western Cape Breton, July, 1937, gave some recaptures across the Gulf to the Gaspé region but none in the year of tagging, the July date being apparently too late.

Migration out of the Southern Part of the Gulf

Tremblay's cod tagging in the Gaspé area July to September 1938 shows some movement out of the Gulf even as early as the winter of tagging. Of 231 mostly local recaptures 4 occurred on the Nova Scotian Banks and 4 near the northern part of Cape Breton at the exit to the Gulf. There were no captures in 1938 in eastern Cape Breton and the winter recaptures of that year were on the offshore banks, possibly indicating an autumn migration at some distance from the eastern Cape Breton Coast.

Tremblay's tagging of cod in the Gaspé area between June and September, 1939, gave 354 recaptures mostly local. Four tagged fish were caught on the Nova Scotian Banks, all in January and March immediately following the tagging, 11 toward the eastern side of the Gulf and two on Rose Blanche Bank at the northern entrance to Cabot Strait. Of the 11 caught on the eastern part of the Gulf 3 were caught in eastern Cape Breton in the winter immediately following tagging and the 4 caught on the Nova Scotian Banks in the same winter were on the inner banks. This probably indicates a more inshore migration out of the Gulf in the winter of 1939 than 1938.

Tagging at Cheticamp in western Cape Breton, July 1937, showed a good migration out to the offshore Nova Scotian Banks with one to St. Pierre Bank and also to the inshore Nova Scotian fishing grounds in the autumn and winter of succeeding years. The migration outward was evidently mainly through the inshore fishing grounds of north-east Cape Breton.

Fifteen hundred and sixty-five cod were tagged between 1930 and 1940 mostly in July and August in the south-western part of the Gulf of St. Lawrence in three localities of Northern P.E.I. - Alberton, Ellerslie and Naufrage; also on Bradell Bank and off North Point, P.E.I. From this tagging two fish were recaptured on Banquereau, one on St. Pierre Bank, one in Fortune Bay, Newfoundland and 7 in eastern Cape Breton. This compares with a capture of 8 on the offshore Nova Scotian Banks, 2 on the Rose Blanche Bank, Newfoundland and 9 in eastern Cape Breton from Tremblay's Gaspé tagging of approximately twice as many (2979) cod. Allowing for the different numbers tagged and the normal variation in results of tagging done in different years with differing intensities of search for tags, the numbers of cod moving out of the Gulf and to the exit from the Gulf are approximately the same in the north Prince Edward Island - Bradelle Bank area as in the Gaspé region.

Movement out of the Gulf on the Newfoundland Side

The tagging of 461 cod at Lark Harbour, Bay of Islands on the West Coast of Newfoundland, October 7 to 20, 1948 gave no less than 12 recaptures outside the Gulf in the following winter and spring, eleven in the Rose Blanche Bank and neighbouring areas to the south coast of Newfoundland and one on Burgeo Bank. An additional recapture was made in the Rose Blanche Bank area in July and four more in essentially the same area in the winter and spring of the following year. From April to June in these years there were seven recaptures half way between the wintering ground near Rose Blanche and the tagging ground at Bay of Islands. Six of these were in the April-June period following tagging: one on April 30, four between May 3 and May 15, and one on June 20. Moreover, there is a large winter and early spring fishery in the Rose Blanche area which declines greatly after April. There is good evidence therefore of an early winter migration southward out of the Newfoundland side of the Gulf of St. Lawrence to the Coastal Banks near Rose Blanche with little migration out of this wintering area until the return to the Gulf which appears to be mostly in the latter part of April and in early May. Tagging at Fortune, June-July, 1934 and 1935, at Burin June 1-July 10, 1948 and on St. Pierre Bank in July, 1935 gave no migration into the Gulf of St. Lawrence. These dates however were probably too late in any case to reveal any regular spring migration into the Gulf. It would, however, appear that on the Newfoundland side of the Cabot Strait entrance where deep water 130 to over 200 fathoms is to be found in the immediate neighbourhood of shore there is little migration to the Banks as far offshore as St. Pierre Bank, the cod spending the winter close to shore in deep but not necessarily very deep water since most of the deep water winter fishing on Rose Blanche Bank is in depths of eighty to ninety fathoms. The deep water below 130 fathoms is probably warm enough - over three degrees, to provide a partial warm water barrier. Usually few cod are caught in this deep water, both deep enough and warm enough for rosefish to exist in quantity.

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FACTORS WHICH MAY INFLUENCE COD MOVEMENT
IN AND OUT OF THE GULF

In the Norwegian area great schools of cod spawn on the west coast near the Lofoten Islands - the eggs and larvae drift northward with the current, the spent fish also going in the same direction and a great many of the immature fish settle and grow up in the region of Bear Island, Spitsbergen and the Barents Sea, returning when mature against the prevailing current to the Lofoten Banks to spawn.

In the Iceland-Greenland area cod spawn on the banks to the south and west of Iceland. In certain years large quantities of cod larvae are carried by the current to east Greenland. Many cod from south and west Greenland migrate back against the current to the Iceland banks to spawn and some spent fish from the Iceland banks follow the current from Iceland to west Greenland.

In the Canadian Atlantic area the spawning grounds of the cod are poorly known and are probably very widespread. The paths of the drifting eggs and larvae from the spawning grounds are unknown except theoretically by considering prevailing currents, and the times of spawning are only approximately known in most of the very large area of well above a hundred and fifty thousand square miles over which cod are found.

What factors then may influence the cod movements which have been observed to occur in and out of Cabot Strait from the Gulf of St. Lawrence area? Currents, temperatures, migration to spawning areas and post-spawning or other dispersal in search of food are among the most likely influences.

Currents

It will be noted with regard to movements into and out of the Gulf of St. Lawrence that on the Cape Breton side the spring migration into the Gulf from the Nova Scotian Banks such as Banquereau is against the prevailing current, while the spring migration into the Gulf on the Newfoundland side from Rose Blanche Bank is with the prevailing current. In the late autumn and early winter, migration out of the Gulf toward the wintering grounds on the Cape Breton side is with the prevailing current while on the Newfoundland side it is against the prevailing current. We are inclined to believe that migration in the spring is migration in the upper water layers while migration in the early winter is almost certainly in deeper water. Much remains to be found out about the behaviour of the surface currents of the Newfoundland side and of the movements of the deeper water currents on both sides of Cabot Strait. There may be deep water currents moving in the opposite direction to the surface currents but the facts available at present do not lead to a logical interpretation of the movements of cod through Cabot Strait as resulting from current action.

Spawning

The fragmentary information on spawning periods handicaps us in our attempts to show the relation of spawning to migration into the Gulf. If spawning is a factor, the separate possibility on each side of the Cabot Strait is a movement inward to spawning grounds in the Gulf or as a post-spawning feeding dispersal from the offshore banks. If spawning occurred outside the Gulf the autumn migration outward could be considered as being for the purpose of pre-spawning gathering on the spawning grounds.

Apparently a large percentage of the cod migrating into the Gulf on the Cape Breton side do so from Banquereau with additions from Middle Ground, Sable Island and Misaine Banks and other neighbouring banks and inshore areas. We shall consider the Banquereau case in detail since it is closer to the Gulf than most other banks on which tagging has been carried out. Little information is available regarding cod spawning on Banquereau apart from the examination of several hundred cod obtained in 25 to 28 fathoms on Banquereau by the Investigator II on May 15, 1950. Only about 12 per cent of these were spent and 83 per cent were in the stage with large numbers of clear eggs which immediately precedes spawning.

Dr. Tremblay has informed us that at Gaspé spawning cod may be found all summer from June to August. In the area between the Magdalen Islands and Gaspé some information exists, meagre but all pointing in the same direction. In McKenzie's unpublished tagging manuscript it is recorded of the tagging off Alberton, P.E.I. in 1939 that 696 cod were tagged from July 8 to 17 by the M.V. Zoarces with Capt. Calder in charge. The cod were caught at a distance of 5 to 17 miles offshore in water about 20 to 40 metres deep and from bottom water about 2° C. In many cases the fish were so near their spawning season that the spawn ran out in handling them during tagging. Also during tagging 25-30 miles NE of North Point, P.E.I. on August 5 and 8, 1936 and on Bradelle Bank August 6 and 7, 1936 the cod were almost ready to spawn quite a few males yielding milt under the handling necessary in tagging and several females yielding eggs.

Similarly Bigelow (Fishes of the Gulf of Maine, 1925) says that spawning cod were caught from the deck of the Grampus (Capt. Hahn in command) on Bradelle Bank in the Gulf of St. Lawrence late in August many years ago.

Samples of cod obtained by the Investigator II in November 1950 on Orphan and Bradelle Banks and from the area northeast of the Magdalen Islands were generally no further recovered from spawning than are the cod of the east coast of Newfoundland in July or August several months after spawning. It is fairly certain, therefore, that the spawning of the cod in this central area of the Gulf is late summer rather than in the spring months as is common on the offshore Banks.

It is obvious from McKenzie's tagging results that most cod entering the Gulf from Banquereau leave this bank before the latter part of April. Consequently it is possible but not proven that the cod leaving Banquereau from the Gulf have not spawned on Banquereau but are cod of Gulf origin entering the Gulf to spawn there.

The peak of the cod spawning in the Sable Island Bank, Emerald Bank area is reported by Dr. Martin of the Atlantic Biological Station at St. Andrews to be late March to mid-April, spawning beginning in February and ending in May. Thus it appears that the spawning in the Sable Island Bank - Emerald Bank area is earlier than on Banquereau.

Cod tagged in the Sable Island Bank - Emerald Bank area showed some migration into the Gulf in March and the first week in April but not from tagging in the latter part of April and in May. Therefore these fish could have left for the Gulf before or after spawning on the offshore banks.

For the Newfoundland side we have no scientific observations on the time of spawning on Rose Blanche Bank where so many of the Gulf cod from the Newfoundland side spend the winter. Captain Baxter Blackwood, however, who was a field technician at the Newfoundland Station for ten years and then became manager of the fresh fish plant at Isle aux Morts which is engaged in the winter fishery says that the Isle aux Morts fish were full or roe to the end of the fishery near the end of April.

In St. George's Bay during the last week of May 1945 we noted that cod ovaries were fairly full and spawning had not occurred. The fishery in the Port aux Basques to Rose Blanche area declines greatly after April and our tagging also indicates migration into the Gulf in April-May in this area. It is thus possible that the cod passing into the Gulf on the Newfoundland side may also be moving in for spawning. Mature cod examined in Port aux Basques by our staff, June 2-9, 1949 were 98 per cent spent. Thus spawning occurred not later than May and could have possibly begun in April.

What evidence there is, therefore, is somewhat conflicting and it is possible that the local resident cod in the deep water wintering area spawn earlier than the cod migrating into the Gulf. Thus on both sides of Cabot Strait it is impossible to say whether the cod migrating inward have or have not spawned.

Food

On the east coast of Newfoundland it is an apparent fact that very large onshore movements of cod occur following the caplin when these fish come inshore to spawn in late June. In more limited parts of the coast there is a "herring run" consisting of schools of cod which follow the herring inshore in May. It is quite possible, therefore, that some of the inward migration into

the Gulf in the spring in late April and early May is due to schools of fish following the migration of herring. Portuguese otter trawler captains have told us of not infrequent catches of several thousand pounds of herring in a drag on Banquereau during the month of April. It is quite possible that these Banquereau herring move into the Gulf for spawning in May and that they are accompanied for some distance by schools of fish from Banquereau. A movement from Banquereau to Gaspe, however, following schools of herring would seem rather unlikely. An argument against the idea of migration into the Gulf being caused by pursuit of herring is the fact that no large schools of cod pursue the herring to Shediac and presumably not to the Magdalen Islands.

On the Newfoundland side, St. George's Bay is the Gulf area most nearly adjacent to the Rose Blanche Coastal Bank where many Gulf cod spend the winter. In St. George's Bay a large run of cod occurs in May following the herring into very shallow water. The fishery tapers off in June especially in the shallow water. It is also possible here, therefore, that many cod follow herring away from the wintering area and into the Gulf.

Temperatures

Spring. In the hydrographic section, Banquereau to Cape Breton, taken by the Canadian Fisheries Expedition on June 3 and 4, 1915, bottom temperatures on Banquereau ranged from 0°C to 0.15°C . Temperatures increased gradually to 4.6° at the surface. Between Banquereau and Cape Breton there was a cold water layer intermediate in position in the deep water but resting on the bottom in the shallow bank and coastal areas. The lowest temperatures were -0.55°C . From this colder layer, temperatures increased gradually to 4 to 4.75°C at the surface. In the Gulf the cold layer with temperatures only rarely below -1.0°C covered the bottom of all but the shallower areas. At this time of year there is a cold below zero centigrade intermediate or bottom layer over the Gulf generally.

On the Newfoundland side of Cabot Strait in a section taken by the same Expedition on June 13, 1915, there was a definite intermediate cold layer in the deep water with warmer water above and below. The lowest temperature in the cold layer was -0.9°C .

In these two areas from which spring migration into the Gulf occurs there is little or no change in the deep warm layer during the spring and little change in the deeper parts of the cold intermediate layer. The only considerable change has been the warming of the surface layer.

In the May "herring-run" of cod to St. George's Bay, the fish run into shallow water of 6 fathoms or less, a good indication that they are migrating to some degree in the surface layer. Also on the east coast of Newfoundland there is some evidence that the June migration towards shore in pursuit of the caplin

occurs in the upper layer of increasing temperature above the cold layer. Below-zero temperatures of -0.5 and up, however, occurring in the Banquereau to Cape Breton area are not always a barrier to cod on the east coast of Newfoundland, especially when they are pursuing food fishes such as caplin and lance.

Autumn. In the late autumn or early winter a condition will arise in a great part of the Gulf of St. Lawrence (where the bottom of the cold water layer is usually less than 100 fathoms by late summer) in which the water column below zero centigrade is almost or completely obliterated as an intermediate cold layer and is raised above zero centigrade largely by mixing and overturn from above and lesser mixing and encroachment from below. When the retreat of the cold layer is proceeding in the autumn, cod desert the shallow turbulent inshore areas long before they have chilled very much and are found most abundant deeper and deeper following the retreat of the cold water layer. Thus on the east coast of Newfoundland the cod are most abundant down to ten fathoms in June, ten to twenty in July and August and progressively deeper to 50 to 70 fathoms in October and November and 70 to 90 in December to January. That is, cod tend to move downward toward the very cold water layer and accumulate in the unused feeding grounds opened up as the cold layer retreats in the autumn. Thus, what little evidence there is, suggests that the autumn retreat from the shore occurs in the deeper water near the bottom and not in the surface layers. During the winter the surface layers chill down so that for a period in late winter and early March temperatures are approximately the same and below zero centigrade throughout the whole upper cold water column from the surface downward, while usually below approximately a hundred fathoms (still deeper on the east coast of Newfoundland) the deep water remains warm. Again there is some evidence for the east coast of Newfoundland that the winter movements are carried out in this deep warm layer. Deep channels with warm water exist in the Gulf throughout the winter and large numbers of cod certainly remain over winter in the Gulf.

We do not at present see any particular cause or mechanism by which cod are forced from the Gulf by lowering temperatures except that there may quite well be earlier chilling of the waters at the same depths to the north on the Newfoundland side and to the west on the Maritime side of the Gulf which may give an outward stimulus. Once cod are in the warm deep layer, however, judging from winter movements apparently in this layer on the east coast of Newfoundland, they may move considerable distances more or less parallel to the coast, the only barriers being the cold water near shore and the presence of too warm and too deep water offshore.

In general, evidence as yet is fragmentary regarding the cause of the movements in and out of the Gulf. The direction of the currents on the two sides of Dabot Strait is opposite while the time of movement in or out is approximately the same on both sides.

The knowledge of spawning times is inadequate. Inward pursuit of herring is possible on both sides but evidence is lacking.

There may be some initiation of deep water outward movements in autumn by temperatures decreasing earliest toward the north and west. The stimulus producing the spring inward movements which are possibly in the surface layer is unknown. It is however a common experience in eastern Newfoundland waters that after spawning the hungry cod come afloat after fishes such as caplin and launce rather than continuing to feed on the bottom and that at this time there is considerable dispersal from the spawning areas. The exact spawning condition of the cod migrating into the Gulf, however, is unknown. In so far as these migratory movements into and out of the Gulf would be almost certainly much less in extent if the waters were not warming in spring and cooling in autumn and winter, it may be said that temperature change is a major influence in the production of these movements.

The greatest volume of cod is caught in the Gulf of St. Lawrence in 1950, being about 100,000 tons. This is due to cold water below -1°C and temperatures below -1°C are not found on surface long-lines. Cod caught on surface long-lines are usually caught either by drift nets below -1°C and especially by drift nets below -2°C . The largest catches of cod on surface long-lines are set in deep cold water. On the east coast schools of the congo-cod migrate to twenty fathoms in winter. The cod when they migrate to very shallow waters are usually caught by dipnets. The cod, therefore, are not cod forcing the basis of the east coast of Newfoundland migration.

These fish will migrate in late May and early June, and their migration is a post-spawning migration.

FEEDING MIGRATION INSHORE WITH CAPLIN

Cod tagged on the western edge of the Grand Bank, June 4 and 5, 1948 were mostly spent or spawning and feeding heavily on caplin. Several weeks later when caplin came to the beaches to spawn in late June and early July some of these fish were caught inshore. A high percentage of fish from the western edge of the Grand Bank and from St. Pierre Bank appears to migrate inshore while from the south-eastern part of the Grand Bank there is very little inshore migration. In the latter half of June when the great inshore migrations of caplin and pursuing cod occur on the east coast of Newfoundland, the cold below-zero layer with temperatures as low as -1.5°C or lower is an intermediate layer over the water deeper than 120-180 fathoms and rests on the bottom at depths from about 10-20 to 120-180 fathoms. The channel separating the south-east Newfoundland coast from the Grand Bank is mostly 60 to 95 fathoms deep and is, except possibly in the shallower bottom parts in early winter, filled with water below -1°C , the greatest volume and the deepest and coldest water, down to -1.6°C in 1950, being near the coast. A similar large volume of cold water below -1°C swings to the east of the bank. At these temperatures below -1°C cod would be expected to die of cold. Cod caught on surface long lines which from the weight of cod sink into these cold waters are reported to freeze. Few or no cod are usually caught either by bait or otter trawl in these temperatures below -1°C and especially the -1.4 to -1.6°C temperatures. The earliest large catches of cod in the St. John's area in May are by surface long-lines set in ten to twenty fathoms, often over the deep cold water. On the occasions when we have detected caplin schools on the echo-sounder in June and July they have been at ten to twenty fathoms in the day time, coming to the surface at night. The cod when they come in after the caplin in June follow them to very shallow water near the beaches where they may sometimes be caught by dipnet during the night. The indications at present, therefore, are that the large June inshore migration of cod forming the basis of the great inshore fishery for cod on the east coast of Newfoundland is an upper layer rather than a bottom migration.

These fish with rare exceptions have all spawned in May and early June, and their migration to the coast in pursuit of caplin is a post-spawning feeding dispersal.

MIGRATION LABRADOR TO THE NORTHERN GRAND BANK

In the area from the southern side of Trinity Bay around the St. John's area to the Burin Peninsula the Channel between the coast and the banks is mostly between 60 and 95 fathoms and generally filled at the bottom with below -1°C water. On the other hand the east coast of Newfoundland from Trinity Bay north and to a lesser extent the coast of Labrador is close to water from 120 to 200 or even occasionally 300 fathoms - water deep enough for warm Atlantic water to exist below the cold layer. Thus cod can spend the winter in suitable temperatures close to shore.

In this area, tagging in Labrador, Englee and Fogo has shown considerable migrations. Judging from early June recaptures in water of 150 fathoms or more, many of these migrations apparently occur during the winter in the deep layer, over the area to the north of the Grand Bank but none of these fish tagged to the north of the Grand Bank have as yet been caught on the bank itself. In considering these migrations along the coastal fringe of the deep water north of the Grand Bank it is worth noting that the offshore area is covered by ice until late spring; there is no commercial fishing although cod are present over a very large area and there is no knowledge of particular spawning areas. Spawning is completed before the late June migration toward shore. The movements appear to be offshore in fall and winter to deep warm water, winter wandering in the deep water to join spawning schools, spawning almost certainly in May and early June and feeding dispersal in the deep warm layer toward the cold water barrier either on the coast or to the north of the Grand Bank with great numbers of the medium sized fish breaking through the cold water layer in pursuit of caplin, entering the warm upper layer and continuing into the shallow inshore water.

On the northern edge of the Grand Bank cod are concentrated in spring and summer in about 100 to 130 fathoms near the cold water barrier plentifully enough for the French and Portuguese trawlers to remain there often from April to November.

Vertebral Counts

The whole east coast of Labrador and Newfoundland area in which access to deep warmer water is relatively easy possesses cod of vertebral count 54.0 to 54.6 with no really significant differences. Some of these schools of cod with vertebral count of 54 or over penetrate as far as St. John's especially during the caplin season in June, July and August. The cod of the deep warm water fringe of the Northern Grand Bank below the cold layer also possesses fish of a high vertebral count, 53.8 to 54.3. There is no barrier between these fish and the north-east coast coastal fish. Both groups spend the winter in the same deep warm layer.

Explorations by the Investigator II in July, 1948, over the Northern Grand Bank revealed great bodies of cod in 100 to 120 fathoms in temperatures of 1.3 to 2.5 C. At this time the northern part of the Grand Bank from 40 to almost 100 fathoms was covered with water below zero centigrade. Since few cod can be caught in this northern portion between 40 and 100 fathoms (except possibly in late autumn and early winter on which there is no information) and the great quantities of cod are to be found at 100 to 120 fathoms or deeper in the warm layer it is apparent that over most of the year at least, a cold water barrier does exist on the northern portion of the Grand Bank. Agreeing with this is the fact that the body of the Grand Bank immediately south of the northern fishing area is populated during the summer time with cod possessing vertebral counts of 52.6 - 52.9 i.e. highly significantly different. With samples of approximately a hundred these cod vertebral counts are significantly different with about a 0.4 difference. These cod of very low vertebral count are related to schools on the south of the bank. These fish appear to retreat southwards to the warmer water to the south of the bank during the winter time. Some of them certainly spawn on the southern part of the Bank in late May and early June, the spent fish moving northward or north-east over the bank as warming proceeds from southwest to north-east in May and June. We consider it likely that many of these cod move northwards in the upper water layers before spawning actually occurs but there is no evidence as yet of this movement.

To the north of the bank where the high vertebral counts exist the slope of the bank is toward the north and therefore it is to be expected that most of these northern cod even if they penetrated the northern part of the bank in the late autumn would retreat to the deep water at the northern edge during winter. Thus the populations so distinct in vertebral count are kept separate and distinct.

About half way down the eastern edge of the Grand Bank approximately in the latitudes 45 to 46 there is, within a very small area of the bank slope, a mixture of cod of significantly distinct high and low vertebral counts. From south to north the vertebral counts are - 52.7, 54.3, 53.8, 52.8, 53.1, 53.9. It is indicated here that northern schools are penetrating southward along the eastern edge of the bank probably in the deeper water and fish from the southern part of the bank are penetrating northward partially at least in the shallow water. The great differences between the vertebral counts indicate the possibility that schools of widely different vertebral counts may exist in the same area without mixing.

On the southern half of the west coast of Newfoundland where tagging indicates that the migration out of the Gulf is in general southward through Cabot Strait rather than northward out of the Strait of Belle Isle, low Gulf vertebral counts (52.7 - 53.0) are also very similar of those at the western corner of the

south coast where so many of these southern west coast fish spend the winter (52.8 - 53.4). Proceeding northward along the west coast there are gradually increasing vertebral counts from 52.7 at Bay of Islands to 53.7 at Port au Choix, to 53.9 - 54.1 just north of Flowers Cove at the southern entrance to the Strait of Belle Isle and 54.2 northward in Domino, Labrador and southward at Englee on the East Coast of Newfoundland outside the mouth of this Strait. There is here, therefore, as in the tagging, an indication that little migration occurs northward out of the Strait of Belle Isle from the southern half of the west coast of Newfoundland but that there is, as is shown by the tagging recaptures, some penetration of east coast fish of high vertebral count inward through the Strait of Belle Isle to the northern third of the west coast.

The channel through the Strait of Belle Isle is at its shallowest cross section only about thirty-five fathoms deep as compared with over 200 fathoms for Cabot Strait. Consequently any movement outward in autumn would probably be early since most cod are to be found deeper than thirty-five fathoms by late autumn and during the winter the whole Strait of Belle Isle would be filled with water below -1 centigrade. There is thus a much shorter period for migration outward through the Strait of Belle Isle, only about 4 months with suitable temperatures along the bottom as compared with 12 months at Cabot Strait.

In the Nova Scotian and southern Gulf areas generally the differences between vertebral counts of neighbouring areas are so little and the overlapping so great that vertebral counts of particular small samples are not of so much assistance in studying the migratory characteristics of the population as in the Newfoundland-Labrador area.

It is evident that tagging of cod thus far on the Atlantic Coast of Canada has been carried out solely with the idea of finding where and when the fish move, leaving the explanation of the cause of movement to chance. It is recommended that in future tagging lengths of the fish be taken, that when possible a full sample of 120 fish taken from the same school as the tagged fish be kept to be examined for spawning condition, for vertebral count and possibly for age and growth. Where feasible the necessary hydrographic work on temperatures and currents, egg-development and egg-distribution studies and investigations of egg and larval drifts should be integrated with the tagging work.

Studies on tag and tagging improvement including methods of obtaining returns especially from foreign ships and countries and the obtaining of better returns after the first year should continue.

The work of finding out where and when fish move is in itself in an unfinished state particularly in the very large Newfoundland area. Also much research is needed to reveal more precisely the times, not certain at present closer than a month, for

offshore and not known at all for inshore, when fish leave the Nova Scotian Bank and inshore areas for the Gulf. Actually by far the highest percentage migration into the Gulf from the offshore banks 4 out of 6 recaptures was from the tagging of only 115 fish on Misaine Bank on March 1, 1937. Two out of four of these Misaine Bank tagged fish were also captured in the central area of the Gulf from which relatively few returns were obtained from tagging on the other offshore banks. Additional tagging on this bank and earlier tagging in all the Nova Scotian Banks would probably give much further information on migration into the Gulf. The autumn spawning cod of the Halifax area could be tagged with profit. Spawning times can be studied with advantage more precisely and in more detail than at present over the whole area.

U.S. Water Transport
Scotian Shelf.

It is possible that with the development of tags which will give equally good returns in succeeding years as in the year of tagging some worthwhile figures on total cod mortality may be obtained. It is necessary to discount figures on mortality obtained in the year of tagging since cod are usually tagged and liberated in areas where heavy fishing is being carried out and many are caught before they can spread to areas of average fishing intensity.

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