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AGE AND GROWTH OF THE REDFISH (*SEBASTES MARINUS*) IN THE GULF OF MAINE

By GEORGE F. KELLY AND ROBERT S. WOLF

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ABSTRACT

Validity of the use of the otolith in age-growth studies of the redfish (*Sebastes marinus*) is demonstrated. Otoliths accrue one opaque and one hyaline band a year. The opaque band begins to form in April, the hyaline band in September. Otoliths preserved in ethanol may be read whole, although those from larger fish are more easily read after they are sectioned. Otoliths stored dry must be sectioned for reading.

Redfish larvae can be collected in surface waters throughout the period of spawning, April to September. The fry descend into mid-depths as they grow and first appear on the bottom in August. Redfish reach an average length of about 50 mm. in their first year of life.

The sexes grow at virtually the same rate until the tenth year, after which the male grows more slowly than the female. Redfish of the Gulf of Maine grow more slowly than those of northern European waters.

While dominant age classes appear in the collections of young fish, they are not obvious in samples of older, commercially available fish.

AGE AND GROWTH OF THE REDFISH (*SEBASTES MARINUS*) IN THE GULF OF MAINE

By GEORGE F. KELLY AND ROBERT S. WOLF, *Fishery Research Biologists*
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The redfish of the Gulf of Maine, *Sebastes marinus* (Linnaeus), has supported an economically important fishery in the United States since the late 1930's. The fishery has played a major role in the livelihood of several New England ports, particularly Gloucester, Mass., and Rockland and Portland, Maine. Redfish fillets have found a ready market in this country and, lately, in many European countries as well. The fishery developed, as have so many others, first in local waters, gradually moving out farther and farther as the closer fishing grounds became less profitable and as gear and techniques improved. Vessels hailing from New England ports now fish as far away as the waters off Labrador. The redfish is also sought after by many European fishermen on the shelf areas of much of the boreal North Atlantic. The vessels of Soviet Russia and Germany have fished for this species from the northern coast of Russia itself to certain isolated fishing grounds off the coast of Canada. This intensive effort has underscored the urgency of understanding the life history of the species.

Sebastes marinus, the redfish or rosefish, belongs to a North Atlantic species-group that is not well understood taxonomically at this time. *Sebastes marinus* (Linnaeus) and *S. viviparus* Kroyer are generally accepted as the only valid species of the genus. The status of *S. mentella* Travin (1951) is not firmly established. Andriiashev (1954) has questioned the validity of the species, stating that of the characteristics used to separate *mentella* from *marinus*—

> all were poor transient characters or showed only average differences . . . these forms were distinguished by insufficient investigation over the extent of their broad range (to the Faeroe Islands, Iceland, Greenland, and the shores of the U.S.A.).

Andriiashev accordingly reduced *mentella* to the status of a subspecies of *marinus*.

Whatever its taxonomic structure, the group in general has been studied by many people in this country and abroad. The importance of this fishery at the international level has greatly increased the amount of research being done, and a particularly spirited controversy has developed about the radically different growth rates derived by various workers. This paper is primarily concerned with the growth rate of the redfish population in the Gulf of Maine. It is to be hoped that the results of this research will have wider application; in any event, this information is necessary for the proper evaluation of the New England redfish fishery.

BRIEF REVIEW OF THE LITERATURE

1880. R. Collett, working on collections made in the Bear Island–Spitzbergen area by the Norwegian Atlantic Expedition of 1876, reported that redfish fry were about 6 mm. long at birth.

1922. Ad. S. Jensen reported on the extensive observations that he made on redfish in West Greenland waters in 1908–9. He collected redfish fry periodically from the time of the first appearance in the plankton, recording the changes in size composition for the first 9 months of life. His data indicated an average length of 5.5 cm. for fish 8 to 9 months of age. He attempted to estimate a growth rate of the redfish from length-frequency data. This particular population ranged from 7 to 71 cm. in length. He suggested that fish in age-group I ranged from 7 to 17 cm. in length, in age-group II from 19.5 to 30 cm. in length, and in age-group III from 31 to 41 cm. in length.

1936. N. P. Smaragdova is to be credited with the first detailed study of the age and growth rate of *Sebastes*. He referred his species to *S. marinus*. His work was based on scales, although he did make a comparative study of scales and otoliths. The material came from the Barents Sea and was collected over a period of 12 years, 1921 to 1932. He reported good agreement between age readings made from scales and those made from otoliths. He concluded that the

redfish is relatively slow growing and long lived. He estimated the length at 1 year to be 5.4 cm. The oldest fish in his collection, with an estimated age of 27 years, measured 57 cm. in length. The data presented by Smaragdova are somewhat erratic but do not differ greatly from that of later workers.

1944. V. V. Veschezerov also studied the age and growth of redfish from the Barents Sea. He used otoliths to estimate the age of 764 fish ranging in length from 3 to 63 cm. He concluded, as had Smaragdova, that the Barents Sea redfish are relatively slow growing and that some of his fish were as old as 26 years. He estimated the length at 1 year to be 5.1 cm. The largest fish, 58.3 cm. in length, was estimated to be 24 years old.

1949. A. Perlmutter and G. M. Clarke published a detailed study of the growth rate of *S. marinus* in the Gulf of Maine and off western Nova Scotia based on age readings obtained from the scales. The study was deliberately aimed at immature fish, or fish less than 23.5 cm. in length. The rate of growth arrived at was comparable to that published by Smaragdova for the Barents Sea population of *S. marinus*. The data suggest that redfish mature at about 8 to 10 years of age and are very slow growing.

1951. V. I. Travin published growth data for *S. marinus* from the Barents Sea in a paper that also described a new species of redfish, *S. mentella*. *S. marinus* was described as being restricted to depths of less than 300 meters, whereas the new species occurred to depths in excess of 300 meters. *S. mentella* Travin is described as having a slower growth rate than that of *S. marinus*. Unfortunately, the growth data for both species are presented simply as average lengths at age without information on the number of fish involved or the method used to age the fish. Travin's growth data for the two species indicate that they grow at about the same rate until 4 years of age, after which *mentella* grows more slowly than *marinus*. At 17 to 18 years of age, *marinus* averages 8 to 9 cm. longer than *mentella* of the same age. His data suggest slightly faster growth than that implied by the data of Veschezerov and Smaragdova for fish up to about 14 years of age. His largest fish, 49.9 cm. in length, was estimated to be 18 years of age. Fish estimated at 18 years by Veschezerov averaged 50 cm. in length, while those considered to be 18 years old by Smaragdova averaged 44.9 cm.

1952. A. Kotthaus, working with material from the coast of Norway and from the Bear Island region, presented very rapid growth rates, which resulted from his conclusion that the redfish developed three sets of hyaline and opaque bands a year on the otolith. His studies were based on nearly 15,000 fish, ranging from 11 to 81 cm. in length. He considered that the modes of the length frequency curve of his entire sample represented the first seven year classes. While we disagree with Kotthaus' conclusions, it must be admitted that his findings are provocative and stimulating.

1953. H. B. Bigelow and W. C. Schroeder state that the redfish is a "very slow growing fish." Their opinion is based on Perlmutter and Clarke's study and on some specimens they had collected that averaged 2½ inches and were considered to be about 1 year of age.

1956. E. Bratberg published a careful study validating the use of scales and otoliths for determining age of redfish. He collected 19 samples of small redfish regularly from three localities along the coast of Norway for a period of 18 months. Bratberg examined a total of 1,860 specimens ranging in length from 5.5 to 22 cm. He demonstrated that only one opaque and one hyaline band is formed in any one year. The periphery of the otolith is opaque from May through September and hyaline from October to April. Although he worked mostly with younger fish, he presented growth data for fish up to and including age 7.

To sum up, with the notable exception of one study, the various published growth data demonstrate general agreement that *Sebastes* species grow very slowly. Whether or not it develops in the future that one or many species are involved, much of the research accomplished to date indicates less variation in the results of different workers than has been observed many times between closely related populations of other species of fish. The data that will be presented in this paper and that presented by Perlmutter and Clarke (1949) strongly suggest a significantly slower growth rate for the Gulf of Maine stock than that reported for the redfish in the Barents Sea and along the coast of Norway.

OBJECTIVES AND METHODS

The primary objective of this paper is to present age-growth information on the redfish population of the Gulf of Maine. This information was needed for the intelligent planning of our research program which is, of course, concerned with determining how this valuable fishery should be managed.

To attain our objective, it was necessary to interpret the banding of the otolith. Related to this was the question of when the first annulus was completed in the otolith. Some difficult problems associated with growth during the first year of life had to be solved. With verified age-growth data available, it was finally necessary to determine the age composition of samples from the redfish population of the Gulf of Maine.

These several problems were approached in many ways. It was decided, after due consideration of the scale markings, to use otoliths for the age-composition studies. The samples were largely obtained from the commercial catches. For the detailed study of the otolith and the seasonal nature of its bands, a special station for sampling small redfish was selected and occupied at appropriate intervals.

SAMPLING THE COMMERCIAL CATCH

Since large quantities of redfish are landed at Gloucester, Mass., and Portland and Rockland, Maine, the bulk of the sampling was performed at these ports. Port samplers removed the otoliths from random samples of 25 fish each from those catches that came from single statistical subareas (Rounsefell 1948). The otoliths were stored dry in separate small paper envelopes on which were recorded the fork length and sex of the fish along with the necessary interview information. These samples were sent to the Woods Hole laboratory for preparation and reading.

SAMPLING BY RESEARCH VESSELS

To augment the sampling of the commercial catch, the R/V *Albatross III* and a chartered small commercial vessel, the M/V *Priscilla V*, were used to collect material. Whenever possible all such collections were made on well-known fishing grounds. These collections provided us with the necessary samples of the smaller sizes of redfish not landed in the commercial catch. A considerable amount of general survey work has also been done with an Isaacs-Kidd midwater trawl (Isaacs and Kidd, 1951).

Certain aspects of our research required large samples of very small redfish. This material was collected at a special fish-sampling station off Cape Ann, Mass., where such small redfish could be obtained in number throughout the year. Designated the New Scantum station (*see* U.S. Coast and Geodetic Survey Chart 71), it is located 42°42′ north latitude, 70°11′ west longitude. Every effort was made to keep the collecting activities within 5 miles of this point.

PREPARING THE OTOLITH

Redfish otoliths, particularly those of smaller fish, may be easily read without any preparation. Otoliths removed from fresh fish or frozen fish may be stored indefinitely in 95-percent ethanol without loss of clarity. For this reason, it became standard procedure aboard the research vessels to slit and preserve in alcohol all fish less than 15 cm. in length. It was not convenient to preserve quantities of larger fish in this way; instead they were frozen. Their otoliths were removed in the laboratory after the fish thawed and were then preserved in alcohol.

Most of the otoliths used in this study were collected from the commercial catch. These were stored dry. Dry otoliths cannot be read whole, but must be sectioned. They were cut with a dull razor blade across the long axis just to one side of the focus. Using slight pressure, the blade was sawed across the otolith, causing the otolith to break into two pieces along the line of cutting. The exposed face, a cross section of the otolith, was polished with a high-speed carborundum cutting disk.

READING THE OTOLITH

The otoliths stored in alcohol were read as whole mounts and needed no further preparation. The whole otolith was placed in a small watchglass filled with 60-percent alcohol and examined directly with a binocular microscope. The watchglass was coated on the outside with black lacquer to provide a contrasting background.

The sectioned otoliths were placed in a slotted cork, polished face up, for examination with a binocular microscope. A lamp provided the necessary illumination along the side of the otolith. The polished face was shaded from direct lighting

with an opaque shield so that light was transmitted up through the otolith from below. The hyaline zones show up as bands of light, when so illuminated, contrasted against an opaque background. In similar manner, the number of light (hyaline) bands were counted from the center to the outer edge along the longest axis of the face. With a little experience, one soon learns to shade the otolith correctly and to position it properly in the path of light for the greatest ease of reading. As might be expected, the outer zones of large otoliths are narrower and more difficult to count accurately than are those of smaller otoliths.

No differences could be detected between each of the otoliths from a single fish; one of the pair was selected for whatever job was at hand without any consideration being given to whether it was the right or left otolith. In fact, the two otoliths of any pair were so much alike that almost anyone could separate out the pairs if a large number of pairs from one age group of fish were combined into a single sample.

STUDIES OF THE OTOLITH

SEASONAL NATURE OF BANDING IN OTOLITH

Our study of the formation of the bands in the otolith, like that of Bratberg (1956), was based on collections made from young fish. In all, 1,921 otoliths from 8 samples of fish collected over an 18-month period were examined to determine the nature of the material at the periphery of the otolith. The results of this study are presented in figure 1. We determined the percentage of otoliths with each type of material at the periphery, hyaline or opaque. The number of otoliths

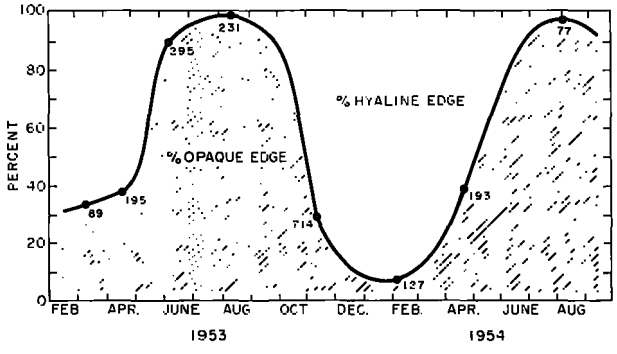

FIGURE 1.—Seasonal variation in the nature of the material at the periphery of the otolith of young redfish from the New Scantum station. Samples were composed of fish from pre-annulus to age-group VII. Figures on curve indicate number of specimens in each sample.

with an opaque margin is at a maximum during the months of July, August, and September. The number of otoliths with a hyaline margin reaches its maximum in January and February. The seasonal change is striking and unequivocal. There can be no question whatever about the annual nature of the banding in the otolith of the Gulf of Maine redfish. While it is more difficult to follow this sequence in the otoliths of older redfish, careful examination reveals no deviations from this general pattern. The outermost margin of any completed hyaline band may confidently be regarded as an annual ring and will be considered here as the annulus that marks the end of a year's growth.

In figure 2, a series of otoliths from the sample of 1,921 otoliths used in the analysis of the peripheral material are arranged by season and age group to demonstrate further the seasonal nature of the banding. Although photographs of material of this sort leave something to be desired, the gradual change in the nature of the peripheral band can be followed.

Bratberg (1956) went one step further. He demonstrated the concomitant formation of annuli on both the scale and the otolith, indicating that, in younger fish at least, comparable growth data may be derived from either scale or otolith.

COMPARING WHOLE MOUNTS AND CROSS SECTIONS OF OTOLITHS

The otoliths from a 7-year-old redfish are shown in figure 3. One otolith as it appears in a whole mount and the other in cross section following the preparation procedure outlined earlier. To determine the extent of agreement, comparative readings were made of whole mounts and cross sections of otoliths from 298 redfish ranging in length from 11 to 40 cm. The results are presented in table 1. There was 85-percent agreement between the two methods in those otoliths with less than nine annuli. The agreement is progressively poorer as the fish increase in length and age. The sample was not large enough to analyze these disagreements with any statistical validity.

COMPARING SCALES AND OTOLITHS

The pattern of annulus formation is the same in the scales and in the otoliths from the same specimen (fig. 4). The results of the age-reading comparisons of the scale and otolith from two

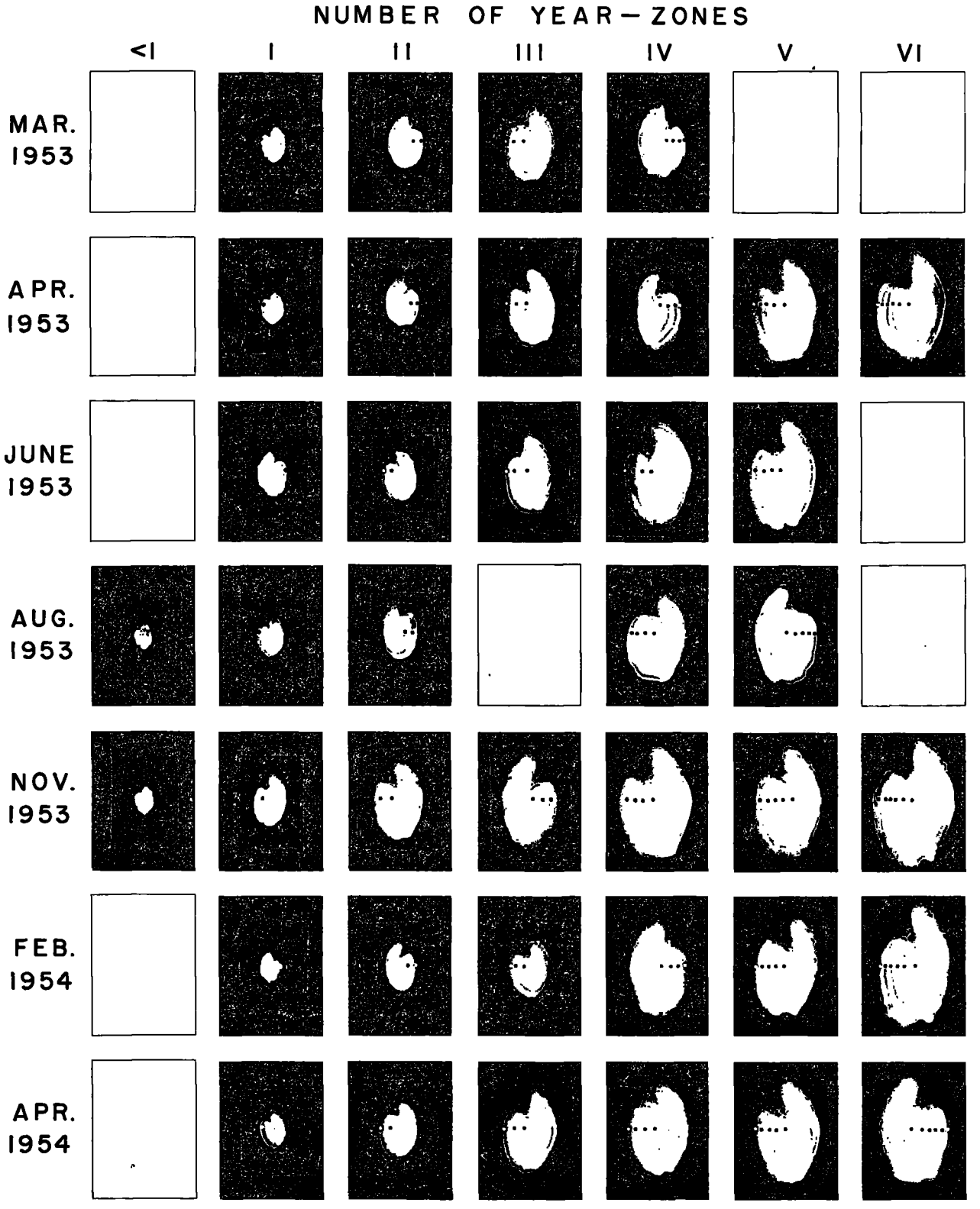

FIGURE 2.—Seasonal change in the peripheral material of the otolith of redfish, by age groups (pre-annulus to age-group VI), in collections from the New Scantum station. The black and white dots indicate the positions of the annuli.

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TABLE 1.—*Age-reading comparisons of pairs of otoliths from the same fish, one otolith cut, the other whole*

[Otoliths from 298 redfish from 11 to 40 cm. in length; collected April 19, 1953]

WHOLE OTOLITHS

SECTIONED OTOLITHS: Number of annuli → / ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Number of otoliths
1																									
2																									
3			1																						1
4				22	1																				23
5				2	90	4																			96
6					10	45	3	1																	59
7						4	26	1																	31
8							3	6		1															10
9								3	4	2	1														10
10									1	4	3	2	3												13
11									1	2	1			1	1										6
12										1	3	2	3	1											10
13											1	2	2	1	1			1					1		9
14										1		2	3	1		2	1	1							11
15																	1	1			1				3
16																	3								3
17															1	1									2
18																1		1							2
19																		1	2		1				4
20																1					1				2
21																						1			1
22																									
23																		1							1
24																								1	1
Number of otoliths			1	24	101	53	32	11	6	11	9	8	11	4	3	5	5	6	2		3	1	1	1	298

TABLE 2.—*Age-reading comparisons of scales and otoliths from young redfish collected at the New Scantum station in 1953*

A. Scales and otoliths from 134 fish, 5–15 cm. in length, collected March 11, before new growth had started

SCALES

WHOLE OTOLITHS: Number of annuli → / ↓	1	2	3	4	5	6	Unreadable scales	Number of scales
1	5							5
2	2	80					2	84
3		1	10					11
4			2	14	2	1	4	23
5				1	9			10
6						1		1
Unreadable otoliths								
Number of otoliths	7	81	12	15	11	2	6	134

B. Scales and otoliths from 201 fish, 5–11 cm. in length, collected April 20, after new growth had started

SCALES

WHOLE OTOLITHS: Number of annuli → / ↓	1	2	3	4	5	6	Unreadable scales	Number of scales
1	9						1	10
2		174		1			5	180
3		1	6	1				8
4				2				2
5								
6						1		1
Unreadable otoliths								
Number of otoliths	9	175	6	4		1	6	201

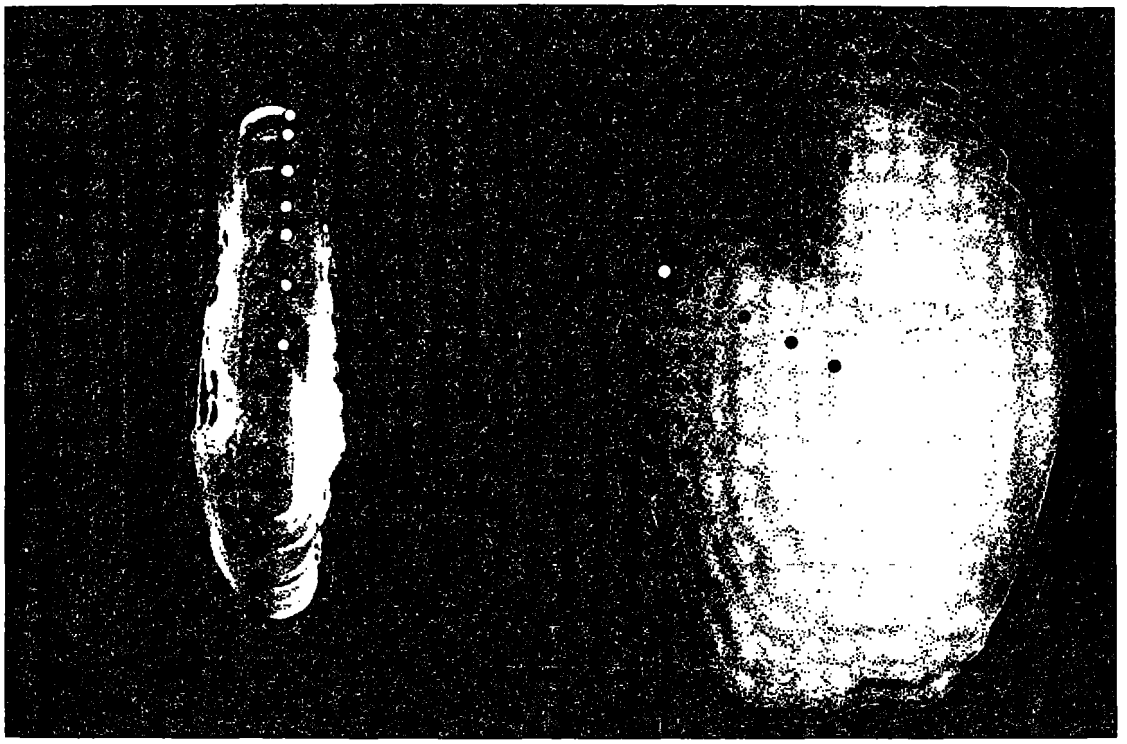

FIGURE 3.—Whole-mount and cross-section preparations of otoliths from an 18.1-cm. female redfish. Seven annuli are visible. Dots indicate hyaline zones.

samples of small redfish collected in March and April 1953, totaling 335 fish, are presented in table 2. The agreement is generally excellent, in one case being 88.8 percent and in the other 95.5 percent. In older fish, the scale annuli become progressively more difficult to distinguish with any certainty, so no attempt was made to run comparison tests in older age groups.

INDEPENDENT READINGS OF OTOLITHS

The number of annuli and the nature of the material at the periphery of the otolith can be determined from whole otoliths with up to at least nine annuli. Two readers independently determined this fact from a sample of 1,809 otoliths (table 3). They were in complete agreement on the annulus count and virtually in complete agreement as to the nature of the peripheral material.

The otoliths of larger fish become progressively more difficult to read as age increases. Three lots of 100 otoliths each from older fish (VII to XX+) also were read independently by two investigators. Thirty-one percent of the age readings agreed exactly, and 59.7 percent agreed to within 1 year. In a few instances, the readings deviated from each other by as much as 9 years. The average agreement between readers for each of the lots was ± 1.16, ± 1.87, and ± 1.85 years. These data illustrate the difficulty of estimating accurately the age of older fish, and suggest the limits of reliability that can be placed on determinations of age of older redfish.

AGE AND GROWTH

Gravid female redfish are commonly found in April and the first of the newborn 5-mm. larvae may be collected at this time; redfish are born from then until September. The larvae quickly ascend to the surface layers of the ocean where they are taken in surface plankton tows. By mid-May, larvae as long as 12 mm. appear in the plankton, and by mid-June, postlarvae 20 mm. long may be collected. The young descend slowly as they grow, and for this reason the size range in the uppermost layers of the water shows little significant change throughout the spawning season. In March, April, and June, 1953, all otoliths from small redfish taken on the bottom had one or more completed annuli. The one-annulus fish ranged in length from 45 to 70 mm.,

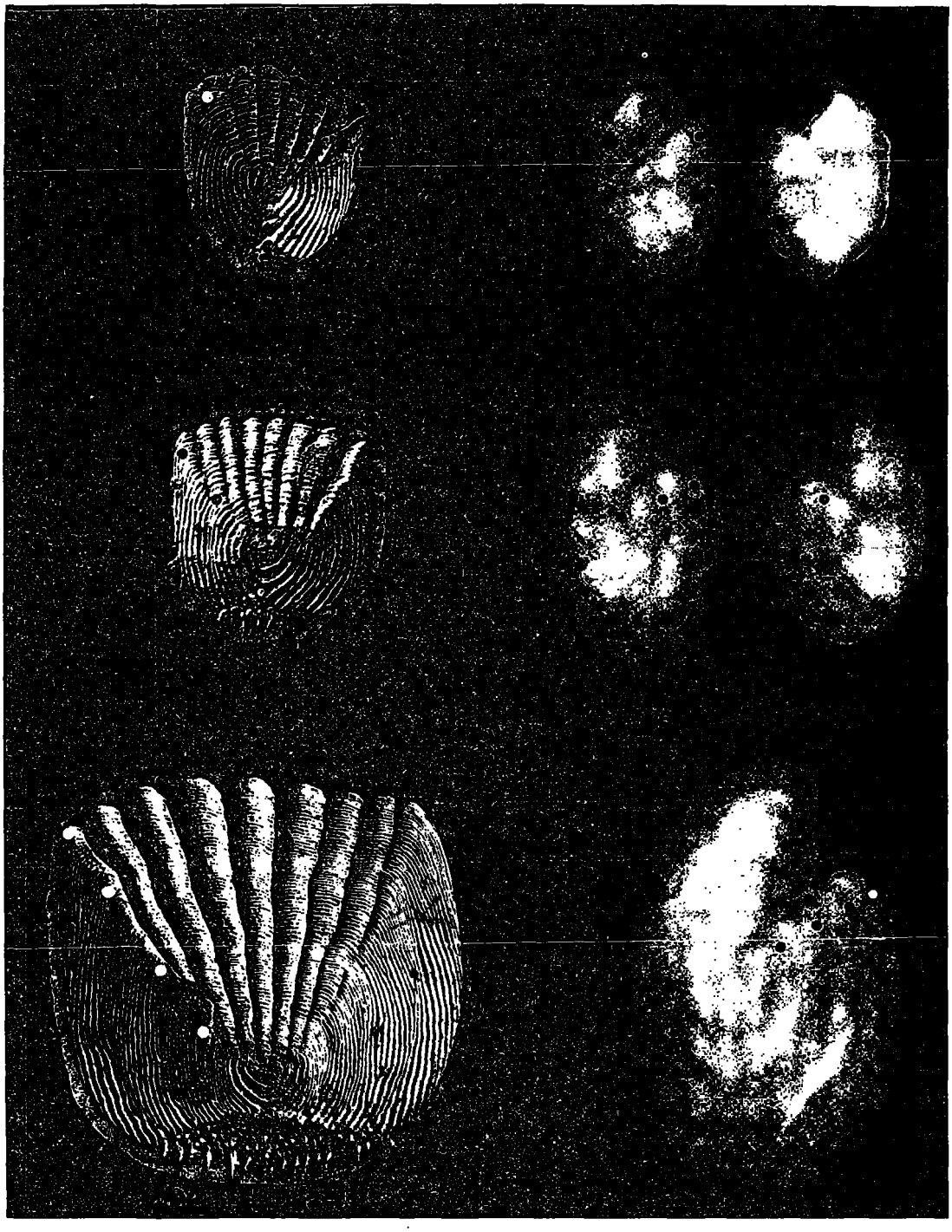

FIGURE 4.—Comparison of scales and otoliths from a 6.1-cm. female with one annulus (top row), a 6.9-cm. female with two annuli (middle row), and a 13.0-cm. male with four annuli (bottom row).

TABLE 3.—*Comparison of age readings by two readers of otoliths from 1,809 redfish, collected at New Scantum station, August 17, 1955*

[O=opaque; H=hyaline]

READER A

READER B: Number of annuli →	1 O	1 H	2 O	2 H	3 O	3 H	4 O	4 H	5 O	5 H	6 O	6 H	7 O	7 H	8 O	8 H	9 O	9 H	Number of otoliths
1 O																			
1 H																			
2 O			2																2
2 H																			
3 O					368	3													371
3 H						7													7
4 O							1,043	7											1,050
4 H								13											13
5 O									27										27
5 H										5									5
6 O											126								126
6 H												2							2
7 O													194						194
7 H														1					1
8 O															9				9
8 H																			
9 O																	2		2
9 H																			
Number of otoliths			2		368	10	1,043	20	27	5	126	2	194	1	9		2		1,809

the two-annulus fish had a range in length of from 55 to 110 mm., while the three-annulus fish ranged from 80 to 120 mm. In the August collections of the same year, a group of fish 21 to 48 mm. in length appeared on the bottom, all of them with uniformly opaque (pre-annulus) otoliths. The periphery of these otoliths, however, showed signs of a developing hyaline edge. Most of these pre-annulus fish had some scales (fig. 5). None of the scales had developed an annulus. The first annulus, therefore, appears to be formed sometime between August and March, probably in late winter.

The scales begin to form first along the lateral line on the posterior half of the body. Redfish 34 mm. in length have been found with much of the posterior half of the body covered with scales (fig. 5). By the time that these small fish are about 40 mm. in length, they have acquired their full complement of scales.

GROWTH DURING FIRST YEAR

The conclusions of Perlmutter and Clarke (1949) concerning the growth of redfish in their first year are reasonable on the basis of the material that they were able to collect and examine. They concluded that young redfish reach a length of about 20 mm. at the end of the first full year. It is, however, our opinion, as well as that of many European workers, that redfish reach 50 mm. or more in length during their first growing season. We believe this because the otoliths and scales of redfish up to about 50 mm. do not show an annulus, and because all of the material that we have analyzed indicates that these young fish reach an average length of 50 mm. in just a few months. We were fortunate in having at our disposal a large number of collections made by other workers. The length frequency data compiled from these collections, from our own collections, and from various published records, are presented in tables 4 to 11 and are illustrated in figure 6.

Redfish larvae are abundant in the surface waters throughout the spawning period. As the season progresses, the greater numbers of larger larvae in the plankton increase the average length slightly: from approximately 10 mm. in May to more than 20 mm. in early September. Young

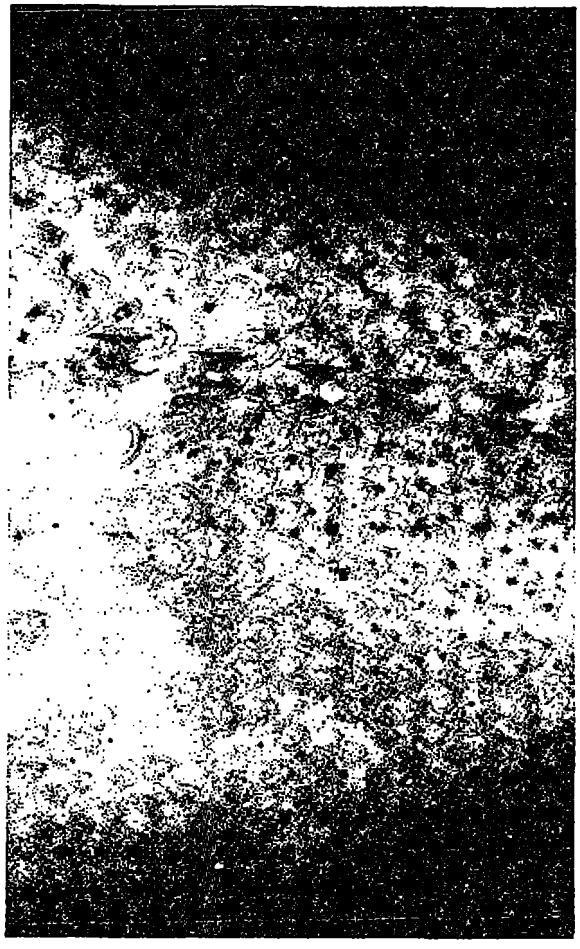

FIGURE 5.—Posterior portion of flank of a 34-mm. redfish, showing the newly formed scales. The scales along the midline have two or more circuli, while the smallest (and newest) scales on the dorsal and ventral surfaces have none or one circulus. Some scales were rubbed off when the fish was captured.

fish varying in length from 20 to 50 mm. appear on the bottom in August for the first time. There is a general lack of fish between 20 and 40 mm. in length in any of these collections. What material we do have leads us to conclude that the fish in this size range were probably somewhere between the surface and the bottom. Recent research, the results of which are not plotted on figure 6, has demonstrated that redfish slowly descend as they grow and that these 20- to 40-mm. fish may be found in the middepths. This particular phase of redfish early life-history will be discussed only briefly at this time.

Some very revealing samples of young redfish were collected at depths of 10, 20, 30, 40, 60, and 100 meters with the Isaacs-Kidd midwater trawl in August 1957 (*Albatross III* cruise 99). At this time, these fish varied from 10 to 40 mm. in length. At 10 meters, all lengths within this range occurred with the average being about 22 mm. The largest collections per tow, made at 20 meters, contained many times more specimens than all the rest of the tows at the other depths. The average length of this sample taken at 20 meters was 23 mm. At 40 meters and at 60 meters the samples were small, but the average length was slightly larger than the average length of fish at 20 meters. The length was approximately 27 mm. at a depth of 60 meters. Two tows at 100 meters failed to collect any young redfish. A similar cruise (*Albatross III* cruise 102) in September 1957 demonstrated the further growth and descent of the young. The largest samples per tow came from depths of 80, 100, and 110 meters. The average lengths varied from 34 to 40 mm. without any marked relation to depth.

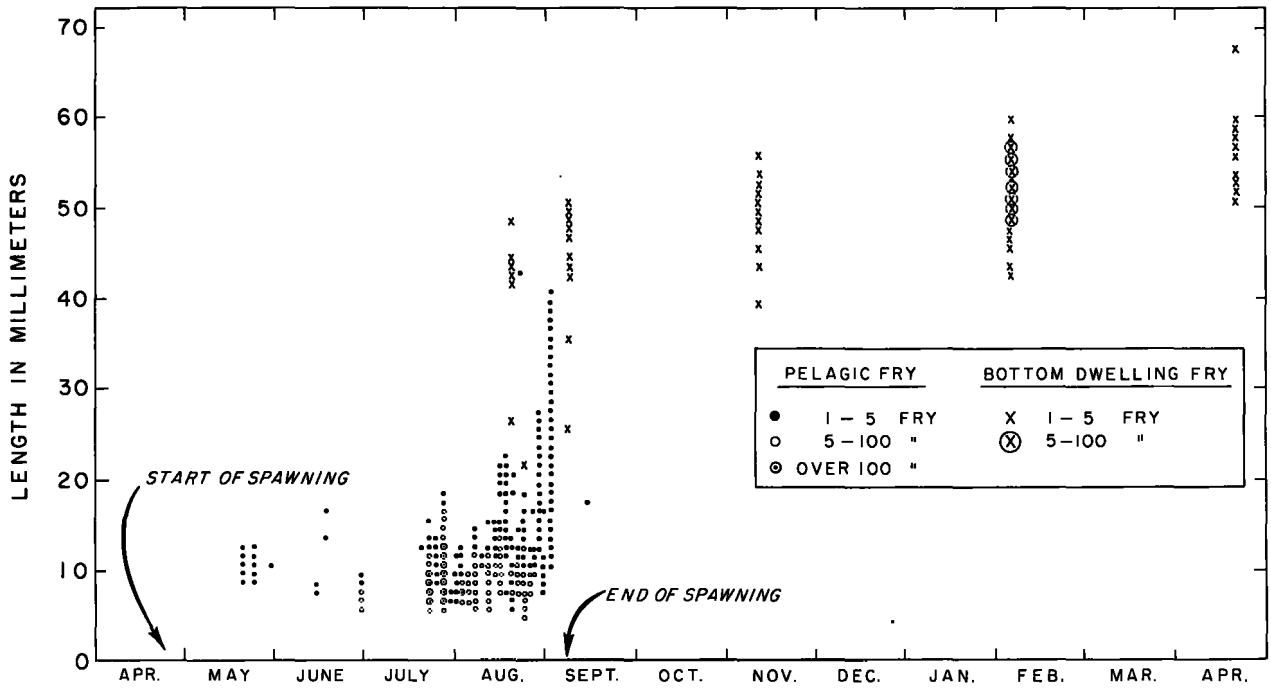

FIGURE 6.—Length frequencies of young redfish taken by research vessels in the Gulf of Maine. Data of tables 4–11 plotted by time of collection.

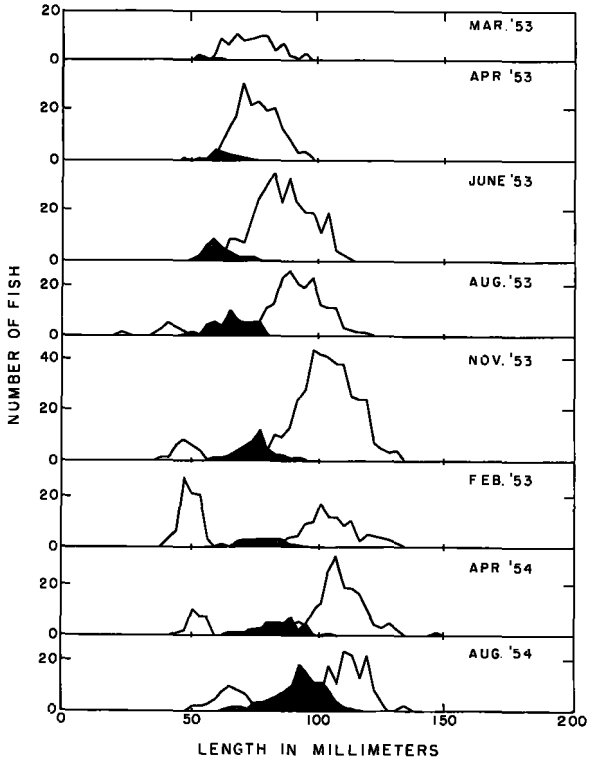

FIGURE 7.—Length composition of the three youngest age groups collected at the New Scantum station in 1953 (<I, I, and II) and 1954 (I, II, and III). The 1952 year class is shaded.

LENGTH COMPOSITION OF SMALLER FISH

The length composition and growth of age-groups I, II, and III (1954) taken at the New Scantum station over an 18-month period is presented in figure 7. Similar data for the first seven age groups are given in table 12. While growth in the second and third years is not as rapid as in the first year, one can clearly observe the progression of modes. It may be noted that most of the growth takes place in the period April to August. Even at these young ages there is a wide range of sizes in any one age group.

TABLE 4.—*Length frequencies of 781 redfish fry from the R/V* Grampus *collections in the Gulf of Maine, 1912*

[Data from Bigelow 1914]

Length	July			August							
	22	24	29	7	14	15	16	22	24	29	31
5 mm				16							
6 mm		3	67	28							
7 mm		2	212	39	8	1	7	7			1
8 mm			24	37	16	3	10	6			1
9 mm			4	69	28	6	7	3	1	3	2
10 mm				23	30	4	3	1	1		1
11 mm		1		14	30		2		1	1	1
12 mm	1			5	10	2		1	1		
13 mm				2	10						
14 mm				1	4		1				
15 mm					4						
16 mm									1	1	
17 mm											
18 mm					1						
19 mm					4						
20 mm					1						
21 mm					1						
Total	1	6	307	234	153	16	30	18	5	5	6

TABLE 5.—*Length frequencies of 457 redfish fry from the R/V* Grampus *collections in the Gulf of Maine, 1914*

[Data from Bigelow 1917; exact count of specimens not available]

Length	July						August				
	24	25		27	28		11	12	13		
5 mm											
6 mm					x						
7 mm					x				x		
8 mm	x	x		x	x						
9 mm	x	x	x	x	x		x			x	x
10 mm	x	x	x	x	x	x	x			x	x
11 mm	x	x	x	x	x	x	x	x		x	x
12 mm	x		x	x	x		x	x		x	x
13 mm	x						x	x		x	x
14 mm							x	x		x	x
15 mm							x	x			x
16 mm								x			x
17 mm								x			x
18 mm								x			x
19 mm								x			
20 mm								x			
21 mm								x			
22 mm								x			
23 mm											
Total	6	38	42	43	150	2	104	21	1	35	15

TABLE 6.—*Length frequencies of redfish fry from the R/V* Grampus *collections in the Gulf of Maine, 1915*

[Data from Bigelow 1917; some material still available was measured and data included; exact count of specimens not available]

Length	May 31	June 14	August				September					Station 10300
			4	6-7[1]	31		1		2		14	
5 mm												
6 mm			x									
7 mm		x	x									
8 mm		x	x									1
9 mm			x	1								2
10 mm	x								x			
11 mm				1					x			
12 mm						x			x	2		
13 mm						x						
14 mm						x	x			1		
15 mm						x	x			1		
16 mm						x	x					
17 mm						x	x				1	
18 mm					x	x	x	1				
19 mm					x	x	x					
20 mm					x	x	x					
21 mm					x	x	x					
22 mm					x	x	x					
23 mm					x	x	x					
24 mm					x	x	x					
25 mm					x	x	x					
26 mm					x	x	x					
27 mm					x	x	x					
28 mm							x					
29 mm							x					
30 mm							x					
31 mm							x					
32 mm							x					
33 mm							x					
34 mm							x					
35 mm							x					
36 mm							x					
37 mm							x					
38 mm							x					
39 mm							x					
40 mm							x					
Total	1	2	Many	2	20	24	Swarm	1	3	4	1	3

[1] Specimens found among old collections and larvae were measured.

TABLE 7.—*Length frequencies of 97 redfish fry from the R/V* Albatross II *collections in the Gulf of Maine, 1931*

[Measurements made from preserved material]

Length	May		June		Between June 18 and July 10
	21	22	17	18	
5 mm					12
6 mm					52
7 mm					15
8 mm	1	1			1
9 mm	2	1			2
10 mm	2	2			
11 mm	1	1			
12 mm	1	1			
13 mm			1		
16 mm				1	
17 mm					
Total	7	6	1	1	82

TABLE 8.—*Length frequencies of 2,234 redfish fry from the R/V* Atlantis *collections in the Gulf of Maine, 1932*

[Measurements of preserved material]

Length	July		
	22	23	24
5 mm	11	75	42
6 mm	15	235	111
7 mm	11	264	147
8 mm	7	189	176
9 mm	3	96	221
10 mm	1	49	201
11 mm		12	173
12 mm		2	99
13 mm		1	44
14 mm			26
15 mm		1	13
16 mm			6
17 mm			2
18 mm			1
Total	48	924	1,262

TABLE 9.—*Length frequencies of 53 redfish fry from the R/V* Albatross III *and M/V* Priscilla V *collections in the Gulf of Maine, 1953*

[Measurements of preserved material]

Length	August 17	September 8	November 10
25 mm		1	
26 mm	1		
27 mm			
28 mm			
29 mm			
30 mm			
31 mm			
32 mm			
33 mm			
34 mm			
35 mm		1	
36 mm			
37 mm			
38 mm			1
39 mm			
40 mm			
41 mm	2		
42 mm	1	2	
43 mm	2	3	1
44 mm	2	3	
45 mm			2
46 mm		2	
47 mm		2	4
48 mm	2	1	2
49 mm		1	3
50 mm		1	3
51 mm			1
52 mm			2
53 mm			3
54 mm			
55 mm			4
Total	10	17	26

TABLE 10.—*Length frequencies of 325 redfish fry from the M/V* Priscilla V *collections in the Gulf of Maine, 1954*

[Measurements of preserved material]

Length	February 6	April 21	August 7
5 mm			36
6 mm			53
7 mm			59
8 mm			31
9 mm			15
10 mm			11
11 mm			7
12 mm			3
15 mm			1
42 mm	1		
43 mm	2		
45 mm	1		
46 mm	2		
47 mm	4		
48 mm	6		
49 mm	6		
50 mm	16	1	
51 mm	8	3	
52 mm	10	3	
53 mm	3	4	
54 mm	8		
55 mm	8	3	
56 mm	5	4	
57 mm	1	3	
58 mm		2	
59 mm	2	2	
67 mm		1	
Total	83	26	216

TABLE 11.—*Length frequencies of 97 redfish fry from the R/V* Albatross III *collections in the Gulf of Maine, 1955*

[Measurements of preserved material]

Length	August		
	17	18	19
4 mm		3	
5 mm	1	13	
6 mm	2	10	
7 mm	5	7	
8 mm	3	5	
9 mm	6	8	
10 mm	1	4	
11 mm		3	
12 mm	2	8	
13 mm	1	3	
14 mm		4	
15 mm		1	
16 mm		2	
17 mm			
18 mm	1	1	
19 mm			
20 mm	1		
21 mm			1
42 mm			1
Total	23	72	2

TABLE 12.—*Length frequencies of redfish, by age*

Length	Age-group <I					Age-group I					Age-group II					Age-group III				
	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.
MALES																				
40 mm				2																
45 mm				1	5		1													
50 mm					5				1											
55 mm					2	1	1	3	1											
60 mm							5	9	3	1		1								
65 mm								2	7	2	3	6	4							
70 mm									3	5	6	24	4	1						
75 mm									5	7	5	18	13	3	1					
80 mm										2	5	23	13	7	4					
85 mm										1	6	9	14	18	8	1				
90 mm												8	14	21	16					
95 mm											2	3	10	18	27					
100 mm													10	15	34	1	1			
105 mm													3	4	29	2	2			1
110 mm													2	2	35	1				
115 mm															20					
120 mm															12			1		
125 mm															2					1
130 mm															4					
135 mm																				3
140 mm																				1
145 mm																				
150 mm																				1
155 mm																				
160 mm																				
165 mm																				
170 mm																				
175 mm																				
180 mm																				
185 mm																				
190 mm																				
195 mm																				
200 mm																				
205 mm																				
210 mm																				
215 mm																				
220 mm																				
225 mm																				
230 mm																				
235 mm																				
240 mm																				
245 mm																				
250 mm																				
255 mm																				
260 mm																				
265 mm																				
270 mm																				
Total males				3	12	1	7	14	20	18	27	92	87	89	192	5	3	1		7
Average length (mm.)				44.2	51.3	57.5	59.6	62.1	68.8	75.3	79.9	79.6	88.6	93.8	106.1	103.5	105.8	122.5		134.6

group and sex, collected at New Scantum station, in 1953

Age-group IV					Age-group V					Age-group VI					Age-group VII				
Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.
	1																		
	1																		
1																			
2																			
2	1	2		1							1								
1	3	3							1										
2	4	2	1	1	1	1	1		4			1							
	3	4		1	1	3			1					1					
2	1	3		2	1	2	2		4			1							
	1	4		7	2	1		1	4										
		4		6		5	2				1								1
				16		10	5		2		2	1					1		
				7		6	4		4										
				4		4	3		4			1		2		1			
						10	4		3		1								
	1			3		5	6		4		3	1		1					
									5		1					2			
						4	3		7		4	1		1					
							3		1		6	3		1		1	1		
						1			2		3						1		
									4		1	1		1		1			
											3	1		1		1	1		
									1			1				2	2		
											1	1				3			
																1	1		1
														1					
																1			
																2			
																2			
																1			
																1			
10	16	22	1	48	5	52	33	1	51	------	27	13	------	9	------	19	7	------	2
117.0	122.8	129.5	122.5	145.9	131.5	166.3	158.4	137.5	159.7	------	175.8	173.3	------	175.3	------	208.8	206.1	------	175.0

TABLE 12.—*Length frequencies of redfish, by age*

Length	Age-group <I					Age-group I					Age-group II					Age-group III				
	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.
FEMALES																				
25 mm				1																
30 mm																				
35 mm					1															
40 mm				3	1															
45 mm					6															
50 mm					4			1												
55 mm					2		1	2	3			1								
60 mm							2	2	4	1	3	1								
65 mm									7	3	1	10	2		1					
70 mm							1		5	2	4	23	4		1					
75 mm									4	8	5	21	4	3	2					
80 mm									1	10	4	15	6	7	3		1			
85 mm										3	1	13	10	17	9					
90 mm										2	1	2	9	18	14		1			
95 mm												1	6	19	27	1	1			
100 mm													6	11	32	2	2			
105 mm													2	14	38	1		1		1
110 mm													1	4	27				2	
115 mm														1	18			2		
120 mm														1	19	1	1	1		1
125 mm															4					1
130 mm															2					1
135 mm																				1
140 mm																				2
145 mm																				1
150 mm																				
155 mm																				
160 mm																				
165 mm																				1
170 mm																				
175 mm																				
180 mm																				
185 mm																				
190 mm																				
195 mm																				
200 mm																				
205 mm																				
210 mm																				
215 mm																				
220 mm																				
225 mm																				
230 mm																				
235 mm																				
240 mm																				
245 mm																				
250 mm																				
255 mm																				
260 mm																				
265 mm																				
Total females				4	14		4	5	24	29	19	87	50	95	197	5	6	4	2	9
Average length (mm.)				38.8	49.3		63.8	58.5	68.8	79.4	75.9	77.6	93.1	96.2	106.0	106.5	100.0	116.3	112.0	136.4
Grand total				7	26	1	11	19	44	47	46	179	137	184	389	10	9	5	2	16
Grand average length (mm.)				41.1	50.2	57.5	61.1	61.2	68.8	77.8	78.2	78.6	90.2	95.0	106.0	105.0	101.9	117.5	112.0	135.6

group and sex, collected at New Scantum station, in 1953—Continued

Age-group IV					Age-group V					Age-group VI					Age-group VII				
Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.	Mar.	Apr.	June	Aug.	Nov.
1																			
1	1																		
1		1																	
	2		1	1															
7				2															
	1	2			1														
2	1	2		2					2		1								
				4	1				3										
		1		3	1	3	1		3										
	3	1		5	1	3	3		3		2								
				4	1	2	2		4					1					
		1		1		13	2		3		1	2				1			
	1	1		10		6	1		3	1	1					1			
	1	1		4		7	4		5		1								
						4			4		2	2							1
				3		3	1		8		1			1			1		
				1		3	2		6		3	1				2			
						1	5		2		5			1		1			
				1			1		2		2	1							
						2			3			1					1		
						1			5		2	1				1			1
									1		1					1			
							1		1		2			1					
												1				1			
											1					1	1		
											1						2		1
											1								1
																1			
																1	1		
																	3		
																	1		
																1			
																1			
12	10	10	1	41	5	48	23	-------	58	1	27	10	-------	4	-------	12	11	-------	4
110.4	127.5	131.0	107.5	146.5	131.5	155.1	160.5	-------	161.5	152.5	176.6	179.5	-------	172.5	-------	199.6	222.0	-------	201.3
22	26	32	2	89	10	100	56	1	109	1	54	23	-------	13	-------	31	18	-------	6
113.4	124.6	130.0	115.0	146.2	131.5	160.9	159.3	137.5	160.7	152.5	176.2	176.0	-------	174.4	-------	205.2	215.8	-------	192.5

LENGTH COMPOSITION OF AGE GROUPS

The length composition of 18 age groups (<1 to XVII) by sex is presented in figure 8 and in table 13. It may be noted again how large a size range there is within any one age group. In the tenth year, when most of the redfish have become mature, the growth rates of the males and females change, the females continuing at the higher rate. This difference becomes quite distinct within a period of only 1 year.

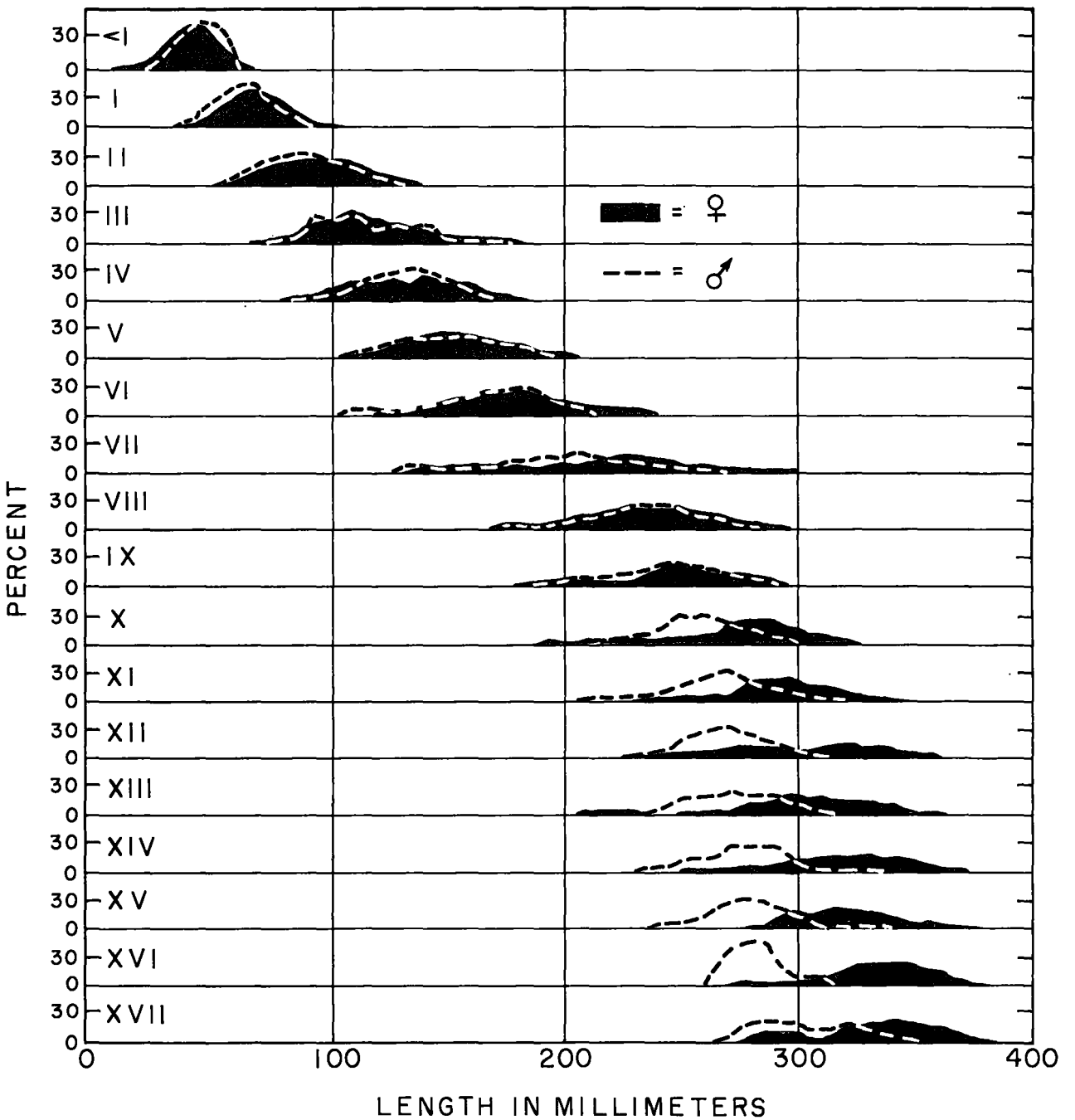

FIGURE 8.—Length composition of all age groups in combined samples of redfish taken in the Gulf of Maine in 1953 by research vessels and the commercial fishery, totaling 1,255 males and 1,251 females. (5-mm. groups smoothed by moving average of 5.)

GROWTH RATE

Growth curves for the redfish, sexes treated separately and combined, are presented in figure 9. The mean lengths at age for the sexes separately and combined are listed in tables 14 and 15. Males and females grow at approximately the same rate for the first 10 years of life. The growth curve is unusual in that for the first 10 years it is approximately linear. At 20 years of age, the growth rate of both the male and the female has markedly decreased, but it is apparent the fish are still making definite growth. Growth curves (fig. 10) in the years 1951, 1952, and 1953 are generally alike but there are some slight differences. Whether these are significant cannot be stated at this time.

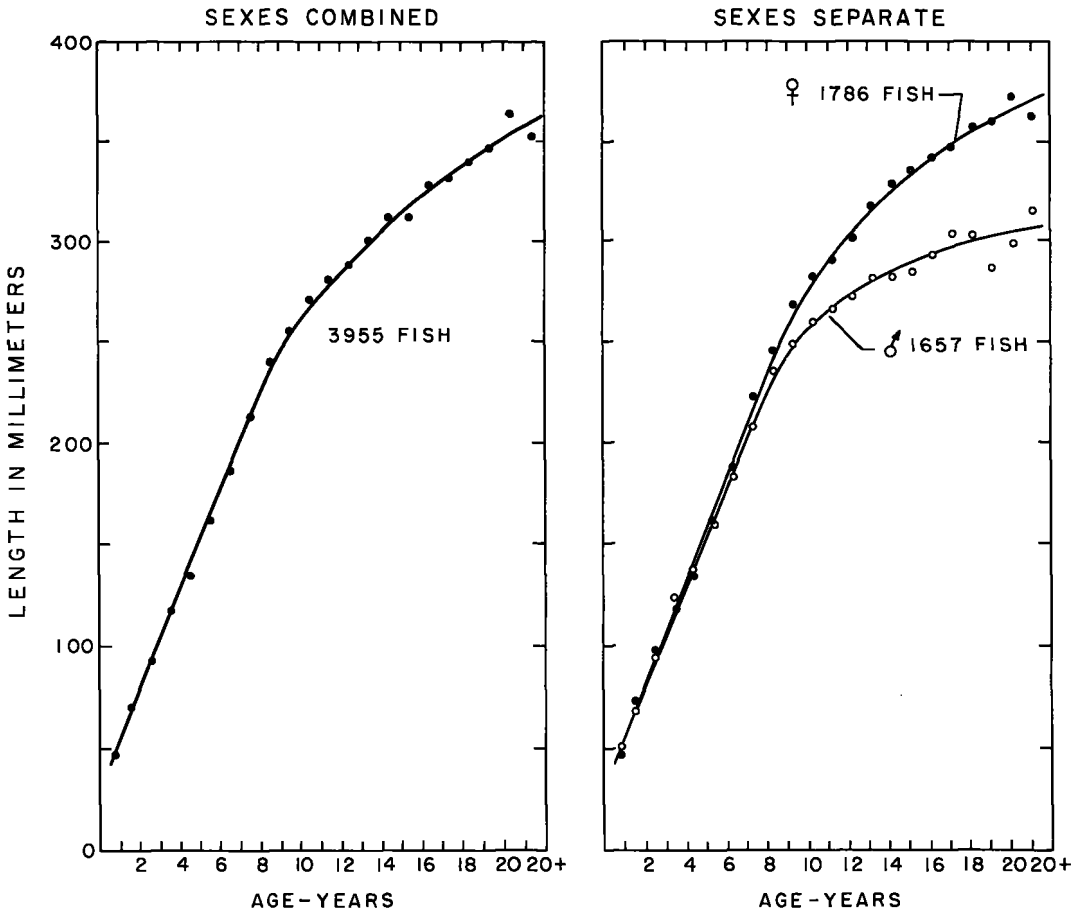

FIGURE 9.—Growth curves for the sexes, separate and combined, fitted to the mean lengths at age and based on samples of redfish from catches of the research vessels and the commercial fishery, collected in the Gulf of Maine in 1951, 1952, and 1953. The growth curve of the sexes combined includes 512 unsexed fish. (*See* table 14.)

TABLE 13.—*Length frequencies of redfish, by age*

[Based on all research-vessel and

Length	Number of males in age-group—																					
	<I	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XX+
25 mm																						
30 mm																						
35 mm																						
40 mm	2																					
45 mm	6	1																				
50 mm	5	1																				
55 mm	2	6																				
60 mm		18	1																			
65 mm		11	13																			
70 mm		8	35																			
75 mm		12	40																			
80 mm		2	52																			
85 mm		1	55	1																		
90 mm			59		1																	
95 mm			60		1																	
100 mm			59	2	1																	
105 mm			36	5	2																	
110 mm			39	1	6		1															
115 mm			20		7	1																
120 mm			12	1	10	7	1															
125 mm			2	1	8	5	1															
130 mm			4		8	9	1															
135 mm				3	12	8		1														
140 mm				1	10	7	1															
145 mm					16	17	3	1														
150 mm				1	7	14		1														
155 mm					4	12	3	1		1												
160 mm						18	2															
165 mm					4	16	6	3														
170 mm						6	2	2	1													
175 mm						15	6					1										
180 mm						4	10	4														
185 mm						5	3	4	2													
190 mm						5	4	1		1												
195 mm							5	3														
200 mm						1	2	7	1													
205 mm							2	3	1	1												
210 mm								5	1	1		1										
215 mm							2	2	2	4												
220 mm								2	3	2		1										
225 mm								3	2		1											
230 mm								3	1	1	2											
235 mm								2	8	5		1										
240 mm								2	7	4	2	3		1								
245 mm							1	1		5	1	1	2		1							
250 mm								1	2	3	5	2	3	3	1	1			1			
255 mm									3	6	6	3	1	2		1						
260 mm										3	9	6	7	4	4				1			
265 mm								1	3	3	1	5	5	2	1	2						
270 mm									2	1	3	6	4	2	1	4						
275 mm									1	4	2	3	5	3	1	4	4			2		
280 mm									1	1	2	5	5	4	6	2	2	2	2	1		
285 mm											2	1	2	1	3	2	1	2				
290 mm									1		2	2	3	4	1	2		2	1			
295 mm												3	1	1	1	3						
300 mm														1	1	1	1					1
305 mm												1			1			1				
310 mm													1	1				2				1
315 mm														1								
320 mm														1				1				1
325 mm															1	1						
330 mm																		2				
335 mm																		1	1			
340 mm																						
345 mm																			1			
350 mm																						
355 mm																						
360 mm																						
365 mm																						
370 mm																						
375 mm																						
380 mm																						
385 mm																						
390 mm																						
395 mm																						
400 mm																						
Total fish	15	60	487	16	97	150	56	53	42	46	38	45	39	31	23	23	8	13	7	3		3
Mean length (mm.)	49.8	67.9	94.2	118.8	135.2	157.1	177.5	203.7	238.9	245.0	262.1	265.9	272.8	278.0	280.5	282.3	283.1	306.3	293.9	279.2		312.5

group and sex, sampled in the Gulf of Maine, in 1953

commercial-catch samples; see figs. 8 and 10]

Number of females in age-group—																					
<I	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XX+
1																					
1																					
4																					
6																					
4	1																				
2	6	1																			
	9	4																			
	10	14																			
	8	32																			
	12	35																			
	11	35	1																		
	3	50																			
	2	44	1	1																	
		53	2	2																	
		49	4	2																	
		54	3	4																	
		32	2	9																	
		19	2	3	1																
		20	4	7	2	1															
		4	1	4	4																
		2	1	4	8																
			1	9	10	2															
			2	4	9	1		1													
			1	2	18	3	1														
				12	10	2	1														
				6	17	1															
				1	8	5	2														
			1	3	12	3	1														
				1	12	4	3														
					8	6	2														
				1	3	4					1										
					5	1	1			1											
					6	6	3		1												
					1	2	1		1												
					2	3	1		2			1									
							2	4	1	1											
						1	2	1	1												
						1	2	3	2												
						2	4	2		1			1								
					1	1	4	6		1											
						1	2	3	2	1											
							6	3			1	1									
							4	3	4			2									
							1	1	4	2	1										
							4	6	5	1	2										
									4	1	2	2									
								4	1	3	2	1					1				
							1		1	1		2	1	1							
							2	1	3	4	2	1		1							
							1	1	1	1	4		3	1							
								2	1	10		4	1	1							
							1		2	7	8	4	3								
							1		5	4	5	2	2	2	1	1	2				
									1	2	2	1			1		1	1			
										1	4		4	3	1						
										2	5	2	4	2	2						
								1		3	3	1	2	2	1				2		
										2	1	4	1	2		3					
										1	2	4	1	4	3	1	1				
											1	2	2	2	2	2	1	1	1	1	1
									2		3	2	3	1	1	2	3	1	2		
												1	3	4	1	3					1
												2		2		3	1	3			2
												4		1	1	2	1	1			
													2	2	1	2	2				
														1		2	1				2
														3		2	1	2			
															1				1	1	
																1	1	1			
															1			1			
																			1		1
																			1		
																					1
18	62	448	26	75	137	50	53	44	44	50	49	42	33	35	17	25	15	11	8	2	8
46.9	72.6	95.2	117.3	134.4	158.5	178.5	220.6	236.9	256.2	278.4	289.7	299.2	306.9	322.2	326.9	336.1	334.5	346.1	346.9	347.5	357.5

TABLE 14.—*Length frequencies of redfish, by age group, sexes combined, from all samples collected in the Gulf of Maine in 1951, 1952, and 1953*

[Includes 512 unsexed fish]

Length	Number of fish (sexes combined) in age-group—																					
	<I	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XX+
25 mm	2																					
30 mm																						
35 mm	2																					
40 mm	15																					
45 mm	19	1																				
50 mm	11	3																				
55 mm	4	15	1																			
60 mm		31	9																			
65 mm		22	38																			
70 mm		19	81	1																		
75 mm		25	97	1																		
80 mm		13	123	2																		
85 mm		4	135	1	1																	
90 mm		2	136	1	2																	
95 mm			130	8	4																	
100 mm			114	11	3																	
105 mm			106	15	12																	
110 mm			72	9	17	1	1															
115 mm			39	7	16	3																
120 mm			32	6	23	11	2															
125 mm			6	7	19	10	2															
130 mm			6	3	20	17	2															
135 mm				6	26	23	2	1														
140 mm				3	22	21	3		1													
145 mm				4	23	37	7	3														
150 mm				2	28	31	6	3														
155 mm				1	12	36	7	3		2												
160 mm					5	31	11	4														
165 mm				1	7	34	12	4	1													
170 mm					1	25	13	6	3													
175 mm					1	28	15	5				1										
180 mm					2	13	25	8	2	1		1										
185 mm						16	17	9	6		1											
190 mm				1		13	22	10	2	2												
195 mm						2	19	17	3	3	1											
200 mm					1	8	22	23	4	2	1		1									
205 mm					1	3	11	13	8	7	3	1										
210 mm						2	7	13	4	3	1	1										
215 mm							11	12	8	6	1											
220 mm						1	5	12	8	2	4	1		1								
225 mm						1	3	10	12	3	4											
230 mm						2	2	9	9	9	5	1	1									
235 mm							1	8	16	6	3	4	2									
240 mm								10	21	15	3	6	3	1								
245 mm							2	4	8	14	7	3	3		1							
250 mm								9	17	14	14	9	9	4	2	1			1			
255 mm							1	6	10	17	10	7	10	6		1						
260 mm								1	13	6	21	12	11	5	5		1		1			
265 mm								3	6	13	6	13	12	6	3	3		1				
270 mm								3	6	10	13	14	13	11	7	9	1					
275 mm								5	5	13	7	11	9	10	7	6	5			2		
280 mm									4	6	16	14	15	10	10	5	5	3	2	1		
285 mm								2		7	13	15	14	4	4	4	2	3				
290 mm								1	1	6	12	10	10	10	6	6	5	4	2		1	
295 mm									2	3	5	8	9	7	5	8	2	3				
300 mm									3	2	6	5	5	8	10	5	2			1		1
305 mm									1	2	6	8	11	9	5	3	1	3				
310 mm									2	1	5	10	7	9	6	1	1	5		2		1
315 mm											3	3	11	6	9		6		2			
320 mm											2	3	6	5	7	6	2	2				1
325 mm										1	1	1	3	6	7	4	3	3	1	1	1	1
330 mm									1	3	1	5	4	7	2	4	4	7	2	3		
335 mm										1			3	5	5	2	4	7	4			2
340 mm												1	2	4	9	5	6	5	6	1		2
345 mm													4	1	9	3	4	2	3			1
350 mm												1		5	5	2	5	5	2	1		
355 mm													1	1	2		4	2	1	5	1	2
360 mm														2	7	5	4	4	4	2	2	
365 mm														1		3	1	1	1	3	2	1
370 mm																1	3	3	2		1	2
375 mm														1		1		1	2	2		1
380 mm												1							1		1	
385 mm																		3		1		
390 mm																				2		1
395 mm																1				1		
400 mm																						1
405 mm																			1			
Total fish	53	135	1,125	90	246	369	231	217	187	180	175	170	179	145	133	89	71	67	38	28	10	17
Mean length (mm.)	46.7	69.7	93.3	112.1	135.4	160.5	185.9	213.0	240.3	254.8	269.8	280.1	287.7	300.0	310.9	310.6	323.6	331.4	339.7	347.3	367.5	351.3

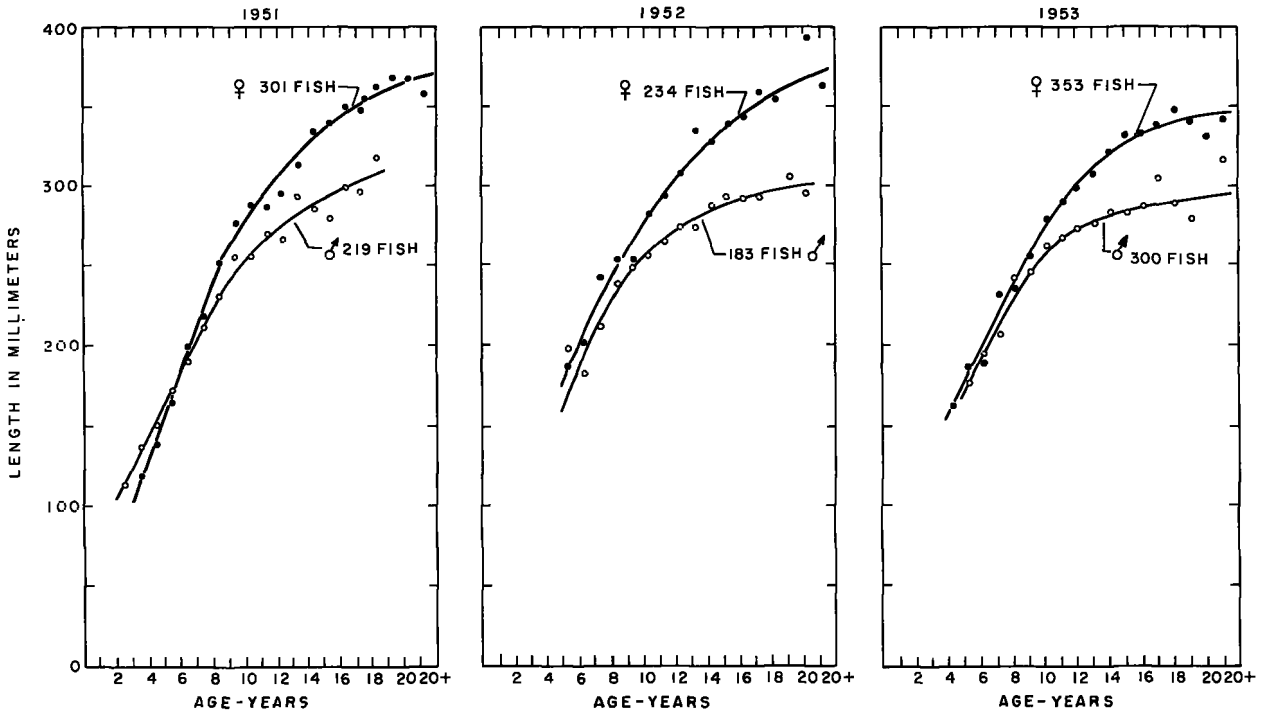

FIGURE 10.—Growth curves for the sexes fitted to the mean lengths at age, for redfish sampled from the commercial fishery in 1951, 1952, and 1953.

AGE COMPOSITION

Age composition of the redfish sampled from the commercial catch in the Gulf of Maine in 1951, 1952, and 1953 is presented in figure 11. These fish ranged in age from 2 to more than 20 years. The bulk of the fish were from 6 to 14 years of age. Certainly in these samples there is no striking evidence of excessive reduction of the older age groups from one year to the next. It is interesting, therefore, to observe the data presented in figure 12 on the changes in length composition of samples that are available for the period 1936 to 1953. The most obvious change is the decrease in the modal groups over the length range of 27 to 32 cm. These are fish of approximately 10 to 15 years of age.

There are possible explanations for the changes observed over this 18-year period. The modes which appear in 1936 dominated the fishery and may very well represent one or more very strong year classes. This could account for the relatively greater number of older fish some years later. There is a detectable shift toward the smaller sizes from 1941 on. In the period 1945 to 1949 there appears to have been another strong year class; the mode moves from about 25 cm. in 1945 to 28 cm. in 1949. Again in 1949, another such group is suggested at around 25 cm., reaching 27 to 28 cm. by 1953. This argument is admittedly tenuous; however, the data do suggest that there may well have been some very strong year classes during the period 1936 to 1953, and since 1936, at least, the biggest fish have not been excessively exploited in proportion to the smaller size groups.

TABLE 15.—*Length frequencies of redfish, by sex and age group, from*

Length	Number of males in age-group—																					
	<I	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XX+
25 mm																						
30 mm																						
35 mm																						
40 mm	2																					
45 mm	6	1																				
50 mm	5	1																				
55 mm	2	6																				
60 mm		18	1																			
65 mm		11	13																			
70 mm		8	35																			
75 mm		12	40																			
80 mm		2	52																			
85 mm		1	55	1																		
90 mm			59		1																	
95 mm			60		2																	
100 mm			59	2	1																	
105 mm			36	5	2																	
110 mm			40	1	6		1															
115 mm			20		8	1																
120 mm			12	2	11	7	1															
125 mm			2	2	8	5	1															
130 mm			4	1	9	9	2															
135 mm				3	13	10		1														
140 mm				1	11	10	1															
145 mm				1	19	17	4	2														
150 mm				2	9	14		1														
155 mm					5	14	4	2		2												
160 mm					1	20	5	1														
165 mm					4	17	7	3	1													
170 mm						8	3	3	3													
175 mm					1	17	7					1										
180 mm						7	15	5	1													
185 mm						6	8	4	5													
190 mm						6	10	4	1	1												
195 mm						1	12	9	1	1	1											
200 mm					1	2	7	10	2													
205 mm					1	3	4	7	1	3	1											
210 mm							2	6	2	2	1											
215 mm							5	5	3	4												
220 mm							1	5	3	2	3	1										
225 mm								4	4	2	2											
230 mm						2		6	4	5	3	1	1									
235 mm								2	11	6	2	2	1									
240 mm								4	12	8	3	5	1	1								
245 mm							1	2	4	7	4	2	3		1							
250 mm								4	5	8	10	4	8	3	1	1			1			
255 mm								1	4	10	9	4	5	4		1						
260 mm									4	3	13	8	10	5	5				1			
265 mm								1	3	8	5	11	7	3	2	3		1				
270 mm									2	5	5	11	9	9	4	7	1					
275 mm									2	7	4	4	7	6	4	5	5			2		
280 mm									2	2	3	8	10	7	8	5	4	3	2	1		
285 mm										2	5	3	5	1	4	4	2	3				
290 mm									1	2	3	3	6	6	2	3	4	2	2		1	
295 mm									1			3	1	3	3	7	2	2				
300 mm										1	1	1	1	1	1	1	2			1		1
305 mm														1	2		1	3				
310 mm													1	1			1	2				1
315 mm														1					1			
320 mm														2				1				1
325 mm														1	1	1						
330 mm																		2				
335 mm																		1	1			
340 mm																			1			
345 mm																	1		1			
350 mm																						
355 mm																						
360 mm																						
365 mm																						
370 mm																						
375 mm																						
380 mm																						
385 mm																						
390 mm																						
395 mm																						
400 mm																						
405 mm																						
430 mm																						
Total fish	15	60	488	21	113	176	101	92	82	90	78	73	76	55	38	38	23	20	10	4	1	3
Mean length (mm.)	49.8	67.9	94.3	122.7	137.3	160.2	183.1	206.8	235.4	248.2	258.6	266.0	270.9	279.8	281.1	283.2	291.4	301.5	301.0	285.0	292.5	312.5

all samples collected in the Gulf of Maine in 1951, 1952 and 1953

Number of females in age-group—																					
<I	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XX+
1																					
1																					
1																					
4																					
6																					
4	1																				
2	6	1																			
	9	4																			
	10	14																			
	8	32																			
	12	35																			
	11	35	1																		
	3	50																			
	2	44	1	1																	
		53	3	2																	
		49	5	2																	
		54	4	4																	
		32	4	9																	
		19	3	4	2																
		20	4	9	2	1															
		4	2	5	4																
		2	2	5	8																
			2	10	11	2															
			2	7	9	1		1													
			2	2	19	3	1														
				14	12	2	2														
				6	19	1															
				2	9	5	3														
			1	3	14	4	1														
				1	14	6	3														
					10	7	4														
				1	5	9	2		1		1										
					7	5	2	1		1											
					7	10	4	1	1												
					1	3	3	1	2												
					3	6	7	2	2			1									
						3	3	7	3	2	1										
						3	4	2	1												
						1	4	4	2	1											
					1	4	6	4		1			1								
					1	3	5	6	1	2											
						2	3	4	3	2											
							6	5			2	1									
							6	8	7		1	2									
						1	2	3	7	3	1										
							5	10	6	2	5	1									
						1	4	6	7	1	3	4	1								
							1	7	3	7	3	1				1					
							2	3	3	1	2	5	1	1							
							3	3	4	8	3	3	1	1							
							5	2	4	3	6	2	4	1	1						
								2	4	11	5	5	3	1							
							2		5	8	12	8	3								
							1		4	9	7	3	4	3	2	1	2				
								1	3	5	5	6	2	2	1		1				
								3	2	5	4	2	6	8	4						
								1	2	6	6	9	7	3	3						
								2	1	5	9	4	7	6	1		2		2		
										3	2	9	5	7		6		1			
										2	3	5	3	6	5	1	1				
									1	1	1	2	4	6	2	3	2	1	1	1	1
								1	2	1	5	4	6	2	4	3	5	2	3		
												3	5	5	2	4	5	3			2
											1	2	4	8	4	5	5	4	1		2
												4	1	8	2	3	2	2			1
											1		5	5	2	5	5	2	1		
												1	1	2		4	2	1	5	1	2
													2	7	4	4	4	4	2	2	
													1		3	1	1	1	3	2	1
															1	2	3	2		1	2
													1		1		1	2	2		1
																		1		1	
																	3		1		
																			2		1
															1				1		
																		1			1
																				1	
18	62	448	36	87	158	83	94	90	81	90	89	87	78	81	43	43	44	27	24	9	14
46.9	72.6	95.2	117.9	134.9	160.1	187.1	222.4	244.9	267.0	281.0	289.3	299.7	315.6	327.1	333.7	340.1	345.3	354.3	357.7	370.3	359.6

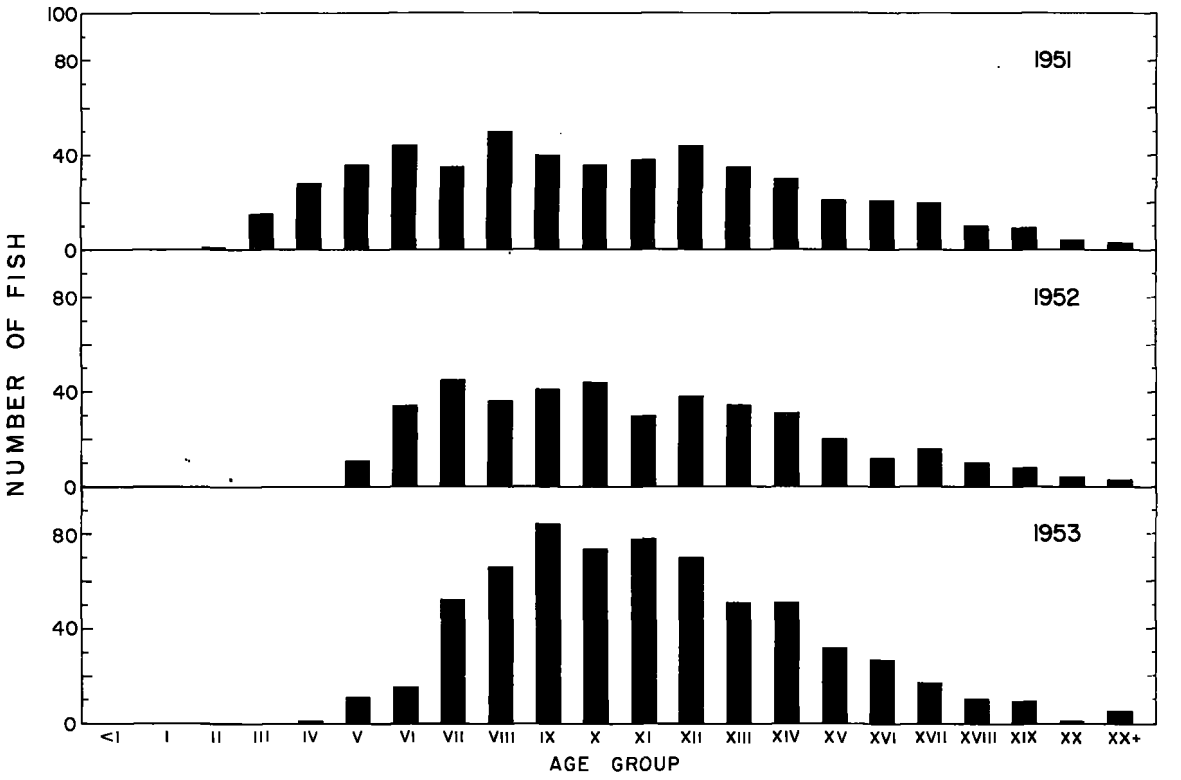

FIGURE 11.—Age composition of redfish sampled from the commercial catch in the Gulf of Maine, 1951, 1952, and 1953.

Age composition of the juvenile fish taken from the New Scantum station off Cape Ann shows large differences in year-class strength (fig. 13). These fish ranged in age from young of the year to 7-year-olds. Age-groups II and V stand out in the 1953 collections. Age-groups III and IV were notably lacking. The same age-group relation existed in the 1954 collections. The age-group data presented in figures 11 and 13 suggest that these age-group differences lessened by the time the fish became available to the commercial fishery.

DISCUSSION AND CONCLUSIONS

Our data show that only one annulus is formed per year in the otolith of the redfish of the western Atlantic. This conclusion is in accord with that of Bratberg (1956) for the redfish of the eastern Atlantic.

There is no doubt in our minds that redfish lay down only one annulus a year. While it is understandable how incorrect interpretations of length-frequency data are possible when one considers the exceptionally wide spread of sizes at age, there is no justification for suggesting that more than one annulus is laid down each year in the otoliths, on the basis of subjective analysis of redfish length-frequency data. Some other form of verification must be submitted before any consideration can be given to the suggestion that more than one opaque and one hyaline band is laid down in a single year in the otolith.

It is our opinion that the young do not normally pass through the winter scaleless and that an annulus is formed in both scale and otolith during the first winter. However, the time of first-annulus formation in the scales could be markedly affected by several factors. Hydrographic conditions vary greatly within the Gulf of Maine. The initial growth of the young redfish may not be sufficient in areas farther north, around Greenland for example, for them to start scales before the first winter. The time at which the larvae are spawned likewise could profoundly affect the growth attained in the first year.

Bratberg established the concomitance of annulus formation in scale and otolith. To detect annulus formation, there must be sufficient new growth to contrast with the old. Bratberg studied changes in the spacing of the circuli in the scale and the seasonal accretion of opaque material

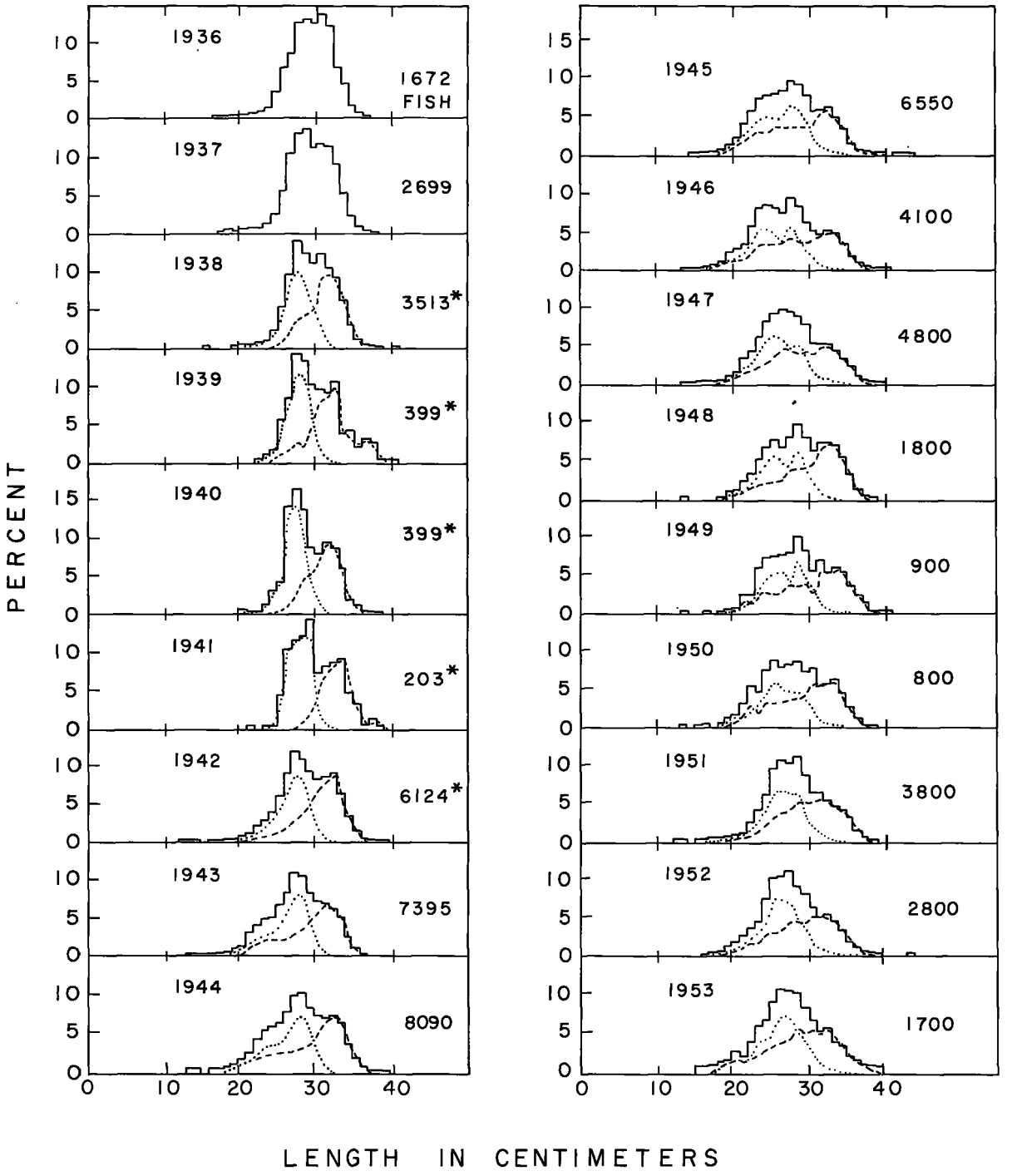

FIGURE 12.—Percentage length composition of redfish, by sex, sampled from the commercial catch in the Gulf of Maine, 1936 to 1953. No data are available on distribution of the sexes for 1936 and 1937; and only a portion of the sample was sexed for the years 1938 through 1942, as indicated by an asterisk (*). Females (dashed line); males (dotted line).

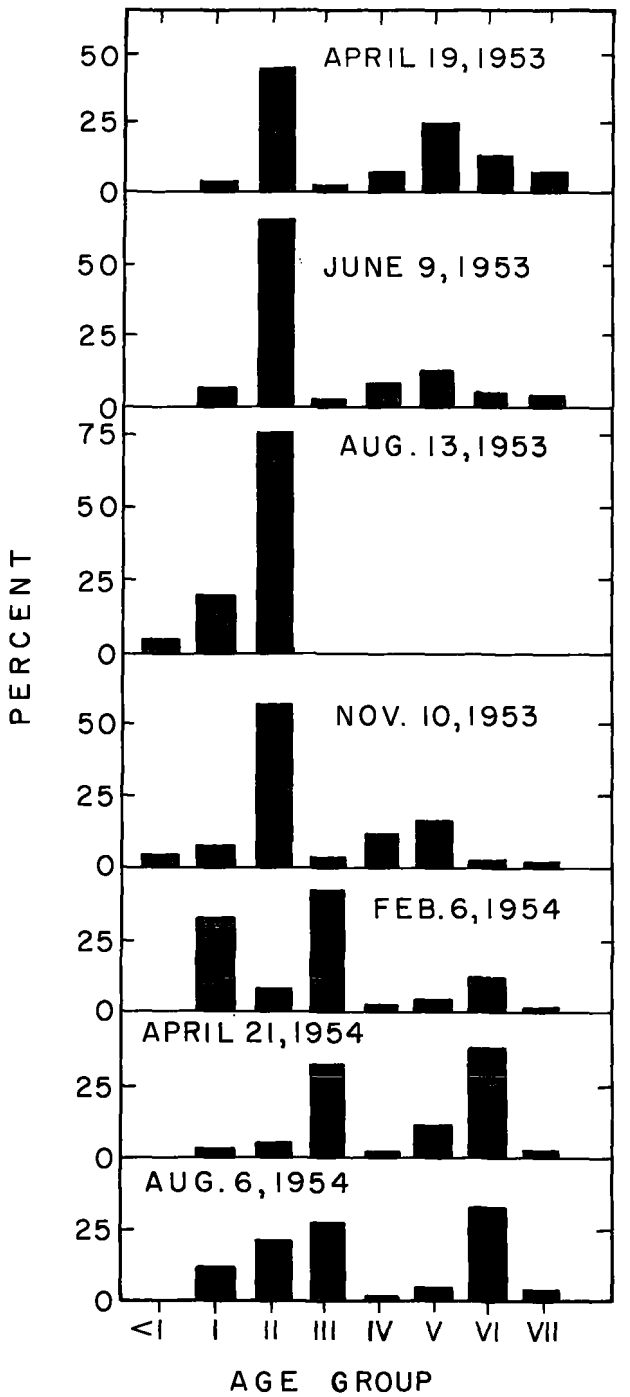

FIGURE 13.—Percentage age composition of redfish, pre-annulus to age-group VII, collected at New Scantum station, April 1953 to August 1954.

in the otolith. His study indicated that the annulus in both the scale and the otolith began to form in March and April. By May all fish showed obvious signs of new growth. Similarly, the studies reported in this paper show a sharp increase in April in the percentage of otoliths with an opaque edge, with over 90 percent of the otoliths having an obvious annulus by the early part of June. Another study—that of Perlmutter and Clarke—showed essentially the same thing. Their data suggested quite strongly that renewed growth may be detected on the scales in April. Further, the greatest number of scales with narrowly spaced circuli were taken from fish collected in February. All of these findings are consistent.

The age-composition studies of small fish provided verification of our interpretation of the otolith. In figure 13, it is apparent that there were two dominant year classes in the samples taken off Cape Ann. This population was followed for a period of 18 months, during which the complete cycle of the banding of the otolith was studied. When the fish were first collected in April 1953, the otoliths were observed to be developing the opaque band. By February 1954, the otoliths uniformly bore hyaline bands. The opaque bands were beginning to develop again in April, and by August all had well-developed opaque bands. It is plain that the sequence observed of year-class dominance could not have occurred had the otoliths laid down several series of bands. If they had, the dominant year classes would have appeared to have aged several years during the 18-month period of sampling.

The wide differences in length at age observed may be the result of the failure of some young fish to form a discernible annulus the first year. More likely, it is a result of the extended period of spawning. Collections made in late summer contain young redfish varying in length from 10 mm. to more than 50 mm. For this reason, even assuming that all these redfish put down a detectable annulus during their first winter, it is not surprising to find that any one age group taken from the commercial catch may have a length range of more than 100 mm. It is not necessary to hypothesize extremes in growth rates to account for the spread of sizes at age.

Most of our data on the length at age is based on samples of the commercial catch, and these samples come from many areas in the Gulf of Maine. Most biologists working with redfish believe that the fish move about very little and this admits the possibility of different growth rates in different areas.

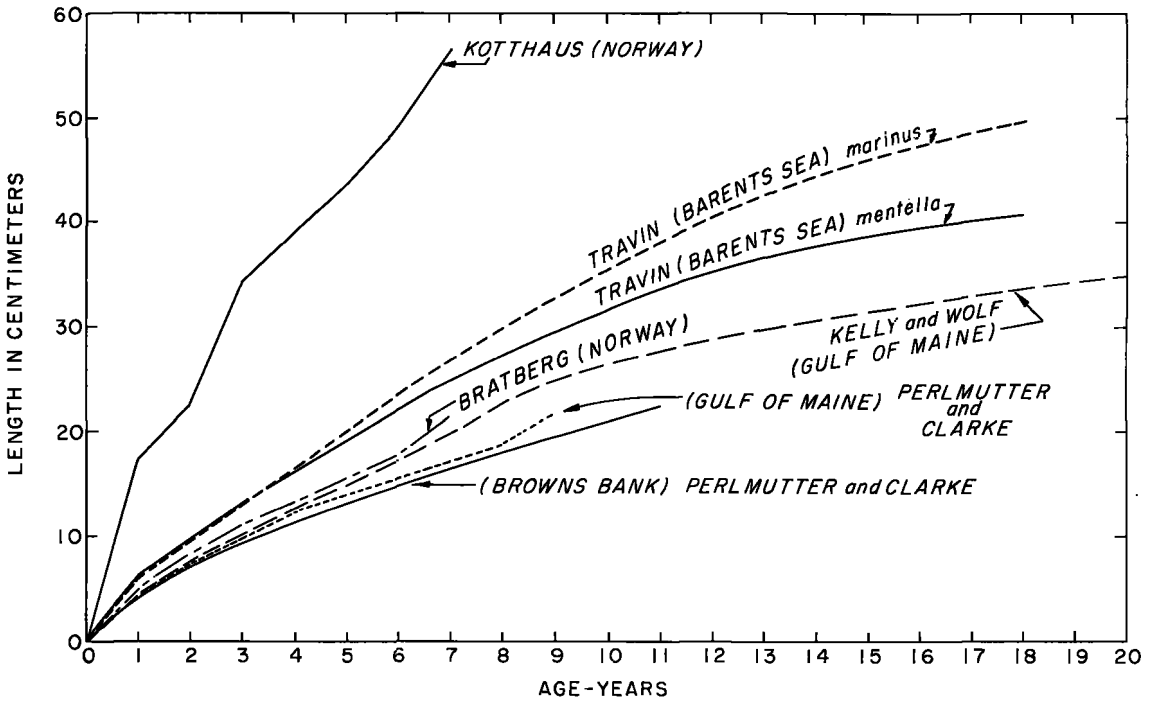

FIGURE 14.—Comparative growth rates of various *Sebastes* populations.

All important and relevant growth data that have been published to date are presented in table 16. All growth data based on the premise of a single annulus a year are consistent. The data of table 16, with the exception of those of Smaragdova and Veschezerov, are presented in figure 14 in the form of growth curves for the purpose of comparison. The erratic nature of Smaragdova's data (the age appears to be underestimated occasionally) was probably due to the fact that he used a geographically mixed sample. To a lesser degree, the same remarks possibly apply to Veschezerov's data. It must be remembered that until Travin published his paper there were at least two fairly well-defined population groups that were not recognized as such in the northern European waters. Travin's age-growth data for the subspecies *marinus* and *mentella* from the Barents Sea show the rate of growth of the populations. A growth rate derived from Bratberg's data is virtually identical to the growth rate for redfish from the Gulf of Maine. Perlmutter and Clarke's growth data on the Browns Bank redfish show the slowest growth of any group of redfish. The curve based on their Gulf of Maine material adjusted for time of annulus formation indicates a somewhat slower rate of growth than we found. The age-length data presented by Kotthaus are also plotted to show the extreme differences between his concept of redfish growth and that of other workers.

Kotthaus (1952) reported fish longer than 80 cm. from European waters. In recent years, several specimens measuring between 74 and 83 cm. in length and weighing from 14½ to 19½ pounds have been landed at Gloucester, and some have been reported in the local newspaper (Gloucester Times, July 30, 1953, and April 5, 1955). Most of these large fish came from the southeastern Grand Bank. It is interesting to speculate on the possible age of such fish. Our data indicate that it would be possible for one of the faster-growing females to reach this size in about 40 to 50 years. It seems probable that some redfish may live to an age in excess of even 50 years.

In conclusion, our results agree with those of several of the earlier growth studies and especially with those which were based on the premise of one annulus being laid down each year. It is evident that *Sebastes* is a slow-growing, long-lived fish.

TABLE 16.—*Growth studies of the redfish,* Sebastes marinus marinus *and* S. m. mentella, *in the North Atlantic Ocean*

[Age in years; average length in cm., on January 1]

Age	Average length of—								
	Sebastes marinus marinus								*Sebastes marinus mentella*
	Barents Sea			Browns Bank	Gulf of Maine		Norway	Norway coast	Barents Sea
	Smaragdova (1936)	Veschezerov (1944)	Travin (1951)	Perlmutter and Clarke [1] (1949)	Perlmutter and Clarke [1] (1949)	Kelly and Wolf [2]	Kotthaus (1953)	Bratberg (1956)	Travin (1951)
1	5.4	5.12	6.26	4.7	5.2	5.5	17.2	5.6	6.28
2	9.7	7.22	9.05	6.9	7.6	7.8	22.2	8.4	10.01
3	10.0	9.96	12.87	9.2	9.9	10.1	34.2	11.3	13.09
4	12.6	12.60	16.50	11.2	12.1	12.5	39.1	13.1	16.30
5	14.7	15.38	19.95	13.2	13.9	14.7	43.8	15.75	19.32
6	17.4	18.20	23.49	15.0	15.4	17.3	49.0	17.95	22.10
7	17.5	21.30	26.61	16.7	16.9	19.8	56.6	21.45	25.27
8	20.1	24.60	29.62	18.1	18.9	22.7			27.77
9	19.6	28.06	32.69	19.3	21.8	24.9			29.84
10	21.6	32.84	35.33	20.8		26.3			31.81
11	22.5	36.68	38.00	22.5		27.4			33.44
12	26.5	38.70	40.46			28.5			35.20
13	28.6	40.08	42.46			29.5			36.47
14	31.3	43.50	44.07			30.4			37.69
15	32.3	45.28	45.82			31.3			38.51
16	36.3	46.40	47.18			32.1			39.12
17	39.2	48.46	48.17			32.8			40.16
18	44.9	50.02	49.86			33.6			40.45
19	46.3	50.62				34.4			
20	47.5	51.02				35.0			
21	51.2	53.00							
22	52.4	53.35							
23	53.9	54.33							
24	54.9	58.33							
25	55.4								
26	57.0								
27	57.0								

[1] Average length adjusted to observed annulus number. [2] Present study.

LITERATURE CITED

ANDRIIASHEV, A. P.

1954. XLII. Family Scorpaenidae. *In* Fishes of the northern seas of Russia. Guides to the fauna of the U.S.S.R. published by the Zoological Institute of the Academy of Sciences of the U.S.S.R. Moscow and Leningrad, Academy of Sciences U.S.S.R., pp. 329–339. [Translated by C. Richard Robins.]

BIGELOW, HENRY B.

1914. Explorations in the Gulf of Maine, July and August, 1912, by the U.S. Fisheries Schooner *Grampus*. Oceanography and notes on the plankton. Bull. Museum Compar. Zool., vol. 58, No. 2, pp. 31–134.

1917. Explorations of the coast waters between Cape Cod and Halifax in 1914 and 1915, by the U.S. Fisheries Schooner *Grampus*. Oceanography and plankton. Bull. Museum Compar. Zool., vol. 61, No. 8, pp. 163–357.

BIGELOW, HENRY B., and WILLIAM C. SCHROEDER.

1953. Fishes of the Gulf of Maine. U.S. Department of the Interior, Fish and Wildlife Service, Fishery Bull. vol. 53, No. 74, 577 pp. (First revision.)

BRATBERG, E.

1956. On the interpretation of the opaque and hyaline zones in the otoliths of immature redfish (*Sebastes marinus* L.). Journal du Conseil, Cons. Perm. Internat. Explor. Mer, vol. 22, No. 1, pp. 66–74.

COLLETT, R.

1880. The Norwegian North-Atlantic Expedition 1876–1878. Vol. 3, Zoology: Fishes, pp. 15–18.

GLOUCESTER TIMES.

1953. Gloucestermen catch, land biggest perch. July 30, 1953. Gloucester, Mass.

1955. Forty or 50 years old, and close to 18 pounds, this mammoth ocean perch entered Gloucester in a trip of the Villa Nova (photograph caption). April 5, 1955. Gloucester, Mass.

ISAACS, J. D., and L. W. KIDD.

1951. A midwater trawl. University of California, Scripps Institution of Oceanography, SIO Reference 51–51, 10 pp., 10 figs., November 1951.

JENSEN, AD. S.

1922. Researches on the distribution, biology and systematics of the Greenland fishes. Videnskalbelige Meddelelser fra Dansk Naturhistorisk Forening i Kjøbenhavn, Bind 74, pp. 89–109. [Translated by Kirstine Soetmann.]

KOTTHAUS, A.

1952. Ecological and scientific fishery research of the red perch (*Sebastes marinus* L.). Berichte der Deutschen wissenschaftlichen Kommission fur Meeresforschung, N. F. Bd. XII, H. 4, pp. 491–511. [Translated by Luddo B. Nanninga.]

PERLMUTTER, ALFRED, and GEORGE M. CLARKE.

1949. Age and growth of immature rosefish (*Sebastes marinus*) in the Gulf of Maine and off western Nova Scotia. U.S. Department of the Interior,

Fish and Wildlife Service, Fishery Bull., vol. 51, No. 45, pp. 207–228.

ROUNSEFELL, GEORGE A.

1948. Development of fishery statistics in the North Atlantic. United States Department of the Interior, Fish and Wildlife Service, Special Scientific Report No. 47, 18 pp.

SMARAGDOVA, N. P.

1936. Growth of *Sebastes marinus* L. in Barents Sea. Bull. Soc. Nat. Moscow, Biological Station, vol. 15, No. 5, pp. 331–337. [Translated by Paul S. Galtsoff.]

TRAVIN, V. I.

1951. A new species of sea perch in the Barents Sea (*Sebastes mentella* Travin, sp. nov.). Communicated by the academician E. N. Pavlovskii. Akademiya Nauk, S.S.S.R., Doklady, vol. 77, No. 4, pp. 741–744. [Translated by C. Richard Robins.]

VESCHEZEROV, V. V.

1944. Materials on the biology and fisheries of marine perch in the Barents Sea. The Knipovich Polar Scientific Institute of Sea-fisheries and Oceanography, No. 8, pp. 236–270. [In Russian.]

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