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Age and Length of Menhaden (Brevoortia tyrannus) in the Waters of Chesapeake Bay, with Comments on the Rate of Growth

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AGE AND LENGTH OF MENHADEN (*Brevoortia tyrannus*) IN THE WATERS OF CHESAPEAKE BAY, WITH COMMENTS ON THE RATE OF GROWTH

by

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INTRODUCTION

Brevoortia tyrannus (Latrobe) is commercially the most important of three species of menhadens occurring on the Atlantic Coast of the United States and the only one recorded in Chesapeake Bay. A second species, *B. smithi*, is found from Beaufort, North Carolina, southward to Indian River City, Florida, and a third of doubtful validity, *B. brevicaudata*, has been reported only in the vicinity of Noank, Connecticut (Hildebrand, 1948). *B. tyrannus* ranges from Nova Scotia through eastern Florida and is fished commercially throughout its range.

The menhaden, a member of the family Clupeidae, is easily distinguished from related genera such as the herrings and sardines or pilchards by its large head, distinctive scales (page 12) and typical coloration. The menhaden is perhaps the most efficient filter-feeder of all the clupeids, for it possesses an extremely effective filtering apparatus in the form of numerous long, fine, close-set gill rakers.

Only fragmentary information is available concerning the life history and habits of the menhaden. The species characteristically travels in schools which are recognized by fishermen from the reddish color they impart to the water and the rippling they cause on the surface. Fish of commercial size enter Chesapeake Bay in April and few are to be found in its waters after October. Little is known about the breeding habits of menhaden, as illustrated by Walford's (1945) reference to "unknown ocean spawning grounds" and his later (1954) statement "they spawn in or near estuaries." Menhaden from Chesapeake Bay evidently spawn in the fall and winter, for, as Smith (1896) and Hildebrand and Schroeder (1927) stated, fish with well-developed gonads are found only in the fall.

Kuntz and Radcliffe (1918) described the eggs and larvae of *B. tyrannus* collected at the mouth of the Potomac River during winter. Dexter Haven (personal communication) found larvae near the mouth of the York River in spring. Massmann, Ladd and McCutcheon (1954) obtained postlarvae in April and May, young in April through October, and juveniles with a mean fork length of approximately 102 mm. in September, in fresh waters of the major tributaries. In the fall young menhaden with a mean fork length of about 135 mm. are abundant in pound net catches in the lower York River.

It is surprising that a fish as abundant as the menhaden is known to so few people other than fishermen. This is probably because it is used only rarely for food. Most menhaden are processed in factories where the body oils are extracted and the remaining "scrap" is used in commercial animal foods. Ten years ago, about 66 per cent of the fish oil produced in the United States was obtained from the Pacific pilchard, Sardinops caerulea, (Banna, 1954). The tremendous decline in abundance of pilchard in recent years, coupled with the apparent rise in abundance of menhaden, has served to increase greatly the volume and value of the menhaden catch. In 1953, more than 90 per cent of the U. S. production of fish oil came from menhaden (Banna, 1954), and the total landings of this species for the Atlantic and Gulf coasts exceeded 800,000 tons, thus surpassing the record established by the Pacific sardine fishery in 1936-37. About eleven per cent of the total catch comes from Chesapeake Bay, and this is almost entirely from Virginia waters.

Menhaden are of prime importance, both commercially and as a food for other fishes. Nevertheless, practically no information is available as a basis for management of the fishery. Smith (1896) gave some rough estimates of the sizes of menhaden in Chesapeake Bay at different times during the fishing season. Bigelow and Welsh (1925) described the growth rate for the population in the Gulf of Maine. Rush (1952) observed markings on the scales which he interpreted as annuli, and calculated a growth rate for menhaden in the Beaufort, North Carolina, region based upon measurements of 34 fish. In 1953 Fred C. June, fishery research biologist of the U. S. Fish and Wildlife Service at Newark, Delaware, began to gather information on the commercial fishery in Delaware Bay (personal communication). A picture of the menhaden fishery in the 19th century and a large quantity of superficial information on the natural history of the species were given by Goode (1879, 1884) and Goode and Clark (1887). Ellison (1951) presented a general review of the history of the menhaden fishery and a summary of the life history. Lee (1952) traced the development of the industry in the United States.

The growing importance of the menhaden industry, and the warning implicit in the catastrophic declines in availability of sardines and other related species of commercial value, call for a close study of the menhaden stocks and the effects of the fishery upon them. The study described herein forms a part of the larger coastwise investigations now under way. Changes in a fish population usually can be followed most easily by examining samples of the commercial catch. The first problem that one meets in such investigations is the need for a reliable method of age determination, for unless the age of the fish is known, the relative contributions of the various years' spawnings cannot be assessed. Important also is a knowledge of the growth rate, for the interaction of growth and mortality determines the stage at which the population can be exploited most effectively. This study of age and growth rate is a necessary preliminary to the routine examination of the catch.

ACKNOWLEDGMENTS

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The author also wishes to thank Mr. Raymond Haynie, manager of the Reedville Oil and Guano Company, Reedville, Virginia, and his plant staff for their aid in the collection of samples from the purse-seine catch.

MATERIALS AND METHODS

Forty-two samples totalling 4,115 menhaden were gathered from two sources, pound-net and purse-seine catches. Purse seines are the more important of the two gears and take about 93 per cent of the menhaden caught in Chesapeake Bay. Although the pound-net catch is relatively small, this gear can be sampled much more easily from the Laboratory at Gloucester Point, for several pound nets are operated nearby. The purse-seine industry, on the other hand, is centered at Reedville, near the mouth of the Potomac River.

Pound-net samples were collected weekly from April 21, 1954, to October 5, 1954, from catches landed at the York River Seafood Company, Perrin, Virginia. Nets were located near the mouth of the York River at varying distances from the shore and in varying depths of water. The fishermen commonly cull the menhaden, herring, and other fishes not sold as food into a separate section of the boat to be sold as crab bait or scrap fish. It was from this portion of the catch that samples were taken. Baskets were handed to a fisherman who filled them with a shovel or by hand under careful observation to ensure that no obvious selection took place.

Purse-seine samples were collected from June 21, 1954, until October 25, 1954, from boats docking at the plant of the Reedville Oil and Guano Company, Reedville, Virginia. The catches were made at many different points scattered about Chesapeake Bay and occasionally in the open ocean not far outside the Bay entrance. Random samples usually were taken by the author personally or under his supervision from the first boat to reach the dock.

When the sample contained more than 100 fish the first 100 were examined, and the rest discarded. For each specimen the following data were secured: fork length[1] to the nearest millimeter, weight

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[1] Until the end of July the standard length (to the end of the silvery area on the caudal peduncle) was recorded. After this date, to make the measurements consistant with those being recorded at other points along the coast, fork lengths were measured for all samples. A conversion factor was calculated and used to convert measurements of the earlier samples to fork length.

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in grams on a Hanson spring balance, sex, stage of maturity of the gonads, and a sample of scales.

All scale samples were taken from an area directly behind the pectoral fin but not including scales immediately adjacent to the fin. It was noted that scales from this area were larger and more evenly shaped than those from any other area of the body. Perlmutter and Clarke (1949) suggested that the larger scales on a fish were most likely the first to appear, and hence should represent the growth pattern most exactly. Scales were placed without cleaning in numbered coin envelopes.

In the laboratory about eight or ten scales were removed from each envelope and placed in separate staining dishes filled with tap water. Several scales, selected by examination under a strong light, were cleaned by running between the thumb and forefinger. The best two scales thus prepared were then placed one above the other on a glass slide. In this way, scales from five fish could be mounted conveniently in sequence on one slide. A second slide was placed on top of the first and the two were fastened together at the ends with scotch tape. A small gummed label bearing the sample number and the serial numbers of the individual fish also was included between the slides to the left of the first pair of scales.

Scales were read with a standard Promi projection microscope at a magnification of 67 diameters.[2] The readings were made in a

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[2] Scales of fish three or more years old and scales of some juveniles near the end of their second year's growth were sometimes too large for this magnification, and were magnified only 30.5 diameters. These readings were then converted to the magnification used on the smaller scales.

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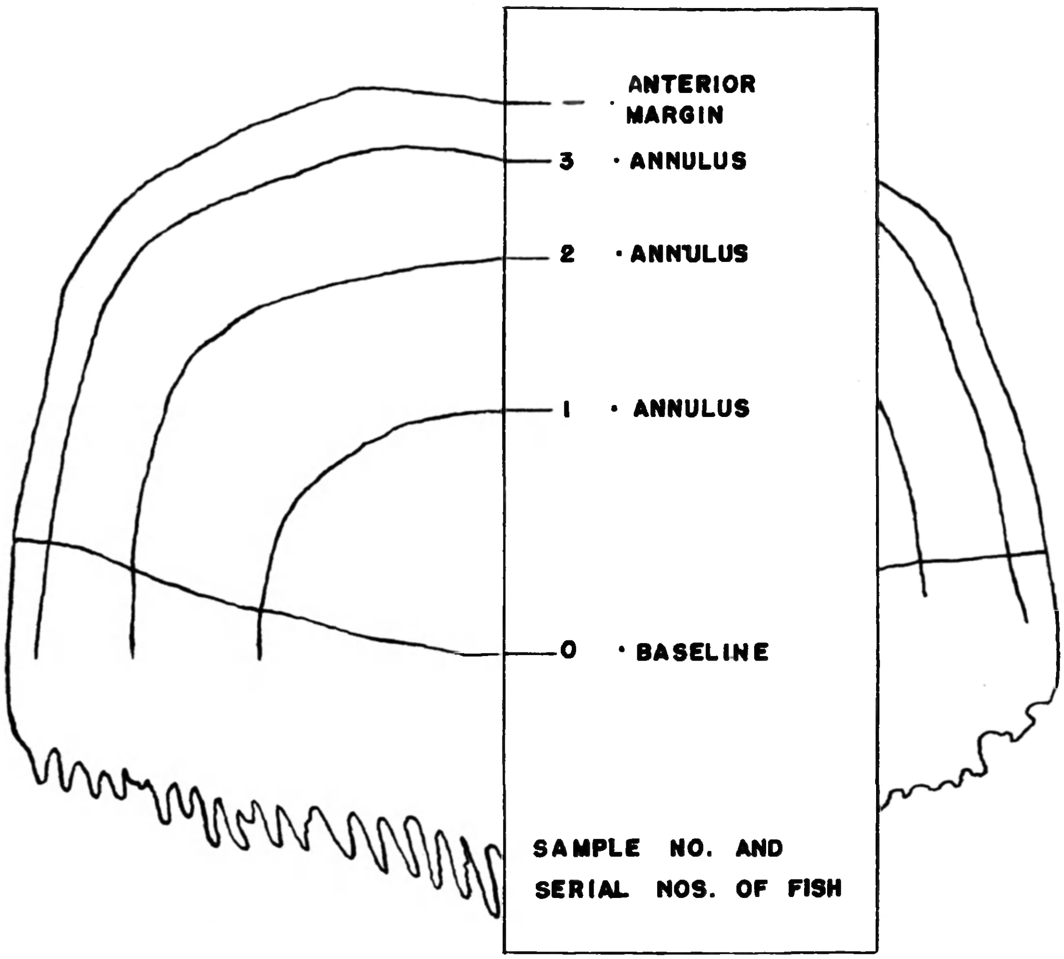
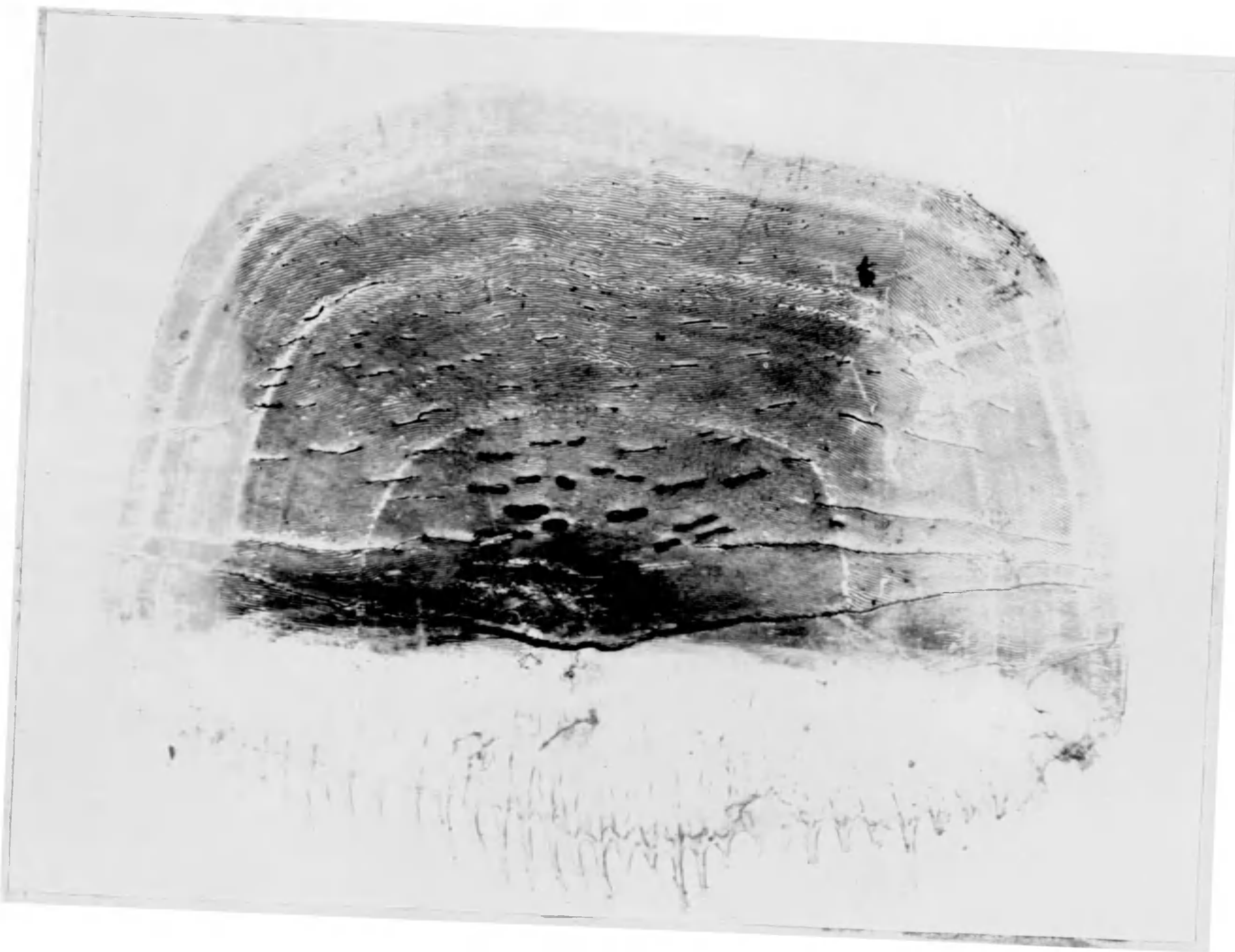
darkened room with the image projected vertically on a clean sheet of white paper on the desk. A card five inches long and one and one-half inches wide was laid with its long axis along the antero-posterior axis of the scale and the critical markings were recorded on the card with a sharp pencil (Fig. 1).

Fig. 1 - Method used for recording critical scale data.

Scale shown has three annuli.


ANTERIOR MARGIN
3 · ANNULUS
2 · ANNULUS
1 · ANNULUS
0 · BASELINE
SAMPLE NO. AND SERIAL NOS. OF FISH



SIZES OF MENHADEN IN THE COMMERCIAL CATCH

Pound Net Fishery

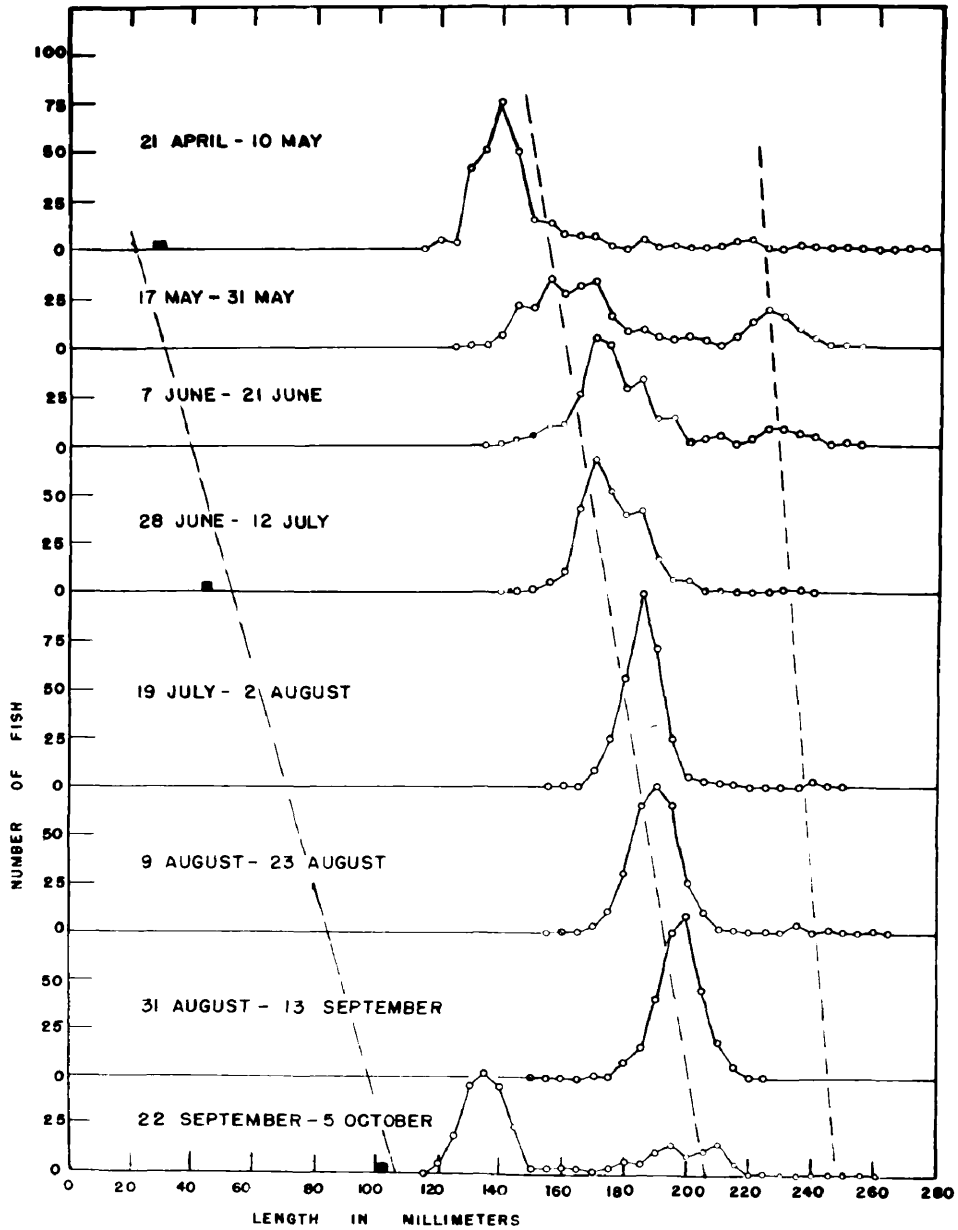
The data in table I and length frequency polygons in figure 2 are characterized by rather distinct peaks or modes. The left-hand peak in the upper distribution in figure 2 may be followed through the entire season, progressing rather regularly toward the right. This might be interpreted as representing the growth of a distinct and homogeneous group of fish. A second, less distinct series, to the right of the first, tends to disappear in the fall. A third group of fish, of smaller size, appears toward the end of the fishing season.

Walford and Mosher (1943) obtained a somewhat similar picture of size distribution in the Pacific sardine, *Sardinops caerulea*. Their argument seems to apply equally well to the menhaden data. When the two principal size groups appear in strength, as in the second half of May, the total range in length is about 120 mm. The available space for other age groups to occupy toward the left is also about 120 mm. It is true of almost all fishes that growth is most rapid in early life, hence the younger age groups are separated more widely in mean length. Thus there would seem to be insufficient room for two age groups on the left side of the principal mode. As a working hypothesis, therefore, it may be assumed that the first peak appearing in the spring catch represents fish beginning their second year of life. This hypothesis is further supported by two facts: (1) the new group of small fish that

TABLE I - Length Frequencies of Menhaden from Pound-Net Samples. Modal lengths are underlined.

Length in mm.	Frequency of occurrence							
	21 April- 10 May	17 May- 31 May	7 June- 21 June	28 June- 12 July	19 July- 20 August	9 August- 23 August	31 August- 13 September	22 September- 5 October
115	-	-	-	-	-	-	-	1
120	5	-	-	-	-	-	-	5
125	3	-	-	-	-	-	-	20
130	41	2	-	-	-	-	-	47
135	50	2	-	-	-	-	-	53
140	76	7	1	-	-	-	-	45
145	50	22	3	1	-	-	-	24
150	15	19	6	1	-	-	1	3
155	13	34	10	5	-	-	-	3
160	8	26	12	11	1	1	-	4
165	7	31	27	43	-	-	-	3
170	7	33	55	70	9	3	2	2
175	2	17	52	52	24	11	1	3
180	-	8	29	39	56	29	8	7
185	4	8	33	42	99	65	16	6
190	1	5	14	17	70	75	41	12
195	2	4	14	7	25	66	75	15
200	-	6	2	5	6	26	84	10
205	-	3	4	1	3	10	45	13
210	2	2	5	1	2	2	19	16
215	3	6	1	-	2	2	7	6
220	5	14	3	-	-	1	1	1
225	1	20	8	1	-	1	-	-
230	-	17	9	2	-	1	-	-
235	1	8	6	2	-	4	-	-
240	1	4	4	-	2	-	-	-
245	1	1	-	-	1	1	-	-
250	1	1	2	-	-	-	-	-
260	-	-	-	-	-	2	-	1
275	1	-	-	-	-	-	-	-

Fig. 2 - Sizes of menhaden in the 1954 pound-net catch of Chesapeake Bay expressed as length frequencies. Samples are grouped by periods of three weeks.



21 APRIL - 10 MAY
17 MAY - 31 MAY
7 JUNE - 21 JUNE
28 JUNE - 12 JULY
19 JULY - 2 AUGUST
9 AUGUST - 23 AUGUST
31 AUGUST - 13 SEPTEMBER
22 SEPTEMBER - 5 OCTOBER
NUMBER OF FISH
LENGTH IN MILLIMETERS

appears in the fall (left-hand peak in the lower polygon) is just slightly less in mean length than the group that forms the major spring peak, (2) the right-hand peak in the fall (lower polygon) consists of fish just slightly smaller than those in the right-hand peak in spring. The entire series of modes, if repeated for several successive years, would appear to form a smooth series, representing the growth of several adjacent age-groups of fish. Furthermore, the available length records of very young menhaden (Massmann, Ladd, and McCutcheon, 1954), as indicated by the black squares and left-hand broken line in figure 2, form a reasonable series with the first mode in the lower polygon, and seem to support the hypothesis that this group indeed represents fish in the first year of life.

The length measurements from pound-net samples therefore seem to show that most of the fish are in their second year of life, that fish in their third year form a small part of the catch early in the season, and fish in their first year appear in appreciable numbers in the fall. The apparent lengths at the end of each year of life are approximately 120 mm. at the end of the first year, 200 at the end of the second, and 250 at the end of the third.

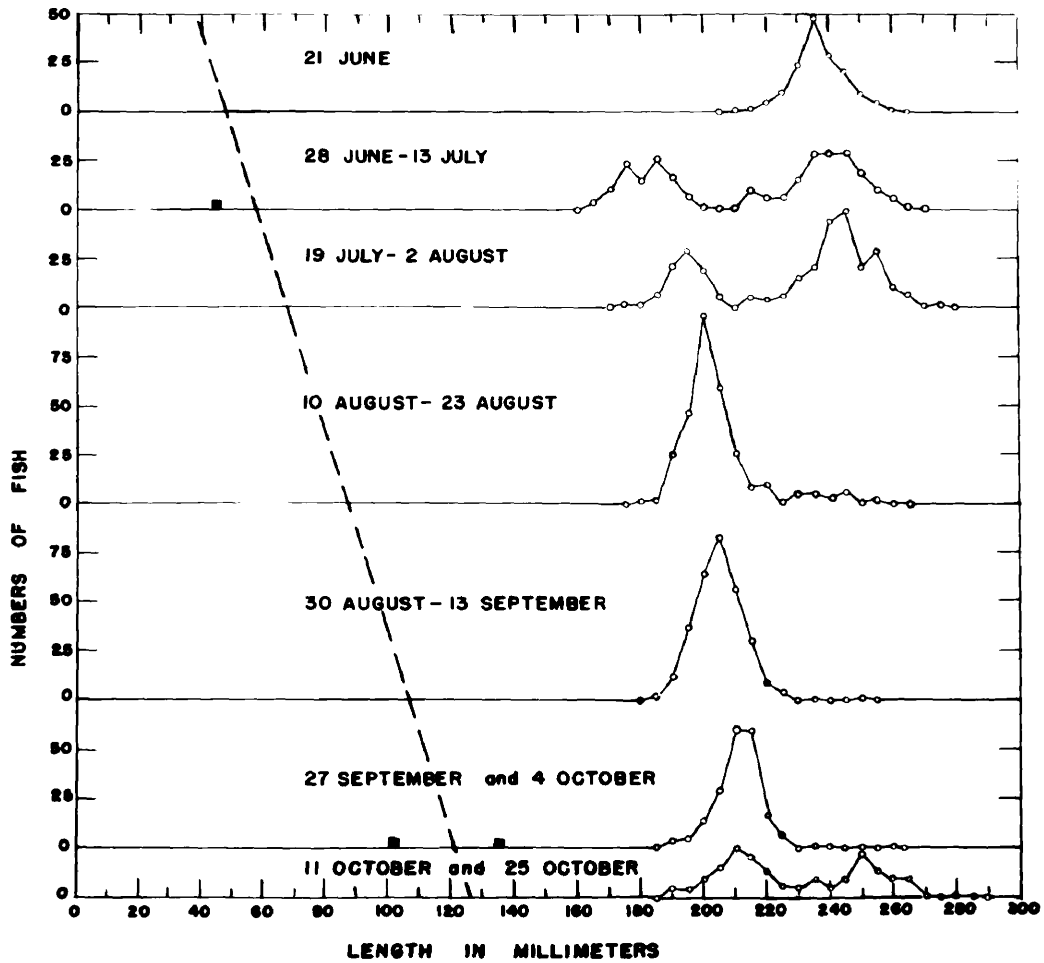
Purse Seine Fishery

The data in table II and length frequency polygons in figure 3 show two distinct modes. The right-hand peak, composed of relatively large fish, dominates the early summer catches but tends to disappear

TABLE II - Length Frequencies of Menhaden from Purse-Seine Samples. Modal lengths are underlined.

Length in mm.	Frequency of occurrence: 21 June	28 June-13 July	19 July-20 August	10 August-23 August	30 August-13 September	27 September-4 October	10 October-25 October
160	-	-	-	-	-	-	-
165	-	3	-	-	-	-	-
170	-	10	-	-	-	-	-
175	-	23	2	-	-	-	-
180	-	16	2	1	-	-	-
185	-	26	7	2	2	-	-
190	-	17	22	25	12	4	4
195	-	7	28	47	37	5	4
200	-	2	24	96	68	14	10
205	-	2	5	58	83	29	15
210	1	2	-	26	56	61	25
215	2	9	5	9	28	60	21
220	4	6	4	10	8	17	13
225	10	7	6	2	4	7	6
230	24	16	15	5	-	-	5
235	48	33	20	5	-	1	8
240	28	32	44	4	-	1	5
245	21	32	49	6	-	-	8
250	9	19	21	1	1	-	23
255	5	11	28	4	-	-	13
260	1	7	10	1	-	1	10
265	-	1	6	-	-	-	9
270	-	-	1	-	-	-	1
275	-	-	1	-	-	-	-
280	-	-	-	-	-	-	1
285	-	-	-	-	-	-	1

Fig. 3 - Sizes of menhaden in the 1954 purse-seine catch of Chesapeake Bay expressed as length frequencies. Samples are grouped by periods of three weeks.



21 JUNE
28 JUNE - 13 JULY
19 JULY - 2 AUGUST
10 AUGUST - 23 AUGUST
30 AUGUST - 13 SEPTEMBER
27 SEPTEMBER and 4 OCTOBER
11 OCTOBER and 25 OCTOBER
NUMBERS OF FISH
LENGTH IN MILLIMETERS

in the fall. The left-hand peak, composed of smaller fish, becomes relatively more important as the fishing season progresses.

The regular progression of the modes to the right in both size groups probably reflects the growth of the fish. Fish represented by the left-hand mode in the lower frequency polygon approach in size fish represented by the right-hand mode in the upper polygon. Information from fall pound-net catches and other available length records of young menhaden (Massmann, Ladd and McCutcheon, 1954) permits a rough estimate of the growth pattern during the first year of life (black squares and broken line in figure 3).

Analogous to conclusions concerning the age of size groups in pound-net catches (page 9) the dotted line to the left in figure 3 seems to represent fish in their first year of life; the left-hand modes of the frequency polygons, fish in their second; and the right-hand modes, fish in their third year of life. Apparent lengths at the end of each year of life as estimated from purse-seine catches are approximately 210 mm. at the end of the second year and 250 at the end of the third.

Smith (1896) reports the sizes of menhaden in the purse-seine catches of Chesapeake Bay and off the Virginia coast in a general way but does not specify how the fish were measured. He says that in October and November fish within the Bay were running rather small averaging six and one-half to eight inches (165-203 mm.) in length. These evidently represent a mixture of fish in their first and second year of life. During the spring and summer he states that fish caught in the seines ranged from four and one-half to eleven inches (114-279 mm.) the average being six to eight inches (152-203 mm.) long. He says "it is reported that since 1890 the average size of fish in the bay has been smaller than prior to that time."

AGE DETERMINATION

Brevoortia tyrannus may be separated easily from the other herring-like fishes of Chesapeake Bay on the basis of the scales alone. Scales from the flatter portions of the body are almost rectangular in shape with a vertical anterior edge. Those from more curving portions of the body such as the back and belly are rounded anteriorly, but the dorso-ventral axis is still relatively long. About one-fifth of the area of the scale, exposed posteriorly, is unsculptured, and its border is equipped with a row of prominent ctenii, structures not found on the scales of other clupeids of the Bay. Menhaden scales, unlike those of most other clupeoids, are quite firmly attached, and little trouble was encountered in obtaining samples from the desired areas of the body.

The anterior portions of menhaden scales are sculptured on the upper surface; and annuli, when present, are the most distinctive markings. These are formed on menhaden scales by a widening of the spaces between striae, usually accompanied, at least in some part of the scale, by a discontinuity in the pattern of the striae. The first problem in developing a method of age determination is to establish that these are truly annual markings. As a necessary preliminary a definite criterion of an annulus must be adopted.

Following the method of Walford and Mosher (1943) the following standards were adopted to identify the annulus in menhaden scales:

1. An annulus must be concentric with the margin of the sculptured

portion of a scale.

2. An annulus need not always be a sharp line, but can be traced, by careful scrutiny if necessary, around the entire sculptured part of the scale.

3. Annuli are clearly separated from one another and do not meet at any point.

4. If an annulus has formed, it is present in all the normal scales of an individual.

5. One annulus, but never more than one, must be formed each year.

Other marks of somewhat similar appearance, termed false annuli, commonly encountered on the scales of many fishes, but seldom seen on menhaden scales, may be distinguished from true annuli as follows:

1. False annuli are less distinct than true annuli, and usually are not continuous around the entire sculptured portion.

2. False annuli may be scar-like or otherwise abnormal in appearance.

3. False annuli rarely appear in all the scales of an individual.

Among other markings present on a scale were the transverse grooves, deep grooves running dorso-ventrally across the scale. The most posterior groove extends across the scale from margin to margin and for convenience in scale measurement has been termed the <u>base line</u>. Almost always the grooves are less distinct towards the imbedded portion of the scale, and appear to degenerate into series of broken lines which become fainter and fainter until they seem to disappear completely on the anterior third or quarter of the scale. Striae cover the sculptured portion, appearing as fine lines running dorso-ventrally across the scale. These are caused by small wave-like upturnings of the scale surface.

All measurements of the projected images of the scales originated at the base line. The base line varied in width and distinctness, but with careful focusing it could be resolved into a fairly narrow and clearly-defined marking. A pencil mark was drawn on the recording card (Fig. 1) at the anterior edge of this line. When an annulus was present, a line was projected onto the recording card where the annulus intersected the antero-posterior axis. If, at this point of intersection, the annulus was diffuse or ill-defined, its position was located by extrapolation of the curvature of the more distinct portions. If a second or third annulus was present it was recorded in similar fashion. The final marking on the recording card coincided with the anterior edge of the sc le.

The first four criteria adopted for recognition of an annulus are arbitrarily-defined characteristics that need no further elaboration. The fifth criterion, however, that one, and only one, annulus be formed each year, must be examined and established. If it can be shown, for fish having an equal number of marks conforming to the first four criteria, that the marginal increment of scale material outside the last mark increases in width throughout the year, and that most, if not all such marks are formed during a definite season, then these markings can be called annuli.

In table III the frequency distributions of increment widths, in classes of three arbitrary units, are shown for fish in their second year of life grouped by periods of three weeks. A steady increase in width as the season progresses is obvious. Figure 4 shows clearly the growth of the marginal increment in scales collected at different times. In figure 5, the mean widths of the marginal increments for successive groups of samples show a steadily increasing trend. The same finding is illustrated in a different way in figure 6, in which an arbitrary dividing line between narrow and wide increments was established, and the proportions of fish having narrow increments were plotted against time. Figure 6 illustrates clearly the point that annulus formation was taking place in the spring, that all annuli for fish in their second year of life had been formed by mid-May, and that the scales grew out beyond the annulus for the remainder of the season.

Surprisingly few scales were impossible to read. Only about three per cent of all scales examined had to be discarded because they were abnormal in some way. Usually a much higher proportion of scales from samples of commercially important fishes are illegible. Perhaps reading would have been less successful if more older fish

TABLE III - Marginal Scale Increments for Menhaden in their Second Year of Life from Pound-Net Samples

Width of marginal increment in arbitrary units	Frequency of occurrence						
	21 April-10 May	17 May-31 May	7 June-21 June	28 June-12 July	19 July-2 August	9 August-23 August	31 August-13 September
2	36	3	-	-	-	-	-
5	73	39	2	-	-	-	-
8	84	90	26	-	-	-	-
11	31	68	59	3	-	-	-
14	4	16	83	13	2	-	1
17	-	6	61	37	12	1	1
20	-	-	21	72	38	17	3
23	-	-	7	68	75	28	6
26	-	-	2	57	61	51	21
29	-	-	-	26	49	48	33
32	-	-	-	8	26	50	38
35	-	-	-	4	12	44	40
38	-	-	-	1	7	27	40
41	-	-	-	1	-	12	26
44	-	-	-	-	3	5	26
47	-	-	-	-	1	-	23
50	-	-	-	-	1	2	8
53	-	-	-	-	-	2	9
56	-	-	-	-	-	-	10
59	-	-	-	-	-	-	4
62	-	-	-	-	-	-	1
65	-	-	-	-	-	-	1
71	-	-	-	-	-	-	1
Mean width	6.61	8.99	14.71	22.62	26.28	30.67	37.78

Fig. 4 - Scales showing increase in marginal increments as the season progressed. Top row from left to right: scale from fish 140 mm. long taken April 21 and scale from fish 137 mm. long taken May 10. Bottom row from left to right: scale from fish 155 mm. long caught June 7 and one from a fish 208 mm. in length taken September 9.

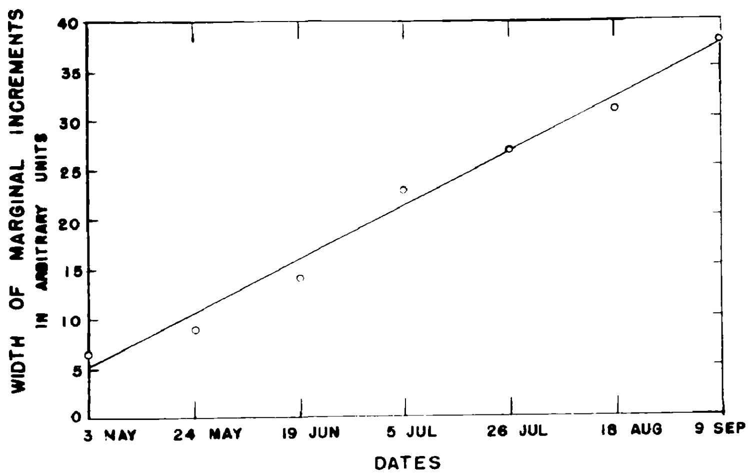


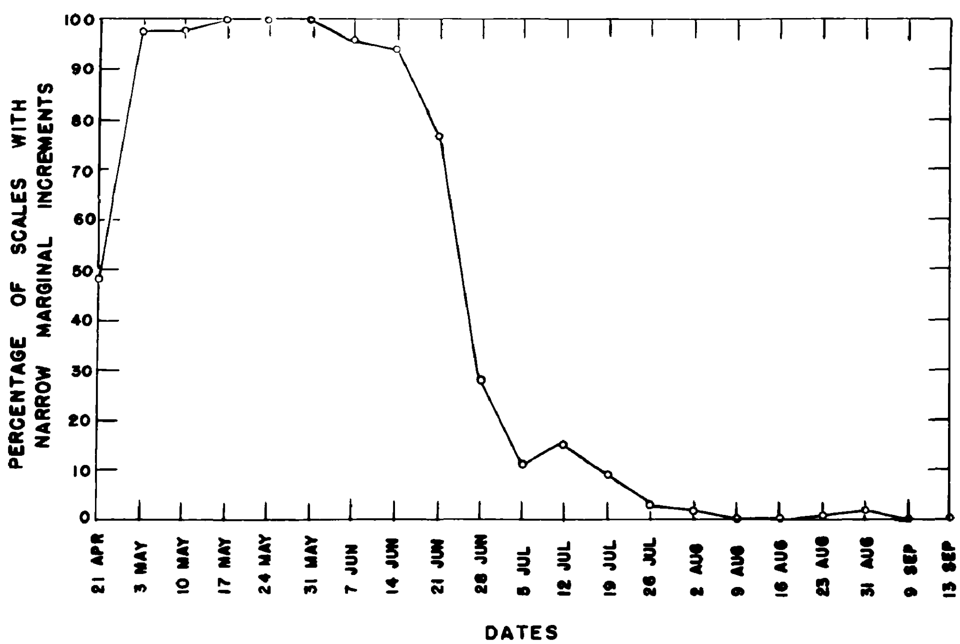

Upper

Fig. 5 - Mean marginal increments of scales of fish in their second year of life taken from pound-net samples grouped by periods of three weeks. Dates are for the middle sample of each group.

Lower

Fig. 6 - Percentage of scales with marginal increments less than 19 arbitrary units of measurement from fish in their second year of life collected each week in the pound-net fishery.


WIDTH OF MARGINAL INCREMENTS
IN ARBITRARY UNITS
40
35
30
25
20
15
10
5
0
3 MAY
24 MAY
19 JUN
5 JUL
26 JUL
18 AUG
9 SEP
DATES


PERCENTAGE OF SCALES WITH
NARROW MARGINAL INCREMENTS
100
90
80
70
60
50
40
30
20
10
0
21 APR
3 MAY
10 MAY
17 MAY
24 MAY
31 MAY
7 JUN
14 JUN
21 JUN
28 JUN
5 JUL
12 JUL
19 JUL
26 JUL
2 AUG
9 AUG
16 AUG
23 AUG
31 AUG
9 SEP
13 SEP
DATES

had been encountered, for it is generally accepted that the difficulty of reading increases rapidly with age. The oldest fish encountered was in its fourth year of life. Typical scales from fish of different ages are illustrated in figure 7.

There was a very close correspondence between the ages of fish as determined from the scales, and the ages deduced arbitrarily by separating the modes in the length frequency distributions (Table IV). Unless both methods were in error, which seems unlikely, this agreement seems to confirm the accuracy of age determination.

The dominant age-group in the commercial fishery in Chesapeake Bay in 1954 consisted of fish in their second year of life. These made up about 70 per cent of the total catch, and the remaining 30 per cent consisted almost entirely of fish in their third year.

Fig. 7 - Scales from menhaden in their second, third and fourth years of life. From top to bottom: scale from a fish 137 mm. long in its second year of life taken May 10, scale from fish 219 mm. long in its third year of life taken May 24 and scale from a fish 261 mm. in length and well along in its fourth year of life taken August 9. Note that although samples were taken progressively later in the season the marginal increments are nearly the same size, demonstrating the slower growth rate of older fish.

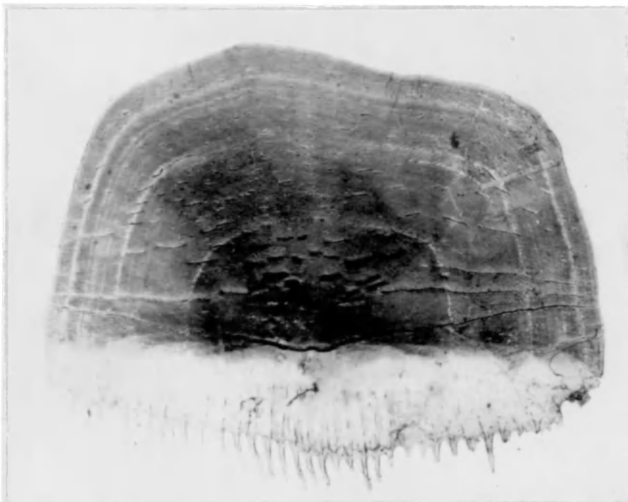


TABLE IV - A Comparison of Menhaden Ages as Determined from Inspection of Length Frequencies and from Scale Readings

Number of annuli from scale readings			Estimated number of annuli from length frequencies		
Number of annuli	Total	Percentage	Number of annuli	Total	Percentage
21 April - 10 May					
0	53	16.72			
1	232	73.19	1	279	87.46
2	29	9.15	2	39	12.23
3	3	0.95	3	1	0.31
7 May - 31 May					
1	223	76.90	1	218	72.67
2	65	22.41	2	82	27.33
3	2	0.69			
7 June - 21 June					
1	260	85.81	1	266	86.36
2	42	13.86	2	42	13.64
3	1	0.33			
28 June - 12 July					
1	290	97.32	1	295	98.33
2	8	2.68	2	5	1.67
19 July - 2 August					
1	285	96.61	1	295	98.33
2	10	3.39	2	5	1.67
9 August - 23 August					
1	286	95.97	1	290	96.67
2	9	3.02	2	8	2.67
3	3	0.10	3	2	0.67
21 August - 13 September					
0	1	0.34			
1	292	99.32	1	300	100.00
2	1	0.34			

Fish in their second year of life are underlined.

RATE OF GROWTH

An impression of the growth rate of menhaden in Chesapeake Bay has been gained already from an inspection of figures 2 and 3, and approximate lengths at the end of each year of life have been stated for pound-net and purse-seine samples. In an attempt to define more precisely the growth rate of the dominant age-group in the fishery, fish in their second year, the average lengths at the time of capture were computed for each group sampled (Tables V and VI, Fig. 8).

Separate lines were fitted by eye to the means for the pound-net and the purse-seine samples. The rates of growth are approximately the same, although the purse-seine fish were consistently somewhat larger. Striking an average between the two sets of samples it appears that menhaden in their second year are perhaps 160 mm. in fork length at the beginning of May and reach nearly 215 mm. by mid-October. There is some suggestion that the growth rate decreases in late September and October. There is also a hint that growth is more rapid in spring than in summer, but this is less well supported by the data.

Striking an average between the pound-net and purse-seine samples, the fork lengths at the end of each year of life for menhaden in Chesapeake Bay are: 120 mm. at the end of the first year; 205 mm. at the end of the second; and 250 mm. at the end of the third.

Evidence from scale measurements indicates that the growth rates calculated for menhaden in their second year may be somewhat

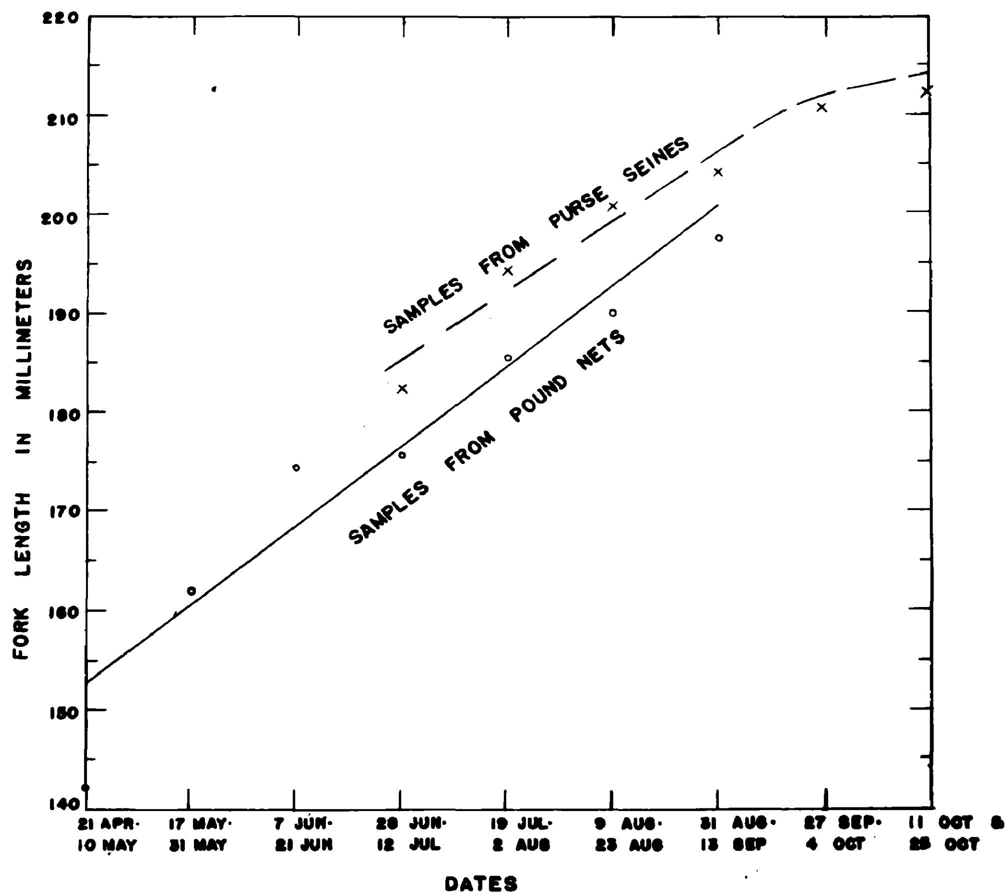
TABLE V - Mean Lengths of Menhaden in Their Second Year of Life from Pound-Net Samples

Length in mm.	Frequency of occurrence						
	21 April-10 May	17 May-31 May	7 June-21 June	28 June-12 July	19 July-2 August	9 August-23 August	31 August-13 September
120	5	-	-	-	-	-	-
125	3	-	-	-	-	-	-
130	41	2	-	-	-	-	-
135	50	2	-	-	-	-	-
140	76	7	1	-	-	-	-
145	50	22	3	1	-	-	-
150	15	19	6	1	-	-	-
155	13	34	10	5	-	-	-
160	8	26	12	11	1	1	-
165	7	31	27	43	-	-	-
170	7	33	55	70	9	3	2
175	2	17	52	52	24	11	1
180	-	8	29	39	56	29	8
185	-	8	31	42	99	65	16
190	-	5	14	17	70	75	41
195	-	4	14	7	25	66	75
200	-	-	2	5	6	26	84
205	-	-	4	1	3	10	45
210	-	-	5	1	2	2	19
215	-	-	1	-	-	2	7
220	-	-	-	-	-	-	1
Mean lengths	141.70	162.06	174.51	175.34	185.41	189.86	197.56

TABLE VI - Mean Lengths of Menhaden in Their Second Year of Life from Purse-Seine Samples

Lengths in mm.	Frequency of occurrence					
	28 June-13 July	19 July-2 August	10 August-23 August	30 August-13 September	27 September-4 October	11 October & 25 October
165	3	-	-	-	-	-
170	10	-	-	-	-	-
175	23	2	-	-	-	-
180	16	2	1	-	-	-
185	26	7	2	2		
190	17	22	25	12	4	4
195	7	28	47	37	5	4
200	2	24	96	68	14	10
205	2	5	58	83	29	15
210	-	-	26	56	61	25
215	-	-	9	28	60	21
220	-	-	-	8	17	13
225	-	-	-	-	7	6
230	-	-	-	-	-	5
235	-	-	-	-	-	-
Mean Lengths	182.22	194.11	200.57	204.15	210.68	211.07

Fig. 8 - Mean fork lengths in millimeters of fish in their second year of life taken from the pound-net and purse-seine fisheries.



220
210
200
190
180
170
160
150
140
FORK LENGTH IN MILLIMETERS
SAMPLES FROM PURSE SEINES
SAMPLES FROM POUND NETS
21 APR-10 MAY
17 MAY-31 MAY
7 JUN-21 JUN
28 JUN-12 JUL
19 JUL-2 AUG
9 AUG-23 AUG
31 AUG-13 SEP
27 SEP-4 OCT
11 OCT & 25 OCT
DATES

below the actual rates. Measurements of the distance from base line to annulus were lumped into three groups and the mean width of the first year's growth for each group computed (Table VII). It was found that distances from the base line to the annulus decreased considerably during the sampling period. Statistically this decrease was found to be highly significant, for there was much less than one chance in one hundred that the scale samples in these three groups could have been drawn from the same population with respect to size as deduced from the scales ($F = 288.41$; $F_{0.01} = 4.60$). It may be that, as the season progresses, new fish are continually being recruited into the commercial stocks. These fish are characterized by a steadily decreasing length at the end of the first year of life, as deduced from the scales.

TABLE VII - Distances from the Base Line to the Annulus on Scales of Menhaden in Their Second Year of Life

Length in arbitrary units	21 April-7 June Number of scales	14 June-26 July Number of scales	2 August-13 September Number of scales
38 - 47	-	-	2
48 - 57	10	8	28
58 - 67	53	124	187
68 - 77	187	311	322
78 - 87	178	165	122
88 - 97	86	47	30
98 - 107	20	2	6
108 - 117	3	1	-
Totals	537	658	697
Mean distance from base to annulus	79.62	74.46	71.84

SUMMARY

This report is based on the examination of 42 samples of menhaden, of about 100 fish each, taken from the commercial pound-net and purse-seine catches in Virginia in 1954.

The total range in fork length of these fish was 119 to 273 mm. in pound nets and 165 to 283 mm. in purse seines. Several distinct modes appeared in the frequency distributions of lengths for the series of samples from each gear. These modes were interpreted as representing fish in their first, second, and third year respectively. Fish in their second year of life appeared in the catches most consistently. Fish in their third year appeared principally in spring and early summer. The second-year fish dominated the pound-net catch throughout the year, and also dominated the purse-seine fishery, although in early summer the older fish were temporarily the dominant group in the seine fishery.

Ages were deduced from lengths on the basis of the distinct modes they produced on the length frequency distribution, and on the apparently reasonable assumption that only one other size group could fit into the left of the first mode to appear. Published information on lengths of postlarvae and young seemed to fit this hypothesis, although these young, which were collected in tidal and fresh waters of the estuaries were somewhat smaller than might be expected in relation to the sizes recorded from the pound-net and purse-seine samples.

However, there was a discrepancy in length also between fish of the same age caught in pound nets and purse seines. This lack of complete agreement is not unexpected in view of the well-known habits of clupeids in which the younger or smaller fish tend to stay near shore and the older or larger individuals inhabit deeper waters farther from land.

The scales of menhaden are distinctive among the clupeids in that they bear a row of ctenii along the exposed posterior border. The annuli are clearly marked, at least in the relatively young fish examined, and ages are relatively easy to determine. The ages as determined from the scales correspond almost exactly with those estimated by the more arbitrary method based on length. The dominant age group in the commercial fishery in 1954 consisted of fish in their second year, which made up about 70 per cent of the total catch in Virginia waters. Of the remaining 30 per cent, almost all were in their third year.

The mean size, obtained by averaging the data from the two commercial gears, was: 120 mm. at the end of the first year, 205 mm. at the end of the second, and 250 mm. at the end of the third.

CONCLUSIONS

Two tentative conclusions can be drawn from this study, firstly that prediction of purse-seine catches at least six months to a year in advance seems a distinct possibility, and secondly that the fishery offers promise of considerable instability.

Prediction may be possible through an examination of the pound-net catches, especially in the fall. The incoming year class, which may contribute the bulk of the commercial catch the following year, appears in relatively large numbers in pound-nets in late September and early October. Perhaps by observing the relative strength of this fall group of young, an accurate forecast may be possible. This hypothesis must be tested over a period of years.

The forecast of instability is based on the low average age of fish in the catch, and the unusual dominance of fish in their second year of life. If this age pattern is typical, it is obvious that a spawning failure, if only for one year, may have decidedly adverse effects on the catch, unless recruitment from other areas is considerable. The reliability of this prediction also must await the accumulation of much more knowledge of menhaden biology.

It is a common opinion among fishermen that the average size of menhaden in Chesapeake Bay has been decreasing for a number of years. Concern has been expressed by biologists that this trend may be evidence of overexploitation of the fishery. However, it would seem that a similar trend occurred in the 1890's (Smith, 1896) involving fish of much the same size as those making up the present-day purse-seine catch. This suggests that causes other than fishing pressure may be operating to cause an average decrease in the size of individuals.

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