A FIVE-YEAR STUDY OF THE STRIPED BASS FISHERY OF MARYLAND, BASED ON SCALE ANALYSES OF FOUR SUCCESSIVE YEAR CLASSES

By

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INTRODUCTION

The striped bass ranks high in value and volume among the species taken in the Maryland commercial fisheries, and in addition is highly prized as a game fish by sportsmen. Rock, as the species is called in the Chesapeake area, are taken during the entire year in Maryland waters, with seasonal peaks of abundance in the late fall and spring months.

The gear used in this fishery varies with the season, and to a lesser extent, with the area fished. Pound nets, which operate during the spring, summer and fall, in the Bay and larger rivers, account for the greater portion of the catch. Gill nets, drifted or anchored in the Bay and larger rivers during the winter and early spring, or fished as stake nets on or near the spawning grounds in the spring, are next in production. Lowest in value of the larger commercial gears are the haul seines, fished principally during the spring and summer. Fyke nets, typically used in the upper regions of rivers for perch and catfish, make only a relatively small seasonal contribution to the total catch of rock. The table following (Table I) was obtained from unpublished records compiled by the Maryland Department of Research and Education, and presents the most recent available data on the catch by gear of this species.

Table I

Maryland Striped Bass Catch by Gear for 1944 and 1945
Chesapeake Bay and Tributaries only, Atlantic
Ocean Catch Not Included.

	Pound nets	Gill nets			Haul Seines	Fyke Nets	Total
		Drift	Anchor	Stake			
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
1944	768,595	522,115	86,622	689,583	502,888	6,315	2,576,118
1945	565,538	196,521	42,460	483,303	186,324	5,709	1,479,855

Records compiled by the U.S. Bureau of Fisheries covering the period from 1887 to 1942 (Table II) show marked variations in the abundance of striped bass taken in Maryland. A complete series for every year during that time is not available, but the following table presents the total catch for all years in which statistics were collected.

Table II

Total Catch of Striped Bass in Maryland for Various Years from 1887 to 1942

Year	Pounds	Year	Pounds	Year	Pounds
1887	1,140,000	1920	1,040,000	1935	927,700
1888	1,123,000	1925	1,414,000	1936	1,864,100
1890	1,366,000	1929	1,291,695	1937	2,011,300
1891	1,265,000	1930	1,227,990	1938	1,714,400
1897	935,000	1931	634,909	1939	1,728,500
1901	824,000	1932	433,811	1940	1,180,100
1904	721,000	1933	313,795	1941	1,223,300
1908	640,000	1934	332,700	1942	2,507,800

According to U. S. Fish and Wildlife Service records for 1940, Maryland produced in that year approximately 40% of the total catch of rock in the United States. Although conclusive proof from tagging is still lacking, there is strong evidence that the Chesapeake Bay is the point of origin of most of the stocks of striped bass along the Middle and North Atlantic coast. Vladykov and Wallace (1937) stated on the basis of tagging experiments during 1936 that only a very small number of the Chesapeake rock leave the Bay. Only about 2.5% of the total recaptures from over 1500 tagged fish were from outside the Bay. It is, however, interesting to note that in 1934 and in 1940 dominant broods of rock were produced, and these "bumper crops" were easily traced up the coast during the early spring months following their first appearance in the Chesapeake catches. Merriman's work on the 1934 brood revealed that scales from northern catches had about the same values for the width of the first and second growth zones as scales from that same year class taken in the Chesapeake area.

This study was initiated in October, 1941, in an effort to determine the value of scale analyses in studying the striped bass fishery of Maryland. The collection and analysis of scale samples was continued for a five-year period, and the age, rate of growth and contribution to the fishery of four successive broods of striped bass was determined. An attempt was also made to evaluate frequencies of calculated and measured length as a possible index to the origin of stocks of striped bass along the Middle and North Atlantic Coast.

Preliminary studies were conducted to establish techniques of collection and preparation of samples, and to generally evaluate the scale method as applied to this species. An indication of compensatory growth was observed from calculations made in these preliminary studies, and the data indicative of this tendency, together with a description of the techniques of collection and analysis, have been previously reported by the author (1942).

The application of the scale-reading technique to commercial fisheries is by no means new to the field of fishery biology. Extensive studies, including determinations of age and rate of growth have been conducted on many marine and fresh-water species.

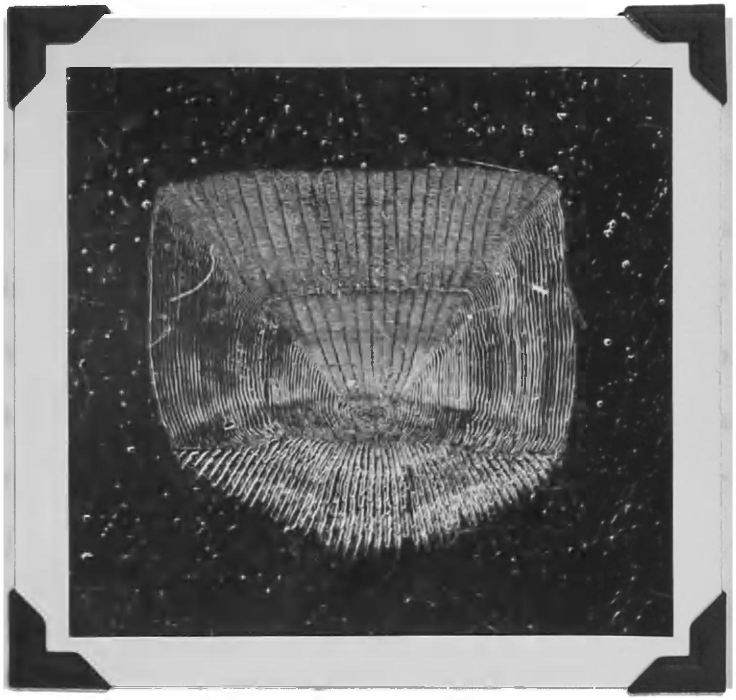
The first growth rate determinations were made by Einar Lea (1910), who showed in a study of the sea herring a direct proportion between body growth and scale growth. Lea expressed this proportion in a formula which has become, with slight modification, a universal tool in fishery investigations. Van Oosten (1926) applied this technique to growth studies of the lake herring or cisco, Leucicthys artedi Le Sueur, and later (1938) to investigations on the common whitefish, Coregonus clupeaformus. The scale method has been employed on the West Coast by Gilbert (1913) and Gilbert and Rich (1927), in the course of investigations on the red or sockeye salmon, Oncerhyncus nerka. C. L. Hubbs, (1921), traced the rate of growth of a fresh-water atherine species, Labieesthes sicculus, and later (1934) working with Cooper, studied growth in the long-eared sunfish, Xenotis megalotis, by means of the scale technique. One of the most recent applications of the method is the work of McHugh (1942), on the growth of the Rocky Mountain whitefish, Prosopium williamsoni.

The growth rate of the species under consideration in this paper, the striped bass, has been studied by means of the scale method by Merriman (1941), who was concerned chiefly with the populations of the Middle and North Atlantic coast, outside of Chesapeake Bay. Scofield (1931) studied the striped bass of California, and employed scale analyses in determining the rate of growth. He further checked the validity of the scale method as applied to this species by using otoliths and opercles in age readings.

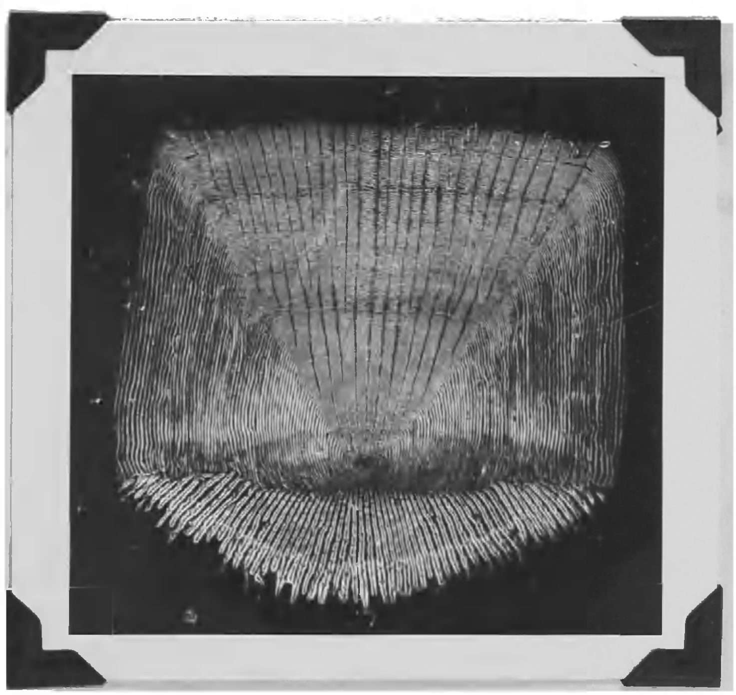
Description of Scales.

Typical striped bass scales showing one and two annuli are shown in the photomicrographs included in Plate I. Generally square or rectangular in outline, these scales have a nearly straight anterior edge, and

PLATE I



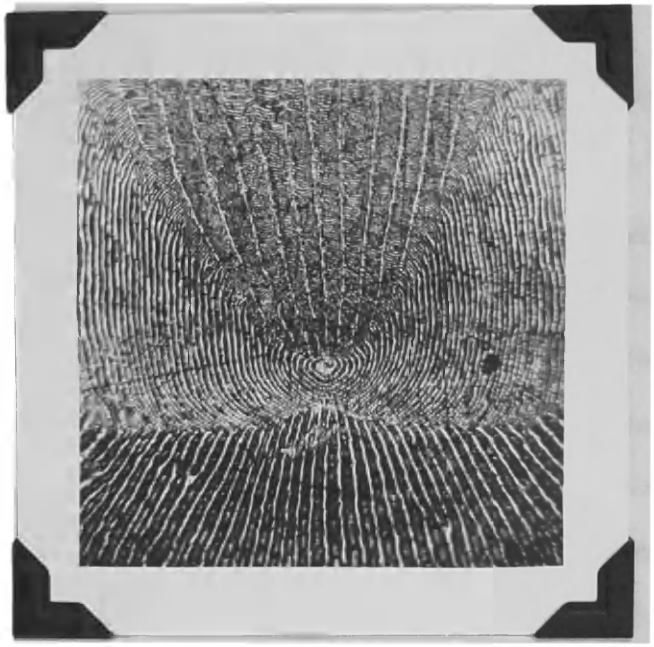
Striped Bass Scale Showing One Annual Ring
(Magnified X 11)



Striped Bass Scale Showing Two Annual Rings
(Magnified X 11)

the posterior edge is broadly tapered. The finely concentric lines characteristic of the anterior portion are termed circuli, and as shown by Scofield (1931) the annuli, or annual rings are formed by a disturbance of the regular pattern of circulus formation. This variation in pattern is manifested as one or two flattened or irregularly formed circuli, which contrast sharply with the arched circuli of normal growth. The resumption of normal rapid growth in the spring, following retarded winter growth, is apparently the explanation for annulus formation. There is an annulus formed each year, and the number of annuli is constant on all scales of the same individual. Irregularities in scale pattern do occur, however, the most common of which is the regenerated scale, characterized by a rough, granular center corresponding in size to the lost scale which it replaces. The central portion of a normal scale, showing the clearly defined focus and circuli, and the corresponding area of a regenerated scale are shown in the photomicrographs included in Plate II. False annuli, superficially resembling the true age marks, but usually not continuous across the entire scale, are sometimes formed by the loss and regeneration of neighboring scales.

PLATE II



Central Portion of Normal Striped Bass Scale
(Magnified X 20)

Central Portion of Regenerated Striped Bass Scale
(Magnified X 20)

TECHNIQUE

Collection of samples.

Two problems became evident in the early phases of the study; first, the selection of a fishing gear which would be least selective in the size of fish taken, and which would therefore present a more uniform cross-section of the total population; and second, the selection of the most reliable body area for the collection of scale samples.

A survey of the types of gear used in Maryland waters, trips with fishermen operating each type, and discussions of the problem with fishery biologists familiar with these gears, eliminated on the basis of size selectivity and irregularity of operation, all but the pound net. This decision was later substantiated by collections from other types of gear, and by statistical data compiled on the catch of each type. Catch records for Maryland by gear and species were collected by the U. S. Bureau of Fisheries (at present the U. S. Fish and Wildlife Service), from 1887 to 1942, and more detailed records which included a break-down of the striped bass catch into small, medium and large size fish, were collected by the Maryland Department of Research and Education in 1944 and 1945. These records, plus the regular nature of pound net operations, further indicated the advisability of using this gear as the source for scale collections. Scofield (1931) was faced with the problem of gear selectivity in his studies of the California catches since the law in that state allows only drift gill nets to be used in commercial fishing operations for the striped bass. Merriman(1941), obtained his data from pound net, rod and reel and haul seine catches.

Using comparative symmetry of scales from different body areas as a criterion for obtaining samples, both Scofield and Merriman advocated as the most reliable body area the region just above the lateral line and between the spinous and soft dorsal fins.

Preliminary studies were conducted to determine the reliability of scales from different body areas, and the results are presented in the section devoted to analysis of data.

In an effort to minimize variations due to environmental or physiological peculiarities which might alter the scale pattern of populations from different areas, uniform procedures were used in every collection. All samples for a single series were taken from the same area on the same day, and successive series were made from the same nets whenever possible.

The areas selected for collection of the series providing data for this study were two important and typical centers of pound net operations, one at Galesville, Maryland, and the other at Flag Pond, near Lusby, Maryland. All samples were taken at random from the catches, usually during the return trip from the nets. In addition, some were taken as the fish were landed, before they were sorted according to size.

The desired scales were removed from the fish with forceps, and placed in small envelopes marked with the length of the fish, the body area from which the scales were taken, and any other necessary data. The standard measuring board adopted by the U. S. Fish and Wildlife Service, equipped with an offset scale divided into half-centimeter units was used, and measurements were made from the snout to the fork of the tail.

Preparation of Impressions.

The fibrous structure and peculiar light-transmitting proper ties of rock scales make detailed microscopic study difficult, so impressions prepared on transparent plastic were substituted.

The impressions were obtained by a method introduced by Mr. Robert A. Nesbit, formerly in charge of Middle Atlantic Fisheries Investigations of the U. S. Fish and Wildlife Service. The techniques employed in preliminary studies are described in the earlier paper referred to previously (Tiller, 1942), and will not be included in this discussion.

With some refinement and modification, the same technique was employed in preparing the impressions used in this investigation. The scales were washed in a dilute solution of household ammonia, and with the aid of a binocular microscope, two symmetrical scales from each sample were selected. These scales were then mounted, rough side uppermost, on 3" X 5" strips of gummed tape of the type used in sealing packages or cartons. Labels bearing the serial and sample numbers were prepared on a typewriter equipped with a Ditto duplicator ribbon. The mounted scales were bound with cellulose tape to a 3" X 5" sheet of cellulose acetate plastic, and the labels taped across the face of the plastic. Four such sheets were prepared at a time, and placed on a sheet of gum rubber approximately .075" in thickness and nine inches square, which in turn was placed on a sheet of .125" aluminum of the same size. A thin stainless steel plate was placed on the plastics, and an aluminum sheet similar to the one previously described placed on the steel. The whole unit was then ready for pressing. A hydraulic press of twenty tons maximum capacity, with eight-inch steam-heated, water-cooled platens, was used in this operation. The platens were heated, the scale unit placed on them, and a gentle pressure applied until sufficient heat was conducted through the aluminum and rubber to soften the plastic. The pressure was then run up to about twelve tons, (3400 lbs./sq.in.) and held for one minute, after which the steam was cut off and cold water run in until the platens were thoroughly cool. The pressure was then released, and the scale tapes removed by bending the plastic sheets. Impressions and tapes were then filed numerically in standard 3" X 5" file drawers. Duplicate sets of impressions could be obtained with no variation in the clarity of detail, but it was found that new labels were necessary after two or three duplicates had been prepared.

Scales from the Northern areas included in this study were collected by Mr. William C. Neville of the U. S. Fish and Wildlife Service. Impressions were prepared in a similar manner, but each sample was mounted and pressed separately on a 1" X 2½" plastic strip instead of the larger sheets used in the Chesapeake series.

Scale Measurements.

A machine developed by Mr. R. A. Nesbit was used in obtaining the scale measurements required in the growth calculations included in this study. The device consists essentially of a horizontally movable stage, used in place of a standard microscope stage, geared to a 4½" disc graduated in units of one twenty-four hundredth of an inch. Geared to the same shaft is a small counter on which the unit recording cylinder is masked. Numbers below ten, equivalent to one hundred graduations on the disc scale, are read directly from the disc, and larger numbers are derived from a combination of the two values. Thus, a value of two hundred and thirty-four would be read as two on the counter scale, and thirty four on the disc. A binocular microscope equipped with an ocular pointer was used in operating the machine. The disc and counter were zeroed and the pointer placed at the focus of the scale. As the operating handle was rotated, the impression was carried across the field of view, and when the pointer reached the desired position at an annulus, or at the margin of the scale, the reading was made.

The Scale Formula.

The investigations of Einar Lea (1910) on the sea herring, and the formula he developed expressing the relationship between scale and body growth, was mentioned in the introductory section of this paper. This formula, subject to correction factors by some investigators (Lee, 1913; Van Oosten, 1926) is as follows:

$$\frac{\text{Length of scale to annulus of year X}}{\text{Total scale length}} = \frac{\text{Body length at end of year X}}{\text{Body length when captured}}$$

Lee (1912) observed in comparing different year classes at corresponding periods of life, a decrease in calculated lengths with increasing age. This apparent change has been designated as "Lee's Phenomenon". In explanation of this change, Lee advanced the hypothesis that a contraction of the scale ocurred with increasing age, while Lea (1913) proposed as a cause of the variation a relationship between sexual maturity and growth.

There was no indication of Lee's phenomenon in this investigation. Merriman's work (1941) indicates that sexual maturity is not reached until four years in the females and two years in the males, thereby discounting the theory that sexual maturity causes the phenomenon. In addition, Merriman presented data showing the relation of scale growth to body growth of the striped bass. Graphically represented, this data produced a straight line, indicating no significant decrease in calculated length with increasing age.

ANALYSIS OF DATA

Selection of Gear for Sampling.

A brief discussion of the four major types of commercial gear used in Maryland was included in the introductory section, together with a table (Table I) indicating the contribution of each to the total catch of striped bass in the State. In addition to exceeding all other individual types of gear in total production, pound nets have other definite advantages which make them a desirable source from which to obtain the most typical samples of a fish population. The regularity characteristic of pound net operations is a highly important factor in their favor. Lifted daily, except in exceptionally bad weather, pounds fish the same waters in the same way throughout the entire fishing season. Under favorable conditions the pound net season may run from March through November, with only a short, midsummer break in their operations. The previously mentioned table shows stake gill nets to be second in total production of striped bass, but this gear, and also drift and anchor gill nets, exert very definite size selectivity. The entire catch of a stand of gill nets may be limited to a single year class, simply because the mesh size can capture only fish falling within a relatively narrow size range. Stake nets, and all other types of gill netting, are fished only during the winter and spring, and their operations are necessarily irregular. Drift nets are the most irregular of this class of gear, since they characteristically work from one area to another, following the movements of the fish. The last of the commercial gears to be considered is the haul seine. This type of net might well be termed a gear of "feast or famine". Seine operations are usually limited to the late spring, summer and fall months, and like drift nets, characteristically follow the fish. Days or weeks may pass without a catch, or several tons may be landed at a single haul. Although less selective in operation than gill nets, haul seines occasionally make almost pure catches from a single year class, particularly when fished in rivers. Table III presents an age composition analysis of samples made from various types of commercial gear outside of the Galesville and Flag Pond areas on which this study is based.

Selection of Reliable Body Area for Sampling.

Preliminary studies to determine the comparative reliability of scales from different body areas were included in the previously mentioned study (Tiller, 1942). Briefly summarized the data obtained indicated that scales from the region used by Merriman and Scofield in their studies gave values for calculated length which approached very closely the average of the values from extreme body areas. The short, broad scales characteristic of the anterio-dorsad region gave consistently lower values than the regular, symmetrical scales of the middle body area, and the large, long scales of the ventral aspect gave values which were consistently higher. The variation in calculated length was therefore determined to be a function of scale size. Table IV, prepared from calculations made on the 89 individuals used in the preliminary study, indicates this fact. Three body areas were selected, and designated as areas A, B, and C, respectively. Area A was located very high on the body, between the bases of the spiny and soft dorsal fins, at the extreme point where reasonably symmetrical scales can be found. Area B, (recommended by Merriman and Scofield) was located on the second and third row above the lateral line between the dorsal fins, and yielded the most symmetrical, regular scales. Area C was located very low on the body,

TABLE III

AGE COMPOSITION OF COLLECTIONS FROM MISCELLANEOUS GEARS AND AREAS

Date (Month)	Gear	Area	1940 Brood No.	1940 Brood %	1941 Brood No.	1941 Brood %	1942 Brood No.	1942 Brood %	1943 Brood No.	1943 Brood %	R. F., others* No.	R. F., others* %	Total No.
1942													
Mar.	Pounds.	Potomac R.	58	72.5							22	27.5	80
July	Seine	Patuxent R.											
Oct.	Pounds	Ches. Beach	95	95.0							5	5.0	100
Oct.	Pounds	York R.	50	59.5	31	36.9					3	3.6	84
Oct.	Pounds	James R.	29	52.7	24	43.6					2	3.6	55
Oct.	Pounds	Rappahannock R.	69	72.6	23	24.2					3	3.2	95
1943													
Jan.	Dr.Gill	Rock Hall	45	90.0	1	2.0					4	8.0	50
Feb.	Dr.Gill	Kent Island	110	94.0	3	2.6					4	3.4	117
May	Pounds	Cedar Pt.	22	81.5	2	7.4					3	11.1	27
1944													
Jan.	Dr.Gill	Rock Hall	3	2.1	9	6.4	127	90.7			1	.7	140
Feb.	Dr.Gill	Kent Island	1	3.8			25	96.1					26
June	Seine	Flag Pond					1	3.3	29	96.7			30

* R. F. -- indicates regenerated focus.

TABLE 4

Area	Body Length (cm/2)*	Total Scale Radius	Average Calc. Length **
AREA "A"			
	49-53	243	18
	54-56	271	21
	57-59	282	21
	60-62	313	21
	63-65	303	26
	66-69	334	29
AREA "B"			
	49-53	284	20
	54-56	315	22
	57-59	325	22
	60-62	350	23
	63-65	355	27
	66-69	377	30
AREA "C"			
	49-53	312	21
	54-56	332	25
	57-59	337	25
	60-62	371	25
	63-65	379	30
	66-69	409	32

Average increase in calculated length

Between A and B --- 1.14 cm/2

Between B and C --- 2.01 cm/2

* -- Body Length at time of capture.
** - Average Calculated Length at end of first year.

one row below the lateral line. The scales were very large and usually noticeably longer than those of the mid-body region.

Rate of Growth.

The growth of rock, as indicated from length frequencies of the age classes observed in this study, appears to be highly variable. Reference has already been made to the possible existence of sub-populations in the Chesapeake Bay, characterized by different rates of growth. Occasional discrepancies in the length frequencies of samples from the Galesville and Flag Pond areas tend to indicate that this might well be possible. Using the least selective of gears from which to obtain samples, and taking the samples in every case at random from unsorted catches, occasional values for mean length occurred which were definitely at variance with the expected values. In some instances, the composition of the catch was such that only a very few samples from certain broods were obtained. It is obvious that a limited number of samples might well present an inaccurate value, and the hypothesis of sub-populations cannot be fully accepted until supported by more conclusive data.

For the most part, however, the growth rate obtained from mean length values of the random samples used in this study appeared very reasonable and reliable. Several interesting facts are indicated in Table V and in Figure 1. First, a close coincidence is seen in the size of all year classes at the time of their entry into the commercial catches. The 1940 and 1941 broods tend to be slightly faster in their rate of growth, and show slightly higher values for corresponding intervals of time. This tendency is not, however, clearly defined in all instances. Trend lines were prepared showing the growth rate of the four year classes under observation, using first the method of least

TABLE V

GROWTH RATE OF STRIPED BASS INDICATED BY MEAN LENGTHS OF SAMPLES COLLECTED FROM POUND NETS IN THE GALESVILLE AND FLAG POND AREAS OF CHESAPEAKE BAY

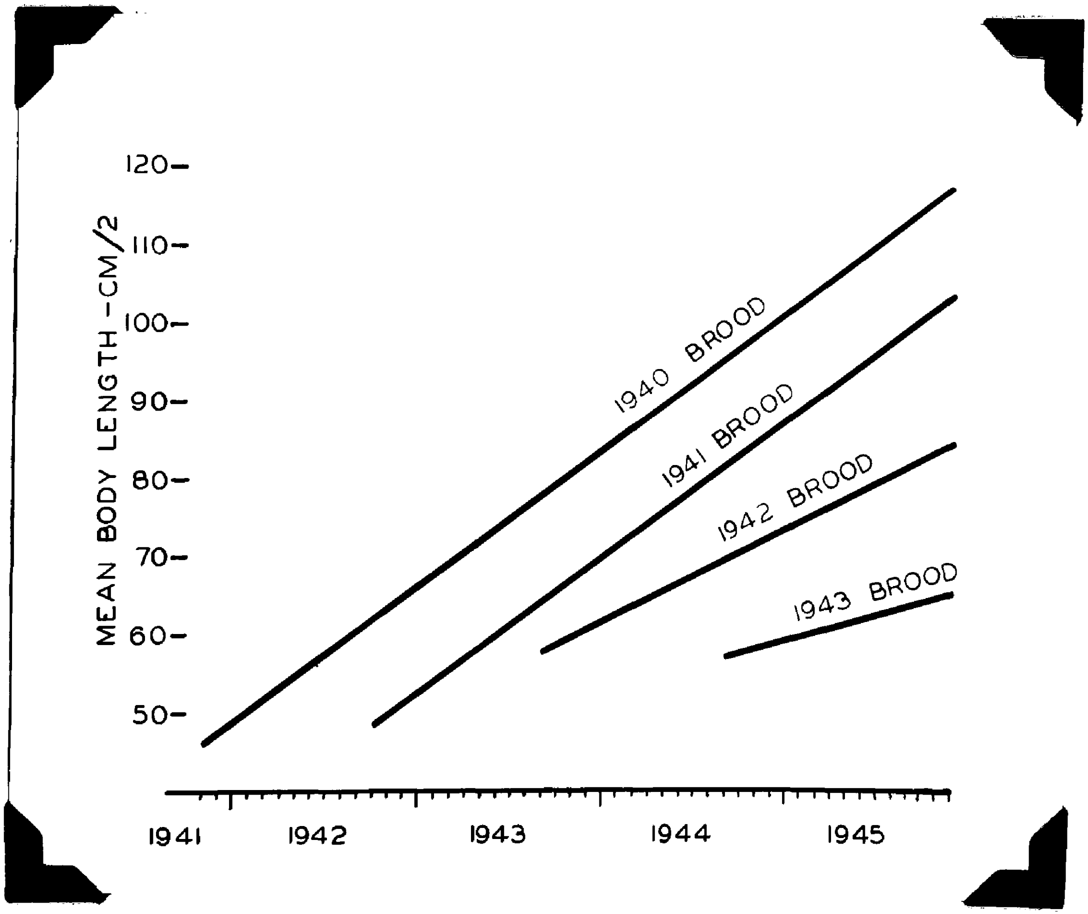
Date (month)	1940 Brood cm/2	No.	1941 Brood cm/2	No.	1942 Brood cm/2	No.	1943 Brood cm/2	No.	1944 Brood cm/2	No.	Area
1941											
Oct.	52.5	23									Flag Pond
Nov.	58.9	87									Flag Pond
1942											
Mar.	57.7	36									Flag Pond
June	56.4	387									Galesville
June	59.6	107									Flag Pond
July	57.6	91									Galesville
Aug.	58.9	18	52.0	2							Flag Pond
Sept.	59.8	52	58.3	3							Flag Pond
Oct.	66.9	67	57.3	3							Flag Pond
Nov.	70.0	96	58.0	3							Galesville
Nov.	73.3	92	57.0	1							Flag Pond
1943											
May	62.1	89	57.8	18							Galesville
Aug.	72.8	103	62.7	66	57.6	327					Flag Pond
Sept.	76.7	4	64.4	14	58.7	87					Flag Pond
Sept.	75.1	7	69.3	6	61.6	42					Galesville
Oct.	82.7	59	68.7	8	62.3	105					Flag Pond
Oct.	83.0	3	61.7	4	61.0	43					Galesville
Nov.	78.4	7	55.0	2	60.1	46					Flag Pond

1944											
Mar.	91.2	20	68.0	3	59.0	10					Galesville
May	96.2	5	77.2	4	64.8	24					Flag Pond
June	101.8	5	76.0	2	57.3	12					Galesville
June	95.7	13	86.2	18	66.0	23					Flag Pond
Aug.	90.1	6	79.3	3	71.1	44	56.2	6			Flag Pond
Sept.	97.0	1	80.3	3	66.9	11	56.9	21			Flag Pond
Oct.		0	77.0	1	66.9	8	60.1	26			Flag Pond
Nov.	101.1	26	84.5	13	77.7	79	62.2	45			Flag Pond
1945											
May	101.5	15	87.2	10	78.2	34	63.1	12			Flag Pond
June	105.2	5	87.5	2	79.3	6	57.1	34			Flag Pond.
Aug.		0		0	76.0	1	60.0	4	53.2	8	Flag Pond
Oct.	112.0	1		0	80.8	10	68.1	66	55.5	36	Flag Pond
Nov.	127.0	1	101.0	5	84.7	24	70.4	61	58.1	58	Flag Pond

TABLE XII

Year	MEAN AIR TEMPERATURE AND DEPARTURE FROM NORMAL						MONTHLY PRECIPITATION AND DEPARTURE FROM NORMAL					
	April		May		June		April		May		June	
	Mean	Dep.	Mean	Dep.	Mean	Dep.	In.	Dep.	In.	Dep.	In.	Dep.
Normal Solomons	54.1	---	64.9	---	73.4	---	2.98	---	2.86	---	3.12	---
1940	50.6	3.5	64.0	0.9	74.6	1.2	5.92	2.94	3.15	0.29	1.13	1.99
1941	57.4	3.3	67.7	2.8	73.4	0.	4.26	1.28	1.61	1.25	3.66	0.54
1942	58.0	3.9	69.0	4.1	75.4	2.0	0.58	2.40	2.35	0.51	4.13	1.01
1943	52.2	1.9	68.2	3.3	79.5	6.1	3.14	0.16	4.92	2.06	3.23	0.11
1944	54.4	0.3	70.7	5.8	75.6	2.2	4.80	1.82	0.47	2.39	2.71	0.41

FIGURE 1



Rate of Growth of Striped Bass, Based on Length Frequencies of Four Successive Year Classes in the Chesapeake Bay.

squares, and second the method of semi-averages (Figure 1). The slope of the lines was virtually identical in both cases. The slight variation in the slope indicates the slight degree of variation in the growth rate of the four broods.

Evidence of Chesapeake Origin of Atlantic Stocks of Striped Bass.

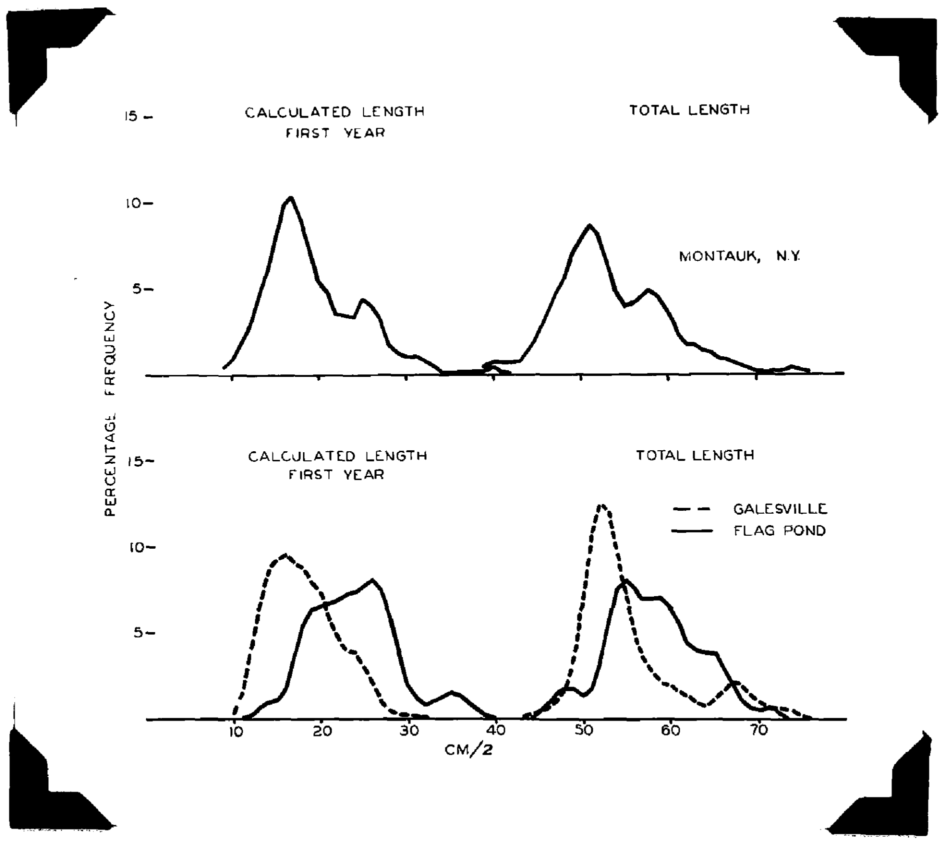
The possibility of using scale analyses as an index of origin to the stocks of striped bass of the Middle Atlantic coast was stated as one of the objectives of this study. The introductory section summarized the conclusions derived from extensive tagging experiments conducted by Vladykov and Wallace (1937), and indicated the existence of a correlation in size frequencies between Chesapeake and coastal runs of bass following the appearance of a dominant year class in the Cheasapeake Bay. Body length measurements and scale readings were obtained for samples from the Galesville and Flag Pond areas of Chesapeake Bay in March and June, 1942, and from Great South Bay and Montauk, Long Island, New York, during the months of May and June, 1942. All samples used were from the 1940 brood of rock, which had appeared in great abundance in the Chesapeake catches during the preceding fall. The mean values for body length and calculated length were obtained for all of the Chesapeake samples, and for a significant number of the Long Island samples. A very close coincidence was observed in total body length between the two series collected in the latter area, and in view of the proximity of the two localities from which the samples were obtained, length calculations were derived only for the Montauk collection. Table VI presents this data, and indicates the close correlation in body length and calculated length between the northern fish and those collected in the Galesville area of the Chesapeake Bay. This data is presented graphically in Figure 2, which shows the striking similarity in percentage frequencies for the two areas. An

TABLE 6

COMPARISON OF GROWTH DATA OBTAINED FROM CHEASAPEAKE AND NORTHERN COLLECTIONS OF STRIPED BASS OF THE 1940 YEAR CLASS

Area	Date (Month) 1942	Mean Body Length (cm/2)	Mean Calc. Length at end of 1st year (cm/2)	No. of Samples
Galesville	March	58.0	23.9	93
Flag Pond	June	55.3	18.0	132
Great So. Bay	May	56.7		190
Montauk	May	53.5	18.0	91

FIGURE 2



Percentage Frequencies of Calculated Length at the End of First Year and Total Body Length at Time of Capture, Determined from Chesapeake Bay and Atlantic Ocean Catches.

interesting contrast to this correlation is shown by the Flag Pond collection, however. This collection, a random sample made in March, yielded significantly higher values for both body length and calculated length, than either of the other collections, which were made in May and June.

Indications of Compensatory Growth.

Data obtained in the preliminary phase of this study proved the existence of a definite compensation in growth between large and small yearling striped bass. The smaller juveniles consistently showed a greater increment in body length during the second year than the larger ones. A complete compensation did not occur, however, since the growth advantage of the larger juveniles was maintained, but the length increments were markedly smaller. A total of 89 fish were used in the preliminary study of this phenomenon, and in order to check the existence of a compensation during the third growth period, 100 random samples of the 1940 brood were collected from pound nets in the Galesville area in July, 1942. Analysis of these scales showed compensation to be present, but to a much lesser degree. Table VII presents the increment values for the second year, and for the third year up to the time of capture. Figure 3 is a graphical representation of this data. The reduction in the slope of the line showing the third year increments indicates a lessening of the tendency toward compensation.

Age Composition of Commercial Catches.

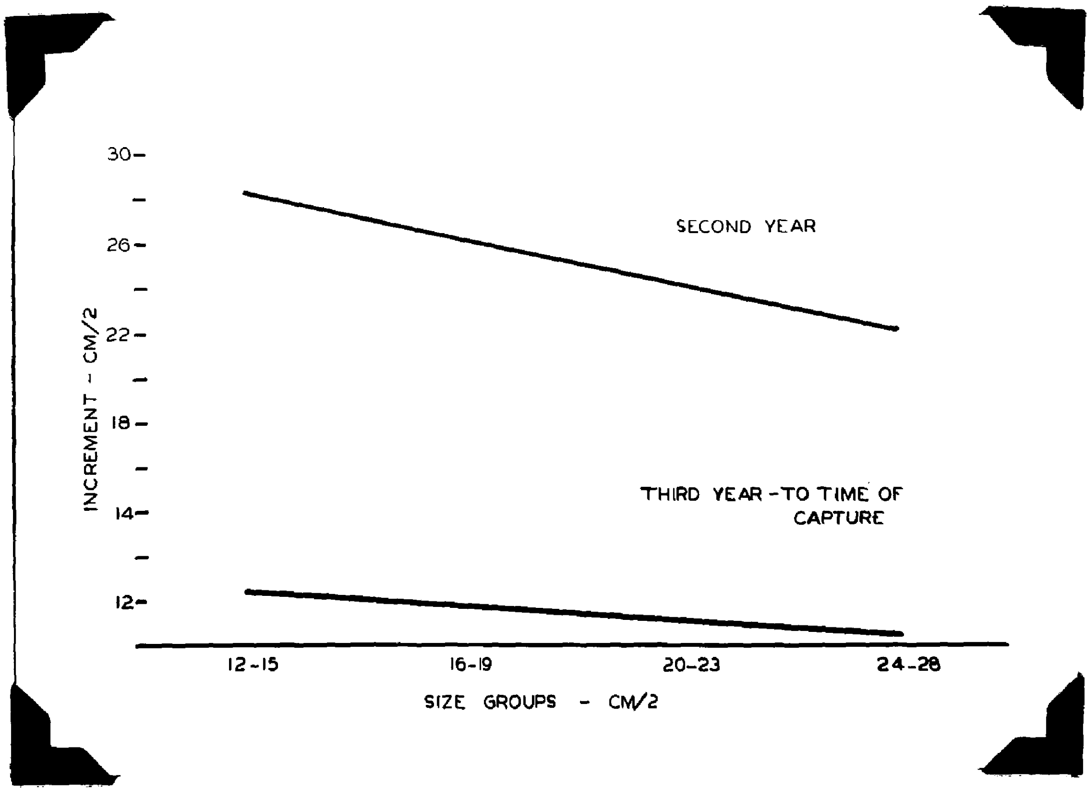
The marked fluctuations in abundance characteristic of the striped bass have already been mentioned in the introductory discussion of the fishery. Occasionally, extremely successful spawning has resulted in the production of what is termed a "dominant year class", so called

TABLE 7

REPRESENTATION OF COMPENSATORY GROWTH OF STRIPED BASS OF 1940 BROOD DATA OBTAINED FROM 100 RANDOM SAMPLES COLLECTED IN JULY, 1942, FROM POUND NETS IN THE GALESVILLE AREA.

Mean Calculated Length at end of 1st Yr. (cm/2)	Mean Increment in 2nd Yr. (cm/2)	Mean Calculated Length at end of 2nd Yr. (cm/2)	Mean Increment to time of capture (cm/2)
12-15 (28 fish)	29.1	42.9	10.3
16-19 (34 fish)	25.9	43.3	9.8
20-23 (25 fish)	25.1	51.9	9.5
24-28 (13 fish)	19.7	52.9	8.5
Total - 100			

FIGURE 3



Indications of Compensatory Growth, Obtained from Body Length Increments During Second Year, and Third Year to Time of Capture.

because its members dominate the commercial catches for several reasons. A "bumper crop" of this type occurred in 1940. Tables VIII, IX, X, and XI indicate the rate at which the 1940, 1941, and 1942 and 1943 broods entered the commercial pound net catches of Maryland waters, and their rate of utilization. Table III, referred to previously in the section devoted to the selection of a reliable gear for sampling, presents the age composition of collections from various other types of gears and other areas. Figure 4 is a graphical representation of the material included in the first four tables listed above, and shows clearly the variation in size of succeeding year classes. The 1940 brood, which entered the fishery in the fall of 1941 as ten to eleven inch yearlings, survived to dominate the catch during 1942 and 1943, and made up a significant part of the catch during 1944 and 1945. The 1941 year class showed a typical variation in the success of spawning, and remained consistently low from the time it appeared in the fall of 1942, until it had virtually disappeared in 1945. Only once during the four years in which the members of this brood appeared in the samples did they comprise more than 20 per cent of the total catch. The 1942 brood again showed the marked fluctuation characteristic of this species, and although not as large as the 1940 group, made a considerable contribution during the fall of 1943 and the entire year of 1944. A sharp drop, indicating nearly complete utilization of the brood, occurred in 1945. Only a relatively few samples were obtained for the 1943 year class, but they indicated relatively successful spawning, considerably better than the 1941 brood, and nearly on a par with the 1942 year class.

The reason for these fluctuations in abundance, characterized by the occasional appearance of dominant broods, has been the subject

TABLE VIII

AGE COMPOSITION OF SCALE COLLECTIONS FROM POUND NETS IN THE FLAG POND AND GALESVILLE AREAS OF CHESAPEAKE BAY

Date (Month)	1939 Brood No.	1939 Brood %	1940 Brood No.	1940 Brood %	1941 Brood No.	1941 Brood %	R. F., others* No.	R. F., others* %	Total No. Samples	Area
1941 Collections.										
Nov.	12.	10.9	94	85.4			4	3.6	110	Flag Pond
1942 Collections.										
Mar.	5	12.2	36	87.8					41	Flag Pond
June	43	9.7	387	87.3			13	2.9	443	Galesville
June	8	6.9	107	93.1					115	Flag Pond
July	4	4.0	91	91.0			5	5.0	100	Galesville
Aug.			18	90.0	2	10.0			20	Flag Pond
Sept.	3	4.9	52	85.3	3	4.9	3	4.9	61	Flag Pond
Oct.	1	1.3	67	89.1	3	3.9	4	5.2	75	Flag Pond
Nov.	5	4.5	96	87.3	3	2.7	6	5.5	110	Galesville
Nov.	6	6.0	92	92.0	1	1.0	1	1.0	100	Flag Pound

* R. F. -- indicates regenerated focus.

TABLE IX

AGE COMPOSITION OF SCALE COLLECTIONS FROM POUND NETS IN THE FLAG POND AND GALESVILLE AREAS OF CHESAPEAKE BAY

1943 Collections.

Date (Month)	1940 Brood No.	%	1941 Brood No.	%	1942 Brood No.	%	R.F., Others* No.	%	Total No. Samples	Area
May	75	75.0	18	18.0			7	7.0	100	Galesville
Aug.	103	20.2	66	12.9	327	64.1	14	2.7	510	Flag Pond
Sept.	4	3.7	14	13.0	87	80.6	3	2.7	108	Flag Pond
Sept.	7	12.7	6	10.9	42	76.4			55	Galesville
Oct.	59	33.5	8	4.5	105	59.7	4	2.3	176	Flag Pond
Oct.	3	6.0	4	8.0	43	86.0			50	Galesville
Nov.	7	12.7	2	3.6	46	83.6			55	Flag Pond

* R. F. -- indicates regenerated focus.

TABLE X

AGE COMPOSITION OF SCALE COLLECTIONS FROM POUND NETS IN THE FLAG POND AND GALESVILLE AREAS OF CHESAPEAKE BAY

1944 Collections.

Date (Month)	1940 Brood No.	%	1941 Brood No.	%	1942 Brood No.	%	1943 Brood No.	%	R.F., others* No.	%	Total No. Samples	Area
Mar.	20	60.6	3	9.0	10	30.3					33	Galesville
May	3	7.5	4	10.0	24	60.0			9	22.5	40	Flag Pond
June	5	20.0	2	8.0	12	48.0			6	24.0	25	Galesville
June	13	23.6	18	32.1	23	40.7			2	3.4	56	Flag Pond
Aug.	6	10.2	3	5.1	44	74.6	6	10.2			59	Flag Pond
Sept.	1	2.8	3	8.3	11	30.5	21	58.3			36	Flag Pond
Oct.			1	2.9	8	22.9	26	74.6			35	Flag Pond
Nov.	25	15.1	13	7.9	79	47.9	44	26.7	4	2.4	165	Flag Pond

* R. F. -- indicates regenerated focus.

TABLE XI

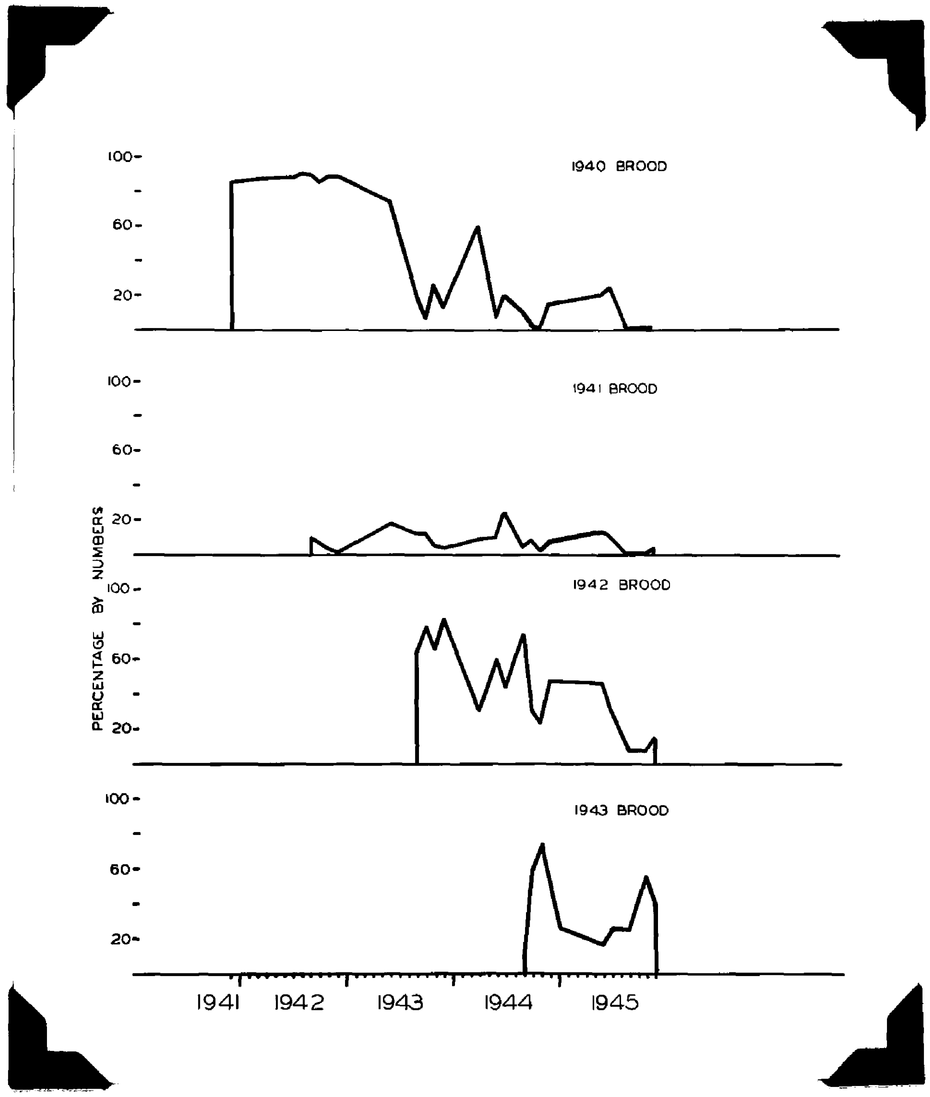
AGE COMPOSITION OF SCALE COLLECTIONS FROM POUND NETS IN THE FLAG POND AND GALESVILLE AREAS OF CHESAPEAKE BAY

1945 Collections.

Date (Month)	1940 Brood No.	%	1941 Brood No.	%	1942 Brood No.	%	1943 Brood No.	%	1944 Brood No.	%	R. F., others* No.	%	Total No. Samples	Area
May	15	20.5	10	13.7	34	46.6	12	16.4			2	2.7	73	Flag Pond
June	5	25.0	2	10.0	6	30.0	5	25.0			2	10.0	20	Flag Pond
Aug.					1	8.3	3	25.0	8	66.7			12	Flag Pond
Oct.	1	.8			10	8.0	66	55.9	36	30.5	5	4.2	118	Flag Pond
Nov.	1	.7	5	3.2	24	15.4	61	39.1	58	37.2	7	4.5	156	Flag Pond

* R. F. -- indicates regenerated focus.

FIGURE 4



Age Composition of Pound Net Catches from Flag Pond and Galesville Areas of Chesapeake Bay, October, 1941 to November, 1945.

of much study by fishery biologists. Merriman (1941) found a close correlation between the production of such broods, and below-mean temperatures preceding and following the spawning season. Data indicating the deviations from normal in air temperature and precipitation is summarized in Table XII. These figures were obtained from the records of the U. S. Weather Service station at Solomons, Maryland, and from the Maryland-Delaware area reports. Water temperature records in the Solomons area are not of sufficiently long duration to establish a normal, but on the basis of a seven-year average, the trends were as follows:

Year	April	May	June
1940	cool	cool	cool
1941	warm	warm	average
1942	warm	warm	average
1943	cool	average	warm

Salinity variations were also considered, and on the basis of short term records from the Solomons area, the variations in salinity from the mean are as follows:

Year	April	May	June
1940	low	low	average
1941	high	high	high
1942	high	high	average
1943	low	low	low

Water temperatures and salinity values at Solomons appear to be somewhat cumulative of weather conditions, but in the shallower areas of the spawning grounds, water conditions might be expected to coincide more closely with the weather.

The air temperature data obtained from both the Solomons and Maryland-Delaware records presents a very good correlation between low temperature and the appearance of the dominant 1940 brood of rock. Subnormal temperatures are indicated for April and May in both sets of records, and values which were only slightly above normal were obtained

Normal
Md.-Del.

1940	48.1	4.0	62.0	0.7	71.8	1.1	5.89	2.31	4.60	1.10	2.16	1.82
1941	56.8	4.6	64.3	1.6	70.5	0.2	2.97	0.59	2.26	1.22	4.92	0.92
1942	55.7	3.4	66.3	3.5	72.2	1.4	1.10	2.41	3.88	0.39	4.01	0.01
1943	48.6	3.6	64.6	1.8	76.6	5.7	3.23	0.28	4.67	1.15	2.75	1.22
1944	51.0	1.2	68.4	5.5	72.5	1.6	4.18	0.66	2.31	1.18	3.06	0.89

Solomons Normals are for 47-year period, 1892-1938.

Maryland-Delaware Normals are calculated for period up to year given and so vary slightly from year to year.

Dep. - departure from normal In. - inches for the month of June. The water temperature records from the Solomons area are even more positive in their correlation, and tend to support Merriman's hypothesis mentioned in the preceding paragraph. The very markedly sub-normal production in 1941 further supports this idea. Both air and water temperature records show above normal values for April and May, and almost exactly average values for June. There is, however, some contradiction in the more successful spawning which occurred in 1942 and 1943. Although neither of these two broods were large enough to be considered dominant, both were very considerably larger than the 1941 brood, and both made major contributions to the commercial catches. With the exception of the air and water temperature values obtained for the month of April, 1943, average or above average temperatures were obtained in all instances.

A factor not considered by Merriman in his investigations is the possible effect of salinity variations on the success of spawning. Abnormally high or low precipitation during the spawning season could unquestionably cause salinity variations in the shallow waters of the spawning grounds. Heavy rainfall, and correspondingly low salinity values are indicated for the months of April and May, 1940, in the Solomons area, and average values for June. A correlation supporting the possible importance of salinity fluctuations appears in the 1941 data. In April, May, and June, 1941, the salinity values were all above normal. Again, however, the relatively successful spawning in 1942 and 1943, is somewhat contradictory. Both of these seasons were almost equally productive, yet conditions of salinity were almost exactly opposite.

DISCUSSION

Rate of Growth.

Definite conclusions regarding controlling factors in growth cannot be drawn from the data included in this study. If, for instance, the effects of environmental competition were considered a possible factor, the parallel slopes obtained for the growth rates of the 1940 and 1941 broods (Figure 1) would tend to confuse the issue, since the former is a dominant year class, and the latter a definitely sub-normal contributor to the rock populations. Theoretically, on the basis of competition, the 1941 brood should have achieved much greater growth than the 1940 fish, and both the 1942 and 1943 classes should have been in closer coincidence with the 1940 brood. Merriman, from analyses of Connecticut collections, (1941) found that the members of the dominant year class of striped bass of 1934 were consistently smaller than the fish of the 1933 or 1935 year classes. His observations also indicated that this below-average length was developed before the fish became two years old. These facts would tend to support the idea of competition, an idea which has been advanced by investigators studying the dominant year class phenomenon in other species. Jensen (1932) in the course of studies on the plaice (Pleuronectes platessa) of the North Sea found that retarded growth was characteristic of dominant year classes in that species. He advanced the theory of competition for food among fish of the same size group as a possible explanation of the growth effect.

Data on the relative abundance in the Chesapeake area of plankton and small forage fish which constitute the food of young rock is unfortunately not available, and until such information is obtained, only hypothetical conclusions can be drawn in regard to the importance of food competition as a controlling factor in growth rate.

Evidence of Chesapeake Origin of Atlantic Stocks of Striped Bass.

The variations in body length and calculated length indicated in the data presented in the section devoted to analysis of data indicated the presence of at least two sub-populations of rock in the Chesapeake Bay, characterized by different rates of growth.

The possible presence of these sub-populations greatly increases the complexity of the problem of origin, and makes positive identification of any one Bay group with a corresponding northern group extremely difficult.

Several conclusive facts, however, do indicate strongly the northward migration of rock from the Chesapeake Bay.

First, a coincidence of dominant year classes is observed between the northern waters and Chesapeake Bay.

Second, an absence in northern waters of sufficient juvenile and yearling fish to account for the volume of the catches.

Third, two-year old bass suddenly appear in northern catches in the spring following their appearance as yearlings in the Chesapeake during the preceding fall.

Fourth, the only other possible source would be from North Carolina, and by direct scale measurements, Merriman (1941) eliminated this area as a significant contributor to the northern catches.

A tagging experiment giving conclusive returns from outside the Bay would be the only method by which this hypothesis could be proved. It does seem safe, however, to assume that the most rapidly growing fish are non-migratory, and that the smaller, more slowly growing group is probably the migratory one.

Merriman's study included a comparison of the width of the growth zones of scales of striped bass taken in three northern areas, and in the northern and southern regions of Chesapeake Bay. All had markedly similar first growth zones, but since his samples included fish having three and four growth zones on the scales, there was a possibility that the Chesapeake collections might have been composed of migrants from the outside. It has already been indicated that rock apparently leave the Bay when two-year olds, and a collection of four-year old fish might well contain individuals entering from other areas, as well as returning Chesapeake populations.

Indications of Compensatory Growth.

Two independently operating factors in the environment or life history of the individuals exhibiting this compensation may be offered in explanation. These are, in the case of the striped bass, the time of spawning and the individual growth capacity. These two factors were discussed at considerable length in the preliminary study (Tiller, 1942), and will be only briefly summarized here.

The first factor, the length of the spawning season, which extends from April through June, make possible a time advantage of three months for the earliest spawned juveniles to establish themselves with little competition in the environment. It is universally recognized that different individuals of the same species, subjected to similar environmental conditions, will exhibit wide variations in growth. This individual growth capacity, the second factor offered in explanation of compensatory growth, can only be attributed to a highly efficient physiological adjustment. If these two factors are considered to function independently, a number of combinations can be expected, with wide variations in growth in various individuals.

The markedly reduced compensation in the third growing period up to the time of capture may possibly be explained on the basis of a closer correlation in total body length between the largest and smallest fish. Although the range of calculated lengths at the end of the second year is only slightly less than at the end of the first year, the proportionate body measurements are much more closely grouped. This closer coincidence in body length might well exert a considerably greater competitive pressure for food, and tend to retard the growth rate of the large and small fish alike, resulting in more equalized growth increments.

Age Composition of Commercial Catches.

The wide variations in abundance of striped bass in succeeding seasons is not restricted to the populations of the Chesapeake Bay. Merriman (1941) and Scofield (1931) working with the striped bass of the Atlantic and Pacific coasts, respectively, found marked variations characteristic of the year classes which they investigated. Dominant year classes apparently occur with little relation to the parental stock. The 1934 brood was the largest to be produced on the Atlantic coast during the period for which catch records are available, although in that year the brood reserve was unusually low. The 1940 brood, under discussion in this study, although not as large as the 1934 class, was definitely a dominant one, and also arose from a small parental stock.

The data presented in the preceding section devoted to analyses tends to support to some extent the hypothesis of Merriman, which showed a correlation between below-mean temperatures before and after the spawning season. The 1940 brood was produced under conditions of this type, and the very insignificant 1941 class had exactly opposite conditions. The more successful broods produced in 1942 and 1943, under nearly similar conditions as those which obtained for the 1941 group, tended to contradict the hypothesis, however.

A correlation between low salinity and the production of the 1940 year class seemed to be indicated, and consistently high salinity values were observed for the 1941 spawning season. Again, however, the more productive spawning of 1942 and 1943 were contradictory.

From the available data, no definite conclusions can be drawn regarding the importance of these two factors, although there is strong evidence of correlation. The probable solution may be found in a complex of these and other factors. Temperature and rainfall, with the accompanying variations in salinity, turbidity and current, influence the planktonic populations which provide food for the juvenile fish. The problem may therefore be not only one of spawning and hatching of larval bass, but also one of competition and survival among juveniles.

Evaluation of the Scale Method as Applied to the Maryland Striped Bass Fishery.

A number of factors must be taken into consideration in evaluating the application of scale analyses to the striped bass fishery of Maryland. The problem of gear selectivity has already been dealt with, and it is obvious that an accurate picture of the population can be obtained only from pound nets. Only this type of gear combines regularity of operation, fixed location, long fishing season and minimum size selectivity. Samples from other types of gear are irregular in interval and locality of operation, and all exert size selectivity to a greater or lesser degree. Samples from other types of gear afford valuable supplementary data, but cannot be regarded as representative in the composition of their catches.

In addition to this easily recognized gear selectivity, there is indication of a seasonal selectivity which must be considered. During August and September, 1943, 560 samples were taken from the same nets, the collections in every case being made entirely at random. A marked decrease was observed in the percentage of 1940 fish. This brood, which during the preceding spring had comprised approximately 75% of the catch by numbers, dropped in one case to as little as 3% of the catch, averaging only about 19% of the catch for the period. In March, 1944, the percentage of 1940 fish rose again to 60%, dropped again during the summer months, and rose again during the following winter and spring. Each successive peak was lower than the preceding one, indicating a gradual utilization of the brood. The seasonal decreases during the summer months did not occur until the third year of life, when the fish had reached an average weight of approximately two pounds. It is common knowledge that striped bass simply do not trap as readily during the summer months as in the colder months of fall and winter. Commercial fishermen firmly maintain that "big rock won't trap", and as a seasonal phenomenon this is unquestionably true. The larger fish are undeniably later in making their appearance in the fall pound net catches.

During the summer months of 1943, and during the early fall months of that same year, haul seines and hand lines took a somewhat larger percentage of the larger fish (1940 brood) than did the pound nets. A satisfactory explanation for this tendency is not available. If water temperature were considered the controlling factor, on the hypothesis that the fish sought deeper, cooler water during the summer, the haul seine and hand-line catches made inshore of pound nets, in even shallower water, would be contradictory. If food were advanced as an explanation, the catches of these two types of gear would again be difficult to explain.

The value of scale analyses in following the trends of fishing intensity in the striped bass fishery of Maryland can readily be seen. The State's rock fishery is prosecuted in what may well be termed a nursery area. Adult fish enter the rivers of Maryland to spawn, and the young remain in those rivers and in the waters of the Chesapeake Bay for at least two years before even a portion of them begin seaward migrations. The fishery is therefore supported to a considerable extent by small fish. In some years, as indicated by the age-composition tables included in the preceding section, nearly all of the catch is composed of yearling rock, about eleven inches in length, and weighing approximately one-half pound. Those surviving the first year in the fishery reach the "medium" market classification the following year, and during the third or fourth year become "large" rock. Male fish may spawn at two years of age, but females are typically four or five years old when they first spawn. The value of scale analyses in determining the brood stock of a population, and the rate of utilization of successive year classes is obvious. Data of this type, supplemented by accurate statistical records of the catch, yields very excellent and very sound information for the proper administration of conservation measures.

Possible inaccuracies characteristic of the scale method have already been indicated, in the discussion of the existence of sub-populations of striped bass in Maryland waters. The scales definitely do not provide an accurate index to origin of striped bass, although correlations of calculated length values indicate that a refinement of this method may offer possibilities. The scales become considerably thickened and consequently much more difficult to read after five years of age. The first annulus is often very hard to distinguish, and false annuli are much more frequently found. Regenerated scales are much more numerous on older fish than on younger ones, and decrease the usable number of samples in the collections. Only rarely, however, does a brood survive the high fishing intensity in Maryland for more than four years, and significant numbers of larger fish are seldom found in commercial catches. As a means of studying the normal course of the Maryland striped bass fishery, the scale technique is unquestionably useful and valuable.

SUMMARY

A five-year study, extending from October, 1941 , to November, 1945, was conducted in an attempt to evaluate the application of the scale technique to the striped bass fishery of Maryland. Special emphasis was placed on the rate of growth and contribution to the fishery of four successive year classes of bass appearing in the commercial catches during the summer and fall of 1941, 1942, 1943, and 1944. The possibility of using calculated length, derived from scale and body length measurements, as an index to origin of the Atlantic Coast stocks of striped bass was also investigated.

A total of 4234 samples from the Chesapeake Bay and 382 samples from the Atlantic Ocean in the areas of Long Island, New York, were collected and analyzed. Samples were in all cases taken at random from commercial catches, and measurements were made from the snout to the fork of the tail.

Cellulose acetate impressions of the scales were found to be more satisfactory for microscopical examination than the scales themselves, and were prepared by a technique introduced by Mr. R. A. Nesbit, of the Fish and Wildlife Service.

Preliminary studies indicated that calculated length values, obtained from the formula introduced by Einar Lea (1910), varied considerably with the body area from which the scales were taken. Three body areas were selected, one high, near the insertion of the dorsal fins; another just above the lateral line at a point directly below the posterior edge of the spinous dorsal fin; and the last area slightly below the lateral line. Scales from the middle body area were found to yield calculated length values which closely approximated the averaged values

of the other two areas.

A survey of the various types of fishing gears used in Maryland waters eliminated on the basis of size selectivity all but the pound net. Two typical centers of Maryland pound net operations were chosen for collecting the samples on which this study is principally based. Occasional collections were made from other types of gear, and from other areas, to supplement the data obtained from the pound net collections.

The rate of growth of the striped bass, indicated by length frequencies of the age classes observed in this study, was found to be highly variable. Differences in length frequency values for samples obtained from closely adjoining areas indicated the possible existence of sub-populations within the Chesapeake Bay, each characterized by a different rate of growth. This indication is not, however, conclusively supported, and until further data is obtained, cannot be accepted as more than a hypothesis. Generally the growth rates appeared very reasonable and reliable. A close coincidence was observed in the size of all year classes at the time of their entry into the fishery. Slight variations in the rate of growth of the four broods under consideration were indicated in a graphical representation of the data. This apparently was not a function of the size of the year class, since the dominant 1940 brood and the decidedly sub-normal 1941 brood both had slightly faster growth rates than the 1942 and 1943 broods, which were of intermediate size.

Frequencies of body length and calculated length for the first year were determined for samples of the 1940 year class taken in 1942 from two pound net areas in the Chesapeake Bay, and from ocean catches in the area of Long Island, New York. A very close correlation was observed between the northern series and one of the Chesapeake series, but the other Bay sample yielded significantly higher values for body length and calculated length. Although unsupported by conclusive evidence, this difference would indicate the existence of at least two populations of bass in the Bay, each having a characteristic rate of growth. Although only a tagging experiment giving returns from outside the Chesapeake Bay could positively identify a migrant population, it seems logical to assume that the more slowly growing fish are migratory, while the rapidly growing group is the non-migratory one. Further indication of the Chesapeake origin of northern stocks is indicated by the coincidence in time of appearance of dominant broods in the Chesapeake and along the upper Middle Atlantic coast, and by previous investigations which eliminate other areas on the basis of scale sculpture and lack of sufficient juvenile stock.

Preliminary studies included the analysis of 89 samples of the 1940 year class to determine the variation in growth rate of large and small juveniles during the second year. A definite compensation was found to occur, since the smaller juveniles consistently showed larger growth increments during the second year than the larger ones. Analysis of 100 random samples of the 1940 brood during 1942 showed a decrease in the degree of compensatory growth during the third year. The growth increment from the end of the second year to the time of capture was more nearly equal in small and large fish, although the small fish still showed definitely more growth.

The characteristic fluctuations in abundance of the striped bass was observed in the analyses of age composition of the catches during the five-year period of this investigation. The 1940 brood, which appeared in the catches in the fall of 1941, was a dominant year class, and survived as a major contributor to the catch until 1944. During 1944 and 1945, the brood still comprised a significant part of the catch, but was replaced by the 1942 and 1943 broods. The 1941 brood exhibited the characteristic variation in abundance of the species, and remained consistently low from the time it appeared in 1942 until it disappeared in 1945. The 1942 and 1943 broods were not dominant groups, but were relatively successful, and made up a considerable portion of the catch during 1943, 1944, and 1945. The origin of dominant year classes is not well understood, and apparently such "bumper" broods can arise with little or no relation to the amount of parental stock. Correlation between weather conditions has been advanced as a possible explanation, but analysis of Chesapeake area weather records showed decided inconsistencies. A possible correlation existed between below-mean temperature before and after the spawning season, but contradictory evidence was present. Salinity records also were considered, and again interpretation of the data was questionable. There was an indication of correlation between low salinity and the production of a dominant year class, but exactly opposite conditions present in the relatively successful spawning of the 1942 and 1943 year classes tended to contradict this correlation.

Evaluation of the scale technique as applied to the Maryland striped bass fishery must take into consideration the gear selectivity, the seasonal selectivity and the high intensity of operation characteristic of the area. The scale technique tends to become inaccurate after about five years of age, but fish rarely survive the fishery in significant numbers for more than five years, and the method is therefore applicable and practical for studying the normal course and rate of utilization of the broods of bass in Maryland waters.

CONCLUSIONS

(1). Pound nets are the only type of gear employed in the Maryland fishery which combine regularity of operation, fixed location, long season, and minimum size selectivity, and therefore provide the most reliable source for obtaining representative samples of the striped bass population.

(2). Scales from extreme body areas, either high or low on the body, yield inaccurate values of calculated length. Scales from the middle region, on the second and third row above the lateral line at a point between the spinous and soft dorsal fins, give calculated values which closely approximate the averaged values of the extreme areas. The variation is a function of scale size, smaller scales yielding lower values, and larger scales higher values for calculated length.

(3). The rate of growth, indicated by length frequencies of the age classes investigated, appears to be variable. There is a close coincidence in the size of the fish at the time of their entry into the fishery, and a degree of coincidence is apparent between the rates of growth of successive year classes. Variations which occurred were independent of the size of the year class, since dominant and sub-normal broods showed closely parallel rates of growth.

(4). There is strong evidence of the Chesapeake origin of northern stocks of striped bass on the basis of correlation between Chesapeake and Long Island collections. Variations in frequencies of body length and calculated length for the first year indicate the possible existence of sub-populations in the Bay, characterized by different rates of growth. Positive identification of any one Bay population with a corresponding northern group is therefore extremely difficult, but it seems safe to assume that the more rapidly growing fish are non-migratory, and the smaller, more slowly growing ones are probably migratory. A tagging experiment giving conclusive returns from outside the Bay is the only method by which this hypothesis could be proved.

(5). A definite growth compensation occurs in the second and third years. The smaller juveniles consistently show greater length increments than the larger ones, but this tendency is less marked in the third year than in the second. A complete compensation does not occur, since the growth advantage of the larger juveniles is maintained.

(6). Marked fluctuations in the size of year classes is characteristic of the striped bass, and occasionally dominant broods arise with no apparent relation to the amount of parental stock. There is a possible correlation between the production of dominant year classes and below-mean temperatures preceding and following the spawning season. A correlation between the production of the dominant brood of 1940 and low salinity during the spawning season is also apparent, but contradictory data in both cases renders these correlations questionable.

(7). Seasonal selectivity of age classes occurs in the pound net fishery. During the summer months the percentage of large striped bass taken in pound nets is not as high as in haul seine and hand-line catches. The fact that the catches of these latter types of gear are often made in pound net areas eliminates water temperature and food habits as possible causes for the selectivity.

(8). Thickening of the scales with increasing age tends to obscure the first

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annulus, and make age determination more difficult, but up to the fifth year the technique is accurate and reliable. The number of regenerated scales increases with age, but neither of these factors is of any great consequence in the Maryland fishery since individual year classes, in significant numbers, rarely survive the high fishing intensity for more than four years.

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