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The Length and Age Composition of Spot, Leiostomus xanthurus, in the Pound Net Fishery of Lower Chesapeake Bay

Anthony Louis Pacheco
College of William and Mary - Virginia Institute of Marine Science

THE LENGTH AND AGE COMPOSITION OF SPOT, *Leiostomus xanthurus*, IN THE POUND NET FISHERY OF LOWER CHESAPEAKE BAY

By

Anthony Louis Pacheco

Virginia Fisheries Laboratory
Gloucester Point, Virginia

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INTRODUCTION

The spot, Leiostomus xanthurus Lacépède, abundant in summer and fall in bays and estuaries along the Atlantic coast of the United States from Massachusetts to Texas, occurs at times in considerable numbers in fresh water. The chief commercial fishery is centered in Virginia and North Carolina (Table I) and the spot is one of the most abundant food fishes in Chesapeake Bay (Fig. 1). In Virginia waters during 1953, haul seines caught 75 per cent, pound nets 15 per cent, and stake, drift and anchor gill nets, fyke nets and hand lines 10 per cent of the spot in the commercial catch. Spot are also an important item in Virginia's salt water sport fishery. In 1955, the first year that information was available for this fishery in Virginia, Richards (MS) estimated that sportsmen caught approximately 250,000 pounds, roughly one-eighth the amount of the commercial catch.

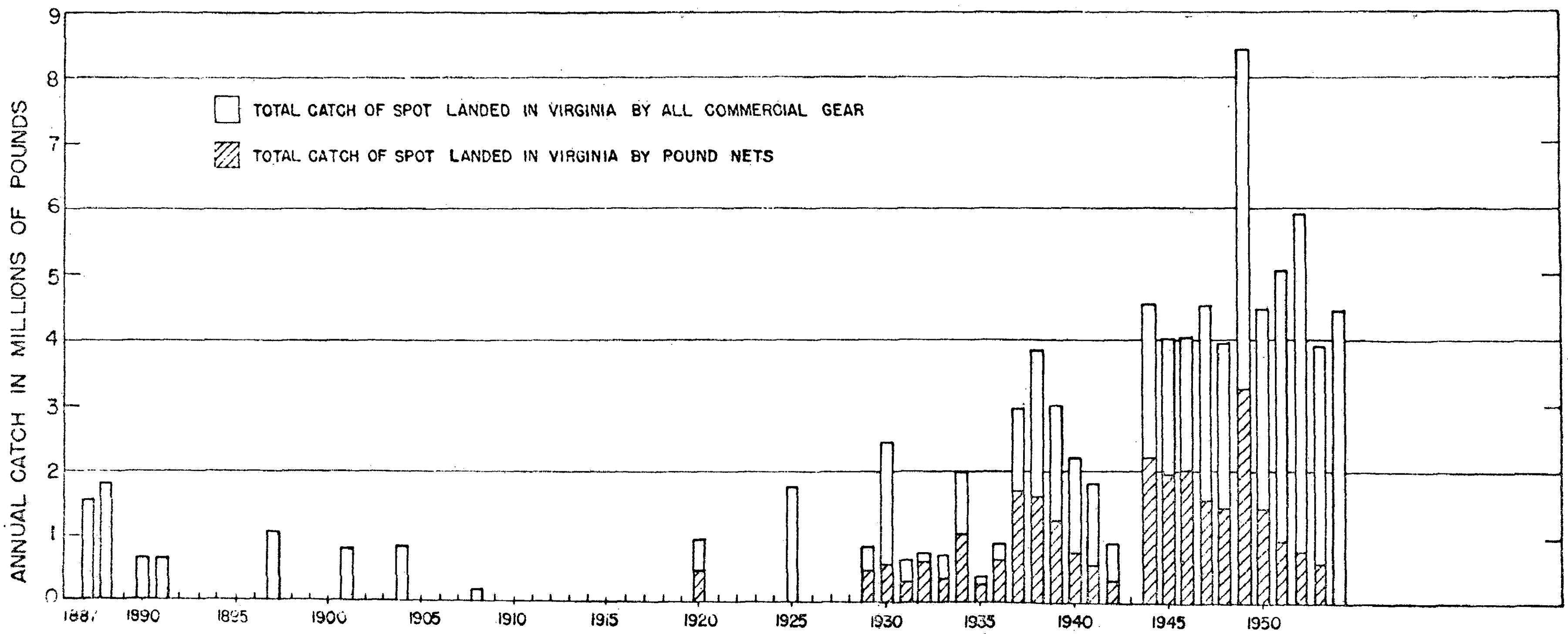
Hildebrand and Schroeder (1927) gave the most comprehensive account of the life history of Chesapeake Bay spot. They reported that spawning takes place in the late autumn and probably also in winter. This assumption was based primarily on the great exodus of spot from the Bay which takes place in September and October, coincident with the enlargement of the gonads. Spawning apparently takes place at sea, but the exact locations of the offshore spawning grounds are not known. Nichols and Breder (1927) stated that Delaware Bay marks the northern limit at which this species spawns in any considerable numbers.

TABLE I

Total Commercial Catch and Value of Spot, Leiostomus xanthurus, in the United States Fisheries. Extracted from "Fishery Statistics of the United States - 1953"

State	Total Catch in Pounds	Value of Catch in Dollars
New York	2,000	1,000
New Jersey	86,000	7,000
Delaware	45,000	3,000
Maryland	233,000	24,000
Virginia	3,913,000	256,000
North Carolina	2,815,000	176,000
South Carolina	440,000	20,000
Georgia	9,000	(unreported)
Florida (east)	345,000	38,000
Florida (west)	275,000	14,000
Alabama	0	0
Mississippi	2,628,000	46,000
Louisiana	1,000	1,000
Texas	0	0

Fig. 1. Total annual reported catch of spot landed by all fishing gears in Virginia and the total annual Virginia catch of spot by pound nets. Extracted from various United States Fish and Wildlife Service Statistical Digests. Information on the 1954 pound-net catch not available.



TOTAL CATCH OF SPOT LANDED IN VIRGINIA BY ALL COMMERCIAL GEAR
TOTAL CATCH OF SPOT LANDED IN VIRGINIA BY POUND NETS
ANNUAL CATCH IN MILLIONS OF POUNDS
0
1
2
3
4
5
6
7
8
9
1887
1890
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950

The time and duration of spawning were fairly adequately determined in the Beaufort, N. C. area (Hildebrand and Cable, 1930). From larval collections made in four years, the first young (3 mm) was taken early in November. The larvae became numerous in December and were abundant for several months. These authors concluded that in North Carolina spawning extends from November to February but is most intense in December and January.

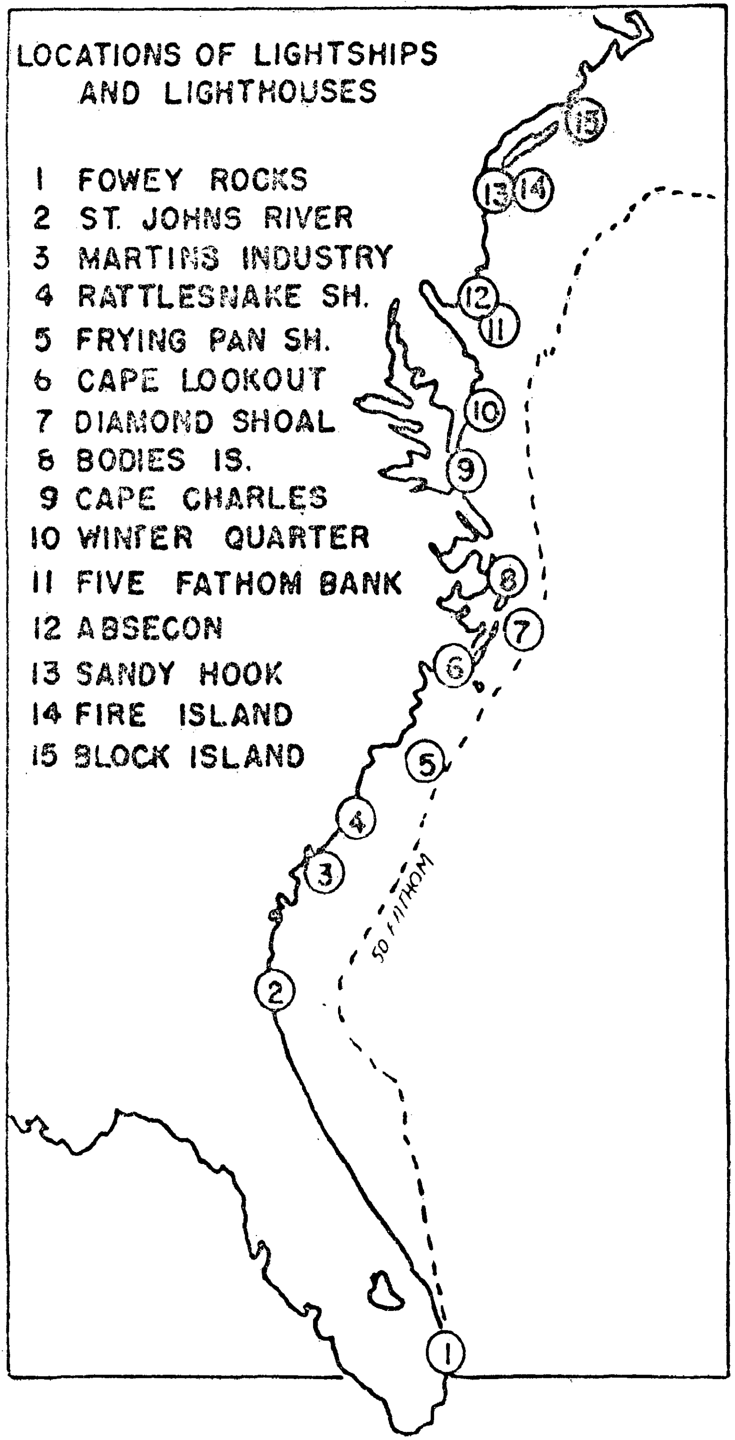
Although a description of the developing eggs has never been published, Hildebrand and Cable (1930) described the larval stages. The smallest fish taken in the Beaufort, N. C. region, 1.5 mm in total length, was assumed to be newly-hatched.

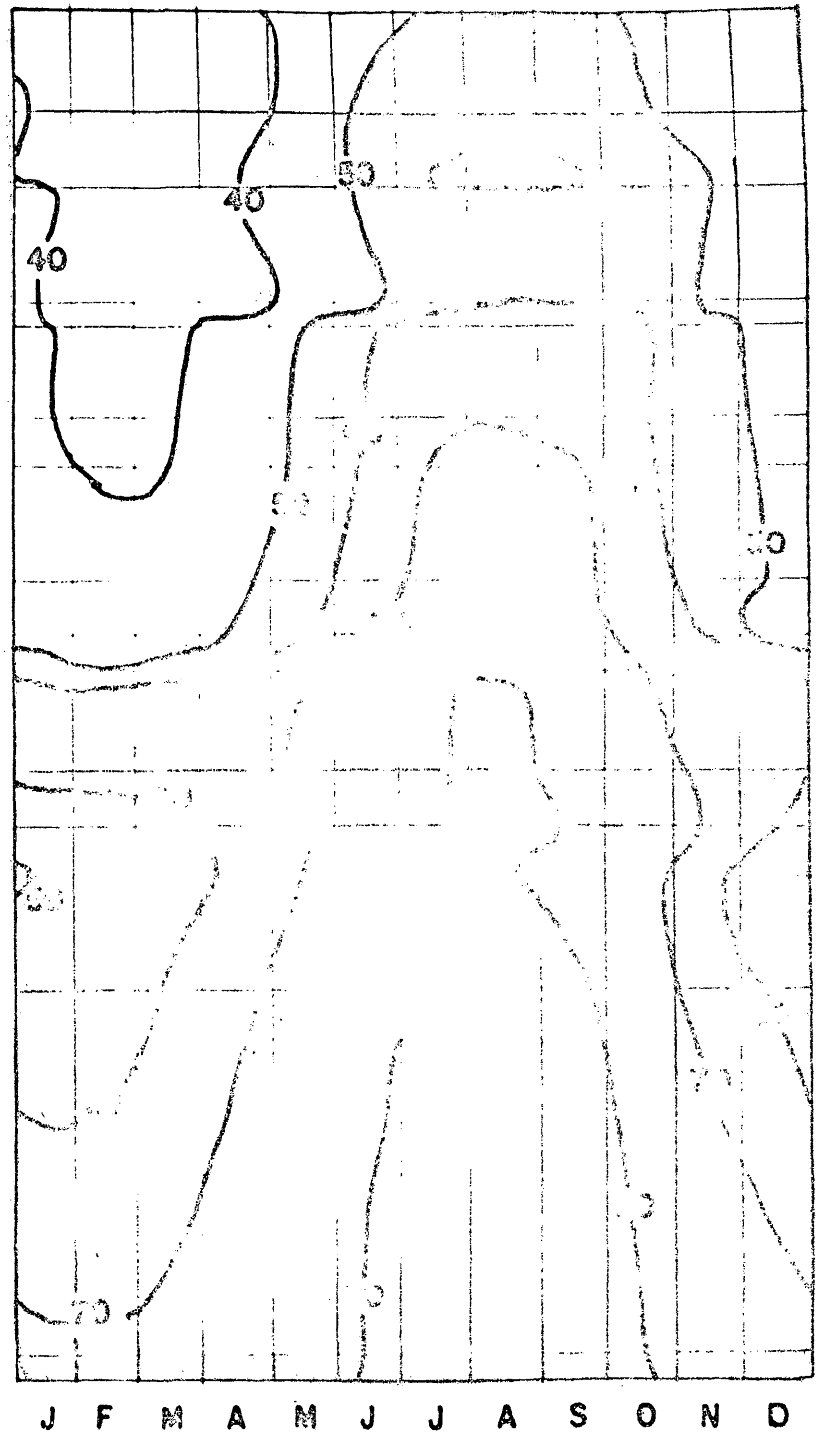
In the Gulf of Mexico, spawning apparently occurs at approximately the same time. Pearson (1928) stated that the height of the spawning season in the Gulf is reached in January and February, but extends from late December to the end of March. The fall migration in the Gulf is apparently not so pronounced as in Chesapeake Bay, but the postlarval spot move into the bays and lagoons soon after hatching, as they do in Virginia waters.

During winter, when spot are absent from Chesapeake Bay and its estuaries, samples were obtained from vessels of the offshore trawler fleet landing in Hampton, Virginia. The winter trawl fishery takes spot in the area southwest of Cape Hatteras in November (Pearson, 1932). These spot are never an important part of the trawl catch and are of little economic value due to their poor condition, which can probably be attributed to the after-effects of spawning. In December 1955 the trawler "Powhatan" obtained a few at a depth of 45 fathoms northeast of Cape Hatteras. In January 1956 a sample was obtained 22 miles north of Cape Lookout. The trawler captain stated that spot are only infrequently taken from the usual trawling grounds at this time and most of the spot in winter are concentrated in inshore waters. It is fairly obvious that the trawlers do not fish in the area where the adult spot spend the winter, otherwise the catch would be much larger. Because the spot probably favors shallow water and is a bottom feeder, it does not seem likely that the wintering grounds lie far offshore. For South Carolina waters, Lunz (1957) states that in November and December, croaker and spot, mostly in spawning condition, were caught during exploratory surveys 40 to 45 miles offshore at depths of 250 feet, in the area between Charleston and the Savannah Lightship, which is anchored off St. Helena Sound.

It is generally assumed that declining water temperatures in fall may stimulate the movement of spot out of the Bay. Fig. 2 depicts the annual temperature cycle in shallow water along the Atlantic coast. In the Hatteras region during winter a temperature ~~discontinuity~~ anomaly, which remains until spring, appears offshore where the Gulf Stream borders the coastal water. Thus the Carolina Cape waters are warmed despite the seasonal cooling of shelf waters to the north and south (Taylor, et al,

Fig. 2. Annual temperature cycle in shallow water along the Atlantic coast (Parr, 1933). Isotherms at 10° F. intervals are drawn from 1928-30 temperature records of the lightships and lighthouces shown. Spot make their first appearance at various points along the coast when the water temperature reaches about 50° F. Therefore the shaded area represents approximately the seasonal change in the geographic range of the species.


LOCATIONS OF LIGHTSHIPS AND LIGHTHOUSES
1 FOWEY ROCKS
2 ST. JOHNS RIVER
3 MARTINS INDUSTRY
4 RATTLESNAKE SH.
5 FRYING PAN SH.
6 CAPE LOOKOUT
7 DIAMOND SHOAL
8 BODIES IS.
9 CAPE CHARLES
10 WINTER QUARTER
11 FIVE FATHOM BANK
12 ABSECON
13 SANDY HOOK
14 FIRE ISLAND
15 BLOCK ISLAND
50 FATHOM


40
40
50
J F M A M J J A S O N D

1951). Whether or not this warm water area south of the Bay in winter is a controlling influence on the movements of spot and other migratory species is not known. Usually, however, spot enter Chesapeake Bay in numbers when the water temperature reaches 50° F and leave when it drops below 50°.

Postlarvae of the current year brood begin to appear in the Bay in spring. They have been taken during April in plankton nets at West Point, Virginia, 30 miles up the York River (Table II), and in April and May with seines from the beach at Gloucester Point, Virginia. Raney and Massmann (1954) took young 20 to 40 mm in length with plankton-nets, and juveniles were trawled and seined in both fresh and brackish waters of the Pamunkey River, upstream of West Point. Massmann (1954) stated that although spot were more abundant near brackish water, a few were found 25 miles above the brackish zone in the Pamunkey, Mattaponi and Rappahannock Rivers.

The appearance of these tiny fish far from their presumed spawning grounds has been attributed to their transport by a net upstream flow of water near the bottom. The existence of this up-Bay bottom current was first postulated by Cowles (1930), and has since been described in detail by Pritchard (1951) who also explained the mechanism by which the circulation is generated and maintained. From his description it is easy to understand how these fish are carried from the oceanic spawning grounds,

TABLE II

Length-frequency Distributions of Postlarval and Juvenile Spot taken in the York River, Virginia

Fork Length (mm)	Plankton Net 17 April 1956 West Point	1/2" Beach Seine 29 April 1956 Gloucester Point
15	3	
16	3	
17	12	
18	14	
19	9	
20	12	
21	7	
22	4	1
23	1	2
24	1	10
25	1	6
26		11
27		17
28		7
29		4
30		4
31		3
32		3
33		3
34		2
35		2
36		2
Totals	67	77

if they remain in the deeper water. Haven (1957) postulated the same mechanism for transport of young croakers up the rivers. He estimated that a drifting postlarva could be carried from the mouth of the Bay to West Point, a distance of approximately 60 miles, in twelve and one-half days. Hildebrand and Cable (1930) found spot larvae at all depths, but most frequently near the bottom.

In addition to their importance as a commercial and sport fish the spot also plays a significant part in the economy of the Bay as forage for the larger carnivorous species. Hollis (1952) observed that spot are prominent in the diet of striped bass, Roccus saxatilis.

The food of Chesapeake Bay spot (Hildebrand and Schroeder, 1927) consists mostly of small crustaceans and annelids, together with smaller amounts of molluscs, fishes and vegetable debris. Welsh and Breder (1923) reported that the chief diet was small crustaceans. Roelofs (1954) expressed the frequency distribution of food items in 73 spot stomachs from North Carolina and found that all contained copepods, 71 per cent contained nematodes, 33 per cent annelids, 23 per cent vegetable debris, and smaller amounts of foraminifera, pelecypods, diatoms, decapods, mysids, algae, fish, ostracods, and mites. According to Reid (1955) young spot (45-69 mm) from the Gulf of Mexico consumed great quantities of planktonic crustaceans and organic debris. He suggests that this debris may also serve as an energy source for the fish.

Previous attempts to determine the age of spot apparently have been based on the interpretation of modes in the length-frequency polygons. Welsh and Breder (1923) considered scales of New Jersey spot difficult to read, because the winter rings were not clearly-defined. Hildebrand and Schroeder (1927) stated that the wide range of lengths of spot taken throughout the year made it difficult to determine a correct rate of growth.

The protracted spawning season makes for a great variation in sizes and therefore, after the second year, the sizes of fish in successive age groups overlap considerably. Hildebrand and Cable (1930) stated that this protracted spawning season had two causes. Well-developed ovaries contained ova of several sizes, suggesting that the eggs are probably cast, a few at a time, over a period of several weeks. Clark (1925, 1929, 1934) has demonstrated such a multiplicity of spawning for the grunion, Leuresthes tenuis, jack smelt, Atherinopsis californiensis, and California sardine, Sardinops caerulea. Hildebrand and Cable (1930) also noticed that sexual development was further advanced in large than in small individuals, suggesting that the large fish spawn earlier.

An important aspect of a fishery biology program is to ascertain the age of individuals in a fish population. Some method of age-determination is essential to all growth studies and because knowledge of the age-composition of the stocks and of their rate of growth underlies all studies of the vital statistics of fish populations.

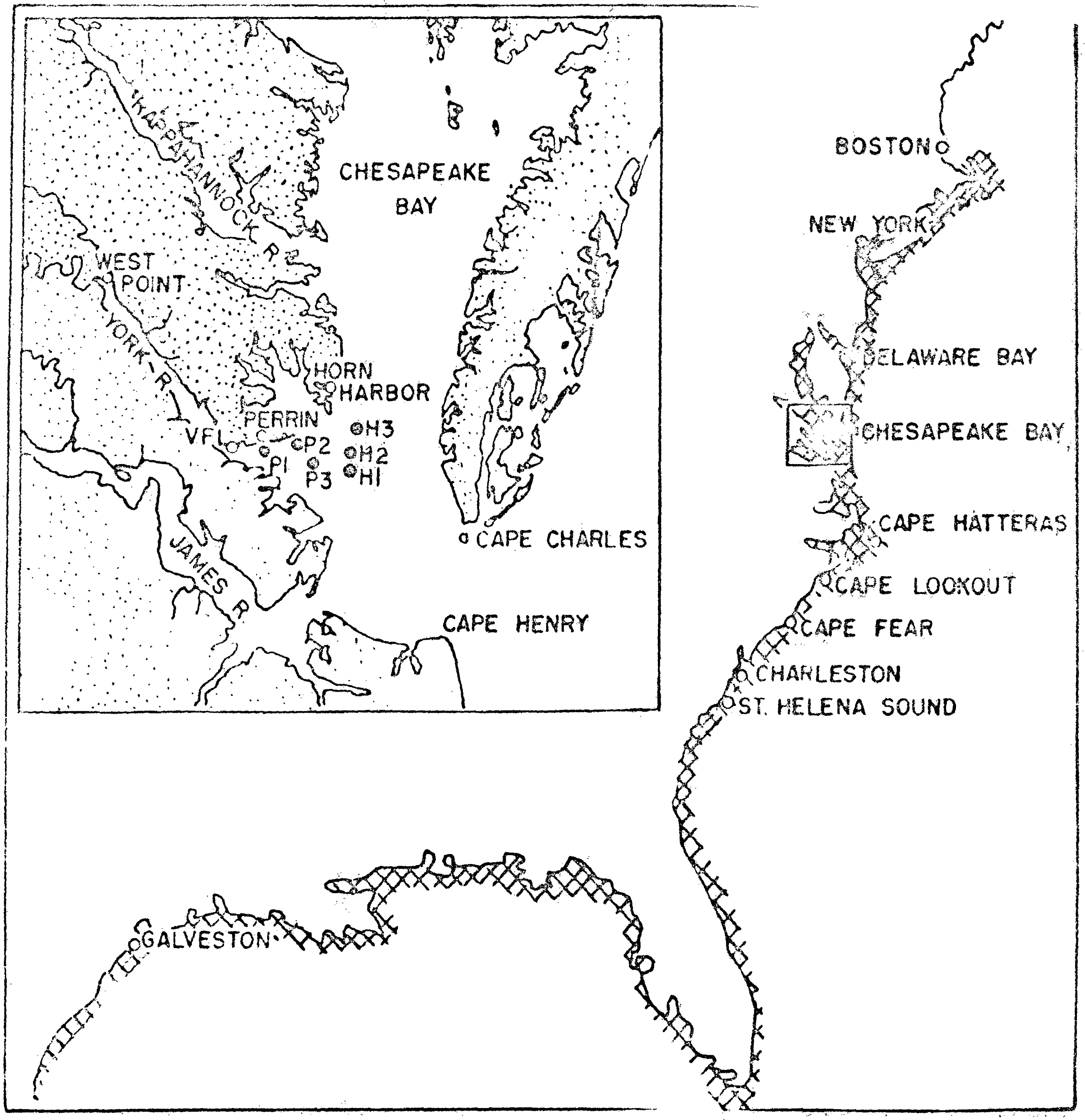
It has been stated (Rounsefell and Everhart, 1953) that perhaps the most valuable achievement of fishery research, and perhaps the most difficult, is the ability to predict abundance. Such biological forecasts depend upon a knowledge of the effects of environmental factors on the success of reproduction and survival. Changes in the average age of the stock, as determined by sampling, may be indicative of changes in the rate of exploitation or the rate of recruitment. This study provides some of the basic information useful for planning a more comprehensive investigation.

MATERIALS AND METHODS

From May to November during the 1955 fishing season, 36 random samples containing 2,190 spot were obtained at approximately weekly intervals from the catch of six pound nets. The nets, situated near Perrin and Horn Harbor, Virginia (Fig. 3) were designated as P_1, P_2, P_3, and H_1, H_2, and H_3, respectively.

The most convenient method of sampling was to accompany the fishermen to the nets on prearranged dates. The fish were measured and scale samples were taken while the boat was running between nets and on the long run back to shore. This method permitted sampling before fish were culled, which eliminated selection by the fishermen.

Fig. 3. Portions of the Atlantic and Gulf coasts of the United States showing localities mentioned in the text. The insert shows the locations of the nets sampled. The distribution of spot along the Atlantic coast is represented by cross-hatching.


CHESAPEAKE
BAY
RAPPAHANNOCK R.
WEST
POINT
YORK R.
HORN
HARBOR
PERRIN
VFL
P1
P2
P3
H1
H2
H3
JAMES R.
CAPE CHARLES
CAPE HENRY
BOSTON
NEW YORK
DELAWARE BAY
CHESAPEAKE BAY
CAPE HATTERAS
CAPE LOOKOUT
CAPE FEAR
CHARLESTON
ST. HELENA SOUND
GALVESTON

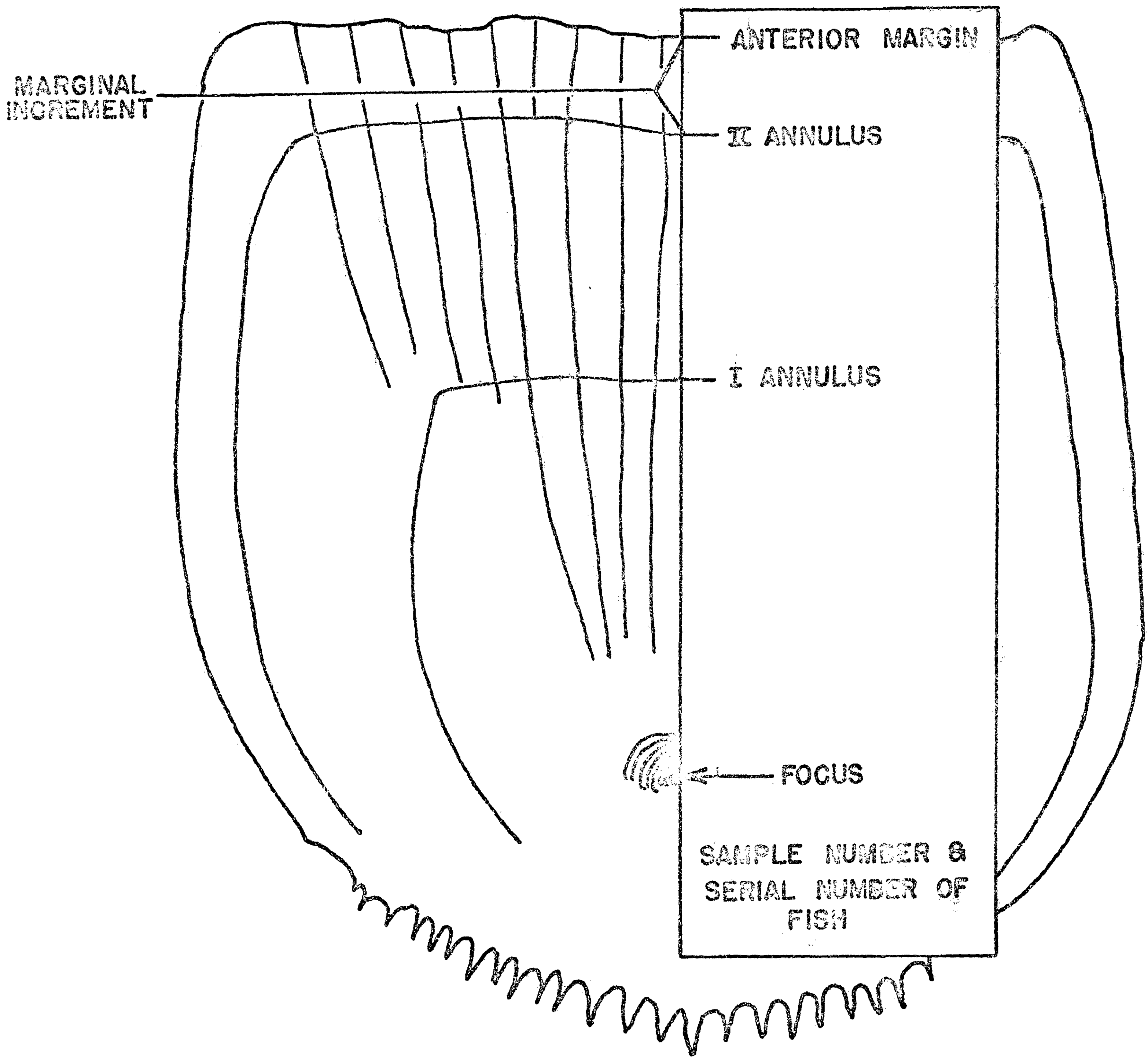
Whenever possible, on each sampling date 100 spot were examined. During early spring and summer spot catches were usually small and often the entire day's catch was less than 100. The proportion of the total catch represented by the sample was estimated.

The spot obtained at Perrin were purchased, brought to the laboratory and the following information was recorded: distance from tip of snout to fork of caudal fin to the nearest mm, weight in grams, sex, and stage of maturity of gonads. A scale sample from each fish was placed in an individual envelope. Only the length and a scale sample were taken from each fish of the Horn Harbor samples.

Because the scales from different parts of the body vary considerably in size and shape, it is best to take them always from the same area. The shoulder region, between the pigmented "spot" and the origin of the first dorsal fin, consistently yielded satisfactory scales of regular shape. Consequently the samples were taken from this area. Hildebrand and Cable (1930) reported that although no scales were visible on fish 25 mm long, at a length of 30 mm almost all the scales had appeared, and the largest were present on the sides of the abdomen and the region just posterior to the opercle.

At the laboratory, a few scales were shaken from each envelope into Syracuse watch glasses containing a dilute solution of NaOH (approximately 0.1M) to facilitate the removal of epidermis, mucus, and pigments.

Fig. 4. Photograph of a spot scale with two annuli showing the various scale features. The overlay indicates the method used for recording critical scale data.


ANTERIOR MARGIN
MARGINAL INCREMENT
II ANNULUS
I ANNULUS
FOCUS
SAMPLE NUMBER &
SERIAL NUMBER OF
FISH

The scales were left in the solution for several minutes and then cleaned by rubbing between the thumb and forefinger or between two soft wooden sticks. Scales were inspected under a strong light and five or six, regularly shaped and undamaged, were placed on a glass slide, on which the collection number was recorded. A second slide was placed over the first and the ends of the two were fastened together with Scotch tape.

Scale images were projected vertically onto a sheet of paper by means of a Promi projection apparatus, set for a magnification of 33 diameters. The positions of critical scale features were marked on a 5" x 1 - 1/2" card by laying its long edge along the antero-posterior axis of the scale image and locating the scale markings on the edge of the card with a pencil.

Marks used to identify the various scale features are explained in Fig. 4. The positions of critical markings on the scale cards were measured and recorded in millimeters.

AGE DETERMINATION

Age in fishes is usually determined by one of two principal methods: from the frequency distribution of fish lengths or from the interpretation of annual markings on the scales or other body structures. In species that have a restricted spawning season or in which most of the spawning occurs within a relatively short time, the lengths may tend to group about certain values, producing modes in the distribution of length frequencies. These modes can often be identified with the year of birth of the fish.

Certain basic assumptions must be satisfied if scales are to be used successfully for age determination. Each individual should have a definitive number of scales, which form early in life, are not normally shed, and grow more or less in proportion to the growth of the body. The development of scale structures and markings may be modified by environmental influences and by the growth of the fish in such a manner that important events in the life history, such as sharp changes in growth rate, are recorded on the scale.

Previous workers have used some technical terms with varying meanings. In this study the following definitions were adopted.

One annulus, and only one, is formed at a definite time of the year (Fig. 4). The characteristics by which an annulus is recognized must be chosen on the basis of familiarity with the scales of the species. The marginal increment is the zone between the last formed annulus and the edge, or margin, of the scale. A spot in its first year of life belongs to the 0 age-group and has no annulus. A fish in its second year, with one annulus, belongs to age-group 1, and so on. These sometimes also are called 0-ring fish, 1-ring fish, and so on. Year class refers to the year in which the fish was hatched. Since spot spawn from November to February, it is convenient to denote January 1 as the date of birth, so that the biological year and the calendar year coincide. Thus the 1954 year class would include all the fish spawned in the period November 1953 to February 1954.

Sizes of Spot in Chesapeake Bay

In the samples from the upriver nets (Perrin) only one mode, at 170 mm, appeared in the length frequency distribution in May (Fig. 5a). In June this mode had shifted 10 mm to the right. In July a second mode appeared, derived apparently from the previously scattered suggestions of a group of small fish. In August the right-hand mode was considerably diminished and this trend continued in September. The October catch again contained a bimodal grouping of lengths.

The fish obtained from the Horn Harbor nets differed from those of the Perrin samples in several respects (Fig. 5b). A bimodal distribution of lengths was present when sampling was begun in June. The modes agreed well with the July modes from Perrin. In September and October only one mode existed, and this lay about halfway between the two modes in the Perrin catch (Fig. 5a) at this time.

In Fig. 5c the Perrin and Horn Harbor length-frequency distributions were combined in order to provide an average representation of the size distribution of spot taken by pound nets in lower Chesapeake Bay.

Fig. 5. Length frequency distributions of spot in the 1955 pound-net catch and the 1955-56 winter-trawl fishery grouped by months. Samples taken with VFL exploratory trawls at the mouth of the York River in 1955 are represented by broken lines. The total numbers of fish are given in the upper left-hand corners.

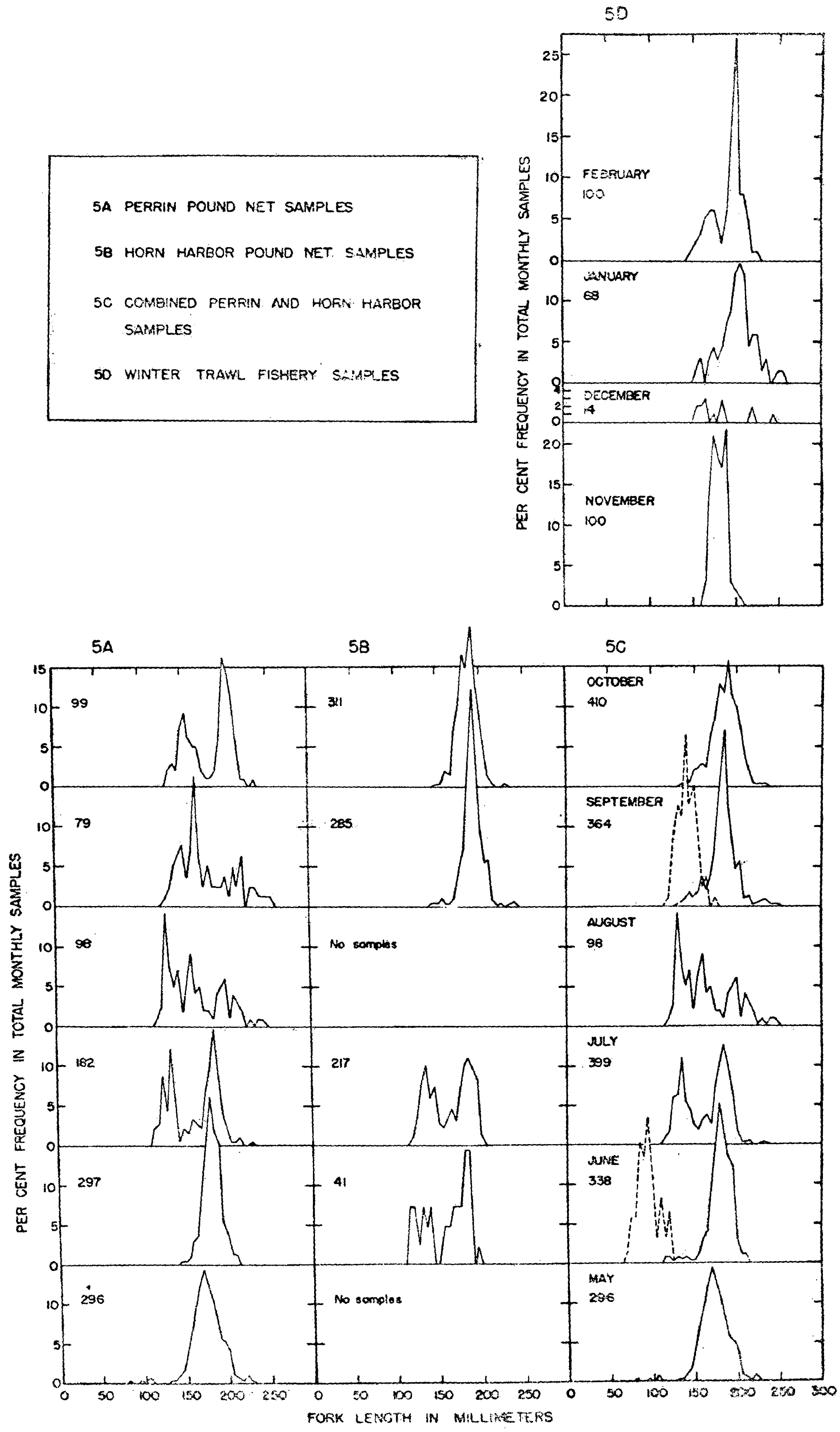

5A PERRIN POUND NET SAMPLES
5B HORN HARBOR POUND NET SAMPLES
5C COMBINED PERRIN AND HORN HARBOR SAMPLES
5D WINTER TRAWL FISHERY SAMPLES
5D
FEBRUARY 100
JANUARY 68
DECEMBER 14
NOVEMBER 100
PER CENT FREQUENCY IN TOTAL MONTHLY SAMPLES
5A
5B
5C
99
79
98
182
297
296
311
285
No samples
217
41
No samples
OCTOBER 410
SEPTEMBER 364
AUGUST 98
JULY 399
JUNE 338
MAY 296
PER CENT FREQUENCY IN TOTAL MONTHLY SAMPLES
FORK LENGTH IN MILLIMETERS

TABLE III

Length Distribution of Spot Sampled in Lower Chesapeake Pound Nets in 1955
and the Winter Trawl Fishery 1955 - 1956

Fork length mm	May	June			July			Aug	Sept			Oct			Nov	Dec	Jan	Feb
	P	P	HH	P+HH	P	HH	P+HH	P	P	HH	P+HH	P	HH	P+HH	WT	WT	WT	WT
80	1																	
85																		
90																		
95	1																	
100																		
105	2																	
110																		
115			3	3	4		4											
120			3	3	5	2	7	1										
125			1	1	16	8	24	5										
130	1		3	3	8	17	25	14	1		1							
135	1		2	2	22	22	44	7	2		2	2		2				
140	3		3	3	9	13	22	5	4		4	3		3				
145	5	1		1	1	16	17	7	5	1	6	2		2				
150	12	1		1	4	6	10	2	6	1	7	7	1	8				1
155	21	3	2	5	3	5	8	6	3	3	6	9	1	10		2	1	2
160	29	9	2	11	6	7	13	9	6	1	7	6	6	12		2	2	3
165	36	11	3	14	5	10	15	4	13	1	14	5	5	10	3	3		5
170	43	32	3	35	4	7	11	5	5	3	8	5	22	27	13		2	6
175	37	47	3	50	13	16	29	2	2	13	15	2	32	34	21	1	3	6

TABLE III contd

Fork length mm	May	June			July			Aug	Sept			Oct			Nov	Dec	Jan	Feb
	P	P	HH	P+HH	P	HH	P+HH	P	P	HH	P+HH	P	HH	P+HH	WT	WT	WT	WT
180	31	63	6	69	18	22	40	2	4	21	25	1	51	52	18		2	4
185	23	50	6	56	27	24	51	1	2	54	56	1	46	47	17	3	3	2
190	17	45		45	19	21	40	4	2	78	80	2	62	64	22		5	6
195	15	16	1	17	9	18	27	5	2	43	45	6	40	46	3		6	15
200	12	11		11	4	3	7	6	3	27	30	16	24	40	2		9	27
205	3	4		4	1		1	1	1	16	17	14	15	29	1		10	8
210	2	4		4	1		1	4	4	17	21	10	4	14			9	8
215	1				2		2	3	2	2	4	5	1	6			3	5
220	3							2	5		5	1		1		2	4	1
225	1									1	1	1		1			4	1
230					1		1	1	2		2		1	1			1	
235									2	1	3	1		1			2	
240								1	1	2	3							
245								1	1		1					1		
250									1		1						1	
255									1		1						1	
	296	297	41	338	182	217	399	98	79	285	364	99	311	410	100	14	68	100

The numbers of spot in each 5 mm length category were summed by months and expressed as a percentage of the entire sample. Illustrated in this way, the monthly pattern of length-frequency distributions was unimodal in May and June, bimodal in July and August, and again unimodal in September and October.

Estimation of Age Based on Length Distribution

In reviewing the distribution of lengths from Perrin (Fig. 5a) a most interesting occurrence is the sudden shift in July to a bimodal distribution. The appearance of a new mode in July may have two causes: (1) below a certain size most young spot escape through the meshes of a pound net; or (2) these young fish were not present in great numbers in the pound-net area, but moved into these waters with increasing size. In August and September this new modal group tended to dominate the catch.

In the identification of age groups on the basis of length, the methods of Walford and Mosher (1943) are appropriate. In July the two principal modal length-groups in the fishery were separated by an interval of 50 mm (Fig. 5 c). The left-hand mode (90 mm) in July probably represented the few small fish which were separated by an interval of approximately 75 mm from the principal mode in May. If there were a group of fish a year younger than this 90 mm group, it should be separated by an even wider interval, because spot, like other fishes, grow most rapidly in early life. A space of only 90 mm lies to the left of this group of small fish and since these early samples probably contain the larger members of their size group, the true position of the mode should be almost certainly much closer to the origin. The smaller spot in this group during June have been caught in considerable numbers with exploratory trawls in this same season and their position is indicated by a broken line in Fig. 5c. It does not seem likely that another distinct modal group of spot a year younger than those could exist. Therefore, it seems reasonable to conclude that these recruits belonged to the current year-class. In successive months the mode progressed toward the right, and a line drawn through the bases of the successive modes should intersect the x-axis near the origin in January. If we remember that the true positions of the modes in May and June probably lie somewhere to the left of their apparent positions, this requirement is approximately satisfied.

A study of the length-frequency distribution suggests that most of the fish taken during the first half of the pound-net season in the area studied were in their second year of life. The positions of this right-hand mode progressed to the right at a slower rate as the fish grew larger. Fish older than two years may have been included in this mode, but if so, they could not be distinguished on the basis of length alone. Gunter (1945) describes a remarkably similar pattern of growth of spot in Copano and Aransas Bays, Texas, and in the Gulf of Mexico.

The length-frequency method embodies some difficulties. Ambiguities are particularly apparent toward the end of the season. The length-frequency distribution of the assumed young-of-the-year fish (Fig. 5a) shows a progression to the right during the course of the season, which probably reflects the growth of these fish. Accompanying the increase in relative importance of this group of young fish is a decrease in relative importance of the right-hand modal group. It should not be inferred that the absolute numbers of fish in the two size-groups are comparable from month to month, because the availability of fish changes considerably throughout the season, but the samples were not weighted according to the availability of spot.

At Horn Harbor the July data (Fig. 5b) agree well with those of Perrin. In September and October the unimodal array of Horn Harbor fish lies halfway between the two modes in the Perrin catch. Fitting this into the previous trends which have been described, the late-season Horn Harbor catch may represent chiefly small two-year-old fish or large young-of-the-year fish. It is not possible to decide this point from the length distribution alone.

Sizes of Spot in the Winter Trawl Fishery

The winter samples of spot (Fig. 5d) were taken from trawlers fishing off North Carolina. It is not known whether these fish originated in Chesapeake Bay.

In November, 1955, a sample was obtained which had been trawled from an unknown locality, probably off North Carolina. The modal length of this sample (Fig. 5d) was nearly the same as for the combined October samples from the Bay (Fig. 5c). In December, 1955, only 14 fish were obtained (Fig. 5d). In January and February, 1956, 100 were sampled each month. For both these months the modal lengths were very close, as one might expect at a time when the growth rate probably reaches a minimum. The mode in winter (Table III) probably represented the 1955 year class.

Estimation of Age from Scales

The scales of *Leiostomus xanthurus* are ctenoid (Fig. 4). The imbedded anterior portion of the scale is sculptured with many closely-spaced circuli, bony ridges concentric with the focus. The origin and function of these same scale features of *Eupomotis gibbosus* has been well reviewed by Creaser (1926).

Certain discontinuities in the pattern of circuli in the scales of many species of fish have been shown to be formed at yearly intervals, consequently, they can be used to determine the age. The following criteria were established by Walford and Mosher (1943) to identify the annulus on the scales of the Pacific pilchard, *Sardinops caerulea*. Although this species is not closely-related to the spot, their criteria appeared to be generally applicable.

"An annulus is concentric with the margin of the scale. It is not always a sharp or unbroken line. The course of an annulus can usually be traced entirely around the sculptured part of the scale, and can sometimes be followed on the unsculptured part. Annuli are clearly separate from each other, and usually do not meet at any point. If an annulus is formed, it is present in all the normal scales of an individual."

Taylor (1916) described one of the features of the annuli of the gray sea trout, Cynoscion regalis, as being a "narrow area parallel with the contour of the scale, in which the regularity of the circuli is interrupted, manifested as branches, breaks, or terminations." This description also applys to the annuli of spot, and probably is the more accurate because these two species are closely related. The most frequent characteristic of a spot annulus was a closer spacing of circuli, associated with incomplete or broken circuli most evident in the postero-lateral scale areas. Usually beyond the annulus, circuli were complete.

Radiating anteriorly from the focus are a variable number of radii (Fig. 4), lines at which the scale may flex in accordance with the undulatory movements of the fish (Taylor, 1916). As Taylor (1916) ound with Cynoscion regalis, the presence of radii may afford a supplementary aid in locating annuli, for new radii often originate at an annulus (Fig. 4).

False annuli were occasionally seen. These were distinguished as follows by Walford and Mosher (1943):

> "They may be short arcs. If they circle the sculptured part, they are usually not concentric with the margin. They may join an annulus at its base. They may be more vague and indefinite or may be much more distinct, with pronounced irregularities of pattern. They rarely appear in all the scales of an individual."

In using the scale to determine age, it is important to establish that the marks identified as annuli are formed only once a year and at a specific time. The annual nature of the zone of growth can be established by showing that the marginal increment (distance from last annulus to the margin of the scale) progressively increases in width throughout the year, from a minimum just after the time of annulus formation, to a maximum just prior to formation of a new annulus.

Table IV presents the frequency distribution of marginal increments in arbitrary units (projected scale image length in mm) for all scales examined. A steady seasonal increase in width for at least the first two age groups is readily apparent. Table IV was derived from the

TABLE IV

Frequency Distribution in Arbitrary Units of the Marginal Increments on the Scales of all Samples of Spot taken from the Pound Net Fishery in Chesapeake Bay, 1955

Projected distance	May			June			July			
	No. of annuli			No. of annuli			No. of annuli			
(mm)	0	1	2	0	1	2	0	1	2	3
0		5	2		5	4			1	
5		57	8		25	9		4	9	
10		101	2		27	2		9	13	1
15		57	5		24	3		13	5	
20		23	3		52			19	4	
25		8			43	1		32	2	
30		5			24	1		43	1	
35		4			10			43		
40		2		3	7		3	35		
45	1	1			5		13	22		
50	2	1		3			37	13		
55				2			25	3		
60	3			2			31			
65	4			3			18			
70	2			3			19			
75	4			1			11			
80	2			1			3			
85				1			2			
90	1						1			
95							1			
100										
105										
	19	264	20	19	222	20	164	236	35	1

TABLE IV (continued)

Frequency Distribution in Arbitrary Units of the Marginal Increments on the Scales of all Samples of Spot taken from the Pound Net Fishery in Chesapeake Bay, 1955

Projected distance (mm)	August			September			October		
	No. of annuli			No. of annuli			No. of annuli		
	0	1	2	0	1	2	0	1	2
0									2
5									
10		1	1			4			
15		2	1		3	2		2	2
20		4			4			4	
25		6	1		6			4	1
30		8			1			4	
35		8			8			3	
40		8			18			3	
45	7	3		1	14		1	3	
50	12	2		1	10		3		
55	14			6	4		10		
60	10			17	2		29		
65	16			13	2		45		
70	4			37			98		
75	4			42			102		
80	2			42			96		
85				43			54		
90				39			26		
95				23			9		
100				9			4		
105				3			1		
	69	42	3	236	72	6	478	23	

TABLE IV (continued)

Frequency Distribution in Arbitrary Units of the Marginal Increments on the Scales of all Samples of Spot taken from the Winter Trawl Fishery, 1955-1956

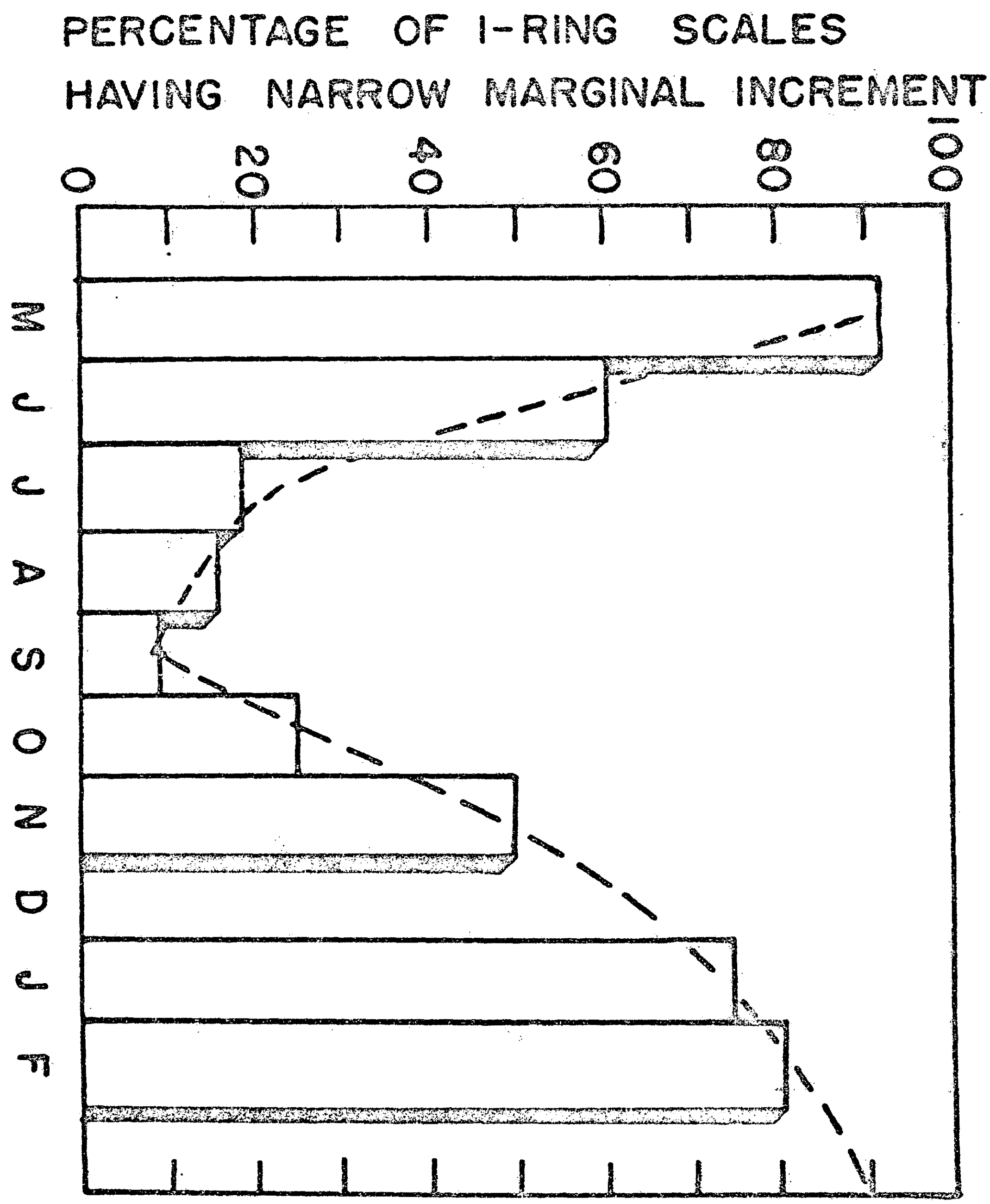
Projected distance (mm)	November No. of annuli 0	1	2	December No. of annuli 0	1	2	January No. of annuli 0	1	2	February No. of annuli 0	1	2	3
0						1		1			2	2	
5								3	8		3	8	
10		1						4	6		13	7	1
15					1			4	1		2	2	
20					1				1		2		
25											1		
30		1						1					
35								2					
40								1			3		
45											1		
50													
55	2						3						
60	12			2			3						
65	30			2			3						
70	31			1			2						
75	12						1						
80	7						2						
85	2			1			1			1			
90				1						1			
95				2									
100													
105													
	95	2		9	2	1	15	16	16	2	27	19	1

commercial catch data and therefore young-of-the year were poorly represented in May and June. From July onward, the increase in width of marginal increments within this group is rapid. The low rate of growth of scales of fish in their third and fourth years may reflect the declining growth rates in length with increasing age.

To define more exactly the time when the annulus appears, an arbitrary boundary was set to separate "narrow" from "wide" marginal increments. Since the 1-ring fish were most numerous and relatively abundant throughout the season, this was the only group used. From Fig. 6 it is apparent that annulus formation began in October and November. In November, 50 per cent of the sample had narrow marginal growth zones. By January and February, 80 per cent of the scales were in this condition, and by May, 92 per cent had narrow marginal increments. Thereafter the frequency of wide increments increased rapidly.

Since spawning time and time of annulus formation coincide so closely with the beginning of the biological year, the previous decision to consider that the biological year and the calendar year as identical is supported. Hence the 1955 year-class, spawned in the winter of 1954-55, formed their first annulus at the end of 1955.

Fig. 6. Seasonal changes in the frequency of scales from 1-ring fish having narrow marginal increments.



PERCENTAGE OF I-RING SCALES
HAVING NARROW MARGINAL INCREMENT
0
20
40
60
80
100
M
J
J
A
S
O
N
D
J
F

AGE COMPOSITION OF THE CATCH

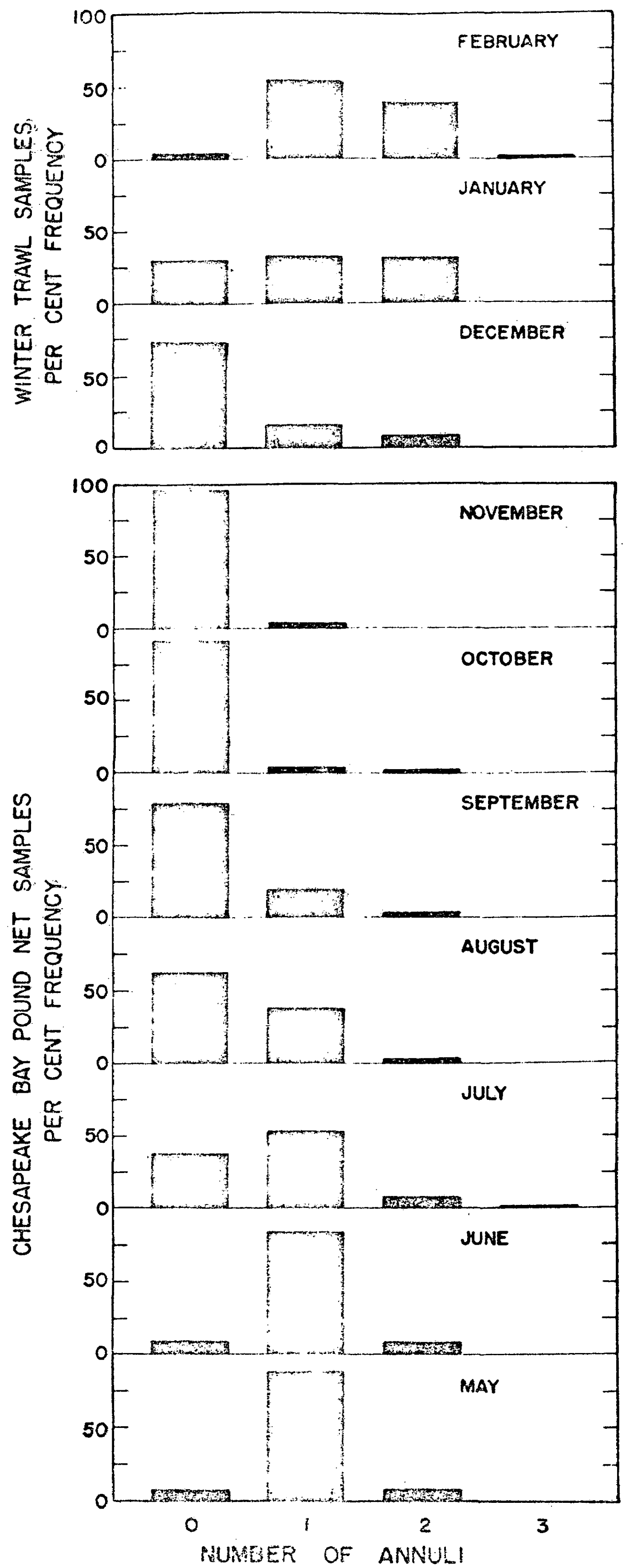
Fig. 7 illustrates the monthly percentage age-frequency distribution of spot as determined from the scales. The data are summarized by months to show the relative changes which took place. In reviewing these data, it should be remembered that they are not weighted in any way with reference to total poundage, and that since they were taken at weekly intervals, they represent only a very small part of the entire catch.

From Fig. 7 it is evident that the 1955 pound-net fishery in the York River was supported chiefly by two age-groups of spot. Fish older than two years made up a very small part of the total catch. Readily apparent is the increasing relative importance of the 0-ring group throughout the season, and the declining relative importance of the one-year-olds.

RATE OF GROWTH

The average size at each age, and hence the rate of growth of spot vary throughout its range. In Texas, spot rarely reach ten inches in fork length and Pearson (1929) stated that because they do not attain sufficiently large size in that region, they are not important commercially. Hildebrand and Cable (1930) reported the average size in North Carolina to be somewhat smaller than at Norfolk, Virginia. Nichols and Breder (1927) inferred that the spot in the New York area grew at the following

Fig. 7. Monthly changes in the frequency of spot with 0, 1, 2, and 3 annuli, in the pound-net fishery during 1955 and winter-trawl fishery during 1955-56.


WINTER TRAWL SAMPLES, PER CENT FREQUENCY
CHESAPEAKE BAY POUND NET SAMPLES PER CENT FREQUENCY
FEBRUARY
JANUARY
DECEMBER
NOVEMBER
OCTOBER
SEPTEMBER
AUGUST
JULY
JUNE
MAY
100
50
0
0
1
2
3
NUMBER OF ANNULI

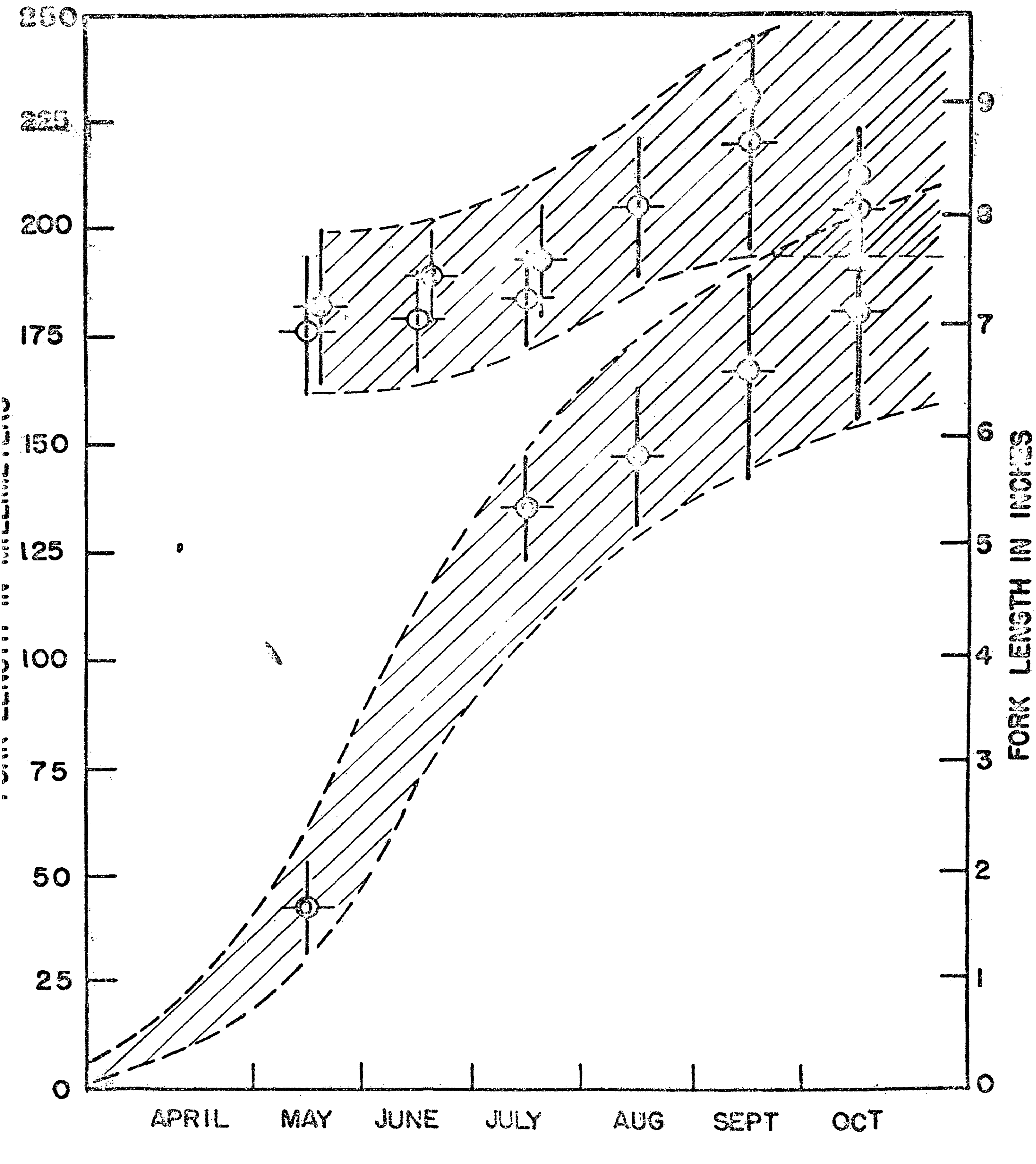
rate; 100 mm at one year, 195 mm at two years, and 265 mm at three years of age.

Roelofs (1951) stated that young spot in the vicinity of Beaufort, N. C. grew rapidly during the summer, reaching a length of four to five inches (100-130 mm) by fall. He also stated that by fall the larger yearlings were as large as the smaller spot of the previous year class. From this point on, growth was difficult to follow, because the year classes overlapped considerably in length.

The Perrin samples were analyzed to extract information on the growth rate of spot (Fig. 8). The vertical bars mark the limits of one standard deviation on each side of the mean monthly fork length. The relative accuracy of the estimates ~~are~~ is indicated by the shaded area, which marks the probable limits of the true growth curve. The May measurements of 0-ring fish were obtained from a sample seined at the Gloucester Point shore. This was included as an early measure of the 0-ring group because these fish do not enter the fishery until July. The mean length attained at the end of the first year of life was about 180 mm. At the end of their second year spot were about 215 mm long, and three-year-old fish about 225 mm. Fig. 8 shows that Roelofs' (1951) general conclusions apply also to Chesapeake spot. They are characterized by relatively rapid growth during the first year and a large amount of overlap in length between age groups.

Fig. 8. Apparent growth rate of spot sampled in 1955 from the Perrin pound nets. The circles are located at the mean values at monthly intervals and the vertical bars represent one standard deviation on each side of the mean. The numbers within the circles refer to the age of the fish i.e. 0-ring, 1-ring, and 2-ring fish.

[illegible]
Fig. 5 follows page 21.



250
225
200
175
150
125
100
75
50
25
0
9
8
7
6
5
4
3
2
1
0
FORK LENGTH IN INCHES
APRIL
MAY
JUNE
JULY
AUG
SEPT
OCT

LENGTH-WEIGHT RELATIONSHIP

In fishery management it is often useful to be able to determine the weight of a fish, when length alone is known. This can be utilized as follows: very often in large-scale projects only lengths and numbers of fish are recorded, as it is difficult if not impossible on a rolling, pitching boat to weigh fish accurately. Once the length-weight relationship has been established the conversion is relatively simple.

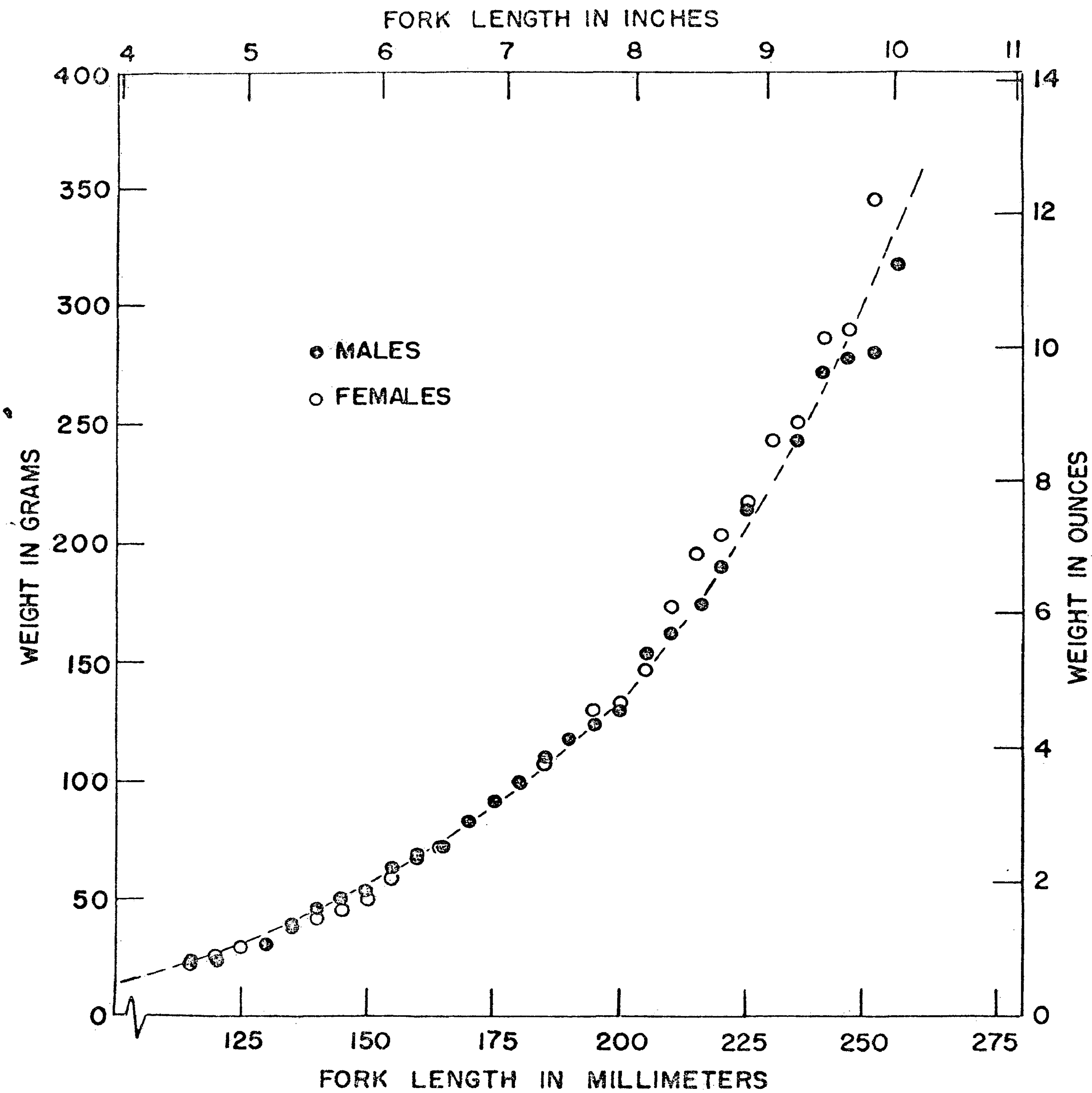
The basis of the calculation is reviewed by Lagler (1952). If the form and specific gravity of the fish remain constant the length-weight relationship can be expressed as a formula having the form: $W = KL^3$, where W = weight, L = length, and K is a constant, representing the slope of the straight line fitted to the logarithms of the two variables, which must be determined for each species.

The formula was computed by the method outlined by Lagler (1952) and an empirical curve was drawn (Fig. 9). The calculated equation for males and females is: $\log_{10} W = -6.48 + 3.76 \log_{10} L$.

SEXUAL DIMORPHISM

The sizes of male and female spot sampled each month from Perrin are shown in Table V. No sexual difference can be detected visually in these data, and larger samples would be necessary to demonstrate any small differences that might exist. A sexual dimorphism in

Fig. 9. The length-weight relationship of spot sampled from the Perrin pound nets in 1955.



FORK LENGTH IN INCHES
4
5
6
7
8
9
10
11
400
350
300
250
200
150
100
50
0
WEIGHT IN GRAMS
14
12
10
8
6
4
2
0
WEIGHT IN OUNCES
MALES
FEMALES
125
150
175
200
225
250
275
FORK LENGTH IN MILLIMETERS

TABLE V

Fork Length Distribution of Male and Female Spot
Sampled from Perrin Pound Nets in 1955
Grouped in 5 mm Intervals

Fork Length mm	May M	May F	June M	June F	July M	July F	Aug. M	Aug. F	Sept. M	Sept. F	Oct. M	Oct. F
75												
80												
85												
90												
95												
100												
105												
110												
115					2	1						
120					2	2						
125						5	2	1				
130					1	3	3	2				
135					10	7	2	1	1		1	1
140	1				4	4	3			1	2	1
145	2			1	1		2	2		1	2	
150	2	3		1	1	2			2	2	3	3
155	3	8		1	2		1			1	2	7
160	6	8	1	5	3	2	4	2	3	1	4	2
165	12	12	5	4	3	2	1	2	5	1	2	2
170	11	14	6	13	3	2	3		3		1	2
175	8	15	12	21	7	6		2			2	
180	16	9	22	19	7	9		2	1	1	1	
185	13	9	16	13	13	13	1		1	1		1
190	8	5	10	23	6	12			1	1		1
195	8	4	2	7	7	2			1	1	2	2
200	4	6	2	5	1	3	2	1	1	1	9	5
205	1	2		2	1			1	1		4	2
210	2		1	3		1	2	1	2	2	1	1
215	1				1	1	1	2	2	3	3	
220	1	1					1	1	7	4		
225		1							3	3		
230							1			1		
235									2	1		
240							1		1	3		
245							1			3		
250									1	1		
255									1			
260												

length is not uncommon in fishes.

SUMMARY AND CONCLUSIONS

This report is based on the examination of 36 samples containing 2190 spot from commercial pound nets in the lower Chesapeake Bay area in 1955 (Fig. 3), and 4 samples from the offshore trawl fishery in the winter of 1955-56.

Two major modal groups appeared in the frequency distribution of length. The mode made up of smaller fish that appeared in July seemed to represent fish in their first year of life. The larger size-group was rather broad, and might include two or more age groups.

It was demonstrated that only one annulus is formed each year. Most annuli were produced in the period November to February. Scale readings showed that the 1955 pound-net fishery in the lower York River was supported chiefly by two age groups of spot, the 0 and 1-ring fish. Fish older than two years made up a very small part of the total catch. In the catch throughout the season the major trend was the increasing relative abundance of the 0-ring, and the declining relative importance of the one-ring fish. This is in close agreement with the conclusions derived from length-frequency distributions and thus the results of the two methods support each other.

The bimodal distribution of lengths in the Perrin catch of October was shown from scale readings to be made up of young-of-the-year fish. In October two samples were collected from the Perrin area, and each of the modal groups represents one sample. This suggests that spot may school according to size and there is reasonsto suspect that the bimodality of the October catch may reflect a differential movement with respect to size. Surveys with exploratory trawls have shown that spot are distributed according to size in the rivers, the smaller individuals occurring upstream. This differential distribution of fish in the same age-group, according to size, seems to be typical of many estuarine forms, as Oglesby (1955) has suggested for menhaden, Brevoortia tyrannus, and Haven (1957) has shown for croakers, Micropogon undulatus. With these considerations, we might hypothesize that since fish were moving out of the river in fall, it is easy to understand how the early October samples would be made up of larger fish than the later samples, as the smaller fish probably came into the area of capture after the larger members of their age group had departed. Confirmation from the more adequately sampled October Horn Harbor catch was given by the length distribution, in which the mode lay about halfway between the modes for the Perrin samples.

The spot caught by the experimental trawl in September were obviously much smaller than those in the pound-net catch. This probably was caused by net selectivity, for the trawl consistently caught the smaller representatives of each species.

Some small fish apparently winter-over in the Bay. Hildebrand and Schroeder (1927) reported small fish, presumably of the 0 age-group, taken in December. These authors tentatively concluded that these fish were the runts of the last spawning while larger members of their year class had departed.

The lengths and age composition of spot sampled from the winter trawl fishery have also been included. From these it seems that little or no growth takes place in winter, however, more adequate sampling of this fishery is necessary. The winter-trawl data included in Fig. 7 again illustrate the time of annulus formation and the apparent shift in age composition is merely a reflection of annulus formation.

If Fig. 7 is considered to represent one cycle of a repetitive process, then another characteristic of the spot population is indicated. In January, 1956, 34 per cent of the sampled fish had two annuli. However, three-year-old fish made up only an insignificant part of the Chesapeake catch the previous spring. Two possibilities are suggested in explanation of this discrepancy: either few 2-ring fish survive the spawning season, or these larger fish do not re-enter Chesapeake Bay in large numbers the following spring. There is, therefore, the possibility that the winter trawlers sample a more representative group of fish.

It may be that most of these larger fish migrate northward in spring. This is characteristic of several coastal species, as mentioned by Smith (1896) for the menhaden, Brevoortia tyrannus, and by Nesbit (1954) for the gray sea trout, Cynoscion regalis.

The obvious characteristics of growth are the relatively rapid growth of the 0 age-group and the great spread and overlap in lengths of the older fish (Fig. 8). Fish in their second year of life continued to increase in length up to September. The reversal of this trend in mean length in October (Fig. 8) probably was caused by the movement of smaller and smaller individuals into the fishing area, as the larger fish migrated out of the fishing area into the ocean.

Fig. 8 shows that there is much variation within, and subsequent overlap between lengths of succeeding year classes. However, at the end of the first year most fish had reached lengths of 155-205 mm. Fish at the end of their second year were 180-245 mm long, and the few three-year-old fish perhaps somewhat larger. Older fish were larger, on the average, than one-year-olds but on the basis of length alone they could not be separated from the younger fish. However, an impression was received that older fish were invariably deeper-bodied and of greater girth than the relatively elongated and thinner young fish.

The length-weight relationship is shown diagrammatically in Fig. 9 for male and female spot of the Perrin samples. No sexual dimorphism in the length-weight relationship is apparent in young spot, but in later life, the females may be slightly heavier for a given length, although the data were not adequate to prove this point. This weight increase, if it indeed exists, may be associated with maturation of the gonads.

From this study it is apparent that the pound-net fishery for spot in lower Chesapeake Bay is principally dependent on two age groups of fish. Early in the season, fish in their second year of life dominate the catch. Summer catches are typically small and erratic. Because they are in poor condition, many of these early-caught spot are sold as trash fish.

The bulk of the spot catch is taken in August, September and October when the fish are moving out of the Bay. Marketable fish are at this time in prime condition. However, also at this time, the smaller members of the 0 age-group are not marketable, and great quantities of these younger fish end up in the trash-fish heap.

Historically, the spot fishery has been quite unstable. Because the fishery exploits almost exclusively only two age-groups of fish, a spawning failure will exert an almost immediate and rather pronounced effect on the catch.

Conventional conservation measures, particularly in the form of mesh-size changes, could be taken to provide the continued catch of older marketable spot and minimize the capture of the smaller unmarketable fish. There is no clear evidence, however, that spot have declined seriously in abundance. Actually over the past few years, there seems to have been a trend towards higher annual poundage; however, this may be associated with the increased haul-seine fishery in recent years, rather than with an increased abundance of fish.

McHugh (1957) has suggested that management of the inshore fishery resources by conventional methods may be difficult, if not impossible. The problem is complex, involving economic and sociological forces (McHugh and Bailey, 1957). McHugh (1957) further stated that, because many of these species migrate farther to the northward as they grow older and larger, management for optimum yield might favor northern states to the detriment of the southern fisherman. He tentatively concluded that the best rate of fishing for the Chesapeake might be a high one and that measures to protect the young fish might penalize rather than aid Virginia fishermen, for the mortality rate obviously is very high, and the maximum biomass produced by a year's brood may occur quite early in life. Thereafter, the decline in total weight is probably very rapid. Any recommendations for management should await further biological study of all the species involved in the fishery.

LITERATURE CITED

CLARK, FRANCES N.,

1925. The life history of Leuresthes tenuis, an atherine fish with tide controlled spawning habits. Calif. Fish and Game Comm., Fish Bull., 10: 1-51.

1929. The life history of the California jack smelt, Atherinopsis californiensis. Calif. Div. Fish and Game, Fish Bull., 16: 1-22.

1934. Maturity of the California sardine (Sardina caerulea), determined by ova diameter measurements. Calif. Div. Fish and Game, Fish Bull., 42: 1-49.

COWLES, R. P., 1930.

A biological study of the offshore waters of Chesapeake Bay. Bull. U. S. Bur. Fish., 46: 277-381.

CREASER, CHARLES W., 1926.

The structure and growth of the scales of fishes in relation to the interpretation of their life history, with special reference to the sunfish, Eupomotis gibbosus. Univ. Mich. Mus. Zool., Misc. Pub., 17: 1-83.

GUNTER, GORDON, 1945.

Studies on marine fishes of Texas. Pubs. Inst. Mar. Sci., 1: 1-190.

HAVEN, DEXTER S., 1957.

Distribution, growth and availability of juvenile croaker, Micropogon undulatus, in Virginia. Ecology, 38(1): 88-97.

HOLLIS, EDGAR HARRISON, 1952.

Variations in the feeding habits of the striped bass, Roccus saxatilis (Walbaum), in Chesapeake Bay. Bull. Bing. Ocean. Coll., 14(1):111-131.

HILDEBRAND, SAMUEL F. and LOUELLA E. CABLE, 1930.

Development and life history of fourteen teleostean fishes at Beaufort, N. C. Bull. U. S. Bur. Fish., 46: 383-488.

HILDEBRAND, SAMUEL F. and LOUELLA E. CABLE, 1934.

Reproduction and development of whitings or kingfishes, drums, spot, croaker, and weakfishes or sea trouts, family Sciaenidae, of the Atlantic coast of the United States. Bull. U. S. Bur. Fish., 48: 41-117.

HILDEBRAND, SAMUEL F. and WILLIAM C. SCHROEDER, 1928.

Fishes of Chesapeake Bay. Bull. U. S. Bur. Fish., 43: 1-366.

LAGLER, KARL F., 1952.

Freshwater fishery biology. Wm. C. Brown Co. Dubuque, Iowa: x + 360 pp.

LUNZ, G. ROBERT, 1957.

Annual report 1955-56. Bears Bluff Laboratories, Wadmalaw

Island, S. C. Rep. S. C. Wildl. Res. Dept., Fiscal year July 1, 1955--June 30, 1956: 1-19.

MASSMANN, WILLIAM H., 1954.

Marine fishes in fresh and brackish waters of Virginia rivers. Ecology, 35(1): 75-78.

McHUGH, J. L., 1957.

Can we manage our middle Atlantic coastal fishery resources? Paper presented at March 1957 meeting of N. E. section of American Fisheries Soc. New Haven, Conn.

McHUGH, J. L. and ROBERT S. BAILEY, 1957.

History of Virginia's commercial fisheries. Va. Jour. Sci., 8(1): 42-64.

NESBIT, ROBERT A., 1954.

Weakfish migration in relation to its conservation. U. S. Fish and Wildl. Serv., Spec. Sci. Rep. Fisheries, 115: 1-81.

NICHOLS, J. T. and C. M. BREDER, JR., 1927.

The marine fishes of New York and southern New England. Zoologica, 9(1): 1-102.

OGLESBY, RAY THURMOND, 1955.

Age and length of menhaden (Brevoortia tyrannus) in the waters of Chesapeake Bay, with comments on the rate of growth. Unpublished M.A. thesis, College of William and Mary: 27 pp.

PARR, A. E., 1933.

A geographic-ecological analysis of the seasonal changes in temperature conditions in shallow water along the Atlantic coast of the United States. Bull. Bing. Ocean Coll., 9 (3): 1-90.

PEARSON, JOHN C., 1928.

Natural history and conservation of the redfish and other commercial sciaenids on the Texas coast. Bull. U. S. Bur. Fish., 44: 129-214.

PEARSON, JOHN C., 1932.

Winter trawl fishery off the Virginia and North Carolina coasts. U. S. Bur. Fish., Inves. Rep., 1(10): 1-31.

PRITCHARD, D. W., 1951.

The physical hydrography of estuaries and some applications to biological problems. Trans. 16th. N. Amer. Wildl. Conf., March 1951: 368-376.

RANEY, EDWARD C. and WILLIAM H. MASSMANN, 1953.

The fishes of the Tidewater section of the Pamunkey River, Virginia. Jour. Wash. Acad. Sci., 43(2): 424-432.

REID, GEORGE K., JR., 1955.

The pound-net fishery in Virginia. Comm. Fish. Rev., 17(5): 1-15.

REID, GEORGE K., JR., 1955.

A summer study of the biology and ecology of East Bay, Texas.

Tex. Jour. Sci., 7(3): 316-343.

REID, GEORGE K., JR., 1955.

A summer study of the biology and ecology of East Bay, Texas. Part II. The fish fauna of East Bay, the Gulf beach, and summary. Tex. Jour. Sci., 7(4): 430-453.

RICHARDS, CLARENCE E., 1955.

Saltwater sport fishing survey. (Unpub. MS) Virginia Fisheries Laboratory, Gloucester Point, Va.

ROELOFS, EUGENE W., 1951.

The edible finfishes of North Carolina (In) Survey of marine fisheries of North Carolina. Univ. of N. C. Press: 109-139.

ROELOFS, EUGENE W., 1954.

Food studies of young sciaenid fishes, Micropogon and Leiostomus, from North Carolina. Copeia, 1954(2): 151-153.

ROUNSEFELL, GEORGE A. and W. HARRY EVERHART, 1953.

Fishery science, its methods and applications. John Wiley and Sons, Inc. New York: xii + 444 pp.

SMITH, HUGH M., 1896.

Notes on an investigation of the menhaden industry in 1894, with special reference to the foodfishes taken. Bull. U. S. Fish. Comm., 15: 285-302.

TAYLOR, HARDEN F., 1916.

The structure and growth of the scales of the squeteague and the pigfish as indicative of life history. Bull. U. S. Bur. Fish., 34: 295-330.

TAYLOR, HARDEN F. and A STAFF OF ASSOCIATES, 1951.

Survey of marine fisheries of North Carolina. Univ. of N. C. Press, Chapel Hill: xii + 555 pp.

UNITED STATES BUREAU OF FISH AND FISHERIES, 1928-1941.

Fishery Industries of the United States, 1926-1938. U. S. Govt. Printing Office, Washington, D. C.

UNITED STATES COMMISSION OF FISH AND FISHERIES, 1887-1927.

Virginia Fishery Products (irregularly published 1887-1925). U. S. Govt. Printing Office, Washington, D. C.

UNITED STATES FISH AND WILDLIFE SERVICE, 1942-1956.

Fishery Statistics of the United States. 1939-1953. U. S. Govt. Printing Office, Washington, D. C.

WALFORD, LIONEL A. and KENNETH H. MOSHER, 1943.

Studies on the Pacific pilchard or sardine (Sardinops caerulea) 2. Determination of the age of juveniles by scales and otoliths. U. S. Fish and Wildl. Serv., Spec. Sci. Rep., 20: 1-34.

WELSH, WILLIAM W. and C. M. BREDER, JR., 1923.

Contributions to life histories of sciaenidae of the eastern United States coast. Bull. U. S. Bur. Fish., 39: 141-201.