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DETERMINING AGE OF YOUNG HADDOCK FROM THEIR SCALES

By ALBERT C. JENSEN and JOHN P. WISE

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CONTENTS

ABSTRACT

The history of age determinations of haddock from various areas is discussed, with a résumé of the previous work in New England and adjacent areas. Various methods of validation of age determination of haddock in New England waters are considered and evaluated. It is concluded that scales provide a satisfactory indication of the age of these fish, particularly for their first 5 years.

DETERMINING AGE OF YOUNG HADDOCK FROM THEIR SCALES

By Albert C. Jensen and John P. Wise, *Fishery Research Biologists*

BUREAU OF COMMERCIAL FISHERIES

Haddock *Melanogrammus aeglefinus* (Linnaeus) are distributed over the continental shelves of the eastern and western North Atlantic Ocean and are the basis for large and valuable fisheries on both sides of the ocean (table 1). In the United States, an economically important fishery for the species has existed since 1925, which contributes to the livelihood of many people living in or near several New England ports, particularly those of Massachusetts.

TABLE 1.—*U.S. and world landings of haddock, dressed fresh (FAO 1959)*

[In thousands of metric tons]

Year	United States	World (including United States)
1953	63.3	294.3
1954	70.3	343.7
1955	61.3	396.2
1956	69.1	430.8
1957	60.6	408.9
1958	54.2	371.5

The fish is a member of the cod family, Gadidae, but is easily distinguished from the cod or any of the other closely related gadids by the black shoulder spot and black lateral line. Bigelow and Schroeder (1953) give a detailed description of the haddock, its habits and habitats, but a few key points in its life history are outlined below.

The haddock is a demersal fish and, except for the spawning period when feeding diminishes, spends its life moving over the ocean floor in search of food. Spawning takes place near the bottom from February to May, with the peak of spawning in March and April. After the eggs are fertilized, they rise and float near the surface of the sea, drifting with the current. An egg hatches in about 14 days, and the larva, which is about 5 millimeters long, continues to drift with the current.

When young haddock are about 4 to 5 months old and 10 to 13 centimeters long, they begin to descend to the ocean floor, where they will spend the rest of their lives.

During their pelagic existence haddock feed on plankton, but as adults on the bottom (Wigley, 1956) their food consists largely of slow-moving invertebrates found on or burrowing in the substratum. Food items vary according to location and season, but in general consist of crabs, shrimps, snails, worms, starfish, sea urchins, sand dollars, and sea cucumbers. Haddock eat squid and occasionally feed on fish, mostly sand lance (*Ammodytes*), but fishes form only a very small part of their diet.

Haddock do not grow to the large sizes attained by cod. They rarely exceed 85 to 90 cm. in length; the largest haddock on record is an Icelandic fish 111 cm. long. Sexual maturity is reached when the fish are about 40 cm. long and 3 years old (Clark, 1959).

The New England fishery for haddock is concentrated on Georges Bank, one of a series of fishing banks which lie off the coast of northeastern United States and eastern Canada. Georges Bank (Schuck, 1951), bounded on three sides by the 100-fathom isobath, has its center about 150 miles east of Cape Cod. The haddock are fished for by a fleet of otter trawlers, the majority of which land their catches in Boston, Mass. The fish are landed in two market categories, "scrod," weighing between 1½ and 2½ pounds (gutted weight); and "large," weighing more than 2½ pounds (gutted weight).

NOTE.—Approved for publication May 2, 1961. Fishery Bulletin 195.

THE NEED FOR AGE DATA

In 1930, the Bureau of Fisheries (now the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service) began an investigation to determine (1) what caused the decline of the haddock fishery in waters fished by U.S. vessels, (2) what could be done to increase the abundance of haddock, or at least to prevent further decline in the catch, and (3) what predictions of future catches were possible.

To carry out the objectives of the investigation, large quantities of data have been and still are collected at important haddock ports (Boston, Gloucester, and New Bedford, Mass.; Rockland and Portland, Maine). Collections have been made routinely at Boston since the early 1930's, and were started later at the other ports.

The background for the collection of these data is reported by Rounsefell (1948). The data include almost complete records of the poundages landed from the various banks, with records of depths and locations from which the fish were taken, the gear used, and the days spent in fishing. Concurrent with this collection, random samples of the lengths of fish in the landings and selected samples of scales were also collected. For our studies, haddock were measured from the tip of the snout to the fork of the tail. About 30,000 fish were measured in 1959 and 3,500 scale samples were collected from an estimated 24 million haddock landed.

The data are analyzed primarily to determine the fluctuations in haddock abundance. Age determinations from scale readings are also used in special studies of the natural and fishing mortality rates, growth rate, and age composition of the catch.

To process the mass of biostatistics and to maintain a smooth flow of information relating to the age composition of the fishery, a quick and reliable method of age determination is needed. Scales have been used for 20 or more years at this laboratory. They are easily removed from the fish and it is possible to measure several hundred fish and take scale samples in a relatively short time at the port. The scales are easily processed in the laboratory; scales from 100 fish, for example, can be processed and read in about 1 man-day. The purpose of the present paper is to document the techniques originally used to validate the scale-reading method of haddock age determination and to present later studies of the usefulness of the method.

PREVIOUS STUDIES

Fishery biologists on both sides of the North Atlantic have for many years determined the ages of haddock from interpretation of scale markings. The publications of many of the workers report age compositions and growth rates but do not validate the method by which the scale ages were determined (cf. Huntsman and Needler, 1927; Schuck and Arnold, 1951; Wise, 1957; Kohler and Clark, 1958). Other workers have reported not only their results but, in addition, have described their methods of interpreting scale age determinations. These papers are of great interest in the present study.

In a study of haddock in Norwegian waters, Saetersdal (1953) reports that in many investigations haddock ages have been determined from scale examinations without testing the validity of the method. He then proceeds to demonstrate the validity of age determination methods for the Norwegian stocks of haddock, using the Petersen method. He points out that part of the year class of fish under observation failed to form a scale annulus in the second year. He also examined the secular record of the scales, including the time of annulus formation, and concluded, "* * * the zones found in * * * the scales were annual formations in the great majority of the cases."

In North American waters, several workers have used haddock scales for age determination. Among them, Needler (1929) used scale readings to derive growth rates for haddock from Lockeport, the Sable Island banks, and St. Andrews (Canada). He states categorically, "The age of haddock may be determined from the scales." and cites Thompson (1923) for his validation of haddock scale readings. (Thompson had examined the scales of North Sea haddock and found that 95 percent of the scales gave what he believed to be the correct age.)

In a later study Needler (1930) read haddock scales for age determination of fish from the Gulf of Maine and Georges Bank and again cited other workers for his proof of the scale method. He concluded, "There can be no doubt of the validity

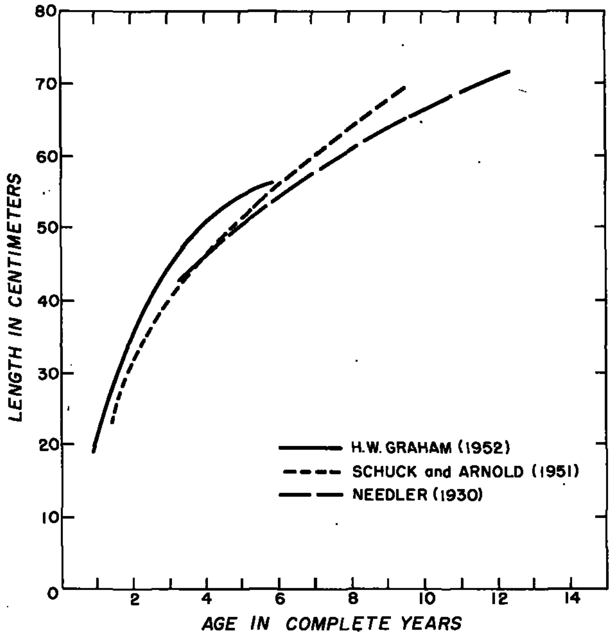

FIGURE 1.—Growth curves for Georges Bank haddock.

of the method, although inaccuracies are bound to occur."

In the 1930 report, Needler derived a growth curve for Georges Bank haddock, based on scale readings from 189 fish collected during May–September 1927. The growth curve is shown in figure 1, and on it we have indicated age-length values derived by Schuck and Arnold (1951) and H. W. Graham's (1952) growth rate. Graham's (1952) age-length data were taken from February 1 (completed year) scale readings. Both Needler (1930) and Schuck and Arnold (1951) obtained their age-length data from mid-year scale readings, thus the length for each age includes additional growth. Figure 1 indicates that Needler, Schuck and Arnold, and H. W. Graham do not differ markedly in their age determinations.

Recently, the more specific problems encountered in aging Georges Bank haddock have been studied by Jensen and Clark (1958), who determined the time of annulus formation on haddock scales; Clark (1958), who reported on the consistency with which different scale readers read the same scale samples; and Kohler and Clark (1958), who reported comparisons of age determinations from otoliths and scales from the same sample of haddock. These recent studies warrant closer examination and will be discussed in detail below.

Our haddock biostatistical data show that in past years more than 80 percent of Georges Bank haddock are caught by the time they have completed their fourth year. Furthermore, we are more confident about our age determinations of young fish. The annuli are most sharply defined in the scales of haddock 2, 3, and 4 years old, and the difference between summer growth and winter growth is very marked (Jensen and Clark, 1958). Needler (1930) noted this, too, when he stated: "In the later years in the life of the haddock, the annual zones become very narrow and the number of circuli in each small. In many of these cases the age is truly an 'estimation,' whereas the age of younger individuals can more truly be said to be 'determined.' "

Our own investigations bear this out, and Kohler and Clark (1958) report no statistically significant differences between scale and otolith ages up to about 7 years; after the seventh year, scale readings are consistently lower than otolith readings.

VALIDATION OF THE SCALE READING METHOD

Haddock scales are cycloid and oval to elliptical in shape (fig. 2). They do not show radii or transverse grooves, sometimes present on cycloid scales from other species. The external surface is sculptured with concentric circuli arranged about the focus, but the internal surface is relatively featureless. The focus is usually anterior to the center of the scale, but occasional scales are found with the focus at the center. Periods of rapid and slow growth are indicated by the spacing of the circuli. In studies of several species of gadids, including the haddock, J. S. Thomson (1904) noted that "* * * the growth of scales is cyclical or periodic, and * * * the rings formed thereby are annual."

J. S. Thomson considered temperature as a factor in forming annual rings only as it affects the food supply. He suggested that the scale circuli are widely spaced during the period of rapid growth in the warm season when food is plentiful and closely spaced during the period of slow growth in the cold season when food is scarce. Cutler (1918) believed water temperature to be the direct cause of annual rings. In an aquarium study with flounder and plaice, he concluded the food supply determined the number of circuli,

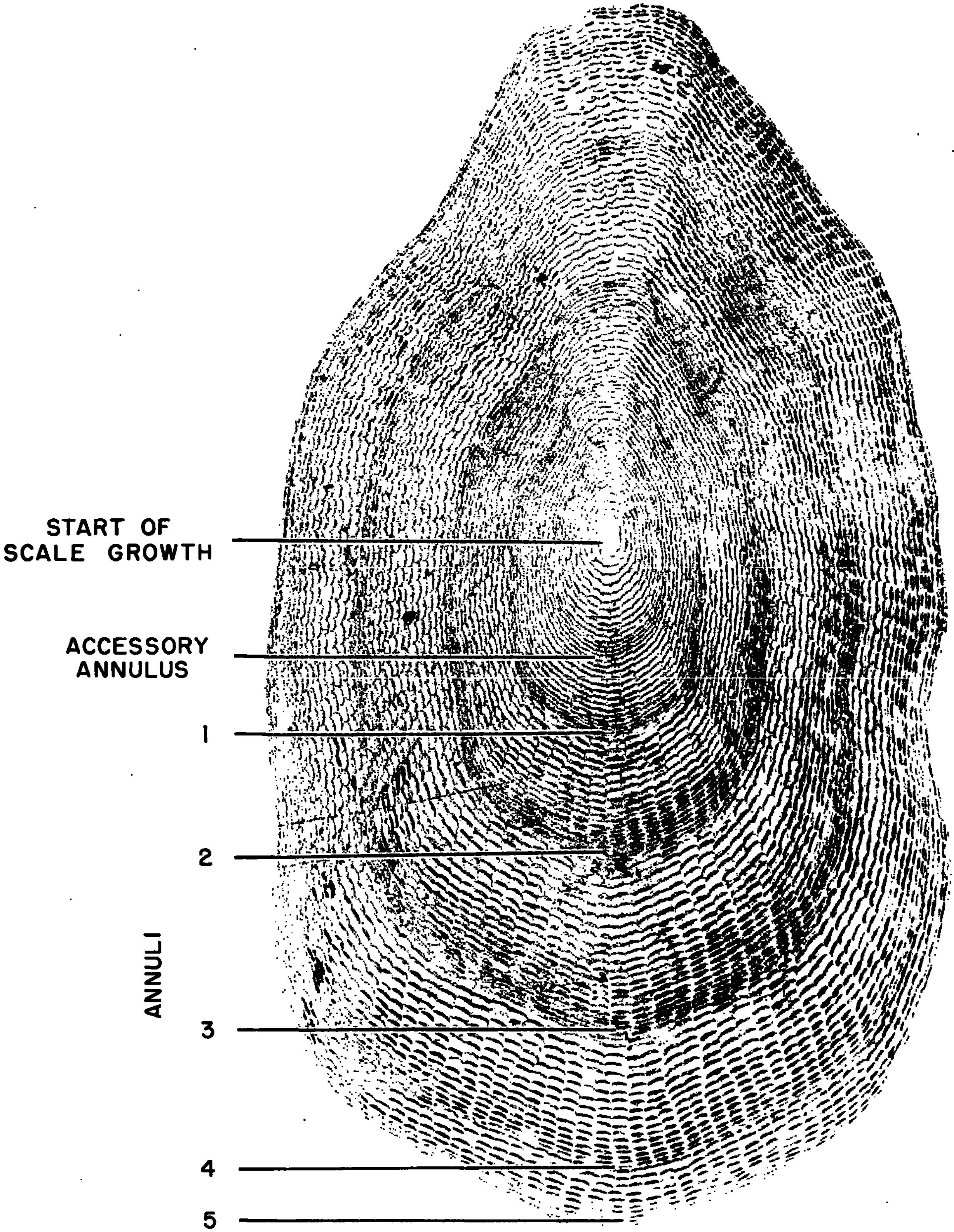

FIGURE 2.—Plastic impression of a scale from a 5-year-old haddock. Five annuli and the accessory annulus are visible.

but the water temperature determined the spacing between circuli. Lee (1920) notes that narrow "sclerites" begin to form on haddock scales in August or earlier, when the water temperature is increasing. She suggests that at this time the fish may be migrating into the cooler offshore waters where the decreased temperature produces the closely spaced circuli or "winter rings."

The role of food and feeding and their effects on haddock scale zones have not been clearly demonstrated, although some indirect evidence has been accumulated. Narrowly spaced circuli generally form on the scales of Georges Bank haddock in the period August–April (Jensen and Clark, 1958). For haddock from Nova Scotia offshore banks, Homans and Vladykov (1954) report November through May to be a season of diminished feeding. The period of least feeding coincided with the spawning period (February, March, and April) while the months of June through October constituted the feeding season. For Georges Bank haddock, Wigley (1956) reports that during the spawning period a decline in feeding, rather than a complete cessation, takes place, and for the period of annulus formation, the average volume of food per haddock rose from 1.8 cubic centimeters in September to 3.0 cubic centimeters in January but was lowest (1.0 cubic cm.) in February. We can see no clearcut evidence, based on Wigley's data, that diminished feeding causes the formation of narrowly spaced circuli.

There seems no reasonable doubt that widely spaced circuli are formed in summer and narrowly spaced in winter, whatever the direct cause. For the purpose of this study the point of interest is that zones are laid down on the scales at the rate of one for each winter and one for each summer, the two zones making a pattern which indicates a single year's interaction of the haddock and its environment.

Haddock Scale Reading Procedure

The annulus used by us in haddock age determinations is the zone of closely spaced circuli. It has the following characteristics:

1. It is concentric with the margin of the scale.
2. It can be traced, by careful scrutiny if necessary, entirely around the scale.
3. It is clearly separated from other such zones and does not ordinarily meet them at any point.
4. If present, it is on all the normal scales of an individual.

The scales from scrod haddock are thin and readily transmit light. Therefore, they are placed dry on a glass slide and examined under a binocular microscope with substage illumination. Large haddock scales are thicker and do not readily transmit light. To overcome this, large haddock scales are routinely impressed in plastic slides as described by Arnold (1951). The impressions are projected with a commercial microprojector at a magnification of about 40×. A minimum of three scales are examined from each fish. Regenerated and deformed scales are discarded.

The number of complete annuli, from the focus to the posterior edge of the scale, is counted to determine the age of the fish in years. The annulus is considered complete on February 1 (the arbitrary "birthday" of Georges Bank haddock), selected because most of the haddock commence spawning in February.

Results from a study of the formation of scale zones of Georges Bank haddock (Jensen and Clark, 1958) have shown that one annulus is formed each year. This was demonstrated by a predominance of widely spaced circuli at the scale edge during May–July and a predominance of narrowly spaced circuli during August–April.

Problems in interpreting scales arise because of the ambiguity of some annuli. For example, in a routine sample of scales from 510 Georges Bank haddock, read by the senior author, only 100 (19.6 percent) had distinct, well-separated annuli and were considered by him as easy to read. The fish were 1 to 5 years old and the annuli were sharply defined. The remaining 80 percent of the scales required detailed study to determine the age.

The most frequent error in scale reading probably arises from counting an accessory annulus usually found in the first zone of broad circuli (fig. 2). Thompson (1923) has termed this annulus a "false winter appearance" and suggests it occurs when the young haddock first descend to the bottom and their growth is checked as they enter the deep cold water. Our studies have shown that this accessory annulus occurs in slightly less than 50 percent of the scales examined for age determination.

We had an opportunity to examine critically the nature of the accessory annulus while doing some scale back-calculations for another study. We examined 513 scales collected in February and March, 1956 and 1957, from Georges Bank haddock, 3 to 6 years old. The scales had been collected as part of the routine port sampling program and represented a typical sample of scales used in our age determination procedure. In the sample of 513 scales, 245 (47.8 percent) showed an accessory annulus. A random subsample of 38 scales was taken for a more detailed study of the accessory annulus. Back calculations were made on the subsample to obtain these data: (1) L_1—calculated fish length at the end of the first year; (2) L_a—calculated fish length when the accessory annulus first began to form; (3) L_b—calculated fish length when the accessory annulus was complete; (4) C_a—number of circuli from the focus to the first narrow circulus in the accessory annulus; and (5) C_b—number of circuli from the focus to the last narrow circulus in the accessory annulus (see table 2).

TABLE 2.—*Calculated fish length-scale length relationship for accessory mark on Georges Bank haddock scales*

Age at capture	Fork length (mm.)	L_1 (mm.)	Accessory mark			
			L_a (mm.)	L_b (mm.)	C_a	C_b
3 years old	423	201	118	135	11	16
	432	359	108	120	9	11
	429	210	111	143	10	18
	425	180	101	112	9	11
	451	187	111	135	10	17
	438	232	128	146	12	17
	430	184	119	145	10	16
	458	183	128	146	12	18
	417	178	125	150	11	19
	402	174	114	131	11	18
	422	201	109	143	12	22
	465	202	130	166	11	22
	320	160	100	120	10	18
	397	186	98	118	9	14
4 years old	456	197	141	162	11	16
	503	214	107	148	7	16
	399	171	124	142	12	17
	418	198	130	145	10	14
	500	188	121	138	9	13
	483	222	118	140	10	14
	468	201	138	158	12	15
	501	192	100	114	7	11
	533	151	89	103	5	8
	446	140	89	102	6	9
	459	170	110	128	9	14
	445	237	145	165	11	17
	462	185	115	131	11	14
	406	200	128	161	12	21
	504	212	121	152	12	21
	484	203	130	149	11	18
	522	204	103	134	6	8
5 years old	572	262	123	161	8	14
	579	185	110	141	10	18
	600	197	116	142	12	18
6 years old	633	178	118	139	11	17
	522	188	91	129	8	20
	597	191	89	129	6	20
	503	165	122	145	11	15
Mean	--------	197	115	139	10	16

The accessory annulus starts to form when the haddock attain an average length of 115 mm. and is complete when the haddock attain an average length of 139 mm. The accessory annulus consists of about seven closely spaced circuli within a zone of widely spaced circuli and includes the 10th through the 16th circulus from the focus. Broadly spaced circuli, denoting rapid growth, are found on the scale after the accessory mark and are in turn followed by a zone of narrow circuli. This zone of narrow circuli is the first true annulus and is considered complete on February 1, although a few additional narrow circuli are formed in February and March. The accessory annulus usually is well separated from the first true annulus and with training and experience can be readily recognized by the scale reader.

Another source of error may arise from mechanical damage to the scale. The exposed posterior edges of some scales, particularly from fish more than 7 years old are ragged and appear to be eroded, suggesting that some annuli may be missing.

Confirmation of Ages from Length Distributions

Comparing the ages read from scales with the modal peaks in a length distribution of a sample of fish (the Petersen method) helps to confirm the scale method and particularly helps to establish the time of formation of the first true annulus. Haddock scale readings were thus confirmed by Duff (1916) for haddock from St. Andrews, by Saetersdal (1953) for Norwegian haddock, and by Schuck and Arnold (1951) for haddock from Browns and Georges Banks.

Figure 3 shows mean lengths of young-of-the-year haddock collected by us in 1957 on Georges Bank and in the Gulf of Maine. The term "young-of-the-year haddock" includes those fish that have not yet completed the first year of life. As explained previously, the year is considered complete on February 1. Small haddock, such as are represented in these data, are difficult to collect in sufficient quantities at one time for detailed length-distribution analysis. Therefore, the various collections were incorporated into one series of data in table 3.

Collections of larval fish, made aboard the *Albatross III* in April 1957, contained haddock

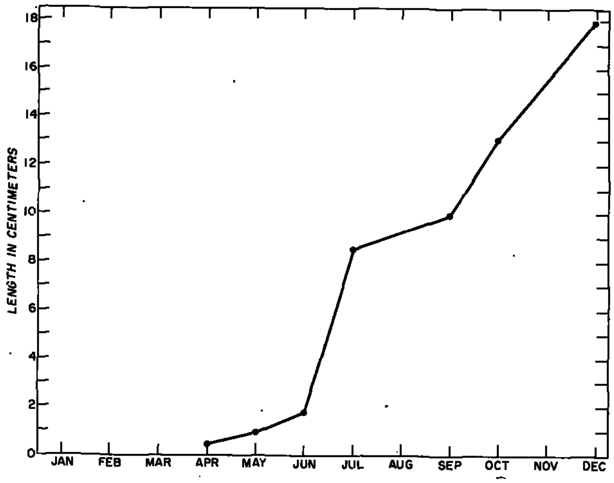

FIGURE 3.—Mean lengths of young-of-the-year haddock collected on Georges Bank and in the Gulf of Maine in 1957.

averaging 4.5 mm. long. Presumably these fish had been spawned only 1 or 2 weeks previously. In collections made in May 1957, postlarval haddock, averaging 9.6 mm. long, were taken. In June, young haddock 18.0 mm. long were collected at or near the surface but by July, the haddock had grown to an average length of 85.8 mm. and were in the middepths, mostly at 20 meters.

Midwater trawling from the *Albatross III* in September caught young haddock, average length 99.2 mm., slightly deeper in the middepths, presumably moving down to begin their existence on the sea bottom.

In a collection of juvenile haddock, made with a one-half-inch mesh otter trawl in October and November 1957, the fish averaged 132.0 mm. It is at this time that most haddock scales form the accessory annulus discussed previously.

The December collection represents juvenile haddock taken by a commercial otter trawler. The young-of-the-year haddock now average 179.0 mm. in length and have almost attained their full first year's growth. The average length for the December sample agrees well with the average length of 196 mm. for 1-year-old fish in the data.

An earlier collection of 419 haddock scales and length measurements was made on Georges Bank during *Albatross III* cruise 56 (Feb. 1–13, 1955) (table 4 and fig. 4). The length frequency of these fish shows distinct modes at 18, 30, and 42 cm. Examination of the scales revealed that all of the 14 haddock that measured from 11 to 21 cm. (the first mode) had one annulus. More than 61 percent of the 105 haddock from 22 to 36 cm. (the second mode) had 2 annuli, while most of the remaining 39 percent of this size group had 3 such marks. The third mode was composed mostly (more than 71 percent) of fish with 3 annuli.

If haddock spawned throughout the year, a length-frequency curve of the population would

TABLE 3.—*Length composition of young-of-the-year haddock collected on Georges Bank and in the Gulf of Maine in 1957*

Length (cm.)	April	May	June	July	Sept.	Oct.	Dec.
0.3	1						
0.4	11						
0.5	7						
0.6	3						
0.7		2					
0.8		3					
0.9		2	3				
1.0		4					
1.1		2					
1.2		3					
1.3			1				
1.4							
1.5							
1.6							
1.7							
1.8			1				
1.9							
2.0			2				
2.1							
2.2							
2.3							
2.4							
2.5							
2.6							
2.7							
2.8							
2.9							
3.0			1				
3.1							
3.2							
3.3							
3.4			1				
3.5							
3.6							
3.7							
3.8							
3.9							
4.0				11			
5.0				20	2		
6.0				33			
7.0				16	3		
8.0				24	6		
9.0				17	23	2	
10.0				51	61	1	
11.0				50	37	17	
12.0				9	4	50	
13.0						70	
14.0						39	
15.0						19	1
16.0						16	
17.0						5	4
18.0							2
19.0							2
20.0							2
21.0							
22.0							
23.0							
24.0							
25.0							
N=	22	16	9	231	136	219	11
Mean=	0.45	0.96	1.80	8.52	9.93	13.23	17.91

TABLE 4.—*Age composition of 419 Georges Bank haddock, by 3-cm. groups*

Length (cm.)	Age group (number of complete annuli)									Total
	1	2	3	4	5	6	7	8	9+	
12	1	-----	-----	-----	-----	-----	-----	-----	-----	1
15	4	-----	-----	-----	-----	-----	-----	-----	-----	4
18	6	-----	-----	-----	-----	-----	-----	-----	-----	6
21	3	-----	-----	-----	-----	-----	-----	-----	-----	3
24	7	-----	-----	-----	-----	-----	-----	-----	-----	7
27	-----	15	1	-----	-----	-----	-----	-----	-----	16
30	-----	33	-----	-----	1	-----	-----	-----	-----	34
33	-----	13	14	-----	-----	-----	-----	-----	-----	27
36	-----	4	17	-----	-----	-----	-----	-----	-----	21
39	-----	2	40	4	-----	-----	-----	-----	-----	46
42	-----	-----	52	8	-----	-----	-----	-----	-----	60
45	-----	-----	40	8	2	-----	-----	-----	-----	50
48	-----	-----	28	5	4	-----	-----	-----	-----	37
51	-----	-----	13	6	7	6	1	-----	-----	33
54	-----	-----	1	2	9	4	1	-----	-----	17
57	-----	-----	-----	1	12	7	3	-----	-----	23
60	-----	-----	-----	-----	4	6	1	1	-----	12
63	-----	-----	-----	-----	2	4	1	1	-----	8
66	-----	-----	1	-----	-----	-----	2	2	-----	5
69	-----	-----	-----	-----	-----	1	1	1	-----	3
72	-----	-----	-----	-----	-----	1	2	-----	2	5
75	-----	-----	-----	-----	-----	-----	-----	-----	1	1
Mean length	19.6	30.5	42.4	46.0	53.8	57.7	62.0	64.8	73.0	-----

consist of an irregular line with its highest point near the ordinate and sloping downward to the right. But haddock spawn in one relatively brief time of the year; the young from a single year's spawning are about the same size and form a mode in a length-frequency graph. The small fish are the young fish; i.e., fish represented by the first mode have no annulus or only one annulus on their scales. Fish represented by the second or third modes have two or three annuli, respectively, on their scales.

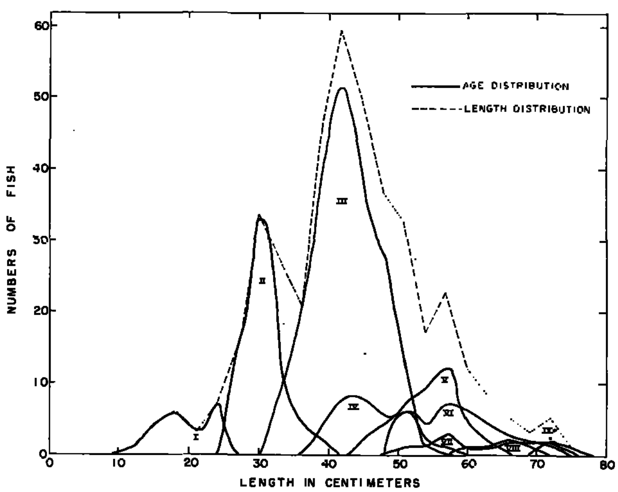

FIGURE 4.—Age analysis of the length composition of 419 Georges Bank haddock collected on *Albatross III* cruise 56, February 1955.

Confirmation from Age Distributions

Long-term observations of a fish population when the age frequencies are plotted will show the progression of strong year classes through the fishery, but this test only demonstrates that the majority of age readings are correct and is not meaningful unless the stock is adequately sampled (M. Graham, 1929). The year-class progression becomes less valuable when the outstanding year classes cease to be dominant and when the scales of the older fish become difficult to read.

In general, dominant year classes remain dominant in an age-frequency histogram for the first few years. Unfortunately, the stronger year classes appear to lose their dominance (in age frequency) in later years. This is due, no doubt, both to errors in scale reading and to differing mortality rates.

Year-class progression is demonstrated in the graph of the catch per day, by age, of Georges Bank haddock landed at Boston from 1948 through 1957 (fig. 5) and represents scale readings from 42,000 haddock. The relative strengths of several year classes are also shown. For example, the 1948 year class of haddock was very large and is well represented by the catch of 2-year-old fish in 1950. The 1948 year class also dominated the landings as 3-year-olds in 1951 and were well represented as 4-year-olds in 1952. However, in 1952, the 1948 brood is about equal in strength to the less successful 1949 brood, and by 1953 it is subordinate to the 1949 brood.

Similarly, the 1950 year class formed a large part of the catch as 2-year-olds in 1952 and as 3-year-olds in 1953. The 1951 year class was relatively poor, but the 1952 year class appeared in large numbers in the landings as 2-year-olds in 1954 and as 3-year-olds in 1955.

These observations tend to support the validity of our age readings. It will be noticed, however, that these strong year classes appear to lose their dominance after about the fourth year. Whether this is due to differential mortality or to age reading error, or both, remains to be resolved.

Comparison of Scales and Otoliths

A detailed study of haddock scale-otolith comparisons was reported by Kohler and Clark (1958) who examined material from 764 Georges Bank and Nova Scotia fish 1 to 13 years old. The two

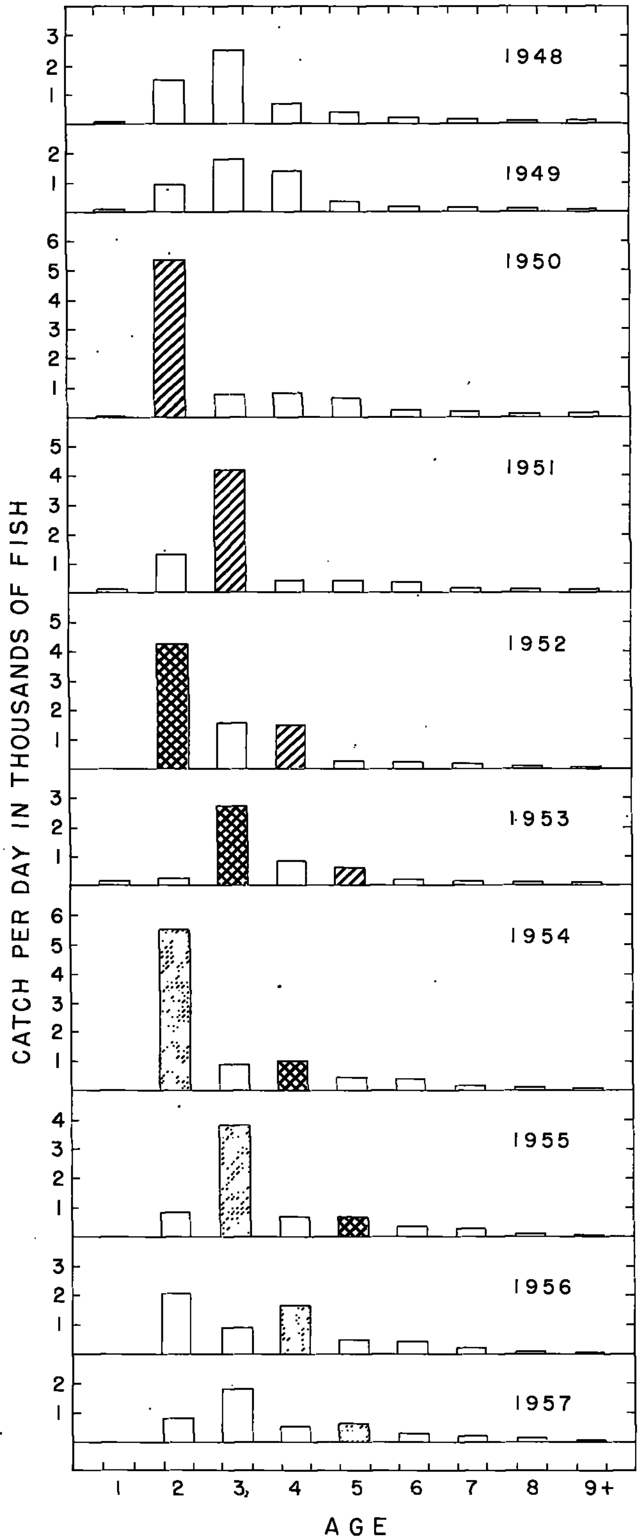

FIGURE 5.—Catch per day of haddock taken in Georges Bank Fishery.

methods agreed in 62 percent of the cases, but closer agreement (73 percent) was obtained when only fish 2 through 5 years old were examined.

M. Graham (1929) has stated that scale-otolith comparisons do not prove the validity of either method unless it is demonstrated that the periodic zones are formed simultaneously on both the scales and otoliths. Such comparisons may serve as indices to the validity of one method if it is supported by the other method.

Confirmation from Tagging

The recapture of marked fish of known age is the most direct means to validate age determinations, since the time parameter is precisely known. The technique is essentially this: the fish are marked and, before they are released, scales are removed for age determination. When a marked fish is recaptured, a second age determination is made and compared with the first. Since the time at liberty is known, any growth can be directly compared to time.

To examine this growth, scales were taken at the time of recapture from 32 tagged haddock and compared with scales taken from the same fish at the time of tagging. The fish were at liberty from 9 to 150 weeks. The scales were examined as follows: "at return" and "at tagging." Scales from each fish were impressed on plastic slides (64 in all). Each slide was identified only by a code number and the month in which the scale sample was taken. All of the slides were examined independently by two experienced scale readers, who marked the annuli for each scale on a card. When the readings were completed, the markings on the cards were compared to determine whether both readers had interpreted the same zones as annuli. Both sets of scales were identically interpreted for 29 of the 32 fish (table 5); the 3 questionable sets were re-examined by both readers together. Two of the fish in question had not formed identifiable annuli for one of their years at liberty; one was at liberty for 105 weeks and the other for 150 weeks. On the scale of the third fish, a zone was identified as an annulus by one of the readers but not by the other. This zone was formed immediately following tagging and perhaps resulted from interruption of growth caused by capture and tagging. It is significant

TABLE 5.—*Comparison of scales from 32 tagged haddock*

Month and year		Weeks at large	Age		
Haddock tagged 1954–58	Recaptured 1954–59		Tagged	Recaptured	Expected
April 1954	July 1954	13	7	7	7
Do	August 1954	14	7	7	7
Do	October 1954	26	3	3	3
Do	December 1954	33	4	4	4
Do	April 1955	50	4	5	5
Do	July 1955	63	4	5	5
Do	do	63	4	5	5
Do	do	65	4	5	5
Do	September 1955	72	4	5	5
Do	May 1956	105	4	5	6
Do	February 1957	150	4	6	7
August 1954	October 1954	9	2	2	2
Do	January 1955	25	4	4	4
Do	March 1955	31	6	7	7
Do	do	31	4	5	5
Do	May 1955	39	4	5	5
Do	June 1955	46	5	6	6
Do	October 1955	64	4	5	5
Do	January 1956	74	5	6	6
July 1956	March 1959	139	3	6	6
October 1957		32	3	4	4
Do	May 1958	49	1	2	2
November	August 1958	49	3	4	4
Do	September 1958	54	4	5	5
Do	November 1958	55	4	5	5
Do	do	63	4	5	5
Do	January 1959	68	5	7	7
Do	February 1959	69	3	5	5
Do	March 1959	72	3	5	5
March 1958	August 1958	20	6	6	6
Do	do	21	5	5	5
Do	February 1959	49	7	8	8

that these "tagging-checks" were not discovered by either reader on scales of any of the other fish.

DISCUSSION

The formation of an annulus on fish scales may be caused by one or more extrinsic or intrinsic factors such as temperature changes or physiological cycles.

Lee (1920) has suggested that haddock form annuli when they migrate from one environmental temperature to another. We know from marking experiments that Georges Bank haddock are relatively sedentary and the thermal milieu on Georges Bank does not vary greatly through the year. It is probable then that the annuli are not caused by marked differences in water temperature.

It might be argued that the scale annuli are spawning checks. The physiological drain in producing large amounts of gametes may cause formation of closely spaced circuli on the scales. As stated, previously, this zone of circuli is the annulus counted in haddock age determinations. The period of annulus formation (August to April) begins almost 7 months prior to the beginning of spawning and 5 to 6 months prior to the maturation and ripening of the sex products. Annuli are also seen on the scales of small, sexually immature fish and could not then have been caused by spawning activities.

Scale annuli may be caused by diminished feeding; a decline in feeding during the spawning season is reported by Wigley (1956). His data for April (height of spawning) are for a group of 256 fish whose average length is 35 cm. Such fish are almost all immature (Clark, 1959), and their reduced feeding intensity probably is due to a cause other than spawning activity.

What causes the formation of the annulus is not definitely known. But not knowing the cause does not remove the effect; annuli, formed once each year, are present on the scales and indicate a consistent annual phenomenon.

Consistency of age determinations is sometimes cited in arguments supporting validity of the determinations. Two or more people reading the same sample of scales and getting the same ages may be a result of (1) their having been trained in one set interpretation of the zones and thus reading the scales "with the same eyes," or (2) using independent interpretations of obvious scale markings. If the readers are using the same interpretation, their readings should agree. If they are using somewhat different interpretations, their readings will agree closely, but not completely. The agreement of haddock scale readers is very close (89 percent to 93 percent agreement in our laboratory) between individuals and with repeated readings by the same individual. This high degree of consistency shows only that the scale markings are usually clear and easily read.

Another consideration is the progression of strong year classes through the fishery as shown by the modes of age-frequency histograms (fig. 5). When a mode advances by 1 year with the passage of 1 year, it shows that the year class represented by the mode has also increased 1 year in age.

When the scales of tagged fish are studied, it might be argued that tagged fish show a "tagging" check on the scale presumably caused by the tagging operation. Following this line of reasoning, the scale-determined age should be 1 year more than the chronological age for recovered tagged fish. It has been shown that most tagged haddock produce one scale annulus per year, and the scales from 29 of the 32 tagged fish mentioned earlier showed only one additional annulus for each year at liberty. It is reasonable to assume, therefore, that haddock, at least, do not form a tagging check. Despite the lack of volume of recapture information, the available data are favorable to the use of scales from tagged fish as a test of age validation since the scales at recapture had grown (either in number of edge circuli or in the total number of annuli) while the tagged fish was at liberty.

CONCLUSIONS

1. Haddock ages determined by scale readings were compared with ages judged from length-frequency curves (Petersen method). The two sets of age determinations were in very close agreement for the first 3 years (100 percent for the first year, 61 percent for the second year, and 71 percent for the third year). Beyond the third year the length-frequency modes are obscured by overlapping of the lengths for each age.

2. The zone of closely spaced ("winter" type) circuli considered to be the annulus is formed during the period August through April. Only one annulus is formed during the year.

3. Age determinations from haddock scales read by different readers agreed in about 90 percent of the readings. The scale annuli are usually clear and easy to read.

4. Ages read from scales and from otoliths for the same fish agreed in 62 percent of the cases for a sample of 764 fish, 1 to 3 years old. Closer agreement (73 percent) resulted from the readings for fish 2 to 5 years old.

5. When catch-per-day data by age class for commercial haddock landings were plotted each year for 10 years, peaks representing outstanding year classes stood out from the adjacent poorer year classes. These peaks could be followed from year to year.

6. From a total of 32 tagged fish, an increase in the number of annuli equal to the number of years at liberty was noted in 29 fish. Scales from 2 fish had fewer annuli than years at liberty: one fish was in the ocean 2 years, but grew only one annulus; the other fish was in the ocean 3 years and grew 2 annuli.

7. Georges Bank haddock-scale annuli are formed one each year; they are true year zones and age determinations from these scales are valid in most of the haddock.

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