

COD GROUPS IN THE NEW ENGLAND AREA

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ABSTRACT

Indications from previous tagging experiments since 1897 result from tagging 2,794 cod by the author from 1955 to 1959, and evidence from other sources indicate four groups of cod in the New England area: (1) The cod of the offshore banks, (2) the cod of the Gulf of Maine, (3) the cod of southern New England and the

Although cod, *Gadus morhua* L., are widely distributed on both sides of the North Atlantic, no cod marked on the European coast has ever been recovered on the coast of North America, nor vice versa. Many cod tagged at Iceland (fig. 1) have been recaptured at West Greenland, but there are only one or two records of fish tagged at Iceland recaptured as far west as Newfoundland waters. Many years of marking experiments by Europeans and North Americans, supported by studies of meristic characters (Schmidt, 1930), have conclusively demonstrated the lack of interchange between European cod and those of the North American coast.

Concentrating, then, on the cod of the western Atlantic, there have been a considerable number of important studies which serve to point out the separation of various groups found here.

Templeman (1953) considers the cod of Labrador separate from those of West Greenland, basing his conclusions chiefly on vertebral counts. In a consideration of growth rates, age at sexual maturity, and parasite infestation, he concludes further that the Labrador cod are distinct from the Newfoundland and Grand Bank fish. He points out (p. 64) that, "Apart from fish tagged

South Channel, and (4) the New Jersey coastal cod which spend the summer in southern New England.

It is suggested that the first three groups are stocks not genetically separate, while the New Jersey fish are a genetic subpopulation. Within all of these groups, except the last, there is a tendency for the larger fish to move permanently to the north and east.

on St. Pierre Bank it is very unusual for any fish tagged in Newfoundland to cross the Laurentian Channel to the Nova Scotia Banks or to the southern side of the Gulf of St. Lawrence."

Martin (1953), in discussing the major ground-fish stocks of Subdivision 4 of the Convention Area of the International Commission for the Northwest Atlantic Fisheries (roughly the Nova Scotian and Gulf of St. Lawrence regions), states (p. 57), "The deep-water Fundian Channel between Georges and Browns Banks and the still deeper Laurentian Channel between St. Pierre Bank and Banquereau are barriers to the movement of cod. Except for occasional movements of individual cod across these channels we may consider that the cod populations along the Nova Scotian coast, in the western Gulf of St. Lawrence, and on the Nova Scotian offshore banks are resident in Subarea 4." As to western Nova Scotia, he reports that, "Resident populations show restricted movement and do not mix with eastern or offshore cod."

The data published by McKenzie (1956) show that from about 20,000 cod tagged along the Nova Scotia and Gulf of St. Lawrence coasts and offshore banks from 1926 to 1940, there were many hundreds of returns east of longitude 65° W.

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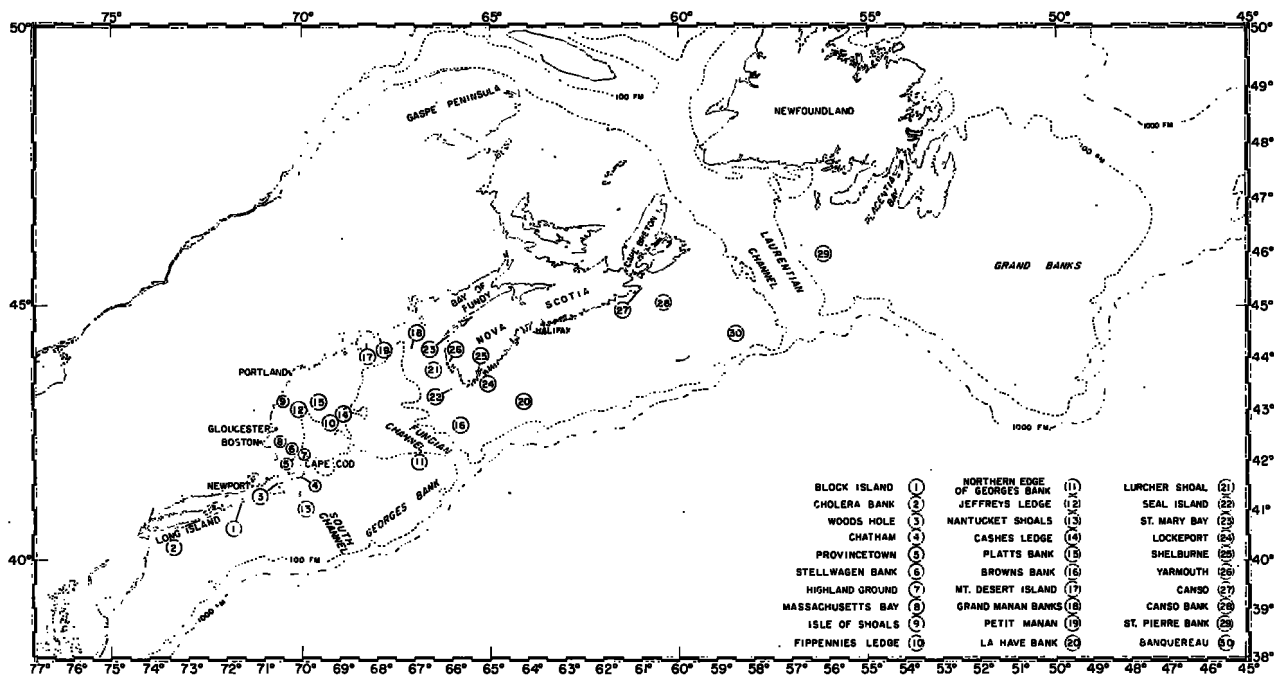


FIGURE 1.—The western North Atlantic area.

However, only about a dozen came from west of 65° , that is from New England waters as considered here.

For purposes of this study, New England waters have been rather liberally defined as those parts of the Atlantic Ocean north of latitude 40° N. and west of longitude 65° W. With this and the results above in mind, it is evident that the New England cod are generally distinct from American cod living to the north and east and may be treated as one or more discrete ecological units. The only exception is the southern stock of cod which infiltrates the New England area in summer (Wise, 1958).

This report presents the results of recent (since 1955) marking experiments in New England waters, taking into consideration, however, the results of previous experiments and other evidence where applicable, to provide the best description possible of the relations of the cod groups in the New England area. (The words "group" and "stock" are used here as defined by Marr (1957).)

PREVIOUS TAGGING EXPERIMENTS

Although cod had been tagged in the northeastern Atlantic as early as 1888, it was not until 1897 that any were marked on the American side.

During the 1920's and early 1930's, under the stimulus of the newly formed North American Council on Fishery Investigations, considerable numbers were marked in New England waters by Canadian and United States biologists. A few publications were issued as a result of this work, but unfortunately many of the experiments were never reported in detail in any permanent form, and the original records are either lost or destroyed. Many of the summary reports are ambiguous and contradictory, particularly as regards the number of fish tagged and recaptured, and the exact locations of tagging and recapture. I have consulted some of the men who engaged in these operations, but after nearly 40 years their memories of dates, places, and numbers are understandably imprecise. Insofar as possible, the following summary, based, unless otherwise stated, on Higgins (1929, 1930, 1931a, 1931b, 1932, 1933, 1934, 1936), Rich (1925, 1926), Schroeder (1928, 1930), and the reports of the North American Council (1932, 1935), presents the most complete reconstruction of all experiments previous to December 1955 in New England waters. The results and conclusions drawn from them, the development and evolution of tags and methods, were also reconstructed from the same sources, and the latter is presented as a separate section.

**TAGGING EXPERIMENTS AND RESULTS
FROM 1897 TO 1955**

Table 1 shows in summary form all tagging previous to 1955. Obviously these experiments were of vastly different scopes, and the results in terms of returns were extremely variable, both in numbers and percentage, from a fraction of 1 percent to numbers approaching one-half of the fish returned, for instance, the 1953 Canadian experiment yielding more than 40 percent by the spring of 1955.

In retrospect, however, they may be grouped with their results in the following way:

1. Southern Nova Scotia and Browns Bank. On the basis of the Canadian work from 1924 to 1927, McKenzie (1934, 1956) concluded that the fish around Shelburne were essentially stationary, while those at Seal Island showed a movement eastward during summer and returned in winter. The U.S. tagging on Browns Bank in 1927 was not successful; the Canadian work from 1926 to 1930, in the Bay of Fundy, was never reported in detail, nor was the U.S. work on Browns in 1928 and 1930. Inshore tagging in 1938 and 1939 yielded less than 20 returns, most of these nearby, but 1 from Georges Bank.

Most of the large numbers of cod reported recaptured by McCracken (1956) from his work off Lockeport, Nova Scotia, in the summer of 1953 were taken more or less locally, a few from the banks directly offshore, about 20 well to the northeast, and 7 from Georges Bank and vicinity.

2. Gulf of Maine. From 1923 to 1932, the U.S. Bureau of Fisheries marked fish in the Gulf of Maine, with a concentration of the work around Mount Desert Island and on Platts Bank. Although good numbers of fish were marked, probably more than 6,000, and the percentages of returns up to about 20 percent in some cases, no report was ever published in detail, and the only available summary occurs in the Proceedings of the North American Council on Fishery Investigations (1932, p. 12), that there was "very little intermingling between the more southern population and the cod of the gulf of Maine, of Georges bank and of Nova Scotia. . . . In general the fish of the Mt. Desert ground have been found, by recapture, to remain chiefly stationary in the locality, the few recorded journeys . . . being nearly all eastward"

3. Georges Bank. The U.S. Bureau of Fisheries marked cod on Georges Bank from 1926 intermit-

TABLE 1.—Summary of all cod tagging experiments in New England waters previous to 1955

[See text for sources not given here]

| Year | Area | Number tagged | By whom tagged |
|----------------------|---|---------------|--|
| 1897-1901 (winters) | Woods Hole and vicinity | 4,019 | H. M. Smith. ¹ |
| 1923 (April-October) | Stellwagen Bank | 12 | W. C. Schroeder. |
| 1924 | Mouth of Bay of Fundy | 56 | Canadian biologists. |
| 1924 (July-October) | Massachusetts Bay | 218 | W. C. Schroeder. |
| | Platts Bank | | |
| | Mount Desert Island | | |
| 1925 | Petit Manan, Maine to Southern Mass | 1,611 | W. C. Schroeder. |
| | Mount Desert Island (April-May) | 604 | |
| | Platts Bank (June-July) | 1,016 | W. C. Schroeder. |
| 1926 (August) | Georges Bank | 1,859 | W. C. Schroeder. ² |
| 1925-1928 (winters) | Woods Hole | 23,555 | W. C. Schroeder. ² |
| 1923-1929 | Southern New England | 300 | |
| | Cholera Bank | 884 | |
| | Southern New Jersey | 4,011 | Biological Board of Canada. |
| 1926 (summer) | Shelburne, Nova Scotia | 28 | Biological Board of Canada. ² |
| | Yarmouth, Nova Scotia | 1,840 | |
| 1927 (June) | Seal Island, Nova Scotia | 477 | U.S. Bureau of Fisheries. |
| | Georges Bank | 904 | |
| 1927 | Browns Bank | 79 | |
| | Platts Bank (April-October) | 321 | U.S. Bureau of Fisheries. |
| 1928 | Cashes Ledge (September-October) | 1,285 | U.S. Bureau of Fisheries. |
| | Massachusetts coast, north of Cape Cod, off New Hampshire and Maine, on or near Browns and Georges Banks. | | |
| 1926-1930 | Bay of Fundy | 61 | Biological Board of Canada. ² |
| 1930 (April-October) | Mount Desert, Georges Bank, Browns Bank, Cashes Ledge, Platts Bank, Nantucket Shoals. | | U.S. Bureau of Fisheries. |
| 1931 | Mount Desert | 1,199 | U.S. Bureau of Fisheries. |
| | Woods Hole (January) | 340 | |
| | Nantucket Shoals (August) | 172 | |
| 1932 | Mount Desert | 1,481 | U.S. Bureau of Fisheries. |
| | Woods Hole (January) | 304 | |
| 1938 | Mouth of Bay of Fundy | 13 | Biological Board of Canada. ² |
| 1939 (April) | St. Mary Bay | 83 | Biological Board of Canada. ² |
| 1953 (summer) | Lockeport, Nova Scotia | 1,804 | Fisheries Research Board of Canada. ⁴ |

¹ Smith, 1902.

² Schroeder, 1930, which includes some 1,184 fish tagged to the south of the area.

³ McKenzie, 1934, 1956.

⁴ McCracken, 1956.

tently to 1930, probably something on the order of 2,000 fish in all, but the records show only 6 recaptures, 3 of them on the bank.

4. Woods Hole. Smith (1902) and Schroeder (1930) report basically similar results from releasing with marks during the winters of 1897-1901 and 1925-28, nearly 6,000 of the cod which had been held at Woods Hole as a source of eggs and milt for the hatchery in operation during that period. Most were recaptured locally, some to the north and east, and some as far south as southern New Jersey. Schroeder incorporated the results of this work in his conclusions about the cod of southern New England (see below). The results of the 1931 and 1932 work were never published.

5. Nantucket Shoals and southward. Schroeder (1930) reports in considerable detail on the tagging from 1923 to 1929 of nearly 25,000 fish, mostly on Nantucket Shoals, and also as far south as southern New Jersey. His most important conclusions from these experiments, taken together with length frequency studies and sclerite counts of the scales were:

(a) The stock of cod living on Nantucket Shoals is for the most part distinct from that living to the north and east of southern Massachusetts.

(b) A large part of this stock makes a fall migration to the Rhode Island-North Carolina region, where many spawn and most remain until spring (see Wise (1958) for another interpretation of this movement).

(c) Part of the cod living on Nantucket Shoals emigrate eastward to the Chatham-South Channel region during certain summers.

(d) The stock on Nantucket Shoals is recruited from younger fish from other regions, most of them from offshore grounds. When they reach about 75 cm. in length, they tend to move off the shoals, perhaps to the offshore banks.

TAGS AND METHODS

Smith (1902) used numbered pieces of sheet copper about three-fourths of an inch by one-fourth of an inch, with a hole in one end through which a fine copper wire was passed. These tags were fastened at various places on the fish, but mostly the upper part of the caudal fin, near the peduncle. About 3.5 percent of the cod were recaptured.

Later, Bureau of Fisheries investigators used a metal tag similar to a cattle ear tag, and in the

beginning attached it exclusively to the upper part of the caudal peduncle by means of special clamping pliers. Various metals were used experimentally: silver, aluminum, copper, silver-plated copper, but monel was finally chosen as best. The vast majority of all cod marked between 1901 and the termination of the experiments in 1932 were marked with this tag and in this manner.

It was estimated early in the work, however, that as high as 60 percent of these tags were shed by the fish within the first year. Later the estimate was revised upward, based partially on recaptures by research vessels of fish which bore unmistakable marks of having been tagged. Beginning in October 1927, some fish of 75 cm. or less were marked with the same tag clamped on the lower jaw between the dentary and articular bones, in the hope that these tags would not be so easily lost. Fish thus marked, however, yielded no higher percentage of return, and in 1928 this method was abandoned.

Some tags made of duralumin, a hard alloy of aluminum, were used after 1929, since it was felt that this metal had all the virtues of monel without its weight.

In 1930, a pair of celluloid discs, resembling the Scottish plaice mark, was used with considerable promise. Half of the cod released at Woods Hole in 1932 were marked with celluloid discs on the tail and half on the opercle; within 11 months 8.5 percent of the opercle-tagged cod had been recaptured vs. 5.3 percent of the caudally tagged. In the same year, experiments were carried out with celluloid strips inserted into the coelom during the Mount Desert experiments. These showed some promise of being more permanent than anything used previously, but the U.S. cod investigations were not carried out long enough thereafter to establish conclusive results.

All of the Canadian work from 1924 through 1939 was done with the monel tag described above. In McCracken's (1956) tagging, he used this tag and also used red and white Petersen discs (one of each color) attached on stainless steel wire through the back of the fish, yellow discs attached similarly, and Lea hydrostatic tags on a stainless wire loop through the back. The red and white discs gave by far the best returns, more than 60 percent, the yellow discs over 50 percent. The hydrostatic and strap tags were a poor third and

fourth, with just above 30 percent each, vs. an overall average of more than 40 percent.

RECENT TAGGING EXPERIMENTS

While marking experiments from 1955 through 1959, like all such work, were somewhat opportunistic, depending on weather, availability of fish for tagging, availability of research and commercial vessel time, etc., in retrospect the coverage of the New England area was reasonably good. The experiments fall naturally into three geographic groups, offshore banks, Gulf of Maine, and off southern New England. Table 2 gives a summary of the time and place of each of the experiments in this series, together with the number of fish tagged and the number and percentage returned. The percentages returned should be taken here as only the grossest indication of

TABLE 2.—Summary of cod tagging experiments, 1955–1959

| Place and time | Number tagged | Number returned | Percent returned |
|-----------------------------|---------------|-----------------|------------------|
| OFFSHORE BANKS | | | |
| Georges Bank: | | | |
| Dec. 1956..... | 113 | 8 | 7.1 |
| Mar.-Apr. 1957..... | 434 | 66 | 15.2 |
| Oct. 1957..... | 51 | 2 | 3.9 |
| Total..... | 598 | 76 | 12.7 |
| Browns Bank: | | | |
| Mar. 1957..... | 149 | 48 | 32.2 |
| Oct. 1957..... | 76 | 11 | 14.5 |
| Total..... | 225 | 59 | 26.3 |
| GULF OF MAINE | | | |
| Cashes Ledge: | | | |
| June-July 1956..... | 114 | 11 | 9.6 |
| Nov. 1957..... | 50 | 5 | 10.0 |
| Jeffreys Ledge: | | | |
| July 1956..... | 20 | 3 | 15.0 |
| Apr. 1959..... | 4 | 0 | 0 |
| Thatchers Island: | | | |
| July 1956..... | 2 | 0 | 0 |
| Lurcher Shoal: | | | |
| Oct. 1957..... | 7 | 1 | 14.3 |
| Grand Manan Banks: | | | |
| Oct.-Nov. 1957..... | 232 | 7 | 3.0 |
| Fippennies Ledge: | | | |
| Nov. 1957..... | 7 | 0 | 0 |
| Total..... | 436 | 27 | 6.2 |
| SOUTHERN NEW ENGLAND | | | |
| Newport, R.I.: | | | |
| Dec. 1955..... | 59 | 7 | 11.9 |
| Chatham, Mass.: | | | |
| Feb.-Mar. 1957..... | 1,020 | 253 | 24.8 |
| South Channel: | | | |
| Oct. 1957..... | 177 | 13 | 7.3 |
| Highland Ground: | | | |
| Oct. 1957..... | 237 | 27 | 11.4 |
| Nov. 1958..... | 42 | 4 | 9.5 |
| Total..... | 1,535 | 304 | 19.8 |
| Grand total..... | 2,794 | 466 | 16.7 |

¹ Actually 248 fish (253 returns) as 4 were caught after tagging, released and caught again, of which 1 was caught, released, and caught again.

the success of a particular operation; the factors affecting these percentages have been taken up in some detail elsewhere¹ and will be considered briefly here.

THE TAGS

The Lea tag has been described by Rounsefell and Everhart (1953). It consists basically of a small plastic tube, stopped at each end. Inside the tube, which is waterproof, directions for the finder are printed on a roll of thin paper. Although this tag is often fastened to the dorsal musculature of the fish with a wire bridle, in this work the tags were affixed to a monel chain which was in turn fastened to a plastic tab inserted in the coelom as described by Wise (1958).

Rounsefell and Everhart also give a good description of the Petersen tag and its development. The discs used in these experiments were of the type they describe as developed by Nesbit, and were bright yellow. The method of attachment was one worked out by scientists of the St. Andrews Biological Station of the Fishery Research Board of Canada, i.e., on stainless-steel wire through the dorsal musculature. A No. 12 hypodermic needle on a pin vise handle was passed through the muscles just in front of the first dorsal fin and the first interspinous bone. The stainless-steel wire bearing the numbered disc was then pushed through the bore of the needle, the needle withdrawn, another disc placed over the free end of the wire, and the wire cut to length and knotted to hold the two discs firmly in place. This method differs from the one most often used by the Canadians in that they place the tag between the first and second dorsal fins, with the wire passing between the interspinous bones.

A very few cod in these experiments were marked with plastic "spaghetti" tags through the dorsal musculature.

HANDLING METHODS

When tagging cod from a trap, the fish were removed by hand or by dip net from the pocket of the trap, as it was dried up, to a small floating live-car. These fish were taken one at a time

¹ Wise, J. P. Factors affecting number and quality of returns from tagging cod with different tags and using different methods of capture in ICNAF Divisions 4X and 5Y in 1957. International Commission for the Northwest Atlantic Fisheries, North Atlantic Fish Marking Symposium. (In press.)

from the live-car, tagged and measured, and released.

During long line operations, either from research or commercial vessels, fish which appeared not to have been seriously wounded by the hook or the other parts of the long line were gently released from the hook, immediately tagged and measured, and released.

The procedure used while otter trawling was quite different. The trawl net was towed on the bottom for periods of time varying from perhaps 20 minutes to an hour and a half; the time varied inversely with the abundance of fish. The objective was to obtain a reasonable number of fish which had been in the trawl for the shortest possible time.

At the end of the tow, the otter trawl was hauled back, the cod end hoisted aboard, and its contents dumped on deck. As quickly as possible the fish which appeared to be alive and in good condition were taken up from the deck by hand and placed in large wooden tanks of running sea water. The obviously dead or dying fish were culled from the tank, and sometimes when another tank was available the more promising specimens were transferred to a second tank. A measuring board was set up on the edge of the holding tank and fish were dip-netted as needed for tagging. Although some workers feel that it is profitable, where possible, to hold tagged fish in tanks for further culling of weak or dying individuals, this procedure was not followed in any of these operations.

Measurements were recorded usually to the nearest millimeter when the fish were less than 900 mm. in length, and to the nearest centimeter when the fish were larger. Because of haste or confusion, some fish were released before being measured. This happened perhaps 1 percent of the time.

RECOVERY METHODS

The message enclosed in the Lea tags and stamped on one of the pair of Petersen discs states that there is a reward for the return of the tag and gives the laboratory address. Although the tags are often returned directly by mail and the reward and information sent via return mail, agents of the laboratory stationed in New England ports have been empowered to pay the reward, a dollar, on the spot and to collect the pertinent information. In the same fashion, agents of the

Fishery Research Board of Canada working under a reciprocal agreement have collected tags and the Board has paid the reward. Since May 1958, agents of the Fish and Wildlife Service have paid an additional dollar when the fish was returned with the tag. These arrangements have undoubtedly fostered getting a good percentage of the tags recovered actually returned to the laboratory, more than if the initiative for sending them in were left entirely to the fishermen. In addition, having the tags and often the fish received by trained technicians has improved the accuracy of the information received, particularly concerning the length of the fish and its reaction to the tags.

These recovery methods, not available to earlier investigators, doubtless account for some of the improvement in returns over past experiments; how much would be difficult to estimate. On the other hand, previous workers, particularly Schroeder, fished deliberately with research vessels for tagged fish and caught some. This was not done in the recent experiments.

RESULTS

The details of the recent experiments, with exact locations and dates of tagging operations and recaptures are available for examination at the Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Mass. Below is a summary of the results, grouped as the experiments are in table 2. The figures show the locations of recaptures, plotted usually by 26-week (half-year) periods, in rectangles of 30 minutes of latitude by 30 minutes of longitude. Experiments which yielded no returns and tags returned with insufficient information were not considered in this summary.

Recaptures from Tagging on Offshore Banks

1. Georges Bank, December 1956 (fig. 2). Only eight of the cod tagged were recaptured, all of them on Georges Bank and all within a year. No seasonal pattern is discernible in the recaptures.

2. Georges Bank, March-April 1957 (fig. 3 (a), (b), (c), (d)). Through the summer and early autumn, 20 were recaptured on Georges, 16 on Browns and along the Nova Scotia shore as far east as Halifax County (fig. 3(a)). The position given in the upper left corner of this and subsequent figures gives the location of a return outside the area of the chart. During the winter, from

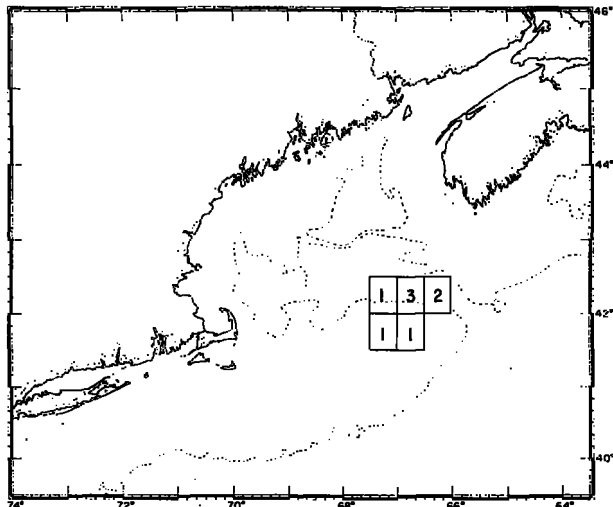


FIGURE 2.—Returns from tagging cod on Georges Bank, December 1956.

October until the next March (1958), 14 were returned from Georges Bank and 1 each from the south and the northeast (fig. 3(b)). The next summer, three were returned from Browns Bank and Nova Scotia (fig. 3(c)). During the winter and spring, three more were taken on Georges and two on Browns. In May and June, two were caught on the Nova Scotia shore (fig. 3(d)).

3. Georges Bank, October 1957. Only two fish were recaptured, and these were near where they had been tagged.

4. Browns Bank, March 1957. Through the summer and early autumn, 13 were captured on or near Browns and the near Nova Scotia shore, 3 from Georges, 3 from northern Nova Scotia, and 1 from the north shore of the Gaspé Peninsula (fig. 4(a)). During the winter and through the next summer (1958), 19 were taken on the Nova Scotia banks and inshore, and 1 on Georges (fig. 4(b), 4(c)). Only a single fish was recaptured, on or near Browns, until the next spring (1959) when three were caught in the same region and one on Georges. The following spring (1960), two were caught in the Browns-Nova Scotia area (fig. 4(d)).

5. Browns Bank, October 1957 (fig. 5). Until the next April (1958) three were taken on Browns. From May through August two more were taken on Browns and three on Georges. During the next summer (1959), one was returned from Browns, and the following spring (1960) one each on Browns and Georges.

Recaptures from Tagging in the Gulf of Maine

1. Cashes Ledge, June–July 1956. Through the next spring (1957) 11 were caught in the Gulf of Maine and near the Massachusetts coast.

2. Cashes Ledge, November 1957. In June (1958) a fish was returned from Georges Bank. Later that year, single individuals were taken in the Gulf of Maine and near Provincetown, and during the following winter (1959), one fish was returned from Georges.

3. Jeffreys Ledge, July 1956 and April 1959. The only returns were from the 1956 tagging. Two were taken near the tagging location, and the next year (1957) one was caught off Rhode Island.

4. Lurcher Shoal, October 1957. One return, near the tagging location.

5. Grand Manan Banks, October–November 1957. Six returns, through March 1960, scattered from the tagging area to the Gulf of Maine and Georges and Browns Banks.

Recaptures From Tagging off Southern New England

1. Newport, R.I., December 1955 (fig. 6). Until February, 1957, 6 were taken off southern New England and Long Island. The summer following the tagging, a single fish was captured on western Georges Bank.

2. Chatham, Mass., February and March 1957 (fig. 7 (a), (b), (c), (d)). Within the first 6 months 122 recaptures were made in or very near the area (see footnote, table 2). Sixteen were taken north of the tagging area, in the Gulf of Maine, along the Maine coast, and as far as the Nova Scotia shore. Five were recaptured on eastern Georges Bank, and one on western Georges (fig. 7(a)). By March (1958), 19 more were taken in or near the tagging area, 3 just north of it, 1 on Georges Bank, 13 to the south and west as far as northern New Jersey (fig. 7(b)). From February through August (1958), 34 were taken in or near tagging area, 19 to the north as far as the Nova Scotia shore, 4 as far south as northern New Jersey, and and 1 on Georges Bank (fig. 7(c)). In August (1958) two were caught in the tagging area or just north of it, and another in January (1959). Later in 1959 another was taken in the Gulf of Maine (fig. 7(c)). The following summer (1960) two curious reports were sent in: a tag found on the beach in the Bay of Fundy and a similar return from Placentia Bay, Newfoundland.

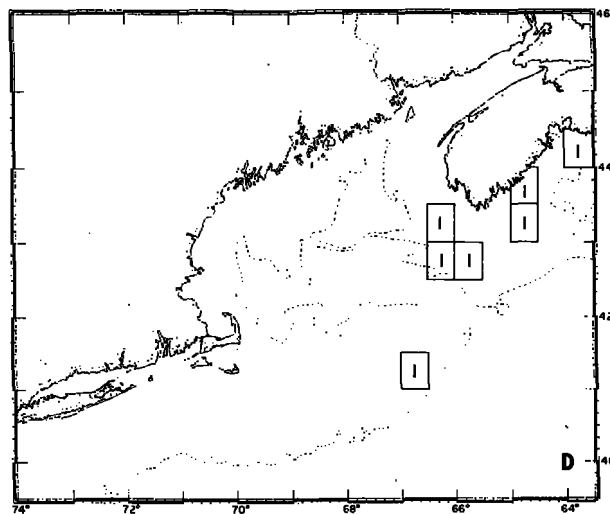
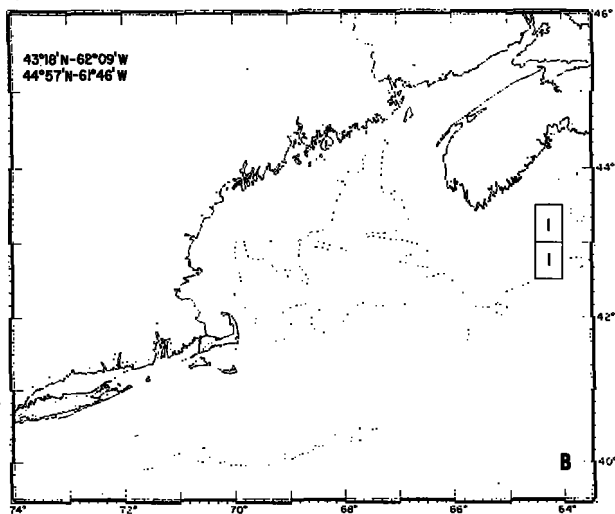
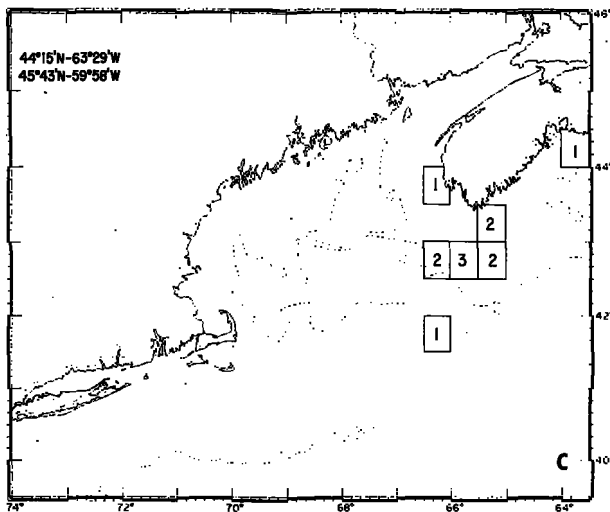
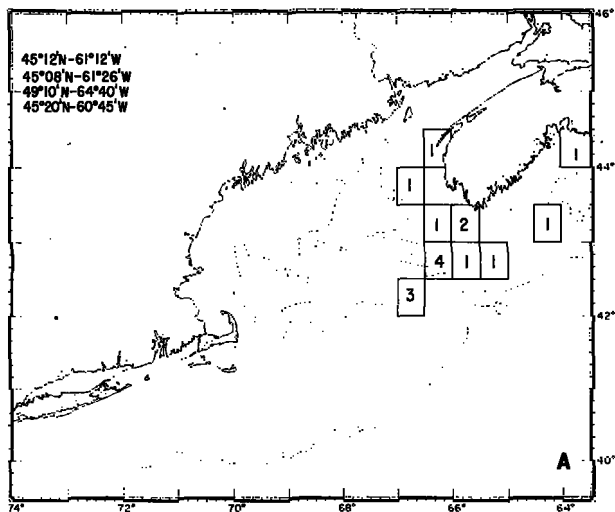


FIGURE 4.—Returns from tagging cod on Browns Bank, March 1957. (a) Within 26 weeks, (b) from 27 to 52 weeks (c) from 53 to 78 weeks, (d) from 79 to 163 weeks.

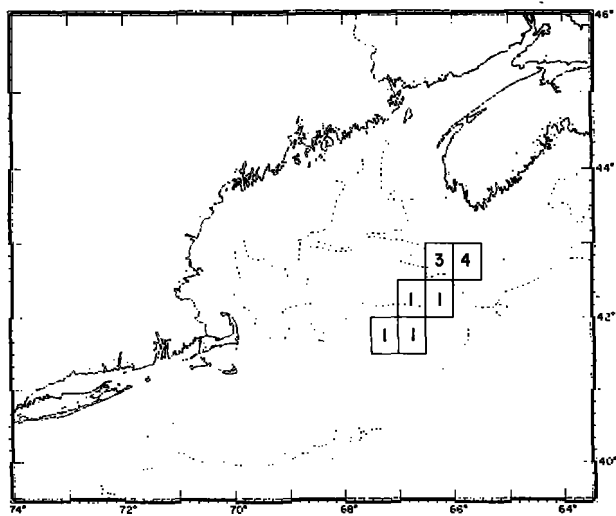


FIGURE 5.—Returns from tagging cod on Browns Bank, October 1957.

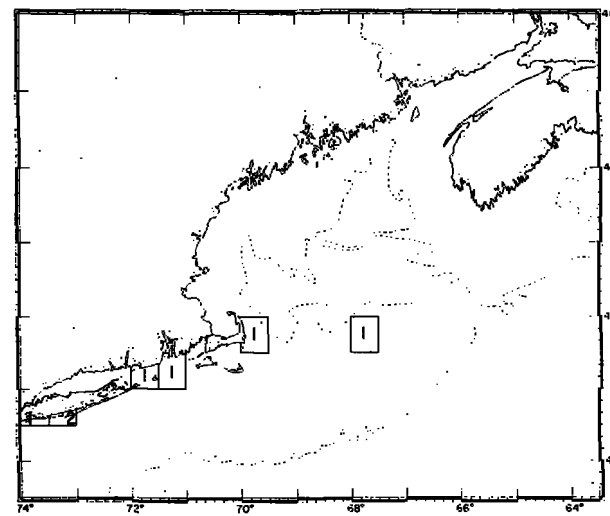


FIGURE 6.—Returns from tagging cod at Newport, R.I., December 1955.

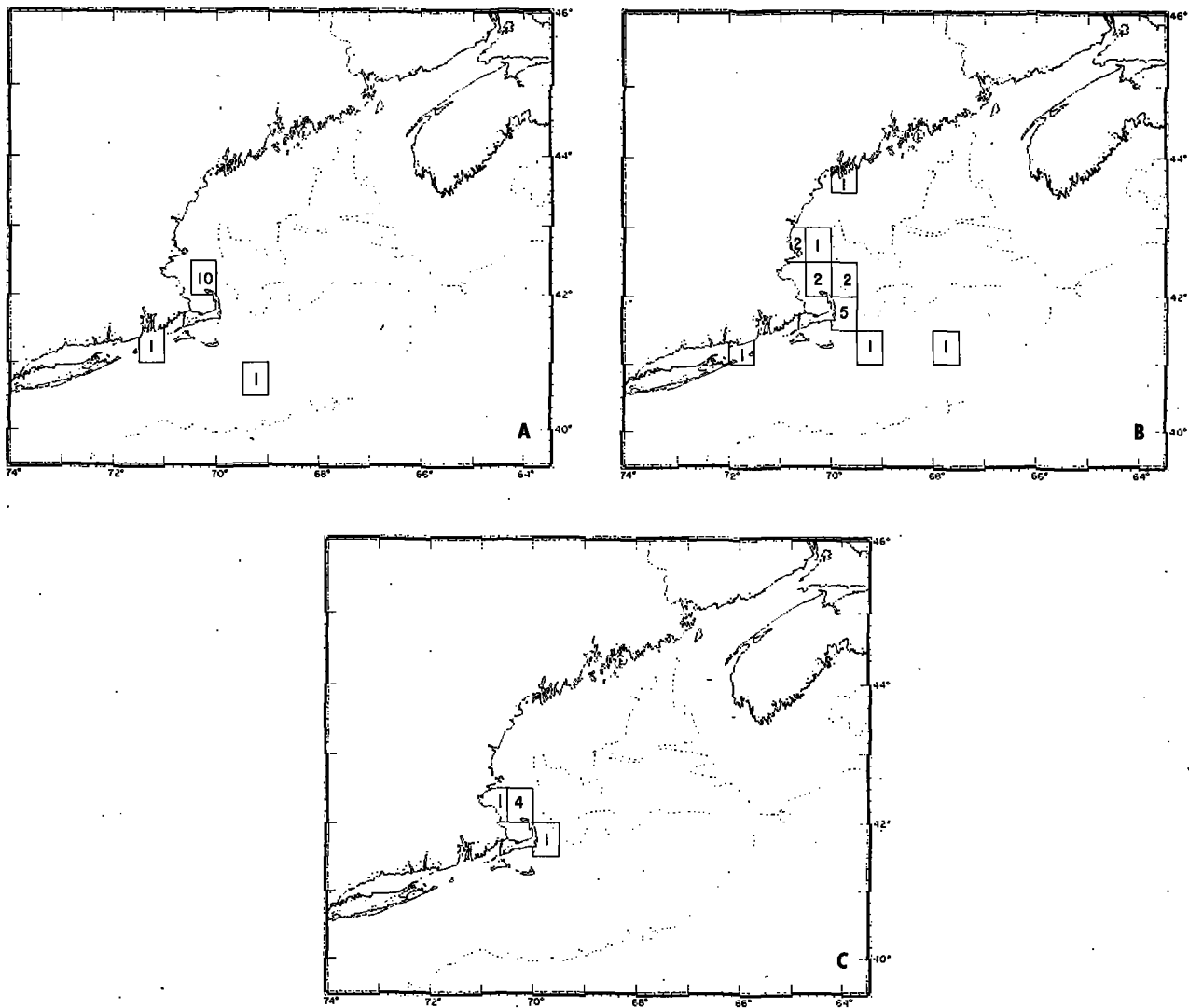


FIGURE 8.—Returns from tagging cod in the South Channel and on the Highland Ground, October 1957. (a) Within 26 weeks, (b) from 27 to 52 weeks, (c) from 53 to 144 weeks.

ments, the effects are minor. It is only if these data should be applied to estimation of population parameters that these variables would become important.

OTHER EVIDENCE OF DISCRETENESS OF GROUPS

THE COMMERCIAL LANDINGS

Although information about groups of fish derived from commercial landings must be interpreted with caution, because of the selectivity of various fishing gears and the culling practices of fishermen, properly chosen data treated appro-

priately can often yield valuable information. For several years we have been collecting information on the length-frequency distribution of the landings of cod caught by otter trawl in New England. These have recently been published in sufficient detail to show differences in the catches in broad areas. The length-frequencies for 1957, 1958, and 1959 (Wise and Murray, 1959, 1960, 1961) show definite differences between the western Gulf of Maine and the Georges Bank-southern New England area. While the means and modes of the length distributions are somewhat variable, there is a definite tendency for a greater percentage of the landings from the Gulf of Maine to

be composed of larger fish (above 80 cm.) than those from the more southerly area. If there is any difference in the nets used, it is that those in the Gulf have on the average somewhat smaller meshes. This could not produce the observed effect, as it has been shown experimentally that larger trawl meshes tend to catch a greater number of larger fish (Clark, McCracken, and Templeman, 1958). This length-frequency distribution alone is strong evidence against a free interchange of fish of all sizes between the two areas.

Indeed, there is evidence of a one-way movement of some of the larger fish from southern New England into the Gulf, and this doubtless contributes to the difference in size composition observed.

PARASITE STUDIES

Sherman and Wise (1961) studied the distribution of the long-lived copepod parasite of cod, *Lernaeocera branchialis*, in the New England area. We found heavy infestations, on the order of 20 percent, in the northern coastal region of the Gulf of Maine and moderate infestation, about 10 percent, in the central Gulf. We interpreted this as meaning that mixing between groups of fish in these areas occurs regularly. On Georges Bank and in the South Channel the infestation was much lower, less than 2 percent. This was taken to mean that there was little mixing between these and the Gulf fish. A sample of migrating cod taken off Rhode Island when they were on their way to the New Jersey coast in autumn had no *Lernaeocera* parasites.

MERISTIC STUDIES

Schmidt (1930) published counts of the number of vertebrae and number of rays in the second dorsal fin of cod from various Atlantic areas. He found large, statistically significant, differences between the cod of Nantucket Shoals, Mount Desert Island, and Grand Manan Banks. While these characters are somewhat variable with time, there were greater differences between the vertebral counts of cod from Nantucket Shoals and Mount Desert Island than there were between those of Mount Desert Island in different years. Grand Manan Banks fish were shown as different from either in one year, but only different from Nantucket Shoals in another.

CONCLUSIONS

The cod of the offshore coastal banks and of southwestern Nova Scotia coastal waters are relatively independent of any other groups in the New England area. There is, however, considerable movement within the group. Fish tagged on Georges Bank are most often caught on Georges Bank, but frequently turn up on Browns Bank and to the eastward in following summers. Fish tagged on Browns Bank are caught mainly on Browns Bank, but also to the eastward in following summers (consideration must be given to the small vessel fisheries of the Nova Scotia coast where fishing is prosecuted more heavily in summer than at any other time of year). Some Browns Bank fish cross over to Georges, but not nearly as large a percentage as cross the Fundian Channel in the other direction. Although a few fish from Georges and Browns are caught occasionally in the Bay of Fundy, only a single individual tagged offshore turned up near the shore of the New England States.

The cod of the waters north of a line between Provincetown, Mass., and the Northern Edge of Georges, and west of Nova Scotia, that is the Gulf of Maine proper, did not yield as high a percentage of returns as did the other groups in these experiments, and even when time of tagging and gear differences are taken into consideration, this is in itself a hint of their relative isolation. There is a considerable movement of some of the larger fish from southern New England into the area, probably in summer, but most of the fish tagged in the region and later recaptured were caught within it, the majority of these not far from where they had been marked. A few leave the area, probably via a northern route around the southwestern part of Nova Scotia, and join the fish on the offshore banks. But the returns from current experiments, taken together with results of previous experiments and the high but variable infestation rates with the parasite *Lernaeocera branchialis*, indicate that there are several more or less discrete groups within the Gulf, intermingling with each other to some extent, but far less with fish outside the Gulf, particularly those of the offshore banks.

The cod of southern New England seem the most mobile of all. A great many tagged in the area are recaptured in the area, even after considerable periods of time. Some individuals have

been repeatedly recaptured near where they were tagged. There is, however, a definite tendency for some to wander to the south and westward during the winter when hydrographic conditions are favorable. They do not go as far, though, as those fish which return to the New Jersey coast to spawn and which are the mainstay of the winter fishery there.

During the summer, the fish of southern New England are augmented by the New Jersey cod, while at the same time some of the larger ones work their way north along the Massachusetts and Maine shores, and a few even go as far as Nova Scotia. It seems doubtful, based on extensive summer tagging experiments in the Gulf, in the 1920's, that many of these fish return to southern New England, particularly those which penetrate as far as the coasts of Maine and Nova Scotia.

Thus, in the light of all evidence to date, there are four major groups of cod in the New England area, all perhaps, and one certainly, divided into subgroups:

1. The cod of the offshore banks, (Georges and Browns) closely related to the fish of the southwestern Nova Scotia coast.
2. The cod of the Gulf of Maine, probably divided into many subgroups, and receiving considerable recruitment from the south.
3. The cod of southern New England and the South Channel.
4. The New Jersey coastal cod, which spend part of the year mingled to a greater or lesser degree with the southern New England fish.

DISCUSSION

Consideration of the topography and hydrography of the region shows that the distribution of the fish outlined above is consistent with the physical features of their environment. A line drawn along the 68th meridian separates the offshore and southern Nova Scotia fish from the more inshore groups; this is a line which runs through or close to the important physical barriers of the deep mud bottoms of the central basin of the Gulf of Maine, the extreme shoals of central Georges Bank, and the relatively barren southern edge of the bank. Only around the narrow northern shelf of the Gulf does this line cross suitable bottom for cod, and all evidence points to this being the most likely path for what little interchange does take place.

Within the Gulf the suitable areas are cut up and patchy, the isobaths meander, the bottom is varied, and these factors doubtlessly foster the subdivision of the Gulf fish into several groups. As Cape Cod is approached from the north, the shelf becomes constricted near Provincetown, forming a bottleneck and limiting effective intercommunication of the Gulf fish with the southern New England group.

South and west of Nantucket Shoals, hydrography plays the most important part in the distribution of the fish. In summer the area is uninhabitable by cod, and the New Jersey fish move north to spend the summer with the southern New England fish. As fall approaches and water temperatures drop, the New Jersey fish migrate back to their spawning grounds, while some of the southern New England fish spread out over suitable bottom along the Rhode Island and Long Island shores.

There is evident in the tag returns from nearly all areas, however, a general movement of fish which cannot be accounted for by anything ordinarily thought of as migration; a tendency for fish which move any considerable distance from where they were tagged to move to the north and/or east. This has been noted previously, first by Schroeder (1930), and later in the Proceedings of the North American Council (1935, p. 15), referring to tagging experiments conducted on the Maine coast, ". . . a noticeable scattering of fish takes place north-eastward to the Bay of Fundy-Nova Scotia region. . . ." (See also quote from the same publication above.) However, when the data on tagging experiments in the northeastern part of the New England area and those from the Canadian coast outside of the area are considered, there appears to be no movement of "Canadian" cod of comparable magnitude in the opposite direction. McKenzie (1956) reports many hundreds of returns from about 20,000 cod tagged along the Canadian Atlantic coast, but only a dozen of these came from New England waters. McCracken's (1956) report of tagging near Lockeport mentions the recapture of more than 700 fish, but only 7 of these came from Georges Bank and vicinity. Contrast these results with those reported above from New England waters where from several experiments a good number of cod were recaptured along the Nova Scotia coast. An attempt has been made

to treat this movement quantitatively (Wise, 1959).

Of course, this effect could be produced by a fishing intensity increasing from the southwestern part of the New England and Nova Scotia area to the northeastern. This is not the case, however, for when the number of days fished per year by all gears except scallop dredges and harpoons (International Commission for the Northwest Atlantic Fisheries 1959) is considered, it is seen to decrease proceeding north and east, roughly:

| | Days |
|----------------------|---------|
| Subdivision 5Z..... | 24, 000 |
| Subdivision 5Y..... | 14, 000 |
| Subdivision 4X..... | 2, 000 |
| Subdivision 4W..... | 5, 000 |
| Subdivision 4Vs..... | 200 |

Whether any or all of the groups defined above are genetically self-sustaining subpopulations, or stocks which display nonheritable differences induced by environment is open to question. The movement of the pelagic eggs and larvae of cod, inferred from the nontidal drift of the surface waters, would generally be to the south and west through the area, promoting mixing in this direction, while the movement of larger fish to the north and east would tend to counteract this to some degree. Of course the size of the fish which appear to emigrate (Wise, 1959) is such that it appears likely that they would have spawned one or more times before they move. Thus, as an hypothesis, it is suggested that the first three groups, those of New England proper, are stocks, not genetically separate, while the New Jersey fish are a genetic subpopulation because of the geographic and hydrographic isolation of their spawning grounds. More detailed studies of morphometric and meristic characters of these four groups should shed considerable light on the question.

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