MIGRATIONS AND OTHER PHASES IN THE LIFE HISTORY OF THE COD OFF SOUTHERN NEW ENGLAND

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INTRODUCTION

The cod is one of the most valuable and best known of all fishes. In the western Atlantic it has been caught from as far north as latitude 67° on the west coast of Greenland (Jensen, 1926, p. 89) to as far south as Cape Hatteras, N. C., and in European waters from Spitzbergen to the region just southwest of Great Britain. A few stragglers enter the Bay of Biscay. Along our coast the most southerly ground where cod are to be found in commercial numbers the year round is off southern Massachusetts, and it is only from November to May when, by migrating, they invade the region extending from Rhode Island to North Carolina. No commercial fishing for cod has been carried on south of Delaware.

The cod has been of great economic importance to North America from the time of the earliest white settlers to the present era. Sette (1927, p. 3) points out that its fishery is probably the most international of any off North America, as no less than five nations take part in it.

During the 30-year period from 1896 to 1925 the annual catch of cod off the east coast of North America has ranged from 872,000,000 to 1,339,000,000 pounds, with an average of 1,103,000,000. Although subject to fluctuations, the general productivity of the cod fishery neither increased nor decreased during this time. The catch for the past 30 years has been divided among the five nations concerned, as follows: Newfoundland, 49 per cent; Canada, 20 per cent; France, 17 per cent; United States, 12 per cent; and Portugal, 2 per cent. (Sette, 1927, p. 13.) In the eastern Atlantic the annual catch of cod amounts to about a billion pounds.

The cod held first rank in the New England vessel fisheries for many years, but recently with the increasing number of otter trawlers and the improved methods of preparing and marketing fillets, the haddock has assumed first place. The landings of cod at Boston, Gloucester, and Portland, expressed in terms of fresh fish, amounted to 67,098,688 pounds, valued at $2,184,141, during 1923;[1] 64,241,619 pounds, valued at $2,138,306, during 1924;[2] 82,586,677 pounds, valued at $2,644,582, in 1926;[3] and 65,342,013 pounds, valued at $2,146,503, in 1927.[4]

Europeans as well as Americans have studied its spawning habits, and each year millions of young cod are artificially hatched and liberated. The cod's preference for certain foods has become known by investigators, who have examined thousands of stomachs. Statistics have been compiled from year to year on the amounts of cod and other fish landed at the important markets along the Atlantic coast and the amounts taken on each of the important fishing banks. Yet, in spite of all the study that has been devoted to the cod, there are still serious gaps in our knowledge of its life history.

That bodies of cod move from place to place has long been known by fishermen. We are reasonably certain that they carry out breeding migrations, for large schools of fish are found in certain localities only during the spawning period. It is probable, too, that bodies of fish move about in search of good feeding grounds, and that they make some effort to avoid extremes of temperature which are unfavorable to them. In general, the smaller fish are the more stationary while the larger are the more migratory. Besides the schools of fish which appear to travel en masse, some individuals, usually the larger fish, seem to lead a nomadic existence. But even these may not migrate far in any given direction if we take tagged fish as a criterion.

[1] Fishery Industries of the United States for 1923, U. S. Bureau of Fisheries.
[2] Ibid. for 1924.
[3] Ibid. for 1926.
[4] Ibid. for 1927.

In Europe the cod has been studied by means of marking experiments for more than 25 years, while in American waters, prior to the present experiment, one was made off Woods Hole, Mass. Although marking experiments have thrown considerable light on the behavior of the cod in European waters, particularly on their migrations, we can not assume that the same conditions obtain along our coast or that the habits of American and European cod are similar in all respects.

The present investigation was undertaken on April 17, 1923, to study the cod's life history not only as a matter of biological interest but so that if a decided decline in the abundance of the fish should ever occur the fishing industry would be able to adjust itself thereto with as full a knowledge as possible of the fish's habits, especially of its migrations, duration of life, rate of growth, and size at different ages. The present study concerns the natural history of the cod after it seeks bottom, including fish as small as about 2 inches in length.[5] Most of the field work during 1923–1925 was carried out by means of the Bureau of Fisheries' vessel *Halcyon*, commanded by G. W. Carlson. A few fish were tagged by the steamer *Fish Hawk*, while specimens and data were collected by the steamer *Gannet*. In 1926 the *Halcyon* and *Fish Hawk* were taken out of service, and since that time all investigations have been carried out with the *Albatross II*, together with small fishing boats.

It was realized at the start of this cod investigation that an extensive territory was available for carrying on operations, including both the shore grounds along the entire New England coast and the offshore banks such as Georges, Browns, Sable Island, and the Grand Bank. As the *Halcyon* was not suitable for fishing the offshore banks, operations from 1923 to 1925 were restricted to within about 40 miles of land.

Nantucket Shoals was selected for the first tagging partly for this reason, partly because (*a*) it is the most southerly region along our shores where cod are caught in abundance in the summer; (*b*) there was a strong probability from Smith's (1902) experiment that a migration of cod occurs between Nantucket Shoals and the region from Rhode Island to New Jersey, so that definite results might be expected from the first year's work; (*c*) cod are abundant in water shoal enough to fish conveniently with hand lines; (*d*) boats fish there from time to time; and (*e*) two of the largest offshore fishing banks—South Channel and Georges Bank—are adjacent, thus affording an opportunity for determining migrations of cod to and from Nantucket Shoals.

Opportunity is taken here to thank Dr. Henry B. Bigelow, of Harvard University, for his helpful advice in the preparation of all parts of this paper. Thanks are also extended to O. E. Sette for suggestions, temperature records, and other data, and to R. A. Goffin for specimens of young cod. Acknowledgment is made to Capt. G. W. Carlson of the *Halcyon*, and later of the *Albatross II*, and to the officers of these vessels for their cooperation, which was so necessary in making the field work a success. Finally, I wish to thank fishermen and those connected with the fishing industry for sending tags from recaptured fish and for supplying information on the habits of the cod.

HISTORICAL

COD MIGRATIONS IN EUROPEAN WATERS

The first real attempt to determine the migrations of cod by means of tagging experiments was made in the North Sea off Scotland, in October and November, 1888, when 16 fish were marked with numbered brass labels. (Fulton, 1890, pp.

[5] Some study has been given to earlier stages by Charles J. Fish: Production and Distribution of Cod Eggs in Massachusetts Bay in 1924 and 1925. Bulletin of the Bureau of Fisheries, Vol. XLIII, 1927 (1928), Pt. II, pp. 253–296.

353–355.) Of these, 3 fish, or 18 per cent, were subsequently recaptured, all of them that same winter and all near where they were tagged. By 1892, around the Firth of Forth, 196 cod had been marked, of which 10, or 5.1 per cent, were subsequently recaught. Fish as small as 7 inches in length were utilized, and only 16 exceeded 20 inches. Most of the recaptures were made locally, the farthest distance away from the point of tagging being 52 miles, and the mean period of freedom being about 75 days. (Fulton, 1893, p. 189.) Further tagging in the North Sea has been recorded by Boreley, Strubberg, Graham, Weigold, and others.

Boreley (1909, pp. 2–3) records the tagging of 252 cod in the North Sea from 1904 to 1907, of which 16.6 per cent were recaptured—32 fish within 6 months after tagging, 8 fish 7 to 12 months later, and 2 fish after 13 to 15 months. Most of the cod were recaptured near the tagging grounds and none were taken outside of the North Sea. Weigold (1913, p. 119) reports returns from North Sea tagged cod as high as 60 per cent—181 recaptures from 301 marked fish, most of them 20 to 39 centimeters long. Nearly all these were recaptured in the vicinity of the tagging grounds.

Strubberg (1922) reports on the marking of cod in Danish waters from 1905 to 1913. Out of a total of 1,547 tagged fish, 338, or about 22 per cent, were subsequently recaptured within the following time intervals: 316 within 1 year, 19 after 13 to 24 months, 2 after 26 to 29 months, and 1 after 47 months. Most of the fish utilized for tagging ranged in length from 25 to 70 centimeters (10 to 28 inches), and most of these were below 50 centimeters (20 inches). A greater proportion of the smaller tagged cod was recaptured than of the larger (25 per cent of 1,170 specimens less than 60 centimeters, 10 per cent of 377 specimens 60 to 109 centimeters).

The great majority of these fish were more or less stationary the first year after tagging, and many had shown no migration up to the beginning of the third year, which represents about the longest recapture interval. A few of the larger fish covered some distance within the North Sea, although the longest migration was that of a small fish (37 centimeters) which traveled 330 miles in 74 days.

Cod tagged in 1921–22 off Flamborough, England, were recaptured near by, most of them the same winter and the summer which followed. About 16 per cent of the cod tagged close to shore were recaptured within about a year, while about 7 per cent of the offshore tagged fish were retaken. (Graham, 1924, pp. 47–50.)

Concerning the migration of cod in northern Norway, Hjort (1926, p. 8) points out that the mature fish undertake extensive migrations, "thousands of kilometers," during the course of a year. He found that there was a yearly migration from the Barentz Sea southward along the Norwegian coast and a return migration back to the Barentz Sea. (Ibid., p. 9.)

Around the Faroe Islands 4,093 cod were marked from 1909 to 1913. (Strubberg, 1916, p. 3.) Most of these were from 30 to 90 centimeters (12 to 36 inches) long, the majority being below 60 centimeters. From 4,086 of these marked fish, 1,658, or 40.5 per cent, were subsequently recaptured. (Ibid., p. 78.) The time interval for the 1,562 recaptures made from the experiments of 1909–1912 was as follows: 1,082 fish within 6 months, 334 fish in 7 to 12 months, 113 fish in 13 to 18 months, 26 fish in 19 to 24 months, and 7 fish over 24 months. As a result of all these cod-marking experiments around the Faroes, the percentage of recaptures from various lots of fish ranged from 14.9 to 62.3, with a mean of 40.6 for all the fish. This being so, Strubberg believes that the values found indicate that from one-seventh to one-half (according to locality) "the growing stock of 35–50 centimeter

fish—the 2-year olds—are taken annually." (Ibid., p. 79.) The 2 and the 3 year old fish were virtually stationary, often being recaptured in the same place after more than 21 months, and a few were even taken later. The older fish were more migratory, although some of these, too, were stationary. None of the cod left the Faroes, and only a few moved as far as 60 miles. "* * * it would seem that the bank (Faroe Bank) has its own stock of cod, * * * the stock, moreover, being capable of itself replenishing the loss occasioned by a fishery of considerable intensity." (Ibid., p. 84.)

Around Iceland cod tagging was done in 1904–5 (Schmidt, 1907) and in 1908–9 (Saemundsson, 1913). During the earlier experiment, in 1904–5, the tagging occurred on the north and east coasts where a total of 491 cod was marked. Most of them were 40 to 60 centimeters (16 to 24 inches) long and, according to Schmidt (1907, p. 13), were not adult fish. Out of one lot of 297 cod tagged off the east coast in 1904, in a locality where a relatively large amount of fishing was done, 26, or 8.7 per cent, were subsequently recaptured, while of 194 tagged about the same time but in a locality where very little commercial fishing was done only 3, or 1.6 per cent, were retaken. Schmidt (1907, p. 15) concludes, and no doubt correctly, that the greater amount of fishing which obtained in the one locality was responsible for the greater return of tags. This also points to the localization of the fish, for 20 were taken the same season, 8 the next, and 1 later, and none migrated farther than a few miles. Even the 8 recaptures made the second season were taken near the tagging grounds, where they spent the winter and spring in water around 0° C., although they could have gone to the south coast where it was warmer. (Ibid., p. 17.)

Cod marking the summer of 1905 was done on the north coast of Iceland. Of the 391 fish tagged, most of which were immature, 2 were recaptured in August and September, 1905, and 6 from May to October, 1906, all of them on the north and northwest coasts. (Ibid., p. 19.) Subsequently 7 more of these fish were reported (Saemundsson, 1913, p. 8); 5 on the north and west coasts and 2 on the west and southwest coasts. These last two recaptures taken the summer of 1907 are of particular importance, for the fish had reached maturity in the two years since tagging and had migrated toward the spawning grounds off southern Iceland. Another lot of 26 cod was tagged on the east coast during the summer of 1905, and of these 2 were recaptured near by the same summer. Cod tagging was continued during the summers of 1908 and 1909, when 27 and 200 immature fish, respectively, were marked. The few fish of 1908 were tagged on the north coast and the one recapture, made 13 months later, was from near the tagging locality. During the summer of 1909 tagging was done for the first time on the southwest coast. Twenty-one of the fish were recaught within 3 months, and 9 of them within 10 to 14 months. All but 1 of the 25 specimens from which good locality records were obtained were taken in Faxa Bay near where they were tagged.

As a result of the cod experiments made off Iceland since 1904, it has been found that the fry which are carried by currents from the spawning grounds on the south and west coasts to the north and east coasts stay there for three or four years, but seek the warmer water off the southern coast of Iceland when maturity approaches. (Saemundsson, 1913, p. 34.) Schmidt (1907, p. 23) believes that the reason these north and east coast Icelandic cod make a spawning migration to the south and west coasts is that they become more sensitive to the cold water as they near maturity. Saemundsson (1913, p. 34) states that Iceland has its own stock of cod because no recaptures of tagged fish were made outside of there.

The great drop in the number of tagged cod that has been reported recaptured after more than a year, particularly in those experiments recorded by Boreley (1909) and Strubberg (1916, 1922), was due in part to the intensity of the local fishing which removed so many of the marked fish within the first year and in part to the large number of fish that lost their tags. Graham (1929b, p. 23) points out that the percentage of marked fish recaptured in a year has frequently been used as a minimum value in calculating the percentage of the stock taken by the fishermen, and that his tank experiments make it apparent that this value should be increased to account for the loss of tags. As we have found in our cod-tagging experiments off the New England coast (1923–1929) that the loss of tags the first year is very great, it is evident that the percentage of tags returned is not a good criterion in estimating at what rate the fishery depletes a stock of fish, other than that the percentage of tags returned must be considerably less than the actual percentage of the stock of fish caught. Most of the cod tagged in the European experiments were less than 60 centimeters long, hence it would not seem that death due to old age was an important factor in the small number of returns subsequent to the first year after marking.

The results of all these cod-tagging experiments agree in one important respect, namely, that most of the fish remain more or less stationary for long periods and that each region—the North Sea, coast of Norway, the Faroes, and Iceland—has its own stock of fish. In a few cases a migration was indicated, as along the coast of Norway and from the north to the south coast of Iceland.

Certainly the thousands of cod that have been tagged in European waters during the past 25 years, and the great percentage of recaptures returned by the intensive fishing which prevailed in all the tagging areas, would have revealed an intermigration if it had occurred between such localities as the North Sea, the Faroes, and Iceland. Very likely deep water prevents an intermingling of these various stocks of fish, although Jensen (1905, p. 11) found cod otoliths (*Gadus callarias*) at the bottom of the polar deep off the Faroes and comments on the fact that both Hjort and Schmidt report cod in the upper 60 fathoms in that region, taken with hook and line and with drift nets, over depths of 350 to 1,000 fathoms. Furthermore, the very fact that cod in the North Sea and elsewhere did not migrate soon after being tagged, but remained in the same general locality for several years, indicates that, taken as a whole, they are not a roving fish even though upon occasion some schools of fish may make extensive migrations.

The causes of migrations such as those of the Icelandic cod are not so evident, although it has been suggested that a low temperature and the urge to spawn caused these fish to seek the southern coast of the island. The fact that cod up to about 4 years of age remain off northern Iceland in the 0° C. water of winter and spring when they could so easily migrate into warmer water is of interest. There are instances in American waters, too, where cod are caught in very cold water as, for example, in the Gulf of St. Lawrence and on the Grand Banks where the bottom temperature is frequently below 0° C.

REVIEW OF COD TAGGING OFF THE NEW ENGLAND COAST

The only previous cod-tagging experiment on the American coast was carried out during the years 1897–1901 by the United States Fish Commission. (Smith, 1902.) These cod were caught primarily for the purpose of securing spawn and were retained in a large cistern at Woods Hole, Mass., until they were spent. All were caught on Nantucket Shoals during late October and November with hook and line

by the Fish Commission schooner *Grampus* and by commercial fishing vessels. The spent fish were weighed, measured, tagged, placed in live cars, and then towed out into Vineyard Sound or Buzzards Bay, where they were liberated.

The tags used in this experiment were made from sheet copper, cut in pieces five-sixteenths to three-fourths inch long and one-fourth inch wide, with a hole punched on one end. A fine copper wire was used to attach the tag to the fish. Different points of attachment were tried, among them the bases of the three dorsal fins, the two anal fins, and the upper and lower caudal lobes. Smith concluded, however (ibid., p. 194), that the upper part of the caudal fin near the base was the best. Smith found that some tags were lost by gradually tearing from the fin, but stated that the available evidence failed to show that many tags could have been lost in this manner. However, no tagged fish were taken by the tagging vessel *Grampus*, and therefore there was no opportunity in the field to check the number of fish having scars caused by the tag tearing loose. The fine wire used by Smith would leave scarcely any wound or scar after it had been lost by the fish, and no fisherman would have recognized a fish as having lost its tag. Without our observations in the field, we, like Smith, would have greatly underestimated the losses of tags. Then, too, the tags used by Smith were in two pieces—sheet metal and wire—therefore movable and more liable to loss than the rigid 1-piece tags used in the present investigation.

TABLE 1.—*Numbers of cod tagged and recaptured as a result of the marking experiments made off Woods Hole from 1897 to 1901*

December-January-February	Fish tagged	Subsequently recaptured	Percentage recaptured
1897–98	562	35	6.2
1898–99	593	30	5.0
1899–1900	1,421	22	1.5
1900–1901	1,443	53	3.7
Total	4,019	140	3.5

TABLE 2.—*Summary of recaptures, by localities and months, of tagged fish released in the vicinity of Buzzards Bay during 1897–1901*

Month released	Locality of recapture	Recaptured												
		During first year											During second year	
		Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Nov.	Dec.	May
December	Nantucket Shoals					2	3	1	2	1		1		
January	do				1	14	9	6	4	1	1			
February	do				2	1	3			2				
December	Marthas Vineyard and No Mans Land.		2											
January	do													
February			2				3						1	
December	Rhode Island	2				3	1							
January	do		1	2	5	7	9	2				1		
February	do				1	2	3	1						1
December	Long Island		4	3	1									
January	do		4	5	1	4	1							
February	do					2								
December	New Jersey		2		1	2								
January	do			1	1	1								
February														
December	Elsewhere				1									
January	do								1					
February														

In discussing the dispersal and movements of the tagged cod Smith (pp. 199–200) states that:

> Shortly or immediately after their release, there was a well-marked southerly and westerly movement to the shores of New York and New Jersey, where they remained during the first four months of the year.
>
> The fish showed but a slight tendency to go to the eastward of Cape Cod or of Nantucket Shoals. A few were taken between May and August, southeast of Chatham, but only one was reported from South Channel and one from Georges * * *.
>
> None of the tagged fish has been taken north of Cape Cod. If the schools with which the tagged fish mingled on Nantucket Shoals and elsewhere behaved as did the tagged fish, it is evident that the cod inhabiting the grounds off southern New England, New York, and New Jersey belong to a distinct body, and are not simply a part of the vast shoals found in Massachusetts Bay and on the coast of Maine.
>
> The conclusion seems legitimate that the cod which resort to the shores of New York and New Jersey in winter do not represent an independent body of fish which have come from some offshore grounds at this season, but are a part of the great schools of shore cod which also frequent the southern New England coast.
>
> Some fish released side by side became widely separated in a short time, while other lots appeared to keep together for several months. Some were moved by individual instincts, others seemed to act en masse. * * *

The tagged cod were found along the Rhode Island shores from November to June and on Nantucket Shoals from April to September. In October and November only 1 tagged cod was reported from Nantucket Shoals despite the fact that the *Grampus* fishing there at that time caught 4,000 to 6,000 cod annually, and commercial fishermen were active there during the same period each of the years from 1897 to 1901. Because of this Smith suggested that the fish which frequent Nantucket Shoals in the spring and summer, when 41 tagged cod had been caught there, represented a different body than was present in the fall when only 1 tagged cod had been caught.

Bigelow and Welsh (1924, p. 419) concur with Smith's views on the movements of the cod in the southern part of its range, for during the period 1901 to 1922 no further experiments were carried on and no information had come to light that could alter the preceding conclusions.

DEFINITION OF TERMS USED

At this time it is desirable to define the terms used in this book which deal with the movements of the fish, for these terms often are broadly interpreted and might easily lead to confusion.

A migration applies to a movement of a body of fish from one region to another and back again.

The term emigration is used to designate a movement of a body of fish away from a region, presumably not to return.

Similarly, immigration is a movement into a region, presumably to remain.

Individuals which appear to leave the main contingents are referred to as strays or stragglers.

The word "shoals" standing alone always refers to Nantucket Shoals.

METHODS

The study of migrations was carried on chiefly by tagging experiments. It was found that by concentrating on restricted parts of the larger fishing grounds, such as Nantucket Shoals, instead of continually searching for new places to fish, there

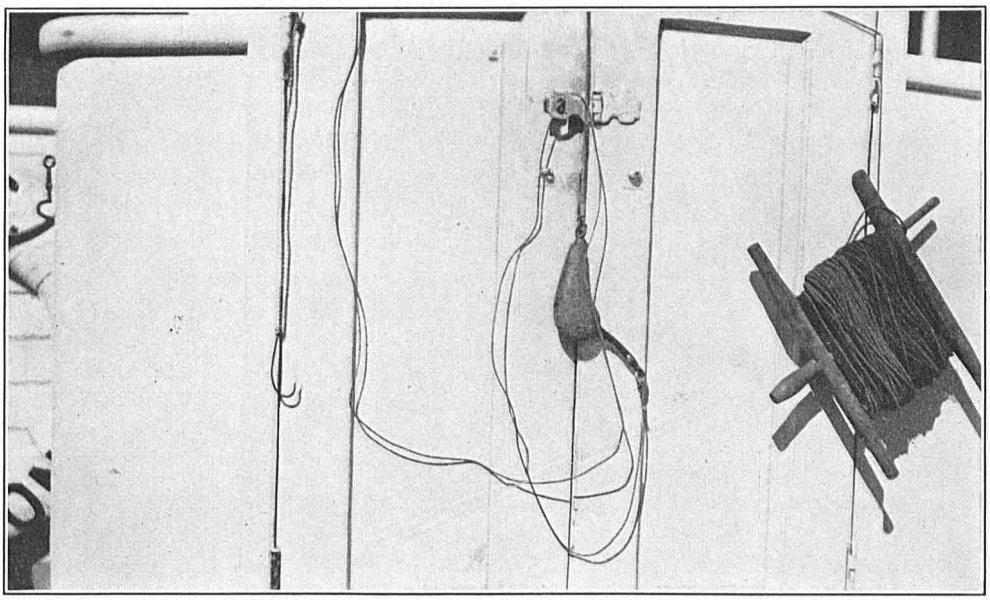

FIGURE 1.—Type of hand-line gear used by New England fishermen, showing reel with 50 fathoms of line, lead weighing 3¾ pounds, 6-foot leader, and hook

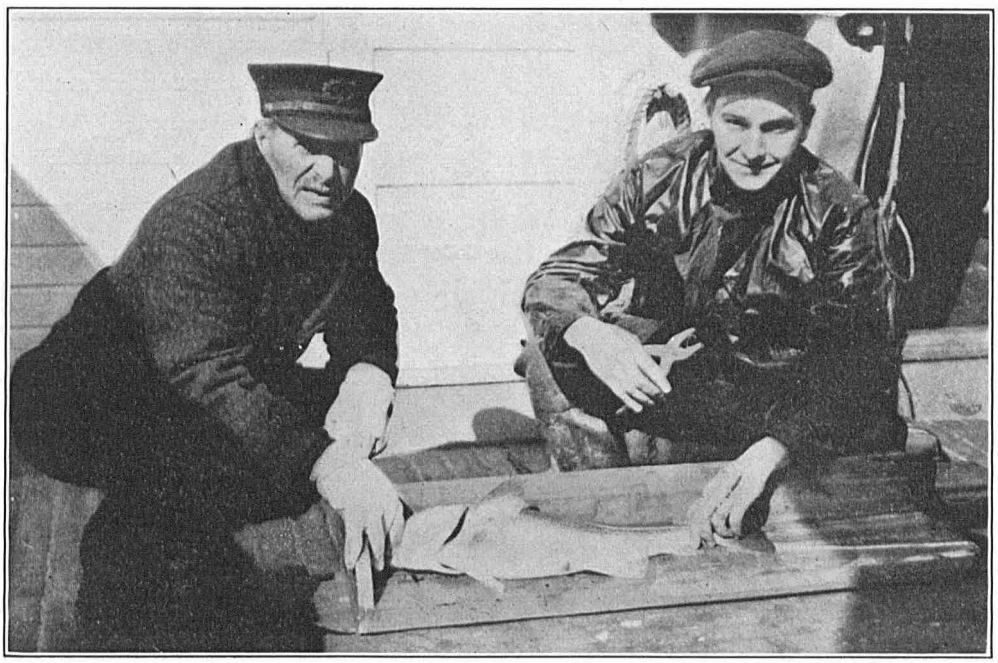

FIGURE 2.—Cod lying on measuring board, about to be tagged

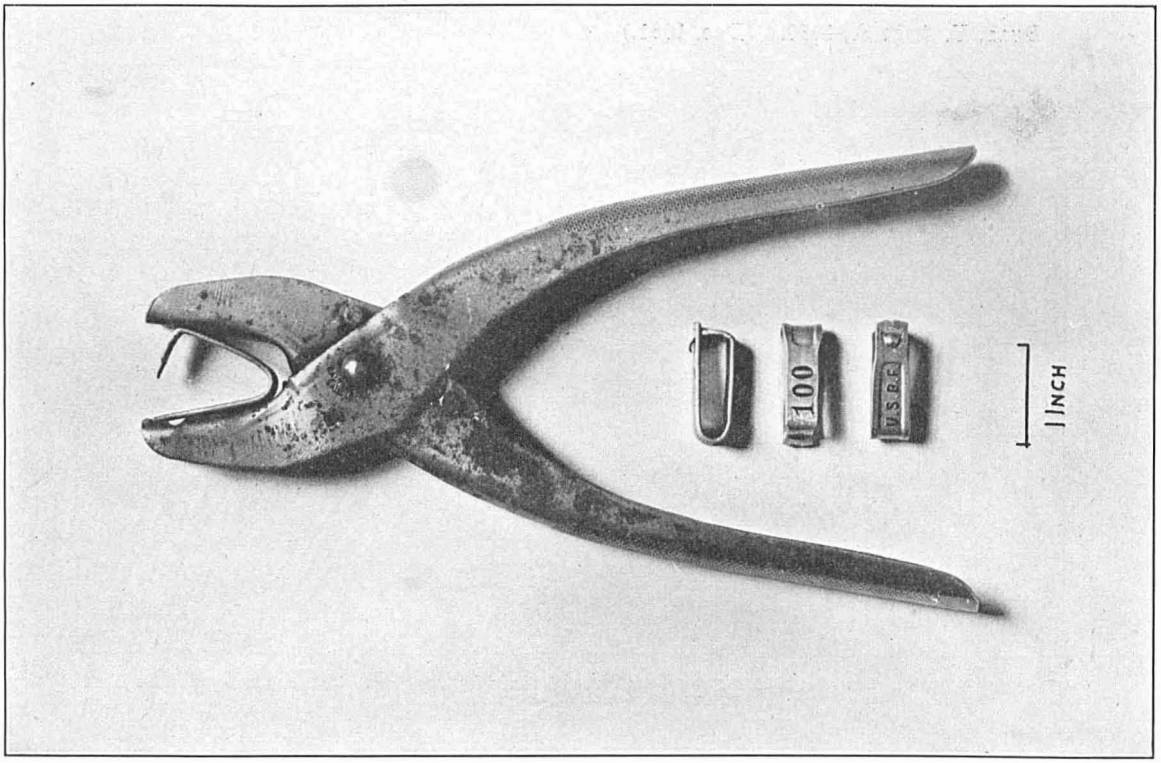

FIGURE 3.—Type of tag, and clamping tongs for attachment, used in the New England cod marking experiments

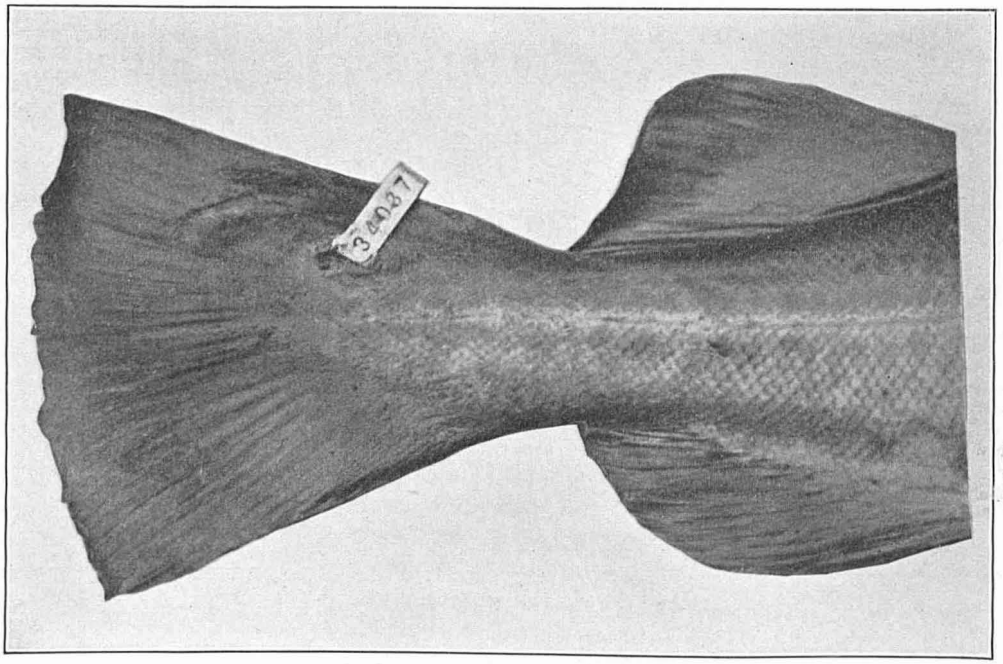

FIGURE 4.—A cod with tag attached to the tail. This fish had carried its tag over one year

was a better chance to get a true picture of seasonal fluctuations in abundance and size, which would reflect any migrations that might take place.

To insure that only fish in good condition were tagged, most of them were caught with ordinary hand lines of a kind in general use by commercial fishermen along the New England coast (fig. 1), for in this way only a small percentage were lost through injury. The use of the otter trawl was prohibited not only by the uneven and rocky bottoms fished upon but because a large proportion of net-caught fish are crushed or drowned by the time they are hauled out of the water. A few hundred of the fish tagged were caught on long lines, or trawl lines.

The most productive fishing was found in depths of less than 50 fathoms. Greater depths were generally avoided, for the fish taken there often are "poke blown"; that is, the æsophagus forced into the mouth due to the sudden change of pressure. Some idea of the losses may be had from the following: In less than 25 fathoms 37,929 cod were caught, of which 8.1 per cent were not suitable for tagging; between 25 and 40 fathoms, 2,730 were caught with an 8 per cent loss; and above 40 fathoms, 2,089 were caught with a loss of 17 per cent.

Frozen herring (Clupea) was used for bait almost exclusively up to 1925, but after then squid and other baits were used in addition. The herring proved to be the best all-around bait off the New England coast, but off New York and New Jersey conchs (Lunatia), surf clams (Mactra), and soft clams (Mya) were found to be much the best.

Immediately after its capture the fish was laid on a measuring board, its length recorded, a tag clamped to the tail (see fig. 2), a few scales scraped from the side, and then returned to the water. These operations usually required from 10 to 15 seconds for each fish. Beginning in October, 1927, certain fish were tagged on the head, chiefly those measuring less than 30 inches in length.

The desideration has always been, from the time of Fulton's first experiments (1890, p. 354) in marking cod up to those of Graham (1929c), that the type of tag should be one that would remain on the fish for a reasonably long while, that would cause no injury, and that would be sufficiently conspicuous to the fishermen. The tag adopted for use in the present cod investigation had been used successfully by Dr. Charles H. Gilbert in marking Pacific salmon and is similar to the type commonly used for ear-marking cattle but smaller, the length being 2¼ inches when the tag is extended. These tags (fig. 3) were easily attached to the tail of the fish by means of a clamp. A tag in place is shown in Figure 4.

It was necessary that the metal used for the tags withstand the chemical action by sea water for a long period and, after experimentation with various sorts, eliminating silver as too costly, monel metal was finally adopted as the most satisfactory. Results obtained from this experimentation are given in Table 3.

TABLE 3.—*The metals used and the number of tags returned to date for each as a result of the tagging on Nantucket Shoals during 1923*

Metal	Tags used	Tags returned	Percentage
Silver	1,000	47	4.70
Aluminum	2,623	102	3.90
Copper	700	35	5.00
Silver-plated copper	300	14	4.66
Monel	5,621	134	2.38

The small percentage of returns for the monel tags is not considered significant because the numbers of tags used for the various metals are not comparable. The metals other than monel were used in April, May, and June, and many of these tagged fish were recaptured during the summer and fall by the *Halcyon*, whereas the fish tagged later in the year with monel tags did not have this same chance of recapture. In 1924, of 4,387 fish tagged with monel tags on Nantucket Shoals, 124 or 2.83 per cent, were subsequently recaptured.

Scale samples were obtained from all the cod caught beginning with 1924. The scales were pressed on the pages of small blank books opposite a number corresponding to that of the tagged fish, and in this way they could be easily referred to at any time. The length of the fish and any other necessary data were kept in suitable record books.

Having established a method of marking the fish and recording the data, it was also necessary to advertise the tagging project among the fishermen and fish dealers. Cooperation naturally resulted, and much credit is due the fishermen for the many tag records which they have sent in. Without these our data would be wholly inadequate to justify sound conclusions regarding migrations.

TABULATION OF THE FISH TAGGED

A summary is given in Tables 4 and 5 of all the cod caught to the southward of Cape Cod and tagged on the present investigations. Not included with these fish are 1,859 cod marked and released directly from the dock of the United States Bureau of Fisheries biological station at Woods Hole, Mass., during each January of the years from 1926 to 1928. Besides these cod tagged between southern New England and New Jersey about 16,000 were tagged to the north and east of Cape Cod.

TABLE 4.—*Summary of all the cod tagged by the "Halcyon" and "Albatross II" off southern Massachusetts and to the westward from 1923 to 1929* [1]

Dates when each cruise began and ended	Locality	Fishing days	Fishing time	Cod tagged [2]
1923		*Number*	*Hours*	*Number*
Apr. 19–May 4	Nantucket Shoals	5	34	244
	No Mans Land	5	32	92
May 23–28	Nantucket Shoals	5	48	424
June 22–28	do	6	46	1,144
Aug. 16–23	do	5	42	1,795
Sept. 5–11	do	7	58	1,354
Oct. 3–8	do	5	41	1,556
Oct. 14–17	do	4	30	996
Total		42	331	7,605
1924				
July 13–17	Nantucket Shoals	5	47	1,254
Sept. 6–12	do	5	34½	964
Oct. 16–22	do	4	29	460
Oct. 25–28	do	4	35	427
Total		18	145½	3,105
1925				
May 5–8	Nantucket Shoals	4	35	854
June 7–12	do	4	33½	673
Aug. 20–25	do	5	31	1,158
Oct. 1–6	do	4	28	1,048
Oct. 24–28	do	2	10	277
	No Mans Land	1	6	33
Total		20	143½	4,043
1926				
Sept. 5–11	Nantucket Shoals	6	49	1,604
	South Channel	1	5	2
Total		7	54	1,606

Dates when each cruise began and ended	Locality	Fishing days	Fishing time	Cod tagged [2]
1927		*Number*	*Hours*	*Number*
May 4–7	Nantucket Shoals	3	16½	1,083
	Chatham grounds	2	15	259
June 17–25	Nantucket Shoals	6	38	1,497
	Chatham grounds	2	14	180
Aug. 31–Sept. 3	Nantucket Shoals	4	29½	1,264
	Chatham grounds	1	4½	36
Oct. 14–17	Nantucket Shoals	4	27	1,176
Nov. 14–21	Cholera Bank, N. Y.	6	33	166
Total		28	177½	5,661
1928				
Feb. 18–27	Southern New Jersey.	7	25½	4
Mar. 23–Apr. 13 [3]	do			133
July 13–21	Nantucket Shoals	5	34¾	693
	Chatham grounds	2	5	19
Oct. 24–29	Nantucket Shoals	6	35½	280
	Chatham grounds	1	2	7
Nov. 8–24	Cholera Bank, N. Y.	10	56	134
Dec. 12–31 [3]	Southern New Jersey.			279
Total				1,549
1929				
Jan. 1–Apr. 8 [3]	Southern New Jersey.			468
June 10–14	Nantucket Shoals	4	32¾	659
	Chatham grounds	1	1½	6
	South Channel	1	4½	37
Total				1,170

[1] A list of all the recaptures that were reported is given on pp. 120 to 131.
[2] The total catch of cod was about 10 per cent greater than the number that were tagged.
[3] These fish were caught with long lines with small boats.

TABLE 5.—*The numbers of cod tagged each year from 1923 to 1929 off southern Massachusetts and to the westward, according to fishing grounds*

Locality	1923	1924	1925	1926	1927	1928	1929	Total
South Channel				2			37	39
Chatham grounds					475	26	6	507
Nantucket Shoals:								
Bass Rip	164							164
Pollock Rip Lightship	31		1					32
Round Shoal buoy	4,881	1,105	1,932	769	2,949	746	105	12,487
Between Round Shoal and Rose and Crown buoys		1,028	76	388	254	139	473	2,358
Rose and Crown buoy	1,328	85	553		84			2,050
5 to 12 miles southeast of Round Shoal buoy		796	515	3				1,314
Between Rose and Crown and Great Rip buoys		28		75	1,173	43		1,319
Great Rip buoy	316		926	369	403	45	81	2,140
Davis Bank	793	63	7		157			1,020
No Man's Land, Mass	92		33					125
Western Long Island, N. Y					166	134		300
Southern New Jersey						416	468	884
Total	7,605	3,105	4,043	1,606	5,661	1,549	1,170	24,739

SIGNIFICANCE OF A RECAPTURE RECORD

The conclusions concerning the migrations of New England cod must necessarily be based largely upon the recapture records as furnished by fishermen and as obtained by the Bureau of Fisheries vessels *Halcyon* and *Albatross II*. Therefore, it is important to consider how much significance is to be attached to each record. The factors affecting the recovery of tagged cod which have an important bearing on this question may be classed as follows: (1) The death rate due to tagging and occurring soon thereafter; (2) deaths due to old age, enemies, disease, etc.; (3) the percentage of fish which lose their tags before recapture; (4) the intensity of fishing as affecting the tag returns; and (5) the percentage of recaptured fish which are not reported. The following discussion concerns chiefly those cod which were tagged on Nantucket Shoals.

The death rate due to tagging and occurring soon thereafter.—We have attempted to keep the loss of fish from this cause at a minimum by utilizing uninjured fish only. Although nearly every fish tagged appeared to be in good condition when returned to the water, nevertheless it is probable that a small number died from various causes attributable to the act of tagging. This loss may arbitrarily be set at 5 per cent.

Deaths due to old age, disease, enemies, etc.—Deaths due to old age doubtless occur. It seems that cod of 48 inches or more in length and upward of 10 years of age lack the vitality of smaller and younger fish, for they die sooner when taken from the water. Fewer of them survive the ordeal of capture and of tagging when returned to the water.[6] But the great majority of the cod caught for tagging purposes have been considerably below this size, hence might be expected to live at least five years longer before old age and consequent weakness would become an important factor in their death rate.

Little is known concerning the death rate due to the attacks of enemies other than man among adult or nearly adult cod. Sharks, including the spiny dogfish (*Squalus acanthias*) are perhaps their chief enemies. Other predaceous fishes such as the goosefish (Lophius) and the pollock (*Pollachius virens*) prey upon cod, although the latter can scarcely be considered a formidable enemy except to the very young. The cod itself is cannibalistic, although I have never known one to contain in its stomach another larger than 12 inches in length. However, it is common to see fresh

[6] That some do survive is proven by the fact that a number of very large cod have been recaptured, some of them a year or more after tagging.

wounds or healed scars on a cod's body, hence the destruction of adult cod by enemies may be greater than we now believe and must be considered a factor of some importance.

Some cod no doubt are killed by parasites and disease—their most apparent external parasite, which attaches itself to the gills, being *Lernæa branchialis* L. Cod living in less than 20 fathoms of water are most afflicted with this pest, but we also found it on cod caught in a depth of 47 fathoms on the northeast part of Georges Bank and in 40 fathoms on Browns Bank. Commonly three out of four cod from shoal water have from one to four of these bloodsucking parasites on the gills, and although many of these fish appear to be healthy it is possible that in time they become weakened and that some of them die, for as a rule the gills of thin fish are covered with this parasite. Sumner et al. (1913, p. 644) remark that they are "often so numerous as to affect the health of the fish." Cod are commonly infested with other parasites both internal and external, such as nematodes and caligids. External cancerous growths are occasionally seen, but deaths from this cause must be very small, for out of about 45,000 cod caught only 1 or 2 fish were afflicted with growths of this sort. About 1 fish in 1,000 of our catch has been extremely thin, while occasional fish, particularly large cod, may be weak and emaciated.

Considering that most of the cod which were tagged on Nantucket Shoals were neither very small nor very large, that almost all of them were sound and healthy, and that they were not unduly afflicted with parasites, the number of marked fish which died from old age, enemies other than man, parasites, and disease probably was not more than 10 to 12 per cent during the first year after tagging. The percentage would increase each year thereafter as the same stock of fish became older.

This is an arbitrary percentage, but the proportion of larger and therefore older fish, actually found among representative stocks of cod suggests that it can not be much too small or much too large.

Percentage of fish which lose their tags within the first year.—The fact that many fish have been caught showing tag marks [7] or the scar on the side where the scale sample had been taken proves that a considerable percentage of the tagged fish lose their tags while at liberty. This was to be expected, for in the North Sea experiments it was also found that some of the cod lost their tags. Concerning those marked on the operculum, Graham (1924, p. 51) writes:

> If the mark was tight the skin and flesh rotted under the button until the button almost fell out in the worst specimens I have, and no doubt did fall out in others which were, consequently, not returned. If the mark was loose the wire gradually worked the hole larger and larger. Some, however, have been returned in a perfectly healthy condition. In these the mark seemed to be just firm, neither tight nor loose, a condition hard to achieve in practice.

Graham mentions that a new tag designed to minimize weight and resistance to water was tried later but proved a failure.

The loss of the tag from its place of attachment requires a certain period of time, depending upon the exact point where it is fastened and upon the thickness of the tail. Cod recaptured one week from the time of tagging show practically no sore around the tag. One month later soreness has set in, but usually there is no evident sign that the tag will soon be lost. Three to four months later, on some fish the flesh is in good condition around the tag, on some suppuration has occurred while others already have lost their tags. About one year later the condition of the tagged fish

[7] By "tag mark" is meant the fresh wound, or healed scar, left when the tag has been lost by "eating" its way through the skin and flesh of the tail.

may be classed as follows: (1) The tail may be entirely healed with the tag securely attached; (2) the tail may be healed but the tag retained by only a small piece of skin and flesh; (3) suppuration may have set in, although the tag is still secure; (4) suppuration may have set in and the tag is on the point of dropping off; and (5) a wound or scar may be left where the tag has eaten its way out of the tail.

We have insufficient data upon which to determine what percentage of the fish fall into each of these categories a year after tagging, but by far the greater part of them belong to the fifth class, as they have lost their tags.

The loss of tags may be caused by insecure attachment in the first place, as in the case of small fish, or by becoming movable because of softened tissue about the point where it penetrates the flesh. There is perhaps some friction as the tag passes through the water, and the swimming movements of the fish itself may assist in dislodging a loosely attached tag. Sometimes barnacles, hydroids, etc., attach themselves to the tag and probably aid in its loss.

Some idea of the percentage of cod that lose their tags was obtained from the marked fish that were recaptured by the *Halcyon* and the *Albatross II*. A comparison of the number of tag-scarred fish with the number of recaptured tag-bearing cod that had been marked at least the year previous gave the following result: In 1924 out of 22 marked cod which fell in this category 15 bore tags and 7 had tag scars; in 1925 out of 12 fish, 6 had tags and 6 had tag scars; in 1926 out of 10 fish, 3 had tags and 7 had tag scars; in 1927 out of 36 cod, 8 had tags and 28 had tag scars; in 1928 out of 18 fish, 8 had tags and 10 had tag scars; in 1929 out of 7 fish, 2 had tags and 5 had tag scars. The total of our own recaptures, therefore, of cod with tags attached that had been at liberty at least from one year to the next numbered 42 and those with tag scars numbered 63.

All the foregoing fish were tagged and recaptured on Nantucket Shoals and most of them were tagged and reexamined upon recapture by the same person, so it is difficult to see how the fluctuations in the loss of tags from year to year could be due to differences in the technique of tagging that would result if more than one person were involved. While the rate of loss of tags from the tail may diminish once the healing has been accomplished, nevertheless our records show that after the fish have been at liberty as long as three and one-half years only about 1 out of 10,000 is recaptured with its tag intact.

In 1927 an attempt was made to reduce the loss of tags and so some of the fish were tagged on the lower jaw. Although it seemed impossible for the tag to become dislodged from its place of attachment, yet the percentage of returns from the fish so tagged has not shown sufficient improvement to justify the discontinuance of the tail-marking method.

Intensity of fishing as affecting the tag returns.—The intensity of fishing on the tagging grounds and in localities to which the fish migrate has a direct bearing on the proportion of the marked fish which are reported recaptured. Unfortunately, the data available are too incomplete to show what degree of correlation might exist in this respect. Mention is made in several parts of this report of the catch of cod taken on Nantucket Shoals and in other regions to which these cod migrate.

The percentage of recaptured fish which are not reported.—Although the tags of some recaptured fish are lost due to various causes, it can be said with assurance that by far the greater part of those obtained by fishermen are reported.

SUMMARY OF LOSSES

These various losses of tags and tagged fish might be estimated as follows: (1) Death rate due to tagging and occurring soon thereafter, 5 per cent; (2) deaths due to old age, disease, enemies, etc., occurring within the first year after tagging, 10 per cent; and (3) fish losing their tags during the first year, 60 per cent.

Within the first year after marking about 3 per cent of the Nantucket tagged cod have been reported recaptured and, if 2 per cent be allowed to cover those fish whose records are not received, the total recovery for this period may be set at 5 per cent. This, added to the 75 per cent loss just described, would leave approximately 20 per cent of the fish at liberty with their tags still attached at the end of one year. If this same rate of loss continued there would remain by the end of the second year only about 4 per cent of the original number of fish that were tagged.

The results have so far agreed very well with this theoretic expectation of tag returns, for out of 24,450 cod tagged to the southward of Cape Cod from 1923 to 1928 the recaptures reported up to the end of 1929 are divided according to time intervals, as follows: 630 fish were retaken within the first 12 months after marking; 160, within 13 to 24 months; 10, within 25 to 36 months; 1, within 37 to 48 months; and 1 was retaken more than 48 months later. As this experiment covered six years of tagging and an additional year during which tag records could be received, the mean period was about three and one-half years.

Compared with this temporal segregation of recaptures, the following results were reported from several of the European cod-tagging experiments:

TABLE 6.—*The numbers of cod recaptured during certain marking experiments in European waters arranged according to the duration of time they were at liberty*

Reference	Time in months		
	12	13–24	Over 24
	Number	*Number*	*Number*
Strubberg, 1916	1,416	139	7
Strubberg, 1922	315	19	3
Borley, 1909	40	2	0

If it were not that the tags dropped from the tails of so many of the fish, and if we knew how many, if any, of the cod died as a result of being tagged, the proportion of tagged fish retaken and the time element would be a most important basis for deducing the decline in numbers of a particular stock of cod, hence of the drain to which it might be subjected by the fishery. As it is, however, our returns do not afford the basis for calculations of this sort nor can the value of a tag record be designated numerically, too much depending on the locality of tagging, on the average size of the individuals making up the stock of fish, on the intensity of the local fishing, and perhaps on other factors of which we are not aware at present.

RESULTS

MIGRATIONS OF COD BETWEEN NANTUCKET SHOALS AND NORTH CAROLINA

EVIDENCE OF MIGRATIONS AS SHOWN BY THE COMMERCIAL FISHERY

It had long been known that cod appeared in the autumn on the grounds extending from Marthas Vineyard, Mass., to Delaware, and even farther south. Since most of these fish disappeared in summer, it was logical to conclude that they came from the east "somewhere off New England," but it was not until Smith's experiments (p. 6) that we had definite proof to show that cod from southern New England do actually migrate along shore to the Middle Atlantic States region and so form part, at least, of the stock of fish on these wintering grounds.

Each fall the first scattering cod to the westward of Massachusetts are caught about the middle of October and apparently are the vanguard of the winter migrants. Large bodies of cod follow soon after, for good catches are made beginning late in October or early in November and continue until the end of December. After this period a decline in the catch occurs off western Long Island and northern New Jersey, which is an indication that the fish continue to migrate westward throughout the fall, but few arrive after December. Off southern New Jersey there is usually no sudden winter decline in the catch of cod per unit of effort, but in this region the fish are scattered over a large area, not concentrated on rocky ledges as they are off the northern coast; hence local fluctuations in their abundance throughout the winter do not throw so much light on their movements.

Just what proportion of the shore waters west of Nantucket Shoals is inhabited by the cod over the winter is not well known. If they are to be found chiefly confined to sand, shell, gravel, and rock bottom, as fishing experience suggests, they are limited to the area inside the 50-fathom contour and, off Long Island and New Jersey, within about 50 miles of the shore. Further off the water deepens rapidly and most of the bottom is soft.

As little fishing is done more than 25 miles from shore to the westward of Nantucket Shoals, it is not possible to follow the migrations of the cod in the offshore parts of their range. But the fishery has produced ample evidence that many migrating cod travel along a route that lies within about 15 miles of the coast. It is within this band that most of the winter's catch of 3,000,000 to 5,000,000 pounds, taken between Rhode Island and Delaware, is obtained.

Our recent tagging experiments have corroborated the general evidence of a cod migration which has been furnished by the commercial fishery, for each year since 1923 cod tagged on Nantucket Shoals during the summer have been recaptured between Marthas Vineyard and Delaware during the following fall, winter, and spring, and a few have been retaken as far south as Chesapeake Bay. The results of these experiments follow.

EVIDENCE OF MIGRATIONS AS SHOWN BY TAGGING EXPERIMENTS

COD TAGGED ON NANTUCKET SHOALS

Following the cod westward from Nantucket Shoals, the nearest region that supports a cod fishery is centered off Rhode Island. As shown in Table 7, many tagged Nantucket cod have been retaken in this locality.

TABLE 7.—*Recaptures of tagged Nantucket Shoals cod made within the region from Marthas Vineyard to Montauk Point*

(A) TEMPORAL SUMMARY

Year tagged	Number tagged	Recaptured during the first fall to spring after tagging									Recaptured during the second fall to spring after tagging				
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Oct.	Nov.	Feb.	Mar.	Apr.
1923 [1]	7,514		7	4	1		1	3	5	[2] 1		1	1	1	
1924	3,105	1	2		1			1				2			
1925	4,010	1	2			1	2	1			1				
1926 [3]	1,606	1		3				1							
1927	5,020		2		1	1		2	1		1	2			2
1928	973		3					1							

(B) REGIONAL SUMMARY

Locality:	Recaptures
Muskeget Channel	1
20 miles southwest of Sankaty Light	1
No Mans Land and Gay Head	11
Mouth of Narragansett Bay	9
Point Judith	5
Quonochontaug	1

Locality—continued.	Recaptures
Fishers Island	2
Gull Island	1
Block Island Sound	[4] 12
Block Island	22
Montauk Point	6

[1] There were received, in addition, the following recapture records from cod tagged in 1923: November, 1925, 2; December, 1925, 2; November, 1926, 2; December, 1926, 1; and January, 1927, 1. All except the January record were received early in 1927 from the same fisherman and, as they do not agree with the rest of the table, are excluded because of probable error in the recapture dates.

[2] This fish was recaptured about 20 miles southwest of Sankaty Light (lat. 40° 50′ N. and long. 70° 20′ W.).

[3] 1 cod was caught in August, 1927, in Muskegat Channel (lat. 41° 25′ N. and long. 70° 19′ W.).

[4] The 7 recaptures of doubtful date, excluded from the temporal summary, were taken in Block Island Sound and are included in the regional distribution.

The numbers of marked cod recaptured, by months, closely parallel the fluctuations in the commercial catch, as the best fishing in this region occurs during November, December, April, and May.

Cod do not enter Long Island Sound farther than the mouth of the Connecticut River, according to the fishermen of that region, and no recaptures of tagged fish have been made within the sound west of Gull Island and Fishers Island. Consequently, the western route must be along the southern shore of Long Island. That this is so is shown by the recapture of 26 tagged cod within the sector between Montauk Point and Fire Island Inlet. (Table 8.)

TABLE 8.—*Recaptures of tagged Nantucket Shoals cod made within the region from west of Montauk Point to Fire Island Inlet, N. Y.*

(A) TEMPORAL SUMMARY

Year tagged	Number tagged	Recaptured during the first fall to spring after tagging							Recaptured during the second fall to spring after tagging		
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Nov.	Jan.	Mar.
1923	7,514			2			1	1	1	2	1
1924	3,105	1		2				2		1	
1925	4,010		2	2	1					1	
1926	1,606					1					
1927	5,020		1	1	1		1				
1928	973		1								

(B) REGIONAL SUMMARY

Locality:	Recaptures
12 miles west of Montauk Point	1
Amagansett	7
Wainscott	2
Watermill	2

Locality—Continued.	Recaptures
Quogue	1
Westhampton	2
Fire Island	11

The paucity of these recaptures, as compared to those from regions farther east or farther west, is partly explained by the fact that there are fewer boats per mile of coast line which fish for cod within this sector than from Fire Island to Cape May, and, also, cod may be less concentrated and therefore fewer are caught.

Farther to the westward, from Fire Island to Barnegat Inlet, there is more sport fishing for cod along the shore than within any locality of equal area along our Atlantic coast. In addition, there is the usual commercial fishing with pound nets, hand lines, trawl lines, etc. Consequently, a relatively large number of tagged Nantucket cod have been recaptured there (Table 9), and useful data have been obtained from fishermen and from masters of fishing vessels.

TABLE 9.—*Recaptures of tagged Nantucket Shoals cod made within the region from west of Fire Island Inlet, N. Y., to Barnegat Inlet, N. J.*

(A) TEMPORAL SUMMARY

Year tagged	Number tagged	Recaptured during the first fall to spring after tagging							Recaptured during the second fall to spring after tagging					Third season
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.	Mar.	Apr.	Nov.
1923	7,514	1	18	10	3	3	3	1	1	1	1	1		
1924	3,105		7	11			2							
1925	4,010		9	3	1		2		1	2			1	1
1926	1,606							[1]1		1				
1927	5,020	2	21	6	3	3	3			3	2			
1928	973		5	1	1	1								

(B) REGIONAL SUMMARY

Locality:	Recaptures	Locality—Continued.	Recaptures
Jones Inlet, N. Y.	9	Long Branch	2
Cholera Bank	26	Bradley Beach	6
Long Beach	6	Belmar	1
Freeport	1	Spring Lake	2
Rockaway and Ambrose Lightship	49	Manasquan	6
Coney Island	3	Bay Head	2
Sandy Hook, N. J.	2	Seaside Park	1
Seabright	6	Barnegat	11
Galilee	4		

[1] This fish was caught in May in a lobster pot off Sandy Hook, N. J.

Here, again, the numbers of tagged fish recaptured agree very well with the trend of the fishery, for by far the greater part of the season's catch is taken in this region, during November and December. The sudden decline in the number of tagged fish taken in January, as compared with December, is in agreement with the big drop in the catch which takes place at that time. While this may be due in some measure to a curtailment of fishing, brought about by weather conditions, experience has shown that cod are much less abundant after the first of the year than they are just before then.

The data obtained from one fishing ground in this region, the Cholera Bank, deserves special discussion, for from them unusually complete and desirable information regarding the coming and going of the cod have been obtained. They serve, therefore, as one of our best checks on the progress of the cod between Nantucket Shoals and North Carolina.

The Cholera Bank lies about 18 miles S. 78° E. true from Sandy Hook Point in the path of cod migrating along shore. It is strategically situated opposite the apex where Long Island joins New Jersey and where cod going westward along the coast must turn southward to continue their journey. It is a relatively small ground, good fishing being limited to perhaps less than a square mile; but in contrast to the

surrounding smooth bottom, parts of Cholera Bank are rocky, and it is over these rough places that most of the cod congregate.

A year-round picture of the fish life on the Cholera Bank is made possible by the considerable amount of sport fishing that is done there from late spring to early winter [8] and even throughout the winter two or three boats generally visit there.

Our ability to draw inferences as to a migration of cod to the Cholera Bank is made possible not only by the many pleasure craft which fish there but also by the local methods of fishing. Instead of fishing a locality at irregular intervals and drifting about, as commercial hand-line fishermen do, these pleasure boats are to be found on the bank every day that weather permits. Furthermore, the boats are anchored in approximately the same place, aided by buoys and land ranges. For these reasons a better knowledge of the fluctuations of the cod stock can be obtained from the reported catches for the Cholera Bank than for any other small ground, and, therefore, these catches are one of the best evidences of a cod migration.

There are good reasons for believing that in the fall migrating cod seek the Cholera Bank region as an objective, not necessarily to remain throughout the winter but at least as a stopping place. The large number of cod caught there during a winter—far more than in any other restricted locality west of Rhode Island—is in itself strong evidence for this belief. Some idea of the number of cod present there during the height of the season may be had from the catch of the *Giralda*, on which about 100 sport fishermen using rod and reel caught 1,156 cod in four hours on December 9, 1928. If it were assumed that these fall migrants spread out evenly over the territory bounded by the 30-fathom contour (within which nearly all the known good cod bottom west of longitude 70° is found), and that those which reached the Cholera Bank were cod that happened to be in line with it, then, measured by the catches made on the Cholera, the number of cod migrating south of there would be very large. But the catches of cod made off New Jersey during the winter and spring by no means suggest that any such vast number of cod are present along that part of the coast, as would be the case if the hundred thousand pounds caught each fall around the Cholera were an unselective sample.

It is particularly important that although the Cholera Bank is less than 1 square mile in area and although it is fished intensively during November and December the stock of cod there is maintained throughout this period. This can only mean that new migrants are arriving daily in large numbers, otherwise the fish would soon be "caught up." That very few migrants arrive after December is proven by the sharp reduction in January in the number of cod caught per unit of effort, for at this time there are scarcely enough fish to satisfy the few pleasure craft that venture out on favorable days.

Further information concerning the status of the cod in the Cholera Bank region has been furnished by the masters of fishing boats, particularly by Capt. William W. Stephens and Capt. Jacob Martin, of Sheepshead Bay, N. Y., who have fished for many years on the grounds off western Long Island and northern New Jersey. Their experience with the cod in this region agrees with what has already been stated, namely, that the cod strike in the end of October and are abundant locally until the end of the year, after which only scattering fish are found. Captain Martin

[8] During the summer as many as 20 to 40 or more pleasure craft carrying in the aggregate a thousand or more passengers fish daily on the Cholera Bank for sea bass (*Centropristes striatus*) and other species. A lull in the fishing occurs early in October, but with the first cod the number of boats is again increased until the cod are depleted in numbers and winter storms blow.

states that during the winter of 1927–28 the first cod was taken October 8 and the first fair catch on the 24th. Good catches of cod were made the first two weeks of January, which was considered unusual for that period.

In order to learn something of the movements of the cod after they migrate from Nantucket Shoals to western Long Island, fish were tagged on the Cholera Bank during November, 1927 and 1928. The recapture records are given in Tables 10 and 11.

TABLE 10.—*Recaptures reported from the tagging of 166 cod on the Cholera Bank, N. Y., November 14–21, 1927*

Date tagged	Chart symbol	Date recaptured	Locality
Nov. 14	*A*	Nov. 17, 1927	Off Jones Inlet, N. Y.
Do	*B*	Dec. 27, 1927	6 miles south of Jones Inlet.
Nov. 15	*C*	Feb. 17, 1928	Off Long Beach, N. Y.
Nov. 16	*D*	Nov. 21, 1927	Bradley Beach, N. J.
Do	*E*	Dec. 11, 1927	3 miles north of Ambrose Lightship, New York.
Nov. 21	*F*	Dec. 26, 1927	Easthampton, N. Y.
Nov. 17	*G*	May 15, 1928	Nantucket Shoals.
Nov. 20	.....	Jan. 15, 1929	Delaware Bay.

TABLE 11.—*Recaptures reported from the tagging of 134 cod on the Cholera Bank, N. Y., November 8–24, 1928*

Date tagged	Chart symbol	Date recaptured	Locality
Nov. 21	*H*	Jan. 19, 1929	Off Cape May, N. J.
Nov. 23	*J*	Dec. 16, 1928	Off Long Beach, N. Y.
Do	*K*	Nov. 29, 1928	3 miles north by west from Ambrose Lightship.

These results may be summed up as follows:

1. No recaptures were reported from the Cholera Bank proper, although the fishing there was very intensive for weeks after the fish were tagged. Accordingly, as this happened both in 1927 and 1928, we can conclude that the schools of cod which arrive on the bank in the fall do not remain there for long but move on to other grounds.

2. Even though the same individual cod do not tarry long on the Cholera Bank in the fall, all of them do not necessarily move far, for a number of marked fish were recaught later in the winter 10 to 20 miles away. This is illustrated by fish *A*, *B*, *C*, and *E* listed in Table 10 and by *J* and *K* in Table 11, shown in Figure 5.

3. Some of the cod which reach the Cholera Bank in the fall continue their migration southward. This is shown in Figure 5 by fish *D* and *H*.

4. The fish *F* and *G* (Table 10 and fig. 5) went eastward and are discussed on page 33.

The percentage of recaptures resulting from the cod tagged on the Cholera Bank during November, 1927 and 1928, amounted to only 4.8 and 2.2, respectively. This was smaller than what might have been expected in view of the very intensive sport fishing that was carried on there during and directly after the marking experiments. On the face of this it would seem that most of these fish moved away very soon after being tagged and, as the number tagged was small, we could expect very few of them to be reported from the many square miles of cod grounds which extend to the eastward and to the southward.

With regard to the Cholera Bank cod taken in Delaware Bay in January, 1929 (Table 10), it is very likely that this fish returned to southern New England during

the spring of 1928 and migrated westward again that fall. If this be so it shows that New England cod may make more than one winter migration to the New York-North Carolina region.

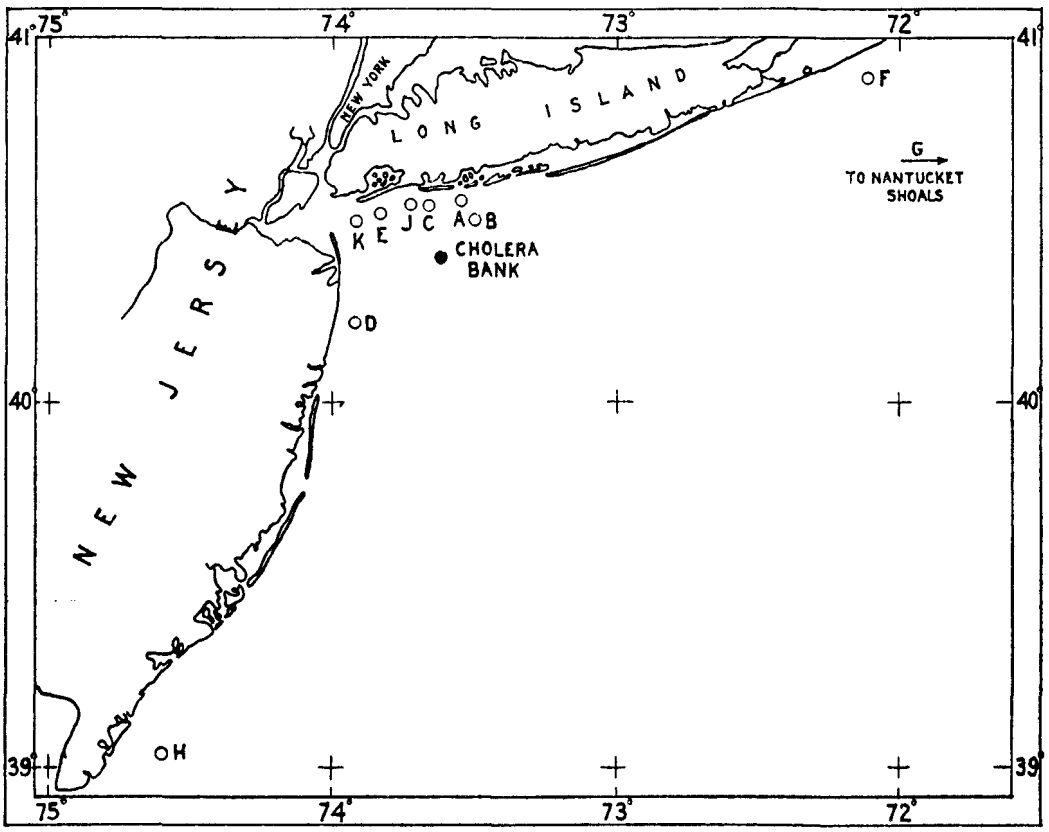

FIGURE 5.—Recaptures made during the winters of 1927–28 and 1928–29 from 300 cod tagged on the Cholera Bank during November 1927 and 1928. Each symbol represents one recapture

That southern New England cod continue their migration along the coast of New Jersey and southward is shown by the many recaptures of marked fish listed in Table 12.

TABLE 12.—*Recaptures of tagged Nantucket Shoals cod made within the region south of Barnegat Inlet, N. J.*

(A) TEMPORAL SUMMARY

Year tagged	Number tagged	Recaptured during the first fall to spring after tagging							Recaptured during the second fall to spring after tagging					Third season
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Dec.	Jan.	Feb.	Mar.	Apr.	Mar.
1923	7,514		3	10	5		1	1	2		1	1		1
1924	3,105	1					2					4		
1925	4,010		1	3	2	3	3							
1926	1,606				1		1							
1927	5,020		4	1	2	3	7	3	4	3	3		1	
1928	973			2	1	1	1							

(B) REGIONAL SUMMARY

Locality:	Recaptures	Locality:	Recaptures
Ship Bottom, N. J.	4	Cape May	20
Beach Haven	5	Delaware Bay	2
Atlantic City	31	Cape Henlopen, Del.	2
Townsends Inlet	1	9 miles east of Indian River	2
Avalon	1	Hog Island, Va.	2
Wildwood	11	Hampton Roads	1

We can not assume that the regional distribution of recaptures along New Jersey reflects a corresponding regional variation in the abundance of fish, because fishing is much more intensive near the chief centers of population—Atlantic City and Cape May—than along the intervening stretches; that is, more returns would naturally be expected there. Without question a good part of the Nantucket cod migrate as far south as southern New Jersey and Delaware, else we would not have obtained the relatively large number of recapture records that we did. It will be noted that in this latter region (Table 12) a greater number of tagged fish were taken from January to April than from October to December—a result opposite to that which obtained for the western Long Island-northern New Jersey sector. (Table 9.) This is explained partly by the fact that the small boats of southern New Jersey fish for cod continuously throughout the winter, whereas off the northern coast and around New York City fishing is considerably curtailed after December and the great amount of sport fishing that is done there early in the year is reduced to a minimum after January 1. But even so, cod have been found to be much less plentiful off the northern coast during late winter and early spring than to the southward between Atlantic City and Delaware Bay. It would seem, therefore, that a good part of the cod which occupy grounds between Fire Island and Barnegat Inlet during early winter move farther southward and spread over the much more extensive grounds there.

Some knowledge as to whether the stock of cod off southern New Jersey are migrating fish or winter residents has been gained from the experiences of the commercial fishermen and from direct observation.

Fishermen, within their own immediate neighborhood, often can follow a body of cod from day to day, inshore, offshore, or up and down the coast by observing on which part of the 1 to 3 miles of trawl line the best catch is made. Very often a fishing boat will lay its trawls in about the same place from week to week and catch cod which are so nearly the same size as to virtually prove them to be of the same body of fish, for a much wider variation in size might be expected if they were transients. Such was our experience during the course of cod tagging off Atlantic City from March 23 to April 13, 1928. (Fig. 9.)

Along the coast of southern New Jersey cod are confined to definite areas, although they may shift ground a very short distance even over night. In cases where two trawl lines are set parallel, say about one-fourth of a mile apart, one often catches 5 to 10 times as many cod as the other. And what proved to be a good "lay" one day often fails the next, although the fish may be only a few hundred feet either side of the trawl. This shifting of the cod for very short distances shows that they must remain well schooled up at such times. Their movements probably are governed largely by their food supply. Yet in March, 1929, off Cape May, when I observed this shifting about of the cod, their stomachs contained the usual bottom forms such as crabs, shrimps, mollusks, and worms. At this time they had eaten very few sand eels, which type of food might easily have explained their moving. Although cod off New Jersey, and probably anywhere west of Rhode Island, often shift short distances from day to day, this does not argue against the belief based upon our

present studies, that a school of fish may remain for weeks or months in the same general locality.

In order to learn something definite concerning the habits of the cod off southern New Jersey, fish were tagged there in March and April, 1928, and again in the winter of 1928–29. None of the former were recaptured locally, but records obtained from the latter (Table 13) are of decided interest.

TABLE 13.—*Cod tagged off Atlantic City and off Cape May, N. J., from December, 1928, to April, 1929, with a record of all recaptures reported up to October, 1929* [1]

Tagging record			Recapture record	
Date	Locality	Number of cod	Date	Locality
Dec. 12, 1928	Off Atlantic City	12		
Dec. 15, 1928	do	50		
Dec. 19, 1928	do	31		
Dec. 22, 1928	Off Cape May	26		
Dec. 27, 1928	do	35		
Dec. 29, 1928	do	55		
Dec. 31, 1928	do	70	Feb. 20, 1929	2 miles off Wildwood, N. J.
Jan. 1, 1929	do	33	Jan. 23, 1929	2 miles southeast of North Wildwood.
Jan. 3, 1929	do	29		
Jan. 22, 1929	do	51	Jan. 27, 1929 Aug. 1, 1929	Inside of Delaware Bay. South Channel, off Massachusetts.
Feb. 11, 1929	do	49		
Feb. 13, 1929	do	52	Apr. 13, 1929	McCries Shoals, Cape May.
Feb. 16, 1929	do	51	Mar. 21, 1929	5-fathom bank, Cape May.
Feb. 18, 1929	do	7		
Mar. 11, 1929	do	26		
Mar. 13, 1929	do	18		
Mar. 18, 1929	do	40	Aug. 5, 1929	South Channel.
Mar. 19, 1929	do	9		
Mar. 21, 1929	do	22		
Mar. 27, 1929	do	11	Oct. 12, 1929	Nantucket Shoals.
Apr. 7, 1929	do	13		
Apr. 8, 1929	do	56		

[1] See p. 131 for additional records.

The few recaptures made of the cod tagged off Cape May the winter of 1928–29 prove beyond a doubt that a large part of the cod present there at that time remained in the same immediate locality without migrating. Thus we have a fish tagged December 31 and another on January 1 which were retaken in virtually the same locality 52 and 23 days later, respectively. Of the fish tagged February 13 and 16, one was retaken 33 days later about 10 miles away and another 59 days later on the same ground where it was tagged. Another fish, tagged January 22, about 10 miles off the coast, moved inshore directly afterwards, for five days later it was recaptured well inside Delaware Bay.

Further proof that these few recapture records of tagged fish are fairly representative of the body of cod as a whole off Cape May during the winter of 1928–29, is shown by an analysis of the length frequencies of various samples of cod.

For example, the length-frequency distribution (fig. 6) obtained in part from the cod tagged off Cape May (Table 13) and in part from cod caught by fishermen in Delaware Bay, may be interpreted as follows:

1. The length-frequency distribution for December and January (shown with long dashes in fig. 6) may be taken as representative of the stock of fish that was found from 2 to 10 miles off Cape May throughout those months. Although not included in the graph, the 93 cod tagged about 8 miles off Atlantic City were of about the same length distribution as these.

2. A large increase in the proportion of small fish around 21 to 23 inches long and a decrease in the large fish around 26 to 28 inches long occurred at some time

beginning in February and lasted until the end of the fishing season in April (shown by the dotted line in fig. 6). The predominance of the smaller fish was greatest in February and became less toward April, as if the larger fish gradually returned to the grounds they occupied during December and January. The cause of the sudden rise in the proportion of small fish in February may have been due to an influx of a school of cod of these sizes, to the emigration of the large fish, or to both causes. We believe that a migration of the larger cod from offshore to inshore (and inside Delaware Bay) was the chief cause, as explained in the next paragraph.

3. The solid line in Figure 6 represents an unselected sample of cod taken inside Delaware Bay on February 25, 1929. Just how representative of the bay as a whole this sample was and how long cod of these sizes were present can not be said, but, as fishermen caught good-sized cod there for some time, we have some basis for believing that the drop in the percentage of 26 to 28 inch cod offshore was caused by their migration into and around the mouth of Delaware Bay. The recapture of a tagged offshore (McCries Shoals) cod inside of Delaware Bay (Table 13) makes this supposition all the more probable.

Letters giving information about the habits of the cod off southern New Jersey were received from several fishermen, including Francis Widerstrom, Fred C. Miller,

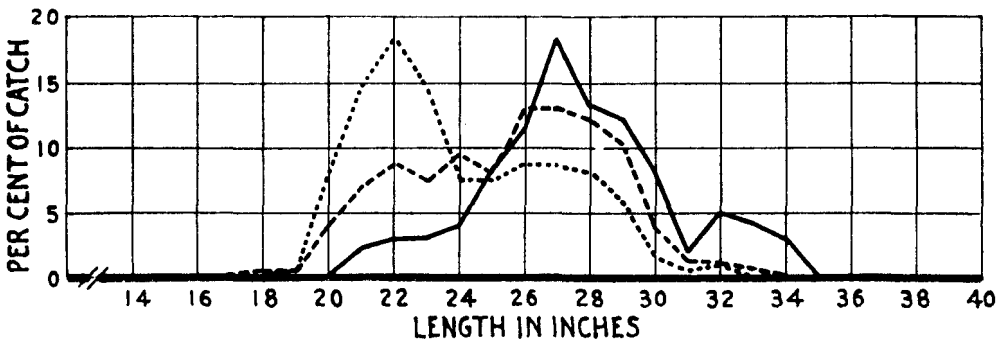

FIGURE 6.—Broken line, 298 cod caught around McCries Shoals, Cape May, in December, 1928, and January, 1920. Dotted line, 354 cod caught around McCries Shoals February 11 to April 18, 1929. Solid line, 98 cod caught in Delaware Bay February 25, 1929

and William Hare, of Wildwood; George Williams, of Cape May; and Harry Donath, of Atlantic City. These fishermen state that the first cod appear some time between October 20 and November 15, along shore in 6 to 8 fathoms of water. In January, February, and March they are found to be more plentiful in 13 to 15 fathoms. During the last of March and in April they again are found in shoaler water, but after about April 15 virtually none are caught until the next fall, although fishing for other species of fish is done throughout the summer on the same grounds where cod are caught during the winter. That all cod do not disappear the middle of April is shown by the few stragglers that are caught as late as May.

On rare occasions in the past a cod has been taken far up the Delaware River, but at the present time, with the increase of commercial activities along the river, such instances are perhaps unknown. Abbott (1871, p. 116) records that—

> On the 23d or 24th of January a healthy, strong, active codfish (*Morrhua americana*) weighing nearly four pounds was taken in a drawnet. The stomach of this fish showed it had been in river water for several days. The fisherman who took this specimen considered it the first instance of the kind on record, but such is not the case. Several have been taken about Philadelphia during the past twenty years.

Several hundred barrels of cod were taken inside Delaware Bay during February, 1928. In February and March, 1929, cod were caught in the lower bay, and in February, 1930, catches were made as far up as Fortesque.[9] Various fishermen interviewed in Wildwood and Cape May asserted that they could not recall commercial catches of cod being made inside the bay prior to the winter of 1927–28, but admitted that before then they had not tried fishing for them. It may be, therefore, that schools of cod enter the bay each winter.

South of Delaware Bay the recapture of only three tagged cod has been definitely recorded, all of them in 1928, but one fishing concern reports that several marked fish were taken in the fall of 1927 but the tags had been lost. One of these southern recaptures is associated with an extraordinary catch of cod made in Chesapeake Bay during March, 1928. Harry R. Houston, commissioner of fisheries of Virginia, writes on April 5, 1928:

> For the first time in the present generation large numbers of cod have been caught inside Chesapeake Bay, the total catch being about 20,000 pounds. The fish were taken early in March in pound nets from near the capes to as far up as Buckroe Beach and ranged in size from 4 to 24 pounds. The Chesapeake Seafood Corporation, of Hampton, Va., caught in one of their pounds near Cape Henry a 24-pound cod bearing on its tail tag No. 56379.

Prior to this unusual catch 160 cod were reported caught in Chesapeake Bay during the first part of January, 1928, by the boat *Hilda Mable* while trying out a new otter trawl. Another good catch of cod was reported from the lower Chesapeake the first half of March, 1930, when as much as 1,000 pounds were taken from a single trap. The fish weighed up to 35 pounds each. It may be that cod enter Chesapeake Bay each winter, but that, like in Delaware Bay, their presence is unknown because there has been very little local fishing at that time. The last pound net is taken up in the lower bay about December 1 and the first is put down in the spring about March 1, so that the presence of cod in the Chesapeake can be made known by means of pound-net catches only during November, March, and April, and not between those months.

Two tagged Nantucket Shoals cod have been recaptured in the vicinity of Hog Island, Va., in pound nets. By a coincidence both fish were recaptured the same day, December 4, 1928, although not in the same net. Oddly enough, neither of these cod was tagged during 1928, but one dated back to September 2, at Round Shoal buoy, and the other to October 17, 1927, 3 miles northeast of Great Rip buoy, Nantucket Shoals. Even so, it is very likely that both of them left Nantucket Shoals in the same school, for they migrated a distance of about 400 miles.

The winter of 1927–28 appears to have been out of the ordinary as regards the movements of the cod in the southern part of its winter range, featuring as it did a migration into various bays along the coast. These catches were as follows:

1. Cod appeared in Sandy Hook Bay, N. J., for the first time in many years. One tagged cod released off Woods Hole was taken there.

2. Cod were caught inside Great Bay, about 10 miles north from Atlantic City. This was considered very unusual by the local fishermen.

3. Cod were caught in large numbers inside Delaware Bay for the first time, because prior to the winter of 1927–28 their presence there in commercial numbers was not known to the fishermen. One tagged Nantucket cod was taken there. Good catches were again made in the winter of 1928–29 and a cod tagged offshore from Cape May was taken inside the bay.

[9] Fortesque, N. J., is about 24 miles from Cape May point, inside of Delaware Bay.

4. For the first time in a generation good catches of cod were made inside Chesapeake Bay, among which one tagged Nantucket cod was reported.

What brought these cod inside Sandy Hook, Great, Delaware, and Chesapeake Bays the winter of 1927–28 can not be known definitely, but it is not at all unlikely that a search for food, together with an unusually large number of fish may have played an important part. It may be significant that large numbers of sand eels were present in Delaware Bay that winter and that the stomachs of the cod caught there were full of them. But if the sand eel drew cod inside Delaware Bay then, the same can not be said for the winter 1928–29, or at least was not noted by the fishermen. During the winter of 1928–29 stomachs examined off Cape May showed that, quantitatively, crabs were the chief food of the cod. They also fed on mollusks (mostly *Lunatia heros*), worms, shrimps, and small fishes. Among the latter were small hake (Urophycis), small sculpins (Myoxocephalus), sand eels (Ammodytes), and even pipefish (Siphostoma) and seahorses (Hippocampus). The cod caught in the Chesapeake during early March, 1930, had been feeding on herring (Pomolobus).

COD TAGGED IN THE WOODS HOLE REGION

The few cod marked off No Mans Land and the recaptures made therefrom are of especial interest because they were tagged in almost the same place where Smith (1902) released all of his tagged cod. The following recapture records of our fish have been received (Table 14):

TABLE 14.—*Recapture records of cod tagged 1 to 3 miles off No Mans Land by the "Halcyon"*

Tagged		Recaptured	
Number	Date	Date	Locality
92	Apr. 21 to May 2, 1923	June 1, 1923	No data.
		Aug. 24, 1923	South Channel.
		Oct. 17, 1925	No Mans Land.
33	Oct. 28, 1925	Feb. 8, 1926	Off Block Island.
		Oct. 28, 1926	No Mans Land.

These recaptures, taken by themselves, are too few upon which to base sound conclusions regarding the migrations of the cod in this region, but, fortunately, other records were obtained from subsequent tagging experiments.

None of the 125 cod tagged off No Mans Land was taken west of Rhode Island, but this can not be considered unusual, because only 8 of Smith's cod, or about 1 out of each 500 tagged, were reported from as far as New Jersey, and nearly all of his western recaptures were made within about 70 miles of the place were the fish were released.

Further tagging in this general region consisted of 946 cod marked January 6 and 7, 1926; 422 on January 3, 1927; and 491 on January 13, 1928. Most of these fish were caught in pound nets set near the mouth of Buzzards Bay and were brought to the Bureau of Fisheries biological station at Woods Hole, where they were held in an inclosure so that their spawn could be collected and incubated in the hatchery. After being tagged, they were released directly from the dock at Woods Hole. The recapture records of these fish are given in Table 15.

TABLE 15.—*Recaptures made from 1,859 cod tagged and released directly from the dock of the United States Bureau of Fisheries biological station at Woods Hole, Mass., during January of the years 1926, 1927, and 1928*

(A) TEMPORAL SUMMARY

Localities where recaptures were made	Recaptured during same year											Recaptured second year				Recaptured third year		
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Oct.	Nov.	Dec.	Jan.	Apr.	July	Dec.	Jan.	Mar.	Apr.
Chatham grounds and South Channel						1	1											
Nantucket Shoals			2						1					1				
Marthas Vineyard and No Mans Land			1													1		
Rhode Island	6		3	3	1			2		1	1	1	1					
Long Island	5	3	2	2	1							2			1		1	
New Jersey		1	2		1													1

(B) REGIONAL DISTRIBUTION

Locality:	Recaptures	Locality—Continued	Recaptures
South Channel	1	Easthampton	1
Chatham grounds	1	Watermill	1
Nantucket Shoals	4	Westhampton	2
No Mans Land and Gay Head	2	Jones Inlet	1
Mouth of Narragansett Bay, R. I.	4	Cholera Bank	1
Point Judith	1	Sandy Hook Bay, N. J.	1
Block Island	7	Scotland Lightship	1
Block Island Sound	7	Off Barnegat Bay	1
Montauk Point, N. Y.	6	Atlantic City	1
Amagansett	5	Cape May	1

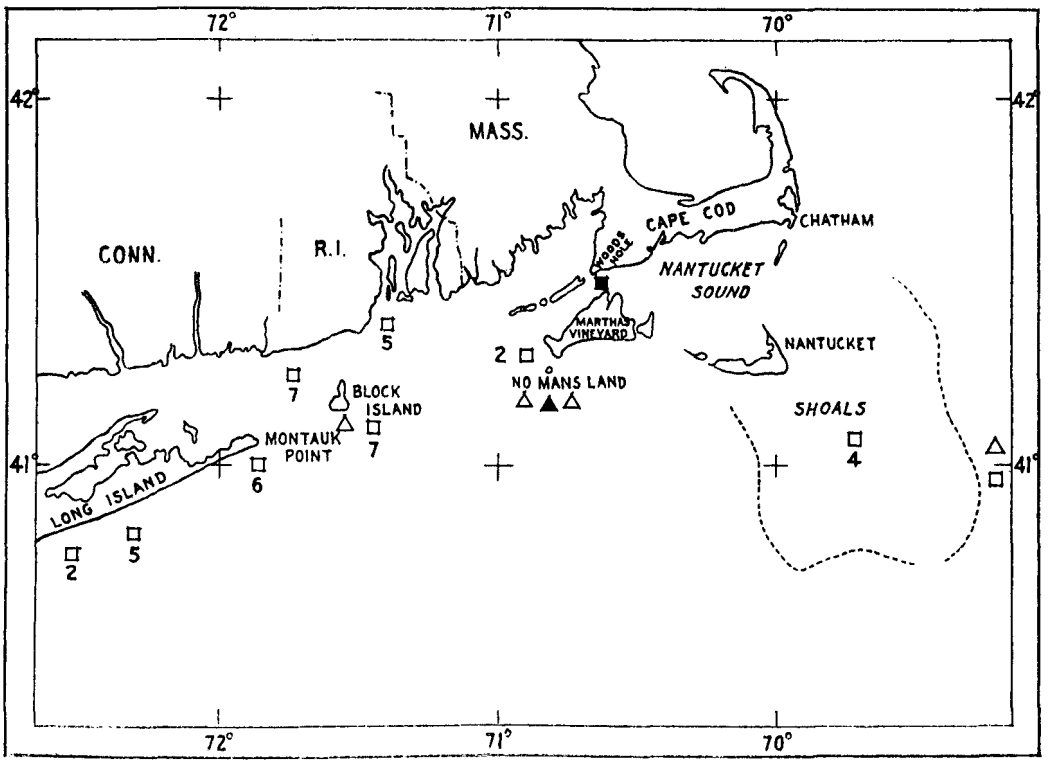

FIGURE 7.—Recaptures made east of longitude 72° 40′ W. of cod tagged off Woods Hole and off No Mans Land, Mass. The dark symbols represent tagging localities and the open symbols recapture localities. The number of recaptures is given where more than one

In general, these results closely parallel those of Smith (1902) in that many of the cod remained off Rhode Island throughout the winter (a few through the summer), some went westward early in winter, and others were recaptured to the eastward in the spring. There was no evidence that any cod went through Nantucket Sound. (Fig. 7.)

COD TAGGED ON THE CHATHAM GROUNDS

Although but few cod were tagged on the Chatham grounds, the recaptures show that the fish living there make virtually the same migrations as do those on Nantucket Shoals (Table 16):

TABLE 16.—*Recaptures of cod tagged on the Chatham grounds*

Tagged		Recaptured	
Date	Number tagged	Date	Locality
May 27, 1923	3	Sept. 17, 1923	Chatham grounds.
May 3, 1927	108	July 12, 1927	Do.
		July 25, 1927	South Channel.
		Mar. 28, 1928	Wildwood, N. J.
		May —, 1928	Ipswich Bay, Mass.
		July 10, 1928	South Channel.
		Mar. 27, 1929	Off Sandy Hook, N. J.
May 4, 1927	151	May 11, 1927	Chatham grounds.
		----do----	Do.
		Jan. 12, 1928	Jones Beach, Long Island, N. Y.
		Jan. 23, 1928	Cape May, N. J.
June 16, 1927	146	July 26, 1927	South Channel.
		Nov. 21, 1927	Barnegat Inlet, N. J.
		Jan. —, 1928	Cape May, N. J.
		Oct. 26, 1928	Nantucket Shoals.
June 22, 1927	34	July 26, 1927	South Channel.
		Sept. 10, 1928	Nantucket Shoals.
Sept. 2, 1927	36	----------	
July 13–19, 1928	19	----------	
Oct. 27, 1928	7	----------	

Of the 475 cod tagged on the Chatham grounds in 1927, 5 were reported recaptured between western Long Island and southern New Jersey the winter of 1927–28. The movements of the two cod tagged in June, 1927, and recaptured on Nantucket Shoals in September and in October, 1928, can not be known. Possibly these fish were on their way from the Chatham grounds to the Rhode Island-North Carolina region at the time they were recaught on the shoals, or they may have made a back-and-forth migration to these wintering grounds during the winter of 1927–28 and upon their return eastward spent the summer on Nantucket Shoals instead of continuing to the Chatham grounds. The same uncertainty is attached to the fish recaptured off Sandy Hook, N. J., in March, 1929, for it may have migrated westward the fall of 1927 or 1928 or both years.

Those Chatham tagged cod which showed no migration are discussed on page 47 and the fish which went to Ipswich Bay is mentioned on page 39.

EVIDENCE THAT MANY RHODE ISLAND-NORTH CAROLINA COD COME FROM SOUTHERN MASSACHUSETTS

The small number of cod with tags (less than 2 per cent) that have been reported from west of Nantucket Shoals during any winter of record might at first sight lead one to believe that the grounds off southern Massachusetts contribute but a small part of the fish which migrate into the Rhode Island-North Carolina region. But many of the marked fish lose their tags (p. 14) and a good portion of the stock of cod on the wintering grounds survive the fishery and return eastward in the spring, thus failing to enter into the records. An illustration of the tag loss occurred the winter of 1928–29 when two fishermen engaged in tagging cod off Wildwood, N. J., noted three fish with unmistakable tag scars, but none with tags, among 653 that were caught.

But the degree of correspondence between tag returns and the total fishery from year to year is more significant than the percentage of tagged fish that are recaptured.

In order to determine whether a parallelism existed between the percentage of tagged Nantucket cod taken to the westward and the amounts of cod caught there by the fishery each winter, the recaptures for the years 1923 to 1928 are listed in Table 17.

TABLE 17.—*Recaptures of cod made the first fall to spring after tagging between Rhode Island and Virginia, divided according to the locality on Nantucket Shoals where they were marked*

Tagging locality on Nantucket Shoals	Number tagged	Recaptures made between Rhode Island and Virginia, the first fall to spring following tagging									Percentage recaptured
		Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total	
1923											
Round Shoal buoy to Rose and Crown buoy	6,209	1	23	24	8	1	6	5	3	71	1.14
Pollock Rip	32									0	
Bass Rip	164		1							1	.61
Great Rip buoy	316		3	1						4	1.26
Davis Bank	793		1	1	1	2			1	6	.75
Total	7,514	1	28	26	9	3	6	5	4	82	1.09
1924											
Round Shoal buoy to Rose and Crown buoy	2,246	3	7	11	1		4	1		27	1.20
5 to 12 miles ESE. of Round Shoal buoy	796			2						2	.25
Davis Bank	63						1			1	1.59
Total	3,105	3	7	13	1		5	1		30	.97
1925											
Round Shoal buoy to Rose and Crown buoy	2,562	1	11	6	2	3	5			28	1.09
Great Rip buoy	926		3		2	1	2			8	.86
5 to 12 miles ESE. of Round Shoal buoy	515			2						2	.39
Davis Bank	7										
Total	4,010	1	14	8	4	4	7			38	.95
1926											
Round Shoal buoy to Rose and Crown buoy	1,160			3	1	1	1		1	7	.60
Great Rip buoy	444	1								1	.23
Total	1,604	1		3	1	1	1		1	8	.50
1927											
Round Shoal buoy to Rose and Crown buoy	3,287	2	26	8	6	1	6			49	1.52
Great Rip buoy	1,576		2		1	5	5	3		16	1.01
Davis Bank	157					1				1	.64
Total	5,020	2	28	8	7	7	11	3		66	1.31
1928											
Round Shoal buoy to Rose and Crown buoy	885		9	2	2	2		1		16	1.81
Great Rip buoy	88			1			1			2	2.27
Total	973		9	3	2	2	1	1		18	1.85
Grand total	22,226	8	86	61	24	17	31	10	5	242	1.09

No statistics of the cod catch taken in the Rhode Island-Delaware region are available for these years. But the general opinion of the fishermen was that the catch of cod during the winters from 1923–24 to 1925–26 were average ones, that 1926–27 was slightly below normal, and that the seasons of 1927–28 and 1928–29 were among the best they had ever experienced. The percentage of tagged fish recaptured, as given in Table 17, followed very closely the trend of the fishery. As there were no marked changes in fishing intensity during this period, we may conclude that the years of heaviest migrations from southern Massachusetts are also the years when the best fishing obtains on the western and southern grounds.

Another interesting point brought out by the segregation of recaptures in Table 17 is that the western part of Nantucket Shoals contributed a larger percentage of its

stock of cod to the wintering grounds than did the eastern part, if tagged fish may be taken as a criterion. Thus, from the Round Shoal, Rose and Crown, Pollock Rip and Bass Rip grounds (northern part of Nantucket Shoals on its western side), where 16,544 cod were tagged, 199 fish, or 1.2 per cent, were recaptured to the westward the first fall to spring following marking; from the Great Rip grounds (southern part of Nantucket Shoals on its western side), where 3,350 cod were tagged, 31 fish, or 0.93 per cent, were recaptured; while from Davis Bank and the grounds 5 to 12 miles east-southeast of Round Shoal buoy (toward the eastern edge of the shoals) only 12 fish, or 0.51 per cent, out of 2,331, were recaptured.

Further proof that the cod which summer off southern Massachusetts make up a large part of the winter population to the westward has been furnished by an analysis of the length-frequency distributions of the fish caught in these regions.

The size distribution of all the cod caught by the *Halcyon* and the *Albatross II* on Nantucket Shoals is shown in Figures 15 to 24. It can be seen that relatively few fish less than 23 inches long were taken on the shoals in 1923 or 1924. In line with this, very few cod less than 23 inches long were reported caught to the westward of the shoals during the winters of 1923–24 and 1924–25. The data for 1925 revealed no outstanding size group off southern Massachusetts nor to the westward. In 1926

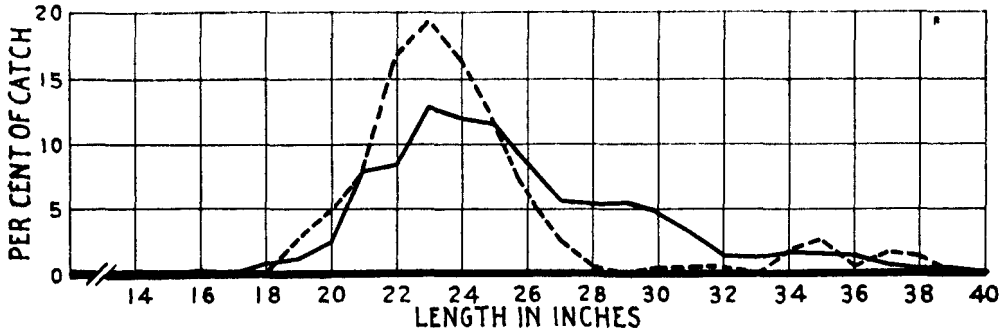

FIGURE 8.—Length-frequency distribution of 1,291 cod caught on Nantucket Shoals October 14–17 (solid line), and 185 taken on the Cholera Bank, November 14–21, 1927 (broken line)

small cod, particularly 17 to 20 inch fish, predominated on those parts of the shoals where tagging was done (fig. 19), and during the winter of 1926–27 cod 16 to 22 inches long were taken between Rhode Island and Delaware in far greater numbers than for many years past; in fact, they were the dominating size groups there that winter. The same was true of 1927, when 20 to 24 inch cod predominated on the shoals and likewise to the westward.

The fall of 1927 it was possible to make a direct comparison between the lengths of the cod on the Cholera Bank in November and those of the fish present in Nantucket Shoals the preceding month. These are shown in Figure 8. It can be seen that the fish centering around 23 inches formed the dominant size group both on the shoals and on the Cholera Bank. The 29-inch Nantucket fish were evidently not present on the Cholera Bank at the time we fished there. These larger fish were caught chiefly at Great Rip buoy, and it is interesting to note that according to the recapture dates of these Great Rip 1927 fish (Table 17) they migrated westward from Nantucket Shoals later in the season than did those from the Round Shoal grounds, which might account for their absence in our Cholera Bank catches.

This, however, fails to explain the paucity of cod larger than 27 inches long off southern New Jersey in March and April, 1928. (Fig. 9.) These fish were caught on a trawl line during 10 days' fishing. Although the similarity between the two catches as they appear in the graph is not close, nevertheless the bulk of the cod present off Atlantic City at that time is best interpreted as of the same stock as had inhabited Nantucket Shoals in October, 1927, for the following reasons:

1. Nantucket tagged cod were recaptured off southern New Jersey the late winter and early spring of 1928. (Table 12.)

2. The increase of 2 inches (from 23 to 25) in the predominating lengths of Nantucket-New Jersey cod may reasonably be charged to the normal growth to be expected from October to April.

3. The great predominance of 25-inch cod off southern New Jersey was due in part to a scarcity of fish larger than 27 inches.

4. The local and temporal scarcity of large cod off Atlantic City was not representative of the coast line or of the winter as a whole, for large cod were reported

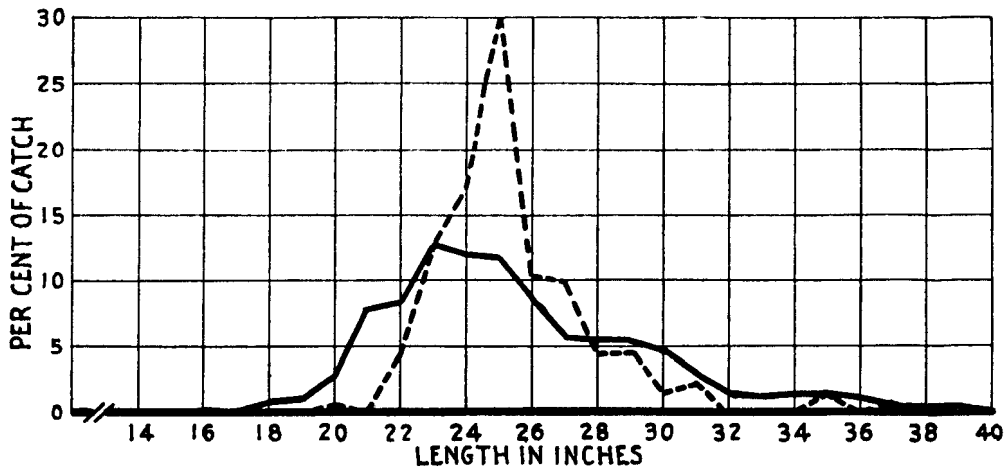

FIGURE 9.—Length-frequency distribution of 1,291 cod caught on Nantucket Shoals October 14–17, 1927 (solid line), and 134 taken off Atlantic City, N. J., March 23 to April 13, 1928 (broken line)

from time to time off Long Island and New Jersey and even as far southward as Chesapeake Bay.

The next winter, 1928–29, more cod were tagged off southern New Jersey, and, as a result, it was possible to compare further the lengths of the cod which summer on Nantucket Shoals with those which winter to the westward. The lengths of these fish are shown in Figure 10. Like the previous winter, there was a 2-inch difference in size between the summer and the winter fish, very likely due to growth. As this increase of 2 inches occurred under very much the same conditions during both years, it must be considered significant in identifying the stock of cod present on the southern wintering grounds with that which summers off Nantucket.

The status of the 27-inch Cape May fish is not so clear, for they are of the same size as the Nantucket fish of the previous fall. Either they had not grown appreciably from October to March or they were so mixed with fish from other regions that their identity was lost.

According to all the foregoing data on lengths, it would appear, making due allowance for the difference in size due to growth, that the cod which populate the grounds off New York and New Jersey (and, no doubt, farther southward) in winter are chiefly from the same stock which spends the summer off southern New England.

There is no doubt that some of the fish come from other regions such as Georges Bank and Massachusetts Bay, for numbers of very large cod, such as we have seldom found on Nantucket Shoals, are taken from time to time during the winter off New York and New Jersey. But as only 5 cod out of about 16,000 tagged to the northward of Cape Cod were reported recaptured to the westward of the shoals (p. 93), it is evident that these northern grounds furnish but a small proportion of the fish which occupy the southern wintering grounds. Still further evidence is furnished by a comparison of the scales of the cod living to the northward and southward of Cape Cod (p. 110), for, considered as a whole, it has been found that the latter fish, but not the

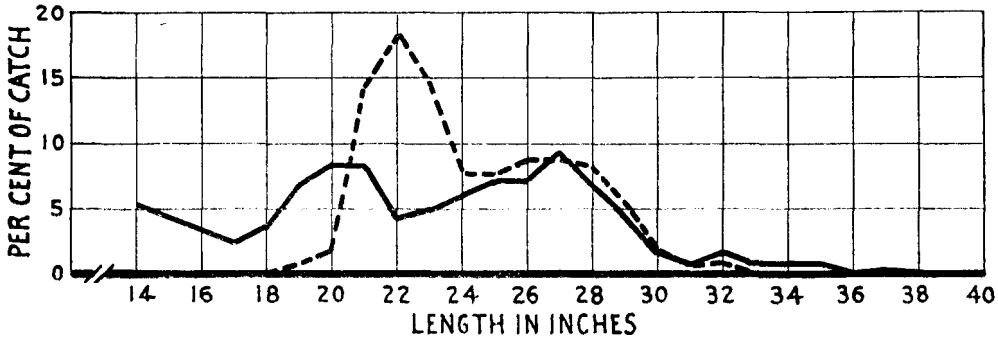

FIGURE 10.—Length-frequency distribution of 304 cod caught on Nantucket Shoals in October, 1928 (solid line), and 354 taken off Cape May, N. J., February 11 to April 18, 1929 (broken curve)

former, possess the same type of scales as do the cod found off New York and New Jersey.

SOUTHERN LIMIT OF THE COD

Relatively few catches of cod have been reported from south of Delaware; hence we have but little knowledge of their migrations or abundance in that region. If the intensity of fishing were anywhere near as great as it was north of Delaware Bay, it is probable that rather large catches of cod would be made in the southernmost part of their wintering ground. Apparently the fish are more scattered south of New Jersey, and it does not pay to fish for them in competition with the large catches taken to the northward. Furthermore, even if cod could be caught in fair quantities off Virginia and North Carolina, it is doubtful if any of the small boats which fish in that region would make the long trip that would be necessary to reach the fishing grounds.

That cod do occur south of Delaware in more than scattering numbers has been shown by a catch made by the mackerel schooner *Relenter*, of Gloucester, which caught some 600 pounds of large cod about 8 miles south of Cape Charles, Va., on April 5, 1880 (Goode, 1884, p. 202), and by the catches made inside Chesapeake Bay in January and March, 1928, and in March, 1930 (p. 24). Other catches of record include one made by the *Clare*, which caught 8 cod off Currituck, N. C., on March 22, 1929, while dragging for croakers, and one made by an otter trawler which took 3 cod off North Carolina in February, 1929.

Along the shore between Delaware and Chesapeake Bays cod are caught each fall in pound nets, and for brief periods a small run occurs. The fall of 1928, 2 tagged

Nantucket cod were taken in nets set off Hog Island, about 22 miles northward of the Cape Charles (Va.), Lighthouse, which is located at the entrance of Chesapeake Bay. In addition to these 2 fish several others were recaptured in the same locality, but their tags were lost.

Smith (1907, p. 382) states that small numbers of cod are taken in fall, winter, and spring as far south as the latitude of Roanoke Island, N. C., while a few round Cape Hatteras, and stragglers have been observed about Ocracoke Inlet. (Goode, 1884, p. 202.) This is the most southerly record for the species. It seems that odd cod even stray into Pamlico Sound. (Smith, ibid., p. 382.)

RETURN MIGRATION OF COD TO NEW ENGLAND FROM SOUTHERN WINTERING GROUNDS

Having followed the cod to their southern wintering ground in the fall, it is logical to conclude that in the spring they return to New England waters by somewhat the same route. However, while the good catches made in the fall along the immediate coast from Rhode Island to Delaware indicate that a large part of the cod follow the shore route westward, the route taken eastward differs from this. Thus, although good catches are made close to shore off southern New Jersey in March and April and off eastern Long Island and Rhode Island in April and May, the catches off western Long Island and northern New Jersey are relatively small after January 1, with only a slight increase in the spring. This scarcity of cod in the angle, contrasted with the good catches made in the spring off southern New Jersey and around eastern Long Island, shows that the fish as they return eastward cut across the New York bight at the apex of this reentrant angle of the coast line, thus shortening their route.

In the most southerly cod region, around Cape Hatteras, the latest records of catch are for the first week of April. Farther north, near the mouth of Chesapeake Bay (off Hog Island), cod are taken in pound nets until about April 15; and along the coast from Delaware to Nantucket Shoals the following are the latest dates when tagged cod have been recaptured and which coincide closely with the end of the commercial fishery: South of Barnegat Inlet, April 22; Barnegat Inlet to Fire Island, May 7; east of Fire Island to Montauk Point, May 2; east of Montauk Point to Marthas Vineyard, May 24.

Cod are seldom caught west of Rhode Island during the summer in spite of the fact that there is considerable sport and commercial fishing there at that time. The latest record for Cape May, N. J., is May 23, when 2 cod were taken there by a flounder dragger. Off northern New Jersey, Capt. Jacob Martin of Sheepshead Bay, N. Y., records the capture of a number of cod during July and August and very exceptional catches of 70 and 35 fish taken on a ground known as the "Farms" on September 22, 1921, and September 22, 1926, respectively. Very likely these fish were "left overs" from the previous winter.

Apparently very few cod move out to the deeper waters off the Long Island and New Jersey coasts to spend the summer, for, although the bottom temperature of 43° to 53° F. at 10 to 50 fathoms (p. 74) is as cool or cooler than the maximum summer temperatures of Nantucket Shoals, and an abundant food supply of crustaceans is present (Linton, 1901, p. 471), tile fishermen who operate along the continental shelf catch only straggling cod in the summer.

That a few cod summer off Rhode Island is proven by the occasional catches that are made there at that time, but these have never been large enough to suggest that a good-sized body of fish are present.

Corroborating the evidence furnished by the fishery that nearly all the cod which winter west of Nantucket Shoals leave there by spring, we have definite proof from tagged fish that a great part of these cod return to the grounds off southern Massachusetts to spend the summer. (Fig. 11.) Thus many of the cod tagged off No Mans Land and Woods Hole by Smith (1902) and on the present investigation (p. 26) summered on Nantucket Shoals, and 2 of the 7 cod that were recaptured from the 166 tagged on the Cholera Bank in November, 1927, had swum eastward, 1 to be recaptured December 26, 1927, off Easthampton, N. Y. (about 75 miles eastward from the Cholera Bank), and the other on May 15, 1928, on Nantucket Shoals. In addition, the 1 recapture to be reported from the 133 cod tagged off Atlantic City in March

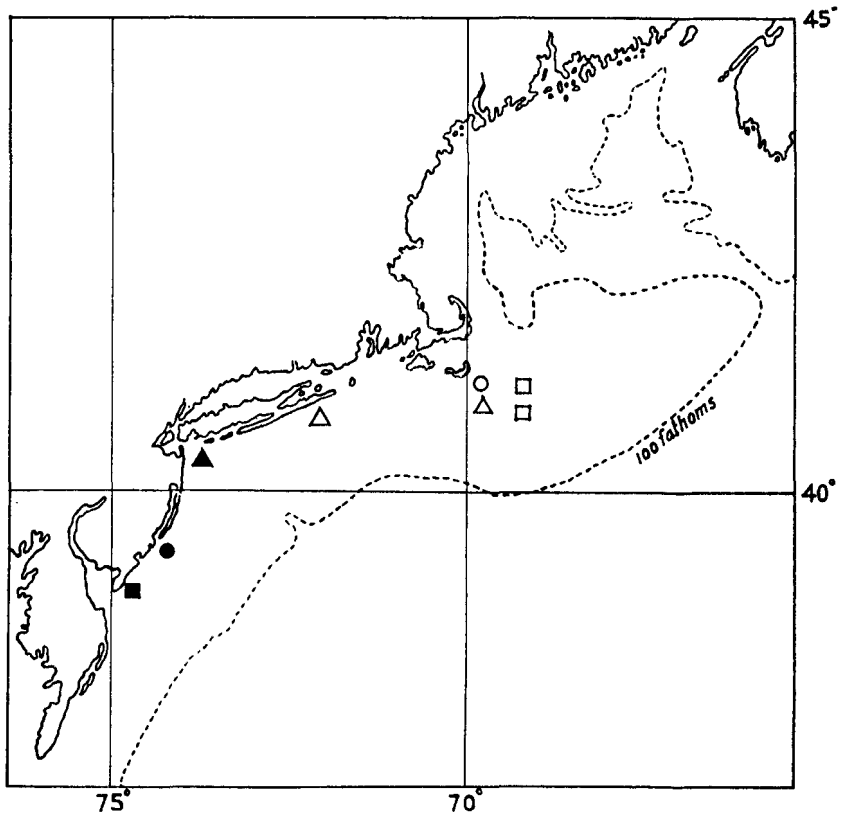

FIGURE 11.—Recaptures made off eastern Long Island and in the Nantucket Shoals region of cod tagged during the winter off Long Island (black triangle), Atlantic City (black disk), and Cape May (black square)

and April, 1928, was taken on Nantucket Shoals July 22, 1928, and 3 of the fish tagged off Cape May the winter of 1928–29 were recaptured in the Nantucket-South Channel region the following August and October. (Table 13.)

These 6 recaptured fish which showed a migration from west to east out of a total of 1,183 tagged to the westward of Rhode Island since 1927 represent a return of only 0.51 per cent, where the returns from the east to west migration have averaged 1.09 per cent out of 22,228 tagged on Nantucket Shoals up to the end of 1928. But if thousands of cod had been tagged west of Rhode Island as they were to the eastward on Nantucket Shoals, and if we had on the shoals the great intensity of sport and commercial fishing which is carried on in the New York-New Jersey region, it is very

likely that a larger percentage of the fish tagged on the wintering grounds would have been taken to the eastward the following spring and summer.

It is probable that a small part of the cod are returning to New England waters throughout the winter, not necessarily waiting until the spring. This is indicated by the November tagged Cholera Bank cod which was recaptured off Easthampton in December, already mentioned. Perhaps this straggling eastward throughout the winter, together with the depletion in the number of fish due to the fishery, etc., may explain why the fishing during the return migration in the spring is notably poorer, with the exception of off Rhode Island, than during the westward migration in the fall.

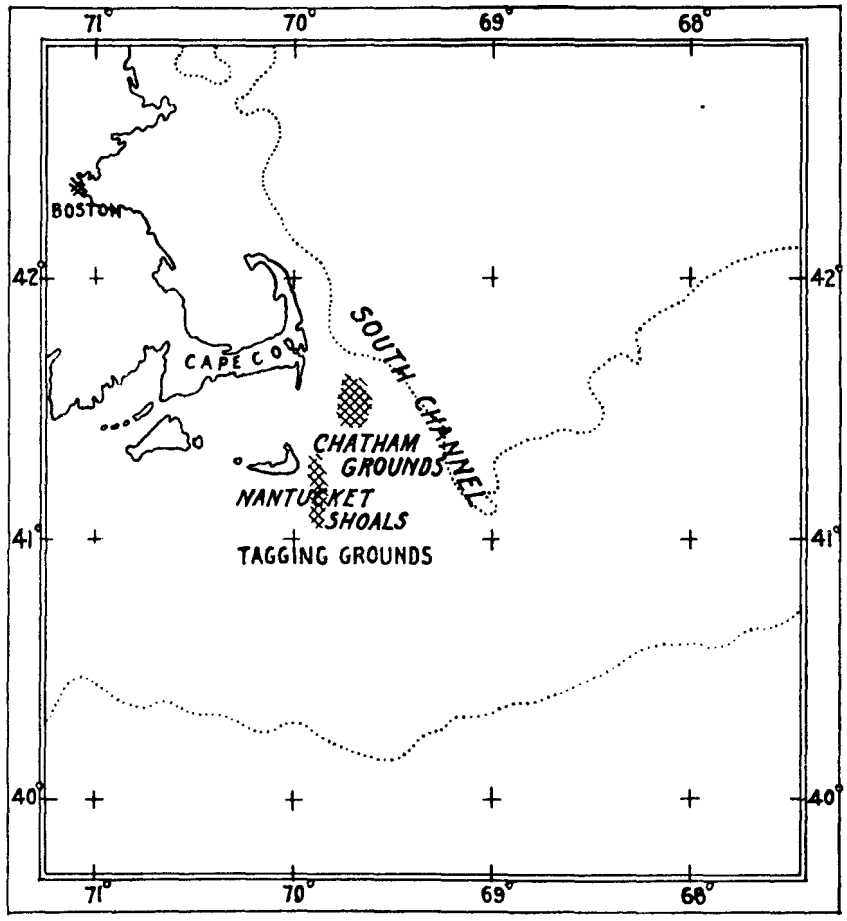

FIGURE 12.—The location of the Chatham-South Channel region with respect to the tagging grounds on Nantucket Shoals

SUMMARY

Each year, beginning about October 15, some of the cod migrate from the grounds off southern Massachusetts into the region extending from Rhode Island to Delaware and even as far south as Cape Hatteras, N. C. This migration continues until December, after which only straggling fish go westward. Cod from north and east of Cape Cod also join in the fall migration to the westward of Nantucket Shoals, but they appear to form a minority of the stock of fish on the wintering grounds. The total number of cod which enter the Rhode Island-North Carolina region each winter

must be large, for the catch there usually ranges between three and five million pounds. After the cod leave southern Massachusetts for the wintering grounds to the westward they drop off along the route anywhere between Rhode Island and North Carolina. Once established in a particular region, many of the fish remain localized for a large part of the winter and do not move far until their return eastward in the spring.

Virtually all the cod from east of longitude 70° W. which survive death or capture after reaching the wintering grounds to the westward and southward of Nantucket Shoals return to New England before or during the spring. Some may return eastward at any time during the winter, but most of them in March and April, and the last stragglers leave New Jersey waters in May. We have as evidence of the return migration the increased catches of cod off New Jersey and New York, made in March and April as compared with January and February, and off Rhode Island in April and May; the recapture during the summer and fall off southern New England of cod tagged off New York and New Jersey the previous winter and spring; the migration to Nantucket Shoals in the spring of cod tagged around Buzzards Bay and at Woods Hole during the winter; and the fact that cod are virtually absent west of Rhode Island during the summer.

MIGRATION OF COD TO THE NORTH AND EAST OF NANTUCKET SHOALS

MIGRATION TO THE CHATHAM-SOUTH CHANNEL REGION

Only about 10 to 40 miles separate the centers of the Chatham-South Channel region from localities on Nantucket Shoals where tagging has been done. (Fig. 12.) Because of this proximity and a considerable amount of commercial fishing which is done on the grounds adjacent to the shoals, it was natural that we should expect many of the Nantucket tagged cod to be recaptured there. But although good returns were had from the Chatham grounds, where the commercial catch has of recent years been small, the recaptures reported from South Channel fell below expectations.

TABLE 18.—*Cod tagged on Nantucket Shoals and recaptured on the Chatham grounds during the years 1923 to 1928*

Tagged during—	Number tagged	Recaptured during the seasons and months shown															
		First season						Second season								Third season	
		June	July	Aug.	Sept.	Oct.	Dec.	Mar.	May	June	July	Aug.	Sept.	Oct.	Nov.	June	July	Aug.
1923	7,514	3	2	5	1	1		1		2		8		1				10
1924	3,105			2						2		6	2		1			
1925	4,010			7	2		1		1			1				1	1	
1926	1,606																	
1927	5,020										1							
1928	973																	

TABLE 19.—*Cod tagged on Nantucket Shoals and recaptured in South Channel during the years 1923 to 1928*

Tagged during—	Number tagged	Recaptured during the seasons and months shown															
		First season						Second season						Third season			
		June	July	Aug.	Sept.	Oct.	Nov.	May	June	July	Aug.	Sept.	Oct.	June	July	Aug.	Oct.
1923 [1]	7,514		2	1	1	1	1		1		1	1	1	1		2	
1924	3,105									1	2	1	1		1		
1925	4,010	1	1	3	1	2		1	1	2	2	1					1
1926	1,606																
1927	5,020			1	1	1				1	1					1	
1928	973						1										

[1] 1 cod was recaptured in October, 1927.

The segregation of recaptures given in Tables 18 and 19 indicate that a fair proportion of the cod living on Nantucket Shoals emigrated to the Chatham-South Channel region during the spring and summer of the years 1923, 1924, and 1925, and that relatively few went there during the three years which followed. The contrast in the magnitude of this emigration during each of the 3-year periods is brought out in Table 20, which consolidates the Chatham and the South Channel recaptures.

TABLE 20.—*The number of tagged Nantucket Shoals cod reported from the Chatham South Channel region during each year from 1923 to 1928*

Tagged on Nantucket Shoals		Recaptured in the Chatham-South Channel region					
Year	Number	1923	1924	1925	1926	1927	1928
1923	7,514	18	16	13	0	1	0
1924	3,105		2	16	1	0	0
1925	4,010			18	9	3	0
1926	1,606				0	0	0
1927	5,020					3	3
1928	973						1
Total		18	18	47	10	7	4

The United States Bureau of Fisheries has collected statistics [10] of the catch of cod taken each month on the Chatham grounds and South Channel so that there is opportunity to make a direct comparison between the total number of fish taken and the number of tagged fish recaptured. These records are listed in Tables 21 and 22.

TABLE 21.—*The reported number of Nantucket Shoals tagged cod taken on the Chatham grounds, from 1923 to 1928 by fishing vessels operating out of Boston, Gloucester, and Portland, together with the catch of cod for each month*

Month	Number of cod taken by the New England fleet and, in parentheses, the catch of Nantucket Shoals tagged cod					
	1923	1924	1925	1926	1927	1928
January	(a)	3,188	4,077	1,855	3,558	40
February	a 624	3,752	2,522	7,052	1,042	3,799
March	a 3,565	2,336 (1)	9,149	1,643	1,856	1,054
April	11,532	3,606	2,069	6,956	1,637	6,498
May	26,347	4,073	2,169	6,243 (1)	1,619	2,347
June	6,707 (3)	159 (2)	2,810 (2)	1,148	0 (1)	1,045
July	158 (2)		2,249	1,763	164 (1)	130 (1)
August	0 (5)	1,008 (10)	7,317 (23)	780 (1)		
September	0 (1)	161	969 (4)	1,115	13	2,534
October	0 (1)	1,170 (1)	564	106	7	
November	2,127		707 (1)	1,365	294	228
December	293	1,834	1,774 (1)	377	300	171
Total	51,353 (12)	21,287 (14)	36,376 (31)	30,403 (2)	10,490 (2)	17,846 (1)

a The first cod of this investigation were marked in April, 1923, so that statistics prior to then can have no relation to the tag returns.

[10] The original statistics give the catch of cod in pounds, and the number of fish is estimated here on a basis of 1 fish for each 10 pounds of catch.

TABLE 22.—*The reported number of Nantucket Shoals tagged cod taken in South Channel from 1923 to 1928 by fishing vessels operating out of Boston, Gloucester, and Portland together with the catch of cod for each month*

Month	Number of cod taken by the New England fleet and, in parentheses, the catch of Nantucket Shoals tagged cod											
	1923		1924		1925		1926		1927		1928	
January	[1] 17,803		27,000		34,162		50,920		52,754		62,115	
February	[1] 23,866		37,472		49,673		40,675		42,488		63,655	
March	[1] 26,658		32,594		28,207		60,429		73,992		62,410	
April	23,686		42,668		40,331		39,353		87,988		59,249	
May	36,333		31,673		31,286		33,293	(1)	56,528		32,613	
June	90,415		70,905	(1)	85,449	(2)	83,665	(1)	67,693		67,345	
July	169,367	(2)	88,961		125,674	(2)	109,783	(3)	96,940		95,599	(1)
August	164,197	(1)	147,454	(1)	155,831	(7)	124,287	(2)	202,296	(1)	247,083	(1)
September	112,014	(1)	169,542	(1)	168,211	(2)	91,573	(1)	210,060	(1)	158,453	
October	91,613	(1)	140,069	(1)	70,818	(3)	135,190		156,774	(3)	131,410	
November	58,745	(1)	48,569		52,968		75,579		107,983		106,181	(1)
December	28,970		29,645		19,314		40,524		67,853		76,222	
Total	843,667	(6)	866,552	(4)	861,924	(16)	885,271	(8)	1,223,349	(5)	1,162,335	(3)

[1] The first cod of this investigation were marked in April, 1923, so that statistics prior to then can have no relation with the tag returns.

The available statistics of the catch of cod taken in the Chatham-South Channel region are not sufficiently complete for the preceding table to give more than a general idea of the relationship between the number of cod caught and the number of tagged cod retaken. For example, the records show no catch of cod on the Chatham grounds for the summer of 1923 or for June, 1927, yet a total of 8 tagged fish were taken there during these periods. (Table 21.) This discrepancy is evidently due to the fact that the Chatham grounds and South Channel merge one into the other, so that boats which fish in this general region might describe their fish as from either place. Yet in spite of this confusion that may obtain from time to time, it is probable that fishermen as a rule do distinguish between the two localities and state their catch correctly as from one or the other.

Only 42 Nantucket Shoals tagged cod were reported among about 6,000,000 cod caught in South Channel from 1923 to 1928, or 1 for each 142,000, whereas 62 were reported from the Chatham grounds among about 167,000 taken there, or 1 out of each 2,700. Direct computation would indicate a concentration of Nantucket tagged cod on the Chatham grounds over fifty times as great as in South Channel. This figure is undoubtedly too high because more tags were overlooked or lost in the channel where otter trawling is the prevailing method of fishing than off Chatham where much line trawling is done. But in spite of this, the small yield of tagged cod in the South Channel region affords rather good evidence that comparatively few Nantucket cod move eastward to the offshore banks.

A comparison of the catches of cod made in the Chatham-South Channel region during the summer and winter seasons of the years from 1923 to 1928 shows a surprising result. On the Chatham grounds only 3 tagged fish were reported among a catch of about 131,000 cod taken from December to May (about 78 per cent of the total catch), whereas from June to November 59 tagged Nantucket cod were reported among a catch of about 37,000 fish (22 per cent of the total catch). In South Channel only 1 tagged cod was reported from December to May among about 1,500,000, while 41 tagged fish were recorded from nearly 4,500,000 cod caught from June to November. This contrast in the numbers of summer and winter recaptures reported from the Chatham-South Channel region was not brought about by chance, for the experiment

extended over a period of six years, from 1923 to 1928, and the results were very much the same during each of these years.

It will be noted in Table 20 that nearly all of the recaptures made in the Chatham-South Channel region during 1924 were of fish tagged on Nantucket Shoals in 1923. This suggests that many of the 1923 cod emigrated eastward the spring of 1924, for only two of the cod tagged on the shoals in 1924 were retaken to the eastward that same year, probably because our first tagging was done so late (July) in the season. Conditions seemed to be right for a large return of tagged cod in 1925 because we had marked a large number in 1923 and in the summer and fall of 1924. Some of these were still present on Nantucket Shoals the spring of 1925, and many fish were tagged that year as early as April and May. Thus, there probably were more tagged cod present on the shoals in May, 1925, than during any other period from 1923 to 1928. But although this may partly explain the large return of tags from the Chatham-South Channel region in 1925, the same line of reasoning can not explain the paucity of recaptures from 1926 to 1928.

No obvious cause for the great difference in the numbers of tags reported during these two 3-year periods has been detected. So far as the yield of the fishery is concerned, the catches made during 1923 to 1925 were actually smaller than during 1926 to 1928. This being so, it is evident that the difference in the yield of tags is due not to fishing intensity but to a corresponding difference in the numbers of fish which took part in the migration from the one region to the other.

It is not fully understood why so many tagged Nantucket cod migrated to the Chatham-South Channel region during 1923 to 1925 as compared with the following three years, but there is some indication that temperature, together with the size of the fish which made up the adult population on Nantucket Shoals, was a contributing cause. For example, it is rather well known that large cod tend to work their way into deep water and that they are more susceptible to environmental changes than are small cod. Inasmuch as many of the cod on the shoals in 1923–1925 were upward of 26 to 28 inches long, and very few fish so large were present there during the next three years, it is not at all unlikely that a large part of the former sought the deeper waters of the Chatham-South Channel region. The fact that the summer of 1925, when the greatest number of recaptures was made in the Chatham-South Channel region, was the warmest of the six years makes this all the more likely.

Our experience has been that the cod living on the Chatham grounds and on Nantucket Shoals carry out very much the same migratory schedule, for from both regions some of the fish move to the westward to spend the winter, while others straggle to the northward. But, unfortunately, the number of cod tagged on the Chatham grounds has been too small to throw any light on the question of an intermigration between there and the Nantucket grounds. The decided predominance of the summer recaptures just mentioned seems to indicate that of the Nantucket cod which summer in the Chatham-South Channel region very few remain to spend the winter, but what part of them return westward to the shoals to join the migration into the Rhode Island-North Carolina region and what part go north is not known.

The number of cod which emigrated from Nantucket to the Chatham-South Channel region was not sufficiently large to make a marked impression on the tagging data of the shoals. We found, for example, that even during 1923 to 1925

many of the cod present on the shoals in the spring and early summer were still there in the fall, and also that the abundance of the cod did not diminish during any of these summers. It is very likely that fewer cod were involved in any one of these summer emigrations to the eastward than in any one of the fall migrations to the westward.

This summer migration of cod may be summarized as follows:

1. A summer emigration of cod from Nantucket Shoals to the Chatham-South Channel region occurred each of the years from 1923 to 1925, during which period many of the adult fish on the shoals were more than 25 inches in length, while the emigration was scarcely noticeable from 1926 to 1928, when the fish averaged below this size.

2. According to tagged-fish records, few Nantucket cod move eastward before May.

3. Scarcely any of the Nantucket cod which summer in the Chatham-South Channel region remain there for the winter. Where they go is problematical, but many of them may return westward in the fall either to remain on the shoals or to continue on to the wintering grounds between Rhode Island and North Carolina. A few probably straggle to the northward.

4. During the summers when this emigration occurred the numbers of cod which took part were probably smaller than the numbers of those that went westward each fall to spend the winter.

SCATTERING OF NANTUCKET-CHATHAM COD TO THE NORTHWARD AND EASTWARD

From a total of 22,228 cod tagged on Nantucket Shoals during 1923–1928 and 501 tagged on the Chatham grounds during 1927–28 miscellaneous recaptures were reported as follows:

Tagging year, 1923: 7,514 Nantucket cod tagged; 276 recaptured; of these 7, or 2.5 per cent, were from miscellaneous localities: 1 on Georges Bank, April, 1923; 1 off Gloucester, August, 1923; 1 on Jeffreys Ledge, August, 1923; 1 off Plymouth, November, 1923; 1 off Hampton Beach, N. H., May, 1924; 1 off Portland, June, 1923; and 1 on La Have Bank, April, 1925.

Tagging year, 1924: 3,105 Nantucket cod tagged; 104 recaptured; of these 4, or 4 per cent, were from miscellaneous localities: 2 on Georges Bank, November, 1924, and June, 1926; 1 in Barnstable Bay, May, 1925; and 1 on Stellwagen Bank, March, 1925.

Tagging year 1925: 4,010 Nantucket cod tagged; 143 recaptured. Of these, 11, or 7.7 per cent, were from miscellaneous localities: 1 on Georges Bank, December, 1925; 1 off Highland Light, October, 1926; 3 on Stellwagen Bank, August, 1925, and February and July, 1926; 1 off Marblehead, May, 1926; 1 in Ipswich Bay, May, 1927; 1 in Salem Harbor, July, 1925; 1 off Monhegan, September, 1925; and 2 off Mount Desert, February, 1926, and fall of 1927.

Tagging year 1926: 1,606 Nantucket cod tagged; 18 recaptured. Of these, 1 fish, or 5.5 per cent, was retaken on Georges Bank in May, 1927.

Tagging year 1927: 5,020 Nantucket cod tagged; 149 recaptured. Of these, 5, or 3.4 per cent, were from miscellaneous localities, as follows: 3 on Georges Bank, December, 1927, and September and October, 1928; 1 on Stellwagen Bank, November, 1927; and 1 off Nahant, April, 1928. On the Chatham ground 475 cod were tagged of which 16 were recaptured, 1 of them being in Ipswich Bay in May, 1928.

Tagging year 1928: 973 Nantucket cod tagged; 23 recaptured; none have been reported from localities to the northward or eastward. On the Chatham ground 26 cod were tagged and none was recaptured.

The recapture localities of the Nantucket fish which went to the north and east are shown in Figure 13. Some idea of the amounts of cod caught on certain of these

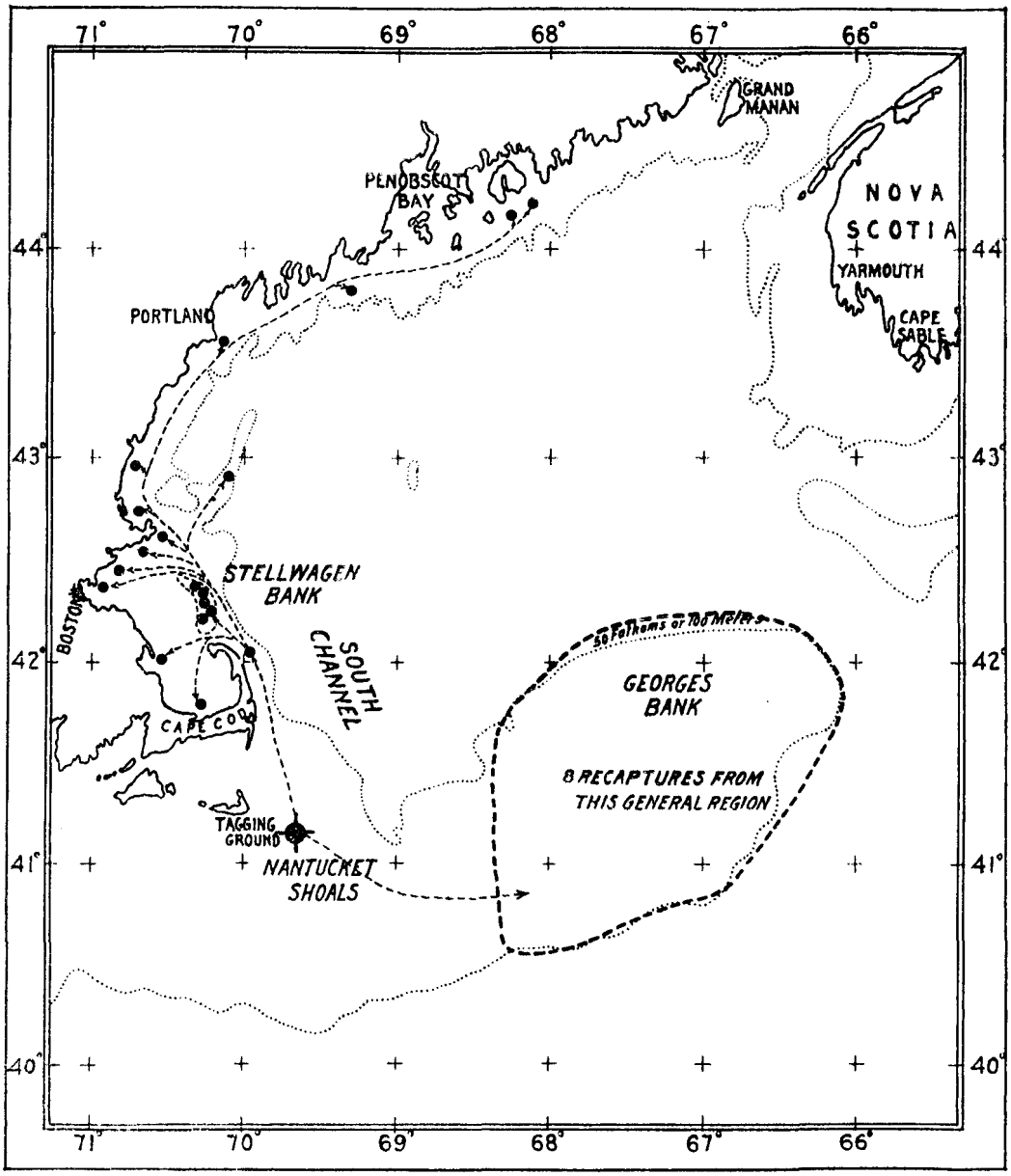

FIGURE 13.—Recaptures made to the northward and eastward of Cape Cod (excepting the South Channel region) from 22,228 cod tagged on Nantucket Shoals from 1923 to 1928. Each dot indicates one fish

grounds may be had from the following catches landed at Portland, Gloucester, and Boston during the year 1924: Immediate shore waters, from Cape Cod Bay to eastern Maine, 5,000,000 pounds; Stellwagen Bank, 280,000 pounds; Jeffreys Ledge, 1,000,000 pounds; and Georges Bank, 21,000,000 pounds. On Browns Bank, from

which no Nantucket-tagged cod have been reported, the catch of cod landed in American ports during 1924 amounted to 5,490,000 pounds.

The foregoing list of recaptures shows that—

1. No seasonal migration of cod took place from Nantucket Shoals to any of these various localities, because the few miscellaneous recaptures were taken during every month of the year except January.

2. On an average only 1 out of 800 cod marked on Nantucket Shoals was reported recaptured to the north and east of Cape Cod. Even allowing for the tag-scarred fish, which were not reported because they were not recognized by the fishermen, the percentage of Nantucket cod which stray to the north and east is very small according to the tag records.

3. According to the limited amount of tagging done on the Chatham grounds, this region, too, contributes only a small part of its cod to the northward and eastward.

4. It is evident that most of those fish which do migrate north and east of Nantucket Shoals, Chatham, or South Channel follow a route along the shore from Chatham to Maine. The only offshore records we have are 8 for Georges Bank and 1 for La Have. It would be interesting to know the route of the latter. The recaptures of Nantucket fish at various points along the coast of northern New England suggest that the La Have fish followed the shore route rather than that it crossed Georges and the deep channel that separates the latter from the Scotian Banks.

The 8 Georges Bank recaptures of Nantucket-tagged cod just mentioned are so few that they constitute further evidence that most of those cod which do migrate north from the shoals select the shore rather than the offshore route, and they give some indication as to why so few recaptures in the face of intensive fishing were reported from the South Channel region, namely, that relatively few cod migrate eastward from Nantucket Shoals to the offshore grounds.

The many unknown factors having to do with the migrations and behavior of the cod, together with the element of chance which always plays a large part in our fisheries, make it unwise to give too much credence to these numerical data. For example, it is probable that the loss of tags tends to reduce the number of returns from northern localities more than from the local or the western migration recaptures of Nantucket cod because the time intervals in the former average somewhat longer than for the latter. But even so, we are justified in saying that on the basis of tag returns over a period of six years only a relatively small proportion of the stock of Nantucket-Chatham cod move to regions east or north of the Chatham grounds and South Channel each year.

COD WHICH GAVE NO EVIDENCE OF MIGRATING

In all previous cod-tagging experiments it has been found that a large part of the fish marked remained for a period of months or years in the immediate locality where they were released. Most of these fish were taken within the first few months, before enough time had elapsed for them to lose their tags, but of those which retained their tags some were retaken as much as a year or more later. Thus many of the cod tagged off the mouth of Buzzards Bay during the winter by Smith (1902) remained near by until spring, when they migrated eastward to Nantucket Shoals, which is the nearest year-round cod ground. And in European waters many of the cod tagged in the North Sea off the Faroes and around Norway and Iceland were recaptured months later without having shown a migration of more than a few miles.

We expected, then, that many of the cod which were tagged on Nantucket Shoals and elsewhere along the New England coast would remain localized for some time, although we could not be sure that fish would remain from one year to the next or for longer periods. However, as the following records show, many of the cod tagged off southern Massachusetts were recaptured a long time later in the same place where they had been released.

LOCALIZATION AS SHOWN BY TAGGED FISH

WOODS HOLE REGION

In this locality, as already stated, cod are present throughout the winter, but most of them go eastward to spend the summer. Cod tagged by Smith (1902) remained near by from early winter to late spring (Table 2, p. 7); and of the cod tagged in January on the present investigation 2 were recaptured near by in August, Table 15, and several of the fish taken in the fall probably remained throughout the year almost on the very spot where they were tagged. In this category may be placed the 2 cod tagged off No Mans Land and recaptured there one and two and a half years later, respectively (p. 25). It is possible that these fish could have summered on Nantucket Shoals, but if they did the chance of their being recaught in the same place where they were tagged appears to be remote.

NANTUCKET SHOALS

Our most extensive data on the localization of the cod come from Nantucket Shoals, where so many fish have been marked and recaptured, so that from these ample proof has been obtained that some cod remain in this region throughout the summer, or from one year to the next. A record of all those cod which were both tagged and recaptured on Nantucket Shoals is given in the table which follows.

TABLE 23.—*Cod tagged on Nantucket Shoals and subsequently recaptured on Nantucket Shoals* [1]

Tagged		Recaptured																				
		1923						1924						1925								
Date	Number	June	July	August	September	October	November	April	May	June	July	August	September	October	April	May	July	August	September	October	November	
1923:																						
Apr. 19–May 4	244			1					1		1											
May 23–27	424		1	2		5			1		1											
June 22–28 [2]	1,144	1	4	4	1	21					2		1	1								
Aug. 16–19 [2]	1,795			1	9	7	1			1	1				1							
Sept. 5–11	1,354				2	7	1				1		1				1	1				
Oct. 3–17	2,552					5		1			6		3	4			2	1				
1924:																						
July 13–17	1,254										1	2	6	3					1			
Sept. 6–12	964													11		2		4	1	1		
Oct. 16–28 [3]	887															1		3		2		
1925:																						
May 5–8	854																	6	1	5		
June 7–12	672																1	2	3	3		
Aug. 20–25	1,158																			5	1	
Oct. 1–6, 24–30	1,325																			1		

[1] The months of December, January, February, and March are not included in these tables because very little fishing is done on Nantucket Shoals during the winter, so that at that season there is little opportunity for recapturing tagged fish.
[2] 1 cod was recaptured in December, 1923.
[3] 1 cod was recaptured in January, 1925.

TABLE 23.—*Cod tagged on Nantucket Shoals and subsequently recaptured on Nantucket Shoals*—Continued

Tagged		Recaptured																				
		1926						1927							1928			1929			
Date	Number	June	July	August	September	October	November	May	June	July	August	September	October	November	July	September	October	May	June	August	October
1924:																					
Sept. 6–12	964			1									1								
1925:																					
May 5–8	854	1	1																		
June 7–12	672	1			1	1	1														
Aug. 20–25	1,158			1	2	1						1									
Oct. 1–6, 24–30	1,325	3	2		4	2			2												
1926:																					
Sept. 5–11	1,606						1	1	1			1	1								
1927:																					
May 4–7	1,083								6		2	6	3	4	6						
June 17–25	1,497									1		5	1			4	2				
Aug. 31, Sept. 3	1,264												1	2	2	1					
Oct. 14–17	1,176															1	1		1	1	
1928:																					
July 13–21	693																2	1			1
Oct. 24–29	280																		1		

The recaptures given in Table 23 prove conclusively that part of the cod living on Nantucket Shoals one summer are to be found there a year or more later. A few tagged fish were retaken on the shoals in the winter, in contrast to the lack of recaptures at that time in the Chatham-South Channel region, where a large number of cod were caught. That the number of tagged fish taken monthly did not follow more closely the fluctuations in the commercial catch (Table 24) was due to the fact that much depended upon what part of the shoals the fishermen were operating. Very often a large proportion of the cod were caught along the eastern edge of the grounds by haddock fishermen and the number of cod tags received from this source was small. We have here a good indication that many of the cod living on the shoals remain localized for an extended time. This is shown further by the comparison between the number of marked fish taken by the tagging vessels, which, of course, fished on the tagging grounds, with that taken by commercial fishermen who generally fished about 10 to 40 miles away. Throughout the period from 1923 to 1928 the *Halcyon* and the *Albatross II* recaptured on the shoals proper 122 Nantucket cod with tags attached, among about 24,000 cod caught, whereas commercial fishing boats reported only 137, among a catch of about 866,000. To make this difference more striking, the time element between the dates of tagging and recapture was very much the same for the fish retaken by fishermen and those retaken by us. The average number of days the fish recaptured by us were at liberty was 72 in 1923, 232 in 1924, 193 in 1925, 336 in 1926, 246 in 1927, and 378 in 1928. Thus it can be seen that sufficient time had elapsed for these fish to have emigrated to other regions if they had so desired.

TABLE 24.—*The reported number of Nantucket Shoals tagged cod taken on Nantucket Shoals from 1923 to 1928 by fishing vessels operating out of Boston, Gloucester, and Portland, together with the catch of cod for each month*

Month	Number of cod taken by New England fleet and, in parentheses, number of Nantucket Shoals tagged cod [1]					
	1923	1924	1925	1926	1927	1928 [2]
January		1,947	3,775 (1)	582	1,931	364
February	1,666				847	323
March					364	659
April		0 (1)	7,298 (1)		364	9,192
May	3,331	5,327 (2)	35,194 (1)	7,582	1,759	28,355
June	16,968	12,129 (1)	12,108	7,456 (5)	706	12,387
July	28,260 (5)	40,718 (4)	6,704 (4)	18,375 (3)	15,615 (1)	9,897 (1)
August	21,677 (5)	9,866 (2)	25,939 (10)	15,227 (2)	14,970	35,811
September	52,805 (12)	4,965 (2)	3,041 (6)	12,274 (4)	19,678 (2)	44,269 (6)
October	32,768 (17)	33,693 (5)	15,261 (6)	26,847 (4)	19,638 (7)	104,202 (4)
November	2,276 (2)	9,187	17,900 (1)	17,090 (2)	10,177 (6)	4,966
December	516 (2)	8,619	1,528	2,728	777	5,268
Total	160,267 (43)	126,451 (17)	128,748 (30)	108,161 (20)	86,826 (16)	255,693 (11)

[1] These statistics were obtained from monthly bulletins, giving the catch landed by vessels in Boston, Gloucester, and Portland, issued by the Bureau of Fisheries. The number of fish is estimated here on a basis of 1 fish for each 10 pounds of catch.

[2] In addition to the recaptures reported for 1928 there were taken on Nantucket Shoals 2 Woods Hole tagged cod (1 in March 1 in October), 1 Cholera Bank cod in May and 1 Atlantic City cod in July.

More proof that cod remain on Nantucket Shoals for an extended period is had from the records of catch, per unit of effort, made by the *Halcyon* and the *Albatross II*, which show that throughout the summer, at least, the cod population was very stable. This is shown in Table 25.

TABLE 25.—*The catch of cod made by the tagging vessels on Nantucket Shoals from April to October, 1923–1928 per unit of effort* [1]

Month	Cod caught						Catch of cod per hour on a basis of six lines fishing					
	1923	1924	1925	1926	1927	1928	1923	1924	1925	1926	1927	1928
April 17–May 3	282						8.3					
May [2]	487		879		1,251		10.1		25.1		65.0	
June	1,278		718		1,705		27.8		21.4		38.6	
July		1,420				748		30.8				16.0
August	1,970		1,292				47.0		41.6			
September	1,454	1,063		1,911	1,460		25.5	30.8		33.6	42.0	
October [3]	2,730	955	1,441		1,294	304	38.4	15.0	38.0		44.5	8.7

[1] This table includes all cod caught whether or not they were tagged. It should be remembered that pollock and haddock were caught with the cod, so that the catch of fish per hour was greater than the figures for the cod alone.

[2] Fishing was done the last week of May, 1923, and the first week of May, 1925.

[3] Two cruises were made during October each year from 1923 to 1925.

It can be seen that the catch of cod was most uniform throughout the summer months, while the greatest fluctuations took place in the fall and spring, at which seasons, respectively, cod were departing from and returning to Nantucket Shoals from their wintering grounds to the westward. It is possible that the stock of fish would be kept fairly constant if cod emigrated during the summer and were replaced by new immigrants. But as few Nantucket tagged cod have been retaken to the north and east of the grounds off southern Massachusetts at any time, it is quite evident that the summer population retains its numerical strength chiefly because most of the fish remain localized.

Certain of the extreme catches given in the preceding table can be explained, at least in part. Thus the small catch made on the first cruise in 1923, which was the first to be made on the present investigation, might be laid partly to our unfamiliarity

of the best fishing grounds. The large catch made in May, 1927, was due to the presence near Round Shoal buoy—one of our chief tagging grounds—of a dense school of medium-sized cod. They probably extended over a large part of Nantucket shoals, for cod were more plentiful on all of our tagging grounds off Nantucket during 1927 than during any of the other years.

The wide fluctuations in the October catch are of interest because it is during this month that the westward migration commences. Thus it would seem that in October, 1924, a large part of the fish had already started westward at the time we fished the shoals. In October, 1928, this was still more apparent, for although during the early and middle parts of the month there occurred one of the best catches of cod on the shoals ever made by commercial vessels (Table 24, p. 44), fish were relatively scarce at the time we fished there during the end of the month.

While we can not be sure that the results obtained on the tagging grounds hold for all of Nantucket Shoals, it is very likely that they represent the conditions over a large part. Numerical data dealing with the catch of fish per unit of effort should always be interpreted broadly, because chance is always an important factor in the finding of fish, especially when only one vessel is operating, and some variation in the catch would occur from this cause alone even though the stock of fish remained virtually the same as to numbers from month to month or from year to year.

Other evidence that cod remain localized on Nantucket Shoals for an extended period is shown by the time sequence and the tag-number sequence of the recaptures, for it was noted that many of the marked fish were retaken in almost identically the same place where they had been tagged and that often when one fish was recaught others would follow soon after as long as we fished the same ground.

Thus the *Halcyon* recaptured 6 cod on August 20, 1925, at Round Shoal buoy by drifting repeatedly over a small spot about one-half mile long during two and one-half hours of actual fishing. These recaptures were taken at the following minutes of the day: 3, 3.15, 3.25, 3.35, 3.40, and 4.10 p. m. Five of these fish had been tagged at Round Shoal buoy the previous May and June. In contrast to this we fished 20 miles to the southward, around Great Rip, from August 23 to 25, for 18 hours, and caught about 1,000 cod, among which there was not one tagged fish. The reason for this was apparent, for we had not tagged any cod at Great Rip since 1923, whereas several thousands of fish had been tagged around Round Shoal buoy between October, 1923, and June, 1925; hence the good return of tagged fish which we obtained there in August, 1925. Not only does this show that a large part of the fish remained on the shoals but that they did not move far from the immediate vicinity of the tagging grounds, else we probably would have caught some of them around Great Rip.

Another case of this sort occurred at Round Shoal buoy on October 3, 1925, when seven hours' actual fishing was done there and 6 tagged cod were recaptured by the *Halcyon*, as follows: 8.20, 8.30, 10.40, 10.45, 10.50 a. m., and 1.30 p. m. All these fish had been tagged at Round Shoal buoy between April, 1924, and August, 1925, on four different cruises.

Other instances of this kind were found not only on Nantucket Shoals but on other grounds in the Gulf of Maine as well. Off the coast of Maine in particular, where we have tagged and recaptured many cod close to shore, and thus could take precise bearings on our tagging localities, there were many instances where tagged fish were recaught in rapid succession and often of nearly consecutive number. There is a good example of this off Petit Manan, east of Mount Desert, Me., where on July 13, 1925,

we tagged 168 cod and on July 14, 226 cod. Returning there on September 14, 1925, the *Halcyon* recaptured 9 of the cod tagged on July 14, but none of those tagged on the 13th. Although fishing was done off Petit Manan most of the day on September 14, 8 of the recaptured tagged fish were taken within the space of 22 minutes and the ninth was taken about an hour later, as follows: 1, 1.10, 1.15, 1.17, 1.17, 1.20, 1.21, 1.22, and 2.15 p. m.

The tag-number sequence of recaptures points to the localization of the cod perhaps even better than do the time sequences, for if cod of nearly consecutive tag numbers are recaptured months later, on the same date and in the same place, we can be reasonably certain that such fish belonged to a school which held together during the interim.

TABLE 26.—*Records of Nantucket Shoals cod of nearly consecutive tag numbers which were recaptured on the same or nearly the same day in the same locality where they were tagged*

Tagged at Round Shoal buoy	Recaptured at or near Round Shoal buoy	Tag numbers	Tagged at Round Shoal buoy	Recaptured at or near Round Shoal buoy	Tag numbers
June 24, 1923	Oct. 6, 1923	10708, 10768.	May 4, 1927	Sept. 3, 1927	47472, 47499.
June 28, 1923	Oct. 3, 1923	231, 309, 336.	May 6, 1927	June 17–27, 1927	47778, 47977, 48053, 48075, 48087, 48090.
Do	Oct. 4, 1923	277, 303.	Do	Sept. 1–3, 1927	47738, 47856, 48022, 48155, 48328.
Do	Oct. 15, 1923	248, 231, 283, 375.	Do	Oct. 8, 1927	47801, 47803, 47809.
Do	Oct. 24, 1923	232, 272.	Do	Nov. 16–19, 1927	47776, 47944, 48020, 48025.
Aug. 17, 1923	Sept. 3, 1923	558, 627.	June 18, 1927	Sept. 1–2, 1927	49103, 49141, 49247.
Aug. 18, 1923	Sept. 17, 1923	916, 917, 919.			
Oct. 15, 1923	July 13–16, 1924	486, 491.			

Most of the recaptures given in Table 26 were taken by the tagging vessels, but in a few cases commercial fishermen made the catch. Examples were selected only from the tagging years 1923 and 1927, because we had opportunity to tag and recapture more cod on Nantucket Shoals those years than any of the others. However, each of the years from 1923 to 1928 produced virtually the same result as regards the close association of the individuals making up various small schools of cod.

Those cod retaken (by the *Halcyon*) in October, 1923, as a result of the tagging done the preceding June, show how stationary the fish must have been on Nantucket Shoals that summer. The May, 1927, cod recaptured November 16–19, 1927, are particularly interesting, for they are the latest group of fall recaptures to be taken on the shoals. It is possible these fish did not migrate over the winter; but that part of the May, 1927, cod had already gone westward, is shown by the recapture on November 16 to 21, 1927, of 4 cod of this same school (Nos. 47545, 47715, 47854, and 48324) off northern New Jersey. It will be noted that the recapture dates of these latter fish coincide with those of the fish retaken on the shoals just mentioned, and it is also noteworthy that, as all of them were tagged on May 6, 1927, the body of fish to which they belonged must have held together rather well, in spite of the fact that they had traveled westward about 200 miles. Other examples of this could be cited.

Another interesting point bearing on the localization of Nantucket cod during the summer is furnished by the records of cod which were recaptured more than once. Such records were made possible because all of the 120 cod retaken and again released on the shoals by the tagging vessels were liable to be recaught a second time. Those fish which fell in this category are listed in Table 27.

TABLE 27.—*Tagged cod that were recaptured more than once*

Tag number	Date of tagging on Nantucket Shoals	First recapture, Nantucket Shoals	Second recapture and locality
231	June 28, 1923	Oct. 3, 1923	Oct. 15, 1923, Nantucket Shoals.
277	....do....	Oct. 4, 1923	Jan. 5, 1924, Rockaway, N. Y.
12017	Aug. 16, 1923	Oct. 6, 1923	Jan. 2, 1924, Rockaway, N. Y.
18674	July 15, 1924	Oct. 27, 1924	Dec. 7, 1924, Cholera Bank, N. Y.
21216	Sept. 8, 1924	May 6, 1925	Aug. 7, 1925, Nantucket Shoals.
21380	Sept. 11, 1924	Oct. 18, 1924	Sept. 12, 1925, Nantucket Shoals.
28015	May 5, 1925	Aug. 20, 1925	Oct. 27, 1925, off Great Point, Nantucket Island.

The additional check given by these "second" recaptures throws further light on the behavior of Nantucket Shoals cod. Thus we have cod Nos. 21216 and 21380, whose recapture records indicate that they may have spent the winter on the shoals without having migrated westward, for they were caught three times in the same immediate locality; and cod Nos. 277, 12017, and 18674, which, although they did winter in the New York region, nevertheless spent the summer, up to at least October, on the shoals. It is of interest to note that although cod No. 28015 was recaptured locally, both on August 20 and on October 27, the last recapture being off Great Point, was at the extreme western part of the shoals—an indication that this fish had begun its migration into the Rhode Island-North Carolina region.

THE CHATHAM GROUNDS

Although only a small number of cod were tagged on the Chatham grounds, several of them were recaptured a sufficient time later to indicate that part of the stock of fish spent the summer there without migrating away. (See Table 16 on p. 27.) So, although no tagged Chatham ground cod were recaptured locally during the winter or during the summer which followed, this is perhaps due to the small number of fish that were marked, coupled with the inevitable loss of tags rather than to all the fish having moved away.

LOCALIZATION AS SHOWN BY LENGTH FREQUENCY DISTRIBUTIONS

Up to this point we have discussed the localization of cod on Nantucket Shoals as shown by tagged fish. Although this method has thrown considerable light on the movements of the cod, it has been found possible to corroborate and even to amplify the results obtained from tagged fish by an analysis of length-frequency distributions.

It is obvious that if the relative proportion of fish of different lengths on a certain ground varies from month to month, or from year to year, not in accord with the normal growth schedule, either some age classes have been locally depleted or others reinforced. Consequently, we may hope to trace the movements of bodies of fish onto or away from any given bank, or the interchange of schools between different banks, by analyzing the length frequencies of unselected catches taken at intervals.

We concentrated our tagging, therefore, on certain parts of Nantucket Shoals (fig. 14), for by so doing it was possible to detect slight changes in the lengths of any given body of fish and also to learn whether many of them emigrated away or whether new immigrants had appeared in the locality in question.

The lengths [11] given in the following graphs (figs. 15 to 24) were taken from cod caught by the *Halcyon* and the *Albatross II*, including all those that were tagged plus some which were injured and killed. It is not possible to say how nearly these hook-caught fish are representative of the population, but there is no apparent reason to doubt the adequacy of the samples for the purposes of the present study, at least for the sizes large enough to take the hook readily.

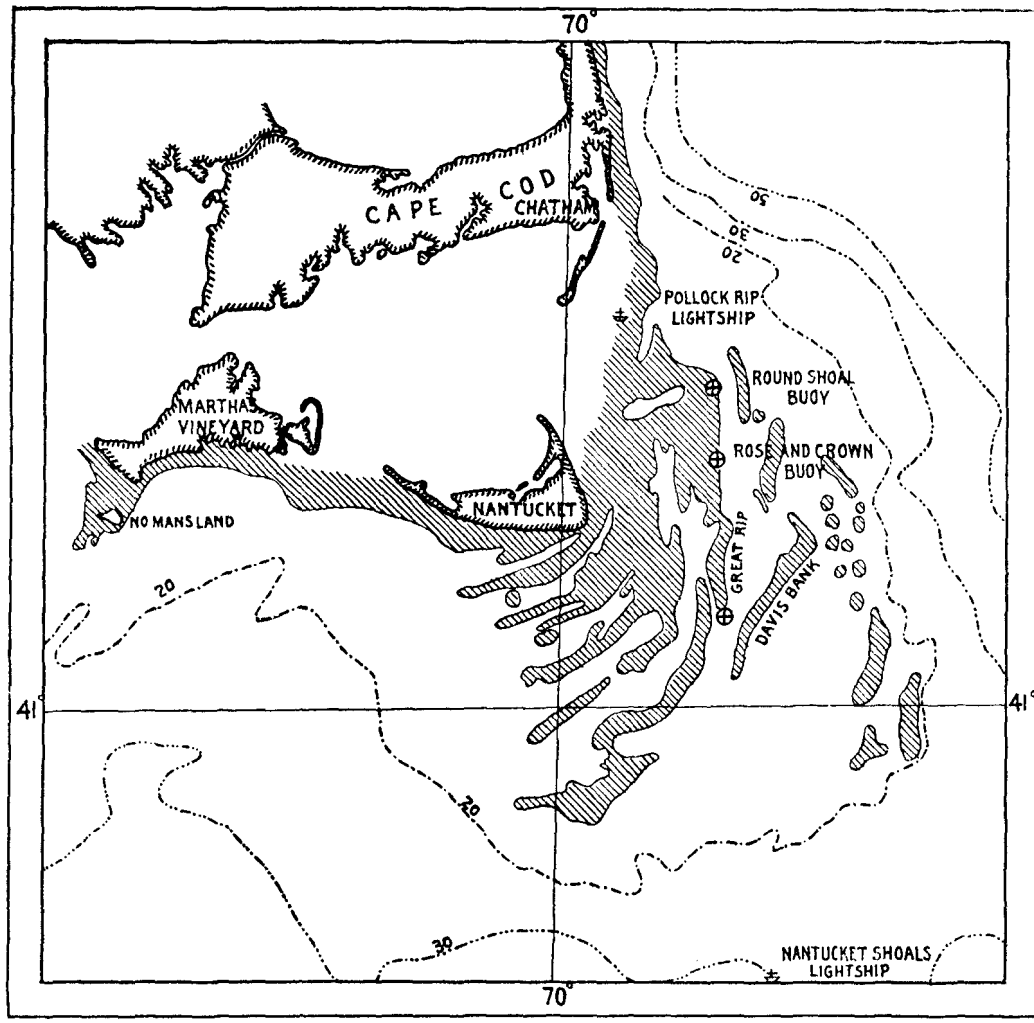

FIGURE 14.—The three buoys on Nantucket Shoals—Round Shoal, Rose and Crown, and Great Rip—around which much of the cod tagging was done. The shaded areas represent depths of less than 10 fathoms

Our length frequencies start from 1923, the first year of the present investigation. Prior to then no lengths for cod caught on Nantucket Shoals were available, so that we had no means of knowing what a normal year might be or how the sizes would fluctuate. That they did fluctuate is shown in Table 28.

[11] All the fish were measured to within the nearest quarter inch and grouped in inch classes, those at the half inch being included with the next highest inch; that is, 20½ to 21¼ inches were classed as 21 inches

TABLE 28.—*Size distribution of all the cod caught on Nantucket Shoals during tagging operations 1923–1929*

Length in inches	Per cent at each length							Length in inches	Per cent at each length						
	1923	1924	1925	1926	1927	1928	1929		1923	1924	1925	1926	1927	1928	1929
Below 14		0.1	0.6		0.1	0.7		30	7.8	5.7	5.0	1.1	1.9	1.2	2.8
14	0.1	.4	1.3	0.1	.1	1.5	0.0	31	5.0	6.0	3.3	.4	1.1	1.1	1.3
15		.6	1.8	1.0	.1	1.9	.6	32	3.6	5.3	2.0	.4	.7	.5	2.7
16	.1	.8	1.9	4.3	.3	1.5	2.7	33	2.5	2.8	1.6	.4	.6	.4	.4
17	.3	.7	1.9	13.0	.7	2.2	8.8	34	2.0	2.7	1.2	.4	.5	.3	.6
18	.5	.4	3.4	17.9	2.1	5.2	10.2	35	1.6	1.6	1.0	.1	.5	.4	.2
19	1.2	.7	6.6	15.8	6.4	5.7	9.4	36	1.3	1.1	.8	.1	.4	.0	.0
20	1.7	1.3	8.0	10.9	13.3	6.7	7.2	37	.6	.9	.4	.0	.1	.3	.3
21	2.3	2.3	9.0	6.0	17.6	7.1	4.0	38	.6	.2	.6	.1	.1	.0	.2
22	2.5	5.4	9.6	4.3	15.9	8.0	6.2	39	.3	.1	.3	.0	.1	.0	.0
23	2.6	10.0	5.0	3.6	12.1	10.7	8.2	40	.3	.2	.3	.0	.1	.0	.0
24	3.9	11.4	3.8	4.7	8.0	11.6	10.0	Above 40	.6	.5	.7	.0	.1	.2	.4
25	7.6	12.8	4.1	5.6	5.7	11.9	6.0								
26	11.6	9.0	5.6	4.6	3.7	8.9	5.5	Total	100.0	100.0	100.0	100.0	99.7	99.7	100.1
27	13.9	6.0	7.0	2.7	2.5	6.3	4.3								
28	13.4	5.5	7.4	1.3	2.6	3.4	4.4	Number measured	7,554	3,102	4,142	1,878	5,712	1,042	704
29	12.1	5.5	5.8	1.2	2.3	2.0	3.7								

One point which stands out in this table is the small number of cod below 16 inches and above 32 inches in length. The scarcity of the small fish in our catches was due in some degree to the selectiveness of the hook-and-line gear. However, using this same gear along the coast of Maine, we have caught many cod as small as 11 inches and a few of 10 inches in length; hence it would appear that our failure to catch small fish on Nantucket Shoals, except at rare intervals indicates either that they are not present or that their feeding habits differ from cod inhabiting the more northern waters. The latter is not likely. With regard to the larger fish, there are strong indications that they tend to move into deeper water and that their scarcity on Nantucket Shoals is not due entirely to the local fishing.

It will be noted that each year from 1923 to 1929 certain size groups were dominant, as, for example, the 26 to 29 inch group in 1923, the 23 to 26 inch group in 1924, etc. The causes for the progressive decline in the dominant sizes which occurred annually from 1923 to 1926 and the progressive increase which occurred thereafter afford an interesting problem. The decline appears to have been caused by the emigration of fish away from and the immigration of new fish to the shoals, while the increase resulted from the growth registered by the same school of cod which occupied the Nantucket grounds for at least three years. These changes will be taken up in detail.

As an aid to a better understanding of the graphs and text which follow, each of the six outstanding schools of cod found on Nantucket Shoals from 1923 to 1929 is designated by a symbol (*A, B, C, D, E,* or *F*).

The term "stock" of fish is meant to cover the entire population inhabiting the region in question. "School," "group," "age class," and "length class" are used almost synonymously to refer to one particular part of the fish population, such as the *A* group in Figure 15. In this case it is obvious that while one age class is outstanding among the *A* fish there is an overlapping of younger and older fish and the term "group" or "school" should not be interpreted to refer to only one age class. As the analysis of the length frequencies given here is made chiefly to determine the migrations of bodies of cod and changes in the population on the various tagging grounds, age and rate of growth are mentioned only when necessary as an aid in understanding the data. These important subjects "age" and "rate of growth" are discussed in a later chapter.

LENGTHS OF NANTUCKET SHOALS COD IN 1923

On all the grounds fished by us during 1923 very much the same frequency distribution was obtained, indicating that one school of cod covered a good part of the shoals. It was not until October that on one of the tagging grounds the length distribution was altered somewhat by the appearance of a body of small fish (fig. 15, No. 1, symbol *B*) which had not been noted from April to September. The *A* fish centered around 26 to 28 inches on all the grounds and at Great Rip the 29-inch size was included in addition.

The fact that the length-frequency distribution of the Nantucket Shoals cod remained rather constant throughout the summer of 1923 suggests that relatively few immigrants arrived during that season, else the frequencies would probably have altered materially. And as the catch of fish taken by the *Halcyon* per unit of effort did not fall during the summer, it appears that the emigration of Nantucket cod to the Chatham-South Channel region, already referred to, involved a relatively small part of the population.

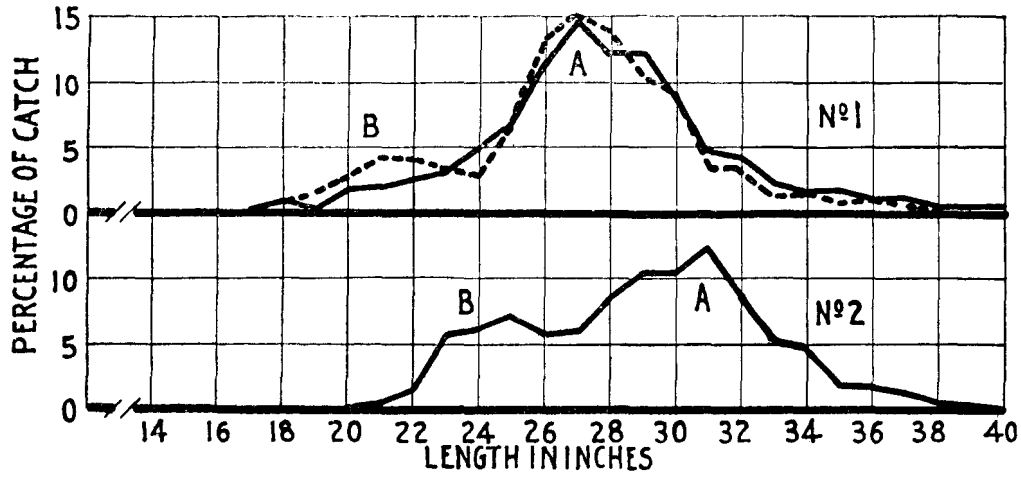

FIGURE 15.—*No. 1*=length-frequency distribution of 1,144 cod caught at Round Shoal buoy June 22-28 (solid line), and 1,071 caught October 3-6, 1923 (broken line). *No. 2*=length-frequency distribution of 788 cod caught 5 to 12 miles ESE. of Round Shoal buoy July 14-16, 1924

LENGTHS OF NANTUCKET SHOALS COD IN 1924

The first cruise in 1924 was not made until July. Two localities were fished at that time, namely, the Round Shoal buoy grounds where we tagged throughout 1923 and a new tagging ground situated 5 to 12 miles east-southeast from this buoy.

We noticed at once that the lengths of the cod taken in July, 1924, differed considerably from those obtained during any month or on any tagging ground during 1923. (Figs. 15 and 16.)

At Round Shoal buoy cod of the *A* group had disappeared, their place being taken by what can be recognized as the *B* group, now centering around 23 to 25 inches, evidently having grown to this size since the previous season when it was last seen at 20 to 22 inches. But on the new tagging ground, 5 to 12 miles east-southeast of Round Shoal buoy, however, the catch was dominated by the *A* group (fig. 15, No. 2), which had increased in length since the summer of 1923. Unfortunately, no tagging was done in 1923 on the grounds east-southeast from Round Shoal buoy; but it would seem that many of these *A* group fish had moved to there, as indicated by the recapture of the *Halcyon*, 12 miles east-southeast of Round Shoal buoy, of a

31-inch cod which had been tagged when 29 inches long in August, 1923, in the immediate vicinity of the buoy. Furthermore, many of the cod tagged in 1923 on Nantucket Shoals were subsequently recaptured during 1924 and 1925 a little to the eastward on the Chatham grounds and South Channel. And to show that it was chiefly this predominating size group which carried out this eastern migration we have the following data: 5,015 fish, or 66.4 per cent of the total of 7,554 cod caught on Nantucket Shoals in 1923, were 25 to 30 inches in length (*A* cod), while 23 fish, or 74.2 per cent of the total of 31 recaptures made on the Chatham grounds and in South Channel, from June, 1924, to August, 1925, were of cod which measured 25 to 30 inches on Nantucket Shoals in 1923.

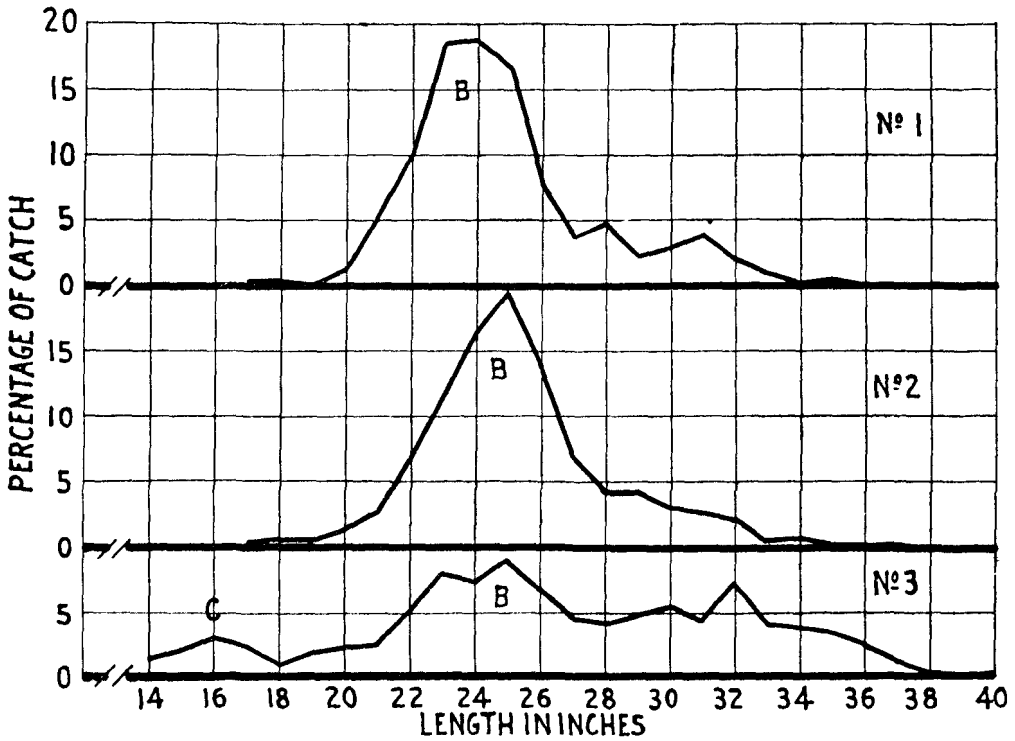

FIGURE 16.—*No. 1*=length-frequency distribution of 466 cod caught at Round Shoal buoy July 13–17, 1924. *No. 2*=length-frequency distribution of 964 cod caught from Round Shoal buoy to Rose and Crown buoy, September 6–11, 1924. *No. 3*=length-frequency distribution of 795 cod caught from Round Shoal buoy to Rose and Crown buoy, October 16 to 28, 1924

With this evidence we can conclude that most of the individuals belonging to this great school of fish (1923 *A* cod) immigrated to the Chatham-South Channel region some time between the fall of 1923 and the summer of 1924, for they were not observed on Nantucket Shoals thereafter. Many of them probably migrated westward in the fall of 1923, the survivors of this migration returning to Nantucket Shoals in the spring and continuing eastward toward the Chatham grounds. Almost all the fish above 33 inches likewise left the Round Shoal buoy grounds over the winter of 1923–24, for they were not present there the summer of 1924.

The 20 to 22 inch fish, *B*, which first appeared in October, 1923 (fig. 15, No. 1), evidently immigrated to Nantucket Shoals in large numbers some time during the winter of 1923–24, for on our July cruise we found that they formed the predominating group at Round Shoal buoy. (Fig. 16, No. 1.) They had grown to 23 to 25 inches

during the interim. That these fish belonged to the same school present the preceding fall is indicated by the *Halcyon's* recapture at Round Shoal buoy in July, 1924, of 12 cod 23 to 25 inches long, 5 of which measured 19 to 23 inches long when tagged there in 1923. Apparently this 23 to 25 school, *B*, was a large one, for even on the grounds 5 to 12 miles east-southeast of the buoy they were abundant enough to stand out in the length-frequency distribution (fig. 15, No. 2), although they were greatly exceeded in numbers by the 28 to 32 inch cod that were presumably moving eastward.

On the cruise made September 6 to 11, 1924, most of the fishing was done on the grounds extending from Round Shoal buoy to Rose and Crown buoy. Practically the same size distribution was obtained from the 298 cod caught at the Round Shoal buoy grounds as from the 637 caught between the buoys, so the total catch of 964 fish from both localities are combined in the graph. (Fig. 16, No. 2.) On the grounds 6 to 8 miles east-southeast of Round Shoal buoy the remnant of the 1923 *A* cod present in July, 1924, had seemingly disappeared by September, as only a few scattering fish were taken there at that time.

It is apparent that the 23 to 25 inch July cod (fig. 16, No. 1) were predominant on the tagging grounds in September; but at that time, due to increased growth, they were 23 to 26 inches long. (Fig. 16, No. 2.) Small fish were absent and large fish above 33 inches were still scarce. The picture was, therefore, almost exactly the same as obtained at Round Shoal buoy in July, 1924, and illustrates how stationary the cod must have been throughout the summer.

Two successive cruises were made to Nantucket Shoals within the period October 16–28, 1924, and, as shown by Figure 16, No. 3, the size distribution which obtained in July and September was very much altered. Whereas the July and September length frequencies showed that no important immigration or emigration of cod occurred to or from Nantucket Shoals throughout the summer (unless a school of cod migrated to or from Nantucket Shoals and had the same length frequencies as the fish already on the shoals; such an instance is possible but not probable, as our data have shown), the October distribution showed that migrations of some sort were taking place, otherwise such a disturbance in the sizes of the cod present would not have occurred. The 23 to 26 inch *B* cod of July and September still formed a large part of the stock of fish present from Round Shoal to Rose and Crown buoys in October, but at least two other schools of cod had appeared in this region. One of them was comprised of 15 to 17 inch cod and will be designated as *C* fish. These, although apparently few in number, were destined to form a very important part of the stock of fish on Nantucket Shoals in 1925. The other school was a somewhat heterogeneous lot of large cod centering around 30 to 32 inches, some of which were present previously. The presence in October of these latter two size groups naturally tended to reduce the proportion of *B* cod considerably below that which was present in September. The departure of some of the *B* cod to the westward would also have reduced their percentage in the total stock of fish.

The appearance in October of these two schools of cod (15 to 17 inches and 30 to 32 inches, fig. 16, No. 3) agreed with the results of our cod tagging the year before, which showed that cod school up and migrate to the westward of Nantucket Shoals in the fall. It is possible that the cod centering around 30 to 32 inches may have been a return of part of the *A* fish which predominated on Nantucket Shoals in 1923 and which last were traced to the east-southeast of Round Shoal buoy in July, 1924

(fig. 15, No. 2), or they may have come from some part of the shoals where no tagging had been done and from where, therefore, no length frequencies had been obtained. It is more likely, however, that the cod centering around 30 to 32 inches, as well as the 15 to 17 inch fish, *C*, came from grounds north or east of the shoals, because we learned in the years which followed 1924 that at least a small part of the cod living on Stellwagen Bank, Georges Bank, and particularly in the Chatham-South Channel region join in the fall migration to the westward of Nantucket Shoals.

Around Great Rip buoy and Davis Bank 89 cod were taken in October—too few to show graphically. There were, however, no small fish present, and a predominance of sizes, irregularly distributed between 25 and 34 inches, suggesting that some of the Round Shoal *B* cod (23 to 26 inches) as well as of the school of uncertain identity (30 to 32 inches) extended that far south on the shoals.

The year 1924 in summary:

The dominant size group of cod, *A*, present in 1923 on all the Nantucket Shoals tagging grounds left the Round Shoal-Rose and Crown buoy grounds some time before July, 1924, and they were found to be traveling eastward toward the Chatham-South Channel region during that month. The *B* cod which first appeared on the Round Shoal buoy grounds in October, 1923, formed the dominant group on the various Nantucket Shoals tagging grounds throughout the summer of 1924. They appeared in large numbers some time between October, 1923, and July, 1924, but just when we can not say surely, as no fish tagging was done within this period. Very likely most of them migrated to and occupied the Nantucket Shoals grounds before the close of 1923. The stock of cod inhabiting the shoals throughout the summer of 1924 carried out no migrations that included large numbers of fish, nor were their numbers augmented materially during that period, but during October, 1924, a school of cod that was apparently on its way westward to spend the winter appeared on the tagging grounds. Some of these very likely remained on Nantucket Shoals throughout the winter and did not continue westward.

LENGTHS OF NANTUCKET SHOALS COD IN 1925

No track was kept of the cod on Nantucket Shoals during the winter of 1924–25 nor during any of the other winters throughout our tagging operations. We are obliged, therefore, to jump from the fall to the next spring or summer in taking up the analysis of the length frequencies.

In preparing the length data for our May cruise to Nantucket Shoals in 1925 the Round Shoal to Rose and Crown region was subdivided into three areas—one being within about a mile of Round Shoal buoy, another in the vicinity of Rose and Crown buoy, and the other between the two buoys, which were about 6 miles apart. Very much the same length frequencies were obtained from each of these areas, excepting that a slightly greater proportion of larger fish was taken around Rose and Crown buoy, and, because there was no important difference, all the lengths were combined in the same graph. (Fig. 17, No. 1.)

This first cruise to the shoals was particularly interesting, for there was some speculation as to whether the small cod below 20 inches in length, which first appeared the preceding October, would still be there in the spring. It will be remembered (fig. 16, No. 3) that in October, 1924, a small peak was formed by the 15 to 17 inch fish, *C*, which sizes comprised 7.4 per cent of the total catch of cod. This same stock of fish, *C*, was present on the shoals in the spring of 1925 and apparently was augmented

by additional immigrants. Due to growth, the 15 to 17 inch October, 1924, cod were 18 to 20 inches long in May, 1925, and these sizes formed 29.7 per cent of the total catch of cod. (Fig. 17, No. 1.) The tagging locality in May, 1925, was the same as that where all the fish given in Figure 16, No. 3 (October, 1924), were taken, namely, Round Shoal buoy to Rose and Crown buoy. The 23 to 26 inch cod, *B*, which comprised a major group in October, 1924, were present on the same tagging grounds and in about the same proportion. They had, of course, grown in length and the 23-inch fish were fading out of the picture while the 24 to 27 inch lengths dominated.

The second cruise to Nantucket Shoals in 1925 was made in June and the size distribution is given in Figure 17, No. 2.

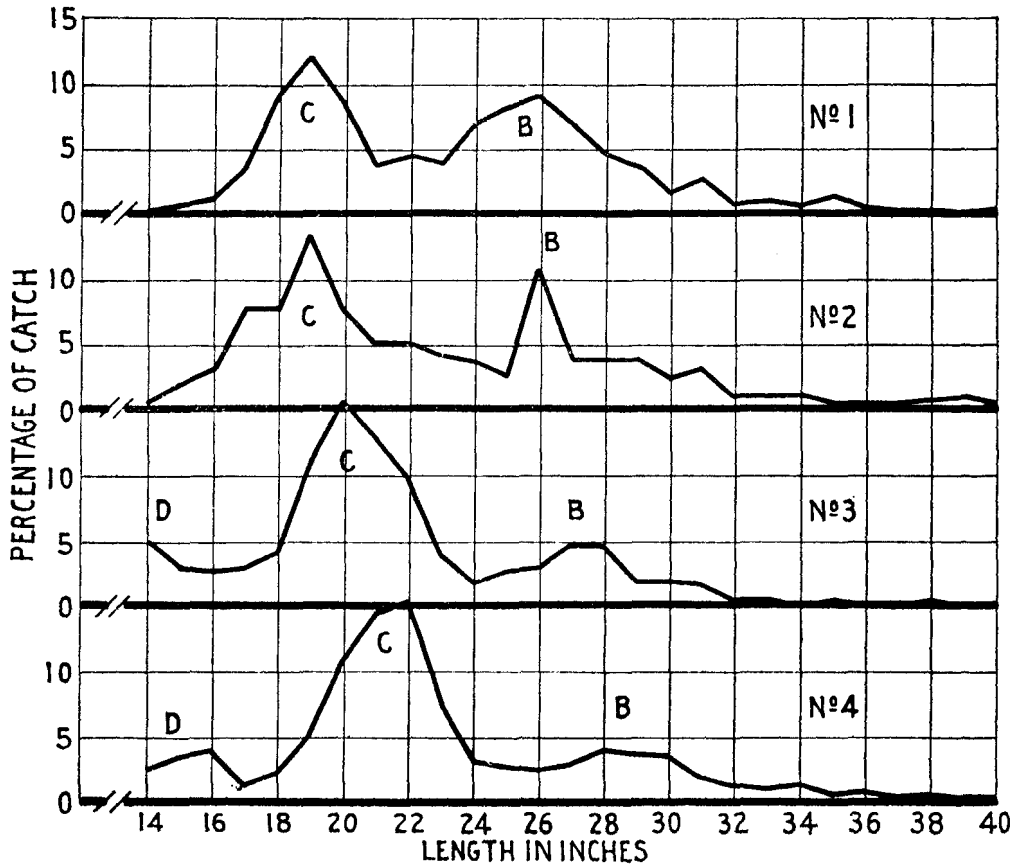

FIGURE 17.—Length-frequency distribution of cod caught between Round Shoal buoy and Rose and Crown buoy. *No. 1*=852 fish taken May 5-8, 1925. *No. 2*=154 fish taken June 7-12, 1925. *No. 3*=253 fish taken August 21-25, 1925. *No. 4*=1,330 fish taken October 1-6 and October 24-30, 1925

Most of the fishing in June was 6 to 12 miles east-southeast of Round Shoal buoy on the grounds where the last of the *A* cod were found in July, 1924. Enough cod were caught in the immediate vicinity of the buoy, however, to show that in June the same 18 to 20 inch school, *C*, had remained from the previous month (fig. 17, No. 2) and apparently no migration occured in the meantime.

The 24 to 27 inch fish, *B*, so plentiful in May, 1925, were represented in June chiefly by the 26-inch size. The number of cod caught in June, however, was too small to draw conclusions other than that the stock of cod around Round Shoal buoy was essentially the same as in May.

The stock of cod 6 to 12 miles east-southeast (fig. 18, No. 1) differed in their length frequencies from those living in the immediate vicinity of the buoy, for we found (1) that the 18 to 20 inch fish, *C*, so dominant at the buoy were barely discernible to the east-southeast, while (2) the 25 to 28 inch fish, *B*, weakly represented by 26-inch fish at the buoy, were the dominant group to the east-southeast. A good proportion of larger fish above 28 inches also were present east-southeast of the buoy; and, though the group was not well enough defined to indicate its origin, it is not improbable that many of them were from the *A* group that were traced to this locality in 1924. The 25 to 28 inch cod, *B*, were apparently the same school which inhabited the east-southeast grounds in July, 1924 (fig. 15, No. 2), when they were 23 to 26 inches long. This, together with the fact that there was a marked decrease in the proportion of *B* cod present on the Round Shoal buoy grounds in June, 1925, as compared with May, indicated that this school moved eastward between early May and early June to join the fish already living on the grounds 6 to 12 miles east-southeast. This same sort of migration occurred in 1924, when our *A* fish were traced to these grounds. The results obtained in August, which follow, likewise favor this theory.

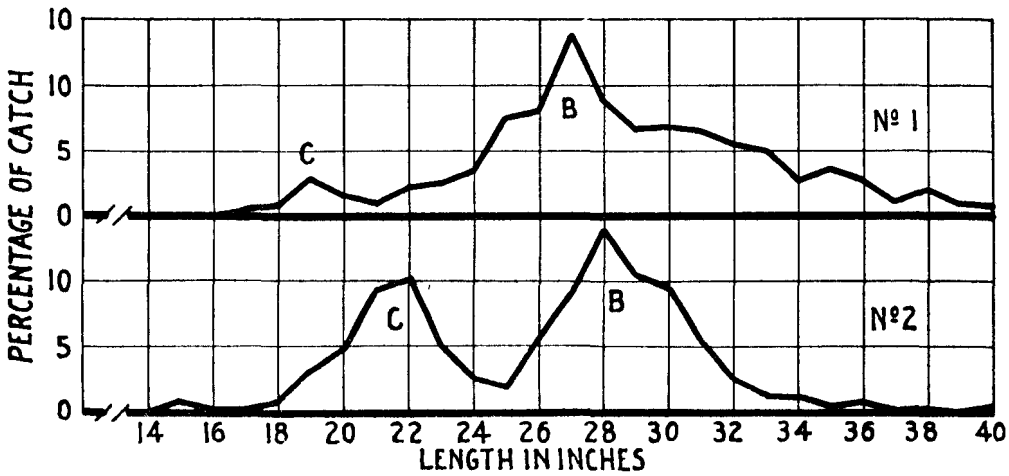

FIGURE 18.—*No. 1*=length-frequency distribution of 517 cod caught 6 to 12 miles ESE. of Round Shoal buoy June 7–12, 1925. *No. 2*=length-frequency distribution of 1,038 cod caught at Great Rip buoy August 21–25, 1925

Fishing was restricted to the grounds near Round Shoal buoy and Great Rip buoy on our next cruise to Nantucket Shoals, August 21–25, 1925.

The *C* school, which predominated at Round Shoal buoy in June, 1925, with a peak at 19 inches, was still the dominant group in August, but the peak had moved to 20 inches (fig. 17, No. 3), doubtlessly, because the fish increased that much in length. The *B* school which was on the wane from May to June, 1925, formed a still smaller part of the stock of fish near Round Shoal buoy by August. The sharp peak at 26 inches in June, 1925 (fig. 17, No. 2), had flattened and centered around 27 to 28 inches by August, due partly to increased growth and partly to the larger sample of fish obtained the latter month. It is apparent from the results of our fishing in May, June, and August that the *B* cod were leaving the Round Shoal buoy grounds. As it was during this time that an emigration of tagged cod occurred from Nantucket Shoals to the Chatham-South Channel region, and as *B* cod were dominant east-southeast of the buoy in June, 1925, and were still well represented at Great Rip buoy in August, 1925, it is apparent that they moved from Round Shoal buoy in an east-to-south

direction. A new school of cod, *D*, appeared at Round Shoal buoy in August, 1925, and the sizes of its individuals formed a small peak at 14 inches. If these small cod had passed out of the picture by October they would scarcely deserve passing mention, but it happened that they were the forerunners of the most dominant group of cod, including the largest number of individuals, of any school found on Nantucket Shoals during the years 1923–1929. There were, then, three distinct schools of fish on the Round Shoal buoy grounds—the dominant C school, the B school of secondary importance and fading out of the picture, and the *D* school just forming and destined to become the greatest of all within the next two years.

The first fishing on the Great Rip grounds in 1925 was not started until August. Unfortunately, no cod were tagged there during 1924, so that we have fewer data to compare than for the Round Shoal-Rose and Crown region. We found, however, that the *C* cod were of secondary importance, the *B* cod were dominant, and the *D* cod had not yet appeared. (Fig. 18, No. 2.)

It will be noted that the length frequencies of the *B* and the *C* cod at Great Rip do not coincide with those of Round Shoal buoy, and the question might justly arise as to whether too much dependence is being placed on the length frequencies alone as a means of identifying these schools of fish. While the *B* cod differ very little, the peak of the Great Rip *C* cod lies between 21 and 22 inches instead of between 20 and 21 inches, as at Round Shoal. A similar situation was found to exist in 1926, when 18-inch cod were present at Round Shoal and 20-inch cod at Great Rip (fig. 19), but an analysis of scale samples of these fish showed that the difference in length was caused by an increase in the rate of growth due probably to a more abundant food supply at Great Rip rather than to a difference in age (p. 58).

During October, 1925, two cruises were made to Nantucket Shoals, the first from the 1st to the 6th and the second from the 24th to the 30th. On each of these cruises fishing was restricted to the Round Shoal to Rose and Crown grounds.

Although we could have reasonably expected some differences between the length-frequency distribution of the late October fish as compared with that of the fish taken earlier in the month, due to emigrations and immigrations which are apt to occur at that time, the lengths were very much the same on both cruises; hence, they have been combined in Figure 17, No. 4. There were, however, somewhat fewer cod present late in October, for whereas a catch of 40 fish per hour per unit of effort was made early in the month only 30 fish per hour were taken the end of the month. This indicated that some of the cod had already started westward by October 24. If cod from east or north of Nantucket Shoals were migrating westward by the end of October there were not enough of them on the Round Shoal grounds at the end of October to materially affect the length-frequency distribution which had obtained since the preceding August. A comparison of Figure 17, No. 3, with Figure 17, No. 4, will show how remarkably stable the stock of fish was from summer to fall.

The year 1925 may be summed up as follows:

On the Round Shoal to Rose and Crown grounds the stock of cod was so much the same from month to month that there can be no question but what the major part of the fish, as we found them on our first cruise in May, remained in the immediate vicinity of these tagging grounds throughout the spring, summer, and fall. Briefly, the outstanding features of this stock of fish were that the *C* cod remained predominant throughout the period from May to October; the *B* cod, although present at all times, consistently declined in dominance from May to October; and,

a new school of cod, *D*, appeared for the first time in August, 1925, and was still present in October.

On the grounds 6 to 12 miles east-southeast of Round Shoal buoy, where we fished only once during 1925, the *B* cod formed the chief part of the stock of fish. A lack of comparable data for these grounds, such as we have for the Round Shoal to Rose and Crown grounds, precludes a worth-while discussion based on Figure 18, No. 1, alone. The recapture of an unusually large proportion of the Round Shoal to Rose and Crown tagged cod to the southeast and northeast (Chatham and South Channel) during the summer, together with the waning of the *B* cod on these grounds, indicates that the *B* cod were dominant 6 to 12 miles east-southeast because they had moved eastward from the western part of Nantucket Shoals.

At Great Rip buoy, where tagging was done only in August, practically the same stock of cod was present as in the Round Shoal to Rose and Crown region, excepting that the *B* cod were much more prominent.

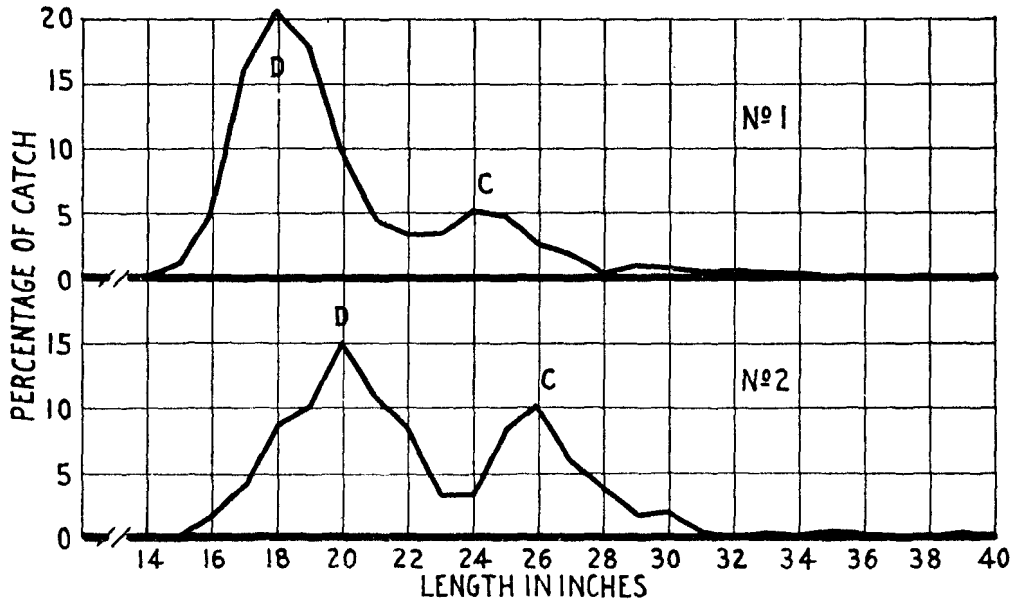

FIGURE 19.—*No. 1*=length-frequency distribution of 1,395 cod caught from Round Shoal buoy to Rose and Crown buoy September 6–11, 1926. *No. 2*=length-frequency distribution of 483 cod caught at Great Rip buoy September 6–11, 1926

LENGTHS OF NANTUCKET SHOALS COD CAUGHT IN 1926

Only one cruise was made to Nantucket Shoals in 1926, but a good sample of the cod living in the Round Shoal to Rose and Crown region (1,395 fish) and around Great Rip (483 fish) was obtained. It was found in September that the Round Shoal to Rose and Crown *B* cod which declined in dominance throughout 1925 were entirely eliminated from the picture, and the *C* cod which were predominant throughout 1925 were now relegated to secondary importance. (Fig. 19, No. 1.) The *D* cod had forged ahead into first place, in fact, comprised about four-fifths of all the fish.

At Great Rip buoy virtually the same stock of cod was present as around Rose and Crown and Round Shoal buoys, about 14 to 20 miles to the northward. Even the *B* cod, so dominant at Great Rip in August, 1925 (fig. 18, No.2), had disappeared from there by September, 1926 (fig. 19, No. 2). The *C* cod which in August, 1925, averaged

about 1 inch longer than the Round Shoal *C* cod had increased their dominant lengths from 21 to 22 to 25 to 26 inches.

The *D* cod formed the dominant school at Great Rip in September. The fact that they averaged about 2 inches greater in length than the Round Shoal fish caused some speculation as to whether the fish from these two regions belonged to a homologous group, particularly as no *D* fish were found at Great Rip the preceding August. The problem appeared to be whether or not the 18-inch Round Shoal to Rose and Crown cod were the same age as the 20-inch Great Rip cod. It seemed entirely possible that if the Great Rip fish found more and better food over an extended period than the Round Shoal fish they could have amassed a net gain of about 2 inches in length in about a year's time.

Fortunately, scale samples of all these fish had been obtained, so that by a study of these it was possible to see if such a growth was registered. As the smaller size group, *D*, made up the larger part of the stock of cod at both Round Shoal and Great Rip Bouys, the scales of these fish were examined, but time was not taken to compare the *C* Round Shoal cod with the supposedly *C* Great Rip cod.

Taking them in the order of their tag numbers, the scales were studied of the first 50 Round Shoal cod that measured 16½ to 19¼ inches (which sizes are rated at 17 to 19 inches on the graphs), and the first 50 Great Rip cod that measured 18½ to 21¼ inches (19 to 21 inches on the graphs), thus including the dominant group of *D* cod in each locality. All these fish proved to be between 2 and 3 years of age, except 2 Round Shoal and 1 Great Rip fish. In addition to these lots of scales another, consisting of 49 fish from Round Shoal, 18½ to 21¼ inches long, was compared with the Great Rip fish of the same size. The first two lots of scales are given in the table which follows:

TABLE 29.—*A comparison in the number of peripheral circuli formed on the scales of certain cod living at Great Rip and Round Shoal buoys, Nantucket Shoals, during the summer of 1926*

Round Shoal buoy			Great Rip buoy		
Length in inches	Number of fish	Average number of peripheral circuli	Length in inches	Number of fish	Average number of peripheral circuli
16½–16¾	5	5.4	18½–18¾	6	6.6
17–17¾	17	5.2	19–19¾	19	8.6
18–18¾	18	5.7	20–20¾	20	8.6
19–19¼	8	6.6	21–21¼	4	8.7
Total	48	5.6	Total	49	8.4

As all these fish were of the same age, as measured in years, if would matter little if the larger fish (19 to 21 inches) had hatched a few months before the smaller ones (17 to 19 inches) because the scales of all of them began the formation of the "summer" rings at about the same time during 1926. Therefore, if circuli indicate growth the greater number formed at the periphery of the Great Rip scales is a good indication that these fish were growing at a faster rate than the Round Shoal fish. Even the 18½ to 21¼ inch Round Shoal cod (which may be considered the fastest growing of the *D* fish at Round Shoal) averaged only 7 peripheral circuli as compared to 8.4 for the Great Rip fish of the same size (which may be considered as average growing *D* fish at Great Rip.)

Further evidence that Great Rip cod grow somewhat faster than Round Shoal cod is indicated by the Round Shoal *C* cod, which centered around 24 inches in September, 1926, as against 26 inches for the Great Rip fish (fig. 19), and by the *D* cod, which in June, 1927, had a peak at 21 inches at Round Shoal compared with 22 inches at Great Rip (figs. 20 No. 1, and 22 No. 2). We are justified, therefore, in considering the 19 to 21 inch Great Rip cod and the 17 to 19 inch Round Shoal fish as parts of the same group (*D* cod, fig. 19).

During 1926, therefore, the stocks of cod at Great Rip and at Round Shoal buoy were essentially the same and had in common the following:

1. A complete absence of small cod below 14 inches, excepting those too small to take the hook and concerning whose presence we have only meager information.
2. An almost complete absence of large cod of more than 34 inches in length.
3. Two outstanding size groups of fish—a dominant group composed of 2-year olds (in their third year) averaging about 18 inches long at Round Shoal buoy and around 20 inches long at Great Rip buoy, and a group of secondary importance, composed presumably mostly of 3-year olds, averaging around 24 to 25 inches at Round Shoal buoy and 26 inches at Great Rip buoy. The difference in size in each instance was due most probably to the rate of growth of the fish within their respective areas.

LENGTH OF NANTUCKET COD IN 1927

The first cruise to Nantucket Shoals in 1927 was made early in May, at which time, 1,159 cod were caught.

At no time since we began our cod tagging in April, 1923, did one size group stand out so prominently as on this cruise. (Fig. 20, No. 1.) It was apparent, too, that the 20-inch peak of May, 1927, and the 18-inch peak of September, 1926 (fig. 19, No. 1), were formed by the same stock of fish, with the difference in size being due to growth.

A few scales of these 20-inch May, 1927, cod, *D*, were examined and they proved to have three annual rings as expected in place of the two annuli plus the wide peripheral circuli possessed by the September, 1926, 18-inch fish. Even more positive proof was furnished by the scales of recaptured fish. It so happened that in May, 1927, only one September, 1926, cod was recaptured with its tag still attached (other September, 1926, Nantucket Shoals cod were recaptured by us in June and September, 1927). This fish, which was 19½ inches long and possessed two annuli in September, 1926, was 22¼ inches long and had three annuli in May, 1927.

The *C* cod of September, 1926, were practically out of the picture in May, 1927, as there was then only a bare suspicion of them at 26 inches. A very few large cod, above 34 inches, were present in May, 1927, at Round Shoal buoy (fig. 20, No. 1), although they were absent in 1926. They might have represented part of a school of cod which came from Georges Bank or elsewhere to join the cod migrating westward toward New Jersey in the fall. But it was surprising that the stock of cod in May, 1927, was so nearly like that of September, 1926—the only changes of note being the disappearance of the *C* cod and appearance of a few large fish.

At Great Rip buoy only 93 cod were caught in May, 1927, the small catch being due to weather conditions and other factors rather than to a scarcity of fish. Ordinarily so few fish would be insufficient upon which to draw conclusions, but in the present instance we can be justified in utilizing the September, 1926, and June, 1927, catches at Great Rip to interpret conditions there in May. (Fig. 22, No. 2.)

It appeared, therefore, that the 22 to 23 inch cod, *D*, caught in May were of the same stock that were 20 inches long in September, 1926. (Fig. 19, No. 2.) It will be noted, also, that the 2-inch advantage in length which the Great Rip fish possessed in September, 1926, over the Round Shoal cod remained the same in May, 1927. The *C* school of cod which formed a good part of the total stock of fish at Great Rip in September, 1926, was practically out of the picture in May, 1927, just as it was at Round Shoal buoy.

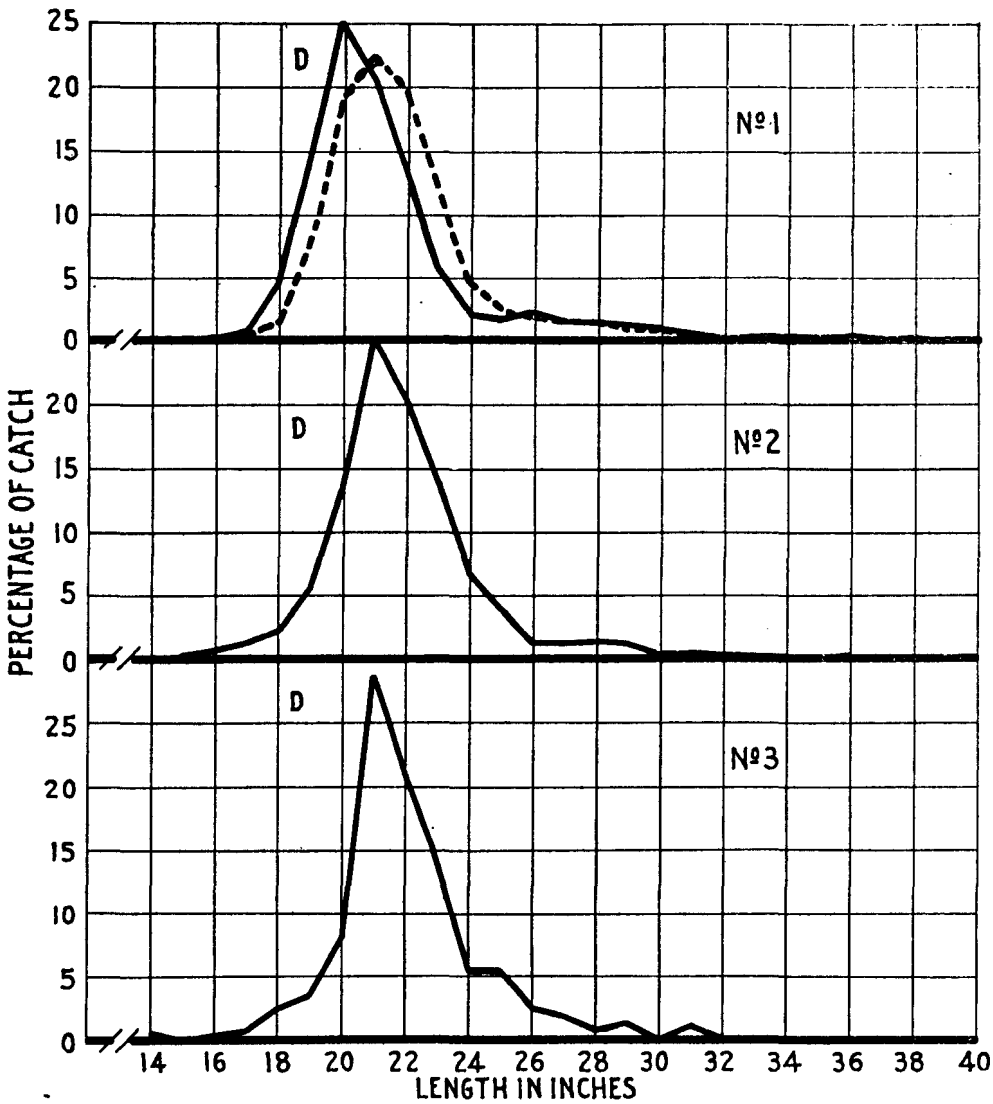

FIGURE 20.—Length-frequency distribution of cod caught between Round Shoal buoy and Rose and Crown buoy. *No. 1*=1,159 fish taken May 4–7 (solid curve) and 878 fish taken June 16–25, 1927 (broken curve). *No. 2*=1,468 fish taken August 31 to September 3, 1927. *No. 3*=275 fish taken October 14–17, 1927

Tagging on the Chatham grounds for the first time during the present investigation was done in May, 1927. It was interesting to find that there, as on the Round Shoal buoy grounds, the *D* cod, with a peak at 20 inches, formed the dominating school. (Fig. 21.) They were not, however, as sharply defined as were the

Round Shoal cod, owing to the presence of larger fish, for whereas only a small percentage of the fish exceeded 24 inches long at Round Shoal buoy an appreciable percentage did so on the Chatham grounds. In the latter locality the small peak at

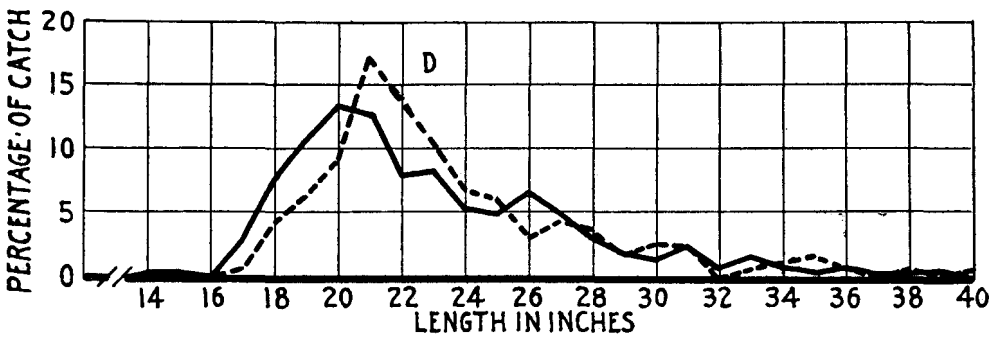

FIGURE 21.—Length-frequency distribution of 299 cod caught on the Chatham grounds, about 12 miles ENE. of Round Shoal buoy, May 3–4 (solid curve), and 161 caught June 16, 1927 (broken curve)

26 inches suggests that the Round Shoal *C* cod of September, 1926, may have migrated over the Chatham grounds and that a remnant of them were left behind. Or it may be that the *C* cod were present in large numbers on the Chatham grounds in 1926 and that the few present in May, 1927, were a remnant left behind after the others had departed.

As a result of the fishing just described, it was found that the same school of cod which was dominant on Nantucket Shoals in 1926 was even more so in May, 1927, extending from Round Shoal buoy to at least 10 or 12 miles east-northeast on the Chatham grounds and about 20 miles southward to Great Rip buoy.

The second cruise to Nantucket Shoals in 1927 was made in June. The length frequencies of the cod caught then were almost identical to those taken in May at all three localities—Round Shoal buoy, Great Rip buoy, and the Chatham grounds.

At Round Shoal buoy the great peak of 20 inches in May had been flattened very slightly and stood at 21 inches in June (fig. 20, No. 1), due to growth of the fish. All the large fish above 32 inches had moved away, probably to deeper water.

At Great Rip the *D* cod were dominant at 22 to 24 inches, compared to 20 to 22 at Round Shoal. (Fig. 20, No. 1, and 22, No. 2.) The curve for June is smoother than that of May because a much larger sample of fish was taken, but virtually the same stock was present both months.

On the Chatham grounds the May and June distribution is likewise very much the same, with the 20-inch peak moved over to 21 inches due to growth (fig. 21), just as occurred at Round Shoal buoy.

Tagging also was done east of Davis Bank in June, 1927, and, although we had no previous data with which to compare, it is evident that the *D* cod extended to that region. (Fig. 22, No. 1.) Davis Bank lies about equidistant from Round Shoal and Great Rip buoys, and it was interesting to find that while the *D* cod were 20 to 22 inches on the Round Shoal grounds and 22 to 24 inches on the Great Rip grounds they were 20 to 23 inches on Davis Bank. Whether it was water temperature or food which caused the small differences in the size of the cod living on these three grounds, the intermediate position of Davis Bank appears to connect up the conditions existing on the other two.

On the next cruise to Nantucket Shoals we fished from August 31 to September 3, 1927, chiefly in the vicinity of Round Shoal and Rose and Crown buoys where 1,468 cod were caught. Unquestionably the *D* cod were still present and fully as dominant as in May and June. The peak still remained at 21 inches at Round Shoal buoy (fig. 20, No. 2), indicating that the fish had not grown appreciably during the interim from late June to the end of August.

It is hard to understand why the fish showed an increase of 1 inch in length from May to June and only about three-fourths inch from June to August—a period when we could have expected them to grow fully as fast as during the spring. Yet

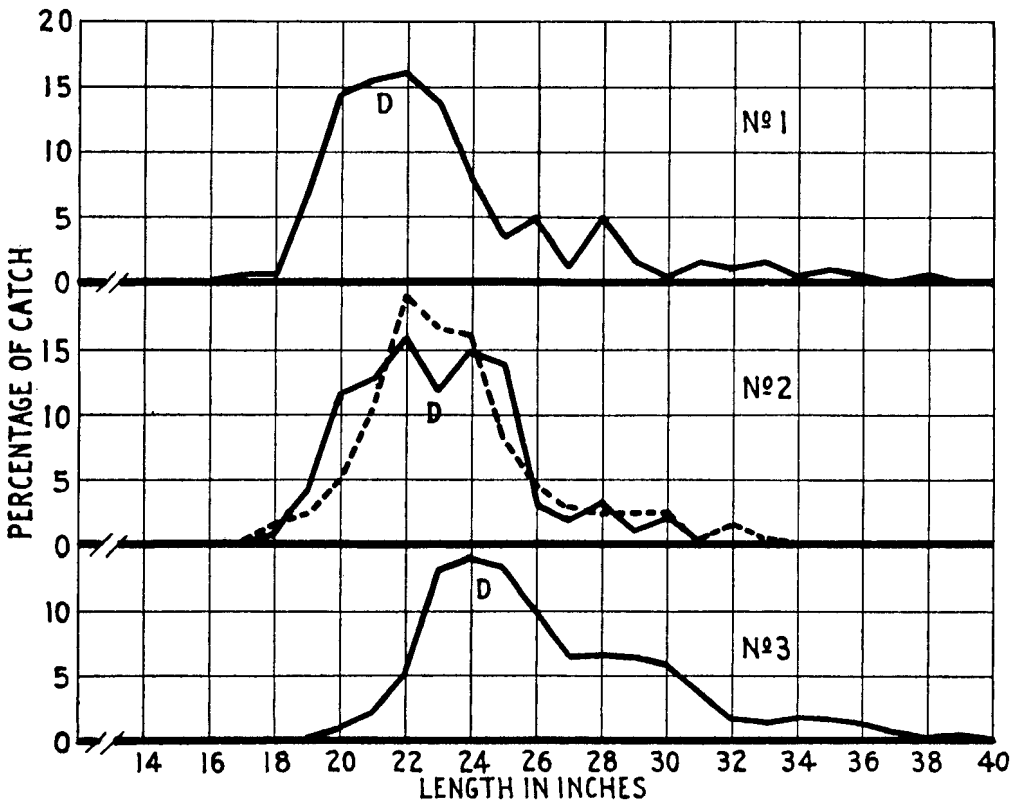

FIGURE 22.—*No. 1*=length-frequency distribution of 180 cod caught 15 miles SE. by E. from Round Shoal buoy June 17, 1927. *No. 2*=length-frequency distribution of 93 cod caught off Great Rip buoy May 4–7 (solid curve) and 643 caught June 16–25, 1927 (broken curve). *No. 3*=length-frequency distribution of 1,016 cod caught at Great Rip buoy October 15–17, 1927

the frequency distributions as shown by Figure 20 show rather conclusively that we are dealing with the same stock of fish.

During very limited fishing on the Chatham grounds 38 cod were caught on September 2—too few to show graphically—but it is significant that 10 of these belonged to the 21-inch class, indicating that the *D* cod were still the dominant school there as they were in May and June.

The last cruise to Nantucket Shoals in 1927 was made in October, when fishing was done from the 14th to the 17th. Both Round Shoal and Great Rip were fished, but not the Chatham grounds.

At Round Shoal buoy a relatively small sample of cod was obtained (275 fish), but it was sufficient to show that the same stock of cod present throughout the spring and summer was still there. (Fig. 20, No. 3.) Although October begins the western migration of cod from Nantucket Shoals and from grounds to the north and east, the lengths of the Round Shoal October cod do not suggest that there had been even a small influx of foreign cod. We did, however, find cod somewhat less plentiful on the Round Shoal grounds in the fall than during the spring and summer of 1927, so that a small part of the stock of fish could have already started westward without such a fact being registered in the graph. Again, the dominant length of the *D* cod remained at 21 inches, as it did during the period from June to late August, and it would appear from this that these cod grew but little throughout the summer.

At Great Rip we had a somewhat different situation in October, 1927. (Fig. 22, No. 3.) The *D* cod were still dominant at 23 to 25 inches, compared to 22 to 24 inches in June, 1927, but a new school with individuals greater than 26 inches long arrived on the grounds some time between the middle of June and October. Apparently this school was not very large, for it was not found between Round Shoal and Rose and Crown buoys. (Fig. 20, No. 3) It is likely that these larger fish were on their way westward and that they originated from a region other than Nantucket Shoals or, at any rate, from a part of the shoals where no tagging had been done.

Summing up the year 1927, we find that the same school of cod was distributed over all the tagging grounds throughout the spring, summer, and fall. These fish, designated as the *D* cod, were first noted on Nantucket Shoals in August, 1925 (fig. 17, No. 3), when they were around 14 inches long and formed only a relatively small part of the total stock of cod. In October, 1925, the *D* cod were just a little more prominent than in August. (Fig. 17, No. 4.) They were next found on the one cruise made in 1926 in September at both Great Rip and Round Shoal, where they formed the dominant school. At Great Rip in 1926 the individuals of the *D* school centered around 20 inches long and at Round Shoal around 18 inches. Throughout 1927 this *D* school was even more dominant than in 1926 and monopolized all the tagging grounds at all times, excepting at Great Rip, where a small school of large fish appeared in the fall.

A smaller percentage of Nantucket cod was recaptured to the westward during the winter of 1926–27 than during any of the other winters since 1923, so it is apparent that a large part of the *D* cod remained stationary on Nantucket Shoals throughout 1926 and 1927, neither emigrating during those summers nor migrating westward during the winter. As the *C* cod disappeared from the shoals during the winter of 1926–27 most of them probably migrated westward the fall of 1926, but a large part of the catch made in the Rhode Island-North Carolina region that winter evidently consisted of fish which migrated from parts of Nantucket Shoals, where no tagging had been done, as well as from the regions to the north and east of Nantucket. If many of the cod came from the latter locality they did not pass over the Nantucket tagging grounds when we were fishing there in October, 1926, nor were they present on the shoals during 1927, or they would have been detected then in the length frequencies of the fish caught. Such of these fish as survived the winter in the Rhode Island-North Carolina region returned eastward in the spring and evidently did not stop on Nantucket Shoals.

LENGTHS OF NANTUCKET COD IN 1928

Two tagging cruises were made to Nantucket Shoals during 1928—the first from July 14 to 21 and the second from October 24 to 29.

It was found on the July cruise that the *D* cod still formed the dominant school on the Round Shoal buoy grounds (fig. 23, No. 1) as they did throughout 1926 and 1927. The very sharp peak made by the *D* cod in October, 1927 (fig. 20, No. 3), had been considerably reduced by July, 1928, due perhaps to the increase in age of the fish, which resulted in a greater variability in the lengths and to the appearance of a school of smaller cod, *E*. These *E* cod, centering around 18 inches long, migrated to the Round Shoal buoy grounds some time between October, 1927, and July, 1928. It will be noted that these fish appeared in very much the same way as the *B* cod which eventually supplanted the *A* (fig. 15, No. 1), the *C* cod which supplanted the *B* (fig. 16, No. 3), and the *D* cod which replaced the *C* (fig. 17, Nos. 3 and 4). It is

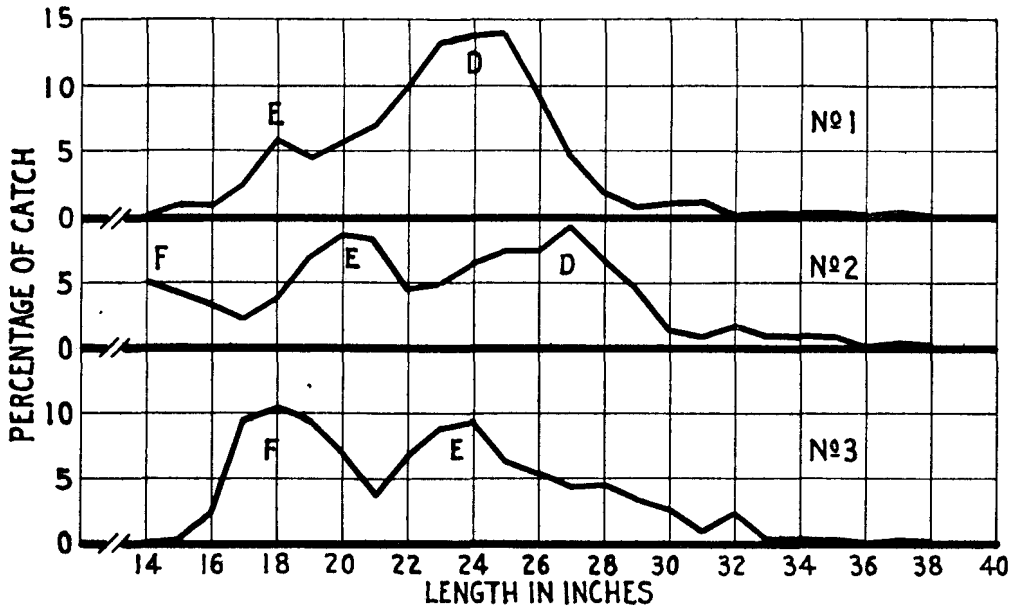

FIGURE 23.—*No. 1*=length-frequency distribution of 694 cod caught at Round Shoal buoy July 14–21, 1928. *No. 2*=length-frequency distribution of 304 cod caught from Round Shoal buoy to Great Rip buoy October 24–29, 1928. *No. 3*=length-frequency distribution of 624 cod caught from Round Shoal buoy to Rose and Crown buoy June 10–14, 1929

possible, therefore, that while the *E* cod formed a relatively small part of the stock of fish in July, 1928, they might become the dominant group on Nantucket Shoals in 1929 and perhaps in 1930.

At Great Rip in July unfavorable weather conditions interfered with operations, with the result that only a few hours' fishing was done there and but 54 cod caught. The lengths of these are not shown graphically, but 7 fish, or 13 per cent of the catch, belonged to the 19-inch size and were possibly *E* cod; and 28 fish, or 52 per cent, belonged to sizes ranging from 23 to 27 inches, suggesting that if a large enough sample had been obtained the *D* cod, which were mostly 23 to 25 inches long at Great Rip in October, 1927, would be found still inhabiting this region.

Out of a total of 748 cod caught at Round Shoal and Great Rip only 4 fish were less than 15 inches long and only 8 fish were more than 31 inches long, so that the

number of fish above and below these sizes present on the tagging grounds was negligible.

On the cruise made to Nantucket Shoals October 24 to 29, 1928, fewer cod were found than at any other time since the beginning of this investigation (p. 44). The *Albatross II* was shifted no less than forty times within the area bounded by Round Shoal buoy, Great Rip buoy, and the Chatham grounds in an attempt to find fish, but only 304 cod were caught. The lengths of these fish are given in Figure 23, No. 2. Because of the small catch of cod and the necessity of combining the several tagging grounds on Nantucket Shoals in order to show graphically an adequate sample, only a general comparison can be made between the October fish and those caught at Round Shoal buoy the previous July.

The *E* and the *D* cod were still present in October, although the gain of about 2 inches in length registered by each of these groups appears to be somewhat greater than we might have expected, judging by previous records, as, for example, the very slight gain in length made by the *D* cod from June to October, 1927. As to the status of the 14-inch cod in October, 1928, they may have just attained a size large enough to take a baited hook or they may have migrated from elsewhere. Their origin is discussed on page 92. Aside from the smallest fish which were caught in October, the length frequencies show that very much the same stock of cod was present then as in July, and that, therefore, few cod from other regions migrated to the tagging grounds on Nantucket Shoals during the interim.

LENGTHS OF NANTUCKET SHOALS COD IN 1929

By the summer of 1929 the *D* cod which were so abundant in July, 1928, and which appeared to be well represented in October, 1928, had disappeared from Nantucket Shoals. (Fig. 23.) It is likely that it was these fish which made up a large part of the migrating body which went westward the fall of 1928, and as a result many of them were caught by the fishery, and the survivors which returned in the spring of 1929 were too scattered to show up in the frequency distribution on the tagging grounds between Round Shoal and Rose and Crown buoys.

The prediction made in 1928 that the *E* cod might become the dominant body in 1929, and possibly in 1930, apparently will not materialize, for in June, 1929, they formed about the same proportion of the stock of fish as they did the previous October, and in all probability they will pass out of the picture over the winter of 1929–30. It seems, therefore, that the *E* cod were a much smaller school than were the *D* fish which were the dominant body of cod on the shoals throughout 1926, 1927, and 1928.

The status of the cod centering around 17 to 19 inches and designated as *F* fish, which were present in June, 1929, is rather uncertain, but, judging from the results obtained during the previous years, they were most likely derived from the fish around 14 inches long present in October, 1928. Whether these *F* fish are present on Nantucket shoals in 1930 or later depends partly on how abundant and widespread they are and on how many of them migrate into the Rhode Island-North Carolina region the fall of 1929. As at least one school of cod is present on the shoals each year, it would seem that the *F* fish would be the most likely inhabitants in 1930.

On the Great Rip tagging grounds only 80 cod were caught in June, 1929, and are not shown graphically. It was found, however, that 21 of these, or about one-fourth the total, were 18 to 20 inches long, or in the category of the *F* Round Shoal-

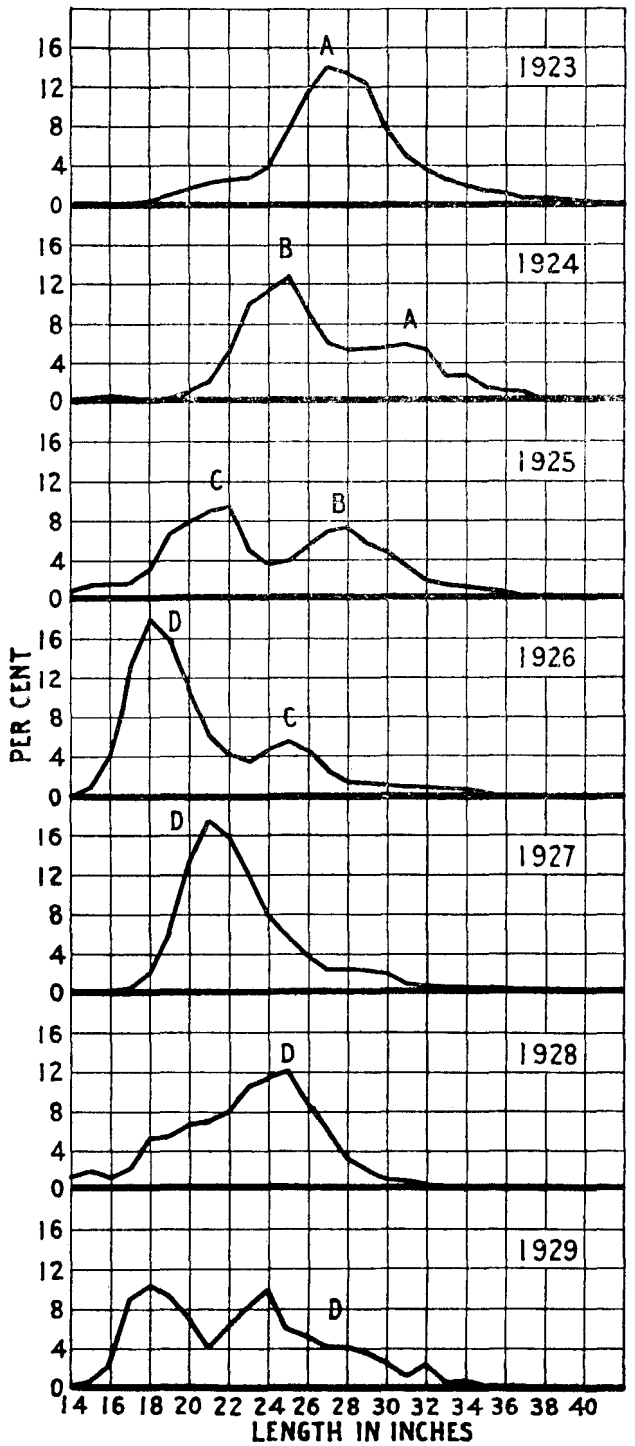

FIGURE 24.—Length-frequency distributions, based on Table 28, of all cod caught on Nantucket Shoals from 1923 to 1929 by the *Halcyon* and the *Albatross II*. The symbols A to D refer to the same stocks of fish as given on Figures 15 to 23

Rose and Crown fish. Here, again, as in almost all previous cases, the Great Rip fish averaged slightly larger than the Round Shoal-Rose and Crown fish, which is added proof that fish living in this region grow a little faster than those living 10 to 20 miles farther northward, around the other two buoys.

We found further evidence in June, 1929, that large cod do not remain on Nantucket shoals for an extended period. At that time scarcely 1 per cent of the catch made by the *Albatross II* consisted of fish more than 34 inches long.

It was found, therefore, that during 1929, up to June, the *D* cod which were first noted in August, 1925, and some of which were still present the fall of 1928, had virtually disappeared; that the *E* cod, which appeared in July, 1928, were on the wane; and that the *F* fish of October, 1928, had become the dominant school of cod on the tagging grounds.

The length distributions of all the cod caught on Nantucket Shoals from 1923 to 1929 by the *Halcyon* and the *Albatross II* are shown in Figure 24 and might be summarized as follows:

1. Length frequencies have shown that the cod population on Nantucket Shoals is rather stable from spring to fall of most years and that usually relatively few cod migrate to or from the shoals throughout the summer.

2. In the fall of some years a marked temporary change in the length-frequency distribution shows that "foreign" cod pass by

Nantucket Shoals at this time, evidently on their way westward, while in the fall of other years virtually no "foreign" cod could be recognized on the Nantucket tagging grounds at the time we fished there.

3. The relationship of lengths (corroborated by tagging experiments) from year to year indicates that (*a*) an appreciable part of the Nantucket Shoals cod do not migrate westward over the winter, but remain stationary; (*b*) many of those Nantucket cod which do migrate westward and survive the winter return to Nantucket Shoals the next spring; (*c*) cod which migrate from such banks as Georges or Stellwagen into the Rhode Island-North Carolina region pass by Nantucket Shoals, and in the spring such "foreign" fish return to the eastward and do not tarry on the shoals, else at that time they would have revealed themselves by their size distribution.

4. Six distinct bodies of cod were found on Nantucket Shoals during our tagging operations from 1923 to 1929. One of these was present when we began fishing the spring of 1923; one appeared in the fall of each of the years 1923, 1924, and 1925; and two the fall of 1928. By the year following their first appearance each of these schools in turn formed a dominating size and age group.

5. The dominant sizes of five schools of cod when they first appeared in the length-frequency distribution were 21 to 23 inches, 15 to 17 inches, 14 to 16 inches, 17 to 19 inches, and 14 inches. These appeared, respectively, during the years 1923, 1924, 1925, and the last two during 1928.

6. Cod below 16 inches were scarce in our catches, due perhaps partly to the selectiveness of our hook-and-line gear, but the sudden appearance of cod as large as 17 to 19 inches and 21 to 23 inches, as just noted, indicates that such fish migrated from some other region rather than that they grew up on the shoals from the fry or yearling stage.

7. The smaller cod on Nantucket Shoals are not as migratory as the larger fish. Cod less than about 24 inches long are apt to remain there for an extended period, while fish about 28 to 30 inches long and larger tend to move into deeper water. The scarcity of large cod on the shoals is, therefore, not due entirely to depletions caused by the fishery.

8. Length frequencies have shown that fish belonging to the same group may average 1 or 2 inches longer on the southern part of Nantucket Shoals than on the northern, due probably to faster growth.

POSSIBLE CAUSES FOR THE MIGRATIONS MADE BY SOUTHERN NEW ENGLAND COD

What is known of other species of fish suggests that spawning, food, and temperature are the most probable stimuli which induce cod to migrate. Unquestionably all cod, taken as a whole on both sides of the Atlantic, do not carry out the same migratory schedule. In fact, the cod is a poor example of a migratory fish, for all tagging experiments that have been made in the past have shown that a large part of the cod living on a ground one season will be found there a year later and sometimes longer. Obviously only mature fish carry out a spawning migration, but whether or not cod migrate in order to spawn depends on local circumstances such as depth, as it is believed that to deposit their eggs they usually seek water shoaler than 35 fathoms.

Many fishes along our shores are present during only part of the year, making their appearance and disappearance regularly at certain seasons. Apparently temperature has either a direct or an indirect influence on such migrations. The cod, taken by and large, is not one of the "disappearing" fish, for on most of the grounds which it frequents it is found throughout the year. Whether or not cod shift ground

to avoid extremes of temperature seems to depend somewhat on the age of the fish. For example, Schmidt (1907, p. 23) found that cod during their first few years of life remained localized in the cold water of the north and east coasts of Iceland, but that as they approached maturity and the urge to spawn they migrated to a warmer region on the south coast, probably because they became more sensitive to external conditions.

The extremes of temperature in which cod have been found range from around 0° to about 15° C. and occasionally as high as 16° to 17° C., although in any given

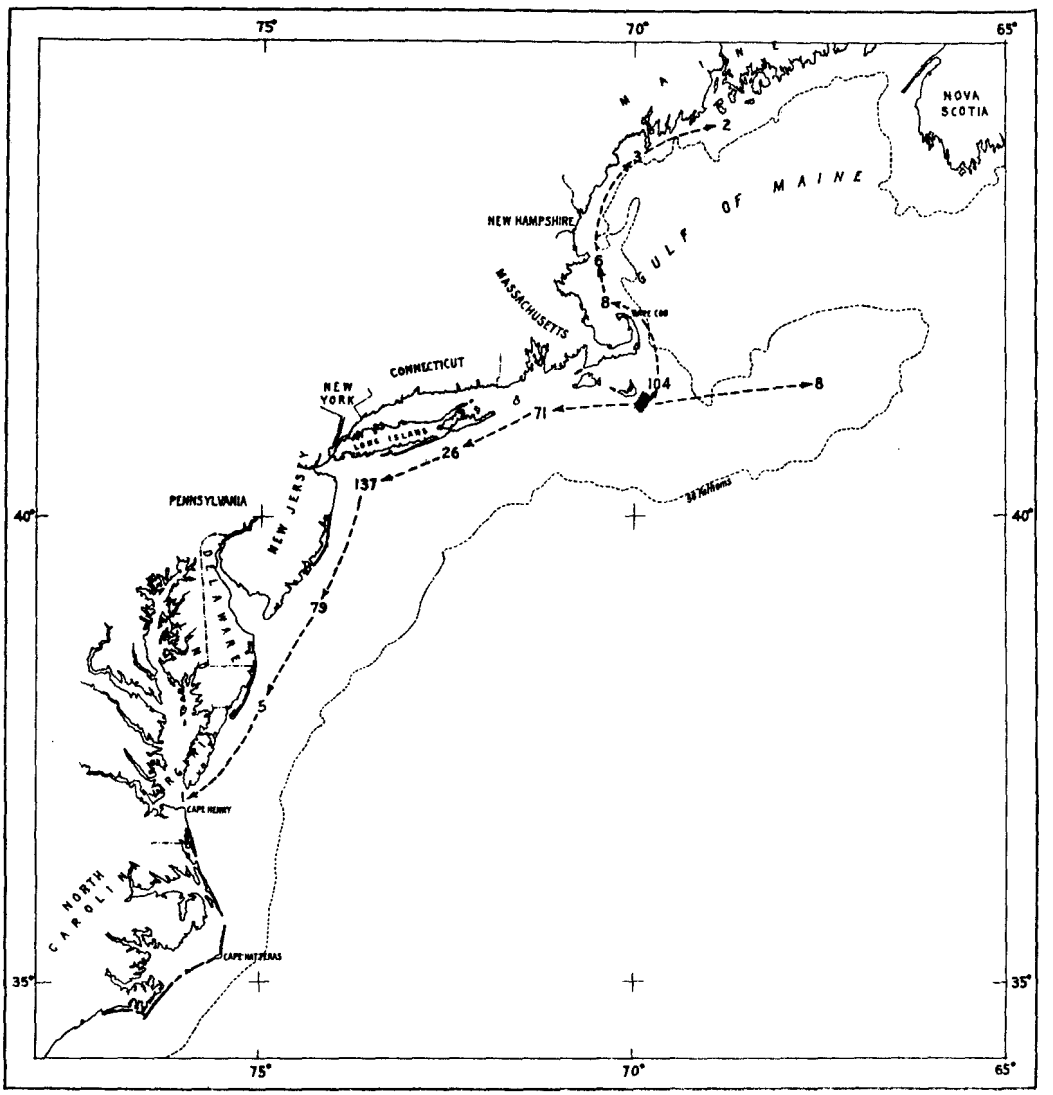

FIGURE 25.—Routes taken by cod which migrate or emigrate from Nantucket Shoals. The figures indicate the number of recaptures reported from each general locality from 1923 to October, 1929. Total number of cod tagged on Nantucket Shoals, 22,228

region the range ordinarily would be smaller than this. Bodies of cod living in very cold water, therefore, might respond differently to a given temperature than cod living in moderately cold water. Huntsman (1925), writing of the cod around the mouth of the Gulf of St. Lawrence, states that "For them 50° F. is rather too warm and 32° F. too cold, and possibly 40° to 45° F. would be considered just right. They

leave northern waters on the approach of winter and pass that season in the ocean south of Newfoundland." In the Barentz Sea, where the annual temperature range on bottom is from about 0° to about 5°, Averinzev (1928, p. 117–126) found that cod and haddock appeared to change ground in order to keep in water of 3° to 4°, shunning 0°, although even in the latter temperature some cod were caught. However, these latter observations do not prove that the cod shifted ground as a result of a direct thermal stimulus, for it may have been that in the warmer water a more abundant food supply was present and attracted the cod thither.

The nature and extent of the cod's migrations depend largely on the geography of its environment, in conjunction with the other factors just mentioned. For instance, the maturing Icelandic cod which migrate from the north to the south coasts might very well continue farther if it were not for the deep water (400 to 600 meters) between there and the Faroes. In the same way the migrations of the Faroes fish are restricted because this bank is surrounded by water deeper than that ordinarily frequented by the cod. The long migrations of European cod, from Lofoton to the Finmark coast (Hjort, 1914, fig. 69), and from Finmark back to Lofoton and even southward (ibid., fig. 134), and of American cod from New England to as far as North Carolina, are allowed by the fact that there are no depth barriers to stop them, and the temperature, at certain seasons at least, is favorable all along the route. But passive factors such as these can not be supposed to provide a stimulus for a regular seasonal migration.

Nantucket Shoals cod make two distinct migrations—one into the Rhode Island-North Carolina region each winter and the other, during certain summers, into the Chatham-South Channel region near by. (Fig. 25.) As these two migrations differ in route, season, and regularity of performance, the possible causes for them are discussed separately.

There are, in addition to the fish just mentioned, which travel over a definite migratory route, other cod which straggle into the region north of Cape Cod. Why so few cod go eastward and north from southern Massachusetts is not known. Apparently these southern grounds afford a very favorable environment for the cod, so that most of the fish which enter it remain there for an extended period. This could still be true, and yet there would be no danger of the cod overpopulating the grounds, for not only is a regular fishery carried on there most of the year, but in addition large numbers of them are caught during their sojourn on the wintering grounds to the westward.

THE WINTER MIGRATION

Spawning as a possible cause.—It might be considered significant that the spawning period of the cod off the New England coast coincides with the time when the migration to the westward of Nantucket Shoals takes place. But Nantucket Shoals itself is an important spawning ground, and it is not likely that cod from there would journey as far as 200 or 300 miles west and south to spawn in a region apparently unsuitable for them during the summer when so many other cod remain to spawn on the shoals, while others gather there for that purpose.

It might again be suggested that the cod which summer on Nantucket Shoals are the ones which go west for the winter, and that the fish which spawn in winter on the shoals come from farther east. But tag records have shown that most of the few fish tagged on Stellwagen, Georges Bank, and off Nova Scotia, and which are known to have migrated toward Nantucket Shoals, passed on, for they were recaptured between Block Island, R. I., and Rockaway, N. Y. Furthermore,

a few of the cod tagged in summer on Nantucket Shoals have been recaptured there in winter, and many marked fish retaken almost on the same spot the year following strengthen the suspicion that such cod did not migrate to Rhode Island or westward over the winter.

Although spawning apparently does not prompt this westward migration, neither did it deter it, because cod are known to spawn all along the migratory route, at least as far as southern New Jersey, as appears from the following lines of evidence:

Off eastern Long Island Fred P. Bradford states that cod with spawn are taken throughout the winter and a few even as late as the first week in April.

On the Cholera Bank, off western Long Island, N. Y., out of 166 fish the *Albatross II* caught 34 males and 6 females from November 14 to 21, 1927, so ripe that the milt or eggs flowed from the vent when the fish were laid on the measuring board. Again, from November 8 to 24, 1928, there were 28 ripe males and 2 ripe females among the 134 cod that were caught.

For the region off southern New Jersey, Smith (1902, p. 208) records nearly ripe cod off Atlantic City. On the present investigation fishermen in southern New Jersey reported that each winter many cod were taken "with large milts and roes." The majority of these spawning cod are taken in November and December, while a few are found throughout the winter, and a small run occurs in late March and early April, at the end of the season. During our tagging operations 13 ripe males and 1 female were noted among 93 cod caught off Atlantic City December 12 to 19, 1928, and 5 ripe males were among 133 cod caught there in March and April, 1928. No record was kept by the fishermen who tagged cod for us off Cape May the winter of 1928–29, but they reported that ripe fish were caught from time to time.

During March and April, 1929, and in May, 1927, O. E. Sette reports that the *Albatross II* caught cod larvæ to as far south as the region between Delaware Bay and North Carolina, and others were caught in this region on cruises made in February, March, and April, 1930.

Although in some years almost all the cod taken to the west of Rhode Island are adult (over about 20 inches long), sometimes, as in the fall of 1926, many fish as small as 16 inches are caught. The *Albatross II* on a chance otter-trawl haul made February 28, 1929, off northern New Jersey caught 6 cod which were of the following total lengths: 14, 15¾, 16, 17¾, and 23½ inches. Some of these were males and some females. All were immature, except the largest one. The presence, at times, of these immature cod west of Rhode Island offers further evidence that this is not fundamentally a spawning migration, even though cod may spawn off New Jersey just as freely as on Nantucket Shoals.

Food.—The same foods that are the staple diet of the cod on Nantucket Shoals—largely crabs (Cancer, Hyas, Libinia), shrimps, worms, small bottom fishes, etc.—are plentiful on all suitable bottoms along the western migratory route.

Crabs, which form the bulk of the cod's food off southern Massachusetts, are present there throughout the year, so it is not because of the seasonal scarcity of them that cod go west. In the New York-New Jersey region rock crabs (Cancer) are plentiful the year around; thus, the return from New Jersey back to Nantucket Shoals in the spring is not induced by a local exhaustion of this food. It is obvious that other bottom forms such as worms, small mollusks, shrimps, etc., can have

no influence on the migration of Nantucket cod, because they are always present all along our coast.

Cod will eat any fish that they can catch, especially the small silvery species that travel in dense schools, and so are easily caught. The most important of these are capelin (Mallotus), herring (Clupea), and sand eels (Ammodytes).

Capelin, of course, are restricted to arctic and subarctic regions and hardly extend south to Maine along our coast. But it is of interest to note that in the far north cod pursue capelin for long distances, feeding voraciously upon them. This occurs regularly off Labrador and Greenland and also off the Finmark and Murman coasts, as noted by Hjort (1914, p. 113).

Cod often feed on herring, both small and large, and there is evidence that they pursue this food, at least for short distances. But Clupea are not particularly plentiful off the southern coast of Cape Cod, while to the westward of Montauk Point they are relatively scarce, and hence could hardly induce the cod's migration into that region.

The sand eel (Ammodytes) is the only one of the really important fish foods of the cod that is found in abundance on Nantucket Shoals and on the wintering grounds to the westward. But although the season when sand eels are abundant alongshore, west of Massachusetts, coincides with the season when cod are present there, we have no proof that cod are induced westward in order to feed upon them. This is made apparent by the fact that although Ammodytes is important to the cod to the westward of the shoals, as well as throughout most of the cod's range, the food that must be depended upon there from day to day is the same sort as on all suitable bottoms off the New England coast, namely, crabs, shrimps, mollusks, brittle stars, worms, and occasional fishes of various species. Thus there is no basis for explaining this as a feeding migration.

Competition for food between the cod and other fishes on Nantucket Shoals and the wintering ground to the westward.—It would seem that ordinarily cod were given relatively little serious competition for their food supply by other species of fish, particularly on Nantucket Shoals, for in this region only the haddock and the pollock, taken both from the point of size and of abundance, can be considered at all of importance in this respect. But as haddock eat chiefly the smaller crustaceans and mollusks, of a size generally disdained by the cod, it seems obvious that neither fish competes very seriously for the other's food supply. The same can be said with respect to the pollock, for the latter feeds largely on squid and fish and, on Nantucket Shoals at least, eats very sparingly of the larger crustaceans which make up the bulk of the cod's food.

To the westward of Nantucket Shoals, excepting possibly the Rhode Island region, neither the haddock nor the pollock are sufficiently plentiful to affect the cod's food supply. But in this westward region other species occur abundantly that are rarely found on the shoals, including the sea bass (Centropristes), the tautog (Tautoga) and the summer flounder (Paralichthys). It so happens that throughout the summer these species occupy the same rocky bottoms, wrecks, etc., that are inhabited by some of the cod during the winter, but this alternative occupation of the grounds goes on year after year, so it is apparent that neither body of fish exhausts the other's food supply. Even if the summer fish did reduce considerably the food supply on the rough bottoms, it remains that much the larger part of the schools of cod distribute themselves over sandy, shelly, and gravelly bottoms whose area far exceeds that of the rocky bottom and whose food supply is scarcely disturbed by the

summer species just mentioned. It appears evident, therefore, that competition for food between the cod of Nantucket Shoals and other species of fish has little or nothing to do with causing them to migrate westward from the shoals in the fall or in limiting their stay on the wintering grounds.

Enemies.—Enemies in the form of other fishes do not drive cod from Nantucket Shoals. Its only important and widespread enemy there is the dogfish (Squalus), but although the dogfish migrate southward in great hordes from the Gulf of Maine to at least the Chesapeake Capes, the first of them appear off New York or New Jersey about a week before the cod, not after them or with them, and they pass on and are not seen again, except for a straggler, anywhere on the cod grounds from Nantucket Shoals to Delaware until the following April when the water has warmed to about 5.5° C. (42° F.). Although both dogfish and cod may migrate westward from Nantucket Shoals at the same time during part of November, cod continue to leave the shoals until well into December, long after the dogfish have passed.

Salinity.—No exhaustive attempt has been made here to correlate the presence and abundance of cod with the salinity of the water. On grounds where cod are present the year around the following salinity data have been taken from Bigelow (1927, p. 815–19): Below 150 meters (about 80 fathoms) the salinity fluctuates only about 0.5 per mille throughout the year and ranges around 33.7 to 34.2. At depths of 100 to 150 meters (about 55 to 80 fathoms), in the coastal zone between Cape Cod and Cape Sable, the variation runs from about 32.38 to 34.11, according to depth, locality, and date. In the 40 to 100 meter zone (about 22 to 55 fathoms), which includes most of the cod grounds off our coast, the range in salinity throughout the year is about 31.8 to 33.2 per mille.

On Nantucket Shoals there appears to be very little fluctuation in the salinity during the summer, autumn, and winter, when, at 20 to 40 meters (11 to 22 fathoms), it probably is around 32 to 32.5 per mille, while in the spring it is only slightly lower.

An indication that cod are not usually influenced to migrate by ordinary changes in salinity may be had from our tagging experiments in the immediate shore waters of Maine which showed that many of the cod remained localized from one year to the next, although the water freshens there in the spring more than it does offshore. In line with this, Needler (1929, p. 9) found that in the Gulf of St. Lawrence cod are often caught in a salinity around 30 per mille, which is fresher than that found on bottom on the banks off New England.

Therefore there is no reason to believe that fluctuations in salinity cause cod living along the New England coast, particularly those on Nantucket Shoals, to make extensive migrations.

Temperature.—One of the striking things about the migration of cod from southern Massachusetts into the Rhode Island-North Carolina region is that it begins each year in October. For this reason it would appear that a falling water temperature was the stimulus which sent the fish on their journey.

As Nantucket Shoals is the most southerly year-around cod ground along our coast, we might reasonably expect that seasonal differences in water temperature would have more influence on the migrations of the cod living there than would be the case in an intermediate region where the extremes of temperature would not be as great. However, an examination of the data for the Nantucket-Delaware region is not so reassuring.

Temperatures taken on Nantucket Shoals are given in Table 31. In general it can be said that the water there reaches a maximum of about 11° to 15.5° C. (52°

to 60° F.) in the late summer, the degree depending on whether it is a cold or a warm year. The minimum temperature in late winter probably is somewhere between 2° and 3° C. (35.6° to 37.4° F.), for on February 24, 1929, we found it to be 1.4° C. (34.5° F.) on the surface and 2.6° C. (36.7° F.) on the bottom in 11 fathoms off Round Shoal buoy where so many of our cod were tagged on the shoals from April to October.

We naturally examine with interest the temperatures west of longitude 70° W., particularly those of late summer, in the hope of finding some explanation as to why cod go there in the fall to spend the winter but leave again in the spring. The temperatures given in Table 30 were selected to cover (*a*) the period when the first cod migrate westward from Nantucket Shoals, (*b*) the period of maximum migration, (*c*) midwinter, (*d*) the period in the spring when the last of the cod are believed to leave their southern wintering grounds, and (*e*) the period in summer when maximum temperatures obtain and when cod have seldom been found west of Rhode Island. The temperatures which are listed were taken on or within a few meters of the bottom and each represents a different station. Those recorded prior to 1926 were taken from Bigelow (1915, 1917, 1922, 1927) and those after were obtained by the *Halcyon* and the *Albatross II* on tagging and hydrographic cruises.

TABLE 30.—*Bottom water temperatures from west of Nantucket Shoals*

[All positions listed are true positions. The letters before the station numbers are to be interpreted as follows: A = *Albatross II*; G = *Grampus*; and H = *Halcyon*]

Reference No.	Station	Date	Position	Locality	Depth		Temperature	
					Meters	Fathoms	° C.	° F.
			° ′	*Off Marthas Vineyard and Rhode Island*				
1	A 20261	May 25, 1927	41 06 N. 70 47 W.	10 miles S. by E. from No Mans Land	30	16	7.7	45.8
2	G 10357	July 26, 1916	41 11 N. 70 44 W.	5 miles SE. from No Mans Land	25	13	14.3	57.7
3	G 10356	do	40 57 N. 70 18 W.	28 miles SE. from No Mans Land	30	16	12.1	53.8
4	G 10355	July 25, 1916	40 43 N. 69 53 W.	57 miles SE. from No Mans Land	30	16	11.0	51.8
5	G 10354	do	40 26 N. 69 24 W.	80 miles SE. from No Mans Land	70	38	6.1	43.0
6		Aug. 2, 1926		1 mile NW. from Gay Head, Marthas Vineyard	13	7	16.1	61.0
7		do		2½ miles SW. from Gay Head, Marthas Vineyard	27	15	16.0	60.8
8	G 10112	Aug. 22, 1913	40 17 N. 70 57 W.	57 miles S. by W. from No Mans Land	110	60	15.4	59.7
9	G 10263	Aug. 27, 1914	41 12 N. 70 57 W.	6 miles SW. from No Mans Land	17	9	13.3	55.9
10	G 10258	Aug. 25, 1914	41 03 N. 70 51 W.	13 miles S. from No Mans Land	30	16	12.1	53.8
11	G 10259	do	40 34 N. 70 46 W.	41 miles S. from No Mans Land	55	30	9.7	49.5
12	G 10262	Aug. 26, 1914	40 02 N. 70 26 W.	80 miles S from east end of Marthas Vineyard	180	98	10.3	50.5
13	G 10260	do	40 03 N. 70 41 W.	80 miles S. from west end of Marthas Vineyard	140	76	11.4	52.2
14	G 10331	Oct. 22, 1915	41 19 N. 70 55 W.	4 miles E. from west end of Marthas Vineyard	30	16	14.5	58.0
15	G 10332	do	40 51 N. 70 55 W.	24 miles S. by W. from No Mans Land	50	28	13.1	55.1
16	G 10333	do	40 26 N. 70 56 W.	48 miles S. by W. from No Mans Land	80	44	11.9	53.4
17		Oct. 28, 1925	41 12 N. 70 51 W.	4 miles S. from No Mans Land	18	10	12.1	53.8
18		Oct. 27, 1925	41 18 N. 71 00 W.	8 miles E. from west end of Marthas Vineyard	33	18	11.7	53.0
19		do	41 11 N. 71 28 W.	6 miles E. from Block Island	22	12	11.7	53.0
20	G 10405	Nov. 10, 1916	41 17 N. 71 03 W.	10 miles E. from west end of Marthas Vineyard	30	16	12.5	54.4
21	G 10406	Nov. 11, 1913	40 37 N. 71 19 W.	34 miles S. from Block Island	60	32	10.0	50.0
22	G 10407	do	40 03 N. 71 43 W.	67 miles S. by W. from Block Island	90	49	7.7	45.8
23	G 10408	do	39 52 N. 71 47 W.	80 miles S. by W. from Block Island	180	98	10.3	50.5

TABLE 30.—*Bottom water temperatures from west of Nantucket Shoals*—Continued

[All positions listed are true positions. The letters before the station numbers are to be interpreted as follows: A = *Albatross II*; G = *Grampus*; and H = *Halcyon*]

Reference No.	Station	Date	Position	Locality	Depth		Temperature	
					Meters	Fathoms	° C.	° F.
				Off Long Island, N. Y.				
24		Feb. 21, 1925	40 21 N. 73 44 W.	21 miles SE. from Fort Wadsworth, N. Y.	22	12	3.6	38.5
25	A 20403	Feb. 28, 1929	40 23 N. 73 52 W.	16 miles SE. by S. from Fort Wadsworth, N. Y.	30	16	2.1	35.8
26	A 20402	do	40 04 N. 73 14 W.	49 miles SE. ½ E. from Fort Wadsworth, N. Y.	45	24	4.4	39.9
27	A 20401	do	39 49 N. 72 58 W.	70 miles SE. from Fort Wadsworth, N. Y.	70	38	6.9	44.4
28	A 20400	do	39 33 N. 72 33 W.	93 miles SE. from Fort Wadsworth, N. Y.	80	44	7.5	45.5
29	A 20399	Feb. 27, 1929	39 23 N. 72 18 W.	110 miles SE. from Fort Wadsworth, N. Y.	150	82	11.4	52.5
30	A 20232	May 19, 1927	40 20 N. 73 48 W.	20 miles SE. by S. from Fort Wadsworth, N. Y.	45	24	4.7	40.5
31	A 20230	do	40 00 N. 73 20 W.	47 miles SE. from Fort Wadsworth, N. Y.	50	28	5.2	41.4
32	A 20253	May 24, 1927	40 39 N. 72 34 W.	13 miles S. by W. from Shinnecock Light	30	16	5.0	41.0
33	G 10067	July 13, 1913	40 29 N. 73 46 W.	16 miles ESE. from Fort Wadsworth, N. Y.	22	12	9.5	49.2
34	G 10362	Aug. 1, 1916	40 22 N. 73 38 W.	24 miles SE. by E. from Fort Wadsworth, N. Y.	22	12	11.9	53.4
35	G 10363	do	40 13 N. 73 21 W.	40 miles SE. by E. from Fort Wadsworth, N. Y.	30	16	8.1	46.6
36	G 10364	do	40 01 N. 72 56 W.	63 miles SE. by E. from Fort Wadsworth, N. Y.	40	22	5.5	41.9
37	G 10365	Aug. 2, 1916	39 41 N. 72 39 W.	84 miles SE. ½ E. from Fort Wadsworth, N. Y.	60	32	4.8	40.6
38	G 10366	do	39 40 N. 72 23 W.	95 miles SE. by E. from Fort Wadsworth, N. Y.	90	49	5.8	42.4
39	G 10367	do	39 34 N. 72 01 W.	112 miles SE. by E. from Fort Wadsworth, N. Y.	200	109	7.9	46.2
40	G 10396	Aug. 26, 1916	40 50 N. 72 07 W.	20 miles SW. by S. from Montauk Point	28	15	12.1	53.8
41	G 10395	do	40 32 N. 72 44 W.	24 miles E. by S. from Fire Island Light	35	19	9.0	48.4
42		Nov. 14, 1927		Cholera Bank	18	10	12.7	55.0
43		Nov. 15, 1927		do	18	10	12.5	54.4
44		Nov. 20, 1927	40 24 N.	do	18	10	11.4	52.5
45		Nov. 21, 1927	73 37 W.	do	18	10	10.8	51.4
46		Nov. 10, 1928		do	18	10	12.2	54.0
47		Nov. 15, 1928		do	18	10	12.1	53.7
48	A 20374	Nov. 13, 1928	40 36 N. 73 05 W.	7 miles ESE. from Fire Island Light	22	12	11.8	53.2
49	A 20375	do	40 16 N. 72 46 W.	30 miles ESE. from Fire Island Light	50	28	12.5	54.6
50	A 20376	do	39 51 N. 72 23 W.	60 miles ESE. from Fire Island Light	75	41	12.6	54.8
51	A 20377	do	39 37 N. 72 09 W.	79 miles ESE. from Fire Island Light	110	61	12.9	55.2
				Off New Jersey				
52	A 20304	Feb. 17, 1928	38 46 N. 74 38 W.	19 miles SE. by E. from Cape May Light	28	15	4.6	40.4
53	A 20305	do	38 24 N. 74 13 W.	48 miles SE. by E. from Cape May Light	47	25	8.8	47.8
54	A 20406	Mar. 3, 1929	38 42 N. 74 51 W.	16 miles SSE. from Cape May Light	15	8	3.3	37.9
55	A 20414	Mar. 4, 1929	38 30 N. 74 25 W.	37 miles SE. from Cape May Light	30	16	5.9	42.6
56	A 20415	do	38 20 N. 74 04 W.	56 miles SE. ½ E. from Cape May Light	45	24	7.2	45.0
57	A 20421	Apr. 14, 1929	38 41 N. 74 51 W.	15 miles S. by E. from Cape May Light	20	11	8.4	47.1
58	A 20438	Apr. 19, 1929	38 30 N. 74 15 W.	41 miles SE. from Cape May Light	30	16	6.8	44.2
59	A 20437	do	38 21 N. 74 03 W.	55 miles SE. from Cape May Light	60	32	10.1	50.2
60	A 20436	do	38 11 N. 73 43 W.	74 miles SE. from Cape May Light	170	93	11.4	52.2
61	A 20228	May 19, 1927	39 42 N. 72 47 W.	63 miles E. ½ S. from Barnegat Light	60	32	4.8	40.6
62	A 20235	May 26, 1927	39 20 N. 74 14 W.	10 miles E. by S. from Absecon Light	15	8	7.3	45.1
63	A 20237	do	39 11 N. 73 43 W.	35 miles ESE. from Absecon Light	40	22	5.8	42.4
64	A 20244	May 21, 1927	38 25 N. 74 16 W.	46 miles SE. from Cape May Light	40	22	6.5	43.7
65	G 10378	Aug. 11, 1916	38 48 N. 74 53 W.	9 miles SSE. from Cape May Light	14	8	21.0	69.9

TABLE 30.—*Bottom water temperatures from west of Nantucket Shoals*—Continued

[All positions listed are true positions. The letters before the station numbers are to be interpreted as follows: A=*Albatross II*; G=*Grampus*; and H=*Halcyon*]

Reference No.	Station	Date	Position	Locality	Depth		Temperature	
					Meters	Fathoms	° C.	° F.
				Off New Jersey—Continued				
66	G 10377	Aug. 10, 1916	38 54 N. 74 44 W.	11 miles E. by S. from Cape May Light	15	8	15.8	60.4
67	G 10379	Aug. 11, 1916	38 46 N. 74 35 W.	21 miles ESE. from Cape May Light	25	13	10.9	51.6
68	G 10375	Aug. 4, 1916	38 59 N. 74 08 W.	40 miles E. ½ N. from Cape May Light	40	22	6.2	43.1
69	G 10373	do	38 57 N. 73 35 W.	66 miles E. from Cape May Light	60	32	4.5	40.1
				South of New Jersey				
70	A 20407	Mar. 3, 1929	37 58 N. 75 02 W.	15 miles E. by N. from Assateague Light	15	8	3.4	38.1
71	A 20408	do	37 47 N. 74 40 W.	35 miles E. by S. from Assateague Light	40	22	5.7	42.2
72	A 20412	do	36 52 N. 75 20 W.	33 miles E. ¾ S. from Cape Henry Light	20	11	5.0	41.0
73	A 20411	do	36 49 N. 75 00 W.	49 miles E. ¾ S. from Cape Henry Light	30	16	7.2	45.0
74	A 20410	do	36 45 N. 74 36 W.	70 miles E. by S. from Cape Henry Light	180	98	9.6	49.4

Combined with what we know of this migration from other sources such as fishing, tagged fish, etc., these temperatures may be interpreted as follows:

When the first schools of cod migrate westward from Nantucket Shoals the latter half of October they leave behind them temperatures ranging from about 9° to 13° C. (48° to 55° F.) and enter a region that is somewhat warmer. In this region immediately to the westward of the shoals, off Marthas Vineyard and Rhode Island, temperatures the end of October (reference numbers 14 to 19, Table 30) in 18 to 80 meters out to about 50 miles from shore have ranged from 11.7° to 14.5° C. (53° to 58° F.). At this time the warmer water is found near shore, but many of the fish take this route, judging from the number that are caught within a few miles of shore late in October. By November, when the migration of cod is in full swing, the bottom temperatures are very much the same near shore as they are further off. Apparently the cooling of the water in the fall plays an important part in bringing about the migration, and even though the earliest fall migrants which leave in October enter a region slightly warmer than Nantucket Shoals at the time, the temperatures are not so high that they afford a barrier to a movement of cod farther to the westward. The fall migrants continue their journey, therefore, with the water becoming cooler and cooler as the season advances. They do not, however, keep pace with the temperature but migrate rapidly and appear off New Jersey only about a week after they pass Rhode Island.

In the late winter the shore waters west of Nantucket Shoals are much cooler than the offshore (reference numbers 21 to 29, 52 to 56, 70 to 74, Table 30), but after the cod reach there in the late fall most of them appear to remain localized until the spring. In general, the cod off the New Jersey coast may move offshore a few miles in the coldest part of the winter, probably to seek water that is 1° or 2° warmer, but there are times, as in January and February, 1928 and 1929, when good catches were made in the shoal water of Delaware Bay, that they remain inshore.

The cod leave their southern wintering grounds and return north and east to southern Massachusetts in the spring, after the water has started to warm. By the

middle of April the majority of the cod have left the New York-New Jersey region, although at that time the water there is still much cooler than it is in the fall when the first cod arrive. A comparison of the Cholera Bank temperatures obtained in November with those taken off Cape May in mid-April will illustrate this (reference numbers 42 to 47 and 57 and 58). A further example is furnished by our results off Atlantic City, N. J., in 1928, when on April 1 it was 4° C. (39° F.) in 7 fathoms where cod were being caught and only 5.5° C. (42° F.) in the same place on April 13, by which time most of the cod had departed (as noted by the almost daily catches of the fishermen).

Even in May the water is still comparatively cool along the New Jersey shore, for during the middle of that month temperatures of 4.7° to 7.3° C. (40.5° to 45.1° F.) were found off the coast about 10 to 60 miles, while off Long Island, late in the month, a reading of 5° C. (41° F.) was obtained. Further eastward, in the vicinity of No Mans Land, the temperature in 16 fathoms taken late in the month was 7.7° C. (45.8° F.) (reference numbers 1, 30 to 32, 61 to 64, Table 30).

In all these cases the water temperature was well below the maximum which obtains on Nantucket Shoals and on many of the cod grounds off New England during the summer, so it is apparent that cod leave the region west of Rhode Island in the spring at least two months before the bottom water approaches the warmth that exists on their summering grounds on Nantucket Shoals.

During the summer, although there are virtually no cod caught west of Rhode Island, there are places which are presumably good cod ground where the temperature is as low and even lower than that on Nantucket Shoals. For instance, in the region 40 to 112 miles southeast by east from New York City (reference numbers 35 to 39) and 40 to 66 miles east of Cape May Light N. J. (reference numbers 68 and 69) temperatures ranging from 4.5° to 8.1° C. (40.1° to 46.6° F.) prevailed in August, 1916. The fact remains, however, that during the summer a large proportion of the best cod ground to the westward of Nantucket Shoals is covered by water, the temperature of which approaches or exceeds the maximum ordinarily tolerated by cod.

Neither the spawning instinct, the availability of food, changes in salinity, nor the presence of enemies appear, therefore, to be the cause of the annual migration of cod from southern Massachusetts into the Rhode Island-North Carolina region. Our present knowledge indicates that ordinarily cod tend to spread and occupy all suitable grounds unless prevented by depth or temperature barriers. As no depth barrier exists between Nantucket Shoals and the grounds to the westward, it would seem that temperature is the more direct cause, particularly as the migration is seasonal and the departure of cod from the shoals begins each fall when the water commences to cool. This assumption does not cover the return migration in the spring quite as well, because the grounds are vacated well in advance of temperatures high enough to constitute a barrier, as judged by the degree of warmth tolerated by cod on Nantucket Shoals in the summer. Nor does it explain why there is not an extensive spread of Nantucket Shoals cod to the north and east.

THE SUMMER MIGRATION

Spawning.—A spawning immigration, bringing foreign cod to the Chatham-South Channel region during the winter, may explain why the commercial catch holds up so well at that season. But this can not explain the summer movement of cod thither from Nantucket Shoals, because spawning in any amount is confined to the autumn, winter, and early spring. And we have no evidence from recaptures of any migration of cod eastward or northward from Nantucket Shoals during the spawning season.

Food.—Except in cases where cod could be observed following bait, such as sand eels (Ammodytes) or young herring (Clupea), it is difficult to ascertain what effect regional or seasonal variations in their food supply may have on their migrations. It has been observed that the bulk of the cod's food on Nantucket Shoals and on the Chatham grounds consists of large crustaceans. No cod stomachs have been examined in South Channel, but, being primarily a haddock ground, we can reasonably assume that the food supply as a whole is less attractive to the cod there than on the Chatham grounds or Nantucket Shoals. Two hauls with a fine-meshed shrimp trawl made in South Channel by the *Albatross II* on June 13, 1929, caught very little cod food such as crabs, medium-sized mollusks, worms, etc., but considerably more sampling must be done before a good picture of the food supply and bottom in the channel can be obtained.

If it should be proven that the food on the Chatham grounds is more attractive to the cod than the food in South Channel, it might explain why the former locality has yielded a greater portion of tagged Nantucket cod than has the channel region. But it would not necessarily prove that Nantucket cod migrate to the Chatham grounds primarily in search of better feeding grounds. On the contrary, nearly all the cod stomachs examined on Nantucket Shoals held a large amount of food, or at least as much as the stomachs of fish caught on various other banks, and nearly all the fish caught by us were fat and healthy. Equally, if food were scarce on the Chatham grounds few fish would live there and the region would have yielded a much smaller number of tagged Nantucket cod than was actually the case. So while it is apparent that the Chatham grounds ranks about the same as Nantucket Shoals in having sufficient cod food for holding bodies of fish the year around, yet there is no basis for believing that the food supply affords the chief stimulus for an intermigration between the two grounds.

Temperature.—There is no cod ground off our coast that has the peculiar temperature variations that obtain to the southeastward of Cape Cod, for there, on Nantucket Shoals, a close similarity exists between the surface and bottom temperatures, due to the tidal currents sweeping over its uneven bottom contour and thus stirring up the water, while, in contrast to this, the waters in the Chatham-South Channel region are stratified as to temperature, except for very brief periods in the spring and the fall. Temperature, therefore, appears to offer a hopeful field of investigation for determining the cause of such migrations of cod as occur between these two regions, particularly as these have taken place, according to our tagged fish, only during the summer.

TABLE 31.—*Various water temperatures, selected to show the wide difference between Nantucket Shoals and the Chatham-South Channel region, particularly in summer* [1]

Reference No.	Station [2]	Date	Position	Locality	Depth		Temperature	
					Meters	Fathoms	° C.	° F.
			° ′	*Nantucket Shoals*				
1	H 10647	Apr. 27, 1923		Rose and Crown buoy	0	0	3.3	37.9
2	A 20221	May 4, 1927		1½ miles SSE. from Round Shoal buoy	0	0	5.0	41.0
					15	8	5.4	41.7
					24	13	5.4	41.7
3		May 7, 1927		1½ miles SSW. from Rose and Crown buoy	0	0	5.5	42.0
					20	11	5.6	42.1
4		do		Rose and Crown buoy	0	0	5.5	42.0
					22	12	5.9	42.6
5		do		Great Rip buoy	0	0	5.5	42.0
					13	7	6.0	42.8
					22	12	6.0	42.8
6		June 7, 1925		1 mile SSE. from Round Shoal buoy	0	0	8.3	47.0
					30	16	8.4	47.1
7		June 17, 1927		Round Shoal buoy	24	13	9.1	48.4
8	H 10655	July 15, 1924	41 22 N. 69 32 W.	10 miles ESE. from Round Shoal buoy	0	0	10.0	50.0
					9	5	10.5	50.9
					18	10	10.5	50.9
					27	15	10.4	50.7
9		July 19, 1928	41 27 N. 69 43 W.	Round Shoal buoy	0	0	11.7	53.0
					22	12	11.9	53.4
10		do		Great Rip buoy	0	0	11.3	52.4
					9	5	11.6	52.8
					18	10	11.2	52.2
11	A 20361	July 21, 1928	40 53 N. 69 40 W.	34 miles S. from Round Shoal buoy	0	0	12.8	55.0
					10	5	12.8	55.0
					20	11	12.8	55.0
					40	22	12.8	55.0
12		Aug. 20, 1925	41 27 N. 69 43 W.	Round Shoal buoy	0	0	11.6	52.8
					13	7	11.4	52.5
					22	12	11.2	52.2
13		Aug. 21, 1925		1 mile E. from Round Shoal buoy	0	0	11.6	52.8
					9	5	11.6	52.8
					20	11	11.6	52.8
14		do		2 miles ENE. from Round Shoal buoy	0	0	11.7	53.0
					15	8	11.5	52.7
					25	14	11.7	53.0
15		do		1½ miles SSE. from Round Shoal buoy	0	0	13.3	56.0
					24	13	13.2	55.8
16		Aug. 23, 1925	41 21 N. 69 43 W.	1 mile NE. from Rose and Crown buoy	0	0	16.4	61.5
					22	12	15.6	60.0
17		do		Great Rip buoy	0	0	14.5	58.0
					22	12	14.6	58.2
18		Aug. 24, 1925		do	0	0	13.8	56.8
					13	7	14.2	57.6
					24	13	14.3	57.8
19		do	41 10 N. 69 40 W.	4 miles E. from Great Rip buoy	0	0	13.9	57.0
					15	8	14.1	57.4
					22	12	14.4	57.9
20		Sept. 2, 1927		Round Shoal buoy	0	0	10.0	50.0
					20	11	10.3	50.5
21		Sept. 7, 1926		½ mile NE. from Round Shoal buoy	11	6	13.9	57.0
22		Oct. 1, 1925		2 miles NE. from Rose and Crown buoy	0	0	12.2	54.0
					13	7	12.7	54.8
					26	14	12.8	55.0
23		do		1½ miles S. from Round Shoal buoy	0	0	11.6	52.9
					13	7	12.0	53.6
					24	13	12.0	53.6
24		do	41 24 N. 69 37 W.	5 miles SE. from Round Shoal buoy	0	0	11.6	52.9
					13	7	11.9	53.4
					26	14	13.5	56.3
25		Oct. 22, 1925		1 mile S. from Round Shoal buoy	0	0	10.8	51.4
					11	6	9.4	48.9
					22	12	9.4	48.9
				Chatham grounds				
26	A 20220	May 3, 1927	41 36 N. 69 31 W.	13 miles NE. true from Round Shoal buoy	0	0	5.5	42.0
					18	10	4.6	40.3
					36	20	4.4	39.9
					54	30	4.4	39.9
27		June 7, 1925	41 42 N. 69 48 W.	6 miles E. true from Chatham Light	0	0	12.7	54.8
					42	23	6.5	43.7
28		June 17, 1925	41 22 N. 69 23 W.	15 miles E. by S. true from Round Shoal buoy	0	0	9.7	49.5
					18	10	6.4	43.5
					33	18	6.3	43.3
29	A 20343	July 13, 1928	41 41 N. 69 39 W.	13 miles E. true from Chatham Light	0	0	15.4	59.7
					12	7	11.3	52.3
					47	26	5.9	42.6

[1] The temperatures prior to 1926 are from H. B. Bigelow, Physical Oceanography of the Gulf of Maine, 1927, Tables 4 to 18, pp. 978–1014. Also recorded in Bigelow 1915 and 1917.

[2] Station A = Albatross II; G = Grampus; H = Halcyon.

TABLE 31.—*Various water temperatures, selected to show the wide difference between Nantucket Shoals and the Chatham-South Channel region, particularly in summer*—Continued

Reference No.	Station	Date	Position	Locality	Depth		Temperature	
					Meters	Fathoms	° C.	° F.
				Chatham grounds—Continued				
30	----------	July 19, 1928	41 35 N. 69 32 W.	12 miles NE. true from Round Shoal buoy----------	0	0	15.8	60.5
					11	6	15.4	59.8
					16	9	13.6	56.5
					18	10	10.8	51.5
					22	12	9.5	49.1
					44	24	6.6	44.0
31	G 10085	Aug. 4, 1913	41 39 N. 69 42 W.	12 miles E. from Chatham Light----------	0	0	17.5	63.5
					18	10	6.4	43.6
					48	26	5.8	42.4
32	G 10257	Aug. 24, 1914	41 39 N. 69 49 W.	6 miles E. from Chatham Light----------	0	0	20.0	68.0
					25	14	6.8	44.2
				South Channel				
33	A 20345	July 16, 1928	41 16 N. 69 23 W.	19 miles SE. by E. true from Round Shoal buoy------	0	0	11.6	52.8
					20	11	7.0	44.6
					45	24	5.3	41.5
34	G 10354	July 25, 1916	40 26 N. 69 24 W.	57 miles SSE. true from Sankaty Head, Nantucket----	0	0	13.6	56.5
					30	16	8.7	47.7
					70	39	6.1	43.0
				Georges Bank (western part)				
35	G 10059	July 9, 1913	41 06 N. 68 42 W.	68 miles SE. by E½ E. true from Chatham Light-----	0	0	13.3	56.0
					27	14	12.6	54.6
					55	30	12.6	54.6
36	G 10347	July 23, 1916	41 06 N. 68 51 W.	64 miles SE. by E. true from Chatham Light---------	0	0	11.4	52.5
					30	16	10.9	51.6
					60	32	9.6	49.3
37	G 10348	-----do------	40 49 N. 68 21 W.	90 miles SE. by E. true from Chatham Light---------	0	0	11.7	53.0
					25	14	11.3	52.4
					50	27	11.2	52.2
38	A 20212	Sept. 5, 1926	41 12 N. 68 35 W.	68 miles SE. by E. true from Chatham Light---------	0	0	13.9	57
					13	7	14.8	58.6
					53	29	13.7	56.6

It can be seen from Table 31 that there is a striking difference in the summer temperature on bottom between Nantucket Shoals and the Chatham-South Channel region, the latter being much the cooler. If then cod on the shoals wish to avoid the relatively warm water (50° to 60° F.) that obtains there in summer they need migrate eastward only 10 to 15 miles to find an environment of about 40° to 45° F., and even a shorter distance to find intermediate temperatures. Yet, only a small part of the Nantucket cod population at times make this summer emigration, for it was only the years from 1923 to 1925 during this investigation that the number was at all appreciable, as only stragglers journeyed eastward from 1926 to 1928.

If a good series of temperatures had been obtained for each of these years some correlation between the warmth of the water and the tendency of cod to emigrate eastward from the shoals might have been found. But our records are too incomplete for such an analysis. It was found, however, that during 1925, which was the warmest year of the six, considerably more cod did move eastward into cooler water than during any of the other years of record. (See Table 20, p. 36.) But in spite of this result we have no substantial proof based on temperature alone that Nantucket cod shift ground to avoid warm water in summer.

So far as the tendency for cod to seek cooler water is concerned, the small differences that exist in the maximum temperatures on the shoals each summer appear to be of less importance than the average size of the adult and near-adult cod which make up the population there. For example, if the lengths of the cod caught by the *Halcyon* and the *Albatross II* are averaged for the three years from 1923 to 1925, when a perceptible emigration of Nantucket cod occurred to the eastward, and for

the three years from 1926 to 1928, when fewer fish emigrated, the following result is obtained:

From 1923 to 1925 the weighted mean length of the 14,629 cod tagged on Nantucket Shoals was 26.6 inches. Recaptures of these fish reported from the Chatham-South Channel region throughout the same period amount to 83 fish, or 0.56 per cent of the total number tagged. (See Table 28 for length distributions.) From 1926 to 1928 the weighted mean length of the 7,599 cod tagged on the shoals was 22.43 inches. Recaptures of these fish reported from the Chatham-South Channel region throughout the same period amount to 7 fish, or 0.09 per cent of the total number tagged.

Although the percentages of recapture in both cases are very small, they are based on a large number of fish and involve a mean period of about one and one-half years in each case; hence are significant. Of chief importance is the fact that the proportion of cod which are known to have made this journey during 1923–1925, when their average size was 26.6 inches, was about six times as great as during 1926–1928, when the average size was only 22.4 inches. That this difference in the percentage of recaptures was not due to a corresponding difference in fishing intensity for the two 3-year periods has been pointed out on page 38.

Further evidence showing that there is a tendency for the larger Nantucket cod rather than the smaller to emigrate to the Chatham-South Channel region may be had from the following data: Out of 37 cod tagged on the shoals in 1924 and recaptured there in 1924 and 1925, 21 fish were 25 inches long or less, while 16 were 26 inches or more at the time they were tagged; the average size was 25.3 inches. Out of 18 cod tagged on the shoals in 1924 and recaptured in the Chatham-South Channel region in 1924 and 1925, 5 fish were 25 inches long or less, while 13 were 26 inches or more; the average size was 27.7 inches. Of the cod tagged on the shoals in 1925 good records were obtained for 25 local recaptures, and 15 of these fish were 25 inches long or less at the time they were tagged and 10 were 26 inches or more; the average size was 24.5 inches. In contrast to this, of 17 cod tagged on the shoals in 1925 and recaptured in the Chatham-South Channel region that same year, 5 were 25 inches long or less, while 12 were 26 inches or more; the average length was 27.4 inches.

According to these results, when Nantucket cod average upward of about 26 inches in length a larger proportion of them immigrate eastward into the cooler water of the Chatham-South Channel region than when the fish average smaller than this, and when in addition the summer is a warm one, as in 1925, it would seem that optimum conditions for this immigration prevail.

SIZE OF THE COD POPULATION ON NANTUCKET SHOALS

One of the most desirable results that can come from an investigation of this sort is a knowledge of the size of the cod population in the locality under consideration. Fortunately, for the Nantucket Shoals region we have obtained what seems to be sufficient data to give some idea of the general order of magnitude of the stock of grown cod that were present there from 1923 to 1928. In order to make such an estimate, there are, of course, both known and unknown factors that must be dealt with. Under the known we have the number of cod both tagged and recaptured by our own vessels, while under the unknown there are the reductions in the numbers of

marked fish present on the tagging ground due to the fishery, natural deaths, and emigrations, which, if they could be closely estimated, would add considerable accuracy to the calculations.

In addition certain basic assumptions must be made, for whether the estimated population of the tagging grounds can be extended to include all the grounds on Nantucket Shoals depends on (*a*) whether we are justified in assuming that cod are equally abundant on all the ground in this region which appears to be suitable for them, and (*b*) whether the estimate of the total area of both the tagging grounds and all of the shoals is correct.

As for the first assumption, we have no definite data as to the density of cod on Nantucket Shoals except for the tagging ground, but it is known that fishing vessels make good catches in places other than this ground; in fact, most of the commercial catch of cod on the shoals is taken along the eastern and southern parts where no marking has been done. If, therefore, all the bottom on the shoals which supports cod, containing as it does some areas where the fish are concentrated and others where they are sparse, be averaged, it is probable that the density of cod in the region designated as the "tagging ground" is very much the same as that on any other part of Nantucket Shoals of about the same area and average depth.

With regard to the area of the tagging ground, it is estimated to comprise about one-fourteenth of the total, for almost all of our fishing there was done along a strip about 20 miles long and 2½ miles wide. The total area of cod bottom on the shoals is estimated at about 700 square miles.

An estimation of the size of the cod population on the tagging ground must depend largely on the number of marked fish that were present there, available for recapture, during the spring to fall of the years 1923 to 1929. Unfortunately, it is virtually impossible to gage this accurately, for we have scarcely any data that throw light on the degree of gain or loss in the number of marked fish present from year to year. We can, however, obtain some idea of what the minimum population may have been.

A hypothetical example may make this clear. Suppose, for instance, that all the cod tagged on Nantucket Shoals during one year disappeared by the next, but that virtually all these fish were available for recapture on the tagging ground during the summer when they were tagged. (We have some basis for making this last assumption, for most of the fish remain localized during the summer and the chief losses would be caused by natural deaths and by recaptures made by the fishery; these would probably be small in so short a time interval.) Under such circumstances, if 5,000 cod were caught and tagged on the shoals from the spring to the fall of one year you might say that, taking the whole period as a unit, an average of about 2,500 of them were available for recapture there by a tagging vessel during the course of its fishing on the shoals that year. If 20 of these fish were recaptured by the time the catch of 5,000 had been completed, then we might conclude that 1 fish out of each 250 within that area designated as the "tagging ground" had been marked. The total population of the tagging grounds would be, therefore, two hundred and fifty times the number of marked fish available, or 250 × 2,500, which gives a result of 625,000.

Applying this method of calculation to the number of cod actually caught, tagged, or recaptured by the tagging vessels on Nantucket Shoals as given in Table 32, the following interpretation might be made:

TABLE 32.—*The ratio of marked to unmarked cod on Nantucket Shoals, as found by the tagging vessels, together with the estimated number of marked fish that on the average, were available for recapture there* [1]

Year	Approximate catch of cod	Estimated Average of marked cod available for recapture	Marked cod recaptured by tagging vessels	Ratio of marked to unmarked fish
	Number	*Number*	*Number*	
1923	8,100	3,750	32	1:256
1924	3,400	1,550	38	1:89
1925	4,400	2,050	26	1:170
1926	1,850	800	10	1:185
1927	5,500	2,850	53	1:104
1928	1,050	500	19	1:55
1929	700	325	7	1:100
Average	3,571	1,689	27	1:132

[1] The number of cod caught by the tagging vessels includes the injured fish as well as those utilized for tagging, for it is upon the total catch that the ratio is based. The estimated number available for recapture, on the average, is approximately one-half of the actual number tagged during each year of record. The recaptures taken by the tagging vessels include tag-scarred fish as well as those bearing tags.

From 1923 to 1929 an average of 3,571 cod were caught annually by the tagging vessels on the regular tagging ground, among which 27 [12] bore tags or tag scars. This is a ratio of 1 marked fish to 132 that were unmarked. If an average of 1,689 fish (see Table 32) were available for recapture on the tagging ground the population of this ground, during the summer at least, might be set at 1,689 × 132, or about 223,000. If the assumptions are correct regarding the density of fish and proportionate area of the tagging ground with respect to all of the shoals, then the total population might be estimated at about 3,000,000 cod of marketable size.

This, however, should be looked upon as somewhere near the minimum number, based as it is on the supposition that of the cod present one summer on the tagging ground virtually none remain until the next. But not all the individual cod present one summer have left the shoals by the next, for although about 7 per cent of the marked fish were taken annually by the fishery (2.29 per cent were actually reported and the remainder include the estimated number of tag-scarred fish and those with tags which were not reported), part of them die from natural causes, while others emigrate to other regions. Recaptures made on the tagging ground one and even two years later (Table 23) show that part of the cod either remain for that length of time or reappear there.

What proportion of the fish remain on the tagging ground from one year to the next is not known, and any attempt to determine this by calculations based on recaptures made one or two years after marking by the tagging vessels would be subject to error due to loss of tags. However, the returns of tagged cod give at least a minimum idea of the carry-over from one year to the next. From Table 23 it may be calculated that the recaptures during the second year after release average about 50 per cent as high as during the first season. The persistence of characteristic size groups in frequency distributions also indicates a substantial carry-over from one year to the next. If we assume that there were available for recapture not only most

[12] A large part of these were recaptured 6 months or more after tagging, and so fit rather well with the other data.

of the fish marked the same year but in addition about 50 per cent of the fish that were marked the year before, then the summer cod population of the shoals could be estimated at 4,500,000. Probably the average population of the shoals lies between 3,000,000 and 4,500,000 cod.

It is of course, not practicable to set a numerical value for the average number of cod present on Nantucket Shoals during each year of this investigation as many unknown factors were involved, but if the deductions just given are substantially sound they will give a general idea of the population's general order of magnitude.

It would be interesting to know what proportion of the grown fish are lost to Nantucket Shoals each year by deaths and emigrations, for whatever their number may be they seem to be replaced by other fish, thus keeping the population at somewhere near an equilibrium. (See catches per unit of effort made during the summer, Table 25, p. 44.) It appears, therefore, that immigrants and small fish growing to market size on Nantucket Shoals are enough to maintain the stock there, so at the present time there is no apparent reason for believing that this ground is overfished.

ORIGIN OF NANTUCKET SHOALS COD

The means by which the cod population may be kept up on Nantucket Shoals or on any other cod ground are (*a*) local production, (*b*) the drifting of fry from other regions, (*c*) the immigration of bottom fry, and (*d*) the immigration of older fish. Any one or two of these sources may prove to be of considerably more importance than the others, depending on various factors, but particularly on the geographic location of the ground in question and on the hydrographic conditions which obtain.

The important part played by these latter—that is, temperature and currents—in the distribution of fish eggs and larvæ is well known to all who have worked on such problems. (See Bigelow, 1926, p. 69–78.) The fact that cod eggs and larvae may be carried long distances from the place they were produced, has been illustrated by Schmidt's (1909, p. 22) results when he found large numbers of cod eggs and fry on the north and east coasts of Iceland, although spawning takes place only on the south and west coasts. And, as the bottom fry of the cod have been found in large numbers in the Baltic and in the White Sea, where adult fish seldom, if ever, spawn, the number of larvæ transported by the currents must be vast in some cases, as Damas (1909, p. 127) points out.

The same currents which carry the eggs and larvæ passively along also probably control to a large extent the destiny of the young fry, although as these near the bottom stage they evidently are able to govern their vertical migrations, if not their horizontal. Sars (1869), in his classic account of the Norwegian cod, found that the first few days after hatching the larvæ are kept at the surface by the yolk sac, but after this is absorbed they begin a more independent existence, although they are not able to resist the currents. Schmidt (1909, p. 20) found that the youngest or earliest stages are found nearest the surface and the larger ones farther down. M'Intosh (1897, p. 194), speaking of cod larvæ in Scottish waters, states that by the time they are as small as one-half to three-fourths of an inch, they may descend considerably in the water. This general thesis has since been corroborated by many observers, both in Europe and in America. The smallest cod taken on bottom in the North Sea by Graham (1926, p. 12) were 30–52 millimeters (1⅛–2 inches) long.

It is a general belief that it requires about six to eight weeks from the time cod eggs are hatched until the fry reach the permanent bottom-dwelling stage, though there is certainly much variation in this respect.

LOCAL PRODUCTION OF COD ON NANTUCKET SHOALS

Cod spawn on Nantucket Shoals from November to April, but chiefly during December and January. As the circulation of the water and to some extent its temperature on and near Nantucket Shoals, govern the destiny of the cod eggs spawned there, it will be of interest to consider whether many of the resultant eggs and larvæ may be expected to remain there in large numbers and so to maintain the stock of Nantucket Shoals cod by local production, or whether they tend to drift away.

For the winter period we have almost no data on the nontidal current for the Nantucket Shoals region that would bear on the drift of cod eggs spawned there other than that compiled by Bigelow (1927, p. 864) from the current measurements made by the United States Coast and Geodetic Survey in 1913–14 at Nantucket Lightship. These measurements, each of 29 days' duration, showed a dominant set averaging 5.3 miles per 24 hours N. 86° W., during October, when very few cod spawn on the shoals, while during each of the months from November to March, with the exception of January, covering the chief spawning season, the set was toward the east and south quadrant, its mean direction S. 51° E.; its mean velocity 2.6 miles per day. In the spring, by which time nearly all the local spawning has been completed, the set was again toward the north and west, the average for April being N. 75° W. at 1.4 miles and for May N. 62° W. at 4.3 miles per 24 hours.

It is true that in the summer Bigelow (1927, fig. 174) found that the dominant drift divides on Nantucket Shoals, one part going in a general westerly and the other in a general easterly direction. But as we have no proof that this condition obtains in winter, and some indication that it may be altered, no sound discussion on the subject, for that season, can be given at the present time.

A good series of winter temperatures is lacking for Nantucket Shoals, but, judging from the 10° to 12° C. surface records obtained in October, it is probable that they would range from an average of about 8° C. for November to the 2° to 3° C. obtained in late February (1929) by the *Albatross II*. The incubation period for cod eggs at these temperatures ranges from about 11 to 23–28 days.

If the Nantucket Lightship winter-current measurements are typical for most of the shoals each year, then it is apparent that the southeastward drift of 2½ to 3 miles per day would carry off most of the cod eggs spawned there before they hatch and that the resultant fry would travel considerably farther before reaching the bottom stage. Consequently, it may be accepted that only a negligible part of the cod living on Nantucket Shoals grow up there from eggs produced locally. Hence, we must look elsewhere for the source of the small cod fry that are known to be present on Nantucket Shoals in the summer (p. 91).

THE PROBABLE DRIFT OF COD FRY FROM OTHER REGIONS TO NANTUCKET SHOALS

It is probable that during most of the winter almost every square mile of water off the New England coast contains some cod eggs, larvæ, and fry; for spawning occurs on suitable grounds, both inshore and offshore, over a large part of the Gulf of Maine and through a period extending from October to April or May. The number of fish which spawn in this region each year is very large and the number of eggs produced is enormous.

Given favorable currents, any area in the Gulf of Maine is thus a potential source of supply for any cod ground there; hence for Nantucket Shoals the question of the circulation of the water is the crucial one in this connection. More specifically, whether or not Nantucket Shoals is particularly favored with cod fry depends upon whether the nontidal drift flows toward that region from important spawning grounds far enough away for the eggs and larvæ to develop into bottom-dwelling fry by the time they reach the shoals.

For determining the general circulation of the ocean off the New England coast numerous drift-bottle and current-meter experiments have been made by Bigelow and others. The drift-bottle experiments at best can give but a rough picture of the circulation of the upper stratum. Conditions may change from day to day, so that an average result, covering perhaps one to two months of time, is all that can be obtained as to routes and velocities between the setting out and recovery of the bottles. However, it is almost certain that part of the drifting cod eggs, larvæ, and to some extent the fry, follow the same route as the bottles. Up to the present the experiments made with these latter furnish our most dependable means of tracing the destiny, in a general way, of the cod spawn discharged in any particular part of the Gulf of Maine.

Bigelow (1927, p. 972) found that the Gulf of Maine is dominated by an anticlockwise nontidal circulation, differing in velocity and in detail with the season. A rough picture of the circulation in July and August is given in Figure 26. As the currents from offshore do not pass over the cod grounds south of Cape Cod, except possibly by a long and tortuous course, they are not treated here. To the westward of Nantucket, although little is known of the conditions existing in winter, the fact that Bigelow found a shore drift to the Rhode Island-North Carolina region in summer, carrying flotsam away from the shoals, suggests that this region does not constitute a prolific source for Nantucky Shoals fry. A large number of cod spawn in this westward region, so that a study of its hydrography presents an important problem for the future.

The dominant drift in the Gulf of Maine, which sets in a southwesterly direction along the coast of Maine, veers to the eastward well off Cape Cod, and thence toward Nova Scotia, but part of it follows the coast southward past Cape Cod and down to Nantucket Shoals. It is this part of the drift that is of most importance in bringing to Nantucket Shoals pelagic cod fry originating from eggs spawned to the northward of Cape Cod.

In late winter and early spring the northeast-southwest drift along the coast of Maine and southward past Cape Cod is most definite and reaches its greatest velocity of the year. Bigelow (ibid., p. 975) states that "under these circumstances flotsam of any kind (buoyant fish eggs, for instance, or the larvæ hatched therefrom) that may drift from the north into the northern side of Massachusetts Bay or that may be produced there tends to drift out of its southern side." This being so, we have favorable conditions for the drift of cod fry to Nantucket Shoals from regions north of Cape Cod, providing that the velocity of drift is such that the resultant fry will reach the southern Massachusetts region at a time when they are seeking the bottom.

With regard to the velocity of the dominant nontidal drift in the Gulf of Maine in so far as it affects the destiny of cod fry, the year falls into two periods—a winter season from October to May, when prevailing northwesterly winds enhance the speed of the current along the shores of Maine and Massachusetts and hold it close

in, and a summer season from June to September, when prevailing south and southwesterly winds both retard it and direct it offshore.

The following velocities for the winter and spring have been obtained for the region between the Bay of Fundy and Nantucket Shoals.

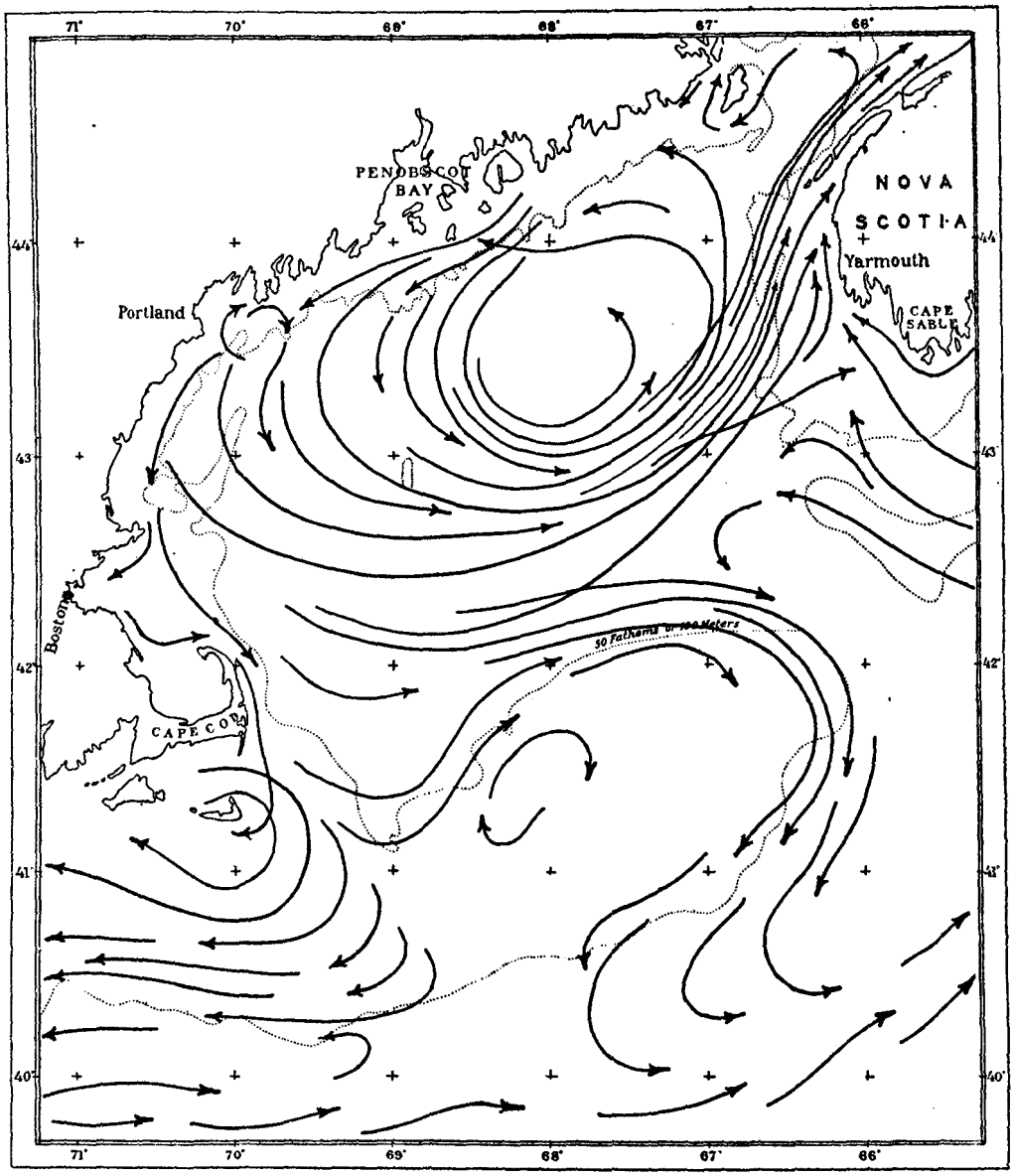

FIGURE 26.—Schematic representation of the dominant nontidal circulation of the Gulf of Maine, July to August. (After Bigelow, 1927)

At Portland Lightship measurements made by the United States Coast and Geodetic Survey (Bigelow, 1927, p. 861) show a mean dominant set of about 8 miles a day to the south and west from October to December of two different years. According to prevailing winds, the October-December conditions probably continue until May.

Recoveries from a line of drift bottles run 10 miles off Cape Ann, Mass., in April, 1926 (Bigelow, ibid., p. 878), showed the following periods of drift between there and the Nantucket Shoals region: 1 bottle was recovered 32 days later at Race Point, Cape Cod, a distance of about 37 miles, or an average velocity of 1.15 miles per day;[13] 2 bottles went to Chatham, 70 miles, in 30 and 38 days, respectively, at an average for the two of 2.09 miles; another was taken off Monomoy, Cape Cod, after 49 days, 75 miles, at 1.53 miles per day; 2 reached the island of Nantucket, the mean rates being 57 days, 115 miles, at 2 miles per day; and another went to the south shore of Marthas Vineyard in 74 days, about 130 miles, at 1.76 miles per day.

The following results were obtained from a line of drift bottles set out in Massachusetts Bay February 6 and 7, 1925 (Bigelow, 1927, p. 876, and Fish, 1928, p. 277): Out of 90 bottles 27, or 30 per cent, were recovered, of which 4 went around Cape Cod or toward the Nantucket Shoals region. Of these 1 was reported 29 miles east-southeast from Stellwagen Bank (there is some doubt about the exact locality of recovery) 9 days later and about 49 miles away, a velocity of 5.4 miles per day; 2 were taken on the south shore of Nantucket, 88 miles in 128 days, and 80 miles in 144 days, respectively, from the place and time of release, an average velocity of 0.62 mile per day (these latter may have been delayed inside the arm of Cape Cod or elsewhere); and 1 was recovered after 149 days, off Fire Island, N. Y., and had traveled about 220 miles, at an average velocity of 1.48 miles per day.

In May, 1925, drift bottles were put out in various parts of Massachusetts Bay. (Bigelow, 1927, p. 877, and Fish, 1928, p. 278.) The recoveries include 2 bottles which crossed the bay in 5 and 6 days, at a velocity of 3.6 and 2.5 miles, respectively; 1 bottle went from the southern tip of Stellwagen Bank to 75 miles southeast by east from Cape Cod Light (which places it in South Channel), a distance of about 90 miles in 22 days at 4.1 miles a day; another went to Dennisport, on the southern coast of Cape Cod, about 80 miles in 17 days at 4.7 miles per day; while another was found near Edgartown, Marthas Vineyard, 65 days later, a distance of about 120 miles from its place of release near the middle of Cape Cod Bay, and average velocity of about 1.8 miles per day.

In addition to these drift bottle records, current measurements by the United States Coast and Geodetic Survey (Bigelow, 1927, p. 864) were made along the outside coast of Cape Cod. That the current runs strong there is shown by the 12 miles per day southward drift that was obtained off Nauset Light. Current measurements taken from June to September, 1911, at Pollock Rip Lightship and at Round Shoal Lightship, which are on the fringe of Nantucket Shoals at the entrance to Nantucket Sound, showed a dominant drift toward the southeast at velocities of 9 to 10 and 2 to 3 miles per 24 hours, respectively.

As a result of these various bottle experiments and current measurements there is some evidence that during the winter and spring the velocity of that part of the dominant drift which sets southward along the coast of Maine and out and around Cape Cod to southern Massachusetts is of about the following order of magnitude: About 5 to 8 miles per 24 hours from eastern Maine to Cape Ann, 2 to 5 miles across Massachusetts Bay to the north tip of Cape Cod, and about 2½ miles from Cape Ann to the Nantucket Shoals region. The latter rate is based on the average velocity of eight bottles which drifted from Cape Ann and Massachusetts Bay to South Channel, Nantucket, and Marthas Vineyard.)

[13] These are minimum velocities, for, no doubt, some of the drift bottles were anchored on the shore for some time before they were found.

According to these velocities, it is evident that fry coming from eggs spawned between eastern Maine and Cape Cod are carried to Nantucket Shoals in a relatively short time. Many of them, no doubt, drift far beyond before attaining the bottom-

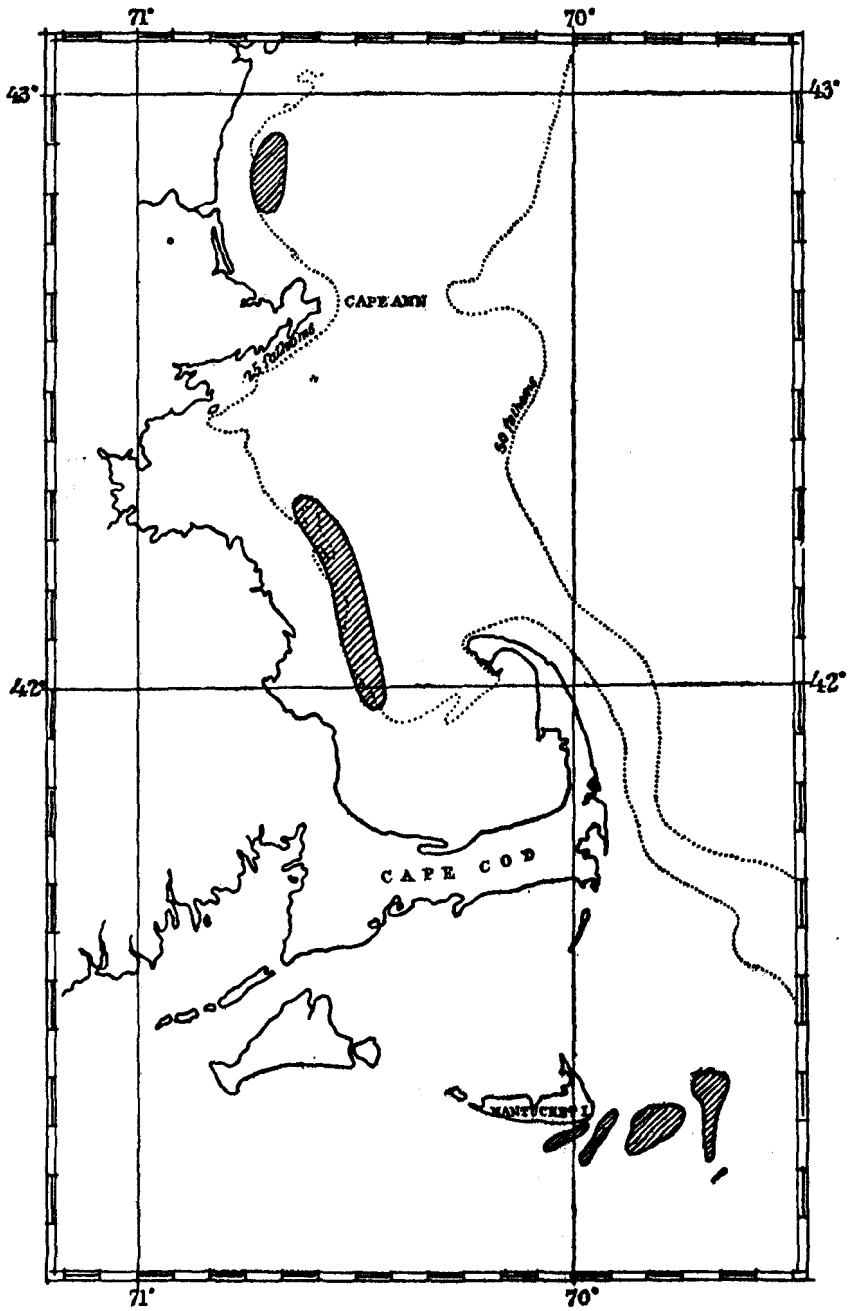

FIGURE 27.—Chief spawning grounds of cod in the western side of the Gulf of Maine. (After Bigelow, 1925)

dwelling stage. Fish (1928, p. 283) found newly spawned cod eggs in the western part of Massachusetts Bay and late embryos in the eastern part and concluded that the anticlockwise drift carried them out of the bay before they hatched. We have

also the catches of cod larvæ [14] made by the *Albatross II* along the outer coast of Cape Cod. These included a catch on May 28, 1927, off Race Point, of 148 larvæ 3½ to 6½ millimeters long, taken in one haul, and another off Cape Cod Light on the same date of 194 larvæ which measured 3½ to 9½ millimeters. It is apparent from the size of these larvæ that they would be carried beyond the Nantucket region by the time they reached the bottom stage.

It is safe to assume that most of the eggs spawned north of Cape Cod hatch in 15 to 30 days, depending on the season and, therefore, the temperature. If approximately 50 days are allowed for the development of the larvæ and fry, it can be seen that spawning grounds located 65 to 80 "drift days" away and in line with the southerly drift are well situated for supplying southern Massachusetts with fry. Exceptions, of course, would occur, for the velocity of drift might be greater some months than others; eggs spawned early in the season might hatch in as little as 10 days; and delays en route, such as might be caused by eddies, would enhance or retard the chances of fry reaching the shoals, depending upon how far they had to drift.

Along the course of the southerly drift there are various important spawning grounds. Farthest north and east, between Cape Elizabeth and the Bay of Fundy [15] the grounds are scattering and small, but in the aggregate a large number of cod eggs are probably produced there. More important spawning grounds are located between Cape Ann and Cape Elizabeth (chiefly in Ipswich Bay), and others between Cape Ann and Cape Cod. (Fig. 27.)

Although cod spawn throughout the winter in most localities, the time when the height of egg production occurs may vary even on two grounds close together. Thus Bigelow (1924, p. 422) shows that on the north side of Cape Ann ripe fish are not common until January or February and much of the spawning occurs from February to April, while off Plymouth, only 50 miles distant, the important part of the season usually is in January and February. Fish (1928, p. 290) found considerable spawning taking place off Plymouth as early as November 12, in 1924. Between Cape Elizabeth and the Mount Desert region most of the spawning takes place from March to May.

Variation in the incubation period of the eggs (see Table 33), according to temperature, makes it pertinent to consider the approximate conditions which exist over the spawning grounds which lie in the path of the drift toward Nantucket Shoals at the time of spawning.

TABLE 33.—*Period of incubation for cod eggs* [a]

Water temperature		Days	Water temperature		Days	Water temperature		Days	Water temperature		Days
° F.	° C.		° F.	° C.		° F.	° C.		° F.	° C.	
31	−0.6	50	36	2.2	25	41	5.0	16	46	7.8	11
32	0.0	40	37	2.8	23	42	5.5	15	47	8.3	10–11
33	+0.6	35	38	3.3	21	43	6.1	14			
34	1.1	31	39	3.9	19	44	6.7	13			
35	1.7	28	40	4.4	17	45	7.2	12			

[a] From A Manual of Fish Culture, p. 206, in Report U. S. Commissioner of Fisheries, Pt. XXIII, for 1897.

[14] These larvæ were discovered among plankton hauls made by O. E. Sette during mackerel investigations.

[15] Because of the unusual physical conditions of the water in the Bay of Fundy, larvæ from pelagic eggs are rare there. (See Huntsman, 1918c, p. 65.)

The coast of Maine from the Bay of Fundy to Cape Elizabeth.—For this long stretch of coast it is difficult to set an average time and place for the spawning of the cod or an average temperature. Cod eggs spawned there in March would hatch in about 25 to 31 days in the 1° to 2° C. temperatures prevailing, 16 to 19 days in 4° to 5° C. water in April, and 11 to 14 days in 6° to 8° C. water in May. The distance from this region to Nantucket Shoals, over the shortest route that can be taken by the dominant drift, is about 180 to 360 miles. Arbitrarily assuming an average drift rate of 3 miles per day, it would require 60 to 120 days for flotsam to cover the distance from this region to the shoals. Allowing an incubation period of 12 to 28 days for the eggs and a pelagic existence of about 50 days for the larvæ and fry, they would travel 62 to 78 days before the latter reached the stage when they seek bottom.

This region, therefore, constitutes one of the most probable sources of the cod fry found on bottom on Nantucket Shoals.

Cape Elizabeth to Cape Ann.—Eggs spawned in this region in January, drifting southward and around Cape Cod, would incubate in a temperature averaging around 3° C., while in February and March it would be closer to 2° C. During the principal part of the spawning season, therefore, hatching would there require about 23 to 28 days. The center of this region is about 150 miles distant from the shoals, along the probable route of the drift, which at an average velocity of 3 miles a day would carry flotsam to Nantucket Shoals in about 50 days. Allowing 73 to 78 days of drift for the eggs, larvæ, and fry, it appears that most of the latter would pass well beyond the shoals before seeking bottom and, consequently, that this region is less favorably situated than the preceding with respect to stocking the shoals with cod fry.

Massachusetts Bay region.—Cod eggs spawned here as early as November would hatch in about 10 days in 9° C. water, while in December the period would be 14 to 19 days, for the temperature then ranges from 4° to 6° C. In January and February, when much of the spawning occurs in this region, the temperatures along the route to Nantucket Shoals average about 2° C.; hence the incubation period occupies 25 to 28 days. The distance from both the Plymouth grounds and Stellwagen Bank to Nantucket Shoals is about 80 miles, and the time required for flotsam to accomplish the drift at 3 miles per day would be about 27 days. From the time the eggs are spawned there cod fry would drift about 60 to 75 days before taking to the bottom, by which time those which passed over the shoals would probably go far beyond. It seems clear that this region is much less favorably located than others farther north for supplying the shoals with cod fry.

These estimates, rough at the best, are meant to apply to the principal spawning grounds along the western part of the Gulf of Maine, to the height of the spawning period, and to the approximate velocity of the dominant drift along a direct course. For example, spawning on most of the grounds progresses throughout the winter, so that while as many eggs, or more, may be deposited during one or two months (when the season is at its height) as during the rest of the season combined, the secondary period, in the aggregate is very important. And it is possible that fry may at such times reach the shoals from grounds that do not contribute to the former at the height of the breeding season.

Although many cod fry are carried past Nantucket Shoals by the dominant drift, the probability must not be overlooked that some of these seek bottom near by and thus are an important factor in keeping up the stock of cod off southern New England in general, if not on Nantucket Shoals in particular.

In sum, cod eggs spawned along the coast of Maine east of Cape Elizabeth are probably the most prolific source of the cod fry present on Nantucket Shoals.

THE PRESENCE OF JUVENILE COD ON NANTUCKET SHOALS

In American waters little is known concerning the habits and migrations of young cod from the time they first take to the bottom until they are about 2 years old (about 12 to 14 inches long). Consequently, we must turn to European sources for information as to this stage in the cod's life.

Off the Norwegian coast, Hjort and Dahl (1900, p. 154), in summing up Sar's findings on the cod, point out that cod fry approach the shores in summer and in autumn when about 10 to 12 centimeters (about 4 to 5 inches) long. They live close by the shore in sandy bays and in the uppermost seaweed. McIntosh (1897, p. 194–195) states that in Scottish waters the fry frequent shallow rock pools, but that they go offshore as they become older. Schmidt (1907, p. 16) records cod fry 4 to 5 centimeters (1½ to 2 inches) long in the fjords around Iceland in September, while various European investigators mention the presence of young fry floating under jellyfish (Cyanea). Not all records of the fry have been from alongshore, for Hjort (1914, p. 10) states that, although the younger stages live as a rule in shallow water in the southerly regions, observations made to the northward (east of Vardo and in the Varanger Fjord) have shown that small cod, from the earliest bottom stages upward, are to be found widely distributed throughout great parts of the Barentz Sea, even as deep as 100 to 200 fathoms.

How closely the habits of European and American cod fry agree, particularly with respect to the environment in which they pass their first year, is not yet known. We have no proof that cod fry make extensive migrations off the New England coast. Comparatively few have been found in the immediate shore waters during recent collecting, although offshore they were quite generally scattered over all good cod bottom wherever experimental hauls were made between Nantucket Shoals and southern Nova Scotia.

A few hauls made on Nantucket Shoals with a small otter trawl [16] yielded the following young cod:

Haul No. 1.—June 22, 1927; 10 miles east of Round Shoal buoy; one-half hour; depth, 21 fathoms; 5 cod, 63 to 93 millimeters long (2.5 to 3.7 inches).

Haul No. 2.—June 24, 1927; near Great Rip buoy; one-half hour; depth, 12 fathoms; 14 cod, of which 12 were 61 to 122 millimeters (2.4 to 4.8 inches) and the other two, 297 and 343 millimeters long (11.7 and 13.5 inches).

Haul No. 3.—October 16, 1927; near Great Rip buoy; one-half hour; depth, 12 fathoms; 2 cod, 184 and 203 millimeters long (7.2 and 8 inches).

In addition to the fry taken in trawls others were found in the stomachs of larger fish, chiefly cod. As a rule about 8 or 10 young cod from about 3 to 7 inches long were found per 100 stomachs examined not only in cod caught on Nantucket Shoals but in many other localities as well.

Although small cod less than 8 inches long and not over about 1 year of age have been found quite generally distributed over Nantucket Shoals and other offshore grounds, only a small part of them appear to survive there, for a striking paucity of fish a little larger, between 8 and 15 inches long or 1 and 2 years of age, has been

[16] The trawl used had a spread of about 30 feet between the boards and was of ¼-inch square mesh. Usually the cod end was lined with bobbinet of about 3/32-inch mesh.

found. This is illustrated by the following list of the smallest cod which we caught on Nantucket Shoals with hook and line:

TABLE 34.—*The total catch of cod less than 16 inches long taken by the "Halcyon" and "Albatross II" on Nantucket Shoals from 1923 to 1928 with hook and line*

Date	Cod caught	Number below 16 inches [1]					
		11 inches	12 inches	13 inches	14 inches	15 inches	Total
1923:							
April-May	336				1		1
May	411						
June	1,144				2		2
August	1,790						
September	1,352						
October	2,521						
1924:							
July	1,254						
September	964				2		2
October	884			4	12	18	34
1925:							
May	852				3	7	10
June	671		1		1	3	5
August	1,291	2	3	9	15	16	45
October	1,328			9	36	47	92
1926:							
September	1,878				2	17	19
1927:							
May [2]	1,252						
June [2]	1,701					2	2
September	1,468		1	2	1	2	6
October	1,291				2		2
1928:							
July	748		5			7	12
October	304		1	1	16	13	31
Total	23,440	2	11	25	93	132	263

[1] None were caught under 11 inches.
[2] In addition there were caught on the Chatham grounds 460 cod, which included one 14 and one 15 inch fish.

The question naturally arises as to what extent selectiveness of the hook-and-line gear is responsible for the very small proportion of cod below 16 inches that was taken, for we found fish so small to be scarce not only on Nantucket Shoals but in all our catches made on the offshore banks as well. Alongshore the results have been much different, for there we have caught large numbers of cod 12 to 15 inches long with the same sort of hooks as was used in the Nantucket region. For example in the shore waters off Mount Desert, Me., where we caught 9,894 cod from 1924 to 1928, a total of 38 per cent of the cod (compared with 1 per cent for Nantucket Shoals, was less than 16 inches long, divided according to size, as follows: 10 inches, 5; 11 inches, 76; 12 inches, 416; 13 inches, 959; 14 inches, 1,163; and 15 inches, 1,139 fish.

The scarcity of these small cod in our catches on Nantucket Shoals and other offshore grounds might be due, to a small extent, to the aggressiveness of the large fish in seizing the bait, but this possibility fails to explain the vast difference in the percentage of young fish taken in the shore waters as compared with the offshore.

It will be of great importance to know with certainty what now seems a probability, namely, whether the large numbers of cod fry scattered over our offshore banks are almost completely wiped out by the depredations of larger fish, for if this be so our stock of adults must be drawn largely from the nurseries alongshore such as that along the coast of Maine. More sampling must be done with nets as well as with various sizes of hooks before we can hope to answer this question. Observations along this line were made in September, 1929, when I observed the catches in 40 hauls made by a commercial otter trawler on the northeastern part of Georges Bank. Although the bunt of the net used was of a mesh fine enough (1 inch square) to retain cod at least as small as 10 inches in length, only a few hundred (fig. 28) were small enough to fit in the 10 to 15 inch class. (The catch of cod consisted of several thousand fish, nearly all of them between 18 to 45 inches long.)

It seems apparent that only to a small extent do the cod fry which seek bottom on Nantucket Shoals contribute to the stock of fish there, for, whatever may happen to them, few survive on the shoals after they reach about 1 year of age. Consequently, the population must be kept up largely by the immigration of older cod (young adults and near adults) from other localities. A discussion of these follows.

IMMIGRATIONS TO NANTUCKET SHOALS OF ADULT AND NEARLY ADULT COD

That schools of medium-sized cod appear on Nantucket Shoals from time to time was learned from the length-frequency distributions of the fish caught by the *Halcyon* and the *Albatross II*. Unfortunately, none of these fish bore tags from other grounds; hence, definite information as to their source is lacking. However, recaptures taken along a route to Nantucket Shoals and beyond of cod tagged to the north and east of Cape Cod throw some light on this question. Their records follow.

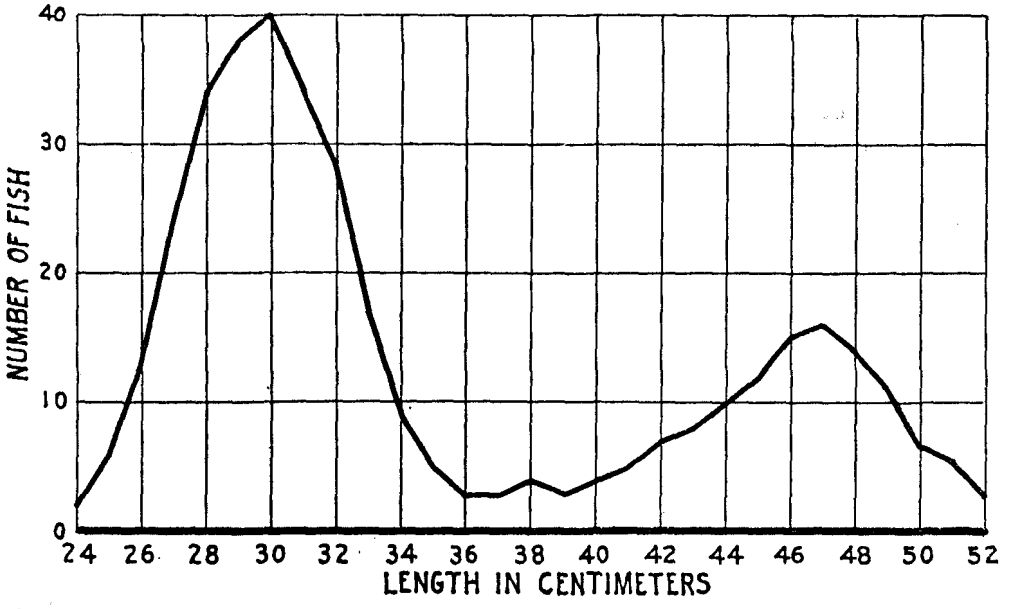

FIGURE 28.—Length-frequency distribution of the young cod caught in an otter trawl during the course of a week's fishing on northeastern Georges Bank September 19–25, 1929. Smoothed once by a moving average of 3

Year 1923.—Only 12 cod were tagged on grounds other than Nantucket Shoals during 1923—all on Stellwagen bank (between Cape Cod and Cape Ann). Out of the three recaptures subsequently made one fish was taken at Rockaway, N. Y.

Year 1924.—A total of 3,144 cod was tagged along shore between New Hampshire and Mount Desert, Me., and on the following offshore banks: Stellwagen Bank, Boone Island, Jeffreys Ledge, and Platts Bank. There were 396 recaptures reported, of which the following fish migrated toward or past Nantucket Shoals: 2 fish were taken 10 to 23 miles off Highland Light, Cape Cod; 2 off Chatham, 3 in South Channel, 2 near Round Shoal buoy on Nantucket Shoals, and 1 at Rockaway, N. Y. In addition a southerly direction was taken by one of the fish tagged near Portland, which was recaught on Stellwagen Bank, and by 2 Mount Desert cod, 1 of which was taken on Jeffreys Ledge and 1 on Platts Bank.

Year 1925.—A total of 6,389 cod was tagged on the same grounds north of Cape Cod as in 1924, of which 918 were subsequently reported recaptured. Of these 1 Stellwagen cod was taken off Atlantic, City N. J., and there is a somewhat doubtful record of a Mount Desert fish taken off Race Point, Cape Cod. In addition, Mount Desert cod were taken, 1 each at Matinicus, Portland Lightship, and Ipswich Bay.

Year 1926.—Tagging was restricted somewhat this year, and the number of cod tagged other than on Nantucket Shoals amounted to 1,016 on Georges Bank and 945 off Mount Desert. The subsequent recaptures numbered 169 and included 1 Georges Bank cod, which was taken off Rhode Island, and 1 Mount Desert fish, which was caught off Matinicus, Me.

Year 1927.—A total of 3,190 cod was tagged in the following localities: Georges Bank, Browns Bank, Cashes Ledge, Jeffreys Ledge, Platts Bank, Stellwagen Bank, and off Mount Desert. The recaptures reported numbered 298, of which 2 came from South Channel. In addition, a Browns Bank cod was taken off Magnolia, Mass., and a Platts Bank cod was taken off Plymouth, Mass.

Year 1928.—During this year 1,285 cod were tagged in the Gulf of Maine, north and east of Nantucket Shoals and South Channel; and from these 33 recaptures were reported, of which 4 were taken along the route to Nantucket Shoals. Two of these were cod from the northeastern part of Georges Bank, 1 of which was taken on the southwestern part of the bank and 1 on Nantucket Shoals. One cod migrated from Cape Sable, Nova Scotia, to the Chatham grounds, while another migrated from Stellwagen Bank to Rhode Island.

This summary shows that only 29 tagged cod out of 1,817 recaptures reported from 15,981, marked on grounds other than Nantucket Shoals and Chatham, from 1923 to 1928, showed a tendency to migrate toward Nantucket Shoals. Of these 29 only 19 cod, or about 1 per cent of the total recaptures, were taken in the Nantucket-Chatham-South Channel region proper and on the wintering grounds to the westward. This result, taken by itself, would seem to indicate that no important migration to Nantucket Shoals occurred from any of the grounds where we have tagged a large number of fish to the north and east throughout the six years of this experiment. However, if the region north and east of Massachusetts be taken by sections the dispersals made by these fish take on added interest.

Only 5 cod out of about 10,000 that were tagged along shore between Cape Elizabeth and Mount Desert, Me., were recaptured along a route to southern Massachusetts. This region, therefore, is not a likely source of the young adult cod which appear on Nantucket Shoals from time to time. Although the coast of Maine appears to play an unimportant rôle with regard to supplying Nantucket Shoals with adult cod, we must not lose sight of the fact that the shore waters there form one of the greatest nurseries for young cod along our coast, and that most of the 10,000 fish which were tagged off Mount Desert were younger (3 years old or less) than the cod tagged elsewhere in the Gulf of Maine. It may be that as these fish grow older, reaching upward of 4 years of age and move out into deeper water, that many of them may find their way into the southern Massachusetts region, probably by way of the offshore banks. Direct evidence of this from marked fish is lacking, because nearly all these fish would have lost their tags during the long period elapsing before their meanderings could bring them to the Nantucket region.

A small proportion of the cod living on Platts Bank and Cashes Ledge, and probably in their general vicinity, emigrate toward southern Massachusetts, for 6

tagged cod (out of 1,600 marked) from these banks were recaptured along the coast of Cape Cod.

If some of the cod from the north and east of Cape Cod which migrate to the wintering grounds between Rhode Island and North Carolina drop off, either on their way southward or on their return northward, to live on Nantucket Shoals, then the stock of fish in this latter region is kept up partly by grown fish from the Massachusetts Bay region and from the offshore grounds between southern Nova Scotia and Georges Bank. Evidence of this is shown by the following data: Out of a total of only 196 cod tagged on Stellwagen Bank, in Massachusetts Bay, from 1923 to 1928, 1 fish was recaptured between Rhode Island and New Jersey during the fall of each of the years 1923, 1924, 1925, and 1928 (no cod were tagged in Massachusetts Bay in 1926 and only 10 in 1927), showing that there was a decided tendency for some of these fish to go southward each year.

That some of the cod living offshore migrate to or beyond Nantucket Shoals is shown by the following recapture records: 1 of the 263 cod which we tagged off Cape Sable in 1928 was retaken off Chatham, Mass. On Browns Bank, 1,100 cod were tagged in 1927–28; and of the 28 recaptures reported up to the end of 1929, 2 fish had crossed the deep channel to the south and west, for 1 of them was taken on Georges Bank and the other in South Channel. On the northeastern part of Georges Bank, about 150 miles from Nantucket Shoals, 1,598 cod were tagged from 1926 to 1928, of which only 12 were reported recaptured. But 3 of these, or one-fourth of the total, have been recorded from along the route to southern New England, as follows: 1 cod, tagged September 26, 1928, in about latitude 42° 00′ N., longitude 66° 22′ W., was retaken on October 20 about 100 miles to the westward, toward Nantucket Shoals; while another fish tagged on the same date and in the same locality was recaptured on the shoals in May, 1929; of the cod tagged on Georges Bank in August, 1926, 1 was recaptured off Rhode Island in April, 1927. Some cod were tagged off southern Nova Scotia by the Biological Board of Canada. Among the recaptures are several fish taken on Georges Bank and several taken off Rhode Island.

SUMMARY

The size of the summer population of adult or nearly adult cod on Nantucket Shoals from 1923 to 1928 might be roughly estimated at between 3,000,000 and 4,500,000 fish.

Immigrant fish and the young which grow up in the Nantucket Shoals region have been sufficient to keep up the population there by offsetting losses due to deaths and emigrations.

A large part of the cod fry which seek bottom on Nantucket Shoals appear to come from eggs deposited along the coast of Maine. But although fry may be plentiful on the shoals, it would seem that they contribute only in a small way in keeping up the local population, for relatively few 1 to 2 year old cod have been found there.

Indications are that the stock of cod on Nantucket Shoals is kept up chiefly by the immigration of young adult and near-adult fish. Recaptures of tagged fish have indicated that the region to the northward of Cape Cod contributes annually but a small number of adult cod to the Nantucket Shoals grounds. The South Channel grounds and the southwest part of Georges Bank appear to be a more probable source, for, although scarcely any cod were tagged there and we have no

direct evidence, these grounds are adjacent to Nantucket Shoals and support a large stock of fish. Another indication that a large part of the Nantucket adult cod are derived from near-by regions and not from the northward is to be had from scale studies which have shown that the cod to the north of Cape Cod differ materially from those to the southward in the early growth of their scales (p. 110).

AGE AND RATE OF GROWTH OF COD, PARTICULARLY THOSE ON NANTUCKET SHOALS

On the present investigation we did not specialize in a study of the factors which cause fluctuations in growth other than the collections of water temperatures and observations on the cod's food. We were concerned, however, in determining the growth of the cod in various parts of its habitat along the New England coast and in doing this utilized three methods, namely, length frequencies, scales, and growth registered by recaptured tagged fish.

Many observations have been made, especially in European waters, on the age and rate of growth of cod. The majority of the records obtained cover only the first year of growth, because most of the collections have been of young fish that were obviously in their first year of life. Even up to the completion of the second year records are not lacking, but above this age data become fewer and fewer as the fish grow older.

There is no particular rate of growth nor any average size at a given age that will cover the cod for all parts of its range. Environmental conditions affect growth in some cases to a marked degree, for in general the cod in Europe appear to grow more slowly than off the coast of America, and growth evidently is more rapid in the southern part of the fish's range than in the northern.

There has been much discussion as to whether food or temperature is the more important in regulating the growth of fish and various experiments in this direction have been undertaken.

Fulton (1904, pp. 170–171) believed that temperature was of first importance because it acted directly on the metabolism of the fish and affected the rapidity of digestion. He pointed out in his experiments with cod, haddock, and other species that fish gave up feeding altogether when the water became very cold (less than 3.8° C.), because under such conditions the ferments upon which digestion depends acted slowly or not at all. Appetite waits on digestion, and the latter may be correlated with the metabolism in the tissues. Cod and haddock living in cold-water aquaria in the winter were sluggish and moved about very little, whereas fish kept in artificially heated aquaria were very active and had a good appetite. However, 3.8° C. does not mark a critical temperature below which all cod cease feeding, for in some of the regions where cod live the year around, as off Labrador, Greenland, Iceland, and on the Grand Bank, the temperature is below 3.8° C. most of the time. Jensen (1926, p. 91), fishing for cod (*Gadus callarias*) off the west coast of Greenland with hooks baited with frozen herring, caught virtually no fish during June, when the bottom temperature on Fyllas Bank ranged from 0.20° to 1.06° C., but made good catches early in July at temperatures of 0.87° to 1.68° C. and again the middle of the month at 2.09° to 2.74° C. and Hjort and Ruud (1929, p. 17) record that the *Michael Sars* found excellent hand-line fishing for cod on August 5, 1924, in latitude 63° 55′ N., longitude 53° W., in 67 meters, where the temperature was about 1.6° C. The cod had been feeding on shrimps, amphipods, crabs, and sand eels. Cod in this region, therefore, feed when the temperature is appreciably below 3° C.

Undoubtedly there is some correlation between temperature and the desire of the cod to take food, but we know comparatively little on this subject with respect to the various "races" of *Gadus callarias*. Certainly we could expect Labrador cod, living in a temperature of, say, −1° to +5° C. to behave differently than Nantucket cod living in a temperature of 2° to 15° C. Yet even the latter fish do not cease feeding in the winter when the temperature drops below 3° C.

Along the New England coast an examination of cod stomachs at different seasons has shown that more food is eaten in summer than in winter. This, of course, may be due as much to a falling off in the food supply as to a loss of appetite due to a low temperature, for in February, 1928, off Delaware Bay, we found that instead of the cod being on their regular feeding grounds in 4° to 5° C. water they were around and inside the bay feeding on sand eels (*Ammodytes*) in about 2° C. water.

Cutler (1918, p. 488) kept flounders and plaice in water of various temperatures, made observations on the scales, and concluded that the amount of food did not affect the production of summer and winter bands, but that the formation of wide sclerites (generally produced during rapid growth) was due to high water temperatures while low temperatures resulted in narrow ones.

Winge (1915, p. 18), in his work on cod scales, sums up the effects of temperature and food on the growth of the cod, as follows: "Everything seems to indicate that the rate of growth of the cod is highly dependent upon conditions of temperature in the water, although perhaps in the main indirectly through the effect of temperature upon the quantity of nourishment."

Some light is thrown on the effects of temperature in retarding or increasing the rate of growth of cod fry by observations made in Norwegian waters. Dannevig (1925, p. 7) cites a rearing experiment carried out by Capt. G. M. Dannevig in 1886. At that time newly hatched cod larvæ placed in a pond, grew from a length of 3 millimeters on April 26 to an average length of 10 millimeters by May 31. A second experiment of the same sort, but made later in the spring, was carried out near Arendal on May 25, 1909, where Dannevig (1919, p. 45; 1925, p. 8) released about 100,000 1 to 2 day old cod larvæ (4 millimeters long) in the station's rearing pond in water having a temperature of 9.5° C. The larvæ grew as follows: June 12 they averaged about 20.5 millimeters (2 fish); June 16, 27.5 millimeters (2 fish); and on June 18, 24.5 millimeters (8 fish). The temperature in the pond on June 16 was 20° to 21.4° C. and must have been considerably warmer than that which obtained during the experiment in 1886. This difference is reflected in the rate of growth, for whereas the cod in 1886 averaged only 10 millimeters in length at 35 days old (April 26 to May 31), those reared in warm water in 1909 had reached a length of about 25 millimeters in 25 to 26 days (May 23–24 to June 18). Although other factors, such as the food supply, may have had some influence in bringing about this difference in rate of growth, it seems obvious that temperature played the most important part.

H. Thompson (1926, p. 6) is inclined to believe that the amount of food more than temperature decides the rate of growth, although haddock and gadoids which he had under observation in aquaria had a lessened desire for food from January to March. He concluded that, in general, captive haddock living in water of about the same temperature as at sea but supplied with a regular diet grow about twice as fast as they would under natural conditions.

Duff (1929, p. 16), who studied Sable Island (Nova Scotia) cod, concluded that adult fish in this region reach their maximum rate of growth during May, June, and July, and their minimum during January and February.

Whether it be temperature or food that is the more important factor in bringing about fluctuations in the rate of growth of cod, it has been found that, according to the scales, a period of rapid and of slow growth occurs each year, alternating throughout the life of the fish.

EVIDENCE FROM LENGTH FREQUENCIES

The first attempts at determining the age of cod were based upon length frequencies. (Hjort, 1914, p. 121.) In discussing the length-frequency method of age determination, first applied to fish by Peterson (1892), it is pointed out by Dahl (1909, p. 759) that this method is workable as a rule only up to the third year. He says further (ibid.):

> The method in fact rests on the supposition, that the start in size which the fry of one year possesses compared to the fry resulting from next year's spawning, that this start in size is retained also during subsequent years.
>
> To a certain extent this holds good, where the spawning season is short, and where growth is uniform. But experience shows that a long spawning season, unequal growth in different years and different localities, besides active and passive migrations, combine to blot out the "annual groups" in most species after the lapse of very few years. After the lapse of even one year the single individuals of a year group could not in all cases be recognized as belonging to a certain group and after a lapse of a few years a recognition of the year classes even as groups became almost impossible.

It would seem that the cod falls in that category, which makes it difficult to determine age classes by the length-frequency method for the spawning season is long, the fry carry out passive and many of the adults active migrations, and there is a regional variation in the rate of growth. But in spite of these difficulties year classes up to the third, and in some cases even to the fifth, may be recognized, provided fair-sized samples of fish are measured from each locality that is selected for study.

In European waters Graham (1926, p. 24) found that North Sea cod fry averaged about 3.6 centimeters early in July, 4.8 centimeters early in August, and 7.9 centimeters late in September.

Dannevig (1925, p. 10) found the average size of cod seined near Arendal, Norway, on the Skagerrack, to be 8 to 12 centimeters in October. Fry of these sizes were placed in a rearing pond and attained a length of about 15 centimeters (6 inches) by the following April when presumably about 1 year old.

Off the east coast of Scotland, Fulton (1901, p. 227) found that cod hatched around April were 4½ inches long by November, 5¼ inches by December, and 5⅝ inches by January.

Off the east coast of England, Wallace (1923, p. 17) found that the lengths of yearling cod ranged from 3 to 7 centimeters (1⅞ to 2¾ inches) in July and from 5 to 14 centimeters (2 to 5½ inches) in October, but the number of cod so taken were too few to form dependable modes.

In the Irish Sea, Johnstone et al. (1924, p. 8) report catches of young cod taken by a prawn trawler, as follows: August, 137 fish, 4 to 19 centimeters, average 8.1 centimeters (3.19 inches); October, 64 fish, 9 to 19 centimeters, average 13.56 centimeters (5.34 inches); November and December, 48 fish, 9 to 19 centimeters, average 14.23 centimeters, (5.60 inches).

Off the east coast of Iceland, where the bottom water temperature is around 0° C. a good part of the year and where cod live from the fry stage until they are several

years old, they reach a length of about 7 to 8 centimeters (3 inches) in April when about 1 year old. But in the warmer water off the southern coast of Iceland and around the Faroes "the cod grow much more in their first year." (Schmidt, 1907, p. 16–17.)

Around the Faroes cod spawn from February to May, and by early June the fry are about 1 to 2 centimeters long; by August, 5 to 6 centimeters; and by the following May and June, at the age of 1 year, 9 to 22 centimeters, with an average of about 16 centimeters (6.3 inches). At the end of their second year they average about 30 to 35 centimeters (12 to 14 inches). (Strubberg, 1916, p. 80–84.)

In the Barents Sea cod 1¼ years old were found to average about 12 centimeters (4¾ inches) in length. (Hjort, 1914, p. 129.)

According to these results, European cod grow during their first year to a length of about 6 inches in the North Sea, 5 inches around the Faroes and southern Iceland, 3 inches off the east coast of Iceland, and 4 inches in the Barents Sea. Thus its growth is more rapid in the southern part of its range than in the northern.

Very few catches of cod fry numerous enough for rate-of-growth determinations by means of length frequencies have been made in American waters. Bigelow and Welsh (1924, p. 420–21) cite the 1½ to 3 inch fry caught by Earll (1880) off Cape Ann in June, and the experiment of Smith (1901, p. 307), who obtained records of growth from the survivors of about 2,000,000 newly hatched larvæ which were placed in a lagoon at Woods Hole on January 11. The fry were seined periodically and exhibited the following growth:

TABLE 35.—*Lengths of cod fry seined at Woods Hole, Mass*

Date	Extreme lengths, millimeters	Average length		Date	Extreme lengths, millimeters	Average length	
		Millimeters	Inches			Millimeters	Inches
Apr. 8	29–38	32.9	1.3	May 25	28–68	64	2.5
Apr. 25	34–49	40.0	1.6	June 6	71–76	75.5	3.0
May 13	35–51	42.8	1.7	June 20	73–77	75	3.0

In addition to these, other cod fry have been seined off Woods Hole during spring and summer collecting, and from time to time some of these were preserved and in this way became available for study. These specimens, together with others taken on Nantucket Shoals by the *Albatross II* with a small otter trawl, are listed in the table which follows:

TABLE 36.—*The lengths of cod fry less than 6 inches long taken in miscellaneous catches off southern Massachusetts, from 1913 to 1927*

Locality and date	Number of specimens	Range in size, millimeters	Average size		Locality and date	Number of specimens	Range in size, millimeters	Average size	
			Millimeters	Inches				Millimeters	Inches
Woods Hole region:					Woods Hole region—Contd.				
April, 1913	5	36–44	40	1.6	June, 1916	24	43–60	52	2.0
April, 1921	1	27	27	1.1	July, 1913	3	79–107	97	3.8
May, 1916	7	47–59	52	2.0	July, 1914	2	67–90	79	3.1
May, 1923	7	43–70	56	2.2	Nantucket Shoals region:				
May, 1924	14	38–43	40	1.6	June, 1927	17	61–117	85	3.3

These records give a general idea of the growth of cod fry off southern New England up to the age of about 6 months. At that time (in midsummer) they are about 3 to 4 inches long.

It is but natural that there should be considerable variation in the size of the fry taken in the same catch. Not only is there some difference in the rate of growth among the fry, but the long spawning season makes it possible to catch on the same date fish all of which are less than 1 year old but some of which are as much as 6 months older than others. Thus in July or August 3 and 9 month old cod may be taken together. As a rule, however, although there may be a wide difference between the extreme sizes in a large catch of cod fry, most of the fish are of a rather uniform size, indicating either that they were derived from eggs spawned in some definite area and at a particular time during the spawning season, or that fish of a size tend to school together.

It is unfortunate that no catches of cod fry adequate for length-frequency determinations have been recorded from southern Massachusetts for the fall or the winter. But the many specimens of cod about 5 to 7 inches long observed in the stomachs of fish caught on Nantucket Shoals in September and October indicate that the fry living in this region attain a length of about 7 to 8 inches long when approximately 1 year old.

The scarcity of cod between 10 and 15 inches long taken in our catches on Nantucket Shoals already has been commented upon. Length-frequency data for these sizes are therefore lacking for this region, but some idea of the rate of growth of 1 to 2 year old southern Massachusetts cod might be had from a catch that was observed on Georges Bank. (Fig. 28.) These fish were taken in September and had a well-defined mode at 30 centimeters (about 12 inches). Their scales showed but one annulus, with a wide periphery of summer growth, so they were probably about 1½ to 1¾ years old.

If these fish are of the usual size attained by 1½ to 1¾ year old cod on the offshore grounds in the Gulf of Maine and if the rate of growth of the fish on Nantucket Shoals does not differ materially from this, then we might expect cod in the latter region to be about 14 to 15 inches long by the time they are 2 years of age.

Data on the growth of cod 2 years or more of age have been obtained from the length-frequency distributions of cod caught throughout our fish-tagging operations. Graphs dealing with these fish have already been given (figs. 15 to 24) in discussing the stock of fish on Nantucket Shoals. From these certain groups of fish have been selected to show rate of growth and are presented in the table which follows. The mean length of the cod in each group was calculated by selecting arbitrarily as many inch classes (usually three or four) as can be identified with a mode. For example, the average size of the *B* group of July 13–17, 1924 (fig. 16, No. 1), was calculated to be 23.9 inches by obtaining the weighted mean of the 23, 24, and 25 inch fish. This method must admit of some degree of error in locating the modal length of each group, but this is unavoidable because it is impossible to obtain the true mean length of the fish included in a "dominant group," as the limits of such a group are in this case unknown. But even if these limits were known, they probably would alter the calculated length but little.

The value of these calculations depends largely on whether or not we are dealing for the most part with fish from the same population. That we are doing so is suggested by the ease with which the dominant groups *A* to *D* (fig. 24) can be identified from the time they were first found on Nantucket Shoals until they passed out of

the picture there. Furthermore, in spite of certain unknown factors that must of necessity be involved in a calculation of this sort, the data have an unusual degree of reliability because they include the records of thousands of cod living under natural conditions during all seasons.

TABLE 37.—*Rate of growth of cod caught on Nantucket Shoals from 1924 to 1928, as determined from length frequencies*

Symbols on figs. 16 to 23	Average date of capture	Average length of dominant size group	Average date of capture	Average length of dominant size group	Increase in length, inches	Time interval in days	Rate of growth per month of 30 days
B	July 14, 1924	23.9	Sept. 10, 1924	24.6	0.7	58	0.35
B	Sept. 10, 1924	24.6	May 6, 1925	25.6	1.0	239	.15
C	May 6, 1925	19.0	June 9, 1925	19.0	.0	34	.00
C	June 9, 1925	19.0	Aug. 23, 1925	20.2	1.2	75	.50
C	Aug. 23, 1925	20.2	Oct. 8, 1925	21.3	1.1	46	.70
C	Oct. 8, 1925	21.3	Sept. 8, 1926	24.4	3.1	335	.30
D	....do	15.1	....do	18.3	3.2	335	.30
D	Sept. 8, 1926	18.3	May 5, 1927	20.4	2.1	239	.25
D	May 5, 1927	20.4	June 20, 1927	21.0	.6	46	.40
D	June 20, 1927	21.0	Sept. 1, 1927	21.5	.5	73	.20
D	Sept. 1, 1927	21.5	July 17, 1928	24.0	2.5	319	.25

It was interesting to find, as might be expected, that there was a seasonal difference in the rate of growth. Thus in Table 37 the fish included in the two spring records (0.00 and 0.40) averaged 0.20 inch of growth per month, in the four summer records (0.35, 0.50, 0.70, 0.20) 0.44 inch, in the two fall to spring records (0.15, 0.25) 0.20 inch, and in the three records which embraced nearly a year's time (0.30, 0.30, 0.25) 0.28 inch. Accordingly, these Nantucket Shoals cod made their slowest growth from the fall to spring and their fastest during the summer.

At an average rate of growth of 0.28 inch per month the growth per year would be about 3.4 inches. Making allowances for somewhat faster and slower growth, it might be said that, based on the length-frequency method of determination, cod from about 15 to 26 inches long living on Nantucket Shoals increase in length about 2½ to 4 inches a year.

EVIDENCE FROM TAGGED FISH

Our records of growth made by recaptured tagged cod have yielded perhaps the most dependable information, for they are based more on fact than on theory. Of course some degree of error may obtain even here, for we can not be sure that in all cases the growth of a tagged fish was the same as it would have been if the fish had never been tagged. The suppuration which often occurs around the point where the tag is attached to a fish has already been described. It is probable that in a case of excessive irritation normal growth is curtailed; in fact, we have a few instances where cod recaptured a year or so after tagging, in poor condition, had gained scarcely anything in length. But eliminating such records from our calculations and considering only the fish that were in reasonably good to fine condition when recaptured, we are justified in accepting the growths as being almost the same as they would have been if the fish had not been tagged.

The growth records of tagged cod obtained by the tagging vessels *Halcyon* and *Albatross II* and those furnished by fishermen were at first separated in order to determine whether the results varied appreciably, for while all of our recaptures were measured by the same standard and usually by the same person, those of the fishermen may have been measured by a number of different methods. It was found, however, that the two groups of data agreed very well, and, therefore, the records were com-

bined in the table which follows. About one half of these remeasurements were made on Nantucket Shoals by the tagging vessels, while the half which came from fishermen were from fish nearly all of which were recaptured between Rhode Island and Delaware.

TABLE 38.—*Increase in growth registered by Nantucket Shoals cod between the time of tagging and recapture*

Lengths of fish in inches at time of tagging	Number of fish	Average time in months from date of tagging that fish were recaptured	Average increase per month in inches
17 to 20	28	8.4	0.32
21 to 24	58	5.3	.33
25 to 28	54	5.8	.21
29 to 32	35	6.7	.22
33 to 35	6	7.7	.19

The average time of recapture from the date of tagging, given in Table 38, includes many records of fish caught after they had been at liberty only one to three months, but these are balanced by other recaptures made as much as 20 to 24 months later. The average increase per month was obtained from each individual recapture record. Thus, a fish recaptured after two months showing a gain in length of 0.50 inch would be classed at a rate of 0.25 inch per month, as would also a fish taken 12 months later showing an increase of 3 inches.

We are justified in using the increase in length per month to calculate the increase per year because cod recaptured after they had been at liberty for more than one year had not grown at a rate appreciably different from those which had been at liberty only a few months. Data on the 12 to 24 month fish are as follows: Fish 17 to 20 inches long at the time of tagging grew 0.29 inch per month (8 fish); 21 to 24 inch fish, 0.30 inch (10 fish); 25 to 28 inch fish, 0.22 inch (9 fish); 29 to 32 inch fish, 0.25 inch (8 fish); and the 33 to 35 inch fish, 0.19 inch (2 fish).

Among the individual records of fish taken long after tagging are the following: A 28-inch cod gained 5 inches in 18 months; a 26¼-inch cod gained 5.25 inches; a 16¾-inch fish gained 6.25 inches in 20 months; a 16½-inch cod gained 11¼ inches in 24 months; and a 23½-inch cod gained 3 inches in 37 months. This latter fish was in poor condition and its growth was considerably below normal. It was not included in Table 38.

An attempt was made to detect a difference in growth between winter and summer by segregating the recaptured and remeasured cod into two groups. But as none of the fish fell wholly within the winter season, no marked difference in the rate of growth was noted between those fish tagged in the fall (September–October) and recaptured in the spring (April–May) and those tagged in the spring and recaptured in the fall, possibly because in each instance there was a fast and a slow growing period which balanced each other. A seasonal difference in the rate of growth was more evident from our length-frequency data.

According to the growth registered by tagged fish, Nantucket cod 17 to 24 inches long increase in length about 4 inches a year, while fish 25 to 35 inches long increase about 2½ inches a year. These size segregations were made arbitrarily, for it is obvious that there is not a sharp demarcation between the two groups, and as the fish become older there is a gradual decrease in the gain in length that occurs each year.

Increases in growth registered by recaptured tagged fish were very much the same in European waters as off our own coast.

Gains in length shown by the cod tagged in Scottish waters by Fulton (1889–1892) amounted to about one-fourth to one-half inch in several months for fish ranging in length from 14 to 25 inches. The greatest increase was that made by a 15½-inch cod which measured 18 inches about seven months later (Fulton, 1893, p. 190). Fulton believed that the abrasion caused by the tag retarded natural growth. (Ibid., p. 177.)

Schmidt (1907, p. 17) obtained only four dependable remeasurements from recaptured cod as a result of the tagging around Iceland in 1904 and 1905. These fish, about 20 to 24 inches long when tagged, increased about 2½ inches a year. Later tagging experiments done in Faxa Bay, on the southwest coast of Iceland, showed that 8 of the cod (40 to 66 centimeters long when marked), recaptured 10 to 14 months later, had increased in length about 18 centimeters (7 inches) per year. This was a more rapid rate of growth than was found on the north and east coasts of Iceland, where the water is colder. (Saemundsson, 1913, p. 30.)

Three cod (38 to 43 centimeters) tagged off the Faroes in August and recaptured in May, nine months later, had increased in length about 12 centimeters. (Winge, 1915, p. 13.) In Danish waters some lots of tagged cod (35 to 57 centimeters) increased about 12 centimeters (4½ inches) during the first year after marking, while others (45 to 65 centimeters) increased only 7 to 9 centimeters. (Strubberg, 1922, p. 33.)

According to these few records obtained from recaptured tagged cod, fish from about 14 to 25 inches long grew about 1½ to 3 inches in length during one year off the east coast of Scotland, 3 to 4½ inches in Danish waters, and as much as 6 to 7 inches off the Faroes and the southwest coast of Iceland. The latter appears to be much too high, especially when it was found that fry living around the Faroes and southern Iceland grew more slowly than those living in the North Sea (p. 99). The data on which these records are based are very meager, and, as Saemundsson (1913, p. 30) says, with respect to the Icelandic fish, they should be accepted with caution. If reliable remeasurements had been obtained from a large number of recaptured tagged fish instead of but few it is probable that cod ranging in length from 14 to 26 inches, living in the North Sea, would show an average increase of about 3 inches a year, with the smaller fish gaining somewhat more than the larger; in other words, very much the same rate of growth as was found for southern New England cod.

EVIDENCE FROM SCALE STUDIES

No attempt will be made here to give a detailed account of the studies that have been made on fish scales. This has been well covered by such authors as Thomson (1904), Dahl (1909), Taylor (1916), Lee (1920), Van Oosten (1929), and Graham (1929b). Growth of the cod's scale has been described by Cunningham (1905) and Winge (1915) and scales in general by Paget (1920) and Creaser (1926).

In this paper I have compared the growth and age of the cod according to its scales with that shown by length frequencies and the actual growth made by marked fish. Data are also presented concerning the zones of growth laid down on the scales, particularly the first growth zone and its significance in throwing light on the migrations of the cod.

The scales of cod afford perhaps the most ready means for determining age and rate of growth. Up to the sixth or seventh year they are reasonably dependable, but beyond this age they become increasingly difficult to interpret. Occasionally a very old fish has remarkably well-defined scales, and such fish assist in placing the more doubtful ones in their approximate year class.

Not only has the scale method of age determination for the cod been verified by tagged fish, but scales have been compared with otoliths and skeletal structures. Winge (1915, p. 19) found that the number of growth zones laid down on the otoliths agreed very well with the number of winter or slow-growing zones on the scale. The oldest cod examined by Winge was 13½ years old according to its scales, compared with a determination of about 14½ years according to its otoliths. Cunningham (1905, pp. 137–139), working with rather young cod, found that the number of annual zones laid down on the scales and on the otoliths was the same. He also utilized the pectoral girdle and the vertebræ, but found these skeletal structures to be untrustworthy as a means of determining age. Saemundsson (1923, p. 6–7) used otoliths, the coracoid, and the pelvic bone in determining the age of Icelandic cod and was able to check the age of comparatively young otoliths with the scales. Graham (1929a, Pt. I, p. 42) concludes that by using the precise method of making scale tracings (Graham, 1926) the majority of cod scales will give a correct age reading. He found, too, that otoliths showed some degree of correspondence with the scales.

Typical cod scales under magnification somewhat resemble a thumb print. They are usually oval in shape and are marked with concentric rings, or circuli, the first one of which is generally offcenter, away from the pigmented part of the scale. The numerous circuli form growth zones, each of which, with the exception of possibly the first growth zone which may have all its circuli about equally spaced, is divided into two parts—one composed of widely spaced circuli, the result of rapid growth, and the other of closely spaced circuli formed during a period of relatively slower growth. (Fig. 29.) The wide and the narrow circuli in each zone, when taken together, are believed to mark about one year of growth. Winge (1915, p. 10, figs. 5*a* and 5*b*) shows by means of tagged Faroe cod, which were recaptured one to two years later, that a "minimum," or annulus, is formed during the winter. That one annulus forms each year has been found on the present investigation, too, for those tagged fish recaptured a year later had the additional year of growth registered on their scales. (Fig. 30.)

It is the seasonal variation in growth registered on the scales that permits the age of the fish to be calculated by this means. And as there may be regional differences in growth dependent upon the physical and biological conditions of the fish's immediate environment, each cod region that differs appreciably from another in temperature, food supply, etc., offers a separate problem with respect to the interpretation of the growth zones on the scales.

Winge (1915, p. 12) found that cod from the Faroes grew more rapidly and laid down widely spaced circuli on their scales in summer and closely spaced circuli in winter. It was his opinion that cod in other localities probably do the same. Saemundsson (1923, p. 27), who worked with the cod around Iceland, found, according to the scales and otoliths, that the most rapid growth took place on the south coast, with a gradual decrease as one goes to the right around the island. The slowest growth was found on the east coast. At Arendal, Norway, Dannevig (1925, p. 21), who experimented with young cod in a rearing pond which had very much the same characteristics as the sea which it adjoined, raised some of the fry to an age of 2½ years.

FIGURE 29.—Scale of a cod 17 inches long, in its third year, showing narrow and wide circuli. The scale on the left is focused to accentuate the ridges of the platelets, or sclerites, while the one on the right is focused to show the basal parts

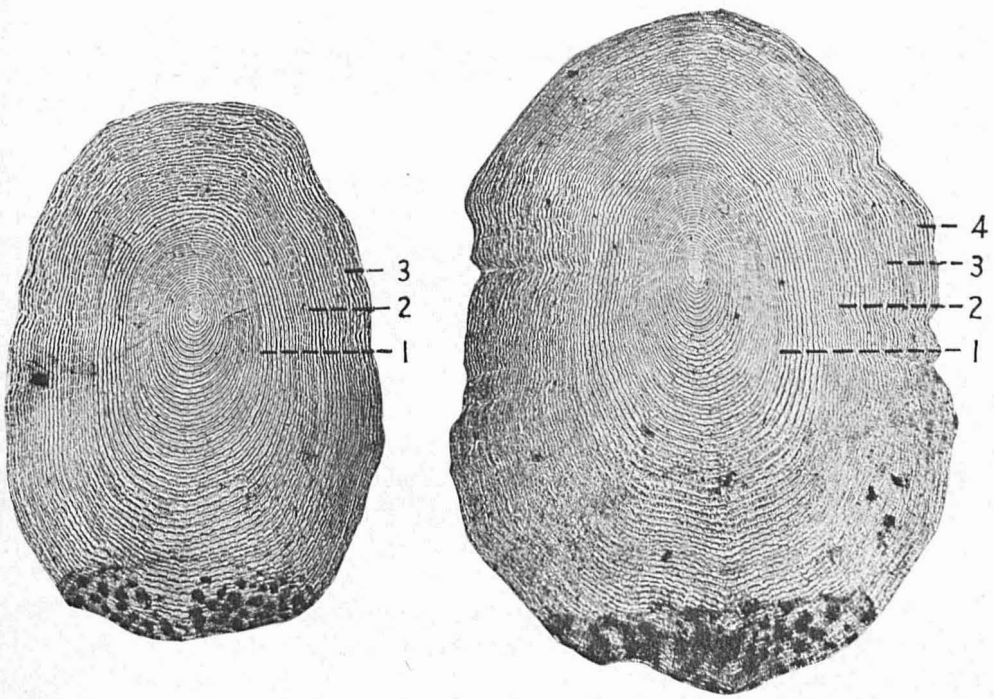

FIGURE 30.—The scale on the left shows a cod in its fourth year, tagged on Nantucket Shoals, October 17, 1924, length 25¾ inches. The one on the right is from the same fish in its fifth year, recaptured on Nantucket Shoals, October 24, 1925, length 30½ inches (+ 21)

He found that the formation of the closely spaced circuli took place in the late summer or autumn and the widely spaced circuli during the winter. Because of this, he states that the term "winter zone" should be abandoned and suggests using "zones of minimum sclerites, or resting zones." Dannevig intimates, however (ibid., p. 22), that scales taken from cod living under natural conditions might have produced different results. Duff (1929, p. 11), who studied the peripheral circuli of cod 50 to 55 centimeters long caught on the Sable Island Banks (Nova Scotia), found that the zone of broad circuli was formed on the scales from March to July, inclusive, and most of the narrow circuli from August to December. Such few circuli as formed during January and February were narrow.

Ordinarily the widely spaced circuli on the scales of southern New England cod are laid down from April to September or October and the closely spaced circuli during the remainder of the year. Some of them, however, begin adding widely spaced circuli as early as February and March and the narrow circuli may start to form as early as August. Occasionally a fish is found that exhibits rapid scale growth during the winter as well as the summer. For example, a sample of 51 adult cod caught off Atlantic City, N. J., within the period from March 23 to April 2, 1928, showed the following peripheral growth on their scales: 39 fish had only closely spaced circuli; 11 fish had from 1 to 4 widely spaced circuli, indicating that more rapid growth had begun as early as February (if not January) and the beginning of March; while 1 fish had 6 very wide circuli, which appeared to represent a full year's (its fourth) growth.

In regions where food and temperature fluctuate widely we can expect, and often do find, that the scales are more sharply defined as to age than in regions where more stable conditions obtain. J. S. Thomson (1904, p. 99) made observations on a whiting (*Gadus merlangus*) from the time it was a month or so old (10 to 20 millimeters) in May, 1902, until it died in July, 1903, and was 8½ inches long. The fish had been fed regularly during this time and the water temperature in the aquarium was fairly constant, although there was a marked difference between summer and winter. Upon examination the scales of this fish showed uniform growth, without distinct areas of summer and winter growth such as was registered on scales of other young whiting taken from the sea. Thomson believed, therefore, that it is variation in food supply rather than variation in temperature which influences metabolism and indirectly brings about the formation of annual rings on scales. Mention has already been made of H. Thompson's experiments (1926, p. 4), showing increase in growth due to an ample food supply; of Fulton's experiment (1904, p. 162), showing that a low water temperature retards feeding and, as he suggests, growth; and of Cutler's experiment (1918, p. 488), from which he concludes that temperature and not food caused the summer and winter bands on the scales of flounders.

Winge (1915, p. 13) throws some light on the rôle which the environment plays in the spacing of the circuli on the cod's scales. Three of his cod which had been tagged August 16, 1911, off the Faroes (about 15, 16, and 17 inches long), were recaptured on the same ground, two on May 17 and one on May 25, 1912. Scale samples had been taken at the time of tagging and again when the fish were recaptured nine months later. As the fish were recaptured in the same place where they had been tagged, it was assumed that they had not migrated away and had lived together under the same conditions during that time. Winge plotted curves showing the distance between the circuli, utilizing five scales for each fish. Not only did each of the five scales from the same fish exhibit the same fluctuations but the scales for all three fish showed that they had responded in the same way to environmental

conditions between the time of tagging and recapture and also for some time previous to then. A mean growth curve of the five scales examined from each of these fish is given in Figure 31, in which the broken line *A* sets off the growth of the scales for

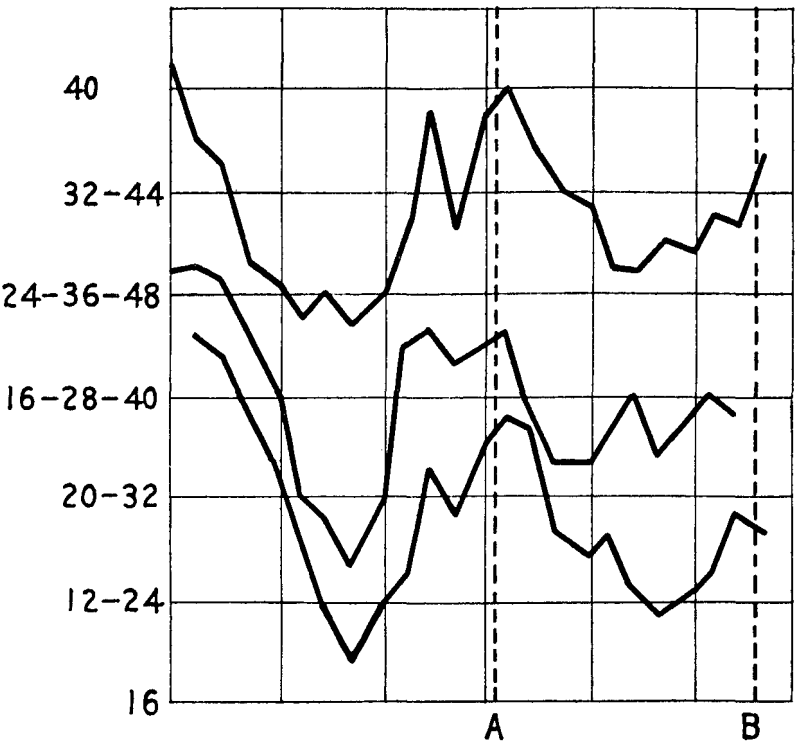

FIGURE 31.—"Mean scale" curves for three companion cod taken off the Faroes. *A*, at the time of first capture, August 16, 1911; *B*, at the time of second capture, May 17-25, 1912. (After Winge)

a time preceding the capture of the fish on August 16, 1911, and *B* the growth between then and May 17 to 25, 1912. The scale of another cod recaptured 6 to 8 miles away from the three fish just mentioned showed different fluctuations in growth.

Winge's results, just cited, throw so much light on the question of growth, as registered on the scales of the cod according to the response of the fish to its environment, that I have examined scales from New England tagged cod in order to see whether they, too, would exhibit this result.

The scales were studied of several cod that had been tagged together and which were recaptured in the same locality more than a year later. Fish of about the same size were selected. Starting from the focus and running along a radius extending to the periphery, the distance between the circuli was measured under rather high magnification and the results were arranged graphically. But in none of the six or eight fish examined was I able to get such a clear-cut agreement in the fluctuations of growth as was obtained by Winge. For example, a comparison was made of the scales of 2 Nantucket cod tagged May 6, 1927, and recaptured by the *Albatross II* July 19, 1928. These fish were 18½ and 19½ inches long, respectively, on the former date and both of them were 22 inches long on the latter. Although these cod had very likely lived in close association for over a year, one of them gained 1 inch more in length than the other; and, although each of them had added an annulus to its scales,

the minor fluctuations in growth, circulus compared with circulus, did not appear to correspond.

The first zone of growth on the cod's scales presents difficulties, for it is often hard to calculate whether it represents the first full year of growth or only part of a year. Scales first appear when cod fry are about 1½ inches (38 millimeters) long, about six to eight weeks after hatching and at about the time they take to the bottom. As cod larvæ hatch from fall to late spring, it is possible that the formation of the first "annulus" might be completed on the scales of some fish when they are only 6 or 8 months old, while others may be as old as 12 or 14 months.

It is assumed that the widely spaced circuli which marks the beginning of the second year's growth begin to form the first spring following the fall to spring that the fish was hatched. The demarcation between the first annulus and beginning of the second zone of growth is generally sharp on the scales of cod living off our coast, but is not so clear on the scales of some European fish. Graham (1926, p. 346), studying North Sea cod, measured the distance between circuli on the cod scale very much as did Winge (1915) in order to determine the limit of the first "winter" zone. He gives his technique (ibid., p. 351) as follows:

> The width of the narrowest pair of adjacent sclerites in the innermost suspected narrow zone is taken on dividers and fitted to the width of the widest sclerite in the adjacent wide zone outside it. If the dividers fall within it the narrow zone is the first "winter" ring. If they span or straddle the wide sclerite the criterion rejects the suspected narrow zone.

Graham did his measuring directly on the projected scale, magnified about 100 diameters. While this method apparently is helpful in identifying a secondary minimum within the first zone of growth, it, of course, can not determine whether the 15 or 20 circuli within the first zone represents 6, 8, or 12 months of growth.

While the trend of growth should be the same on all typical scales found on the same fish, there is considerable variation in the number of circuli, depending on what part of the body the scale is found, as already pointed out by various investigators. The small scales along the back, near the head, or on the belly do not have as many circuli as the large scales along the side. And even two scales lying almost side by side may vary somewhat in the number of their circuli. For example, Winge (1915, p. 6) found on a fish with two distinct minima on all of its scales that a large scale from between the lateral line and the second dorsal had 48 circuli, a scale from the base of the pectoral had 45, and a scale from the dorsal area, obliquely in the rear of the eyes, had 32. Because of this variation, it is difficult to compare the fluctuations in growth as between two scales from the same fish or between scales from two fish of about the same size, living together, unless comparable scales having about the same number of circuli are selected.

In order to gain some idea of the average number of circuli that form on the scales of southern Massachusetts cod during their first full year of growth, the scales of fish less than a year old were examined, with the following result:

TABLE 39.—*Number of circuli on the scales in relation to length of juvenile fish*

Number of specimens	Length	Range in number of circuli	Average number of circuli	Number of specimens	Length	Range in number of circuli	Average number of circuli
1	*Millimeters*				*Millimeters*		
2	21–30			4	71–80	5–8	6.1
7	31–40	1	1.0	8	81–90	5–13	7.5
9	41–50	1–4	1.7	5	91–100	6–9	7.8
6	51–60	1–6	3.4	1	101–110	9–11	10.0
	61–70	2–8	5.0	2	111–120	9–11	10.0

These tiny scales were sampled by scraping a scapel along the side of a specimen and wiping on a slide. By so doing, scales were taken from a large part of the body and they included the smaller ones along the back and near the median line of the belly as well as the larger ones along the middle of the side. The smaller scales had fewer circuli than the larger, so that the count obtained from any one fish might run from 2 to 5, 4 to 6, 5 to 8, etc. A variation of this sort is shown by Meek (1916, p. 219), who records cod of about 5.8 centimeters taken in July, with 0 to 2 circuli; and in October, fish 6.9 centimeters long with 2 to 4 circuli, and fish 11.1 centimeters with 7 to 9 circuli on their scales.

The fish listed in Table 39 were taken during several collecting years. In general, the smaller ones were caught in April and May and the larger in June and July. Accordingly, southern Massachusetts cod 4 or 5 inches long in the summer have about 8 to 12 circuli on their scales. Such fish are less than 1 year old, so that by the time a full year has been completed the number of circuli should be appreciably greater than 12. Young cod caught between Cape Cod and eastern Maine had nearly the same circulus count, with respect to their size, as did the southern Massachusetts cod, but as we had only 17 young fish from Maine (50 to 120 millimeters long) taken not from April to July but from August to September, a fair comparison could not be made.

Five cod caught on Nantucket Shoals in October, selected at random, had the following circulus count on their scales: Length of fish 156 millimeters, scale circuli 21 to 22; 168 millimeters, 21; 171 millimeters, 21; 189 millimeters, 21; 197 millimeters, 19 to 21. All these scales had only one zone of growth, but as they were caught well into the fall they probably were nearly 1 year old. Another specimen 178 millimeters long, taken with the above ones, had 13 closely spaced circuli in the first zone of scale growth, followed by 5 widely spaced circuli. This fish apparently hatched in a different season than the others.

It is not understood why the 156 millimeters cod had as many circuli as the 198 millimeter fish, for whether they were the same age, with one growing faster than the other, or whether they grew at the same rate, with one being older than the other, one might expect the larger fish to have the more circuli on its scales.

According to the scale growth of the few 156 to 197 millimeters cod, presumably nearly 1 year old, taken off southern Massachusetts, we could expect that cod living in this region, from the fry to adult stage, should have about 20 to 22 circuli on their scales within the first zone at the end of about one complete year of growth. To determine this, the scales of adult Nantucket cod were examined. The first growth zone on some of these scales, no doubt, represented somewhat less than a full year's growth and on others somewhat more, but, as a large sample was utilized, the average must have been just about between.

TABLE 40.—*The number of circuli formed on the scales of Nantucket Shoals cod within the first zone of growth (presumably the first year's growth), segregated according to the size of the fish*

Length of fish, inches	Number of fish	Average number of circuli in first zone of growth	Length of fish, inches	Number of fish	Average number of circuli in first zone of growth
20	6	22.0	31	17	19.9
21	4	18.5	32	17	18.8
22	11	20.4	33	2	18.0
23	12	19.0	34	5	21.2
24	19	20.3	35	5	21.6
25	35	19.7	36	8	18.9
26	66	19.7	37		
27	79	20.1	38	4	19.0
28	63	20.8			
29	55	20.9	Total	438	20.2
30	30	29.7			

As the scales of this sample of adult Nantucket Shoals cod had an average of about 20 circuli in the first growth zone of their scales, or about the same number as the 156 to 197 millimeters yearling cod just mentioned, it is evident that approximately this number is formed when the fish have completed their first year. Therefore when the first growth zone contains relatively few circuli, say 10 to 15, it is apparent that these represent less than one year's growth, and when the number is large, say over 25, it is probable that they are the result of more than one year's growth.

One striking result brought out by the tabulation given in Table 40 is that the average number of circuli in the first growth zone on the scale is about the same, regardless of whether the fish were as small as 22 or 24 inches long or whether they were as large as 36 or 38. This is as it should be if we are to believe that cod do not shed their scales but retain them from the time they first form, throughout their lifetime. Regenerated scales which take the place of those which are lost (through injury) can always be easily detected by a central area without circuli, which often takes up about one-half of the entire scale. Creaser (1926) and Van Oosten (1929) have established experimentally the correctness of this interpretation of these central areas devoid of circuli.

Segregation of cod stocks as shown by scale structure.—Perhaps the greatest value to be obtained from a study of the first-zone circuli is the light which it throws on the origin and migrations of the cod, for it seems apparent that if the growth of the scales from two separated grounds should differ, then no general intermingling of the cod dwelling in the two regions in question will have occurred. The fact that Winge (1915, p. 15) found that cod living around the Faroe Islands usually form only about 12 circuli on their scales during their first year of life, much fewer than Nantucket cod, led to an examination of cod scales from various localities along the New England coast. The chief object of this was to determine whether there was a noticeable difference in the first-zone circulus count, on the average, between the cod living to the northward of Cape Cod and those living to the southward; and, if so, whether the difference was great enough and consistent enough to separate the New England cod into two or more great stocks of fish.

TABLE 41.—*The number of circuli formed within the first zone of growth on the scales of cod living north of Cape Cod compared with those living to the southward*

Locality	Date	Number of fish	Average length, inches	Average number of circuli within the first growth zone of scale
North of Cape Cod:				
Browns bank	September, 1928	21	23.1	15.8
Northeast Georges bank	January, 1924	53	38.2	13.9
Do	September, 1928	41	28.0	16.0
Mount Desert, Me	August, 1924	40	16.1	15.4
Do	August, 1928	35	18.7	16.9
Platts bank	April, 1927	35	26.0	14.9
Stellwagen bank	July, 1924	29	25.3	15.6
Do	October, 1925	44	22.6	14.9
Total		298		15.3
South of Cape Cod:				
South Channel	June, 1929	36	26.4	20.6
Nantucket Shoals	Summer, 1923	573	26.3	20.1
Do	Summer, 1927	32	22.5	19.0
Do	Summer, 1928	62	22.2	20.1
Cholera bank, N. Y	November, 1927	50	25.2	21.2
Do	November, 1928	36	23.9	21.3
Atlantic City, N. J	March, — April, 1928	51	25.1	21.3
Total		840		20.5

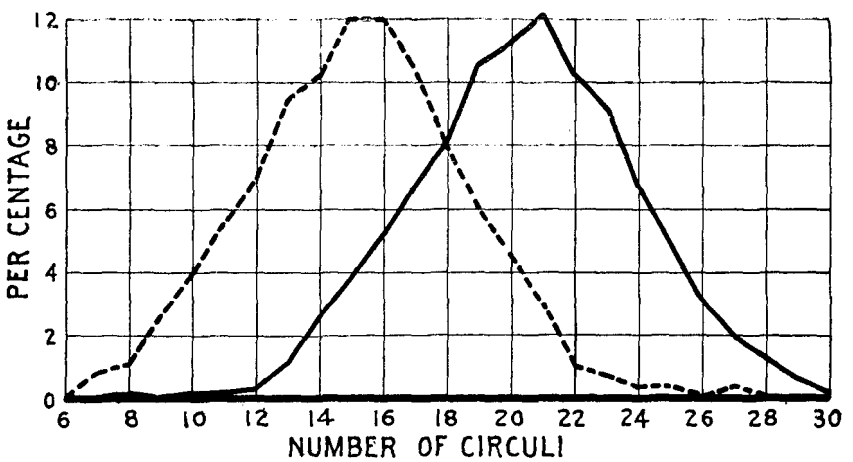

FIGURE 32.—Frequency-distribution of the number of circuli within the first zone of growth on the scales of the cod listed in Table 41. Broken line for the north of Cape Cod; solid line for the south of Cape Cod. Smoothed ounce by a 3-class moving average

There is unquestionably a significant difference in the count of the first-year scale circuli between the cod living north of Cape Cod and those living to the southward in the samples presented in Table 41. All these scale samples were selected at random, without respect to the size of the fish, so that small, medium, and large cod are included in almost every group of scales that was studied. Both the north of Cape Cod and the south of Cape Cod scales gave a simple mode in the frequency distribution of the first-year circulus count, as shown in Figure 32.

Regardless of what may have caused this marked difference (whether differences in the rate of growth or in the time of spawning), the fact that it exists indicates that the stocks of cod living north and east of Cape Cod are for the most part distinct from those living to the southward in that the fish from the two regions do not intermingle in a large way.

This conclusion is supported by the results of our tagging both to the north and the south of Cape Cod and was much the same conclusion arrived at by Smith some 25 years before (p. 8), when he found that none of his cod were reported recaptured to the northward of Cape Cod.

As most of the cod given in Table 41 averaged from 22 to 28 inches long and were from 3 to 5 years old, it is apparent that up until that age most of them remained in the general vicinity of the region where they first took to the bottom as fry. If this were not the case and if there were an extensive intermigration of cod between Nantucket Shoals and grounds to the northward, then we could expect very little difference in the count of first-year circuli between the fish living to the northward of Cape Cod and those living to the southward.

No scale samples were obtained from cod living in the western part of Georges Bank, intermediate between the northeastern part of the bank and the Nantucket-South Channel region, so we do not know if the fish from there have a first growth-zone circulus count that falls somewhere between 15 and 20. But a sample of scales taken from 45 cod caught May 3, 1927, on the Chatham grounds 13 miles northeast of the most northern tagging ground on Nantucket Shoals had an average of 18.1 first-zone circuli, which number falls between the averages of 14.9–15.6 obtained on Stellwagen Bank and the 19–20.6 found in the Nantucket-South Channel region.[17]

The fact that the scales of cod caught on the Cholera Bank near New York City and off Atlantic City, N. J., agree in circulus count with those from the Nantucket Shoals region and disagree with those from the north and east of Cape Cod is significant, for we have here further proof that the grounds off southern New England supply a large part of the cod which migrate each winter to the Rhode Island-North Carolina region.

Beyond the first growth zone the differences in scale circulus count between the cod living north of Cape Cod and those to the southward tend to disappear, so that from the third year on the count is virtually the same for both groups of fish.

Age and rate of growth of cod as determined from their scales.—Lea's (1910) method of determining the annual growth[18] of fish by means of their scales has been used by various investigators with more or less success. It was based on the supposition that the scales and body of a fish grow at proportionately the same rate, at least nearly enough so that the lengths calculated for each year of life would be essentially correct. Other investigators using this method have found that, although it is workable, corrective factors must be established for each species because, as Lee (1920, p. 21) points out, the ratio of length of the scale to the length of the fish changes with age.

Thompson (1923, p. 75) points out in the case of the haddock that the scales first appear along the flank of the body and then only when the fish has reached about 3 centimeters in length and that the size of the first platelet is proportionately smaller than that of the fish, so that about a half centimeter must be added to the calculated first-year size. Scales which appear later on other parts of the body may increase this error to as much as 2½ centimeters. Cod scales, too, appear when the fry is about 3 centimeters long, and the first ones are found along the sides of the body.

[17] The South Channel scales were obtained from fish caught on the extreme western edge of South Channel in about longitude 69° 24′ W., latitude 41° 17′ N., which is to the southward of the Chatham grounds and which might, in fact, be termed the eastern edge of Nantucket Shoals.

[18] Annual growth is calculated by measuring the growth zones along any convenient radius on the scale and comparing each zone with the total length of the radius selected and the total length of the fish.

Winge (1915, p. 11), working with the cod, concluded that there was a close agreement between the growth of the scales and that of the fish. He selected 7 scales from each of 4 fish (31 to 43 centimeters long) at the time of tagging and again 1 to 2 years later, when these fish were recaptured (when 43 to 66 centimeters long.) As a result he found that each of the scales examined from the same fish increased in size in approximately the same proportion and that in each case the "increments of growth in scale and cod, respectively, are very nearly directly proportional." However, Huntsman (1919, pp. 65–66) points out that the scales of Winge's smallest cod had grown somewhat faster than the fish, while the scales of the larger cod had grown proportionately less than the fish, and states that "these results indicate a definite change in the growth of the scale relative to the growth of the fish, namely, an early more rapid and a later less rapid growth. This is similar to what I have found for other fish by a different method." Huntsman (1918a) discusses the errors resulting from calculating lengths from the annuli formed on the scales and describes a method for reducing the degree of error. Duff (1929, p. 10) concurs with Huntsman's views, for he found that the rate of growth of the cod and its scales are not equal but vary throughout the year, and that the scales of small fish were longer in proportion to the length of the fish than the scales of large cod.

Lee (1912, p. 15) found that on herring and haddock scales the calculated lengths attained at 1 year of age were larger for the younger fish than for the older. For example, the scales from one lot of haddock made it appear that on their first birthday the 2-year-old fish averaged 18.3 centimeters; the 3-year fish, 17.6 centimeters; the 4-year fish, 16.6 centimeters; and the 5-year fish, 15.1 centimeters. This same progressive decline obtained for the second and succeeding years, making it seem that with increasing age the fish showed a decreasing rate of growth in the calculated values for each year of their lives. This is called by Lee "the phenomenon of apparent change in the growth rate." Thompson (1923, p. 15) concurs with the findings of Lee in regard to the haddock, for he found that while there was little error if 1+-year old haddock were used in calculating the size attained at 1 year of age the error increased as the scales from older fish were examined.

Whether the rate of growth calculated from cod scales will show a progressive decrease, as was found with the scales of haddock and certain other fish, is not definitely known at present. According to the sample of scales given in Table 42, there appears to be a slight tendency of this sort which, although not shown by the averages, manifests itself in the 6, 7, and 8 inch values of the III, IV, and V year classes.

TABLE 42.—*Length attained at the completion of the first growth zone as calculated from the scales of Nantucket Shoals cod of various ages caught during the summer of 1923*

Age of scale	Calculated length in inches at completion of first growth zone												
	3	4	5	6	7	8	9	10	11	12	13	Total	Average
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Inches*
II					5	8	1	1				15	7.86
III	3	5	16	17	29	19	9	4	5			107	6.93
IV	1	8	28	81	100	65	23	21	10	1	1	339	7.18
V		2	11	22	15	6	8	10	3			77	7.18
VI			2	4	3	7		4	1	1		22	7.91
VII			1		3	1	2		1			8	7.87
VIII			1						1			2	8.00
IX			1	2								3	5.66

The number of fish included in the III, IV, and V year classes in this table appear to be sufficient to give a good idea of the frequency distribution of lengths at the completion of the first growth zone for this particular sample of fish. Thus the III and the IV year olds present simple modes at 7 inches, while the V-year fish have two modes, at 6 and at 10 inches, respectively. This does not necessarily imply that the V-year fish during their first year of life were divided into slow-growing and fast-growing groups. What is more probable, the fish may have originated from different spawning periods, for the 6-inch fish might have come from eggs deposited late in winter, while the 10-inch fish could have hatched early in the winter. If this were so the difference in the calculated first-year size (between 6 and 10 inches) could be due largely to a difference in age and not to rate of growth.

The rôle of the circulus count in defining the first full year of growth already has been discussed.

In order to show the relation between the calculated lengths at the end of the first year and the number of circuli formed in the first growth zone, most of the III, IV, and V year scales included in the preceding table have been arranged in Table 43 according to number of first-zone circuli.

TABLE 43.—*Relation between number of first-zone circuli and calculated length at the formation of the first annulus*

Circuli in first zone	Average length, in inches, calculated from first growth zone	Fish	Circuli in first zone	Average length, in inches, calculated from first growth zone	Fish	Circuli in first zone	Average length, in inches, calculated from first growth zone	Fish
8–9			16–17	6.0	56	24–25	7.8	58
10–11	3.3	1	18–19	6.2	94	26–27	9.2	19
12–13	5.1	1	20–21	7.0	123	28–29	10.0	5
14–15	4.3	4	22–23	7.4	103			
	5.5	39						

It is significant that the calculated lengths of fish with 20 to 21 circuli in the first-growth zone of their scales averaged 7 inches, for this agrees with the 7 to 8 inches estimated as the average size at 1 year attained by southern New England cod, based on collections of juveniles. In Table 44, which follows, therefore, the extremes in the calculated sizes for each age group are due partly to a difference in age, as measured by months. This is particularly evident in the I-year class, which may include individuals as young as about 8 months and as old as about 15 months, but would not be so evident with the higher age classes, for the first year's discrepancy, not being cumulative, would tend to be of less and less importance in comparison with the actual differences in the rates of growth which do exist.

TABLE 44.—*Frequency distribution of the calculated lengths at the end of each year of life, as determined from the scales of cod caught on Nantucket Shoals during the summer of 1923*

Length in inches	Complete years of growth									
	1	2	3	4	5	6	7	8	9	10
3	5									
4	34									
5	104									
6	131									
7	147									
8	74	1								
9	40	2								
10	30	8								
11	7	30								
12	1	39								
13		70								
14		76	1							
15		94	4							
16		85	18							
17		80	28	1						
18		49	48	1						
19		23	57	1						
20		10	82	5						
21		5	94	17	1					
22		1	110	29						
23			51	58						
24			38	80	2					
25				20	103	11	1			
26				4	72	17				
27				2	49	26				
28					21	22	3			
29					9	11	3	1		
30					4	13	7			
31						8	3	1		
32						2	8	1		
33							8	3		
34							3	2	1	
35								2	1	
36								3	1	
37									2	
38									1	2
39										1
40										1
41										1
Total	573	573	557	450	113	36	13	6	4	1
Average length	6.7	15.1	20.8	24.8	27.7	31.1	33.6	36.1	38.7	41.0

These calculated sizes for each year of life may be subject to a small correction because body and scale growth are not in exact proportion. But that they are approximately correct is indicated by their close agreement with the ages with respect to a known size, of the samples of fish listed in the table and graph which follow:

TABLE 45.—*Age of cod as determined from the scales*

Length in inches	Summer-caught cod, by age and size																	
	South Channel, June, 1929					Nantucket Shoals, May to September, 1923						Nantucket Shoals, July, 1924						
	3½	4½	5½	6½	7½	2½	3½	4½	5½	6½	7½	1½	2½	3½	4½	5½	6½	7½
12																		
14																		
15																		
16												1						
17																		
18													1					
19	2																	
20						2							1	1				
21	2					1	3							17				
22			1				5	1					2	32				
23	2						8	2						70	1			
24		2					10	8						69	7			
25		3					14	17						56	21			
26		1					9	37						21	22			
27		2	1				6	41	5	1				8	26	2		
28		1	4					40	7	1					26	12		
29			3					30	9	4					18	16	1	
30			4					16	9	3					15	24	4	
31			2					10	4	2					13	29	4	1
32				1	1			1	5	1					1	22	1	
33				1					2	2						9	7	1
34				1	1				2	4						10	6	
35										1	2					2	2	
36										7	2						1	2
37																	2	3
38											2						1	
40																	1	1
41																		1
Total	6	9	15	3	2	3	55	203	43	26	6	1	4	274	150	126	30	9
Av. length	21.0	25.6	28.6	33.0	33.0	20.3	24.4	27.4	29.8	32.5	36.3	16.0	20.5	23.8	27.4	30.8	33.3	36.4

TABLE 45.—*Age of cod as determined from the scales*—Continued

Length in inches	Summer-caught cod, by age and size												Autumn-caught cod, by age and size				
	Nantucket Shoals, July, 1928					Summary							Nantucket Shoals, October, 1923				
	1½	2½	3½	4½	5½	1½	2½	3½	4½	5½	6½	7½	2¾	3¾	4¾	5¾	6¾
12	1					1											
14																	
15																	
16																	
17		1				1											
18							1										
19							1										
20			1					3									
21			2	1			3	3	1				4	1			
22				1			1	22	1				2				
23			2				2	39	1	1			6	1			
24			2					82	3					3			
25			1					80	17					5	1		
26				1				70	42					11	5		
27				1				30	61					11	21	1	
28			1	2				15	71	8	1			14	31		
29									67	23	1			3	28	3	
30									48	28	5				27	5	
31									31	37	7				13	3	
32					1				23	36	6	1			5	2	
33									2	27	3	1			1	2	
34										11	10	1				2	
35										12	11	1				2	
36										2	3	2				1	1
37											8	4					1
38											2	3					
40											1	2					
41											1	1					
												1					
Total	1	1	9	6	1	2	8	344	368	185	59	17	12	49	132	21	2
Average length	12.0	17.0	22.2	24.3	31.0	14.0	20.0	23.8	27.4	30.4	32.9	36.0	21.2	25.6	27.9	30.5	34.5

Length in inches	Autumn-caught cod, by age and size																		Winter-caught cod, by age and size, Atlantic City, N. J., March, 1928			
	Nantucket Shoals, October, 1928						Cholera bank, November, 1927			Cholera Bank, November, 1928				Summary								
	1¾	2¾	3¾	4¾	5¾	6¾	2¾	3¾	4¾	1¾	2¾	3¾	4¾	1¾	2¾	3¾	4¾	5¾	6¾	3	4	5	6
12		1												1									
14		1												1									
15		3												3									
16		1								1				2									
17		1												1									
18			1												1								
19			2	1			1				1				4	1							
20			6				1				4	1			15	2				1			
21			1	1			1	5				1			4	7							
22			2	1				7			1	3			9	12					2		
23				3			2	8				6			2	20				2	2	1	
24				2	1			6				1	1			14	3				11		
25				1	3			3	2			3	1			18	11				14	1	
26					4			4				2	1			17	26	1			3		
27					3							1	2			15	36				6	1	
28					3								1			3	32	3				1	
29													1				28	5			1	3	
30													1				14	3				1	
31													1				6	2					1
32					1												1	3					
33						1												2	1				
34																		2					
35																		1	1				
36																			1				
37																							
38																							
40																							
41																							
Total	7	12	9	14	1	1	5	33	2	1	6	18	9	8	35	109	157	22	3	3	39	8	1
Average length	14.9	20.1	22.6	26.3	32.0	33.0	21.2	23.2	25.0	16.0	20.1	23.5	27.4	15.0	20.6	24.3	27.7	30.5	34.6	22.0	24.9	27.5	31.0

The calculated lengths (broken line) in Figure 33 include a large part of the fish given in Table 44, while the lengths at time of capture include all those given in Table 45. The calculated lengths suggest that during their earlier growth the fish had been slightly smaller at each year of age than the fish of those same ages proved to be when measured. But the difference is so small that the curves confirm rather than contradict each other with respect to the approximate sizes attained at particular ages.

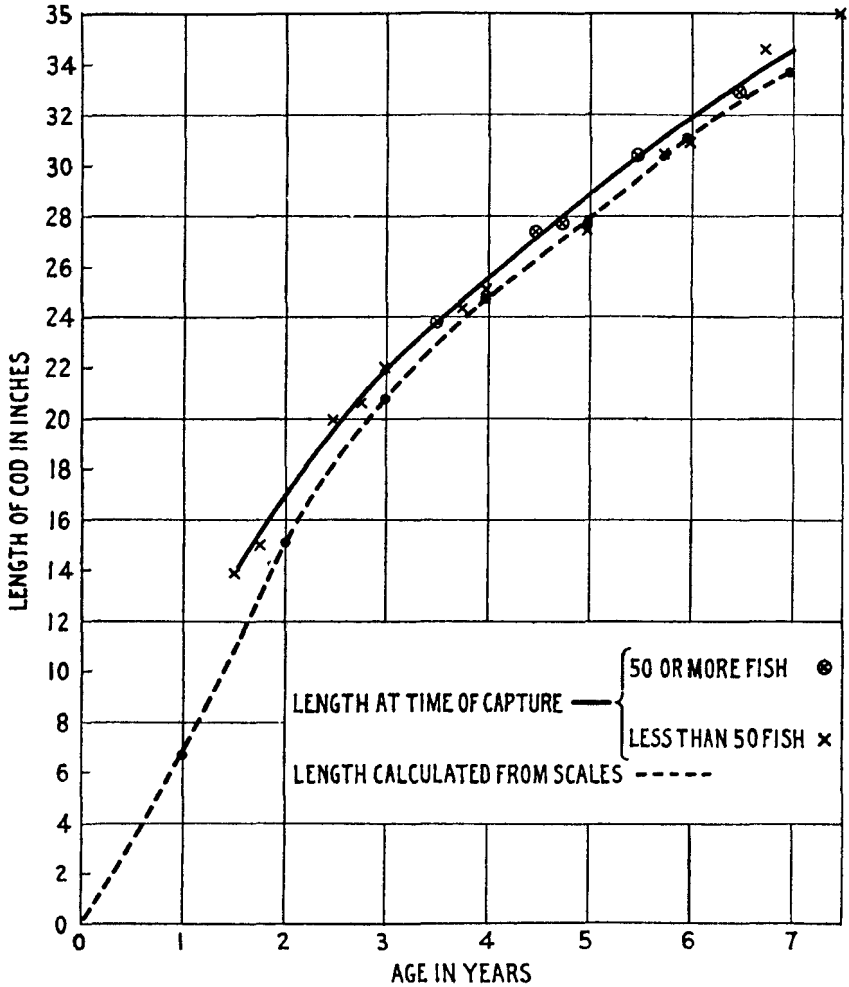

FIGURE 33.—Rate of growth of cod caught to the southward of Cape Cod, as determined from their scales

It is interesting to see whether the dominant lengths of the cod living on Nantucket Shoals during this experiment were in agreement with the growth curve. An attempt to do this is made in Table 46. In this case the age was first estimated according to the lengths of the fish and the season when they were caught, without regard to their scales.

TABLE 46.—*Estimated ages of Nantucket Shoals cod, based on season of capture and lengths of the fish* [1]

Estimated age in years	Average length of dominant size group			Estimated age in years	Average length of dominant size group		
	B group	*C* group	*D* group		*B* group	*C* group	*D* group
1¾			15.1	3½	23.9		21.0
2¼		19.0		3¾	24.6	24.4	21.5
2½		20.2		4¼	25.6		
2¾		21.3	18.3	4½			24.0
3¼			20.4				

[1] These data were obtained from Table 37.

All these fish were caught in the same immediate locality (between Round Shoal and Rose and Crown buoys), and while the *B* and *C* cod were dominant during the years 1924 to 1926, the *D* fish were dominant during the years 1926 to 1928. This is perhaps the first time that observations dealing with the growth of the cod have been made over a period of years on the same stock of fish living in a particular locality, and to do this it was necessary, of course, that a good part of the population remain localized from one year to the next.

That these estimated ages are approximately correct is shown by the agreement of the *B* and *C* groups with the growth curve, and this would seem to lend considerable weight to the correctness of the calculations. The *D* cod, however, suggest a rate of growth that is much different than that of the *B* or the *C* groups, for in effect the former required a year longer to reach a certain length than did either of the latter. Because of this, an examination of some of the scales was made in order definitely to locate the fish in their correct age classes. The results are given in Table 47.

TABLE 47.—*Age, according to scales, of certain groups of cod listed in Table 46*

Group	Average length, inches	Age [1]				Total number examined	Group	Average length, inches	Age [1]				Total number examined
		I	II	III	IV				I	II	III	IV	
B	24.5			16		16	*D*	15.1	49	3			52
B	25.6			2	11	13	*D*	18.3		48	2		50
C	21.3		50			50	*D*	20.4			25		25
C	24.4		1	21		22	*D*	24.0			10	45	55

[1] The age given here represents completed years of growth. For example, the III-year old fish had 3 annuli on their scales and were in their fourth year.

The segregation of ages given in Table 47 seems to prove conclusively that the distribution given in Table 46 is essentially correct, hence it appears that the *D* cod grew more slowly than the fish belonging to either of the other groups.

The cause of this difference in the rate of growth of the *D* cod, as compared with the other two groups, is not definitely known. It was thought that perhaps they would exhibit some peculiarities of scale growth that would set them apart from the other groups, but an examination showed that the circulus count was in general agreement with all the other samples of southern New England cod whose scales have thus far been studied, for those *D* cod listed in Table 47 had an average of about 21 in the first growth zone.

It would be natural to look to the scales of the 15.1-inch *D* cod as a means of ascertaining the early growth of this group of fish. (Table 46.) But this may have given an erroneous result, because these fish centering around 15 inches were probably the largest individuals of their class on account of the selectiveness of hook-and-line gear. However, lengths calculated from the scales of older fish showed that at the completion of the first growth zone the *C* cod were 8.1 inches long, while the *D* cod were but 6.3 inches, and that therefore much of the 3-inch difference in size between the *C* and the *D* cod at 2¾ years of age had already been made early in the life of the fish.

It was considered that the *D* cod possibly were genetically or inherently a slow-growing group. Such might be the case if they originated from eggs spawned in northern waters where cod presumably grow more slowly than they do to the southward. It is possible that under unusual circumstances the larvæ and fry from such eggs might reach the Nantucket region, but that this happened in the present instance is not likely. It is more probable that the difference in growth was due to unusually favorable conditions which may have obtained during 1923 when the *C* cod hatched as compared with 1924 when the *D* brood originated.

These various growth and age determinations might be summed up as follows:

1. Length frequencies obtained from time to time from what were presumably the same stocks of fish indicate that on Nantucket Shoals cod 15 to 26 inches long increase in length about 2½ to 4 inches a year.

2. Recaptures of tagged Nantucket Shoals cod have shown that fish 17 to 24 inches long grow about 4 inches a year, while fish 25 to 35 inches long grow about 2½ inches a year, the smaller fish in each of their length groups and those in the preceding paragraph showing a somewhat greater increment than the larger.

3. Growth was somewhat faster during the summer than from fall to spring.

TABLE 48.—*Age with respect to size*

	I	II	III	IV	V
	Inches	*Inches*	*Inches*	*Inches*	*Inches*
Estimated from length-frequency distributions	7–8	14–16	19–22	23–25	
Calculated size, according to scale growth	7	15	21	25	27–2
Size, according to age determinations from scales		16–17	22	25–26	28–2

RÉSUMÉ OF CONCLUSIONS

1. Cod are to be found on Nantucket Shoals throughout the year, but are most abundant there from spring to fall.

2. The stock of cod living on Nantucket Shoals, consisting chiefly of young adult and nearly adult fish, is for the most part distinct from that living to the north and east of southern Massachusetts, for there is no general intermingling of the fish belonging to these regions. This conclusion is supported by the recapture records of tagged fish and by scale studies. According to the first named, only a very small percentage of the Nantucket cod stray to the north and east annually, and, conversely, only a few cod tagged to the north and east stray to Nantucket Shoals.

3. A large part of the Nantucket Shoals cod population make a fall migration into the Rhode Island-North Carolina region, where most of them remain until the spring. These fish are joined by others from the north and east of Cape Cod; but

that southern New England cod form the bulk of the fish which occupy these wintering grounds is indicated by the paucity of recaptures there of fish tagged to the northward and eastward of Cape Cod and by the general similarity in length frequencies between the population in this wintering region and the summer cod on Nantucket Shoals. In the spring the fish return eastward, the majority of them stopping to summer on Nantucket Shoals, but others, chiefly the larger fish, most of which probably came from the north and east of Cape Cod, continue on to deeper water.

4. The number of cod which take part in this migration must be large, for the catch made each winter between Rhode Island and Delaware has ranged between three and five million pounds.

5. Many of the cod spawn on these wintering grounds, but whether most of the resultant larvæ are carried southward by the currents and are lost or whether many return to New England waters and thus help replenish the stock there is not known at this time.

6. The earliest migrants go west from Nantucket Shoals about the middle of October the movement of fish reaching its height during November and subsiding toward the end of December, after which it virtually ceases. The migration back to the eastward occurs chiefly during March and April, although a few fish may return as early as December and a few as late as May.

7. Temperature, either directly or indirectly, may be the cause of this migration, for the cod leave in the fall when the water begins to cool and return eastward in the spring when it begins to warm, although there seems to be no correlation between a particular temperature and the coming or going of the fish.

8. During the summer a cod is rarely caught west of Rhode Island and relatively few even off the latter coast, although the summer bottom temperature in the New York-Delaware region is as low or lower over certain of the grounds frequented by the cod in winter than it is on Nantucket Shoals.

9. Part of the cod living on Nantucket Shoals emigrate eastward to the Chatham-South Channel region during certain summers. This emigration was most apparent during the three years from 1923 to 1925, when most of the Nantucket cod averaged upward of 25 inches in length, and was scarcely noticeable, by means of tagged fish, during the three years from 1926 to 1928, when the fish were smaller. Not only the size of the fish but temperature, too, appears to influence this emigration, for it was largest during that year (1925), which was somewhat warmer on Nantucket Shoals than any of the others.

10. Fewer cod took part in the summer eastward emigrations than in the fall westward migrations, for length-frequency distributions, recaptures of tagged fish, and the abundance of the fish as shown by the catch per unit of effort, showed that a large part of the cod population on the shoals remained localized throughout the summer.

11. The average summer cod population on Nantucket Shoals from 1923 to 1928 might be roughly estimated as between three million and four and one-half million adult and nearly adult fish.

12. The number of grown cod which live on Nantucket Shoals appears to be fairly uniform from year to year. Losses are caused by (*a*) deaths from natural causes, (b) fish taken by the fishery not only on Nantucket Shoals but also on the wintering grounds to the westward, and (*c*) emigrations to other regions. The gains are brought

about by (*a*) cod fry which take to the bottom on Nantucket Shoals and reach maturity there and (*b*) the immigration of older fish.

13. A large part of the cod fry which seek bottom on Nantucket Shoals appear to come from eggs spawned along the coast of Maine. But so few fish between 1 and 2 years of age have been found on the shoals that it is probable that the fry succeed only in a small way in keeping up the stock of adult fish.

14. The stock of cod on Nantucket Shoals is kept up chiefly by young adult and nearly adult fish which immigrate from other regions. (Recaptures of tagged fish indicate that most of these immigrants come from the offshore grounds and that very few come from alongshore to the eastward of Cape Ann.)

15. Georges Bank and South Channel, because of their proximity and the large stock of cod which they support, and because they formed the route of a good proportion of the tagged cod which immigrated to southern New England, are the most likely source of the cod which appear in schools on Nantucket Shoals from time to time.

16. The same individual cod may remain on Nantucket Shoals for two or three years or, if some of them winter to the westward, they may be found on the shoals for several successive summers. But cod do not remain on the shoals indefinitely, for the great majority of the grown fish are between 18 and 30 inches long, and the larger ones of this size group tend to move away into deeper water. Few remain after they reach 34 inches, while those above 40 inches form less than 1 per cent of the population, although in deep water on the offshore banks these latter fish may often form from 10 to 20 per cent of the catch.

17. Cod living off southern Massachusetts are approximately 7 to 8 inches long at 1 year of age, 14 to 17 inches at 2 years, 19 to 22 inches at 3 years, 23 to 26 inches at 4 years, and 27 to 29 inches at 5 years.

TABULATION OF THE RECAPTURES

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured [1]	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals			
	Inches				
11004	30	Rose and Crown buoy	Apr. 19, 1923	July 30, 1923	South Channel.
11020	34	do	do	do	Nantucket Shoals.
11037	38	do	do	June 7, 1923	Portland, Me.
11058	31	do	do	May 30, 1924	Nantucket Shoals (35½).
11161	38½	do	Apr. 27, 1923	July 16, 1923	South Channel.
11177	38¼	do	do	Oct. 15, 1927	Do.
11397	30	do	May 23, 1923	Aug. 17, 1923	Nantucket Shoals.
11446	21½	do	do	Aug. 31, 1923	South Channel.
11462	28	do	do	Oct. 24, 1923	Nantucket Shoals.
11466	32	do	do	Oct. 16, 1923	Nantucket Shoals (33½).*
11507	26¼	do	do	Dec. 29, 1923	Cape May, N. J.
11611	20½	do	May 24, 1923	Dec. 27, 1923	Manasquan, N. J.
11621	25	do	do	Jan. 7, 1925	Westhampton, N. Y. (27½).
11622	26½	do	do	Nov. 4, 1923	Seabright, N. J.
11675	26½	do	do	June 29, 1923	Off Chatham.
11714	19¼	do	May 25, 1923	July 13, 1924	Nantucket Shoals (24¾).*
11725	23	do	do	Nov. 29, 1923	Plymouth, Mass.
11726	34½	do	do	Nov. 24, 1923	Cholera Bank, N. Y. (37).
11737	30¼	do	do	May 24, 1924	Nantucket Shoals.
11746	26	do	do	July 25, 1923	Off Chatham.
11810	25¾	do	do	June 19, 1923	Do.
11833	28	do	do	July 5, 1923	Nantucket Shoals.
11863	27½	do	May 26, 1923	Dec. 11, 1923	Bayhead, N. J.

[1] In cases where a fish was measured upon recapture, the length, in inches, is given in parentheses.

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
11914	*Inches* 26½	Rose and Crown buoy	May 26, 1923	Aug. 30, 1923	Off Chatham.
11922	38	do	do	Aug. 17, 1923	Jeffreys Ledge, off Cape Ann.
11928	26¼	do	do	Oct. 24, 1923	Nantucket Shoals.
11937	26½	do	do	Oct. 15, 1923	Nantucket Shoals (26½).*
11940	31	do	do	Aug. 28, 1923	Off Chatham.
13207	30¾	do	Sept. 5, 1923	Aug. 14, 1924	South Channel.
13256	28	do	do	Dec. 4, 1923	Ship Bottom, N. J. (29).
13736	29	do	Sept. 7, 1923	Mar. 23, 1924	Jones Inlet, N. Y.
13742	25¼	do	do	Fall, 1925	Block Island Sound, R. I.
13744	32½	do	do	Sept. 11, 1924	Nantucket Shoals (34½).*
13930	25½	do	do	Fall, 1925	Block Island Sound, R. I.
14111	28	do	Oct. 3, 1923	do	Do.
14117	26¾	do	do	Apr. 11, 1924	Jones Inlet, N. Y.
14177	25¾	do	do	Nov. 16, 1923	Do.
16189	26¼	do	Oct. 14, 1923	Mar. 4, 1924	Wainscott, N. Y. (27½).
16208	30½	do	do	Aug. 4, 1925	South Channel.
16244	28	do	do	Feb. 14, 1924	Rockaway, N. Y.
16709	25¾	do	Oct. 16, 1923	Nov. 18, 1923	Cholera Bank, N. Y.
16760	26¼	do	do	May 7, 1924	Block Island, R. I.
16852	25¾	do	do	Nov. 29, 1924	Do.
16989	21¼	do	do	July 15, 1925	Nantucket Shoals.
17003	28¾	do	do	Nov. 29, 1923	Cholera Bank, N. Y.
17015	29½	do	do	Dec. 17, 1924	Cholera Bank, N. Y. (32¾).
17078	29½	do	do	Aug. 26, 1925	Off Chatham.
17422	26¾	do	Oct. 17, 1923	Oct. 28, 1923	Nantucket Shoals.
17473	27½	do	do	June 16, 1924	Off Chatham.
17484	30½	do	do	—— —, 1923	No data.
17537	25¾	do	do	July 2, 1924	Off Chatham.
17585	24½	do	do	Sept. 12, 1924	Nantucket Shoals (27¼).*
11944	26¼	Round Shoal buoy	May 26, 1923	Feb. 9, 1925	Cape Henlopen, Del. (31¼).
11945	47	do	do	June 29, 1923	Off Chatham.
11984	27½	do	do	Aug. 16, 1923	Off Gloucester, Mass.
10008	30¾	do	May 27, 1923	Oct. 24, 1923	Nantucket Shoals.
10073	27½	do	June 22, 1923	Oct. 15, 1923	Nantucket Shoals (27½).*
10094	22	do	do	Aug. 27, 1923	Nantucket Shoals.
10121	32	do	do	July 27, 1923	No data.
10224	29¾	do	do	Dec. 3, 1923	Rockaway, N. Y.
10233	32	do	June 23, 1923	Aug. 19, 1923	Off Chatham.
10239	28	do	do	do	Nantucket Shoals (28½).*
10264	30	do	do	Oct. 28, 1923	Nantucket Shoals.
10265	27½	do	do	Oct. 24, 1923	Do.
10325	23¾	do	do	July 13, 1924	Nantucket Shoals (23½).*
10336	31	do	do	Aug. 18, 1923	Nantucket Shoals (31½).*
10377	24¾	do	do	June 26, 1923	Nantucket Shoals (24¾).*
10379	27¼	do	do	July 1, 1923	Nantucket Shoals.
10409	26½	do	do	Aug. 20, 1924	Off Chatham.
10428	25	do	do	Nov. 5, 1923	Gull Island, N. Y.
10495	26¾	do	June 24, 1923	July 15, 1923	Nantucket Shoals.
10513	29	do	do	July 24, 1923	Do.
10548	29	do	do	May 8, 1924	Block Island, R. I. (30).
10552	26¾	do	do	Jan. 21, 1924	Cape May, N. J.
10588	27	do	do	Dec. 21, 1924	Atlantic City, N. J.
10645	29	do	do	Oct. 3, 1923	Nantucket Shoals (29¼).*
10651	26½	do	do	Feb. 1, 1924	No data.
10668	25	do	do	Oct. 15, 1924	Off Chatham.
10680	35	do	do	Sept. 17, 1923	Nantucket Shoals.
10706	25	do	do	Nov. 23, 1923	Rockaway, N. Y.
10708	38	do	do	Oct. 6, 1923	Nantucket Shoals (38).*
10719	31¼	do	do	Oct. 15, 1923	Nantucket Shoals (31½).*
10760	30	do	do	Nov. 13, 1923	South Channel.
10768	25¼	do	do	Oct. 6, 1923	Nantucket Shoals (25¾).*
10772	22	do	June 25, 1923	July 5, 1924	Nantucket Shoals.
10773	37	do	do	July 30, 1923	Do.
10831	29¾	do	do	Dec. 4, 1923	Ship Bottom, N. J. (31).
10861	23	do	do	Oct. 24, 1923	Nantucket Shoals.
10880	28¼	do	do	Apr. 10, 1924	No Mans Land, Mass.
10894	26¾	do	do	Dec. 3, 1923	Fire Island, N. Y.
10956	32½	do	do	Aug. 27, 1923	Off Chatham.
10980	30½	do	do	Sept. 3, 1923	Nantucket Shoals.
10997	28	do	do	Nov. 9, 1923	Narragansett, R. I.
34	27¼	do	June 26, 1923	Sept. 12, 1924	Nantucket Shoals.*
66	31¼	do	do	Oct. 24, 1923	Nantucket Shoals.
77	30	do	do	Oct. 6, 1923	Nantucket Shoals (30¼).*
86		do	do	Oct. 16, 1924	Nantucket Shoals (34¼).*
172	31½	do	June 28, 1923	Jan. 18, 1924	Cape May, N. J. (31½).
184	30	do	do	Aug. 9, 1925	Off Chatham.
208	27¾	do	do	Oct. 27, 1923	Bayhead, N. J.
224	26	do	do	Oct. 4, 1923	No data.
229	30¾	do	do	Aug. 17, 1923	Nantucket Shoals.*
281	27¼	do	do	Oct. 8, 1923	Nantucket Shoals (28).*

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
	Inches				
231	27½	Round Shoal buoy	June 28, 1923	Oct. 15, 1923	Nantucket Shoals (98).*
232	28¾	do	do	Oct. 24, 1923	Nantucket Shoals.
248	39	do	do	Oct. 15, 1923	Nantucket Shoals (39).*
257	28¾	do	do	Fall, 1926	Block Island Sound, R. I.
272	29½	do	do	Oct. 24, 1923	Nantucket Shoals.
277	29	do	do	Oct. 4, 1923	Do.*
277	29	do	do	Jan. 5, 1924	Rockaway, N. Y.
283	31¾	do	do	Oct. 15, 1923	Nantucket Shoals (32).*
303	29½	do	do	Oct. 4, 1923	Nantucket Shoals (29¾).*
309	31¼	do	do	Oct. 3, 1923	Nantucket Shoals (32¼).*
320	24½	do	do	Nov. 2, 1923	Long Beach, N. Y.
336	26	do	do	Oct. 3, 1923	Nantucket Shoals (26¼).*
337	28½	do	do	Oct. 18, 1923	No data.
375	29½	do	do	Oct. 15, 1923	Nantucket Shoals (30).*
383	29½	do	do	—— —, 1924	No data.
12017	27¾	do	Aug. 16, 1923	Oct. 6, 1923	Nantucket Shoals (28).*
12017	27¾	do	do	Jan. 2, 1924	Rockaway, N. Y.
12058	28¾	do	do	Sept. 17, 1923	East of Orleans, Cape Cod.
12249	26	do	do	June 14, 1924	Off Chatham.
12259	26¼	do	do	Sept. 17, 1923	Nantucket Shoals.
12272	31½	do	do	May 27, 1924	Hampton Beach, N. H.
12296	26	do	do	Dec. 27, 1923	Atlantic City, N. J. (27).
408	32	do	Aug. 17, 1923	Aug. 20, 1924	Off Chatham.
420	27¼	do	do	Dec. 14, 1923	Galilee, N. J. (28).
431	27	do	do	Dec. 11, 1923	Rockaway, N. Y.
440	25¼	do	do	Sept. 26, 1924	South Channel.
453	29¾	do	do	Nov. —, 1923	Block Island, R. I.
471	30½	do	do	Aug. 9, 1825	Off Chatham.
479	28¾	do	do	Mar. 20, 1924	Off Barnegat, N. J.
513	39	do	do	Nov. 15, 1923	Cholera Bank, N. Y.
558	27½	do	do	Sept. 3, 1923	Nantucket Shoals.
572	28½	do	do	Oct. 8, 1923	Do.
627	26½	do	do	Sept. 3, 1923	Do.
632	32	do	do	Aug. 28, 1923	Do.
642	29	do	do	July 15, 1924	Nantucket Shoals (31).*
669	27½	do	do	Dec. 4, 1923	Ship Bottom, N. J. (28¼).
672	36½	do	do	Sept. 17, 1923	Nantucket Shoals.
692	33	do	do	Oct. 17, 1923	Nantucket Shoals (33).*
724	30½	do	do	Fall, 1926	Block Island Sound, R. I.
12335	19¼	do	do	June 16, 1924	Nantucket Shoals.
12345	27½	do	do	Oct. 24, 1923	Do.
12362	26½	do	do	Fall, 1925	Block Island Sound, R. I.
12415	28	do	do	May 24, 1924	Block Island, R. I. (30).
12425	29¾	do	do	Aug. 20, 1924	Off Chatham.
12457	25¾	do	do	Jan. 21, 1925	Fire Island, N. Y.
12461	26¾	do	do	Mar. 25, 1924	Point Judith, R. I.
12482	29	do	do	Dec. 6, 1923	Narragansett, R. I.
12512	30½	do	do	Aug. 27, 1924	Off Chatham.
12630	28	do	do	Mar. 9, 1925	Atlantic City, N. J. (33).
12637	23½	do	do	Nov. 29, 1923	Rockaway, N. Y.
12651	29¼	do	do	Nov. 20, 1923	Atlantic City, N. J. (30).
12690	27	do	do	Sept. 26, 1923	Nantucket Shoals.
12691	25¼	do	do	Mar. 23, 1925	Barnegat, N. J.
12714	26	do	do	Jan. 13, 1924	Cape May, N. J. (27½).
786	27	do	Aug. 18, 1923	Nov. 7, 1924	Fire Island, N. Y.
856	25½	do	do	Jan. —, 1927	Block Island Sound, R. I.
916	26¼	do	do	Sept. 17, 1923	Nantucket Shoals.
917	29¼	do	do	do	Do.
919	27	do	do	do	Do.
986	29½	do	do	Aug. 20, 1924	Off Chatham.
1122	27¾	do	do	Aug. 17, 1925	South Channel.
1163	34½	do	do	Apr. 10, 1925	Nantucket Shoals.
1172	29¾	do	do	Oct. 13, 1923	Off Chatham.
1229	28	do	do	Oct. 4, 1923	Nantucket Shoals (28½).*
1240	24¼	do	do	Oct. 9, 1923	Nantucket Shoals.
1268	25¼	do	do	Aug. 11, 1925	Off Chatham.
1439	27¾	do	do	Nov. 1, 1923	Block Island, R. I.
1471	31	do	do	Sept. 17, 1923	Nantucket Shoals.
1492	29	do	do	Mar. 24, 1924	Off Chatham.
1561	27½	do	Aug. 19, 1923	Dec. 1, 1923	Rockaway, N. Y.
1623	27	do	do	Oct. 28, 1924	Manasquan, N. J. (28).
1662	31	do	do	Aug. 26, 1925	Off Chatham.
1712	31	do	do	Apr. 14, 1924	Water Mill, N. Y. (32½).
1770	30	do	do	Nov. 26, 1923	Seabright, N. J.
1835		do	do	Nov. 3, 1923	Nantucket Shoals.
1866	33	do	Aug. 23, 1923	Oct. 3, 1923	Do.*
1881	28½	do	do	Aug. 20, 1924	Off Chatham.
1954	27	do	do	Apr. —, 1924	No Mans Land.
1958	24	do	do	Dec. 21, 1923	Nantucket Shoals.
1968	25¾	do	do	Sept. —, 1923	South Channel.

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
12808	28	Round Shoal Buoy	Sept. 5, 1923	Dec. 4, 1923	Ship Bottom, N. J. (28¾).
12819	28	do	do	Nov. 20, 1923	Atlantic City, N. J.
12831	29½	do	do	Nov. 2, 1923	Nantucket Shoals.
12840	29¼	do	do	July 14, 1924	Nantucket Shoals (31¼).*
12847	37	do	do	Sept. 8, 1924	Off Chatham.
13263		do	do	Dec. 4, 1923	Block Island, R. I.
2028	28	do	Sept. 9, 1923	Nov. 16, 1923	Do.
2037		do	do	Oct. 4, 1923	Nantucket Shoals (28½).*
2044	28½	do	do	Sept. 17, 1923	Nantucket Shoals.
2070	24¼	do	do	Oct. 6, 1923	Nantucket Shoals (25).*
2080	28½	do	do	Dec. 16, 1923	Block Island, R. I.
2094	27	do	do	Oct. 17, 1923	Nantucket Shoals (27).*
2124	30	do	do	Sept. 17, 1923	Nantucket Shoals.
2129	26	do	do	Oct. 3, 1923	Nantucket Shoals (26).*
2197	25¾	do	Sept. 10, 1923	Oct. 15, 1923	Nantucket Shoals (25¾).*
2200	30½	do	do	Oct. 4, 1923	Nantucket Shoals (30¾).*
2221	28½	do	do	June 10, 1924	South Channel.
2241	29	do	do	Aug. 9, 1925	Off Chatham.
2249	24¾	do	Sept. 11, 1923	Dec. 18, 1923	Montauk, N. Y.
2300	30	do	do	Aug. 9, 1925	Off Chatham.
2370	28½	do	do	Fall, 1926	Block Island Sound, R. I
14021	26¾	do	Oct. 3, 1923	Oct. 16, 1924	Nantucket Shoals.
14025	23¾	do	do	Jan. 5, 1924	Quonochontaug, R. I.
14084	28	do	do	Nov. 20, 1923	Coggeshall Ledge, R. I.
14287	26	do	do	Aug. 10, 1925	Nantucket Shoals.
14303	28¾	do	do	Nov. 29, 1923	Cholera Bank, N. Y.
14310	29½	do	do	Nov. 9, 1923	Rockaway, N. Y.
14349	28¾	do	do	Nov. 12, 1923	Do.
14358	27½	do	do	Nov. 22, 1923	Bradley Beach, N. J.
14383	27¾	do	do	Oct. 17, 1923	Nantucket Shoals (29).*
14451	29	do	do	Dec. 4, 1923	Beach Haven, N. J.
14489	27¼	do	do	Apr. 20, 1924	Nantucket Shoals.
14515	30¼	do	do	Mar. 24, 1925	Block Island, R. I.
14525	27½	do	do	Dec. 18, 1923	Rockaway, N. J.
14681	20½	do	do	Sept. 20, 1924	Nantucket Shoals.
14735	24	do	do	Dec. 23, 1924	Cape May, N. J. (29).
14769	25½	do	Oct. 4, 1923	July 14, 1924	Nantucket Shoals (27¼).*
14888	30¼	do	do	July 1, 1924	Nantucket Shoals.
14958	26½	do	do	Oct. 24, 1923	Do.
14975	29½	do	do	Oct. 15, 1923	Nantucket Shoals (29¾).*
15024	27½	do	do	Apr. 18, 1925	Fire Island, N. Y.
15065	20¼	do	do	Sept. 11, 1924	Nantucket Shoals (24).*
15077	28¾	do	do	Dec. 28, 1923	Rockaway, N.Y.
15085	31¼	do	do	Oct. 23, 1924	Nantucket Shoals.
15125	29	do	do	Dec. 22, 1923	Avalon, N. J.
15374	26	do	Oct. 5, 1923	Dec. 15, 1923	Atlantic City, N. J.
15466		do	do	Jan. 12, 1924	Rockaway, N. Y.
15607	28	do	Oct. 6, 1923	Nov. 17, 1923	Block Island, R. I.
15616	30	do	do	Mar. 2, 1924	Rockaway, N. Y.
15645	29½	do	do	Aug. 20, 1924	Off Chatham.
15653	25¾	do	do	Oct. 10, 1923	Nantucket Shoals.
15668	29	do	do	Mar. 6, 1924	Cape May, N. J. (31).
15671	28¾	do	do	Jan. 5, 1924	Atlantic City, N. J.
15697	29¼	do	do	Apr. 13, 1924	Atlantic City, N. J. (31½).
15703	25½	do	do	June 5, 1924	Lat. 40° 50′ N., long. 70° 20′ W.
15708	29½	do	do	Apr. —, 1924	No Man's Land.
16019	27¼	do	Oct. 14, 1923	July 14, 1924	Nantucket Shoals (29½).*
16259	38	do	Oct. 15, 1923	Dec. 18, 1923	Townsends Inlet, N. J.
16282	34¾	do	do	Apr. 15, 1924	Lat. 41° 57′ N., long. 66° 46′ W.
16308	30½	do	do	Oct. 18, 1924	Nantucket Shoals (33¼).*
16486	20¾	do	do	July 16, 1924	Nantucket Shoals (24).*
16491	22	do	do	July 13, 1924	Nantucket Shoals (23¼).*
16494	28¾	do	do	July 31, 1925	Nantucket Shoals.
16565	30	do	do	May 6, 1924	Montauk, N. Y.
16592	33½	do	do	Nov. 19, 1924	Barnegat, N. J.
17281	28½	do	Oct. 17, 1923	Dec. 21, 1923	Cholera Bank, N. Y.
15798	28¾	Great Rip buoy	Oct. 8, 1923	Oct. 16, 1924	Nantucket Shoals (30¾).*
2421	27	do	do	Aug. 25, 1925	Off Chatham.
2426	26½	do	do	Dec. 18, 1923	Quogue, N. Y.
2516	28	do	do	Nov. 20, 1923	Cape May, N. J.
2540	26¾	do	do	Nov. 11, 1923	Rockaway, N. Y.
2560	31	do	do	July 22, 1924	Nantucket Shoals.
2618	31	do	do	Nov. 29, 1923	Cholera Bank, N. Y.
11212	24½	Bass Rip	May 3, 1923	Apr. 15, 1925	La Have Bank.
11215	28½	do	do	Aug. 24, 1923	Nantucket Shoals.
11256	24	do	do	Aug. 18, 1923	Off Chatham.
11312	25½	do	do	Oct. 15, 1924	South Channel.
11317	23	do	do	Nov. 24, 1923	Cholera Bank, N. Y.
11365	27	do	May 23, 1923	Aug. 5, 1923	Nantucket Shoals.
11372	28	do	do	Mar. —, 1926	Atlantic City, N. J.

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
	Inches				
12875	27½	Davis Bank	Sept. 5, 1923	Oct. 10, 1923	Nantucket Shoals.
12954	30½	do	do	Mar. 19, 1924	No data.
13064	25	do	do	Oct. 20, 1923	South Channel.
13344	29¼	do	Sept. 6, 1923	Nov. 1, 1923	Rockaway, N. Y.
13393	32¼	do	do	Aug. 29, 1925	Off Chatham.
13404	28¾	do	do	July 15, 1925	Nantucket Shoals.
13451	25½	do	do	Feb. 1, 1925	Point Judith, R. I.
13453	27¼	do	do	do	Manasquan, N. J. (27½).
13456	26¾	do	do	Aug. 5, 1925	Nantucket Shoals.
13478	27¼	do	do	Jan. 4, 1924	Anglesea, N. J.
13499	23½	do	do	Dec. 8, 1923	Coney Island, N. Y.
13584	27½	do	do	June 27, 1925	South Channel.
13586	27	do	do	Aug. 9, 1925	Off Chatham.
13640	28	do	do	May —, 1924	Block Island, R. I.
13720	21¼	do	Sept. 7, 1923	Feb. 3, 1924	Rockaway, N. Y.
13791	29¾	do	Sept. 8, 1923	Feb. —, 1925	Atlantic City, N. J.
17702	22½	Round Shoal buoy	July 13, 1924	Sept. 12, 1924	Nantucket Shoals (23).*
17720	20¾	do	do	Sept. 6, 1924	Nantucket Shoals (20¾).*
17737	27	do	do	Dec. 9, 1924	Cholera Bank, N. Y.
17745	24¼	do	do	Oct. 21, 1924	Newport, R. I.
17828	27	do	do	Aug. 20, 1924	Off Chatham.
17842	25	do	do	Sept. 11, 1924	Nantucket Shoals (25½).*
17852	28¼	do	do	do	Nantucket Shoals (28¼).*
17853	24½	do	do	Oct. 29, 1924	Beach Haven, N. J.
17866	23¾	do	do	Dec. 31, 1924	Amagansett, N. Y.
18043	26¼	do	July 14, 1924	Dec. 7, 1924	Rockaway, N. Y.
18674	?	do	July 15, 1924	Oct. 27, 1924	Nantucket Shoals (21¼).*
18674	?	do	do	Dec. 7, 1924	Cholera Bank, N. Y.
18708	23½	do	July 16, 1924	Sept. 12, 1924	Nantucket Shoals (24).*
18726	25¼	do	do	Nov. 15, 1924	Fishers Island, N. Y.
18741	22¾	do	do	Sept. 5, 1925	South Channel.
18769	22	do	do	Dec. 17, 1924	Cholera Bank, N. Y.
19122	22¾	do	July 17, 1924	Nov. 28, 1924	Jones Inlet, N. Y.
20991	26½	do	Sept. 6, 1924	June 22, 1925	Off Chatham.
21047	32½	do	do	Oct. 18, 1924	Nantucket Shoals (32¾).*
21070	24½	do	Sept. 7, 1924	Oct. 6, 1924	Nantucket Shoals.
21080	24½	do	do	Nov. 15, 1924	Rockaway, N. Y.
21216	22¾	do	Sept. 8, 1924	May 6, 1925	Nantucket Shoals (24¾).*
21216	22¾	do	do	Aug. 7, 1925	Nantucket Shoals.
21265	25¼	do	do	Oct. 16, 1924	Nantucket Shoals (25½).*
21279	22¾	do	do	May 6, 1925	Nantucket Shoals (25).*
21281	27¼	do	do	Oct. 7, 1924	Nantucket Shoals (27¾).*
21318	22	do	do	Nov. 29, 1925	Off Chatham.
21331	21¾	do	do	Oct. 27, 1924	Fire Island, N. Y.
26259	32	do	Oct. 16, 1924	Sept. 9, 1925	Off Chatham.
26360	32¼	do	do	Mar. 16, 1925	Barnegat, N. J.
26377	31¾	do	do	Aug. 17, 1925	South Channel.
26647	25	do	Oct. 18, 1924	Nov. 22, 1925	Narragansett Bay, R. I. (28).
26696	29	do	do	Sept. 9, 1925	Off Chatham.
26778	25¼	do	do	Nov. 29, 1924	Cholera Bank, N. Y.
26785	19¾	do	do	Oct. 3, 1925	Nantucket Shoals (24).*
26851	19½	do	do	Aug. 20, 1925	Nantucket Shoals.
26903	25¼	do	Oct. 22, 1924	Mar. 27, 1925	Off Race Point, Cape Cod.
21362	24¾	Between Round Shoal and Rose and Crown buoys.	Sept. 11, 1924	Aug. 28, 1926	Nantucket Shoals.
21369	26	do	do	Aug. —, 1925	No data.
21380	20½	do	do	Oct. 18, 1924	Nantucket Shoals (20¾).*
21380	20½	do	do	Sept. 12, 1925	Nantucket Shoals.
21423	26¼	do	do	Oct. 16, 1924	Nantucket Shoals (28).*
21434	25	do	do	Oct. 27, 1924	Nantucket Shoals (25¼).*
21460	33½	do	do	Mar. 15, 1926	Off Indian River Inlet, Del. (37½).
21488	27¾	do	do	Mar. 26, 1925	Atlantic City, N. J. (31½).
21523	26½	do	do	Dec. 11, 1924	Cholera Bank, N. Y.
21539	24¼	do	do	Oct. 16, 1924	Nantucket Shoals (24½).*
21557	21½	do	do	Aug. 5, 1925	Nantucket Shoals.
21586	32¼	do	do	Aug. 4, 1925	Off Chatham.
21686	22½	do	Sept. 12, 1924	Oct. 27, 1924	Nantucket Shoals (23¼).*
21695	23½	do	do	Fall, 1927	Block Island Sound, R. I.
21722	30¾	do	do	Mar. —, 1926	Atlantic City, N. J.
21728	21	do	do	Nov. 29, 1924	Rockaway, N. Y.
21780	25¼	do	do	July 8, 1926	South Channel.
21785	26	do	do	Oct. 16, 1924	Nantucket Shoals (26¼).*
21806	22¼	do	do	Aug. 6, 1925	Nantucket Shoals.
21817	26	do	do	Dec. 19, 1924	Barnegat, N. J. (27).
21824	22¾	do	do	Oct. 1, 1925	Nantucket Shoals (25½).*
21833	24¾	do	do	Aug. 4, 1925	South Channel.
21858	25½	do	do	Dec. 1, 1924	Cholera Bank, N. Y.
21908	25½	do	do	Aug. 9, 1925	Off Chatham.
21912	26	do	do	Aug. 1, 1925	Nantucket Shoals.
21928	23¼	do	do	Oct. 17, 1927	Nantucket Shoals (26½).*

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
22043	*Inches* 23¾	Between Round Shoal and Rose and Crown bouys.	Sept. 12, 1924	Nov. 10, 1924	Jones Inlet, N. Y. (24).
22064	23¼	do	do	Oct. 18, 1924	Nantucket Shoals (23½).*
26405	25¾	do	Oct. 16, 1924	Dec. 3, 1924	Cholera Bank, N. Y.
26445	28¾	do	do	Aug. 25, 1925	Off Chatham.
26490	24½	do	do	Aug. 27, 1925	Do.
26505	25¼	do	do	Apr. 25, 1925	Montauk, N. Y.
26600	25¾	do	Oct. 17, 1924	Oct. 24, 1925	Nantucket Shoals (30½).*
26624	22	do	do	Jan. 10, 1925	Nantucket Shoals.
26634	33¾	do	do	June —, 1925	Off Chatham.
27034	28¼	do	Oct. 25, 1924	May 15, 1925	Nantucket Shoals.
27053	34¾	do	do	Apr. 18, 1925	Fire Island, N. Y.
27379	23½	do	Oct. 27, 1924	Jan. 6, 1925	Point Judith, R. I.
27441	30¼	do	do	Mar. 17, 1925	Atlantic City, N. J.
27474	29½	do	do	Dec. 23, 1924	Amagansett, N. Y. (30).
27581	32¼	do	do	Nov. 29, 1924	Cholera Bank, N. Y.
27583	28¼	do	do	Oct. 3, 1925	Wainscott, N. Y.
27977	26¼	do	Oct. 28, 1924	Jan. 27, 1926	Montauk, N. Y.
27616	27¼	Rose and Crown buoy	Oct. 27, 1924	Aug. 9, 1925	Off Chatham.
27654	28	do	do	Aug. 5, 1925	Nantucket Shoals.
27662	33½	do	do	June 21, 1926	Georges Bank.
27686	25¾	do	do	Dec. 12, 1924	Belmar, N. J. (26).
18853	23½	5 to 8 miles ESE. of Round Shoal buoy	July 16, 1924	July 6, 1925	South Channel.
18940	27½	do	do	Aug. 20, 1924	Nantucket Shoals.
18969	35¼	do	do	Sept. 1, 1925	Do.
18974	29¾	do	do	Aug. 20, 1924	Off Chatham.
19011	28	do	do	Mar. —, 1926	Atlantic City, N. J.
19018	27¾	do	do	Nov. 10, 1924	Montauk, N. Y. (29).
19047	34½	do	do	Nov. 12, 1924	S. W. Georges Bank.
21235	27¼	do	Sept. 8, 1924	Dec. 7, 1924	Cholera Bank, N. Y.
18052	26¼	12 miles ESE. of Round Shoal buoy	July 14, 1924	Oct. 20, 1924	Nantucket Shoals.
18081	27½	do	do	Aug. 29, 1925	Off Chatham.
18112	30¾	do	do	Fall, 1924	Nantucket Shoals.
18187	24¾	do	do	—— —, 1926	No data.
18198	26¼	do	do	Oct. 26, 1925	South Channel.
18218	26	do	do	Nov. 23, 1924	Atlantic Highlands, N. J.
18264	30¾	do	July 15, 1924	Aug. 20, 1924	Nantucket Shoals.
18284	23¼	do	do	May 18, 1925	Barnstable Bay, Mass.
18329	28½	do	do	Nov. 13, 1924	Long Beach, N. Y.
18436	30¾	do	do	July 16, 1924	Nantucket Shoals.*
18474	31	do	do	Mar.—, 1926	Atlantic City, N. J.
18537	28½	do	do	Sept. 9, 1924	Nantucket Shoals.
27266	21¾	Davis Bank	Oct. 26, 1924	Aug. 27, 1925	Do.
27318	25½	do	do	Mar. 16, 1925	Barnegat, N. J.
2990	29	Round Shoal buoy	May 5, 1925	June 25, 1926	South Channel.
28015	19¾	do	do	Aug. 20, 1925	Nantucket Shoals (21¾).*
28015	19¾	do	do	Oct. 27, 1925	Great Point, Nantucket (22).
28066	25	do	do	July 26, 1926	Nantucket Shoals.
28193	36½	do	May 6, 1925	June 5, 1926	Do.
28197	25	do	do	Mar. 19, 1926	Block Island, R. I. (28).
28198	25½	do	do	Sept. 14, 1925	South Channel.
28244	25¾	do	do	Nov. 21, 1925	Bradley Beach, N. J.
28288	25¼	do	do	Nov. 23, 1925	Jones Inlet, N. Y.
28294	25¾	do	do	Aug. 18, 1925	South Channel.
28296	19¼	do	do	Oct. 3, 1925	Nantucket Shoals (20¼).*
28344	39¼	do	do	Aug. 14, 1925	Off Race Point, Cape Cod.
28349	18½	do	do	May 26, 1927	Ipswich Bay, Mass.
28253	23	do	do	Oct. 2, 1925	Nantucket Shoals (25).*
28362	25¾	do	do	Oct. 19, 1925	Block Island, R. I. (26).
28447	18¾	do	do	Aug. 17, 1925	Nantucket Shoals.
28799	19	do	do	Oct. 2, 1925	Nantucket Shoals (20½).*
28890	28	do	do	Oct. 3, 1925	Nantucket Shoals (28).*
28892	27	do	do	Aug. 20, 1925	Nantucket Shoals (27½).*
28968	25	do	May 7, 1925	Aug. 21, 1925	Nantucket Shoals (26¼).*
28971	31	do	do	Sept. 15, 1925	Monhegan Island, Me.
28987	26¼	do	do	Nov. 30, 1925	Fire Island, N. Y.
29024	27	do	do	Aug. 20, 1925	Nantucket Shoals (27¼).*
29054	29	do	do	Aug. 27, 1925	Off Chatham.
29065	25½	do	do	Jan. —, 1926	Little Duck Island, Mount Desert, Me.
29091	23¾	do	do	Oct. 9, 1925	South Channel.
29092	34½	do	do	Dec. 19, 1925	Georges Bank.
29112	17¾	do	do	Aug. 20, 1925	Nantucket Shoals (19¾).*
29459	18	do	May 8, 1925	Dec. 15, 1925	Atlantic City, N. J. (20).
29559	27½	do	do	Aug. 11, 1925	Off Chatham.
31388	32	do	June 7, 1925	Aug. 25, 1925	Do.
31391	29	do	do	Oct. 26, 1926	Off Freeport, N. Y.
31409	23¾	do	do	Sept. 9, 1925	Off Chatham.
31627	24¼	do	June 10, 1925	Oct. 3, 1925	Nantucket Shoals (24¼).*
31683	24	do	do	Apr. 4, 1926	Portland, Me.
31756	18¼	do	do	Aug. 20, 1925	Nantucket Shoals (19¼).*

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
	Inches				
31857	18	Round Shoal buoy	June 11, 1925	Oct. 31, 1926	Coggeshall Point, R. I. (20).
31892	24¾	do	do	Oct. 12, 1925	Nantucket Shoals.
31905	25¼	do	do	— —, 1925	No data.
36886	23	do	Aug. 20, 1925	Jan. 11, 1926	Cape May, N. J. (25).
36898	22½	do	do	Oct. 3, 1925	Nantucket Shoals (23).*
36901	25½	do	do	Oct. 5, 1926	Nantucket Shoals.
36909	25	do	do	Dec. 7, 1925	Off Chatham.
36933	16½	do	do	Sept. 1, 1927	Nantucket Shoals (27¾).*
36964	21¾	do	do	Oct. 25, 1925	Monomoy Point, Cape Cod.
37041	20¾	do	Aug. 21, 1925	Aug. 28, 1926	Nantucket Shoals.
37238	21½	do	do	Oct. 3, 1925	Nantucket Shoals (22¼).*
37965	20¼	do	Aug. 25, 1925	Dec. 29, 1925	Rockaway, N. Y. (21).
39855	28	do	Oct. 1, 1925	Nov. 28, 1926	Cholera Bank, N. Y. (31).
39870	25¾	do	do	Sept. 8, 1926	Nantucket Shoals (27).*
39878	26	do	do	July 20, 1926	Stellwagen Bank.
39885	26	do	do	Feb. 16, 1926	Boston Bay.
39899	28¾	do	do	Aug. 16, 1926	Off Chatham.
39922	21¼	do	do	Nov. 19, 1925	Galilee, N. J. (21¾).
39946	29½	do	do	Nov. 17, 1927	Rockaway, N. Y.
39968	37¼	do	do	Fall, 1927	Mount Desert, Me.
40087	20½	do	Oct. 2, 1925	Dec. 11, 1925	Atlantic City, N. J.
40102	19¾	do	do	Mar. 22, 1926	Cape Henlopen, Del. (21).
40107	26½	do	do	June —, 1926	Nantucket Shoals.
40117	22	do	do	June 5, 1926	Do.
40127	31	do	do	Mar. 19, 1926	30 miles SE. from Atlantic City (31½)
40135	21	do	do	July 22, 1927	Off Chatham.
40152	27¼	do	do	Apr. 9, 1927	Barnegat, N. J.
40444	28	do	Oct. 3, 1925	Nov. 22, 1925	Rockaway, N. Y.
40459	27½	do	do	July 16, 1926	South Channel.
40473	19½	do	do	Aug. —, 1926	Do.
40516	19¾	do	do	June 23, 1927	Nantucket Shoals (24½).*
40529	28½	do	do	Nov. 10, 1925	Rockaway, N. Y.
40453	18¾	do	do	Sept. 8, 1926	Nantucket Shoals (19½).*
40556	20¾	do	do	July 26, 1926	Nantucket Shoals.
40558	16¾	do	do	Sept. 21, 1926	Do.
40581	22	do	do	May 11, 1926	Off Chatham.
40681	19¾	do	Oct. 6, 1925	Oct. 5, 1926	Nantucket Shoals.
40710	20½	do	do	July 26, 1926	Do.
40742	21½	do	do	Mar. 7, 1926	Montauk, N. Y.
40763	29¼	do	do	Nov. 23, 1925	Fire Island, N. Y.
40767	22	do	do	Sept. 25, 1926	South Channel (27).
42263	23¾	do	Oct. 24, 1925	Oct. 5, 1926	Nantucket Shoals.
42278	20	do	do	Oct. 4, 1926	15 miles off Cape Cod Light.
42295	19½	do	do	Jan. 3, 1927	Amagansett, N. Y.
42322	22¼	do	do	June 5, 1926	Nantucket Shoals.
28599	28½	Rose and Crown buoy	May 6, 1925	Nov. 10, 1925	Fisher's Island, N. Y.
28703	31	do	do	Dec. 11, 1925	Amagansett, N. Y.
29194	28	do	May 7, 1925	Sept. 15, 1925	Nantucket Shoals.
40223	21½	do	Oct. 2, 1925	Jan. 25, 1926	Watermill, N. Y. (23).
40246	28	do	do	Nov. 21, 1925	Bradley Beach, N. J.
40254	27¼	do	do	Oct. 6, 1925	Nantucket Shoals.*
40255	30½	do	do	Mar. 30, 1926	Barnegat, N. J.
40283	21	do	do	Nov. 29, 1925	Rockaway, N. Y. (22).
40336	22¾	do	do	Dec. 8, 1925	Jones Inlet, N. Y.
40338	22¼	do	do	Dec. 15, 1925	Amagansett, N. Y.
40340	28½	do	do	Feb. 8, 1926	Montauk, N. Y.
40356	29	do	do	— —, 1926	No data.
40359	22½	do	do	Feb. 8, 1926	Atlantic City, N. J. (25)
40895	22¼	do	Oct. 6, 1925	Nov. 10, 1925	Jones Inlet, N. Y.
40928	21¾	do	do	— —, 1926	No data.
40937	20¼	do	do	Feb. 9, 1926	Atlantic City, N. J.
40960	20¼	do	do	Oct. 15, 1927	South Channel.
40972	21½	do	do	Nov. 4, 1926	Rockaway, N. Y. (25).
42123	16¾	do	Oct. 24, 1925	June 23, 1927	Nantucket Shoals (23).*
42126	21¼	do	do	Sept. 11, 1926	Nantucket Shoals (24½).
31915	34¾	6 to 12 miles ESE. of Round Shoal buoy	June 11, 1925	Aug. 7, 1925	Nantucket Shoals.
31923	24¼	do	do	Oct. 2, 1925	Do.
31956	30	do	do	July 31, 1925	Do.
31983	29	do	do	May 12, 1926	South Channel.
32040	23	do	do	Oct. 18, 1925	Do.
32065	27¼	do	do	Aug. 26, 1925	Off Chatham.
32072	23¼	do	do	Aug. 25, 1925	Do.
32083	27¼	do	do	June 17, 1927	Off Chatham (31¼).*
32108	28	do	do	July 26, 1925	Off Salem, Mass.
32136	33¼	do	do	Aug. 17, 1925	South Channel.
32184	27	do	do	Sept. 12, 1925	Nantucket Shoals.
32198	24¼	do	do	Sept. 7, 1926	Do.
32214	19¼	do	June 12, 1925	— —, 1925	No data.
32216	27½	do	do	Dec. 14, 1925	Atlantic City, N. J. (28¾).
32327	27½	do	do	July 6, 1926	No data.

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
	Inches				
32341	30	6 to 12 miles ESE. of Round Shoal buoy	June 12, 1925	Apr. 10, 1926	No Mans Land, Mass. (31½).
32401	30¾	do	do	Oct. 4, 1926	Nantucket Shoals.
32410	34	do	do	July 14, 1925	South Channel.
32471	27¾	do	do	Aug. 26, 1925	Do.
32473	30¾	do	do	Aug. 29, 1925	Off Chatham.
32477	44½	do	do	Sept. 12, 1925	Nantucket Shoals.
32533	28¼	do	do	Aug. 25, 1925	Off Chatham.
32565	24¾	do	do	Sept. 9, 1925	Nantucket Shoals (25).
32576	26½	do	do	Dec. 20, 1925	Rockaway, N. Y. (26¾).
32622	23¼	do	do	Nov. 4, 1926	Nantucket Shoals.
32638	26½	do	do	May 16, 1926	Marblehead, Mass. (28¾).
32639	37	do	do	June 18, 1926	Nantucket Shoals.
32667	38½	do	do	June 27, 1925	South Channel.
32689	25½	do	do	Sept. 9, 1925	Off Chatham.
37267	18¼	Great Rip buoy	Aug. 23, 1925	—— —, 1927	No data.
37331	20¼	do	do	Mar. 30, 1926	Barnegat, N. J.
37467	20¾	do	do	Jan. 17, 1926	Cape May, N. J.
37502	28¼	do	do	Oct. 3, 1925	Nantucket Shoals.
37506	27¾	do	do	Aug. 14, 1926	South Channel.
37511	28	do	do	Sept. 27, 1926	Nantucket Shoals.
37661	22	do	do	Sept. 24, 1926	Do.
37675	29½	do	do	Nov. 7, 1925	Narragansett, R. I.
37732	29¾	do	Aug. 24, 1925	Nov. 13, 1925	Rockaway, N. Y.
37790	19¼	do	do	July 31, 1926	South Channel.
37868	29	do	do	Oct. 3, 1925	Nantucket Shoals.
37998	26	do	Aug. 25, 1925	Nov. 1, 1925	Monomoy, Cape Cod.
38002	30¼	do	do	Feb. 9, 1926	Atlantic City, N. J.
38116	23¼	do	do	Nov. 20, 1925	Do.
38214	21¼	do	do	Mar. 10, 1926	Cape May, N. J.
38216	21	do	do	Jan. 23, 1926	Jones Inlet, N. Y.
43980	19½	Round Shoal buoy	Sept. 6, 1926	May 6, 1927	Nantucket Shoals (22¼).*
44163	19½	do	Sept. 7, 1926	Apr. 4, 1927	No Mans Land, Mass.
44167	18	do	do	Jan. 19, 1927	Cape May, N. J.
44546	28½	do	Sept. 8, 1926	May 1, 1927	Georges Bank.
44594	17¼	do	do	Dec. 15, 1926	Block Island Sound, R. I.
44600	20½	do	do	Mar. 7, 1927	Cape May, N. J.
44711	25¼	do	do	Aug. 13, 1927	Muskeget Channel, Mass.
44452	20½	Between Round Shoal and Rose and Crown buoys.	Sept. 7, 1926	Feb. 25, 1927	Fire Island, N. Y. (22).
44468	17¾	do	do	Nov. 30, 1927	Rockaway, N. Y.
44483	18½	do	do	—— —, 1927	No data.
44526	19¼	do	do	Dec. 4, 1926	Narragansett, R. I.
45240	25	do	Sept. 10, 1926	May 10, 1927	Off Sandy Hook, N. J.
45328	31	do	do	Dec. 10, 1926	Block Island Sound, R. I.
45302	16¾	do	do	Sept. 1, 1927	Nantucket Shoals (20½).*
45414	20	Between Rose and Crown and Great Rip buoys.	Sept. 11, 1926	Nov. 25, 1926	Monomoy, Cape Cod.
45426	21¼	do	do	Oct. 1, 1927	Nantucket Shoals.
45075	30	Great Rip buoy	Sept. 9, 1926	June 24, 1927	Nantucket Shoals (32¼).*
45407	25¾	do	Sept. 11, 1926	Oct. 29, 1926	Block Island, R. I. (26).
47472	21¼	Round Shoal buoy	May 4, 1927	Sept. 3, 1927	Nantucket Shoals (21¾).*
47483	19¾	do	do	Nov. 2, 1927	Atlantic City, N. J.
47497	20½	do	do	Nov. 26, 1927	Off Anglesea, N. J. (21½).
47490	22½	do	do	Sept. 3, 1927	Nantucket Shoals (23¾).*
47545	21½	do	May 6, 1927	Nov. 15, 1927	Galilee, N. J.
47588	18½	do	do	July 19, 1928	Nantucket Shoals (22).*
47715	20¼	do	do	Nov. 21, 1927	Bradley Beach, N. J. (24).
47731	22½	do	do	Mar. 4, 1928	Off Anglesea, N. J.
47738	20½	do	do	Sept. 1, 1927	Nantucket Shoals (20½).*
47759	21¾	do	do	July 14, 1928	Nantucket Shoals (22¾).*
47776	19¼	do	do	Nov. 16, 1927	Nantucket Shoals.
47778	18¼	do	do	June 17, 1927	Nantucket Shoals (18¾).*
47799	21½	do	do	July 21, 1928	Nantucket Shoals (25).*
47801	18½	do	do	Oct. 8, 1927	Nantucket Shoals.
47803	28½	do	do	do	Do.
47809	23½	do	do	do	Do.
47854	19	do	do	Nov. 16, 1927	Rockaway, N. Y.
47856	21¾	do	do	Aug. 31, 1927	Nantucket Shoals (22).*
47913	21½	do	do	Mar. 7, 1928	Atlantic City, N. J. (22¾).
47944	19¾	do	do	Nov. 19, 1927	Nantucket Shoals.
47965	27	do	do	Mar. —, 1928	Long Beach, N. Y.
47977	29¾	do	do	June 17, 1927	Nantucket Shoals (29¾).*
48020	21½	do	do	Nov. 19, 1927	Nantucket Shoals.
48022	20	do	do	Sept. 1, 1927	Nantucket Shoals (20¼).*
48025	21½	do	do	Nov. 19, 1927	Nantucket Shoals.
48053	22½	do	do	June 23, 1927	Nantucket Shoals (23).*
48075	22½	do	do	June 27, 1927	Nantucket Shoals.
48076	28	do	do	July 20, 1928	Nantucket Shoals (30).*
48087	20	do	do	June 22, 1927	Nantucket Shoals (20½).*

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
	Inches				
48090	21	Round Shoal buoy	May 6, 1927	June 18, 1927	Nantucket Shoals (21¼).*
48118	20	do	do	Mar. 7, 1928	Rockaway, N. Y.
48141	19½	do	do	July 19, 1928	Nantucket Shoals (22).*
48155	26	do	do	Aug. 31, 1927	Nantucket Shoals (26½).*
48160	31¼	do	do	July 19, 1928	Nantucket Shoals (34).*
48269	24	do	do	Sept. 1, 1927	South Channel.
48324	20¼	do	do	Nov. 19, 1927	Long Beach, N. Y.
48328	20¾	do	do	Sept. 2, 1927	Nantucket Shoals (20¾).*
48492	22¼	do	May 7, 1927	Jan. 15, 1928	Block Island Sound, R. I.
48866	19	do	June 17, 1927	Feb. —, 1929	Atlantic City, N. J.
48879	27½	do	do	Jan. 12, 1928	Amagansett, N. Y.
48887	20½	do	do	Nov. 17, 1927	Cholera Bank, N. Y.
48950	27¼	do	do	Jan. 11, 1928	Manasquan, N. J.
48956	24½	do	do	Sept. 15, 1927	Nantucket Shoals.
48984	24½	do	do	Nov. 8, 1927	Block Island, R. I.
49055	22¾	do	do	Feb. 4, 1929	Cape May, N. J. (28½).
49068	24¼	do	June 18, 1927	Jan. 4, 1928	Cape May, N. J.
49103	19¾	do	do	Sept. 2, 1927	Nantucket Shoals (20¾).*
49126	19	do	do	May 1, 1928	No Mans Land, Mass.
49127	22¾	do	do	Dec. 21, 1927	Western part of Georges Bank.
49141	21¾	do	do	Sept. 1, 1927	Nantucket Shoals (22).*
49222	21¾	do	do	Aug. 15, 1927	South Channel.
49247	20¾	do	do	Sept. 1, 1927	Nantucket Shoals (21).*
49270	20¼	do	do	Oct. 27, 1927	Seabright, N. J. (21½).
49330	21¼	do	do	—— —, 1928	No data.
49344	20¾	do	do	Dec. 3, 1928	Cape May, N. J.
49412	21¼	do	June 22, 1927	Dec. 1, 1927	Off Manahawkin, N. J.
49428	21¼	do	do	Nov. 8, 1927	Long Beach, N. Y.
49544	25½	do	June 23, 1927	Nov. 16, 1927	Rockaway, N. Y.
49562	20½	do	do	Dec. 7, 1927	Manasquan, N. J.
49579	20	do	do	Dec. 23, 1927	Westhampton, N. Y. (21).
49589	22¾	do	do	Dec. 14, 1927	Off Spring Lake, N. J. (23¾).
49616	23¾	do	do	Sept. 3, 1927	Nantucket Shoals (23¾).*
49621	21	do	do	Dec. 11, 1928	Cholera Bank, N. Y. (25).
49649	19	do	do	Nov. 10, 1927	No Mans Land, Mass.
49697	20¼	do	do	Apr. 3, 1928	Nahant, Mass.
52829	20½	do	Aug. 31, 1927	Nov. 13, 1927	Rockaway, N. Y.
52835	22½	do	do	July 30, 1928	Off Chatham.
52836	22½	do	do	Nov. 26, 1928	Rockaway, N. Y.
52853	20	do	do	Jan. —, 1929	Atlantic City, N. J. (27½).
52856	21	do	do	—— —, 1928	No data.
52863	22	do	do	Dec. 31, 1928	Seabright, N. J.
52887	22	do	do	Jan. 10, 1928	Cape May, N. J.
52955	20	do	do	Oct. 18, 1928	Georges Bank.
52973	21¼	do	do	Nov. 26, 1927	Cholera Bank, N. Y. (22).
53003	25½	do	do	Nov. 6, 1927	Atlantic City, N. J. (26).
53015	21	do	do	Nov. 14, 1928	Point Judith, R. I. (23).
53016	23½	do	do	Apr. 5, 1928	Wildwood, N. J. (26).
53029	20¾	do	do	Oct. 15, 1927	South Channel.
53098	24	do	do	Nov. 22, 1927	Stellwagen Bank.
53216	21½	do	Sept. 1, 1927	Dec. 7, 1927	Coney Island, N. Y.
53254	21¼	do	do	July 20, 1928	Nantucket Shoals (23¾).*
53289	21½	do	do	Nov. 8, 1928	Rockaway, N. Y. (24).
53305	20¼	do	do	Nov. 19, 1927	Nantucket Shoals.
53308	20¾	do	do	Nov. 14, 1927	Beach Haven, N. J.
53323	19	do	do	Nov. 18, 1927	Rockaway, N. Y.
53325	20½	do	do	Nov. 16, 1927	Do.
53336	20	do	do	Feb. 25, 1928	Manasquan, N. J.
53349	23	do	do	Mar. 5, 1928	Wildwood, N. J. (24).
53364	21¼	do	do	Apr. 4, 1929	Block Island, R. I.
53404	22¾	do	do	Nov. 23, 1927	Rockaway, N. Y. (23½).
53488	22½	do	do	Nov. 18, 1927	Rockaway, N. Y.
53583	20¾	do	do	Oct. 29, 1927	Off Seaside Park, N. J. (21).
53439	20¼	do	Sept. 2, 1927	Nov. 14, 1927	Rockaway, N. Y.
53616	22	do	do	Dec. 19, 1927	Spring Lake, N. J. (22½).
53634	23	do	do	Dec. 4, 1928	Off Willis Wharf, Va.
53707	22¼	do	do	Oct. 17, 1927	Nantucket Shoals (22¼).*
53707	22¼	do	do	Sept. 29, 1928	Nantucket Shoals.
53710	20½	do	do	Jan. 8, 1928	Seabright, N. J.
53758	25	do	do	Dec. 11, 1927	Jones Inlet, N. Y.
53785	20¾	do	do	Nov. 14, 1928	Long Branch, N. J. (25½).
53837	21¼	do	Sept. 3, 1927	Nov. 2, 1928	Rockaway, N. Y. (25).
53987	24½	do	do	Dec. 11, 1927	Rockaway, N. Y. (25¾).
53990	24¾	do	do	Nov. 16, 1927	Rockaway, N. Y.
54038	23¼	do	do	Nov. 7, 1927	Beach Haven, N. J.
54051	23¾	do	do	Nov. 10, 1927	Galilee, N. J. (24½).
54053	22	do	do	Oct. 8, 1928	Coggeshall Point, R. I.
54108	23¾	do	do	Nov. 20, 1927	Bradley Beach, N. J. (25).
54221	19½	do	do	Nov. 16, 1927	Nantucket Shoals.
54257	20¼	do	do	July 20, 1928	Nantucket Shoals (23½).*

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Nantucket Shoals—Continued			
50391	*Inches* 19¾	Between Round Shoal and Rose and Crown buoys.	June 25, 1927	Nov. 23, 1927	Barnegat Inlet, N. J. (20½).
50414	21¾	do	do	Apr. 15, 1928	Block Island Sound, R. I.
55687	20¾	do	Oct. 14, 1927	Aug. 20, 1928	South Channel.
55731	21½	do	do	June 10, 1929	Nantucket Shoals (25½).*
55822	18	do	Oct. 17, 1927	Mar. —, 1928	Delaware Bay.
56895	20¾	do	do	Nov. 21, 1927	Bradley Beach, N. J.
49776	20¼	Between Rose and Crown and Great Rip buoys.	June 24, 1927	Sept. 15, 1927	Nantucket Shoals.
50074	27¼	do	do	Feb. 24, 1928	Wildwood, N. J.
50082	22½	do	do	Oct. 25, 1927	Nantucket Shoals.
50089	18¼	do	do	Sept. 29, 1928	Do.
50099	23¾	do	do	Apr. —, 1928	Cape May, N. J.
50249	30	do	June 25, 1927	Sept. 10, 1928	Nantucket Shoals.
55864	25¾	do	Oct. 15, 1927	Jan. 7, 1928	Long Beach, N. Y.
55905	23	do	do	Feb. 7, 1928	Long Branch, N. J. (23½).
55926	29	do	do	Dec. 3, 1928	Cape May, N. J.
55928	29½	do	do	Apr. 5, 1928	Wildwood, N. J.
55941	29½	do	do	Apr. 19, 1929	Atlantic City, N. J.
56022	20½	do	do	Mar. —, 1928	Off Delaware Bay (22½).
56140	23¾	do	do	—— —, 1928	No data.
56186	22½	do	do	Mar. 26, 1928	Barnegat, N. J. (23¾).
56251	25¼	do	Oct. 16, 1927	Jan. 1, 1929	Wildwood, N. J.
56296	32½	do	do	Feb. 15, 1928	No Mans Land, Mass.
56321	25¾	do	do	Feb. 4, 1928	Beach Haven, N. J.
56333	30	do	do	July 2, 1928	South Channel.
56379	35¼	do	do	Mar. 10, 1928	Chesapeake Bay, Va.
56414	24¼	do	do	Aug. 3, 1929	Nantucket Shoals.
56450	28¾	do	do	Mar. 15, 1927	Atlantic City, N. J.
56522	23¼	do	do	Sept. 14, 1928	Nantucket Shoals.
56524	23	do	do	Aug. 15, 1929	South Channel.
56656	27	do	Oct. 17, 1927	Nov. 16, 1927	Fire Island, Inlet, N. Y.
56688	24¼	do	do	do	Cholera Bank, N. Y. (25).
56691	25¼	do	do	Dec. 4, 1928	Off Hog Island, Va.
56717	22½	do	do	Apr. 3, 1928	Gay Head, Mass.
56718	34	do	do	Apr. 20, 1929	Sakonnet Point, R. I.
56732	29	do	do	Sept. 23, 1928	Georges Bank.
56741	24¾	do	do	Winter, 1927-28	Wildwood, N. J.
48339	19½	Great Rip buoy	May 7, 1927	Sept. 15, 1927	Nantucket Shoals.
49806	20½	do	June 24, 1927	Feb. 28, 1928	Wildwood, N. J.
49882	21	do	do	Sept. 10, 1928	Nantucket Shoals.
49883	24½	do	do	Mar. 4, 1928	Amagansett, N. Y.
50346	20	do	June 25, 1927	Winter, 1927-28	Wildwood, N. J. (24).
48736	23¾	Davis Shoal	June 17, 1927	Sept. 24, 1927	Nantucket Shoals.
48741	23¾	do	do	Nov. —, 1928	Block Island, R. I.
48847	21	do	do	Feb. 14, 1928	Seabright, N. J.
48851	19	do	do	—— —, 1928	No data.
58080	21½	Round Shoal buoy	July 14, 1928	Spring, 1929	Block Island, R. I.
58092	20¾	do	do	Nov. 28, 1928	Rockaway, N. Y.
58106	24	do	do	Feb. 14, 1929	Delaware Bay.
58153	23¾	do	do	Feb. 20, 1929	Rockaway, N. Y.
58368	23¾	do	July 19, 1928	Nov. 13, 1928	Do.
58369	27	do	do	Nov. 25, 1928	Barnegat, N. J.
58423	24½	do	do	Nov. 8, 1928	Rockaway, N. Y.
58512	23¾	do	do	Oct. 26, 1928	Nantucket Shoals.
58580	24	do	do	Nov. 22, 1928	Point Judith, R. I. (26).
58611	22½	do	July 20, 1928	Oct. 26, 1928	Nantucket Shoals (23).*
58621	25½	do	do	Oct. 11, 1929	Nantucket Shoals.
58709	21½	do	do	Nov. 15, 1928	South Channel.
58745	23	do	do	Nov. 19, 1928	Rockaway, N. Y. (26¼).
58808	22½	do	do	Nov. 13, 1928	No Mans Land, Mass.
58824	20	do	do	May 18, 1929	Siasconset, Nantucket.
58849	22	do	do	Nov. 19, 1928	Fire Island, N. Y.
60953	24	do	Oct. 24, 1928	Dec. 1, 1928	Rockaway, N. Y.
61060	28¾	Between Round Shoal and Rose and Crown buoys.	Oct. 26, 1928	Jan. 2, 1929	Seabright, N. J.
61066	35	do	do	Jan. —, 1929	Atlantic City, N. J.
61071	27	do	do	Dec. 13, 1928	Do.
61082	26	do	do	Nov. 14, 1928	Newport, R. I.
61122	25½	do	Oct. 28, 1928	June 14, 1929	Nantucket Shoals (26).*
58894	24½	Great Rip buoy	July 21, 1928	Dec. 3, 1928	Cape May, N. J. (26).
61247	26	do	Oct. 29, 1928	Mar. 25, 1929	"Old Ground," Cape Henlopen, Del. (26½)
		Other points			
3405	29½	Woods Hole, Mass	Jan. 6, 1926	June 16, 1926	Chatham Bay, Mass.
3535	30	do	do	Jan. 27, 1927	Amagansett, N. Y. (32½).
3602	30½	do	do	Jan. 20, 1928	No Mans Land, Mass.

TABLE 49.—*A list of all the recaptures of cod tagged between the nantucket shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
		Other points—Continued			
	Inches				
3612	29½	Woods Hole Mass.	Jan. 6, 1926	Mar. 15, 1926	Sea Girt, N. J.
3764	31½	do	do	Jan. 15, 1926	Montauk Point, N. Y.
3776	28	do	do	Apr. 12, 1928	Sandy Hook Bay, N. J.
3805	33	do	Jan. 7, 1926	Mar. 27, 1926	Montauk Point, N. Y. (33).
3845	27¾	do	do	Apr. 17, 1926	Jones Inlet, N. Y.
3862	25½	do	do	Aug. 10, 1926	Block Island, R. I.
3960	31¼	do	do	Apr. 6, 1927	Brentons Reef, R. I.
3969	27¼	do	do	Mar. 11, 1926	Nantucket Shoals.
3984	30	do	do	Dec. 13, 1926	Block Island, R. I.
4036	35	do	do	Jan. 25, 1926	Watermill, N. Y.
4041	32	do	do	Jan. 13, 1926	Amagansett, N. Y.
4051	26½	do	do	Feb. 13, 1926	Montauk, N. Y.
4091	29	do	do	July 21, 1927	Nantucket Shoals.
4098	29½	do	do	Jan. 3, 1927	Newport, R. I. (33½).
4106	27	do	do	Feb. 13, 1926	Westhampton, N. Y.
4184	26	do	do	Mar. 20, 1928	Montauk, N. Y.
4187	31½	do	do	Aug. 10, 1926	Block Island, R. I.
4213	24½	do	do	Mar. 21, 1926	Montauk, N. Y.
4220	26	do	do	Dec. 14, 1927	Cholera Bank, N. Y.
4242	32	do	do	May 2, 1926	Montauk, N. Y. (32¾).
4329	26½	do	Jan. 3, 1927	Jan. 18, 1927	Block Island, R. I.
4334	24½	do	do	May 7, 1927	Sandy Hook, N. J. (26).
4353	29	do	do	Jan. 10, 1927	Block Island Sound, R. I.
4460	22	do	do	Jan. 8, 1927	Block Island, R. I. (22).
4495	28¼	do	do	do	Watch Hill, R. I.
4546	23	do	do	Jan. 19, 1928	Point Judith, R. I.
4569	23¾	do	do	Jan. 24, 1928	Amagansett, N. Y. (31).
4577	27	do	do	Apr. 15, 1927	Off Narragansett Bay, R. I.
4605	32½	do	do	Jan. 8, 1927	Amagansett, N. Y.
4728	21¾	do	do	May 5, 1927	Watch Hill, R. I.
4756	29	do	Jan. 13, 1928	Apr. 4, 1928	Westhampton, N. Y. (30).
4774	25	do	do	Feb. 8, 1928	Atlantic City, N. J. (26).
4818	24	do	do	Apr. 15, 1928	Watch Hill, R. I.
4894	20¾	do	do	Feb. 11, 1928	Easthampton, N. Y.
4933	25	do	do	Spring, 1928	Off Rhode Island.
4952	24½	do	do	Oct. —, 1928	Nantucket Shoals.
4964	25½	do	do	Jan. 18, 1928	Block Island, R. I.
7390	21¾	do	do	Mar. 25, 1928	Nantucket Shoals (22).
7407	28	do	do	Mar. —, 1928	Cape May, N. J.
7488	28	do	do	Apr. 15, 1928	Newport, R. I.
7495	23¾	do	do	Mar. 12, 1928	Gay Head, Mass.
7509	27¼	do	do	Jan. 27, 1928	Amagansett, N. Y.
7535	23¼	do	do	July 23, 1928	South Channel.
7545	28	do	do	Mar. —, 1928	Block Island, R. I.
7596	24¾	do	do	Spring, 1928	Off Rhode Island.
7599	28½	do	do	Jan. 18, 1928	Block Island, R. I.
11072	28	No Mans Land	Apr. 21, 1923	June 1, 1923	No data.
11114	23½	do	Apr. 24, 1923	Oct. 17, 1925	No Mans Land.
11152	26½	do	Apr. 26, 1923	Aug. 24, 1923	South Channel.
42348	28	do	Oct. 28, 1925	Feb. 8, 1926	Block Island, R. I.
42396	27¼	do	do	Oct. 28, 1926	No Mans Land.
10012	35	Off Chatham	May 27, 1923	Sept. 17, 1923	Off Chatham.
47101	27	do	May 3, 1927	Mar. 27, 1929	Sandy Hook, N. J. (32½).
47108	23¼	do	do	July 12, 1927	Off Chatham.
47152	21¼	do	do	May —, 1928	Ipswich Bay, Mass.
47183	29½	do	do	July 25, 1927	South Channel.
47210	29¼	do	do	Mar. 28, 1928	Wildwood, N. J.
47215	27¼	do	do	July 10, 1928	South Channel.
47287	18¼	do	May 4, 1927	Jan. 12, 1928	Jones Inlet, N. Y. (19).
47371	23¾	do	do	May 11, 1928	Off Chatham.
47378	27¾	do	do	do	Do.
47384	19½	do	do	Jan. 23, 1928	Cape May, N. J.
48512	23¼	do	June 16, 1927	Nov. 21, 1927	Barnegat Inlet, N. J. (24).
48533	25¼	do	do	July 26, 1927	South Channel.
48610	22	do	do	Oct. 26, 1928	Nantucket Shoals.
48628	28	do	do	Jan. —, 1928	Wildwood, N. J.
49392	27½	do	June 22, 1927	July 26, 1927	South Channel.
49398	19½	do	do	Sept. 10, 1928	Nantucket Shoals.
57704	23½	Cholera Bank, N. Y	Nov. 14, 1927	Dec. 27, 1927	Jones Inlet, N. Y.
57706	20½	do	do	Nov. 17, 1927	Do.
57726	22¾	do	Nov. 15, 1927	Feb. 17, 1928	Off Long Beach, N. Y. (23½).
57735	23¼	do	Nov. 16, 1927	Nov. 21, 1927	Bradley Beach, N. J.
57762	23½	do	do	Dec. 11, 1927	3 miles north of Ambrose Lightship, N. Y.
57787	22	do	Nov. 17, 1927	May 15, 1928	Nantucket Shoals.
57829	23	do	Nov. 20, 1927	Jan. 15, 1929	Delaware Bay (27).
57857	28	do	Nov. 21, 1927	Dec. 26, 1927	Easthampton, N. Y.
61347	21¾	do	Nov. 21, 1928	Jan. 19, 1929	Cape May, N. J.

TABLE 49.—*A list of all the recaptures of cod tagged between the Nantucket Shoals region and southern New Jersey*—Continued

[Those marked with an asterisk (*) were taken by one of the tagging vessels, the *Halcyon* or the *Albatross II*]

Tagged				Recaptured	
Tag	Length	Locality	Date	Date	Locality
		Other points—Continued			
	Inches				
61380	21¼	Cholera Bank, N. Y.	Nov. 23, 1928	Dec. 16, 1928	Off Long Beach, N. Y.
61390	22	do	do	Nov. 29, 1928	3 miles north of Ambrose Lightship, N. Y.
57887	23	Atlantic City, N. J.	Mar. 25, 1928	July 22, 1928	Nantucket Shoals.
61823	25½	Wildwood, Cape May, N. J.	Dec. 31, 1928	Feb. 20, 1929	Wildwood, N. J. (25¾).
61869	22¾	do	Jan. 1, 1929	Jan. 23, 1929	Wildwood, N. J. (23¼).
61927	27¼	do	Jan. 22, 1929	Jan. 27, 1929	Delaware Bay.
61936	26	do	do	Aug. 1, 1929	South Channel.
61507	24½	do	Feb. 13, 1929	Apr. 14, 1929	Cape May, N. J.
61569	22½	do	Feb. 16, 1929	Mar. 21, 1929	Do.
62065	28	do	Mar. 18, 1929	Aug. 2, 1929	South Channel.
62125	28½	do	Mar. 27, 1929	Oct. 12, 1929	Nantucket Shoals.

TABLE 50.—*The following recaptures were reported too late to enter into the records*

Tagged				Recaptured	
Tag No.	Length	Locality	Date	Date	Locality
	Inches				
7553	25	Woods Hole, Mass.	Jan. 13, 1928	Oct. 12, 1929	Nantucket Shoals.
52860	33¾	Lat. 41° 17′ N., long. 69° 24′ W.	June 13, 1929	June 22, 1929	South Channel.
62883	26	do	do	Sept. 5, 1929	Do.
62222	18½	Nantucket Shoals, between Round Shoal and Rose and Crown bouys.	June 10, 1929	Nov. 24, 1929	Rockaway, N. Y. (18¾).
62253	21	do	do	Nov. 2, 1929	Seabright, N. J.
62247	22½	do	do	Nov. —, 1929	Delaware Bay.
62450	19½	do	June 11, 1929	Jan. 8, 1930	Delaware Bay (20).
62538	25¼	do	do	Dec. 10, 1929	Amagansett, N. Y.
62564	26½	do	do	Sept. 1, 1929	South Channel.
62581	22	do	do	Oct. 11, 1929	Nantucket Shoals.
62644	23¾	do	do	Oct. 14, 1929	Do.
62808	26¼	do	June 12, 1929	June 22, 1929	South Channel.
62982	25	do	June 14, 1929	Sept. 16, 1929	Nantucket Shoals.
48846	19½	Nantucket Shoals, Davis Shoals	June 17, 1927	Feb. 22, 1930	Cape May, N. J.
62682	32¾	Nantucket Shoals, Great Rip bouy	June 11, 1929	July 16, 1929	Do.
58456	28½	do	Oct. 16, 1927	Mar. 21, 1930	Delaware Bay (34).
61248	29½	do	Oct. 29, 1928	Nov. 23, 1929	Cape May, N. J.
61239	18	Nantucket Shoals, Rose and Crown buoy	Oct. 28, 1928	Mar. 1, 1930	Delaware Bay.
61748	31¾	Cape May, N. J.	Dec. 29, 1928	Jan. 4, 1930	Off Jones Inlet, N. Y.
61540	24¾	do	Feb. 13, 1929	Oct. 31, 1929	Elberon, N. J. (26¼).
61579	20¼	do	Feb. 16, 1929	Dec. 12, 1929	Off Fire Island Inlet, N. Y.
62049	20½	do	Mar. 18, 1929	Apr. 22, 1930	Cape May, N. J.
62144	27¾	do	Apr. 7, 1929	Mar. 10, 1930	Virginia Beach, Va.
62182	24¾	do	Apr. 8, 1929	Oct. 16, 1929	Fire Island, N. Y.

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