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Divisions in Cod Stocks of the Northwest Atlantic
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Introduction

The available information from which divisions in stocks of cod, Gadus morhua L., of the Northwest Atlantic can be deduced consists mainly of vertebral numbers, migratory studies, growth, year-class strength, spawning times and places and time and location of pre-spawning and other concentrations.

Much of this information is unpublished and has been supplied in a general form by various cod investigators so that detailed information is not available. Also, a detailed presentation of vertebral and migratory data etc. is beyond the scope of this paper. Much of the basic information, therefore, will have to be discussed on its face value but in many cases the pattern is clear enough that this method of examination will be sufficient for the present purpose.

The basic vertebral and migratory data leading to hypotheses or beliefs in stock divisions will be presented first and this will be followed by an attempt to unify this material and add other pertinent knowledge for purposes of preparing diagrams of and discussing the divisions in cod stocks.

Figure 1 shows place names and Danish zone divisions for the Greenland area and Fig. 2 (placed between Fig.1&3) the many place names of this paper for the Labrador-Cape cod region.

Figure 3 shows total cod landings from the various ICNAF divisions in 1959. Information on the Canadian Atlantic offshore cod fishery east of Halifax is found in McKenzie (1942) and on the distribution of cod in the Newfoundland inshore fishery, 1947-49, in Templeman (1958). These and the many statistical publications of ICNAF will provide some information on the relative quantities of cod available from certain stocks and areas and will serve to supplement the information provided in the present paper on divisions of cod stocks.

In this paper the word "population" will refer to the cod occupying any defined area at a particular time. The word "stock" will be used to denote more unity in the group with regard to its greater degree of intermingling within itself and considerably less mixing with other groups, or a withdrawal to its own territory during some part of the year, whether for spawning or feeding, etc. A stock is a recognizable unit in which most of the fish have a similar area-occupying and migratory pattern. Along with this partial isolation of a stock from neighbouring stocks there are often other physical differences such as in growth, vertebral numbers, etc.

In addition to published information the author has had the benefit of stock division maps, spawning and other information provided for the Greenland area by Paul Hansen, for Subarea 4 by Yves Jean and for the Gulf of Maine by Albert C. Jensen. He has also through W. R. Martin been able to consult a very great amount of original data on cod vertebral averages (each sample usually about 100 fish) gathered by R.A. McKenzie of the St. Andrews Station during the period 1933-41 and forming the basis of the paper by McKenzie and Smith (1955). Much unpublished data from the St. John's Station on cod vertebral averages, cod spawning and the results of tagging experiments at the St. John's Station have also been used.

Vertebral numbers

Introduction

Apart from possible genetic differences, a discussion of which is impractical at the present time, and although any factor affecting the rate of egg and possibly early larval development can have an important effect on vertebral number, differences in vertebral averages of cod in the North Atlantic are apparently produced chiefly by different temperatures in the upper layers of water during early development. High temperatures produce low and low temperatures high vertebral numbers. This in turn is related to the time of spawning in relation to the area and the year. Consequently stocks having spawning times related to similar surface temperatures may have similar vertebral numbers. Different stocks may have similar vertebral averages but adult stocks having very different vertebral numbers cannot be the same stocks.

Consequently vertebral averages can often give the broad picture of stocks which either must be or are likely to be essentially distinct without much intermingling, and stocks which may be the same or may intermingle widely but are not necessarily one stock and require other methods of attack to define the stock divisions.

As a rule the discussion of the reasons for vertebral differences is outside the scope of the present paper.

Although we have found no statement on the matter in Schmidt (1930) and Hansen (1949) it is evident by comparing Schmidt's cod vertebral averages for the Northwest Atlantic with our more recent vertebral averages that Schmidt (and Hansen) followed the common European practice of including the urostylar half-vertebra as a vertebra. We do not include the urostylar half-vertebra in our vertebral counts and consequently in using Schmidt's and Hansen's vertebral averages we have subtracted 1 vertebra in each case.

Greenland and Iceland

Vertebral numbers from cod collected between 1924 and 1937 (Schmidt, 1930; Hansen, 1949) show that, omitting some local fjord stocks, vertebral averages off West Greenland increase from south to north (in this period 52.11-52.42 south of Frederikshaab to 52.31-52.86 from Godthaab to Sukkertoppen and 52.67-52.93 in the Christianshaab to Disko area). The vertebral averages at East Greenland (Angmagssalik), 51.93-52.14 (if we combine Schmidt's small sample with his large one as he has done in his chart), are lower than those of southern W. Greenland but still higher than West Iceland, 51.29-51.96. The vertebral numbers, therefore, indicate the lack of complete intermingling between the northern and southern West Greenland stocks and between southern West Greenland and East Greenland and West Iceland stocks. They also indicate the possibility of more intermingling between southern W. Greenland, and still more East Greenland stocks, with West Iceland stocks than between the stocks of the latter two areas and those of northern W. Greenland. There are also, at least in certain years, strong drifts of cod larvae from Iceland to Greenland (Taning, 1934, 1937; Hansen, 1949).

Local fjord stocks may have widely different vertebral averages from those of the neighbouring outside stocks. The single vertebral average from Ikertok Fjord (53.01) is the highest and the single average from Kangia Fjord (51.95) the lowest in West Greenland.

Greenland and Labrador

On the Canadian side cod do not extend as far north as in West Greenland, the most northerly individuals found in the A.T. Cameron 1959 cruise from off Cape Dyer, Baffin Island (Lat. $66^{\circ}47'N$) southwards being at 125 and 150-160 fathoms (230 and 275-295 m) at Lat. $63^{\circ}N$ and the first significant but small numbers off Frobisher Bay at Lat. $62^{\circ}14'$ to $62^{\circ}20'N$ in 150-200 fathoms (275-365 m) and in Ungava Bay (Templeman, 1960).

From the area of central and southern West Greenland which are the most likely regions of immigration of cod from Greenland to the Baffin Island-Labrador area the vertebral averages are approximately 2 vertebrae higher in Labrador than in West Greenland. Thus it is unlikely, as both cod populations are large, that there is any very considerable migration of adult cod from Greenland to Labrador or vice versa. This has been noted previously by Schmidt (1930), Thompson (1943) and Hansen (1949).

Labrador-Newfoundland region

Between northern Labrador and the southern part of the east coast of Newfoundland as far as St. John's, both coastal and offshore vertebral averages in different samples usually range between 53.8 and 54.6 and vertebral averages as high as 54.4 may be found south as well as north. There is consequently no reason, based on vertebral numbers, for believing that there are basically different stocks of cod in this large area. Moreover, in the deep water over or close to 100 fathoms (185 m) on the northern and northeastern parts of the Grand Bank there are large shoals of cod with vertebral numbers very similar (53.8-54.3) to those of the coastal and offshore populations of the east coast of Newfoundland and Labrador. Again, with some slight admixture from local and shallower-water Grand Bank stocks, these stocks may be considered to be basically part of the northern high-vertebral-number stocks.

The plateau area of the Grand Bank shallower than and enclosed by the 50-fathom (90-m) contour together with the deeper areas, also, to the southward including the southwestern slope and the southern two-thirds of the eastern slope are occupied by cod with vertebral averages between 52.2 and 53.3 with almost all the averages below 53. There is a small area of mixture of the northern and southern types lying near the 100-fathom (185-m) contour on the eastern slope of the Grand Bank between $45^{\circ}30'$ and $46^{\circ}N$.

The vertebral numbers of Flemish Cap cod during the summer are on the average slightly lower than those on the neighbouring north-east corner of the Grand Bank from which Flemish Cap is separated by the Flemish Channel over 600 fathoms (1,100 m) deep.

Cod on or near the northwestern border of the 50-fathom (90-m) contour of the Grand Bank and in the Avalon Channel between the bank and the coast show vertebral averages of 53.2-53.7, usually intermediate between the generally-below-53 vertebral number of the surface of the bank populations and the vertebral averages of 53.9-54.2 usually found on the northern part of the Avalon Peninsula and near the 100-fathom (185-m) contour of the northwestern Grand Bank, but very much like the vertebral averages of the southern part of the Avalon Peninsula.

Farther west the vertebral averages of St. Pierre Bank are variable, between 52.7 and 53.7, but usually 53.3 or lower, overlapping the 53.0-53.7 averages of the neighbouring coastal Fortune Bay, Placentia Bay, Burgeo Bank and Ramea areas but with some averages lower than in these latter areas.

Gulf of St. Lawrence

In the Gulf of St. Lawrence on the Newfoundland side vertebral averages are usually below 53 to beyond the southern entrance of the Strait of Belle Isle where high vertebral averages (53.9-54.5) similar to those of the east coast of Newfoundland and southern Labrador are encountered. There is, however, 1 record of a 53.7 vertebral average together with another of 52.7 from off Port au Choix near the northern end of the deep Esquiman Channel which suggests the possibility that some schools of east coast cod pass somewhat farther into the Gulf than the Strait of Belle Isle.

A vertebral average of 52.4 on Centre Bank in the middle of the Strait of Belle Isle and vertebral averages between 52.4 and 53.0 at the western entrance to this Strait on its northern side show no evidence of penetration of high-vertebral-count Labrador cod inward on the northern side of the Strait of Belle Isle. On the North Shore of the Gulf of St. Lawrence west of the Strait of Belle Isle vertebral averages (from the offshore part of the coastal shelf) rise somewhat and lie between 53.10-53.70, enough higher than the 52.3-53.0 averages of the west coast of Newfoundland south of Port au Choix to suggest some separation between the stocks.

Somewhat similar vertebral averages to those of the North Shore of the Gulf (usually 53.0-53.6) are typical of most samples from the Gaspé area and in the vicinity of the 100-fathom (185-m) contour marking the southern border of the Laurentian Channel as far as off eastern Cape Breton, and also Banquereau.

Lower vertebral averages, however, of 52.1-52.8, are generally present in the Gulf of St. Lawrence south of the Laurentian Channel over the central and southern areas of the Magdalen Shallows and some samples in this vertebral range occur in Bay Chaleur and off its mouth while others in the Bay Chaleur area, especially near the northern entrance to the bay, are in the lower part of the range of the Gaspé type.

The very large numbers of vertebral averages, all between 52.0 and 52.8 and almost all between 52.2 and 52.6, taken by McKenzie almost entirely from June to August, mainly north and west of Prince Edward Island and near the Magdalen Islands with a single average from each of Bradelle and Orphan Banks, indicate that these Magdalen Shallows cod are essentially a separate stock from that near Gaspé (or a number of stocks related to the various banks and island areas).

The cod population north of the Gaspé Peninsula from Cape Gaspé west possesses high vertebral averages between 53.0 and 53.7 (and usually 53.3-53.6) in 10 averages by McKenzie. This population with slightly lessened vertebral numbers, 52.9-53.2, in McKenzie's original averages extends southward to near Cape d'Espoir and outside the mouth of Bay Chaleur while the population in Bay Chaleur has vertebral averages mainly but not entirely, in McKenzie's original records, between 52.4 and 52.8. Presumably outside the mouth of the bay is an area of intermingling between the Gaspé and Bay Chaleur stocks with the Gaspé type predominating.

A few vertebral averages taken by the St. John's Station in random samples of southern Gulf cod in 1950-51, about 10-15 years after McKenzie's samples, agree generally with McKenzie's results: 2 samples on Bradelle Bank west of the Magdalen Islands, 52.8; 1 at the mouth of Bay Chaleur, 52.5; 3 off Bonaventure Island, Gaspé, 52.9, 53.0 and 53.1; and 2 farther west off Cape Gaspé, 52.9 and 53.4.

The main cod population of the Gulf, quantitatively, is the Gaspé-Bay Chaleur population at and off the mouth of Bay Chaleur from northern New Brunswick to Gaspé and northward around the Gaspé Peninsula.

The western Cape Breton population has vertebral averages (in 11 averages in June-August by McKenzie) of 52.4-53.0 (8 averages between 52.8 and 53.0), slightly but definitely higher than those of the neighbouring Prince Edward Island and Magdalen Islands and hence has the vertebral characteristics of a population somewhat separate from the populations of these 2 areas.

Nova Scotian Shelf

For the Scotian Shelf the usual 52.9-53.6 vertebral averages of the northern part of the Shelf are similar to those of the cod populations of the Gaspé-southern contour Laurentian Channel populations. Across the Laurentian Channel the vertebral range of the St. Pierre Bank population, 52.7-53.7, includes the range of the northern Scotian Shelf vertebral stock but has a wider range of vertebral averages.

Passing southward along the Scotian Shelf the vertebral averages gradually decline. The Sable Island Bank-Emerald Bank population is slightly lower in vertebral number than the Banquereau population. South of the Scotian Gulf there is a continuing slow decline in vertebral numbers, accentuated south of Lockeport so that from Cape Sable west to the Bay of Fundy the usual range is between 52.3-52.7.

In the northern Scotian Shelf area McKenzie and Smith (1955) noted that vertebral averages increase off Cape Breton during summer months and on the Nova Scotian banks during winter months indicating a northerly (westerly) movement of higher-vertebral-count fish than the resident stock of these areas in summer and a southerly (easterly) movement in winter.

Gulf of Maine

For the Gulf of Maine there is little information. Judging by the few averages available the vertebral averages on the northeastern tip of Georges Bank, 2 samples each 52.7, are not much different from those on the neighbouring Browns Bank on the Nova Scotian Shelf, 52.5-53.0. In the western coastal area a vertebral average of 53.0 has been recorded by Schmidt (1930) for Mt. Desert I. Schmidt's Nantucket Shoals vertebral average of 51.9 is lower than any of the vertebral averages from the Gulf of Maine and evidently represents a different stock from those in the coastal Maine area and on northeastern Georges Bank.

Additional stocks

In addition to the large stocks of cod providing the great bulk of the fishery and whose vertebral numbers have already been discussed, there are certain small stocks which due to their isolated spawning or spawning-time situations have vertebral numbers widely different from those of neighbouring stocks. For example the autumn-spawning cod of Halifax Harbour and the neighbouring St. Margaret Bay (McKenzie, 1940) had low vertebral averages, 51.6-51.8 compared with 52.9 for spring spawners caught in the same general area off Halifax.

In the landlocked Ogac Lake located at 62°52'N and 67°21'W at the head of Ney Inlet on the southern side of Frobisher Bay on Baffin Island there is a relict population of cod with a very low vertebral average of 52.1 (in information supplied by Ian A. McLaren of the Fisheries Research Board of Canada Arctic Unit, Montreal, Que.,

sample size, 121 fish) compared with the vertebral averages of close to or over 54 found in the open-sea cod population just southward of this lake.

Similar to this but less extreme is Hansen's (1949) highest vertebral average for Greenland, 53.01, from Ikertok Fjord, from small fish presumed to be produced from spawning in the fjord.

Doubtless many other small stocks will be found which, spawning in isolated locations or in different seasons and surface temperatures from the main stock of an area, will be found to have vertebral numbers distinctly different from the main stock of the area.

Caution in dealing with vertebral numbers

Extreme caution must be exercised in combining vertebral samples. An adequate random sample of 100 or more fish should be used as a basic unit, and in areas where 2 stocks overlap as on the eastern edge of the Grand Bank what appear to be separate schools of the 2 stocks may sometimes be found, for example, proceeding southward on the eastern slope of the Grand Bank, vertebral averages of (nautical miles between adjacent averages in parentheses) 53.9, (14) 53.1 and 52.8, (8) 53.8, (24) 54.3, (29) 52.7 have been found in our samples.

Great care must be taken in combining samples from different depths because, apart from the usual size and year-class differences, the deep-water stock may be a separate stock from that on the top of the bank, migrating into the area from elsewhere.

Thus, on the northern fringe of the Grand Bank the fish in the deep water in summer are usually of the northern high-vertebral-average stock, 53.8-54.4, whereas in shallower water, 15-70 nautical miles (30-130 km) distant, vertebral averages as low as 53.0-53.1 are found. A similar but not so clear-cut example is seen in the many low vertebral averages of Bay Chaleur and the higher but variable vertebral averages of cod from the nearby Gaspé area and in part at least from another stock.

At the southern entrance to the Strait of Belle Isle on the Newfoundland side vertebral averages of 54.1-54.5 from cod of the Newfoundland east coast stock and averages as low as 52.4-52.7 for cod of the west coast Newfoundland vertebral stock may be as close as 10 nautical miles apart, or for different years plotted on the same map, may overlap.

McKenzie (1939) says that off eastern Cape Breton in the deeper water 60 or 70 fathoms (110-130 m) and deeper, cod possess vertebral averages of 53.2 or higher (i.e. the Gaspé-southern border Laurentian Channel-Banquereau vertebral type) while those taken from the shallow inshore waters of eastern Cape Breton as well as those of southern and northwestern Cape Breton have vertebral averages of 52.6-52.8.

Combining any of these groups of which many more examples could be given will often hide a great part of the data.

Migration

Introduction

Tagging experiments produce evidence on the dispersal of spawning and feeding populations of cod and on the amount of intermingling with neighbouring populations. A number of tagging designs are worthwhile. A population of cod is often closest to being a well-defined stock when it is concentrated for spawning. The reduction of feeding at this time reduces the tendency for dispersal and because over most of the area January-June spawning predominates, the colder water and the winter descent into deeper water also promote concentration of the stocks. Tagging of these pre-spawning and spawning concentrations allows a study of the amount of intermingling with other spawning stocks in the summer feeding dispersal. On the other hand, tagging during the summer feeding dispersal when many stocks are intermingled should show to which spawning stocks these feeding stocks are related. These ideals are seldom attained. Most tagging has been done in the months of June-September when temperature conditions are favourable for the tagger but often not for the fish. At this time cod are readily caught in shallow water which is a favourable factor but the high temperatures of the latter part of the summer and early autumn are detrimental to survival. Over much of the northern part of the area the amount of winter fishing on the spawning grounds is negligible due to ice and weather conditions and hence the tagged fish are not caught in the spawning areas.

In an area such as the southern part of the Gulf of St. Lawrence, for example, the big fishery is near Gaspé-northern New Brunswick in summer and on the southern edge of the Laurentian Channel off eastern Cape Breton in early spring. Most tags from Gulf types are therefore likely to be returned from these areas. However, if great concentrations of cod existed throughout many months elsewhere in the Gulf they would very likely be fished. On the other hand returns are somewhat lower than they should be from areas of low concentration which are only fished lightly if at all.

In discussing tagging papers we are usually handicapped by lack of knowledge of whether the relative lack of migration is due to the immaturity of the fish or to the fish belonging to a resident stock. Much of the tagging has for the present to be accepted on its face value and we may make some errors in discussing the mobility of the stock. In the Newfoundland tagging we have removed some of the difficulty by tagging only cod 50 cm and over in length. Much of our discussion also refers to the years after the tagging year and thus more of the fish included in the discussion are likely to be mature.

Greenland

Hansen (1949) has summarized the results of cod tagging in Greenland from 1924-39 and Hansen, Jensen and Tåning (1935) in more detail the tagging from 1924-33.

According to Hansen (1949) the great spawning migrations of the cod from West Greenland to Iceland take place mainly from the southern zones. For the 2 northern Zones I and II (Fig. 1) 11.4% of all recaptures from the 1924-39 tagging were made in Iceland. The percentage recaptured in Iceland increases slowly southward to 12.9 in Zone III, 21.8 in Zone IV, 25.9 in Zone V and 34.1 in Zone VII (but only 6.5 in Zone VI, including only Godthaab Fjord), but increases rapidly and abruptly in Zones VIII and IX, the southernmost districts of West Greenland, to 73.5 and 70.3 respectively (Fig. 1). Excluding Zone III where many fish were tagged in fjords and Zone VI which is entirely a fjord

area, both fjord areas having intensive fisheries and consequently high recapture rates, total recaptures in Greenland are fairly uniform in the northern Zones I-VII (3.9-5.5% of the numbers tagged) but lower for the 2 southern Zones VIII and IX (1.6 and 3.2%). For the recaptures at Iceland the reverse is the case, low but rising slightly southwards for the northern Zones I-VII (0.4-2.0%) and higher for Zones VIII and IX (4.4 and 7.5%).

More recently Paul Hansen (personal letter, February 1961) says that from the tagging experiments 1924-39 and since 1946 there is evidence of a strong interchange of cod between the banks in ICNAF Divisions 1A, 1B, 1C and 1D of Fig. 3 and N in Fig. 4 (approximately Zones I-VII of Fig. 1) whereas very few migrations in each direction have been recorded between these banks and the southern area, ICNAF Divisions 1E and 1F of Fig. 3 and S in Fig. 4 (approximately Zones VIII and IX of Fig. 1). In the cod-tagging experiments of 1929-39 a large spawning migration to Iceland occurred mainly from Divisions 1E and 1F. In more recent cod taggings from 1946 to the present time very few recaptures from Iceland have been reported compared with the 1929-39 period and cod tagged in Divisions 1A-1D and Divisions 1E-1F are reported in nearly equal numbers.

Rasmussen's (1958) summary of the results of Norwegian cod tagging, 1948-57, in West Greenland waters recorded many results very similar to those of Hansen above. From the Norwegian tagging, carried out in the Holsteinsborg Deep just north of Lat. 66°N from 1953-56, most cod were recaptured on the southern banks between Lat. 62°N and 65°N in May and June and almost entirely northward between 66° and 68°N in August-September. Of 227 returns only 2 were from West Greenland south of 62°N (61-62°N), 7 from Iceland and 1 from Newfoundland (the Grand Bank). Thus Rasmussen believes that the West Greenland area north of 62°N is dominated by a true West Greenland stock of cod with a more or less closed migration pattern.

Trans-Labrador Sea movements

Taning (1934) reports the capture in northern Newfoundland in 1933 of a cod tagged in the Westmanna Islands off South Iceland in 1931. Presumably this cod reached Newfoundland via West Greenland. Hansen (1949) says that so far no cod marked in West Greenland has been reported from Newfoundland. In 227 returns from Norwegian cod tagging in West Greenland in 1953-56 one was from Newfoundland (Rasmussen, 1958). This individual, tagged on Dana Bank in June 1955 was recaptured April 1956 on the Grand Bank (Rasmussen, 1957). Paul Hansen (Feb. 27, 1962) has supplied a list, prepared by Mr. S.A. Horsted, of 7 recaptures in the Newfoundland area, 1954-59, from the Greenland Administration's cod tagging in West Greenland, 1951-59.

In the other direction Thompson (1943) in 984 returns from Newfoundland and Labrador tagging had only 1 return from West Greenland from a cod tagged at Indian Islands, Labrador on July 7, 1934 and recaptured in August 1938 just south of Disko Bay.

In our more recent tagging, from 670 recoveries (Templeman and Fleming, 1962) there were no recoveries in Greenland, but from more than 5,000 recoveries from 23,000 cod tagged during 1950-55 in the Newfoundland area by the St. John's Station there have been 2 recaptures reported from West Greenland, 1 from Greenland (presumably West Greenland), 1 from the North Sea and 2 from the Barents Sea.

It is often impossible to authenticate these distant recaptures and since trawlers move rapidly between the Newfoundland, Labrador and West Greenland areas and more intermittently to the eastern areas such as the Barents Sea the possibility of error in reporting is great. At least some of the recorded movements to and from West Greenland are probably authentic.

Labrador

For this area, ICNAF Subarea 2, Thompson (1943) has reported on 984 returns from 8,651 cod tagged in 1933-37, and Templeman and Fleming (1962) on 670 returns from 4,200 cod tagged in 1947-48. Additional unpublished information is available at the St. John's Biological Station from cod tagging in 1950-51 and in 1954-55.

Cod tagged inshore in southern Labrador south of Hamilton Inlet both in tagging by Thompson and Templeman and Fleming showed most of the long-distance recaptures to be southward along the east coast of Newfoundland. There appears to be no barrier to movement and from the depth of recaptures in the spring it was indicated that most of these long southward migrations were during the winter in the deep warm water beneath the below-0°C intermediate layer.

From cod tagged in northern Labrador at Nutak in 1948 (Templeman and Fleming, 1962) very few recaptures were reported, 1 fish only migrating as far as southern Labrador and none south of Labrador. In the opposite direction, apart from fish tagged near the northern extremity of Newfoundland, cod tagged in the Newfoundland coastal and bank areas east, south and west only rarely migrate to Labrador (none in Thompson, 1943; and Templeman and Fleming, 1962). The reason for this is probably that cod in this area move into deep water and have a tendency to migrate southward over winter hence bringing some Labrador fish to Newfoundland while the early summer movement of coastal fish though pelagic is most likely toward the coast following schools of capelin. The coastal break at the Strait of Belle Isle leading Newfoundland fish into this Strait close to the coast on the southern side tends to interfere with movement of Newfoundland coastal fish to Labrador during their summer feeding migration.

Newfoundland east coast

Tagging at Raleigh at the northern extremity of Newfoundland in July 1934 (Thompson, 1943) showed migration northward along the Labrador coast, southward on the east coast of Newfoundland and some movement into the Gulf of St. Lawrence on the southern side of the Strait of Belle Isle.

Tagging at Englee on the northeast coast of Newfoundland about 60 nautical miles (110 km) south of Raleigh in September 1947 (Templeman and Fleming, 1962), resulted in intermediate to long movements southward, mainly in the deep water over winter and shorter movements northward with some movement into the Gulf of St. Lawrence along the southern side of the Strait of Belle Isle.

Cod tagging at Fogo on the northeast coast of Newfoundland, August 1950 (St. John's Station unpublished data) with 447 returns showed that considerably more than half of the fish, even after 2 years at liberty, returned during the summer to the tagging area or areas only a few miles away. There was significant movement northward along the Newfoundland coast and some entrance into the Strait of Belle Isle where there were 7 recaptures on the southern side but only 2 on the northern side of the Strait and only 1 in southern Labrador. There was an equally significant coastal movement southward but not beyond St. Mary's Bay on the southern side of the Avalon Peninsula. Some fish, but a much smaller proportion than from the St. John's tagging, moved over winter to the slopes of northwestern Grand Bank where they were caught in March-June.

Tagging at Bay Bulls, 16 nautical miles (30 km) south of St. John's in 1933-37 (Thompson, 1943) and at St. John's, 1948 (Templeman and Fleming, 1962) gave migrations all along the east coast of Newfoundland as far north as the entrance to the Strait of Belle Isle but no migration to Labrador. There were southward and westward coastal movements only as far as the eastern shores of the Burin Peninsula. An occasional fish migrated to the western and northwestern edges and slopes of the Grand Bank and southwest to the Haddock and Halibut Channels. Tagging at St. John's, August-September 1950 (St. John's Station unpublished data) gave the same coastal migrations as the previous tagging except that 2 out of 784 returns were from southern Labrador (1 inshore, 1 offshore) and 1 was on the south coast of Newfoundland west of the Burin Peninsula. Almost all the many offshore recaptures from this latter tagging were in March-June on the northwestern slope of the Grand Bank between Lat. $46^{\circ}20'$ and $48^{\circ}40'N$. It appears that by far the greatest movement in winter from the St. John's region is toward the northwestern slope of the Grand Bank. Judging also by the large number of northward coastal captures in the year following the tagging year there is likely to be some over-winter and spring migration northward in the deep water. Also it is possible to take small numbers of cod throughout the winter in the deep water of the Avalon Channel several to 20 or more miles off St. John's and Bay Bulls. Thus all the cod do not move during winter to the slopes and channels of the neighbouring banks.

In migrating pelagically in the surface layers toward the coast in June there is a much-greater-than-random return to the general area of tagging but a great deal of movement also following the capelin more directly toward shore.

Grand Bank

Tagging on the southern Grand Bank in July 1935 (Thompson, 1943) and in May 1947 (Templeman and Fleming, 1962) gave some movement inshore to the southern part of the Avalon Peninsula and the Burin Peninsula, mainly from the fish tagged on the northerly half of the southwestern slope of the bank, but most fish migrated eastward, northward or north-westward to occupy the less-than-50-fathom (90-m) area of the bank during the late spring and summer.

Tagging on the northwestern slope of the Grand Bank at about $46^{\circ}30'N$ on June 4-5, 1948 (Templeman and Fleming, 1962) gave mainly inshore recoveries entirely from the eastern part of the Avalon Peninsula in the year of tagging and coastal migrations as far northward as Notre Dame Bay in ensuing years. There was significant summer movement also to the northern slope of the Grand Bank.

Additional taggings in the same area of the NW slope and in the Avalon Channel at about $47^{\circ}N$ about half-way between the Avalon Peninsula and the Grand Bank on April 12-17, 1951 (unpublished data, St. John's Station) gave inshore recoveries mainly from the Avalon Peninsula but several as far as the Bonavista Peninsula and Cape Freels on the east coast of Newfoundland. Most of the remaining returns were from neighbouring areas to the tagging area in the Avalon Channel and on the western Grand Bank in April-June.

St. Pierre Bank

Tagging on St. Pierre Bank (southern plateau, Thompson, 1943; southwestern slope at about $45^{\circ}20'N$, June 8, 1947, Templeman and Fleming, 1962; and on the northern plateau from May 20-June 2, 1954, unpublished data, St. John's Station) gave recoveries, apart from large numbers on the bank itself, chiefly in the inshore area to the northeast, mainly from Hermitage Bay and the Burin Peninsula to the Avalon Peninsula south of St. John's. A very few recoveries were from the

western half of the south coast of Newfoundland and from the Gulf of St. Lawrence as far as the Port au Port Peninsula on the west coast of Newfoundland and from the Scotian Shelf and the Grand Bank. (This assessment depends largely on the unpublished results of the 1954 tagging from which much larger numbers of returns were obtained than from the 2 previous taggings).

Newfoundland south coast

Tagging at Fortune in June-July 1935 (Thompson, 1943) on the western side and at Burin and Corbin from June 19 to July 10, 1948 (Templeman and Fleming, 1962) on the eastern side of the Burin Peninsula produced recaptures along the south coast of Newfoundland both east and west of the tagging localities, but not in the Gulf of St. Lawrence, and along the whole east coast of Newfoundland with only a few fish passing northward beyond the Avalon Peninsula. Some fish moved over winter to the Halibut and Haddock Channels and some occasionally to the northwestern Grand Bank.

Burgeo Bank

Tagging on Burgeo Bank, April 22-May 14, 1954 (unpublished data, St. John's Station), apart from the large numbers caught on the bank itself, gave returns chiefly between May and September and mainly from the coastal region from Hermitage Bay to Cabot Strait. There were smaller numbers of returns from the west coast of Newfoundland and from the eastern part of the south coast of Newfoundland as far as the Avalon Peninsula. There were also small numbers of returns, but more than usual from taggings in the Newfoundland area, from across the Laurentian Channel and the other deep channels of the Gulf of St. Lawrence from fish caught on the southern and western parts of the Gulf of St. Lawrence and on the Scotian Shelf. There were a few returns from St. Pierre Bank and occasional Grand Bank returns.

Newfoundland west coast

Tagging off Port au Port in July and September 1934 and 1935 (Thompson, 1943) and off Bay of Islands on Oct. 7-20, 1948 (Templeman and Fleming, 1962) gave some winter but mainly March-April returns from outside the Gulf of St. Lawrence along the western part of the south coast of Newfoundland. The farthest eastward recovery was from west of the mouth of Hermitage Bay, and very few fish, 1 from each tagging, were recovered from Burgeo Bank and none from St. Pierre Bank. The recaptures and the decline of the fishery indicated that by late April, May and June the cod were migrating northward again along the west coast of Newfoundland.

Trans-Laurentian Channel movements

In 984 recoveries of cod tagged in the Newfoundland area (Thompson, 1943) only 2 trans-Laurentian Channel migrants were reported, to Banquereau and Sable Island Bank from St. Pierre Bank and Fortune respectively.

Templeman and Fleming (1962) in 670 recoveries from cod tagged in the Newfoundland area also had 2 recoveries from across the Laurentian Channel to the Scotian Shelf, 1 from tagging at Port au Port on the west coast of Newfoundland and 1 from the southern Grand Bank.

Out of 2,200 recoveries of cod tagged between the Laurentian and the Fundian Channels (McKenzie, 1956) there were 33 trans-Laurentian Channel migrants to the Newfoundland area. Northward migration across the Channel naturally occurred more frequently from the taggings nearest the Channel.

McCracken (1957) in 277 recoveries from tagging at Louisbourg near the southern edge of the Laurentian Channel had 3 trans-channel migrants to the Newfoundland area, whereas in 215 recoveries from tagging a little farther south at Canso there were no returns from the Newfoundland area.

Out of 1,022 recoveries of cod tagged in northern New Brunswick in June-September 1955-56 (McCracken, 1959) 18 returns came from across the Laurentian Channel to the Newfoundland side between Hermitage Bay and the northern slope of St. Pierre Bank and Cape St. George.

From cod tagged at the Magdalen Islands in July 1957 and May 1958, Martin (1959) in his diagrams shows, out of 185 recoveries, 5 from across the Laurentian Channel in the Newfoundland area between Fortune Bay and Bay of Islands. Crossings of the Laurentian Channel, therefore, are chiefly from populations bordering the Channel, and occur in only small numbers.

Gulf of St. Lawrence south of the Laurentian Channel

On the whole the recoveries from tagging in the Gulf of St. Lawrence (McKenzie, 1956) support the hypothesis that there is at least 1 Magdalen Shallows stock of which in summer most of the same individuals year after year are separate from the Gaspé stock but with some mixing in and off Bay Chaleur. This hypothesis is supported by the tagging off Naufrage, P.E.I. in August 1940; off Ellerslie, P.E.I. from July to November 1930-36; on the eastern edge of Bradelle Bank, August 6-7, 1936; and off North Point, P.E.I. and west of Bradelle Bank, August 5 and 8, 1936. The only southern Gulf of St. Lawrence summer tagging in McKenzie's paper showing an unusual amount of intermingling with the Gaspé fish is that off Alberton, P.E.I. in July 1939 (McKenzie's fig. 42). It may be significant that in this year (McKenzie, 1939) during the spring migration the higher-vertebral-count Banquereau-Gaspé cod passed through the eastern Cape Breton area in the shallower water instead of the usual migration track in offshore waters over 60 fathoms (110 m) deep. It is possible that these cod went pelagically south of the Magdalen Islands instead of north and thus mingled with the Alberton population.

Almost all the cod entering the Gulf of St. Lawrence from tagging on Banquereau and eastern Sable Island Bank (McKenzie, 1956) were caught near the Gaspé Peninsula and north of Cape Breton Island at the entrance to the Gulf. Of 4 Gulf recoveries from cod tagged on Misaine Bank, however, 2 were caught in the Magdalen Shallows area, 1 in Bay Chaleur and 1 at Gaspé.

Recent tagging (McCracken, 1959), from June to September, mainly in or close to the mouth of Bay Chaleur gave almost all recaptures in winter on the southern edge of the Laurentian Channel, mainly about the 100-fathom (185-m) depth, in the region from Bird Rocks but chiefly St. Paul's Island to north of Misaine Bank with a few recaptures from eastern Banquereau. In summer these fish were concentrated near the area of tagging in and off Bay Chaleur and northern New Brunswick and southern Gaspé. There were not many captures elsewhere in the Gulf, a few north of the Gaspé Peninsula and around the Magdalen Islands and very few near Prince Edward Island.

Tagging at the Magdalen Islands in July (Martin, 1959) gave the same winter distribution as the Bay Chaleur-northern New Brunswick tagged fish. In the summer of the year after tagging, recoveries south of the Laurentian Channel, according to Martin's diagram, were Gaspé, 8; Orphan Bank, 6; northern New Brunswick, 3; Prince Edward Island, 1; Magdalen Islands, 12. Thus, although movements to Gaspé are

significant, the large proportion recovered in the year after tagging in the Magdalen Islands area is in great contrast to the very small proportion of recoveries in this area, from McCracken's tagging off and near the mouth of Bay Chaleur (McCracken, 1959, fig. 2); 16 in the Magdalen Islands area compared with 293 in the vicinity of the tagging areas off southern Gaspé and northern New Brunswick, for a year after the tagging year.

This Magdalen Islands summer stock therefore has some of the characteristics of a local stock.

Tagging off Cheticamp, on the western side of Cape Breton Island in July 1937 (McKenzie, 1956, fig. 38) gave in the years after the tagging year the following returns from Gulf of St. Lawrence: 4 from Gaspé, 1 from the Magdalen Islands and 14 from near Cheticamp. Again this western Cape Breton stock is essentially a local stock with (allowing for the lack of fishing along the slopes of the Laurentian Channel during the period of McKenzie's tagging) probably a strong movement out of the Gulf in winter and return in spring.

The earlier Gulf of St. Lawrence tagging in 1930-36 (McKenzie, 1956) showed very little evidence of the strong outward winter migration from the Gulf of St. Lawrence because no large deep-water winter fish existed at that time on the slope of the Laurentian Channel at the southern entrance to the Gulf. Martin (MS, 1961) from winter compared with summer otter-trawling surveys showed that most commercial-size cod had migrated outward from the southern Gulf by January and were concentrated in greatest numbers between 100-125 fathoms (185-230 m) at bottom temperatures of 2 to 4°C along the slope of the Laurentian Channel at the southern entrance to the Gulf of St. Lawrence off St. Paul's Island-Sydney Bight. These surveys, however, also showed that small immature cod of pre-commercial sizes were present in small numbers in winter off northern New Brunswick and Gaspé and that very small cod of the 0 and 1 age-groups were still present in shallow water off Shippegan Island in January at bottom temperatures of -1°C and lower.

Martin (MS, 1961) reported on the movements of cod tagged in 80 fathoms (145 m) off Sydney Bight in early February 1960. Of 52 recoveries from June to December 1960, 50 were taken from the western Gulf of St. Lawrence, mainly off northern New Brunswick and Gaspé. It would be interesting to tag at various depths and localities along the winter distribution of the Gulf cod between Bird Rocks and Misaine Bank to find if any of the smaller Gulf stocks related to other summering areas are to some degree localized in their winter distribution.

Scotian Shelf

The following notes are after McKenzie (1956) and refer to cod taggings in the years 1935-38: cod tagged at Misaine Bank March 1-2, and northern and eastern Banquereau April 18-20, showed a fairly large percentage of the migrants (apart from those captured near the tagging area) recaptured in the Gulf of St. Lawrence (especially in the Gaspé area), or near northeastern Cape Breton probably on their way to and from the Gulf. Tagging on eastern Sable Island Bank, March 28-April 6, showed less but still significant movement to the Gaspé region of the Gulf. Small numbers of cod tagged on Banquereau April 23-26, April 30-May 3 and larger numbers tagged on May 4-5 and May 28-29 and cod tagged on Sable Island Bank April 20 and May 30 and on or near Middle Ground north of Sable Island Bank on May 13 and June 15-29 produced little or no migration into the Gulf - none beyond the eastern perimeter of the Gulf. Tagging south of Emerald Bank March 5-26,

gave returns mainly from the neighbouring southwestern half of Sable Island Bank with some spreading farther northward, especially in summer.

From both Banquereau and Sable Island Bank some cod migrated in summer to the neighbouring outer coast of Nova Scotia. These cod could either be coastal cod which had spent the winter on these banks or bank cod on feeding dispersal after spawning. Probably both of these alternatives occur.

Cod tagged mainly in May-September in the inshore areas of Nova Scotia, at St. Mary Bank, and near Seal Island, Shelburne, Lunenburg, Halifax, Jeddore Rock to Egg Island, Canso and Glace Bay produced recaptures mainly within a few miles of the tagging areas in ensuing years, with some intermingling with adjacent populations and some seasonal movement, offshore in winter and return in summer, between the Halifax-Glace Bay area and the neighbouring offshore banks. There was a little scattering to the Gulf of St. Lawrence and Newfoundland regions. Movement to the offshore banks in winter increased from south to north.

Similarly tagging off Lockeport, Nova Scotia, May-October 1953, off Louisbourg near Glace Bay, Nova Scotia in June and July 1954 and off Canso in July and August 1954 (McCracken, 1956, 1957) gave essentially the same results as McKenzie's tagging in the same or neighbouring inshore areas of Nova Scotia. The Canso fish moved little and the Louisbourg fish more than those of Canso. There was little intermingling between the 2 stocks. Most recoveries were from within the tagging region and recoveries from outside the tagging region were mainly from neighbouring inshore grounds and in the Canso and Louisbourg tagging during the winter-spring from neighbouring offshore banks of the Scotian Shelf. There was some winter movement to neighbouring deeper water.

Trans-Fundian Channel movements

In more than 2,200 recoveries of cod tagged between the Laurentian and Fundian Channels (McKenzie, 1956) there were only 11 from across the Fundian Channel on New England fishing grounds. From 757 recoveries of cod tagged off Lockeport, Nova Scotia (McCracken, 1956) there were only 7 from across the Fundian Channel about 80 nautical miles (150 km) distant, 6 of these from the neighbouring Georges Bank.

Gulf of Maine and southward

Tagging on the northern side of the Gulf of Maine in the Nova Scotian region has already been discussed. Smith (1902) reports the results of the tagging of over 4,000 mature cod caught at Nantucket Shoals and liberated near Woods Hole, about the end of January 1898-1901. Schroeder (1930) discusses the information on the migrations of southern New England cod obtained from the tagging of over 23,000 cod on and near Nantucket Shoals, southeast of Cape Cod during 1923-29. He also reviews Smith's results. Schroeder concluded that a large part of the Nantucket Shoals cod population migrates southward in autumn to the Rhode Island-North Carolina region where most of them remain until spring. Only a small proportion of the cod from north and east of Cape Cod make this southward migration. The cod return eastward in spring, most of them summering on Nantucket Shoals, but some of the larger fish, which probably before the tagging occurred had migrated southward from north and east of Cape Cod, continue northward and eastward to deeper water. Although in the winter the cod catch between Rhode Island and Delaware ranged between 3 and 5 million pounds, in the summer relatively few cod were caught off Rhode Island and cod were caught only rarely west of Rhode Island. During some summers part of the Nantucket Shoals cod move eastward to the Chatham-South Channel region.

Wise (1958) discusses the results of his tagging of 448 cod off southern New Jersey in the winter of 1955-56 and of Schroeder's (1930) winter cod tagging in the same area. He concludes that the cod which range mainly from Long Island (and Block Island) to North Carolina in winter and spring should be regarded as a separate wintering and spawning population which in summer feeding migration moves northward to Nantucket Shoals and in individual cases (Schroeder, 1930) probably to the Gulf of Maine and Georges Bank. This is the southernmost stock of cod.

Wise and Jensen (MS, 1960) say that returns of several hundred tagged fish, from cod taggings in the Gulf of Maine region since 1955, indicate that the eastern Georges Bank population is of most importance and apparently mixes little with the more westerly and northerly groups; but some of the older fish wander to the southwestern Nova Scotian area. West of about 68°W Long. on Georges Bank there is another cod population which spends the summer in South Channel, about 69°N, especially on the western side of this Channel and which spends most of the remainder of the year inshore in the Nantucket Shoals-Chatham area. North of this stock are 1 or more largely sedentary stocks living on the coastal shelf and banks along the northwestern border of the Gulf of Maine.

Divisions of cod stocks

Introduction

The question of division of cod stocks in the ICNAF area has been discussed in recent years especially by Hansen (1949) for Subarea 1; by Templeman (1953), and Fleming (1960) for Subareas 2, 3 and Division 4R; by Martin (1953), McKenzie and Smith (1955) and McKenzie (1956) for Subarea 4; and by Wise and Jensen (MS, 1960) for the whole ICNAF area. Meanwhile, new information has accumulated, especially from tagging and although for all stocks much information is still needed it is now possible to give a more complete but in many respects still tentative picture of the identity and the degree and season of intermingling of many of the chief cod stocks of the ICNAF area.

In the divisions between cod stocks discussed here research papers and unpublished information related to vertebral and migratory studies and already discussed will not be referred to in detail again and whenever general statements regarding these matters are made the reader is referred back to the reviews in the earlier parts of this paper.

Although it is necessary in a chart to draw rather definite lines between stocks it must be understood that generally stocks are not so clearly divided as the maps show and the lines are meant only to include the major part of the stocks.

Almost every part of the cod life-history has a bearing on the reasoning regarding distinctions between stocks but we have only had time here to review in detail the vertebral and migratory patterns which are on the whole of broadest importance and available in greatest amount for the reasoning. Other life-history patterns bearing on stock divisions will be included piecemeal in this discussion as they are needed.

Greenland stocks

Figure 4 and information regarding it have been provided by Paul Hansen, rather reluctantly in view of lack of clear divisions between the stocks other than some of the fjord stocks. (See also Hansen, 1949.) The stocks have been divided into: N, northern West Greenland stock; S, southern West Greenland stock; E, East Greenland stock; and some fjord stocks (small in numbers compared with the outside stocks): F₁, Ikertok Fjord stock; F₂, Sukkertoppen stock (from Kangia Fjord and Angmasivik Fjord); F₃, Godthaab Fjord stock; and F₄, the Julianehaab stock (from fjords of this area). The divisions have been based mainly on differences in migratory pattern. There are also some differences in vertebral averages, these being lower for southern than for the northern West Greenland stock and still lower for East Greenland. Vertebral averages of fjord stocks taken at a time when the fjord stock is not intermingled with the offshore stocks may sometimes be considerably different either higher or lower than those of the neighbouring coastal and offshore stock. The growth rate is lower for the southern than for the northern West Greenland stock and the growth of the East Greenland stock is similar to that of northern West Greenland. There are often some differences between N and S in year-class strength.

The stock of N is to a great degree self-contained and in the years of large migrations to Iceland these largely took place from S. Relatively little tagging has yet been reported on from E.

Tagging experiments have shown that very few cod belonging to F₂, F₃ and F₄ migrate to the offshore area. Tagging experiments with young cod in F₁ have shown that cod when 7 years old leave the fjord and migrate to the offshore banks.

All the fjord stocks have growth rates slower than the stocks on the offshore banks. The otoliths have narrow zones and (especially in F₄) have many secondary rings. F₃ (Godthaab Fjord), the best known stock, has a composition of year-classes different from the offshore stock. Apart from having its own special population a fjord may receive even more numerous visitors from the outside. In Ikertok Fjord, for example, there is a local population (F₁) characterized by slow growth and relative lack of migration of the young cod and the highest (on 1 average) vertebral average in West Greenland, spawning in the fjord in spring at which time it is caught by Greenlanders through holes in the ice. There is, however, a great cod fishery in the fjord later in the year, based on cod from the outside which have migrated into the fjord. Cod also spawn in Kangia Fjord (F₂) and in Godthaab Fjord (F₃).

The cod of West Greenland (N and S) spawn from March to May, with a maximum in April and mainly south of Lat. 65°N at depths of 200-450 metres.

Greenland and Labrador stocks

The difference of approximately 2 vertebrae, the Labrador stock having the higher number, between the cod populations of West Greenland and Labrador and the passage of only occasional strays in both directions across the Labrador Sea from the great numbers of cod tagged in West Greenland and in the Labrador and Newfoundland regions indicate no movement of adult cod between these regions large enough to affect significantly the characteristics of the great cod populations of these 2 areas. Hence the cod stocks of West Greenland can be considered to be well separated from those of the Labrador and Newfoundland regions.

Hansen (1958) showed that in 1957 there was probably a greater-than-usual transfer of West Greenland water toward the American coast with a resultant drift of cod larvae farther west than usual. Templeman (1961) also produced evidence that the young redfish found off Baffin Island came by way of West Greenland. There is no evidence from the Labrador vertebral numbers of the introduction in recent or earlier years of large numbers of individuals with the low-vertebral-count characteristic of cod of West Greenland origin. Almost all of the cod vertebral averages taken by the St. John's Station along the coast and offshore on the Labrador Shelf in 1959-60 have been over 54. The most northerly sample, however, taken off Frobisher Bay in August 1959 had a vertebral average of 53.8 whereas the nearest samples southward had averages of 54.4 in Ungava Bay and 54.6 off Cape Chidley. This sample taken off Frobisher Bay, however, was only of 20 fish and the differences between this and neighbouring samples are not statistically significant.

Ogac Lake stock

This is a small relict stock in Ogac Lake in Frobisher Bay, eastern Baffin Island, not in the ICNAF area. It is characterized by vertebral averages about 2 lower than the nearest cod of the outside waters.

The production in West Greenland of year-classes of cod very significantly more numerous than those of other year-classes whereas in Labrador the dominance of individual year-classes is not very noticeable or common, and the considerably lower growth rate of the Labrador cod, are additional evidences of the essential separation between the West Greenland and the Labrador stocks.

Labrador-Newfoundland stocks

Labrador-Newfoundland stock. The cod populations of the east coasts of Labrador and of Newfoundland and to the north of the Grand Bank have been shown in Fig. 5 as 1 large stock, the boundaries of which can also be extended to include the cod population of Ungava Bay and northward to the limit of the cod stock off Frobisher Bay along the east coast of Baffin Island. The basis of including this whole group in 1 major stock division is the presence of similar high-vertebral-count characteristics and the lack of migratory divisions in the area. The whole area is characterized by the presence of cold water, usually below -1°C from surface to 100 fathoms (185 m) or deeper during winter and early spring, ice cover during the winter and deep warmer water with temperatures above 0°C at depths of usually 100-140 fathoms (185-260 m) close to the shallow coastal water where great numbers of the smaller cod spend the summer. Thus there is a general offshore winter, onshore summer movement of cod in the whole area, but the onshore movement is earlier in the south than in the north. Although information during the actual spawning season is relatively poor or lacking over much of the area spawning is probably chiefly from late April to early June with a peak in May throughout most of the area occupied by the Labrador-Newfoundland stock, at least from southern Labrador and Hamilton Inlet Bank southward. The onshore movement producing the inshore fishery is mainly from the latter half of June on the southern part of the east coast of Newfoundland to the first week of July in southern Labrador and to the first week of August farther north at Nutak. This is a feeding migration with mostly spent and immature fish following the spawning capelin to shore.

In the coastal waters during the summer there are no barriers to migration apart from the break at the Strait of Belle Isle which will interfere with near-bottom migration when the bottom water is cold in 40-50 fathoms (75-90 m) in June-September, and the distances and interference involved by the deep bays and projecting headlands. Even these do not interfere much when the cod in June and early July are in the pelagic phase following the pelagic capelin. The deep water throughout the whole north-south range of the area is approximately of the same temperature at the same depth and thus apart from inherent restrictions of the fish there are few barriers to movement in the deep water except the great projections of the coastal shelves, bottom contours and occasional deep channels.

From lack of more detailed evidence on other characteristics than those we have mentioned above we have not for the present attempted to define closely the partially separated populations within this large Labrador-Newfoundland stock. However, growth differences exist. For inshore cod the slowest growth of this stock is off Labrador and in the Labrador population there is a slight increase in growth rate from north to south, approximately 3 cm difference at each size between inshore or coastal cod of the northern ICNAF Divisions 2G and 2H and of the more southern Division 2J (May, MS, 1961). There is also a gradual increase in growth rate southward from Labrador along the east coast of Newfoundland (Fleming, 1960). There is considerable difference in the condition of the cod when they arrive in the inshore waters. The cod of the Labrador-Newfoundland stock at the southern end of the range are in excellent condition with fat creamy-white livers when they arrive in June and this condition declines northward until off Labrador the cod arrive on the coast as thin fish with thin, brown livers, so depleted of fat that most of the livers sink in sea water. Usually feeding heavily on capelin, they recover rapidly after arrival on the coast and soon are in good condition. The cod remaining in deep water in summer were, in the virgin condition of the offshore fishery, large toward the south off Bonavista to Fogo and gradually smaller toward the north to St. Anthony and Labrador (Templeman and Fleming, 1956; Templeman and Fleming, MS, 1962). The retention of a large proportion of the cod close to the tagging areas for many years after tagging and the lack of recovery in the Bonavista area, where over-fishing has produced continued low catches in spite of relatively good catches from the Baccalieu region to the south and the Fogo Shelf region to the north (Templeman, 1959, 1960; Fleming, MS, 1959), make it likely that each large shelf region, such as the Bonavista Shelf, the Fogo Shelf and the St. Anthony Shelf, projecting seaward with deep water on each side has a basic stock of its own, some of which it loses temporarily in the summer by coastal or pelagic feeding migrations and in the winter by movements in the deep water, while receiving some migrants from other areas. There is generally little or no greater maximum migration of tagged fish of this area beyond that in the year after the tagging year. Consequently most of the cod are probably retained within the boundaries of their particular sub-stock and return to wintering and spawning areas and to feeding areas each year within the same general pattern.

Up to the present most of the tagging of these fish has been done in the summer feeding areas when they are dispersed from their spawning areas. When the over-winter pre-spawning and spawning concentrations have been tagged it may be possible to separate the sub-stocks of this area as for West Greenland into groups which intermingle far more among themselves than between adjacent areas. One such division inshore could be at the Strait of Belle Isle and the offshore topography indicates that Hawke Channel, south of Hamilton Inlet Bank, might offer a north-south impediment to the movements of offshore cod. However, the water in the bottom of this Channel is almost 2 degrees colder than

the over 5°C water at the bottom of the Laurentian Channel and consequently may not be so great an impediment to cod movement. Meanwhile the present ICNAF divisions of the main area covered by the Labrador-Newfoundland stock are reasonably adequate for comparing biological differences between different parts of this large stock.

Flemish Cap stock. The slightly but significantly lower vertebral averages in summer of the Flemish Cap stock than those of deep-water cod on the slopes of the neighbouring northeastern Grand Bank, and the spawning of the Flemish Cap cod mainly in March (Travin, 1959; Templeman, MS, 1962), whereas the neighbouring cod of the northeastern and northern Grand Bank have a spawning season chiefly in May-June, make it certain that this Flemish Cap stock is a separate stock. Although from lack of tagging in the area the amount of westward pelagic feeding movement in summer to the Grand Bank area is unknown, the movement to the south of the Cap for spawning (Templeman, MS, 1962) together with Flemish Channel to the westward (600 fathoms (1,100 m) or more) very likely retain most of the cod on this bank through the year.

The lack of Lernaeocera branchialis in the Flemish Cap cod, while small but significant rates of infection with this parasite are found in cod of the neighbouring northeastern slope of the Grand Bank (Templeman and Fleming, MS, 1961), is another evidence of the isolation of the Flemish Cap stock from that of the Grand Bank.

Grand Bank stock. This stock has a low vertebral number, over 1 vertebra lower than the Labrador-Newfoundland stock. Summer migrations from the southern part of this stock are northward over the surface of the bank. Many of these cod (and until recently we had believed almost all belonging to this stock) spend the winter on the southwestern and southeastern slopes and partly on the southern part of the Grand Bank itself. In March 1961, however, in a set of the A.T.Cameron just east of the North Cape of the Grand Bank at 100 fathoms (183 m) we found a great accumulation of adult cod, with a low vertebral average (53.03) within the range of vertebral averages of this southern Grand Bank stock, whereas at 122 fathoms (223 m) the vertebral average was 53.8 and at 199-244 fathoms (364-446 m), 54.4. It seems possible, therefore, that low-vertebral-average populations of the Grand Bank stock may also spend the winter and spawn on the northern slope of the bank. If this is a usual situation it immediately raises the question of whether there is not more than 1 low-vertebral-count stock on this bank, 1 spending the winter and spawning southward and 1 spending the winter and spawning northward and each with at least part of its population passing over the surface of the Grand Bank in summer.

This stock in the southern part of its area, at least, has the fastest growth rate and the greatest size and age at sexual maturity (Fleming, 1960) of all the cod stocks of the Newfoundland-Labrador area, ICNAF Subareas 2 and 3. Spawning is in April-June with spawning at its peak during the last half of May.

The cod of the southern Grand Bank and of the general plateau areas of the Grand Bank (not including those on the northern, northeastern and northwestern slopes) have a very low rate of infection by Lernaeocera branchialis (Templeman and Fleming, MS, 1961) compared with the much higher rates of infection of the nearest coastal areas. On the southern part of the bank the rate of infection decreases with distance from the coast. This is evidence that there is no very great relation between the coastal Avalon Peninsula stocks and the Grand Bank stock (surface and southern Grand Bank) but that, as might be expected, the cod of this stock closest to the coast have a little more intermingling with coastal stocks than those farther away toward the tail of the bank.

Spring and early summer tagging has shown that the Grand Bank stock has some late spring to summer migrants from the northern part of the southwestern slope of the Grand Bank to southeastern Newfoundland. Although it is better, where possible, to consider the spawning stock as the concentrated unit of the stock which spreads out to feed, and these western migrants probably spawn on the Grand Bank, it is more convenient and may be more suitable here to consider that these western migrants to the coast of the Avalon Peninsula belong to the coastal Avalon-Burin stock which, because of the coastal cold water and the lack of neighbouring warm deep water such as occurs to the northward and westward, pass the winter offshore on the slopes of the neighbouring banks.

St. Pierre Bank stocks. On St. Pierre Bank the winter-early spring concentrations of cod are on the western and southern slopes of the bank with a large concentration at the southern entrance to the Halibut Channel and there are late spring, summer and autumn feeding concentrations on the shallower parts of the bank. Many of the cod over-wintering on St. Pierre Bank migrate to the inshore waters of the eastern half of the south coast of Newfoundland in late spring to early summer but as on the Grand Bank there is apparently a bank stock also which tends to remain throughout the year on St. Pierre Bank.

Spawning is in April to early July with peak spawning in the last half of May and early June. The fish are slower growing than those on the Grand Bank (Fleming, 1960).

Studies of the incidence of cod nematodes (Templeman, Squires and Fleming, 1957) and of Lernaeocera branchialis (Templeman and Fleming, MS, 1961) for both of which infection apparently occurs mainly in the inshore waters, show that, as would be expected, the cod of the northern part of St. Pierre Bank are much more related to those of the neighbouring inshore area than are those of the southern part of the bank. The cod very closely related to the inshore area are those of the northern quarter of St. Pierre Bank, and the remainder of the cod are less closely related, with those of the southern part of the bank showing the least indication of having been in inshore waters previously.

Avalon-Burin stock. The Avalon-Burin stock is an inshore stock, with intermediate vertebral averages, extending from the outer coast of the Avalon Peninsula south of St. John's westward around the Burin Peninsula into Fortune Bay. Migration is considerable within the stock but occurs only to a small extent outside the main limits of the stock. This stock overlaps with the Burgeo Bank stock and during the winter usually to a limited extent with the West Newfoundland stock. During the winter some of its members are intermingled with the St. Pierre Bank and the western Grand Bank stocks with a relationship to the northern St. Pierre Bank stock which may be close enough so that it may be inaccurate to separate the stocks. The tagging reported for this Avalon-Burin stock thus far has been all from the western and eastern coasts of the Burin Peninsula. Thus not so much is known of the amount of mixing of the part of this stock on the southern half of the Avalon Peninsula with neighbouring stocks including the part of the Avalon-Burin stock to the westward.

In the general neighbourhood of St. John's, which we have shown in Fig. 5 as the southern boundary of the high-vertebral-average Labrador-Newfoundland stock, the vertebral averages of the fish at the time of the large inshore trap fishery in June-August are over 54 whereas for the larger inshore fish caught by linetrawl within several miles of the shore, but deeper, in the autumn the vertebral average declines until it is 53.5 or lower, generally similar to the vertebral

numbers of the Avalon-Burin stock. When cod are tagged at St. John's some migrate in summer southward as far as the Burin Peninsula and others northward as far as the Strait of Belle Isle and many are caught in winter in the deep water to the north of the western Grand Bank. Also some cod tagged south of St. John's as far west as Burin and Fortune move east and north to the east coast but mainly not beyond the Avalon Peninsula. Thus the St. John's area is at the boundary of the Labrador-Newfoundland and the Avalon-Burin stocks, receiving its greatest abundance of northern high-vertebral-count Labrador-Newfoundland stock fish in summer and smaller quantities of fish from the intermediate-vertebral-number Avalon-Burin stock in late autumn. North of the St. John's area the contributions of low-vertebral-count fish from the southern stocks are not usually sufficient to lower the vertebral average below 54 and south of this area the contributions of northern stock fish are not usually great enough to raise the vertebral average to as high as 54. The limiting factors are the supply of high-vertebral-average cod fry which are restricted to the northern stock and very likely the habit of this northern stock to retreat each year to the deep waters to the north of the Grand Bank for wintering and spawning. This would limit their southward feeding dispersal.

Populations not divided between stocks in Fig. 5, occupying the area between the Labrador-Newfoundland, Grand Bank, Avalon-Burin and St. Pierre Bank stocks. These areas are often supplied with abundant cod at various times of the year, often, near the coast, with cod migrating from the inshore stock to the bank slopes and channels in winter. The vertebral-average characteristics are in summer intermediate between those of adjacent stocks showing admixture of stocks with the characteristics of each stock in turn predominating near its own main borders. Sometimes, however, what appear from vertebral characteristics to be almost pure schools of each type may be found close together, but in some cases at different depths, in the intermediate area between the main borders of these adjacent stocks. These remarks presumably apply to other blank spaces in the Nova Scotian and Gulf of Maine areas and presumably there are a number of spawning and other stocks not yet delimited on these stock division charts but for which future research will reveal division at least at certain seasons.

Burgeo Bank stock. Tagging results have shown that this cod stock occupying Burgeo Bank in the winter to early spring spends the summer in the inshore waters of the western half of the south coast of Newfoundland, intermingling to a modest extent with the cod of the West Newfoundland stock and the Avalon-Burin stock and to a more limited extent with stocks adjacent to these. (Note remarks, however, under West Newfoundland stock.) This Burgeo Bank stock has a low vertebral average of the West Newfoundland type and spawns in April-June with the spawning peak in late April to early May.

West Newfoundland stock. Tagging returns and the location of great concentrations of cod in winter and spring, but not in summer and autumn, mainly between 60-130 fathoms (110-240 m) off the southwest coast of Newfoundland immediately outside and inside the Gulf of St. Lawrence near the northern entrance of Cabot Strait, show that there is a West Newfoundland stock of cod. This stock, except for strays, does not pass eastward in winter-spring beyond the western quarter of the south coast of Newfoundland, but occasionally reaches Burgeo Bank and the western part of the Avalon-Burin stock. In the winter-early spring of 1962, however, unusual numbers of cod, partly, at least, from the West Newfoundland stock since some cod tagged in January 1962 off the west coast of Newfoundland were included, were caught as far east as Hermitage Bay. Hence it is possible that returns from new tagging experiments will show that the Burgeo Bank stock is only the most southward extension of

the West Newfoundland stock and that it intermingles with the southern part of this stock too much to be readily separated. Fish tagged as far south as Bay of Islands in autumn rarely pass northward through the Strait of Belle Isle. Cod of the northern Quebec Coast (North Shore) of the Gulf of St. Lawrence also join the West Newfoundland stock in winter.

On the southern or Newfoundland side of the Strait of Belle Isle vertebral numbers and tagging indicate significant passage of Newfoundland east coast cod inward to the southern end of the Strait with no great quantities passing farther inward although some pass inward through the Strait on the southern side. In this connection Fleming (1960) for cod collected at Eddie's Cove at the southern entrance to the Strait of Belle Isle on the Newfoundland side found that the small and mainly immature cod up to about 6 years of age were similar in growth rate to those of the west coast of Newfoundland whereas the cod of 10-14 years of age had the same growth rate as cod from the northern part of the east coast of Newfoundland. The growth rate of 7-, 8- and 9-year-old cod was intermediate, with that of the 7-year-olds very close to the west coast type whereas the growth of 9-year-olds was close to that of cod of the northern part of the east coast. Thus it is indicated that the younger cod of the area were mainly resident Gulf fish while the larger and older fish were mainly inward-migrating east coast fish. Spawning in the cod of the West Newfoundland stock probably begins in April and continues to October but with most individuals spawning before the end of June.

North Shore Gulf of St. Lawrence and Anticosti stocks?

It is likely that the cod populations of these 2 areas are enough separate from the West Newfoundland and other Gulf stocks in summer to be described as 1, 2 or more separate stocks, but essential migratory and other information is at present lacking.

On the northern or Labrador side of the Strait of Belle Isle vertebral numbers in summer and early autumn are very low and do not in any way indicate the passage of significant quantities of high-vertebral-number Labrador cod into the Gulf, nor of low-vertebral-number Gulf cod outward. Recoveries from tagging in southern Labrador and northern East Newfoundland (unpublished data, St. John's Station) indicate only a small amount of passage into the Strait on its northern side.

Vertebral averages of the North Shore cod are apparently a little higher than for the purely west coast of Newfoundland stock but there is a wide shallow bank area south of the Strait of Belle Isle where the West Newfoundland stock must mix with the cod population of the North Shore. The cod from the North Shore and Anticosti populations join the West Newfoundland stock in their winter migration southward. Recent information from Yves Jean (April 13, 1962) reveals that cod tagged in the Seven Islands area in the western part of 4S in 1961 were caught in the winter of 1961-62 in 4R and 3P-N among the West Newfoundland stock. This would indicate a winter migration track following the Anticosti slope to its eastern peak, then across the moderately shallow 140 to 150-fathom (255 to 275 m) Esquiman Channel to the west coast of Newfoundland and from there southward along the West Newfoundland Coastal Shelf.

Alexandre Marcotte of the Station de Biologie Marine, Grande-Rivière, Gaspé, Quebec has sent information (April 17, 1962) on his tagging near the end of June 1954 along the Quebec North Shore at Natashquan, La Tabatière, River St. Paul, Blanc Sablon and Red Bay, Labrador. Out of more than 360 returns 19.9% were recovered in February-March from the southern part of the west coast of Newfoundland and an additional 9.7%,

also February-March, from the western part of the south coast of Newfoundland, while only 0.7% were captured south of the Laurentian Channel at Gaspé. It is thus apparent that the summer stock of the Québec North Shore is strongly intermingled in winter with the West Newfoundland stock but not enough information is available at present to indicate the degree of summer intermingling or separation of the Québec North Shore and the west coast of Newfoundland populations.

Greater depths of about 180-200 fathoms (330-365 m) with accompanying warmer water exist in the Laurentian Channel southward of the area of tagging off Seven Islands and south of Anticosti Island, apparently forming a greater barrier to southward movements to join southern Gulf stocks than to eastward movements to join the West Newfoundland stock.

Stocks in the Canadian region south of the Laurentian Channel

Although strays pass in both directions over the Laurentian Channel, especially from tagging carried out on the stocks bordering the Channel, there do not appear to be any migration tracks or any considerable intermingling across this Channel and stocks on each side of the Channel are thus separate. The temperatures of over 5°C in the deep water of the Channel and the depth of the Channel also tend to prevent bottom movement across the Channel and limit the intermingling to pelagic crossings of the Channel.

For this region the author has had the great benefit of a stock division chart provided by Yves Jean of the St. Andrews Station. The author has, however, modified the chart somewhat, combining in certain areas and dividing in others so that only the Louisbourg, Canso, Lockport, Banquereau, Sable I. and winter habitat of the Gulf stocks are basically unchanged from the original chart presented to ICNAF in 1961. Our changes have been the splitting of the southern Gulf stocks during the summer, the introduction of the Glace Bay-Sydney Bight stock and the Halifax sub-stock, the combining of the Lunenburg-Halifax-Jeddore stocks into one Lunenburg-Jeddore stock, and the dividing of the East Fundy-Seal Island stock into 2 stocks. The winter abode of the Sable Island Bank stock has been extended to take in the Emerald Bank area. Much of this changing has been a matter of personal choice from the arguments for and against combining or dividing, and moderately good arguments could often be developed for leaving the original stock outlines unchanged.

Southern Gulf of St. Lawrence stocks. On the basis of the information given under vertebral numbers and migrations there is evidence for the separation in summer of a Gaspé stock mainly extending from the northern entrance to Bay Chaleur and the mouth of Bay Chaleur to the Laurentian Channel and northward for some distance around the Gaspé Peninsula. This stock evidently mixes especially on the north side and off the mouth of Bay Chaleur with the Bay Chaleur stock. There is evidence for a Bay Chaleur stock which is well intermingled with Gaspé stock in the north and may be considerably intermingled with the western part of the Prince Edward Island stock, a doubtful Magdalen Islands stock possibly including Bradelle Bank, a Prince Edward Island stock which is different from the northern part of the Bay Chaleur stock in having none of the high-vertebral-average characteristics of the Gaspé stock, and a West Cape Breton stock. All these stocks while intermingling to some degree with other stocks have either vertebral or migratory characteristics or both which show that a great part of the population returns each summer to the location of its parent stock. The Magdalen Island stock is the most difficult to delimit or indeed to show that it is essentially a separate stock, because part of all the other stocks except the West Cape Breton stock may intermingle with this stock during the autumn-early winter outward and the spring-early summer inward

migration. There is also an area of doubt regarding whether the western part of the Prince Edward Island stock is not much more closely related to the Bay Chaleur stock than we have shown in Fig. 5. The tagging at Alberton in July 1939 (McKenzie, 1956, fig. 42) indicates this relationship whereas tagging at nearby Ellerslie (McKenzie's fig. 41) indicates a more separated Prince Edward Island stock. The vertebral averages of the Prince Edward Island stock, however, in McKenzie's original records are definitely lower than those of the Bay Chaleur stock even if the samples with Gaspé-type high vertebral averages are eliminated when considering the Bay Chaleur stock. It is also impossible for reasons of geography, the stocks meeting in and off Bay Chaleur, to use a single line to separate the Bay Chaleur and Gaspé stocks, so that the Bay Chaleur stock is at present only poorly defined.

This division of the Gulf stocks is very similar to that made by McKenzie and Smith (1955) who on the basis of vertebral averages concluded that there were 4 cod stocks in the southwestern Gulf of St. Lawrence: Gaspé, Bay Chaleur, Prince Edward Island and Cape Breton stocks.

In winter, although many of the youngest immature fish remain near the summer abode of the stock, most of the larger or mature fish of all the Gulf stocks move along the southern slope of the Laurentian Channel to occupy the region mainly between 60 and 130 fathoms (110 and 240 m), and according to Martin (MS, 1961) especially 100-125 fathoms (185-230 m), from just west of the Bird Rocks, Magdalen Islands region of the Gulf to the Misaine Bank region with strays as far as Banquereau. With migration along the southern border of the Laurentian Channel unrestricted by deep-water intercepts the vanguard of the southern Gulf stocks moves out of the Gulf farther toward the offshore banks than the West Newfoundland stock which tends to follow along the coastal shelf at the western end of the south coast of Newfoundland, and whose movements in the direction of St. Pierre Bank are intercepted by the deep Hermitage Channel. Very likely these outward movements are earlier, farther and return migration is later in very cold winters with severe ice conditions than in warmer winters. Because of the inward current, also, on the north side of Cabot Strait there is usually less ice here than on the Cape Breton side.

During the winter and early spring these various southern Gulf stocks doubtless mix considerably with local resident stocks in their extension over the northern fringe of the Scotian Shelf. According to Powles (1958) and information presented to the ICNAF Environmental Subcommittee by the St. Andrews Station, the southern Gulf stocks spawn not in their winter abode off Cape Breton but in the Gulf of St. Lawrence between May and September with peak spawning at the end of June and in July. (In the remainder of the discussion for Subarea 4, unless authorities are mentioned it should be understood that the spawning-time information is that presented by Yves Jean for the St. Andrews Station in 1961 to the ICNAF Environmental Subcommittee).

Although on present published knowledge it is not possible to separate the southern Gulf stocks in their winter abode at the southern edge of the Laurentian Channel off Cape Breton it is possible that tagging the southern Gulf stocks in July or August in the same year may in the following winter show differences between the stocks in depth distribution during winter and in the distance which each stock moves out of the Gulf. These stocks also should have different migration tracks which are to some degree concealed by relatively small amounts of fishing in the central part of the southern Gulf. Recent Gulf of St. Lawrence tagging has been in the neighbourhood of Bay Chaleur and the Magdalen Islands and McKenzie's tagging which covered

a wider area was in an earlier period before the establishment of a European trawler fishery at the entrance to the Gulf of St. Lawrence.

In practice it is not possible because of their winter intermingling and spring and fall intermingling movements to treat these southern Gulf stocks for management purposes other than as a large southern Gulf super-stock (Fig. 5 - inset) of which the other stocks mentioned will form sub-stocks for which partial separation at least is possible in summer-early autumn.

Banquereau stock. This stock is located on the eastern plateau and slope of the bank during the winter and passes westward and shallower to occupy the whole surface of Banquereau and impinges also on neighbouring banks and to some extent mixes with the coastal stocks of northern Nova Scotia in summer. Or it may be that coastal stock migrants wintering on this Bank return to the coastal area in summer. Very likely both possibilities occur. In winter it is intermingled with the most distant migrants of the southern Gulf stocks and to some degree with neighbouring Nova Scotian coastal stocks. Spawning occurs in April-June with peak spawning in May (McKenzie, 1956 and St. John's Station observations by the author in mid-May, 1950).

Sable Island Bank stock. Similarly, as for the Banquereau stock, the Sable Island Bank stock is located more seaward and extends deeper on the seaward slope in winter whereas in summer it is distributed more shoreward on the northerly parts of Sable Island and over its northern projection, Middle Ground. In winter also there are some fish on this bank from the neighbouring Nova Scotian coastal stocks and a few strays from the Gulf of St. Lawrence and as for Banquereau and with the same qualifying remarks, there are some migrants from Sable Island Bank to the neighbouring Nova Scotia coast in summer. Tagging on Emerald Bank (McKenzie, 1956, fig. 27) and also McKenzie's original vertebral averages, chiefly 52.8-53.4 in both areas, indicate that the Emerald Bank stock is enough related to and intermingled with that of southwestern Sable Island to be considered as part of the Sable Island stock. Spawning at the southwestern part of the bank and Emerald Bank is in March-April, chiefly in April, while on the western part on Middle Ground it occurs a little later, in April-May (McKenzie, 1956).

Nova Scotian coastal stocks. These 7 Nova Scotian coastal stocks shown in Fig. 5 are local stocks, generally with their distribution a little more concentrated and coastward in summer and a little more dispersed and seaward in winter. They have been named chiefly from the locations of the tagging from which so much of the information on the limits of the stocks has been derived. From southward to northeast they may be called the East Fundy-St. Mary Bay, Seal Island, Lockeport, Lunenburg-Jeddore, Canso, Louisbourg and Glace Bay-Sydney Bight stocks. However, if tagging had been carried out in areas between some of these locations, other inshore stocks with restricted migration could presumably be named. These stocks have some but not much movement along the coast and mixing with neighbouring stocks and some but except in the more northern stocks not much movement offshore in winter to mix with the offshore bank stocks.

Additionally there is the Halifax fall-spawning stock with a significantly lower vertebral average than the spring-spawning stock of that area.

The limits of the East Fundy-St. Mary Bay and the Seal Island stocks are based on tagging at St. Mary Bay and Seal Island (McKenzie, 1956) and the Lockeport stock on the results of tagging off Shelburne (McKenzie, 1956) and off Lockeport (McCracken, 1957).

The small St. Mary Bay tagging (16 recoveries from 83 tagged) shows an area of admixture on the western fringe of the area and further tagging is needed in this area to show to what degree this stock is separate from the Seal Island stock. In many recoveries from tagging at Seal Island, however, only an occasional stray reached the East Fundy-St. Mary Bay area. Thus there is apparently very little mixing between the western half of the East Fundy-St. Mary Bay stock and the eastern half of the Seal Island stock. On the east there is some movement of the Seal Island stock both summer and winter into the western part of the area occupied by the Lockeport stock. The Seal Island stock is, however, enough separate from the Lockeport stock that, from southeast of Cape Sable west to off Port Maitland at Lat. 44°N which includes almost all the Seal Island stock migrants and the eastward extension of the St. Mary Bay migrants, in McKenzie's original vertebral averages 21 of 22 averages were from 52.2 to 52.6, whereas in the approximate area to the eastward of Cape Sable occupied by the Lockeport stock, 22 of 25 vertebral averages were between 52.8 and 53.1. Two of the remaining 3 averages were 52.5-52.6 on the eastern fringe of the Lockeport stock and presumably belong to the Lunenburg-Jeddore group which has low-vertebral-average fall spawners from the Halifax area included in it; and only 1 average below 52.8 occurred in 23 averages in the main area occupied by the Lockeport stock. In spite, therefore, of some intermingling in the vicinity of Cape Sable, the Lockeport stock is essentially distinct from the Seal Island stock.

While in the Seal Island stock the vertebral averages in McKenzie's original records were between 52.2 and 52.6, in the western sector north of Lat. 44°N (the East Fundy-St. Mary Bay stock) 10 of 18 vertebral averages were between 52.3 and 52.6 and 8 were 52.7-52.8. Thus there is not a strong separation on the basis of vertebral averages between the Seal Island and East Fundy-St. Mary Bay stocks.

The delimiting of the Lunenburg-Jeddore stock is based on taggings off Lunenburg, Halifax and Jeddore (McKenzie, 1956). Each of these taggings gave in ensuing years strong localization of returns to the tagging area in summer, but more spreading in winter between the 3 tagging areas and in lesser degree to the offshore banks. In McKenzie's original vertebral averages the area of the Lunenburg-Jeddore stock has vertebral averages, omitting the obvious low-vertebral-average fall-spawning group, almost entirely between 52.8 and 53.2 with occasional averages very slightly higher than those of the Lockeport stock. There is also intermingled in the Lunenburg-Jeddore stock a small fall spawning group with vertebral averages from 51.6-52.0. Each of the 3 sub-stocks included in the Lunenburg-Jeddore stock has some of the migratory characteristics of a separate stock. However, the areas are close together, there are no vertebral average differences and there is a moderate amount of mixing in summer and considerable in winter. Presumably taggings between the Lunenburg, Halifax and Jeddore locations would give other partly localized, partly mixing populations. Thus these 3 sub-stocks have been included in this paper as 1 stock.

Migratory information on the Canso stock has been obtained from taggings off Canso (McKenzie, 1956; McCracken, 1957). Recoveries are strongly localized both winter and summer in the tagging area with very little intermingling either in winter or summer with the Lunenburg-Jeddore stock to the west or the Louisbourg stock to the east and only a little winter movement to the offshore banks mainly to the southwestern end of Sable Island Bank.

Tagging at Louisbourg (McCracken, 1957) outlined a Louisbourg stock with almost all recoveries, in the summer after tagging, coming from the vicinity of the tagging and with little intermingling with the Glace Bay-Sydney Bight stock to the northward and little if any with the Canso stock to the westward. In the winter following tagging most of the returns were from near the tagging area but in the following winter only about 1/4 of the returns were from near the tagging area. Winter recaptures, apart from those in the tagging area, were mainly from Sable Island Bank with some offshore from northeast Cape Breton, from along the outer Nova Scotian coast on Banquereau and from the Newfoundland area.

The boundaries of the Glace Bay-Sydney Bight stock are indicated from tagging at Glace Bay in July-August 1927 (McKenzie, 1956). There has been no tagging reported from Sydney Bight itself. However, the Glace Bay tagging showed little movement into the neighbouring area to the southwest occupied by the Louisbourg stock although there must be some mixing in the intermediate fringes of the 2 stocks. There was a strong summer movement of the Glace Bay fish into the Sydney Bight area, possibly enough to include the cod population of this area with that off Glace Bay. There were few summer migrants into the Gulf of St. Lawrence. In winter coastal fishing off northeast Cape Breton is considerably interfered with or prevented by ice, so most of the winter recaptures were on the banks of the northern half of the Scotian Shelf.

Spawning in the Louisbourg area off eastern Cape Breton is from May to June with a peak in May and for the Canso stock from April to May with maximum spawning in April. In the Lunenburg-Jeddore area the peak spring spawning is in April, but the fall-spawning stock of this area spawns from October to December with peak spawning in November. In southwestern Nova Scotia from Lockeport southwards to beyond Cape Sable spawning is from April-May with a maximum in April, whereas farther westward in the East Fundy-St. Mary Bay area spawning extends from January to April with a peak in April (McKenzie, 1934, 1956). These spawning dates are often not yet well enough defined but the St. Mary Bay spawning beginning in January may be additional evidence for the separation of the East Fundy-St. Mary Bay cod as a separate stock from that of the Seal Island stock.

Gulf of Maine stocks

The part of Fig. 5 showing the cod stocks of the Gulf of Maine was obtained from the U.S. Dept. of the Interior, Fish and Wildlife Service, Biological Laboratory at Woods Hole, Mass., through Mr. Albert Jensen. It represents the unpublished results of cod tagging in this area by the Woods Hole Laboratory. There are Browns Bank and eastern Georges Bank stocks, essentially separate but with some inter-migration in both directions across the Fundian Channel. The coastal Maine stock is a local stock of limited movement, similar in the restricted nature of its migrations to the Nova Scotian coastal stocks. The South Channel stock spends the summer in South Channel, especially on the western side of this Channel, and for most of the remainder of the year migrates southward and inshore to the Nantucket Shoals-Chatham region.

The Browns Bank stock (from information supplied by the U.S. Fish and Wildlife Service Biological Station at Woods Hole) spawns from March to May with peak spawning in late March. The eastern Georges Bank stock spawns in February-April with a peak in late February.

Middle Atlantic stock

This southernmost stock of cod (only partially shown in Fig. 5) spends the winter and spawns (Wise, 1958) southward outside the ICNAF area, mainly from Long Island to North Carolina, and in feeding migration moves northward to summer at Nantucket Shoals (near Cape Cod) with strays passing to Georges Bank and the Gulf of Maine. In parts of this stock spawning cod are to be found from November to April (Schroeder, 1930).

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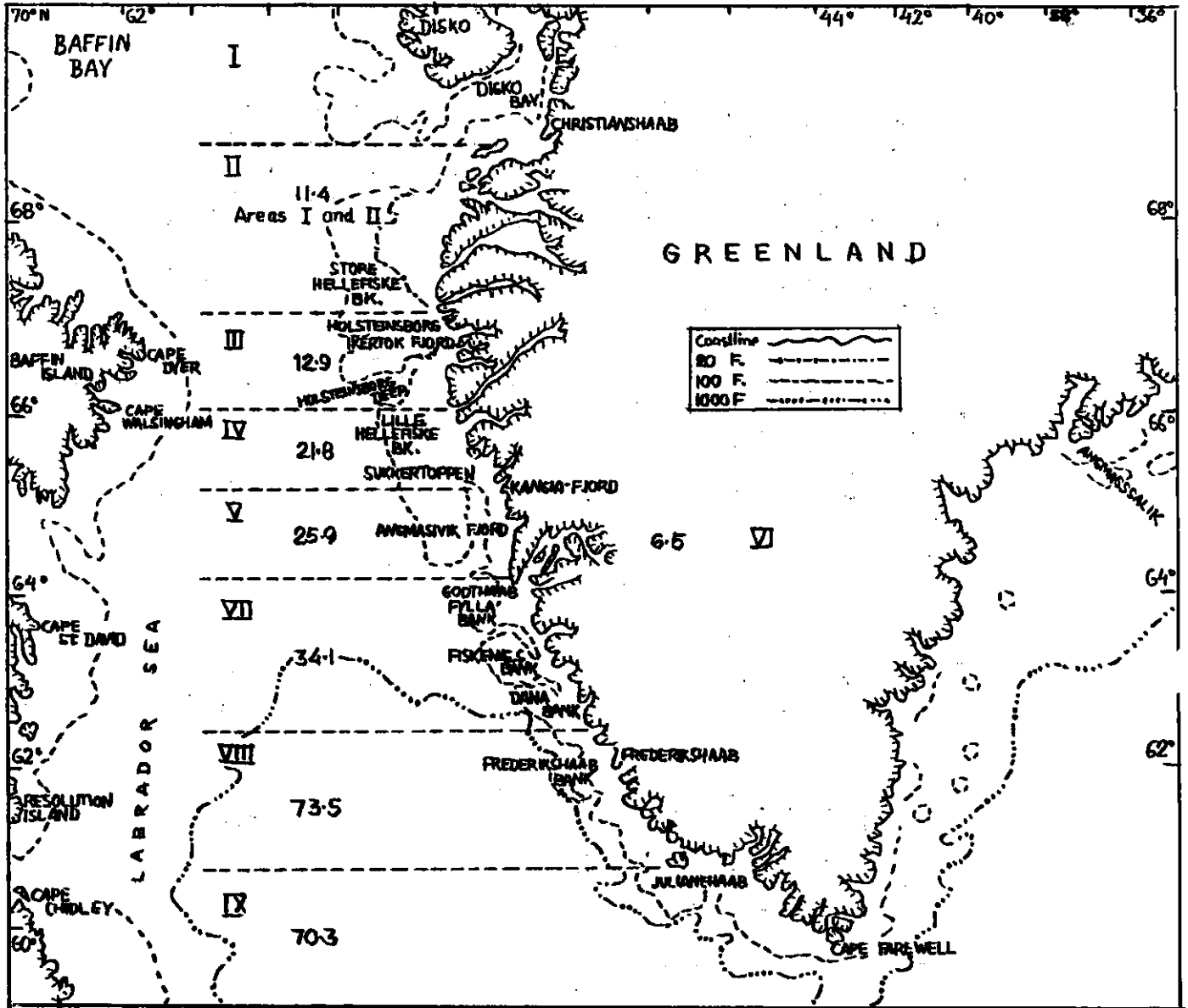
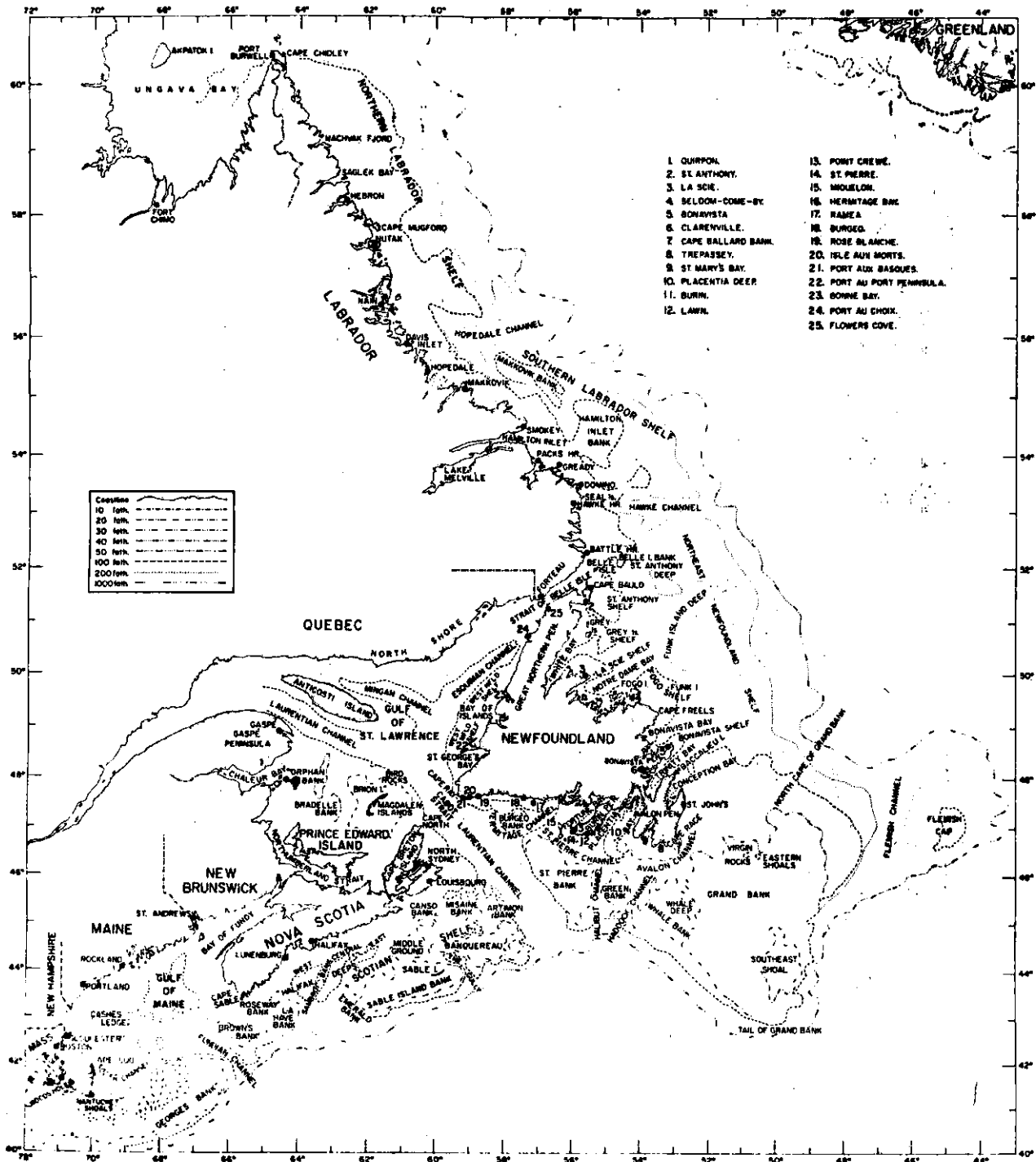


Fig. 1. Place names for Greenland area and Hansen's (1949) Zones I-IX in West Greenland, ICNAF Subarea 1. (Numbers in zones indicate percentages of total recaptures of cod, from taggings in each zone, recaptured in Iceland.)



Map showing names mentioned in the text as well as recognized names for some localities related to fishing and chief fishing grounds of Subareas 2, 3, 4, and 5 and, also, suggested names for other features of the fishing grounds chiefly in Subareas 2 and 3.

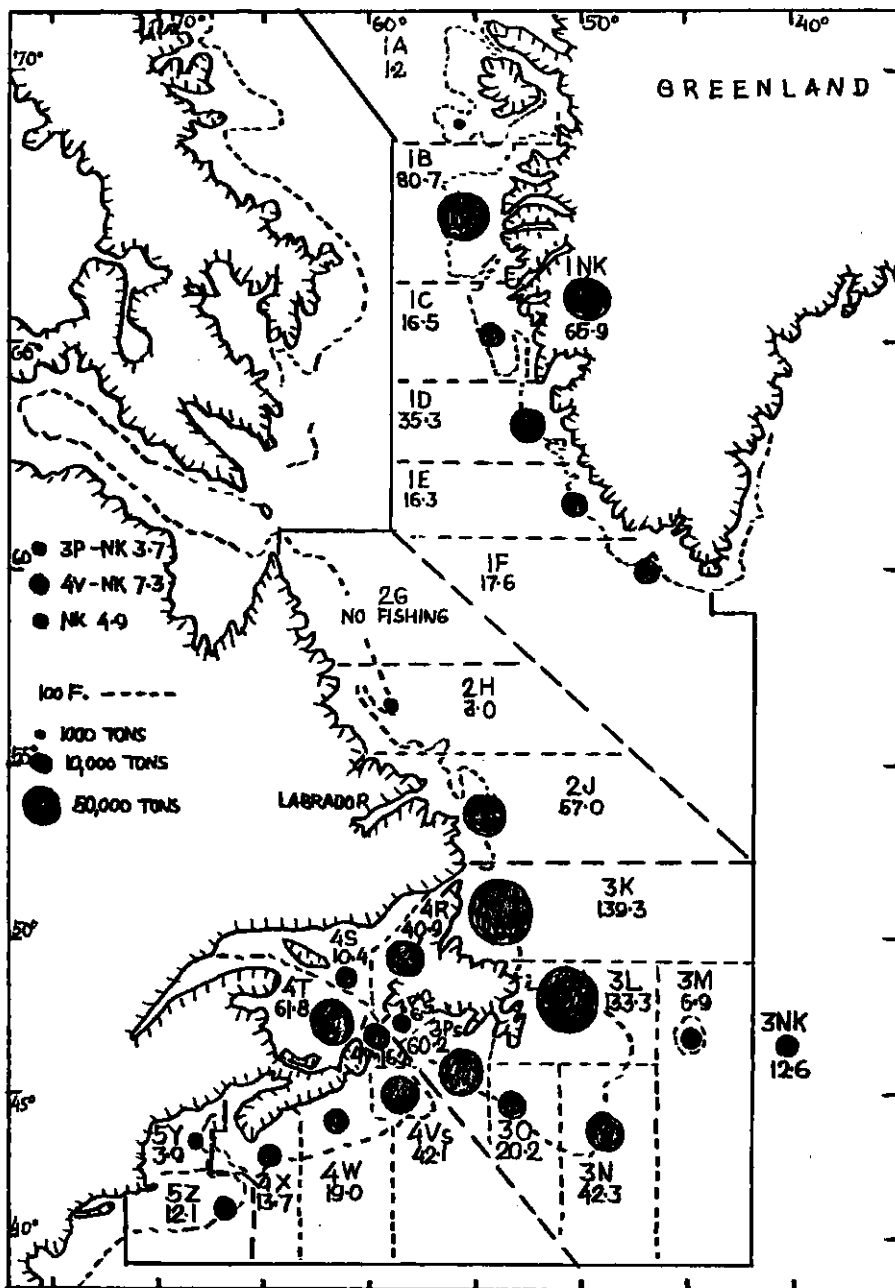


Fig. 3. Relative quantities of cod caught in 1959 in ICNAF Divisions. (Circle area is proportional to metric tons caught. NK = not known. NKI = in Subarea 1 but Division not known. Data from ICNAF, 1961). Total catch in metric tons: whole ICNAF area, 953,517; Subarea 1, 233,542; Subarea 2, 59,994; Subarea 3, 425,261; Subarea 4, 213,468; Subarea 5, 16,350; unassigned, 4,902.

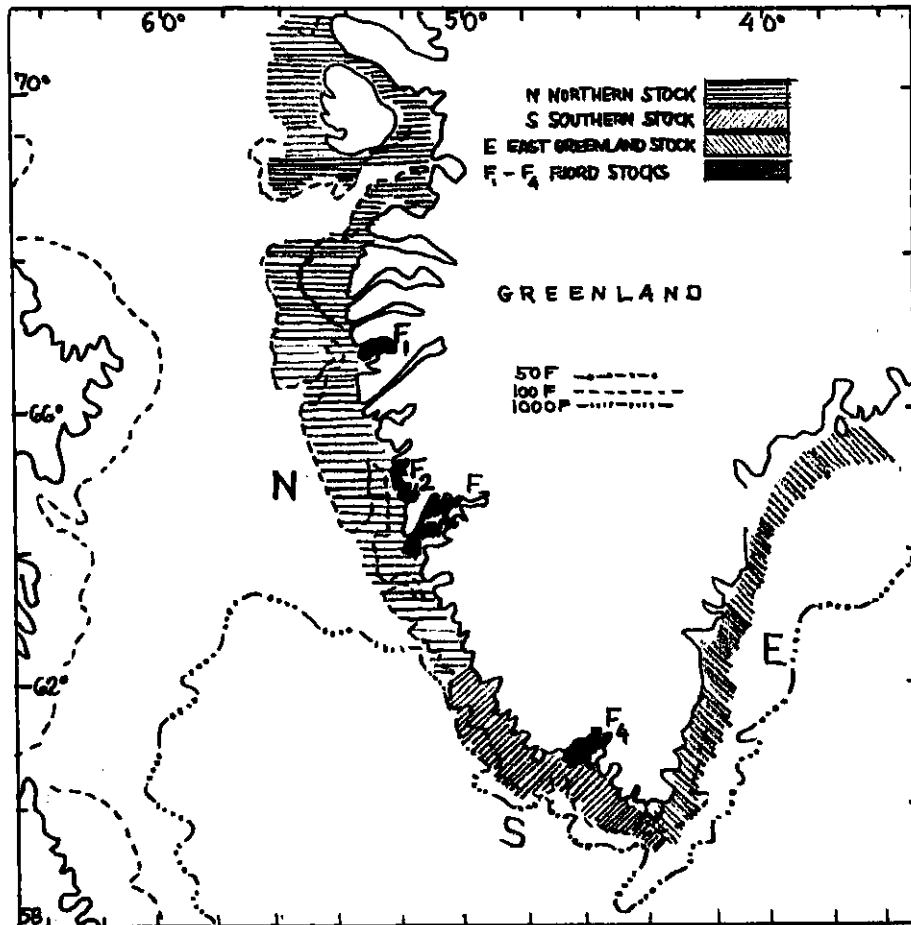


Fig. 4. Cod stocks of the Greenland area.

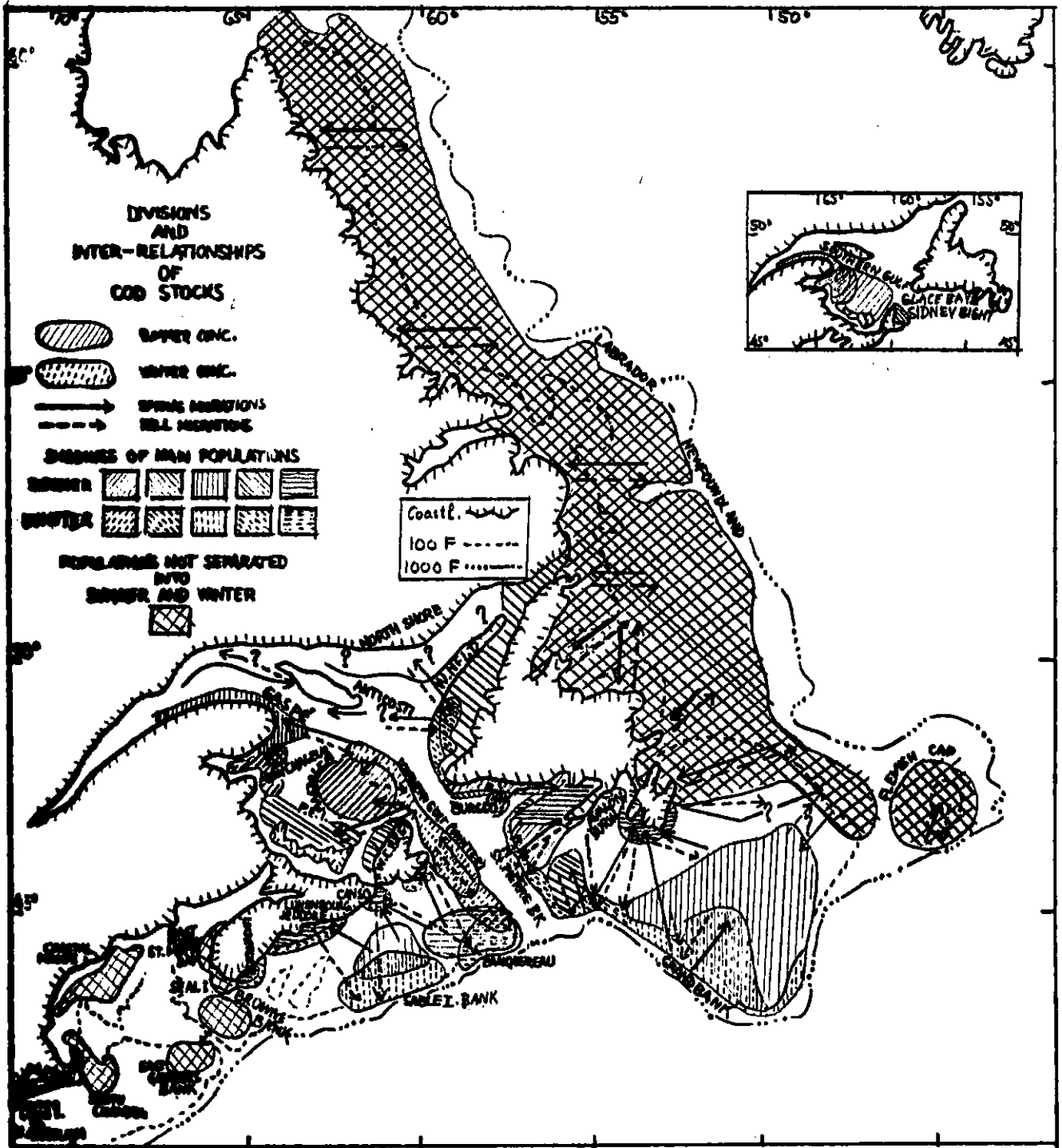


Fig. 5. Cod stocks of Subareas 2-5 and southward of Subarea 5. (Inset shows (from Yves Jean) outlines and concentrations of the southern Gulf of St. Lawrence population in summer when considered as a separate stock. Inset also shows the Glace Bay-Sydney Bight stock in summer).