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THE STRIPED BASS
Roccus saxatilis

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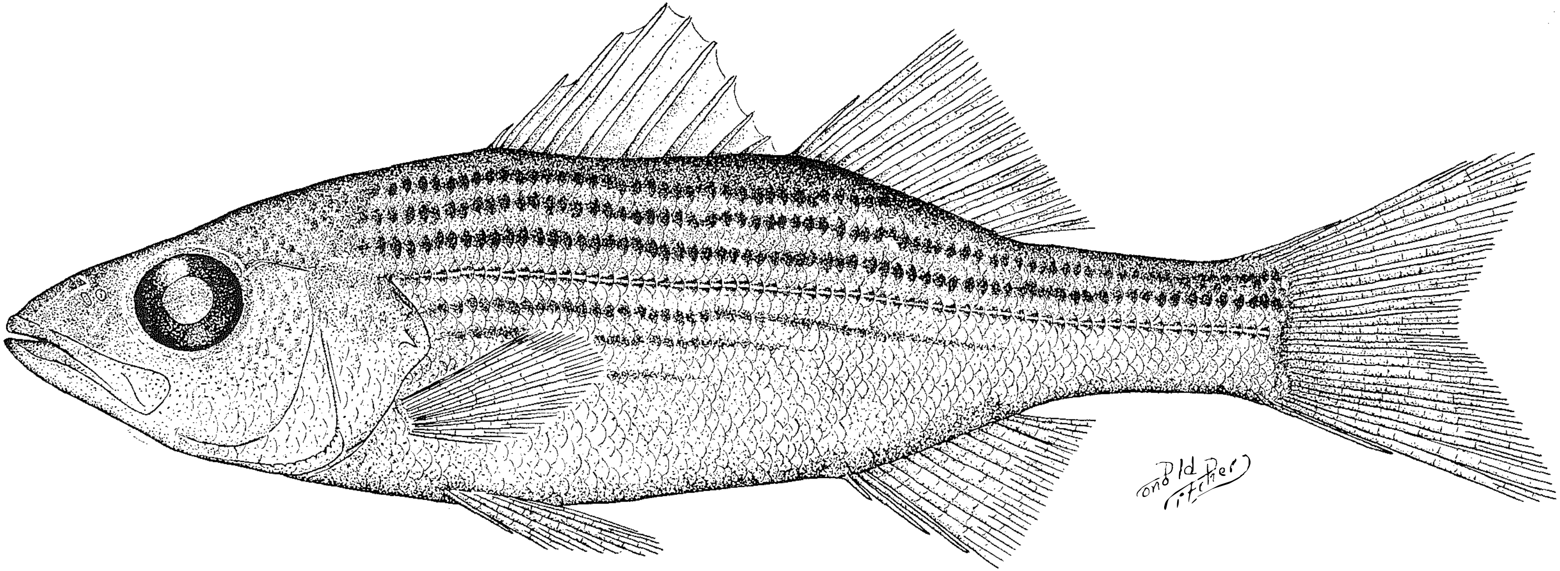

Striped bass, drawn from a specimen 4 inches in standard length.

From "Studies on the Striped Bass (*Roccus saxatilis*) of the Atlantic Coast," a dissertation presented to Yale University in candidacy for the degree of Doctor of Philosophy by Daniel Merriman, June 1938.

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THE LIFE HISTORY OF THE STRIPED BASS, *ROCCUS SAXATILIS* (WALBAUM)

By

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ABSTRACT

The striped bass, *Roccus saxatilis*, is important to both commercial and sporting interests on the Atlantic and Pacific Coasts of North America. This study reviews the literature dealing with its biology, notes the research projects now under way, and makes recommendations for future research.

Keys give characters by which this fish may be separated from its relatives; there are also references to published descriptions and illustrations of the eggs, larvae, postlarvae, young, yearling and adults. Racial studies indicate that the soft dorsal rays, anal rays, and pectoral rays give some promise as a means of separating different populations. A study of the growth rates, as revealed by the scales during the first two years, indicates the possibility of identifying various stocks.

On the Atlantic Coast the striped bass is distributed from the St. Lawrence River to the St. Johns River in northern Florida and in the Gulf of Mexico from western Florida to Louisiana. Introduced in the Pacific in the last quarter of the nineteenth century, it now occurs from southern California to the Columbia River, Oregon. In salt water it is coastwise in distribution. Freshwater populations consist of spawning fishes, usually found near the mouths of rivers, and other stocks which are found upstream as much as 200 miles from salt water.

Bass travel in large schools, especially after reaching two years. Considerable tagging was done from 1933 to 1940, and additional tagging, in a less systematic manner, is under way at present. These studies have shown that striped bass move out of wintering areas, such as Chesapeake Bay and more limited regions in New Jersey and New York, in early spring and travel northeastward to New England and perhaps to southern Canada. Here this stock mingles with more limited groups of bass that have overwintered in rivers from the Hudson northward. Some populations, such as those found in Nova Scotia, New Brunswick and the St. Lawrence River, may be indigenous, but additional research is needed to prove this point. In September and October the bass move southwestward to New York, New Jersey, Chesapeake Bay and possibly to North Carolina, reaching the south in November or December. These seasonal migrations are made by bass two or more years old. Most of the basic migratory stock, at least for the large 1934 and 1940 year-classes, appears to have been produced in the Chesapeake Bay region. Additional studies are now needed to determine if more northerly localities, such as the Hudson River, are also important producers of migratory stock. Details of schooling and migration in Chesapeake Bay are given. The available data indicate that North Carolina bass contribute little to migratory schools which move northward into New England and have little exchange with Chesapeake Bay populations. The results of tagging in California and Oregon are also discussed.

The composition of schools by sex varies somewhat with the season. Males comprise 55 % of all bass sexed in Chesapeake Bay; however, the sex ratio varies from

about 50–50 in August to 83 % males in March. In the north, 90 % of those taken in summer from Long Island and New England are females.

Striped bass reproduce in fresh or virtually fresh river water from April to July. No way is known by which the sex may be determined externally. Immature ovaries have ova no larger than 0.29 mm, while mature ovaries have eggs 1.0 mm or over, these averaging 1.35 mm before spawning. The large ova are evenly distributed through the ovary. Female bass do not always spawn every year. The number of eggs produced varies with size; 14,000 are produced by a three-pound female and nearly 5,000,000 by a 50-pound specimen. Some females reach maturity at four years, more than half are mature at five years, and virtually all are mature at six. Most males are mature at two and all are mature at three years. Most males spawn at a length of 10 inches or more, and most females are mature at 17 to 18 inches. The spawning migration occurs mostly in April and May and consists of fishes that are virtually ready to breed. Spawning grounds vary somewhat from riffles in turbulent areas to relatively quiet tidal areas. Principal nursery and spawning grounds on the east coast are Chesapeake Bay and its tributaries, Pamlico Sound, North Carolina, upper Delaware Bay, and the lower Hudson River. Although occasional spawnings may occur in the rivers of Connecticut and more northerly areas, these waters seem to be of only minor importance as far as production of the major stock is concerned. On the west coast, the lower reaches of the Sacramento and San Joaquin Rivers, California, and Coos River, Oregon, are important spawning sites. Spawning, varying from early April in Alabama to June and early July in New Brunswick, occurs mostly when the water temperatures range from 58 to 70° F. At spawning, a single large female is surrounded by a few or many (up to 50) males. The eggs, deposited near the surface during the splashing which accompanies the so-called "rock fights," are spherical, nonadhesive, slightly heavier than fresh water, greenish in color, and contain an amber oil globule. Shortly after laying they are about $\frac{1}{16}$ of an inch in diameter. The incubation period varies with temperature, being about 48 hours at 64° F. The young average from two to five inches at the end of the first year. Artificial propagation has been carried on for many years at Weldon, North Carolina, but with varying success and dubious results in increasing the stock.

The striped bass is voracious and carnivorous; it feeds mostly on other fishes, but it also takes considerable quantities of invertebrates, especially crustaceans. Members of a school normally feed periodically and at about the same time. Young bass in salt water feed chiefly on shrimp, other crustaceans and marine worms; when about three inches in length they shift largely to a diet of small fishes. In Connecticut the silverside is the most common summer food; menhaden, killifish and shrimp are also important items. In Chesapeake Bay, anchovy, menhaden, spot and croaker are eaten most often. Invertebrates, mostly crustaceans, are also eaten, but they occupy a negligible percentage by weight. Seasonable food habits and the variations in feeding in the fresh and salt water of Chesapeake Bay are reviewed. Most of the fishes eaten by striped bass are gregarious forms and most of them are not important as sport or commercial food fishes. In Oregon and California some young salmon and trout are taken at the time when they are making their seaward journey. Spawning bass eat little or nothing.

The methods of determining age by studies of scales, length-frequency distributions, otoliths, and opercles are discussed. The annulus of the scale is formed

with resumption of growth in the spring. The validity of the scale method has been demonstrated from recoveries of tagged bass a year or more later. Several types of false annuli have been noted. It is difficult to age bass more than ten years old. Growth of east coast bass is similar to that of California bass. Slight increase in length occurs in winter. The top weight of striped bass is about 125 pounds; most of those caught by anglers at the present time are less than 55 pounds.

The available data indicate a rather gradual decline in numbers from colonial times to the present, broken occasionally by unusually succesful hatchings which have produced dominant year-classes. These large year-classes may be produced when the stock of large adults is low—e.g., in 1934 in the Chesapeake Bay area. For Chesapeake Bay, unusually successful year-classes are known for 1934, 1940, 1942 and 1943. Much of the recent abundance along the New England Coast appears to have resulted from the migration of bass two years old and older from Chesapeake Bay and perhaps from other spawning areas as well. The combination of biological, chemical and physical conditions which make for a dominant year-class are not understood, although there has been a correlation with subnormal air temperatures in a number of years. Pollution, silting, dam building, and over-fishing are assessed as causes of depletion of the striped bass stock. The history of the fishery in the east and its introduction and increase on the west coast are reviewed, and statistics of the commercial fishery are given. Parasites, diseases, and abnormalities are treated briefly.

INTRODUCTION

The striped bass, *Roccus saxatilis,* is one of the most valuable anadromous and coastwise fishes found on the coasts of North America, especially in the area from North Carolina to Maine. Its history, like that of many other anadromous fishes, has been marked by a rather steady decline over the past hundred years or more. This decline has been broken only occasionally by the production of an unusually large or dominant year-class, such as the one that was produced in the Chesapeake Bay area in 1934 and which chiefly supported a large sport and commercial fishery during 1936 and 1937. Just prior to 1934 the stock of the striped bass reached an all-time low, and biological studies of this species were undertaken in the Chesapeake Bay region by the U. S. Bureau of Fisheries. In 1936 the Chesapeake Biological Laboratory of the Maryland Department of Research and Education began a study of striped bass of the Chesapeake Bay area, and in the same year, with the support of the Connecticut State Board of Fisheries and Game, Daniel Merriman started a study of the striped bass of the Atlantic Coast. For several years these studies were prosecuted with much energy and ability and use was made of some of the newer methods that had been developed in the field of fishery biology, such as scale analysis and tagging. Some of the important findings were published by Pearson (1938) and

Merriman (1937a, 1937b, 1938, 1941). Truitt (1937) and Truitt and Vladykov (1936, 1937) gave some of the preliminary results of studies on striped bass of Chesapeake Bay. More recently Tiller (1950) has studied the Chesapeake Bay fishery, and papers by Tresselt (1952), Hollis (1952) and Vladykov and Wallace (1952) are included in this volume. Jackson and Tiller (1952) have reported on spawning potential.

In California, the introduced striped bass became an object of considerable study and a number of papers were published, that by Scofield (1931) being the first important biological treatise.

Since 1940, little work has been done on the biology of the striped bass in the east except for the studies by Tiller (1950) and Tresselt (1952). A number of successful spawnings and survivals, such as those of 1940 and 1942 (see Tiller, 1950), occurred in the Chesapeake Bay area, and possibly there were others that were not studied. In general, striped bass fishing since 1936 has been fairly good and often excellent from North Carolina to Massachusetts. The recovery of the striped bass population in the east resulted in a tremendous resurgence of interest on the part of the angling public, especially since 1949, when a plentiful supply of large bass became available during the summers. A number of sportsmen manifested an interest in having studies of the striped bass begun while the population was still large enough to be investigated so that some recommendations could be made for the conservation of this species. In February 1949 the writer was approached by Henry Lyman, publisher of the *Salt Water Sportsman* (140 Federal St., Boston 10, Mass.) and Chairman of the Striped Bass Committee of the Atlantic States Marine Fisheries Commission, and by A. Heaton Underhill, then Field Secretary of Massachusetts Fish and Game Association, with the suggestion that a preliminary review be made of the information now available. With the assistance provided through the efforts of these gentlemen, the writer undertook a survey which had the three following objectives: (1) To review the published literature regarding the biology of the striped bass; (2) to search out and evaluate unpublished manuscripts on the striped bass and to obtain their publication if feasible; (3) to review the research projects now under way on the striped bass and to make recommendations for a future research program.

The report, completed in November 1949, included several then unpublished manuscripts of Tiller (1950), as well as papers by Hollis (1952) and by Vladykov and Wallace (1952) published herewith. This report, made available to several research projects on the striped bass that have since been completed (Tresselt, 1952) or are still underway, is published herewith through the efforts of Daniel Merriman.

Also, information in the report has served as a basis for a series of popular articles by Henry Lyman which appeared in the *Salt Water Sportsman* in 1950 and 1951.

ACKNOWLEDGMENTS

It is a pleasure to acknowledge the assistance of those who helped in this task. Without the impetus and assistance of Henry Lyman and A. Heaton Underhill, the project never would have been undertaken. In Washington, D. C., conferences were held with Lionel A. Walford, Clinton E. Atkinson, David H. Wallace, Edgar H. Hollis, and later with John C. Pearson. In Yorktown, Virginia, Nelson Marshall, Jay D. Andrews, William H. Massmann, and John T. Wood of the staff of the Virginia Fisheries Laboratory were helpful. Willis King, then Chief of the Fish Division, North Carolina Wildlife Resources Commission, assisted with recent southern studies. At the Chesapeake Biological Laboratory, Solomons, Maryland, assistance was obtained from R. V. Truitt, George F. Kelly, Galen Maxfield, and L. E. Cronin. Neil D. Richmond assisted in the collection of young striped bass in the Chickahominy and James Rivers, Virginia. Collections of young striped bass made during the summer of 1949 in the Pamunkey River, Virginia have been received through the efforts of William H. Massmann. At Woods Hole, Cecil K. Drinker, John H. Cunningham, William C. Schroeder, Richard E. Tiller, and William F. Royce had many suggestions of value. On several occasions Daniel Merriman, James R. Westman and Vadim D. Vladykov freely gave the benefit of their knowledge. The following have also aided substantially: Henry B. Bigelow, John R. Greeley, Cecil Heacox, Wayne D. Heydecker, Edward E. Hueske, Herbert W. Jackson, William M. McLane, and William C. Senning. On the west coast, those who pointed out sources of information include Alexander J. Calhoun, William I. Follett, Carl L. Hubbs, Donald L. McKernan, H. John Rayner, and Richard Van Cleve.

Especial thanks are due to Daniel Merriman and Yngve H. Olsen of the Bingham Oceanographic Laboratory who have made many suggestions for the improvement of this paper.

LITERATURE

The significant references dealing with the striped bass, in whole or in part, are given alphabetically by author in the BIBLIOGRAPHY. It also seems desirable to arrange the more pertinent papers chronologically for the east and west coasts (see APPENDIX A, p. 96) and to give the best references to the various eastern geographical regions proceeding from eastern Canada to the Gulf of Mexico (see APPENDIX B, p. 97). In the introduction to each of the chapters the pertinent literature has been summarized for that particular subject. No attempt has been made to analyze the plethora of popular accounts that have appeared in the recent past, since most of them deal with fishing stories drawn from personal experiences and seem to be of little value for our purpose.

COMMON AND SCIENTIFIC NAMES

STRIPED BASS, New Jersey and northward; ROCK, south of New Jersey; STRIPER, ROCKFISH, GREENHEAD (25–60 pound specimens; Mease, 1815); SQUID HOUND (Goode, 1884). The name STRIPED BASS is used in the American Fisheries Society's "A list of common and scientific names of the better known fishes of the United States and Canada" (1948) and in the Outdoor Writers Association of America's "Standard check list of the common names for principal American sport fishes."

Roccus saxatilis (Walbaum) is apparently the first name correctly applied to the species. *Roccus lineatus* (Bloch) was used for many years, but the evidence indicates that this name was applied to a related Mediterranean species (Jordan, Evermann and Clark, 1930: 307). The synonymy is given by Jordan and Eigenmann (1890: 423), who also treat of the relationships of both American and European species. Additional synonyms are noted by Jordan and Evermann (1896: 1133) and by Jordan, Evermann and Clark (1930: 307).

RELATIONSHIPS

The striped bass is a bony fish of the order Perciformes (Acanthopterygii), family Serranidae (sea basses), a family whose members are widely distributed in tropical and warm seas, some entering fresh water. The sea basses are related to the sunfish family, Centrarchidae, but they may be separated by the characters given in Table I. The sunfishes and black basses, Centrachidae, are limited to fresh water (or slightly brackish water). The largemouth bass, *Micropterus s. salmoides* (Lacépède), is now found in the same habitat with small striped bass in many eastern rivers.

Some species of the perch family, Percidae, occasionally are found with striped bass in fresh water and may be distinguished from the latter by the presence of one or two anal spines (three in Serranidae).

The white perch, *Morone americana* (Gmelin), a related species of the sea bass family, is common in fresh and brackish water along the Atlantic Coast, and it may be separated from the striped bass by the

TABLE I. Characters Which Separate the North American Species of Serranidae (Sea Basses) from Centrarchidae (Basses and Sunfishes). After Hubbs and Bailey (1938: 6)

Serranidae	Centrarchidae
1. Pseudobranchiae present and exposed	1. Pseudobranchiae covered by a membrane
2. Most ribs attached on ends of transverse processes extending from the vertebrae	2. All but one to three pairs of ribs attached on the vertebrae
3. Small plate of bone (subocular shelf) extending under the eye from the second circumorbital	3. Small plate of bone (subocular shelf) absent
4. Supramaxilla lacking	4. Supramaxilla present

TABLE II. A Comparison of the Striped Bass, *Roccus saxatilis*, and the White Perch, *Morone americana*. After Merriman (1941: 3)

Striped Bass	White Perch
1. Dorsal fins clearly separated, not touching at base; viz. contiguous	1. Dorsal fins continuous
2. Dorsal aspect of body less arched	2. Dorsal aspect of body more strongly arched
3. Second anal spine intermediate in length between first and third anal spines, and slenderer	3. Second anal spine almost equal in length to third anal spine, and robust
4. Fin spines in general thinner and lighter	4. Fin spines thicker and heavier
5. Two sharp spines on margin of opercle	5. One spine on margin of opercle
6. Soft anal rays 10-11, normally 11	6. Usually 9 soft anal rays

TABLE III. A Comparison of the Striped Bass, *Roccus saxatilis*, and White Bass, *Morone chrysops*

	Striped Bass	White Bass
Teeth on base of tongue	In two parallel patches	In a single series
Body	Elongate, little compressed, depth less than one-third the standard length	Deep and compressed, depth more than one-third the standard length
Contour of back	Little arched	Considerably arched
Head at nape	Not notably depressed	Markedly depressed
Lateral line scales	57–67	52–58
Soft rays in 2nd dorsal fin	11–12	Usually 13
Soft rays in anal fin	10–11	12 or 13

characters given in Table II. The yellow bass, *Morone interrupta* Gill, of the Mississippi River and other Gulf of Mexico drainage systems may sometimes be taken at the same locality with the striped bass, but it differs from the striped bass in the same ways as does the white perch (see Table II). However, like the striped bass, its body has pronounced horizontal stripes. The white bass, *Morone chrysops* (Rafinesque), is also found with the striped bass in the St. Lawrence River and perhaps in the lower Mississippi River. The two may be separated by the characters given in Table III. Vladykov (1947) has given additional differences between striped bass and white bass. An early report by Roosevelt (1865) of a striped bass taken in Lake Ontario at Lewiston, reported by Jordan and Eigenmann (1890: 423) and by Jordan and Evermann (1896: 1133), may have been based on a white bass, although it is not impossible that a St. Lawrence striped bass could have moved that far.

DESCRIPTION

The best descriptions in the literature are those by: Jordan and Evermann (1896: 1132), Bigelow and Welsh (1925: 251), Hildebrand and Schroeder (1928: 247), Merriman (1941: 3), and Vladykov (1947: 197). An excellent general description of the morphological characters and of colors in life has been given by Merriman (1941: 3), who has also given the skeletal structure in detail with illustrations (1940: 55). Gregory and LaMonte (1947: 12) have illustrated the muscles and organ systems by photographs of models now on exhibition in the American Museum of Natural History.

Many photographs have been published. Walford (1931: 88) and Scofield (1931: 20) have reproduced a good photograph that has been used in many California publications. Vladykov (1947a: fig. 2) published excellent photographs of striped bass and white bass. The excellent line drawing in Goode (1884: pl. 170), made from a specimen taken in the Potomac River in the vicinity of Washington, D. C. (U. S. Nat. Mus. No. 25219), has been used in many subsequent government publications, including Merriman's paper (1941). The frontispiece in Scott (1869) figures a striped bass painted by J. B. Stearns. Color plates of the striped bass have been published by Denton (1900: 247), Smith (1907: 272, pl. 12), Greeley (1937: pl. 4), and Calhoun and Woodhull (1948: fig. 69).

Pearson (1938: 833, 834) has given line drawings of newly fertilized eggs and other stages made 15 minutes, 12 hours, 24 hours, 36 hours and 48 hours after fertilization. Merriman (1941: pl. 1, figs. A. B, and C) has shown photographs of eggs 1 hour, 17 hours and 29 hours after fertilization.

Pearson (1938: 834–836) has given excellent line drawings that show all stages, and Merriman (1941: pl. 1, figs. D, E, and F) gave photographs of larvae. Partial descriptions of eggs and fry based on fish cultural operations have been reported by Ferguson and Hughlett (1880), Worth (1882, 1883), Ryder (1887), Scofield and Coleman (1910), Bigelow and Welsh (1925), and Scofield (1931). Pearson (1938: 837, figs. 17, 18) has produced good line drawings of young 1.4 and 5 inches in length. The figures of young striped bass in Calhoun (1948: 8, figs. 3, 4) seem to be taken from Pearson (1938: 834, figs. 8, 12).

RACES

The intraspecific variation in the striped bass over its entire range has not been investigated thoroughly, although this is potentially an important matter from the standpoint of future management. However, some attempts have been made to study populations of striped bass from various localities with a view to determining their differences, if any, and the level of differentiation attained. From such studies it has been assumed that the striped bass has not differentiated into subspecies. Since any measurable or countable character may have been modified, no structure should be overlooked.

In a study of 525 Chesapeake specimens, Truitt and Vladykov (1937: 225) obtained counts of 25 vertebrae in all but one, which had 24. Vladykov and Wallace (1952), in more than 2,500 specimens, found only one individual with 24 vertebrae, all others having 25. They considered the gill raker counts to be less reliable for racial studies in striped bass; they showed that older specimens have fewer well developed gill rakers. Truitt and Vladykov (1937: 225) noted that, in 1000 bass, the first dorsal fin had nine spines, the second dorsal 11.90 soft rays, and the anal fin 10.95 soft rays. To be of maximum utility in future studies, such data should be presented as frequency distributions.

Vladykov and Wallace (1938: 76; 1952) also presented in summary form the number of soft rays in the second dorsal and anal fins of striped bass from several localities, with the mean value indicated. On the basis of these figures they stated that there are two distinct populations in the Chesapeake Bay area, namely the upper Chesapeake and James River; according to their results, there was also some indication that the Potomac River population is distinct and that the North Carolina populations are somewhat different, falling between the upper Chesapeake and the James River populations. They stated that the differences are significant, but additional studies are needed.

No progress was made by Merriman (1941: 47) on racial analysis based on fin-ray counts because of the impracticality of making such counts accurately in the field, where for the most part his specimens were tagged and liberated. However, he took scale samples from all specimens, and since conditions that effect growth rate, such as temperture and food, may differ in different localities, Merriman theorized that the scales, which reflect the growth rate, might show differences at least in the first two years before striped bass have undertaken long migrations. He showed (1941: fig. 32) that during the second summer the striped bass that were spawned in 1935 in Carrituck Sound, N. C. grew faster than those of the 1934 year-class taken farther north in Chesapeake Bay; Montauk, New York; Harkness Point, Conn.; and Cape Cod Bay. But he (1941: 49) also pointed out the possible fallacy in comparing the second year's growth from different year-classes (for example, 1934 with 1935). From material obtained in 1942 from two localities in Chesapeake Bay and from Long Island, Tiller (1950: 13) studied the growth rate of the 1940 year-class during the first two years. He found that there is a striking similarity in percentage frequencies for the two areas.

If, upon further investigation, it is demonstrated that the growth rates are significantly different in the first two years for striped bass of the same year-class from different localities, it may be an important contribution to the possible management of the species. Of course it would be necessary to carry on such an investigation for several years. It would be of interest also to compare fin ray and other counts of Pacific striped bass with those of the Atlantic.

DISTRIBUTION

General. Pearson (1938: 827, fig. 1) has given a map of the present distribution, which is coastwise in the Atlantic from the St. Lawrence River in the north to the St. Johns River in northern Florida and the Gulf of Mexico tributaries in western Florida, Alabama, Mississippi, and Louisiana. In the latter part of the last century it was introduced in Pacific waters, where it now occurs from southern California (Orange and San Diego Counties) at least to the Columbia River, Oregon, and Grays Harbor, Washington. There are unconfirmed reports from fishermen of occasional specimens taken in Alaskan waters.

Atlantic. Vladykov (1947a; 1947b: 48; and personal communication) believes that the rather large population known to be present in the St. Lawrence River is indigenous, since tagging done up to the present time has resulted in no recoveries outside of the St. Lawrence. All of those tagged in the Quebec region have been retaken within a distance of approximately 50 miles up or down stream. The early records of Jordan and Eigenmann (1890: 423) and Jordan and Evermann (1896: 1133) of striped bass from the Niagara River at Lewiston are based on Roosevelt's (1865) record, which may have been a white bass, *Morone chrysops.* According to Vladykov and McKenzie (1935: 91), striped bass were relatively plentiful in Shubenacadie River, Nova Scotia, and Grand Lake, New Brunswick. Following several years of relative scarcity, the striped bass increased sufficiently so that there was a revival of angling in Nova Scotia in 1949 and 1950 in the Annapolis and Shubenacadie Rivers. Merriman (1941: 41) feels that these populations are resident. Bigelow and Welsh (1925: 253–255) have given an excellent summary of the status of the striped bass along the shores of the Gulf of Maine. In Maine itself they are irregularly distributed and fluctuate greatly in abundance. Towne (1941), during a superficial survey of waters in Maine, took them at several places. For Connecticut there are the more recent reports of Merriman (1941, and earlier).

Its center of abundance appears to be from Cape Cod to northern North Carolina, including Chesapeake Bay, and it is in this area where most of the recent studies have been done. In the Hudson River there is a population of adult striped bass that regularly go as far upstream as Albany, New York, but according to Greeley (1937: 100) most of these are young or juvenile fish. At least two striped bass have been taken in the Mohawk River-Barge Canal in recent years, and the New York Conservationist (December–January 1950–51: 30) pictures a 13-inch specimen in its third summer taken in Niskayuna Lake above Lock 7, about 140 feet above the Hudson River level.

Pearson (1938) and Hildebrand and Schroeder (1928: 248) have given accounts of its distribution in the Chesapeake Bay region. Truitt, Wallace, and Vladykov, in various papers, have also given many data on its distribution within this Bay. Smith (1907: 271) has noted the distribution of the North Carolina population, which Merriman (1941: 42) thinks is probably different from that of Chesapeake Bay.

The large rivers of South Carolina and Georgia may have populations of considerable size, for the striped bass is known to occur there. In 1949 a large population of small striped bass was present in the Santee-Cooper Reservoir.

William M. McLane (in correspondence) has given data on five striped bass weighing from 3 to 13 pounds caught in the St. Johns River, Florida from 1946 to 1949. Apparently it has never been common there, and the species definitely avoids southern Florida.

In the Gulf of Mexico, according to Pearson (1938: 827), it is found in fresh or brackish coastal rivers west to Louisiana, but it is not known in salt water (see Jordan [1929] and Gowanloch [1933] for other references). In recent years a considerable sport fishery has taken striped bass weighing 5 to 40 pounds in the Coosa River at Wetumpka and in the Tallassee River at Tallapoosa, Alabama, which are freshwater situations several hundred miles from the Gulf of Mexico. In February 1951, Ralph Terrell captured a 25-pound specimen near Horse Bluff, in Tickfaw River, above Lake Maurepas, Louisiana; this was one of the largest bass reported from Louisiana in years. The possibility of any exchange between the striped bass populations of the Gulf and the Atlantic seems exceedingly remote.

The striped bass is definitely coastal in its habitat and is seldom found more than several miles from shore. Bigelow and Schroeder (1936: 333) mentioned the unusual capture of a six-pound fish in a gill net on Cod Ledge, 3 or 4 miles off Cape Elizabeth, Maine, in 1941. William C. Schroeder also reports (in correspondence) the unusual off shore capture by the dragger CAPTAIN BILL of a striped bass about 18 inches long taken in February 1949 some 70 miles to the southward of Block Island in about 70 fathoms. According to Schroeder this was a stray, since the fishermen could not recall having taken another during five years on the offshore fishing grounds, nor could Schroeder find a record of any taken in the 20–30 fathom zone off southern Massachusetts where many boats fish for the yellowtail during the winter. Other departures from the strictly coastal habitat of this species occur during the spring and fall migrations, when, for example, the fish cross the open (east) end of Long Island Sound.

The striped bass is at home in salt, brackish, or fresh water and has been known to survive for long periods when planted in small freshwater ponds. Bean (1903a) has reported that it will grow rapidly in freshwater ponds if sufficiently fed. In a Rhode Island pond, where food was plentiful, one is reported to have grown from a weight of one pound in June to six pounds in October. In the New York Conservationist (February–March, 1951: 34) it is reported that a 22-pound, 36-inch striped bass was recovered in Wallace Pond (fresh water) near Peekskill, New York in the fall of 1950; apparently it was the survivor of a known planting of five 12-inch bass in 1941.

The species can stand low temperatures, as witnessed by its presence in Nova Scotia, New Brunswick and in the St. Lawrence River. Also, although most of the population appears in the spring and disappears in the fall off the Niantic River, Connecticut, when the water is 42.8–45.5° F, it is well known that some fish winter in southern New England estuaries, and netters have been able to take them through the ice in most of the rivers from New Jersey northward. Off North Carolina, schools have been found moving first when temperatures were 44.6–46.4° F. The striped bass may be found at the extremes of its range at all times of the year, so it apparently has a wide temperature tolerance.

In more northerly waters it prefers rocky places where there is some current. James R. Westman informs me that there are fairly large populations in lower New York Bay and in other areas about Long Island where it is apparently able to tolerate the high incidence of domestic and industrial pollution.

The species needs a rather extensive spawning ground with some current and a nearby nursery area where food is abundant. In the east, the tidal mouths of the rivers entering Chesapeake Bay meet its requirements, and in California the lowland section of the Sacramento and San Joaquin Rivers in the San Francisco Bay area provide good spawning and nursery areas.

Pacific. In 1879 and 1881 yearling striped bass were seined from the Navesink River, New Jersey, and 435 were transported by train and liberated in San Francisco Bay. The plant was successful; in 10 years bass were available in commercial quantities, and by 1899 the commercial net catch alone was 1,234,000 pounds. By 1915 the greatest commercial catch was recorded when 1,784,448 pounds were marketed. But commercial fishing was stopped by law in 1935 in California despite the findings of biologists that the population could support both a commercial and a sport fishery. The bays and rivers near San Francisco continue to be the center of its abundance on the Pacific Coast. In California, striped bass have been taken from as far south as Orange and San Diego Counties (Calhoun, 1948), and in Oregon, according to Morgan and Gerlach (1950: 3), it is most abundant in Coos Bay, with small runs in the Coquille and Umpqua Rivers. Occasional strays have been taken in the Columbia River; in 1948 (Oregon Fish Commission Research Briefs, Vol. 2[2]: 32) several adults were captured between Vancouver and Bonneville, so it appears that it is now established in the Columbia River. In the west it is found in coastal waters, bays, estuaries and rivers.

GENERAL BEHAVIOR AND MIGRATIONS

The striped bass is a gregarious fish which travels in large schools during at least part of its life. During the first and second years they remain in small schools or feeding groups, but it has been observed that they exist in large schools by the end of the second summer. These groups may undertake general migrations of considerable magnitude (Merriman, 1941: 26). The species runs upstream to breed. While the older and larger bass may also be gregarious to some extent, they tend to lie or forage among rocks in or near the surf or at least where some current is running.

References. The following have published pertinent material concerning the migrations of striped bass: Pearson (1933a, 1938), Clark (1934, 1936), Merriman (1937, 1941), Vladykov (1947b), Calhoun (1948, 1949), Morgan and Gerlach (1950).

The following (arranged by states) have tagged fish:

Canada (St. Lawrence River): Vladykov (1947b).

Connecticut: Merriman (1937, 1941).

Massachusetts: Salt Water Sportsman (1948–51, unpublished).

Maryland (Chesapeake Bay): Pearson (1933a, 1938); Vladykov and Wallace (1938, 1952).

New York: Neville (1940); Nesbit (in Merriman, 1941); Merriman (1941); Hudson River Shad Survey, U. S. Fish and Wildlife Service (unpublished); New York Conservation Department, near Albany (unpublished).

New Jersey: Wallace and Neville (1942); Nesbit (in Merriman, 1941); Westman (unpublished).

North Carolina: Merriman (1941); Vladykov and Wallace (in Merriman, 1941).

South Carolina: U. S. Fish and Wildlife Service (spring of 1949, unpublished).

California: Clark (1934, 1936); Calhoun (1948, 1949, 1952); Calhoun, Fry and Hughes (1951: 301).

Oregon: Morgan and Gerlach (1950).

Methods of Tagging. Data on migration have been obtained in three ways: by tagging experiments, by analysis of the size and age composition of catches, and by comparison of significant changes in the commercial yields in various places. The first method gives the most information, but it is an expensive and tedious undertaking that requires centralization of records for best results.

Pearson (1933a; 1938: 842), in tagging experiments sponsored by the U. S. Bureau of Fisheries, used the modified Nesbit disc through the back and offered rewards for tags returned; he (1938: 843) indicated that the discs probably became detached after a period of time. Clark (1934: 15), with sportsmen's organizations cooperating, used external disc tags and described the precise method by which the bass were handled and tagged. Vladykov and Wallace (1938: 68; 1952) described the Nesbit modification of the Peterson disc tag and gave several refinements of the method. They also kept young specimens in tanks and noted that the disc tag inserted through the back was satisfactory. One bass was recovered three years and three months after tagging. Merriman (1937a: 27; 1941: 33, fig. 25) described the use of both the external disc and the internal tag and gave illustrations to show the point of insertion of each. He rated the external disc tag as fairly efficient and practical, providing a space of less than one-sixteenth of an inch was left between the disc and the side of the fish; additional space created friction that allowed sores to develop on the side. After the first year only a few tags were returned. Flat discs caused less irritation than saucer-shaped discs, but there was some evidence from the 1938 tagging that the latter may stay on longer. Stainless steel pins were abandoned in favor of heavier noncorrosive nickel pins (No. 20 B & S pure nickel wire) which never showed corrosion in salt water. The disc type of tag has the disadvantages of usually failing to stay on the fish for more than a year and of being impractical for tagging fish less than eight inches in length. For small striped bass, five inches and longer, the internal tag described by Merriman (1941: 36) can be used. But he received few returns and little locality-of-capture data, since most striped bass are sold in the round and the finder has no way of telling the precise date and scene of capture. This tag could be used for local studies in such places as the Hudson River, where commercial fishing is now prohibited, provided a constant effort was made to alert local anglers to the possibility of catching a tagged fish. Wallace and Neville (1942: 19), who also discussed the use of external and internal tags, inserted tags through the gill-covers of some of the larger fish. For some types of study the disc tag is disadvantageous in that there is the chance that it may catch in the thread of gill nets and thus give a false proportion of returns compared with untagged fish. These authors found that disc tags inserted through the back generally remained attached for a period of about one year but that they usually became detached after that by pulling out through the muscles of the back. They concluded that the internal tag is better for long term studies.

Calhoun, Fry and Hughes (1951: 301) have reported significant results of experiments to determine deterioration and corrosion in plastic and metal disk fish tags. For disks, cellulose nitrate, cellulose acetate, and vinylite were tried, all of which presented serious problems. Of the metal wires used with these disks, nickel and monel metal were unsatisfactory because of rapid corrosion on salt water fish and silver wire soon broke. Stainless steel and tantalum showed great promise in preliminary tests.

General Summary of Migrations. The following picture is drawn from the results of tagging by the several authors mentioned above. In their rather extensive coastal migrations, the striped bass move northward and eastward to New England in late winter or early spring from Chesapeake Bay and certain other wintering areas in New Jersey and New York; and in some years they probably travel to Canadian shores. During the summer this stock remains more or less stationary (but not always available to fishermen) in New England waters. Then about the middle of September they begin a movement southward and westward to New York and New Jersey, and by November and December they reach Chesapeake Bay and possibly North Carolina. In recent years, the angler's records corroborate the general situation of an abundance of small bass (12 to 16 inches) in the spring and again in the late fall. However, this may not always be the case. During the summer of 1949 Henry Lyman obtained data that showed the presence of a large wave of small stripers, about 14 to 20 inches in length, along the coast of New Jersey, New York, Connecticut and Massachusetts during early July. In the absence of tagging the source of these bass remains unknown. In 1950, when striped bass were unusually late in their southward migration, huge schools of small bass were observed and caught off Massachusetts, Rhode Island and Connecticut in late November and December.

Overwintering. Certain sections of this migratory group break off from the main southward run and winter in localities such as the lower Delaware River and tributaries of Delaware Bay, in the coastal rivers of New Jersey, and in the lower Hudson River, New York. Such a wintering group, consisting of hundreds of bass, was found frozen in the ice on January 26, 1939 near Stony Brook on the northern shore of Long Island (see Neville, 1940: 34). The Schaefer-Salt Water Sportsman Striped Bass Tagging Program returns reveal that many specimens tagged in 1950 in the New York Harbor area and in the vicinity of the western end of Long Island were recovered in the spring of 1951 in the Hudson River and in the vicinity of Stony Point, New York, where they probably had remained during the winter. It is also known that certain small parts of the summer stock remain and winter for at least one season in New England coastal waters from Maine to Connecticut. The Parker River, Massachusetts population is one such overwintering group, and others have been noted in recent years.

During the winter striped bass are relatively inactive and large numbers are known to congregate in deep pools near the mouths of rivers or in brackish bays and esturaries. Vulnerable to certain types of gear, many are captured by scoop nets, gigs, and similar rigs. Pearson (1933b) has described such a winter fishery in Parker River, Massachusetts, and other descriptions of the northern winter fishery have been given by Tenney (1795), Mease (1815), and Perley (1850). For many years there was a small winter fishery for striped bass in the Hudson River, but commercial fishing is now prohibited by law. Formerly the winter and spring catches consisted largely of small or medium-sized fish of three pounds or less in weight. Relatively few are taken by anglers during the winter, since the bass are quiescent and normally do not feed.

The situation is somewhat different in Chesapeake Bay, where tagging by Vladykov and Wallace (1952) showed that the striped bass move about and that many continue to feed during the winter. Indeed, certain schools are known with certainty to have moved up and down the entire length of the Bay during the winter of 1936–1937. Feeding by controls kept in tanks was also observed.

Calhoun (1948: 2) has noted that California striped bass do not feed very actively when the water is cold and that large fish may be abundant in an area during the winter when angling is poor. This was determined by netting bass for tagging. However, at times good catches have been made by anglers during the winter.

Source of Migratory Stock. Merriman (1941) and Vladykov and Wallace (1952) believe that most of the basic migratory stock is produced in Chesapeake Bay (at least this seems true of the 1934 and 1940 year-classes), but the migratory part of this population is relatively small, probably less than 10% at the two-year-old stage. Besides results from tagging experiments, the rapid increase in the catch in northern waters from New Jersey to New England coincides with the increased abundance of any given year-class in Chesapeake Bay, which is further evidence to support the above conclusion. For example, the 1934 year-class was very large in Chesapeake Bay, and this increase was reflected by increased catches in 1936 and 1937 in northern waters. Wallace and Neville (1942) gave information on the 1940 year-class in Chesapeake Bay; this year-class was also large, and subsequently there was an increase in striped bass in more northern waters in 1942. One may infer that many of the large bass caught during the past few summers may be survivors of these year-classes.

When the striped bass depart from the wintering areas in New Jersey and farther south, often as early as the first half of March, they move rapidly northward and eastward, and their run is augmented en route by wintering populations from various northern regions such as the Hudson River, Long Island, and southern New England. It is apparently true that individual striped bass, or units of the general population, do not always winter in the same region year after year. For instance, some of the New Jersey wintering stock may return to the same place after an absence of a summer while others may winter in the north or move as far south as Chesapeake Bay.

This movement of part of the two-year-old population from Chesapeake Bay north along the coast in 1942 was similar to the migration of two-year-olds which hatched in Chesapeake Bay in 1934 and occurred northward in 1936. Judging from general observations of the catch and from commercial reports, it is estimated that the run in 1942 equaled or even exceeded the spectacular run of 1936. Wallace and Neville (1942), tracing the northward movement during 1942, found that the run first appeared in New Jersey about April 15; the south side of Long Island, New York on April 19; Rhode Island on April 24; the south side of Cape Cod, Massachusetts between May 1 and 5; the east side of Cape Cod by May 25; the vicinity of the lower tip of Cape Cod near Provincetown by the first week in May; and Gloucester, Massachusetts by May 12. That same year, anglers reported first catches on May 22 at the mouth of the Merrimac River in Massachusetts, and small bass, presumably from this run, were being caught later by rod and reel in the Penobscot River, Maine. Apparently this body of small bass moved northward and eastward en masse, leaving as it went small populations all along the coast. The peak of the run at any single place was short lived, usually not over a week to ten days, so that by the end of May no small fish, or relatively small numbers of them, were caught where spectacular catches had been made in April and early May. Most of these two-year-olds were below the legal limits which prevailed in most of the states from New Jersey northward to the Canadian border.

Merriman (1941: 39) has reported that Nesbit tagged 64 striped bass in Sandy Hook, New Jersey April 22–25, 1938, and recaptures in late April and May revealed that many had gone up the Hudson River. Perhaps this was a spawning run. Recaptures made during the summer showed a movement eastward and northward along the coast.

Migration in Chesapeake Bay. The first attempt to determine the movements of striped bass by tagging was made in upper Chesapeake Bay in July and August 1931 by Pearson (1933a; 1938: 842–844). A total of 305 striped bass from 10.2 to 15.7 inches long were caught by hook and line near Hackett's Point, off Annapolis, Maryland, where they were released immediately after tagging. Within the first six months 20% were recaptured, and the total recaptures were 29% of those marked. The monthly recaptures over a two-year period indicated a northern movement to the upper part of the Bay. Only a few were recaptured to the south and no returns were obtained from outside Chesapeake Bay. Pearson (1938: 845) felt that his results showed a preference by the striped bass for fresh or slightly brackish water, since all recoveries, even those captured toward the south, were made in less brackish water. It should be remembered that these fishes were tagged when the population was very low and that results might be different when specimens from a large year-class, such as that of 1934, were foraging in the same waters.

On the basis of tagging returns, Vladykov and Wallace (1938: 67–86) have given extensive data on the movements of striped bass in Chesapeake Bay. Their observations of 1936 and 1937 indicate: 1. Schooling near the surface in open parts of the Bay from June to mid-September. 2. Inshore movement of schools from mid-October to late November. 3. General movement southward in the fall, principally along the western shore of the Bay. 4. General concentration in deeper parts of the Bay in winter though often taken in the shallows in mild weather. 5. Movement northward again in the Bay in spring. 6. Movements based on the migration of fishes on which they feed rather than on variations in salinity or temperature. 7. Movements into the Potomac River and Tangier Sound in early spring probably spawning migrations. 8. The James River school mostly a separate population. 9. Striped bass under two years of age not migratory. 10. Recapture of 42.4% of 1,563 specimens tagged from October 8, 1936 to June 3, 1937 within nine months, indicating capture of a high percentage of the bass in Chesapeake Bay.

If the tag returns are considered reliable, a relatively small part of the 1934 brood left Chesapeake Bay, yet it appears to have been enough to account for much of the increased production observed in 1936 and 1937 in northern waters. Vladykov and Wallace (1952) noted that only 28 (1.5%) of the 1,869 smaller specimens tagged in 1936 and 1937 were recovered from outside the Bay, and they infer that this outward migration is a continuation of the southward Bay migration of the late fall, and that most of them go northward so that there is little evidence of exchange between the Chesapeake Bay and North Carolina populations. One striped bass, recaptured at Cape Ann, Massachusetts, traveled at least 900 miles between October 8, 1936 and June 3, 1937. Individual records show that this species may travel up to 60 miles in a single day.

Tagging off New Jersey and in the Hudson River. Wallace and Neville (1942: 22) have reported that winter populations begin to move out of local New Jersey waters as early as the first part of March, migrate to New England, and remain there during the summer. In the fall they move southward to winter in several areas along the coast and may go as far as Chesapeake Bay. The midsummer catches in New Jersey include some which have wintered in New Jersey waters and others which have moved up the coast from more southern areas. These authors point out that the recommendations for the prohibition of winter fishing in New Jersey would not necessarily improve summer catches in that state but that they might contribute to better summer catches farther north. They also stated that local regulations that provide for restriction or prohibition of bass fishing, especially by certain types of commercial gear, either permanently or during closed seasons within a year or throughout a period of years, would not necessarily accomplish rehabilitation of striped bass. Wallace and Neville (1942: 22) also discussed the 1940 year-class which is known to have been successful in Chesapeake Bay. In 1942 these small fish appeared off New Jersey and New York and still later off the New England Coast when they ranged from 10 to 14 inches in length, most of them being two years old.

Neville (1940: 35) has reported that 100 bass less than 16 inches were tagged and released off South Nyack during the first part of April 1940. Within four days some were caught in shad nets in the vicinity of George Washington Bridge. However, only part of the population moves downstream; some large bass are taken in the Hudson River during the summer at the present time.

Tagging off Connecticut and Long Island. From April 1936 to June 1938 Merriman (1937a: 27; 1941: 36) tagged a total of 3,937 striped bass, of which 2,573 were marked in Connecticut and Long Island waters, the remainder being tagged in waters of North and South Carolina. Those tagged in northern waters were two years or older and were tagged with external discs; 21.1% were recaptured.

In Connecticut waters, from April through October 1936, 1,397 specimens were tagged, 24.1% of which were recovered by July 1, 1938 (see Merriman, 1941: fig. 26, table 17). As a supplement to the tagging experiments, Merriman used information from records of the pound net catches at Montauk, Long Island. For the year-classes involved, the data showed that (1) there was a coastwise northward movement in the spring, (2) a relatively stable population with no movement of consequence in the summer, and (3) a southward migration in the fall and early winter. The peak northward migration was reached in southern New England in May, and in late October the southern movement started, its peak being reached during the first ten days of November. After this date, tagged fish were recaptured farther south but not to the north and east; however, there was the possibility that some tagged specimens were still present in the north although not caught by fishermen. Winter and spring returns were obtained from New Jersey, Delaware, at the entrance of Chesapeake Bay, and from North Carolina.

In the Niantic and Thames Rivers, Connecticut (Merriman, 1941: table 20), some 770 striped bass tagged from April to October 1937 yielded 12.1% returns by July 1, 1938. These returns were in line with the results reported above for Connecticut. Those recaptured during the winter of 1937–38 were taken in southern areas.

From May 15 to 19, 1937, 103 striped bass were tagged and released at Montauk, L. I. None were recovered to the south, but 14 (13.6%) recaptures were made from Long Island Sound, Connecticut, Rhode Island, or Massachusetts. These data indicate that the northward movements may continue through June (see Merriman, 1941: fig. 27). From October 25 to 27, 1937, some 303 bass were tagged at the same place, and 31.3% were recovered within six months. Most of the recaptures were from the south side of Long Island, and some were recaptured southward as far as Pamlico Sound, North Carolina. Some stripers in this particular tagging traveled 12 miles or more in a day.

Before the advent of the 1934 year-class, which contributed a large part of the southern New England catch in 1936 and 1937, a few striped bass had been found north of Cape Cod. Merriman (1941: 40), after a study of the scales of specimens taken north of Cape Cod Bay, concluded that the fish were probably of southern origin except for occasional individuals from northern resident populations such as that of the Parker River, Massachusetts. There is much evidence that striped bass now pass through the Cape Cod Canal in large numbers, where there is known to be good fishing.

Some of the large supply of striped bass available in Maine during 1937 may have been due to a migration from the south, or to a successful 1934 spawning in northern waters, or to a combination of both factors. It is possible that the basic conditions that made for such a good survival in the Chesapeake Bay area in 1934 may have operated in the same way in Maine and Nova Scotia.

Young striped bass probably do not undertake extensive migrations but may move slowly downstream during their first summer. Only rarely did Merriman (1941: 44) encounter striped bass less than two years old in northern waters. In recent years, when bass have been common in the north, the situation is different.

Tagging in North and South Carolina. In North Carolina during the spring of 1938 Merriman (1941: 44) tagged a total of 1,364 specimens that ranged from juveniles to four-year-olds. For juveniles and yearlings he used internal discs, for the older ones external discs. From April 18 to 28 some 506 juveniles and yearlings just becoming one and two years old were tagged in the area between the mouths of the Chowan and Roanoke Rivers in western Albemarle Sound. Before the haul seine fishery closed in May, 47 of these bass were recaptured in the same area and several others were taken only a short distance away. During March and April he tagged 600 two-, three- and four-year-olds (mostly two-year-olds) with external discs at the eastern end of Albemarle Sound, mostly on the outer coast region in the vicinity of Kitty Hawk and Nags Head. Shortly after they were tagged, 62 were caught in the same area, of which 46 were again released. By June 15, 1938 there were 45 returns from these 600 fish from areas some distance away from the point of release, but they did not show a preponderant northern migration. Twenty-four had moved south or west and 21 northward, of which only four had gone as far north as New Jersey. Small numbers of bass were also tagged in North Carolina in the spring of 1937 by Merriman (1941: 46), but there were no returns from these, outside of North Carolina.

Merriman (1941: 46) has also reported some results of tagging carried on by Vladykov and Wallace in Croatan Sound at the east end of Albermarle Sound and on the outer coast of North Carolina from November 15–19, 1937. Most of the 483 bass tagged were one-, two- and three-year-old fish. By June 1, 1938 only two had been recaptured from northern waters, and these were taken at Leeds Point, New Jersey. However, 123 (90%) returns were definitely taken in North Carolina, and 13 other returns from fish markets probably were from North Carolina also.

The available data from tagging experiments indicate that striped bass spawned in North Carolina contribute little to the schools that make their way northward to Cape Cod, and that there is little interrelationship between the populations of North Carolina and Chesapeake Bay.

In the Santee-Cooper system of South Carolina, 251 small bass were tagged in the spring of 1949 by the U. S. Fish and Wildlife Service, but according to Clinton E. Anderson there was only one tag returned, that from a bass captured at Charleston only a few miles from the release point.

Water Temperature and Migration. According to the data summarized by Merriman (1941: 42), both the spring and fall migrations begin when the water reaches approximately 45° F. Strong winds and storms in the north during the fall may also play a part in stimulating the southern migration. Merriman (1941: 43) reported the presence of many dead bass in eastern Connecticut rivers in August and early September 1937 following a long period of warm weather, and he suggested that the maximum water temperature for the striped bass is about 77.0–80.6° F. A movement of tagged fish from the Niantic and Thames Rivers out into cooler coastal waters was noted at the time the river water reached its maximum temperature.

Migration of Older Bass. Merriman (1941: 43) tagged a considerable number of striped bass that weighed from five to 25 pounds, but none were returned except in the immediate vicinity of tagging. He suggests that possibly the two- and three-year-old fish gather in separate schools and travel at different depths. Wallace and Neville (1942) stated that many large bass, 10 pounds or more in weight and eight years or older, apparently "return" to Chesapeake Bay after an absence of possibly five years or more, during which period they spend at least part of this time in northern waters. This belief is based on the assumption that the fishing intensity in Chesapeake Bay removes from 60 to 90% of a single brood during the first year of its availability to the fishery, and that the sudden reappearance of a relatively large number of big fish indicates that they are return migrants from outside of the Bay areas. This supposition, of course, needs confirmation by additional tagging experiments on large bass.

Composition of Schools by Sex. Of 1,211 Maryland striped bass sexed internally by Vladykov and Wallace (1952) in 1936 and 1937, males comprised 55%, and a similar ratio was found in samples from Virginia and North Carolina. During the year the sex ratio was about 50-50 from August to November, but throughout the winter and spring the percentage of males was higher, reaching as high as 83% in March. Possibly the males are more concentrated during the colder months and the females more widespread, or possibly some leave the Bay during the winter. From Long Island and New England waters in 1936 and 1937, Merriman (1941: 44) found that 90% were females. He also found an increasingly smaller percentage of males in the larger size categories in northern waters. From these data he suggested that the bulk of the migratory schools consist of immature females and that the males which may mature at the end of two years remain in the south and perhaps engage in spawning. Northward, Merriman (1941: 44, fig. 31) gives some evidence that striped bass of the large size categories migrate from south to north after spawning is over. Morgan and Gerlach (1950: 27, fig. 19), in studies of sex ratios of Oregon bass taken during two week periods from April 15 to June 24, found that females predominated in late April and early May and that males were more common in early April, late May, and throughout June. Additional data on sex ratios are given in the section on reproduction (p. 34).

Tagging in California and Oregon. Within a period of 36 months, Clark (1936) recovered 9.8% of 1,544 striped bass tagged for the most part in the Sacramento and San Joaquin Rivers of California. An analysis of the results showed a diffusion rather than a migration from the locality at which the bass were tagged; none were caught in the ocean. Calhoun (1948: 9) claimed that large bass do not behave the same as the 12-inch fish marked by Clark, since measurements of large numbers caught on the various fishing grounds indicate that the larger bass indulge in seasonal migrations. More recent tagging experiments on large specimens has confirmed this view. During the summer months the large fish are in the lower bays (San Francisco area) and are believed to enter the ocean in some numbers at this time of year. Then, during September and October, large schools of big stripers pass up through San Pablo Bay and Carquinez Straits into Suisin Bay and into the Sacramento and San Joaquin Deltas, where they spend the winter. In the spring they congregate in the river channels and spawn, and perhaps they are joined at this time by stripers from the ocean and lower bays. The spawned fish move back down the river rapidly, with little feeding en route. Some large ones are caught in San Pablo Bay during May and June.

Recent studies by Calhoun (1952: 391) have shown a mass movement of bass up into fresh water of the Sacramento-San Joaquin Delta, where they remain during the winter. In the spring they disperse out over the Delta and into tributary rivers to spawn, after which they return again to San Francisco Bay and adjacent salt and brackish waters for the summer. This migration pattern was shown by tag returns over four summers.

In Coos Bay, Oregon, Morgan and Gerlach tagged 374 striped bass from April to September 1950 and recovered 49 tags that same year. Recoveries showed an upstream movement in April–June and a second migration into the sloughs in fall. That some coastwise movement takes place on the Pacific Coast is indicated by the natural establishment of populations in Coos Bay, Oregon and in the Columbia River.

REPRODUCTION

The striped bass is an anadromous fish which spawns in fresh or virtually fresh water in rivers from April to July. The young and juveniles stay in the rivers and in the brackish estuaries until nearly two years old and then may undertake movements of considerable magnitude. The more important studies on reproduction are as follows: Worth (1882 to 1910), Coleman and Scofield (1910), Bigelow and Welsh (1925), Scofield (1931), Pearson (1938), Neville (1940), Merriman (1941), Wallace and Neville (1942), Jackson, in Wallace and Neville (1942), Woodhull (1947), Calhoun and Woodhull (1948), De Armon (1948), King (1949), Erkkila, et al (1950), Calhoun (1950a), Morgan and Gerlach (1950), Tresselt (1952), Vladykov and Wallace (1952), and Jackson and Tiller (1952).

Sexual Dimorphism. No valid way has been found to determine the sex of striped bass by the use of external characters (see Merriman, 1941: 20). The gonads must be inspected. Recently Sigler (1948: 299) found that white bass (*Morone chrysops*), a related species, over 10 inches in length could be sexed by external examination of the anal region. In females the genital and urinary ducts have separate external openings, but in males these systems discharge through a common urogenital pore. Also, during the breeding season the female white bass has a pronounced fringe of papilla-like folds around the anterior edge of the genital pore, which is absent or only scarcely evident in the male. The determination of sex from external examination is an important tool for field study, and the matter should be further investigated on striped bass.

Determination of Maturity. The determination of sex in mature males presents no difficulty on examination of the gonads, for the enlarged soft testes contain a bountiful supply of sperm when nearing ripeness. Scofield (1931: 44, figs. 33, 34, and 35), working on striped bass in California, first attempted to determine the maturity of female striped bass by a gross examination of the ovary. He had difficulty due to the variation in size and color and concluded that he could not always distinguish between immature and maturing ova. However, a microscopic examination of the ovary did give a method of determining maturity. An immature ovary contains eggs that average 0.125 mm in diameter, with no eggs over 0.29 mm. A mature ovary contains both small and large ova, and the difference is so great that it can be recognized at a glance. The larger maturing ova are over 1.0 mm in diameter, averaging 1.35 mm before they are spawned. Scofield showed by diagram the increase in size and the maturation of these larger eggs, beginning in December and continuing through June, when the peak size was reached. Also for California striped bass, Woodhull (1947: 98, fig. 26) gave a graph showing the steady increase in size of the larger ova in the ovary of striped bass as they approached ripeness. The increase averaged from 0.76 mm on March 10 when the ovaries were beginning to turn green to 1.28 mm on May 6. When ready to be extruded, the eggs ranged from 1.0 to 1.35 mm. As they ripened, the eggs and ovaries changed from cream to pale green. Merriman (1941: 21 and pl. 2) also studied sections of ovaries and, like Scofield, he found that mature females could be determined by the presence of large ova. He also noted that there was no significant difference in the size of ova found in the anterior, middle, or posterior parts of each ovary. A similar conclusion was reached by De Armon (1948), who sampled the ovaries of three striped bass to determine the distribution of large and small eggs in each. The ovaries inspected were from fish taken in May, November and March, each ovary being sliced in six cross sections and eight samples being taken from each cross section in order to assure thorough study of the egg distribution within the ovary. The "randomized blocks" design was used for the analysis. The large or mature eggs were separated from the small or immature eggs in each sample, all were counted under an ocular micrometer, and the percentage of large eggs present was computed for each sample. An Analysis of Variance on the data obtained from the samples of these three ovaries showed that there was no significant difference in the percentage of large eggs present between any section or any position in the ovary. Thus, it seems clear that the large and small eggs together form a homogeneous matrix.

Jackson and Tiller (1952) confirmed the findings of Scofield (1931: 44) and Merriman (1941: 21) on the structure of mature and immature ovaries. The presence of large ova implies that maturity has been reached, but it does not necessarily mean that the fish will spawn the next season. Jackson and Tiller (1952) also found that normally the large eggs which will ultimately mature in any season in a given set of ovaries average about 15% of the total number of ova present in the ovary.

Vladykov and Wallace (1952) gave monthly (June through March) percentages of the numbers of male striped bass taken in Chesapeake Bay from 1936 to 1938 at various stages of maturity, such as resting, prespawning, spawning and spent.

Frequency of Spawning. Jackson and Tiller (1952: 12) pointed out that mature females do not necessarily spawn every season. They indicated that it is extremely unlikely that a female taken during the height of the spawning season and having large eggs which average less than 0.75 mm could be expected to spawn that year. Merriman (1941: 16) also mentioned the capture of large female striped bass during the spawning season which showed no sign of approaching ripeness, and he suggested that they are not necessarily annual spawners.

Eggs per Female. 14,000 in a 3-pound fish; Worth (1904). 265,000 in a 4.5-pound fish from Weldon, N. C.; Merriman (1941: 19). 900,000 in an 8.8-pound fish from Coos Bay, Oregon; Morgan and Gerlach (1950: 27). 1,280,000 in a 12-pound fish; Anon. (1900); Bigelow and Welsh (1925). 1,337,000 in a 27.5-inch, 13-pound fish; Pearson (1938: 831). 3,220,000 in a 50-pound fish; Worth (1904). 68,000–4,536,800 large eggs in fish 4.4–35 pounds and 4–14 years old; Jackson and Tiller (1952: 13). 4,775,000 in a 50-pound bass from Coos Bay, Oregon; Morgan and Gerlach (1950: 27). An estimate that 10,000,000 would be produced by a 75-pound female; Bigelow and Welsh (1925: 256).

Records at the Weldon, North Carolina hatchery, cited by Merriman (1941: 19), over a period of several years show that the number of eggs per female varied from 11,000 to 1,215,000 in 111 females; the majority yielded 180,000 to 700,000 eggs each. Jackson and Tiller (1952: 13) have found that the number of eggs per female increases with the age and size, at least up to 14 years of age, which was the maximum investigated. A graph showing the relation between the number of eggs and the weight in pounds of 15 females is given by Morgan and Gerlach (1950: 28).

Weights of Ovaries and Testes. Vladykov and Wallace (1952: tables 19 and 20) gave data on the comparative weights of bass and their gonads. Of course the gonads become much larger as the spawning time approaches; in nonspawning males the ratio between the weight of the testes and the body weight is 1:80, at the prespawning stage 1:20, and at spawning time 1:16. The change in the ovaries of females is even more striking; in immature females the ratio is 1:143; in maturing females 1:21, and just before the spawning time it is 1:12. These data are based on very few specimens and need to be supplemented by additional observations. The ovaries of a 50-pound bass taken in Coos Bay, Oregon weighed about 8.5 pounds according to Morgan and Gerlach (1950:27). Vladykov and Wallace (1952) and Jackson and Tiller (1952) found that shortly after spawning the entire ovary is very flabby and the walls are thick and misshapen. The flabby condition persists for about a month, when the ovary again becomes firm and rounded. Any large eggs which were not spawned are resorbed in time.

Age at Maturity. Merriman (1941: 22) found that 25% of female striped bass taken in Connecticut spawn just as they are becoming four years old, that 75% are mature as they reach five years of age, and that 95% are mature by the time they reach six years. He found a similar situation in North Carolina during April and May 1938; out of 25 ripe females six were almost four years old (the smallest being 43 cm), and of the remaining 19 females, 16 were just attaining five, six, or seven years, and three were eight or nine years old. At the same time many hundreds of smaller females from one to three years old were examined, and none were ripe. Most males were mature at two years and all were mature at three.

In Chesapeake Bay, Vladykov and Wallace (1938: 58; 1952) noted that males of the 1934 year-class had reached maturity in the spring of 1937 but that females had not reached sexual maturity in 1937. They concluded that Cheseapeake female bass may mature at four years and that practically all do in the fifth year. Jackson and

Tiller (1952) also concluded that, in the Bay, female bass become established spawners when four or five years old.

For California striped bass, Scofield (1931: 48, figs. 36–37), in the first study of this type, found that 35% of the females mature and spawn first in their fourth year, 87% are spawners in their fifth, 98% in their sixth year, and that 100% spawn thereafter. Calhoun (1948: 7), in a general report on striped bass in central California waters, reported that female striped bass *usually* spawn for the first time when they are five years old and about 22 inches long, while many males reach sexual maturity when they are two years old and about 11 inches long.

In Coos Bay, Oregon, Morgan and Gerlach (1950: 20) noted that no females of year-classes I and II were mature, that 18.2% of year-class III were mature, 67.9% of year-class IV were mature, and 100% of year-class V and older had matured. Mature males were found in all year-classes except zero, which means that some spawned at one year.

Size at Maturity. The smallest mature males observed in Chesapeake Bay by Vladykov and Wallace (1952) were four two-year-old fish ranging from 7¼ to 7¾ inches. Practically all males more than 10 inches in length were able to spawn. No female less than 17 inches long was mature. Only one 17-inch female was mature, 25% of those from 17 to 18 inches long were mature, and 83% of those in the 20–22-inch group were sexually mature. Pearson (1938: 830) measured 70 mature males and 29 egg-bearing females near the mouth of the Susquehanna River, Chesapeake Bay during April and May 1932. The males ranged from 13 to 30.7 inches, with an average near 15.7 to 17.7 inches. Most males were three years old. The females ranged from 19.7 to 30.7 inches. Milner (1876) took ripe males 12 to 18 inches long in the Potomac River, Maryland in late April 1875. In North Carolina, Worth (1904) weighed 19 ripe females and found that three ranged between three and seven pounds, seven from 10 to 18 pounds, four from 23 to 35 pounds, and five from 40 to 70 pounds.

Sex Ratio at Spawning. Pearson (1938: 831) reported many more mature males than females on the spawning grounds, with the females being larger in size. According to Worth (1903), at Weldon, North Carolina one female was surrounded by 20–50 males at the actual spawning time. Merriman (1941: 19) also noted an unbalanced sex ratio at spawning time and mentioned that 10–50 small males may accompany a single female weighing from four to 50 pounds. In May 1938, only six out of 127 striped bass at Weldon were females. He found a similar sex ratio at the same time at Jamesville, North Carolina, a point downstream on the Roanoke River.

Spawning Migration. Several weeks before spawning the striped bass move upstream to fresh water, the males apparently reaching the spawning ground first and being always more common than females, the usual situation in fishes. In central California, Calhoun and Woodhull (1948: 173) noted that a major upstream migration occurred annually in the spring, mostly in April and May, and that the run consisted of striped bass that are ready or nearly ready to spawn. Observations and tagging in Coos Bay, Oregon by Morgan and Gerlach (1950: 18) indicated an upstream spawning migration in the spring and a second or feeding migration into the sloughs in the fall, the adult bass having left the Bay within two or three weeks after the main spawning season in late May and early June.

In the east a few studies have been made of this phenomenon. Nesbit (in Merriman, 1941: 39) reported having tagged 64 striped bass at Sandy Hook, New Jersey, April 22–25, 1938: recaptures in late April and May revealed that many had gone up the Hudson, apparently on a spawning migration.

Feeding at Spawning. Scofield's (1931: 30) statement that California striped bass "feed continuously at the time of spawning" has not held up when tested by stomach analyses of fish taken when spawning. His observations, based on analyses of the food of striped bass captured in the spawning area, were on fish which had not begun to spawn. Calhoun and Woodhull (1948: 185) noted that ripe California striped bass do not usually strike live bait or artificial lures, which is especially true of females. Woodhull (1947: 101) also reported that bass in actual spawning groups in California would not bite even though many anglers were trying for them. In Coos Bay, Oregon, Morgan and Gerlach (1950: 26) noted that food was found in stomachs of maturing and spent female bass but that no females in spawning condition were found to be feeding. Both males and females appear to feed heavily immediately after spawning. Of 29 ripe striped bass 20.5 to 71.0 cm long, captured in pound nets at Turkey Point, Chesapeake Bay, June 1–6, Hollis (1952) reported that 27 had empty stomachs and that two showed only a trace of food.

Spawning Grounds. That striped bass spawn in or near the mouths of rivers in the spring of the year is an occurrence that was observed early by Josselyn (1672). Schoepf (1788) described the run of striped bass in the rapids of the Roanoke River at Weldon, North Carolina, noting that the fish came up the river in millions to spawn and that they "sprung" and "tumble" so that the water foamed. Other early references to spawning grounds may be found in Belknap (1792), Mease (1815), and Mitchill (1815). In the past striped bass probably spawned in most of the rivers from the St. Lawrence to the Savannah River as well as in some of the tributaties of the Gulf of Mexico.

The Roanoke River and Susquehanna River spawning sites indicate a liking for rock-strewn areas; spawning apparently takes place near the fall line, which is characterized by rapids and strong currents. However, spawning does occur in other coastal rivers such as the Chickahominy River, Virginia in the absence of any pronounced rapids such as those found in most southeastern rivers. In 1950, Tresselt (1952) made a thorough study of the spawning grounds of some rivers in Virginia tributary to Chesapeake Bay, namely the James, Chickahominy, Pamunkey, Mattaponi, and Rappahannock. He took eggs in plankton nets during April and May and concluded that spawning activity occurs mostly within the first 25 miles of fresh water in this region. In Maryland, Vladykov and Wallace (1952) gave the spawning grounds as the upper tide-water reaches of fresh-water rivers; the bottom is usually sand or mud and the current 2½ to 3 miles per hour. Striped bass spawn in the area below Conowingo Dam on the Susquehanna, in the Potomac and Choptank Rivers, and in certain rivers that empty into Tangier Sound.

Wallace and Neville (1942), reporting the results of a survey of striped bass spawning areas along the Atlantic Coast, covered most of the inshore region (bays, coves, sounds and coastal rivers) from Delaware Bay in New Jersey to the Calais River in northeastern Maine. This work was based on inquiry concerning the presence of ripe fish in spring catches and on periodical attempts in summer and late fall to collect young striped bass. Taken with what was known already, the results showed that the principle spawning and nursery areas for striped bass are Chesapeake Bay and its tributaries; Pamlico Sound, North Carolina and its tributaries; the upper Delaware Bay, New Jersey, and some of its tributaries; and the lower Hudson River, New York, especially from the vicinity of Newburgh southward to Piermont (see also Neville, 1940: 33). In contrast, the coastal regions of New Jersey and Long Island, New York revealed no evidence of successful local spawning and important survival of young.

Merriman (1941: 16) stated that striped bass formerly spawned in Connecticut, but his field studies in 1936 and 1937, especially in the Niantic and Thames Rivers, failed to reveal young. Furthermore, not a single ripe fish was taken by Merriman in Connecticut during his several years of intensive field work. However, young bass were taken at Cos Cob Harbor, Greenwich, Connecticut in May 1949. In Massachusetts, in the Parker River near Newburyport, Merriman (1941: 17) found young striped bass in 1937, but subsequent attempts to obtain young there have failed (see Wallace and Neville, 1942).

An early and widespread report by Scofield (1931) that California striped bass spawned in still waters of bayous behind flooded islands of the Sacramento-San Joaquin River delta was based on concentrations of bass and not on actual observations of spawning. Hatton and Clark (1942) noted that eggs were not taken in abundance at any time in the San Joaquin Delta, a fact which seemed to "indicate that the main spawning areas are to be found elsewhere." Woodhull (1947: 97) and Calhoun and Woodhull (1948: 171) next found striped bass spawning in rivers in areas of considerable current; these authors reviewed the available data on spawning of striped bass in California and gave an excellent summary of recent work done in locating striped bass eggs and larvae in the Sacramento and San Joaquin Rivers. Calhoun, Woodhull and Johnson (1950) gave data obtained in 1948, and they reported that eggs were present in considerable numbers throughout the lower Sacramento River system (except in the American River) during late May and early June; minimal estimates of the number of eggs passing down the Feather River during a 24-hour period ranged from 2,000,000 to 10,000,000 over a period of 15 days. Additional studies of bass in the Sacramento-San Joaquin Delta with reference to effects of the Tracy pumping plant and Delta Cross Channel have been given by Erkkila, *et al.* (1950: 22). These authors suggested that water temperatures have determined to a great extent the time of spawning and the speed of development of immature bass in the Delta.

In Oregon, Morgan and Gerlach (1950: 13) observed spawning in the tidal area of the upper Coos River and in the lower parts of Millicoma River and South Fork Coos River. The salinity was zero.

Time of Spawning. Striped bass spawn in the spring and early summer, depending on the latitude. In the Alabama River near Montgomery a female with ripe eggs was taken on April 7, 1883 (Pearson, 1938: 829). In the Roanoke River, North Carolina, spawning occurs from late April to May, with a few stragglers as late as June (Worth, 1884a; Pearson, 1938; Merriman, 1941: 18). In tributaries to Chesapeake Bay the period is from May to July (Pearson, 1938: 829; Vladykov and Wallace, 1952). In Virginia rivers (James to Rappahannock) Tresselt (1952) found evidence of spawning in April and May. In the Susquehanna River, May-June, Pearson took eggs a number of times at Garrett Island and Conowingo Dam, an impassable barrier 12 miles upstream. In the Delaware Bay area spawning occurs from late May to the middle of July, with the peak in June (Abbott, 1885; Wallace and Neville, 1942). In the Hudson River, New York, Wallace and Neville (1942) reported spawning from mid-May through June, and Neville (1940: 33) extended the period to include April.

In the Gulf of Mexico area, Bigelow and Welsh (1925: 256) stated that June is the height of the season, and in New Brunswick Pearson (1938: 830) reported ripe fish in the middle of June.

In California (San Francisco region) the following authors provide evidence that spawning occurs from April through June: Woodhull (1947: 98), Calhoun and Woodhull (1948: 184), Calhoun, Woodhull and Johnson (1950: 143), and Erkkila, *et al.* (1950: 22). In Oregon spawning takes place in June in the Umpqua River (Anon., 1946: 58) and in May and June in the Coos River (Morgan and Gerlach, 1950: 14).

Water Temperature at Spawning. Worth (1884b) took ripe striped bass from the Roanoke River at Weldon, North Carolina from April 19 to May 17 at water temperatures that increased from 58 to 71° F. During operations at Weldon in 1931, ripe fish were taken by Pearson (1938: 830) between May 5 and 21 as the water temperature increased from 61 to 71° F. Tresselt (1952) found eggs in the lower reaches of Virginia rivers from April 4 to May 20 when the water temperature was 54 to 70° F. Freshly deposited eggs were found by Pearson (1938: 830) at night in the lower Susquehanna River, Maryland from May 16 to June 8, 1931 when the water temperature increased from 60 to 70° F. Woodhull (1947: 99) noted that the water temperature was 67° at 4 P. M., when striped bass were spawning in the vicinity of Venice Island, San Joaquin River, California. In the lower Sacramento River system, according to Calhoun, Woodhull and Johnson (1950: 143), spawning does not begin until the water temperatures reach about 60° F. Spawning ceased during storms when water temperatures declined and resumed when temperatures increased with clear weather. Erkkila, *et al.* (1950: 29) also pointed out that water temperature appears to exert an important influence in determining both time of spawning and rate of development of larval and post-larval bass in the Delta. As reflected by egg collections, spawning occurred in temperatures of 58° F and higher, with a peak between 60 and 67° F.

Salinity on Spawning Grounds. Apparently there is no conclusive evidence to confirm the statement in the literature that striped bass spawn in brackish water, although eggs have been found in slightly saline situations; most of these reports have been based on the capture of ripe striped bass in brackish water. Among such records that have been noted are Rice's (1883) report of ripe striped bass at the entrance of the Hudson River, and Corson's (1926) record near Barnegat Inlet, New Jersey. Many anadromous fishes appear to be near spawning when found in estuaries, but actual spawning probably does not occur until fresh or virtually fresh water is reached.

Merriman (1941: 20) hazards the statement that, in view of the wide variation in type of river in which the striped bass has been known to spawn, it would seem likely that it might spawn where the water is brackish and perhaps even strongly saline. This point needs further investigation. Woodhull (1947: 99) noted the salinity as one to seven parts of chlorine per 100,000 of water (fresh water) at the spawning locality in the San Joaquin River, California on May 6, 1946. In the Coos River, Oregon, Morgan and Gerlach (1950: 14) found zero salinity in the tidal area where bass were spawning. Some eggs were found in slightly brackish water in Virginia rivers by Tresselt (1952), but most were taken within the first 25 miles of fresh water, and it seems probable that the eggs found in brackish water had been carried downstream by the current.

Spawning Activities. Worth (1903) noted that in the Roanoke River at Weldon, North Carolina, ripe females were accompanied by many males; indeed, large females weighing from 5 to 50 pounds each were surrounded by 20–50 small males weighing not more than two pounds each. Pearson (1938: 831) also noted a similar preponderance of males in 1937. According to Woodhull's (1947: 99) observations in both the San Joaquin and Sacramento Rivers, California, the striped bass, during the spawning season, appear at the surface and splash about in the so-called "rock fights." It is now known that this activity is spawning behavior and not an act of courtship. Woodhull actually observed spawning on May 6, 1946 in the vicinity of Venice Island in the San Joaquin River at a point about 60 miles from the Golden Gate, California. The temperature of the water was 67° F and the water was virtually fresh, rather turbid, and visibility was limited to about 15 inches. The tide had just turned and the water was flowing inland. About 3 P. M. he saw what appeared to be isolated females at the surface, swimming about slowly with parts of the back and dorsal fin above water. Occasionally, when joined by other large fish, they sounded. At about 4 P. M. innumerable groups of from 5 to 30 bass appeared at the surface. Each group milled about for a few moments and then headed up or downstream, the fish rolling over on their sides at about a 45° angle and splashing water in all directions with their threshing caudal fins. These groups remained at the surface for several minutes and the various groups indulged in this activity for a distance of about three miles along the river, mainly in the shallower portions, although a few were seen over deep water. Judging from their actions and from the positions of their bodies they were undoubtedly spawning, and it was easy to approach within several feet of them. A No. 6 plankton net was hauled through a group of these spawning fish, and the eggs taken were not water hardened, an indication that they were freshly laid; their mean diameter was 1.78 mm (about 1/16 inch). Spawning was still in progress at 7 P. M. when Woodhull left the area, but a nearby observer reported that the bass were splashing about all night. The next morning Woodhull observed that a few small groups were still spawning and that splashing continued until about noon. High winds and rough waters made further observations impossible. No spawning bass were taken by the many anglers who were present in the area and who were trying to catch them by every possible means. However, a group of anglers close by obtained 42 males, all with flowing milt. The large fish in the area, presumably females, were not striking any lure. During spawning the very small males dashed in and out of the various groups of spawning fish, sometimes leaping into the air in low graceful arcs.

Morgan and Gerlach (1950: 13) described the spawning of bass in the Coos River, Oregon, the peak of activity continuing for one or two days. Spawning occurred throughout the day, but it appeared to be most common in the late afternoon and early evening, especially on the flood tide. Males greatly outnumbered the females. During the act of spawning, a group of only three or four bass, or many times that number, milled around in a circle, at which time they splashed for about a minute and threw water as much as four or five feet into the air. Shortly after this they submerged abruptly. They could be observed close at hand. Shad were found to be spawning at the same time.

Location of Eggs after Spawning. In plankton net hauls made the day after spawning was observed in California, Woodhull (1947: 101) found developing eggs at water depths of 15 to 35 feet, but generally they were taken within five feet of the river bottom. In Virginia rivers Tresselt (1952) found more eggs at the surface in set plankton nets, but he also took them in numbers on the bottom. Because of their semibuoyant nature, the eggs are undoubtedly swept downstream rather rapidly in places where the current is swift, as at Weldon, North Carolina. Indeed, as Merriman (1941: 19) has pointed out, hatching may not take place until the eggs are close to the mouth of the Roanoke River or even in Albemarle Sound.

Description of Eggs and Incubation Period. Pearson (1938: 831) described the striped bass egg immediately after fertilization (preserved in weak formalin) as spherical, nonadhesive, and 1.28–1.36 mm in diameter. It is slightly heavier than fresh water and sinks in perfectly quiet water; however, only a slight movement of the water keeps the egg off the bottom. The egg membrane is transparent in the living egg but is nearly opaque after preservation. The yolk is heavily granulated, about 1.10 mm in diameter, of a rather intense green in living eggs and usually pale amber in preserved eggs. The yolk contains an amber oil globule which measures 0.56 mm in diameter. Several much smaller oil globules may also be present. Pearson (1938: 833, figs. 3 to 8) has published excellent illustrations which show the development of the egg and has given a detailed description of important changes. In California, Woodhull (1947: 100) found that freshly laid eggs which were not yet water hardened had a mean diameter of 1.78 mm (about 1/16 inch). The Manual of Fish-Culture (Anon., 1900: 187, pl. 1) gave the number of eggs in a quart as about 24,000. Merriman (1941: 19) gave illustrations of both egg and young.

The incubation period, as given by Pearson (1938: 831), is 48 hours at a water temperature averaging 64.2° F. Bigelow and Welsh (1925) gave 74 hours as the hatching time at a water temperature of 58° F, 48 hours at 67° F. Merriman (1941: 9) gave about 30 hours at 71–72° F and 70 to 74 hours at 58–60° F.

Larvae and Postlarvae. Pearson (1938: 832, fig. 8) described the newly hatched larvae as 2.5 mm long with an oval yolk sac. At 60 hours the larvae (Pearson, 1938: fig. 9) measure 3.2 mm in length, and the oil globule in the anterior end of the yolk sac projects beyond the head. At this time the larvae sink to the bottom of still water despite their best swimming efforts, but a strong current keeps the larvae suspended and in more or less constant motion. It is soon after this stage that they are liberated in the rivers from the hatchery at Weldon, North Carolina. At 84 hours they are 4.4 mm long and the head extends beyond the oil globule of the yolk sac. A series of small melanophores appear along the under surface of the body behind the vent, and the eyes have black pigment. Pearson (1938: 832) has also illustrated and described the development of the larvae at 120 hours (5.2 mm), 144 hours (5.8 mm), and 192 hours (6 mm). If food is not available the larvae begin to die at a length of 6 mm; otherwise they reach the postlarval stage at 240 hours after fertilization (9 mm). Details of pigmentation at this stage have been given by Pearson (1938: fig. 15); he has also described and illustrated the postlarvae at 18 days (13 mm), when the dorsal and anal fin rays are well differentiated. Scofield and Coleman (1901) have also given descriptions of the early larval stages.

Leim (1924) took larval striped bass in plankton tows during the summers of 1922 and 1923 near the head of the tidal zone in the Shubenacadie River, Nova Scotia. Calhoun and Woodhull (1948: 172–179) gave a description of a satisfactory plankton net for taking larvae in California rivers. In the San Joaquin Delta area they noted a close correlation between towing time and the number of fry caught, and they assumed that the fry were rather evenly distributed horizontally. On the other hand, the vertical distribution was highly variable.

Young. When three to four weeks old and 36 mm (1.4 in.) long, young striped bass are shaped like the adult, have scales and have fully developed fins and fin rays. Pigmentation consists of minute dark spots scattered over the entire body. About nine V-shaped lines, visible along the midsides, are probably blood vessels (see Pearson 1938: 837, fig. 17–18). When they are 130 mm (5.1 in.) long and about one year old, they have six to eight dark lateral stripes as well as seven fainter vertical dark bars along the sides.

Young which averaged two inches in length were taken in Newburgh Bay in the Hudson River on July 20, 1936 by the New York Conservation Department Biological Survey (see Curran and Ries, 1937: 17). Later these fish were found in considerable numbers from Newburgh to Yonkers where they seemed to prefer gravelly beaches, although a few were found over other types of bottom. At night they were associated with river herring and white perch, but in day seine hauls shad usually replaced the herring. Young of white perch and striped bass were practically always caught together. The Hudson River water at this point has a low salinity (chlorine as chlorides ranged from 10.0–8,560.0 parts per million). Merriman (1941: 17) gave a length-frequency distribution of 628 young striped bass captured in the Hudson in 1936. Neville (1940: 33) took young bass three to five inches long in August 1939 along both sides of the Hudson River from Yonkers to Beacon. During the summer of 1949 many striped bass were taken in the Hudson River by seining during a survey of the survival of young shad made by the New York State Conservation Department; these have been made available by John R. Greeley and Cecil Heacox for study.

Young bass are extremely scarce in Long Island waters. The extensive shore seining by the New York State Conservation Department Biological Survey during the summer of 1938 revealed only one young striped bass three inches long at Bayside on August 5 (see Greeley, 1939: 87). In May 1949, four young striped bass from 3.5 to 5.5 inches long were taken by Leon Nichols in Cos Cob Harbor, Greenwich, Connecticut. Other young have been seen in December and January and in other months of the year at the discharge flume of the Cos Cob Power Station where warm fresh water enters the brackish harbor. This is a possible indication that bass may be spawning in greater numbers in the north now that the number of adult fish has increased greatly.

Three young striped bass 7.1 to 815 mm long were taken by Merriman (1941: 17) in the Parker River, near Newburyport, Massachusetts, on August 4, 1937. They were found over a mud and sand bottom where there was little gravel and a few scattered rocks. White perch, various clupeoids, and snapper bluefish were taken in the same area. Failure to get additional young specimens in this area may be explained by the great difficulty in seining efficiently at this particular locality. According to Wallace and Neville (1942), none were found at this location in some subsequent years.

Bigelow and Welsh (1925: 256) have noted that by autumn the young fry produced in the Gulf of Maine area are two to three inches long, and in the past, when bass were plentiful, many were netted in winter with smelt and tomcod in the Kennebec River and in other Maine streams.

Merriman (1941: 18, fig. 11) gave the length-frequency distribution of 104 small striped bass which were trapped against the screen of the intake wells of a large power plant in the Delaware River at Plainsville, New Jersey on November 8, 1937. The bulk of the specimens were young of the year. He also (1941: 20 and fig. 14) gave a length-frequency curve for 85 young striped bass captured on May 11, 1938 along the shore of Albemarle Sound from Mackeys to Rea's Beach, North Carolina. They ranged from 1.9 to 3.1 cm in length.

For California striped bass, Scofield (1931: 32) has given a length-frequency distribution of young taken in June 1927 when they averaged about 2.5 cm (1 inch). Also, his table 2 shows that young attained an average length of 9.7 cm (3.8 in.) at the end of their first year. Calhoun and Woodhull (1948: 178) have given a table showing the length of larvae and young striped bass taken in central California in 1947; by July 10 they averaged 1.5 inches in fork-length and ranged between 1.0 and 2.6 inches.

Hermaphrodites. Schultz (1931: 64) reported an hermaphroditic striped bass taken on the Pacific Coast on May 19, 1931. It weighed 12 pounds and was 60.3 cm in standard length. The ovary was on the left side, the testis on the right, and Schultz was of the opinion that the fish would have produced both sexual products. In Coos River, Oregon, Morgan and Gerlach (1950: 27, fig. 20) found almost 3% of the bass sampled to be hermaphrodites. Occasionally both ovaries and testes were ripe and in spawning condition at the same time. In all cases the testis was the anterior and the ovary the posterior part of the gonad, and in some the testis was larger.

Artificial Propagation. The only successful operating striped bass hatchery now in existence is that at Weldon, North Carolina. Following the early experiments of Worth (1882, and succeeding papers), which demonstrated that striped bass could be artificially propagated, the hatchery at Weldon was established in 1906, and operations have continued there with minor interruptions since that year. According to the records of the U. S. Fish and Wildlife Service, the number of eggs taken has varied from year to year. The peak year was 1921 when over 55,000,000 eggs were fertilized and about 44,000,000 fry hatched. King (1949: 18) noted that in recent years the number of eggs taken from the Roanoke River has been far below the handling capacity of the hatching station. In 1949, 29 female striped bass provided 6,625,000 eggs. The smallest number received from a single fish was 30,000, the largest number 660,000; the weights of these fishes were not recorded, but a female fish weighing five pounds may produce a half million eggs. King (1949: 20, table 1) has given the number of eggs and fry hatched at Weldon from 1939 to 1949. He noted that there appears to be some evidence of recurring cycles of abundance every three years, but unfortunately there are no accurate catch records kept either by commercial fishermen or by anglers in this area, hence there is no way of actually correlating the number of eggs received per year with the number of fish taken in the river. Actually, so few eggs have been taken in some years that the incidental capture of one or two large females could easily make the records show a big egg year. Generally in the past a small number of females have yielded the total number of eggs taken. The hatchery does not have the personnel to obtain female striped bass and must therefore rely upon fishermen to bring them in. Male fish may be taken in numbers almost any time after a gravid female is found.

After the eggs have been fertilized they are placed in jars similar to the type used in hatching eggs of shad or walleyed pike. Water circulates constantly through the jars, and when the young fish hatch they swim to the surface and out into aquaria. Experience at the Weldon hatchery has shown that the fry are not held successfully for more than 12 to 24 hours after hatching without a high mortality, perhaps due in part to an unsuitable water supply and in part to overcrowding. Bass are usually released just before the yolk sac is fully absorbed; the fry must be handled very carefully to avoid large losses, and the longest haul successfully accomplished took about two hours. Many liberated in the Roanoke River may be lost through the serious pollution from pulp mills at Roanoke Rapids and at Plymouth.

In the light of the negligible results obtained from stocking species like the striped bass, where great numbers of eggs are produced by the female, it seems rather futile to continue operation of the Weldon hatchery or of any other striped bass hatchery. In theory, North Carolina sportsmen have supported the cooperative hatchery at Weldon in the hope of perpetuating the run of striped bass in the Roanoke River and of reestablishing the fish in rivers where the numbers are now so small as to make successful reproduction unlikely. In recent years some improvement in striped bass fishing has been reported from the Tar and Neuse Rivers, and it is possible that the hatchery at Weldon has been responsible in part for this improvement, but this seems most unlikely, since in nature a large survival of young striped bass may be obtained from relatively few adults. The Roanoke River has been a good natural spawning site for striped bass for many years; indeed, this fact was known in colonial times. Therefore, sportsmen in this area would do well to concentrate their efforts on getting rid of the pollution, which undoubtedly has a deleterious effect upon young striped bass larvae in their seaward journey.

According to Pearson (1938: 829), attempts in the past to artificially propagate striped bass at Havre de Grace, Maryland, failed because of the difficulty of getting ripe males and females simultaneously (see Snyder, 1918, 1919). Coleman and Scofield (1910) also ran experiments on the artificial propagation of striped bass in California; Scofield (1910) described attempts to run a striped bass hatchery on the San Joaquin River, a project which was abandoned after three consecutive years of failure to collect ripe spawn.

Pearson (1938: 839) noted that larval striped bass hatched at Weldon, North Carolina on May 14–16, 1937 and planted in a pond at Edenton, North Carolina several days after hatching attained a length of 30–33 mm (1¼ in.) by June 10.

FOOD

The striped bass is a voracious, carnivorous fish that is fairly general in its choice of food. Adults eat many kinds of living fish and crustaceans. It is not a steady feeder and the members of the school normally feed about the same time. Digestion seems to be rapid.

Literature, Atlantic Coast. Verrill (1871, 1873) reported that several specimens taken with menhaden in seine hauls at Great Egg Harbor, New Jersey in April 1871 contained shrimp in large quantities, that a specimen caught at Woods Hole on July 22, 1872 contained a large mass of sea cabbage, *Ulva latissima,* as well as the remains of a small fish, and that individuals taken at Woods Hole in August 1871 contained crabs and lobsters. Goode (1884: 425), summarizing the known information about the food habits of the striped bass, stated that it is a voracious feeder, preying upon small fishes in rivers, eating shad and herring in the spring, and searching along rocky shores of bays and sounds at high tide for crabs, shrimps, and squids, as well as clams and mussels which they obtain by delving with their snouts.

Baird (1889: 73) pointed out that seaweed is found so commonly in the stomachs of striped bass that it must be considered an article of food, although he recognized that some vegetation may be taken accidentally when engulfing shrimps or mollusks. On the other hand, recent stomach analyses have revealed the presence of little plant material. Mosher (1883: 410) stated that striped bass eat crabs and lobsters but do not feed on menhaden. He had worked for many years in the fishery industry preparing striped bass for market, and out of the tens of thousands of striped bass that he handled, he claimed that he never found menhaden as an item of the stomach contents unless the latter had been fed to them as bait (presumably recognized by their cut condition). He was also of the opinion that bass fishing was best on the bottom where crabs and lobsters were most plentiful. His remarks on the lack of menhaden in bass stomachs is interesting in the light of the findings of many modern workers, such as Merriman (1941) and Hollis (1952), who found that menhaden were commonly eaten in Connecticut waters and in Chesapeake Bay. Bean (1891: 33; 1905: 180) pointed out the general predatory nature of striped bass and noted that it eats many kinds of fishes, including herring and shad when in streams, and silversides, anchovies, and killifishes, as well as worms, shrimps, crabs, squid, clams, and mussels. Linton (1901) noted that many striped bass taken in the Woods Hole area had empty stomachs and only a few fish scales in the intestine; he was particularly interested in parasites and gave little quantitative data on food. Smith (1907: 273), in a general summary of the types of food found in bass stomachs in North Carolina, included all kinds of fishes of suitable size, especially shad and alewives in the spring, as well as crabs, shrimps, lobsters, squid, clams, and other invertebrates. Bigelow and Welsh (1925: 255) noted that the bass is a very voracious fish, that it preys indiscriminately on small fish of all kinds, that herring, menhaden, shad, smelt, and the small fry of launce, mummichugs, and silversides are its chief diet in inclosed waters, and that it hunts for crabs, shrimps, lobsters, squid, mussels, and various invertebrates along open shores. Le Compte (1926: 203), in a popular account, noted the presence of alewife and other small fishes as well as small crabs and shrimps in the stomach contents.

The stomachs of 48 specimens taken in Chesapeake Bay were examined by Hildebrand and Schroeder (1928: 248) in the first detailed report on food analyses of striped bass from the east coast. The stomachs of those caught in salt or brackish water of Chesapeake Bay contained fishes, crustaceans, annelid worms, and insects. The larger bass fed principally on fish, whereas the smaller ones had eaten mainly crustaceans, such as *Mysis* and *Gammarus*, and annelids and insects. Haddaway (1930) gave a popular account of its food.

With the advent of the 1934 year-class, which first appeared in the catches in 1936 and 1937, there was a renaissance in the study of the striped bass on the east coast. In the period from 1937 to 1941, much information based on stomach analyses was published. Truitt and Vladykov (1937: 225) published a preliminary account of stomach contents obtained from 100 stomachs of Chesapeake Bay stripers. Hollis (1952) made an exhaustive study of the variations and feeding habits of the striped bass in Chesapeake Bay. His analyses, made on material collected in 1936 and 1937 by Vladykov and Wallace, involved examination of the contents of almost 2,000 stomachs to determine the variations in the quality of food in different parts of the Bay in different seasons. His results are reported in greater detail below. Vladykov and Wallace (1952) also gave a summary of 1,736 stomach contents from Chesapeake Bay, based on the studies of Hollis. Merriman (1937a: 32) examined about 250 stomachs collected along the Connecticut Coast, of which 41% were empty. His findings are reported in detail below in combination with other data which he published in 1941. Curran and Ries (1937: 128) and Townes (1937: 225) reported on the stomach contents of young striped bass taken in 1936 from the Hudson River, New York. Pearson (1938: 839) gave a general summary of food preferences; he stated that the striped bass is a carnivorous, predacious form that is known to consume all kinds of fishes and crustaceans, the shad, river herring, and menhaden being favorite prey in fresh and brackish waters, while crabs and lobsters are eaten along rocky coastlines; shrimps, squids, clams, and other crustaceans have also been noted in stomachs; young striped bass reared in aquaria feed on small *Daphnia*. Merriman (1941: 52) reported on the stomach contents of 550 striped bass taken from April to November in 1936 and 1937; most of these were from Connecticut waters, although some came from the Massachusetts Coast and still others from Long Island and New Jersey. He also gave an analysis of the stomach contents of juveniles and young from Parker River, Massachusetts and Delaware River, New Jersey. In addition, 101 striped bass taken in the Albemarle Sound region and Manteo, North Carolina were analyzed. These results are given in detail below.

Literature, Pacific Coast. Smith (1896: 454) reported that carp appeared to be the principal food of the striped bass in California;

he reported that a Mr. Babcock, who opened hundreds of bass for the purpose of stomach analysis, had never seen any other fish in their stomachs, and he also reported that a Mr. Alexander, who examined bass in the San Francisco market, observed that whenever food was present it was usually a carp, and that through the season about seven out of every 10 bass sold in San Francisco contained carp. Shapovalov (1936: 268) has stated that it is impossible to take the above statement by Smith literally in the light of more recent findings. There are still many carp in the Sacramento River, but the records indicate that they are not a prominent item in the stomach contents of striped bass. Shapovalov also stated that it is difficult to believe that, of the hundreds of bass examined, Alexander did not find other kinds of fish such as minnows or sculpins, which undoubtedly were as common in the river at that time as they are at present.

Scofield and Coleman (1910: 114), who made the first detailed stomach analyses of California striped bass, observed that adults found in the rivers ate mostly carp and other minnows, such as hardheads and splittails. They also reported on the food of 50 young bass from Napa Creek which averaged three inches in length; they had fed largely on crustaceans, marine worms, and to a lesser extent on small fishes. Scofield and Bryant (1926) noted that an occasional dead striped bass was found with a catfish in its throat (caught by its pectoral spines), and that catfish weighing up to two pounds are commonly found in stomachs. Scofield (1928a, 1928b) has expressed the opinion that the migrations of the bass within San Francisco Bay and along the coast are largely dependent upon the food which they are seeking. During the warm summer months the bass school on the mud flats, a place where young striped bass are also found, but when cold weather sets in during the fall the fish leave these areas. Crabs and shrimps are the main dietary items, but almost every living marine organism of acceptable size has been found in the stomachs of Pacific striped bass. Small smelt, which occur in great numbers in summer months, are commonly eaten, as are splittails, bullheads, and young striped bass. Soft shelled crabs, clams, periwinkles, piling worms, herring, gobies, minnows, sticklebacks, sand fleas, and grass are among other minor items listed by this author. Scofield, in a later paper (1931), gave little new information; the data may be summarized as follows: (1) The striped bass, a voracious feeder, has eaten practically every marine form found in the San Francisco Bay area. It eats fishes such as small Pacific herring, smelt, anchovies, splittails, striped bass, shad, gobies, carp, and perch; crustaceans and mollusks such as crabs, shrimps, periwinkles, and clams; and various other forms such as worms, and *Velella*, the Portuguese Man-of-War. (2) Striped bass feed most heavily during the spring and summer months and in general they eat more heartily in salt water than in fresh. Scofield also stated that spawning bass feed while on spawning beds. This point has been refuted by Woodhull (1947: 101), who pointed out that it is very difficult to catch striped bass when they are actually spawning and that the stomachs are empty or nearly so at this time.

Shapovalov (1936: 262) studied the stomach contents of 47 striped bass taken in a rather special situation in Waddell Creek, Santa Cruz County, California in the spring of 1935. Waddell Creek is a small coastal stream with a well developed lagoon which is open during the winter months but which is ordinarily closed by a sandbar during most of the summer. The bass examined were from a school which was observed in the upper end of the lagoon. Sixteen of 22 large bass had food in the stomach and had been feeding largely on salmon, trout, and sculpins. Of all the large bass that had been eating fishes, the stomachs of only four contained food other than fishes (small crustaceans and caddis fly larvae). Of the 25 smaller bass, one had an empty stomach, all but two had been feeding on small crustaceans such as *Gammarus*, *Corophium* and/or *Exosphaeroma*, and all but one had consumed sticklebacks or gobies but no other species of fish. Shapovalov pointed out that this is a remarkable case of selective feeding, especially in view of the fact that the fish had remained in more or less of a school in the one pool or lagoon for over a month. Ten bass, taken on November 24, 1931 in the same Waddell Creek lagoon, had empty stomachs. In the same paper Shapovalov (1936: 266) reported on the stomach contents of 43 striped bass taken from San Francisco Bay and adjacent waters from March 28 to May 15, 1935. Only 12 of these stomachs held food, 11 of which contained fish, including small striped bass (in four stomachs), anchovies, herring, and jack smelt. These data might be interpreted as indicating a partial cessation or at least a diminished feeding intensity near spawning time, but this is not necessarily a valid conclusion, for the specimens may have been captured near the beginning of a feeding period or near the end of a digestive period. Calhoun (1948: 6), in a short summary of the feeding habits of striped bass in California, has stated that anchovies and shrimps appear to be particularly important foods. He also noted that the fish is cannibalistic and devours surprisingly large individuals of its own species. Johnson and Calhoun (1952: 531) have found that shrimps (*Crago*) and anchovies (*Engraulis mordax*) were the predominant foods in 229 striped bass stomachs from the summer and fall fishery in San Francisco Bay and adjacent waters. Small fish predominated in 158 stomachs from the winter fishery.

In Umpqua River, Oregon (Anon., 1946), 66 striped bass ranging from 3⅜ to 25 pounds were examined. Fishes, crabs, and shrimps were found in the stomachs, but no salmon or trout, no doubt due to the fact that striped bass do not appear in the river in large numbers until after the young silver salmon has migrated to the ocean; only a small number of seaward migrants of Chinook salmon were in the lower river at the time the bass were abundant. However, striped bass do eat small salmon and trout. Thus Shapovalov (1936: 261) reported that each of six large bass taken in Coos Harbor, Oregon, contained 10, 11, 14, 15, 20 and 22 trout and salmon fingerlings; the young salmon were practically all silver salmon on their way to the sea.

A significant study of bass food in Coos Bay, Oregon, was made by Morgan and Gerlach (1950: 24). In 1948–1950, a total of 1,018 stomachs were examined, and of these 49.6% were empty and 6.3% had unidentifiable contents. A seasonal breakdown is given in graphic form. During most of the year gregarious fishes such as viviparous perch, herring, anchovies, sand launces, and surf smelt were the principal food items. Also important on a yearly basis were sculpins, shrimps and crabs, with blennies and flatfishes present in smaller numbers. In the period from April to June, when the presence of large schools of bass coincides with the heavy downstream movement of young salmon and trout, numerous trout, salmon fry and fingerlings were eaten. No small striped bass were found in bass stomachs.

Food of Young. In California, Scofield and Coleman (1910: 114) studied the stomach contents of 50 young striped bass taken in Napa Creek on September 10, 1908. Marine worms comprised 50% of the food, marine crustaceans 48%, and small fishes only 2%. The young shrimp and fishes were taken from stomachs of young bass three to four inches in length, and the other small crustaceans were found in stomachs of specimens three inches and under.

In the Hudson River, New York, Curran and Ries (1937: 128) and Townes (1937: 225) found that 117 young and a few yearling striped bass, ranging from 3 to 11 cm in standard length with the majority between 3 and 5 cm, were feeding mostly on freshwater shrimp, *Gammarus*, which formed about 60% of the food. Diptera (chironomid) larvae were the next most important item. The remains of small fishes and plankton crustaceans formed a small percentage of the food.

Merriman (1941: 53) observed that three juvenile specimens 6.0–7.5 cm in standard length from the Parker River, Massachusetts had shrimp (*Crago*) in their stomachs. Merriman also noted that 19 out of 30 juvenile and yearling striped bass from 11 to 23 cm long, taken in the Delaware River near Pennsville, New Jersey on November 8, 1937 contained remains of fishes. A herring-like fish, probably menhaden, formed the main diet, and white perch and spottail shiners were also commonly eaten. He pointed out that small striped bass often eat rather large prey, for in this sample a 6½-inch bass swallowed a 3-inch white perch, while a 7¼-inch bass had eaten a 4-inch minnow, *Notropis*. In Chesapeake Bay, Hildebrand and Schroeder (1928: 248) noted that a young striped bass had fed on crustaceans (*Mysis* and *Gammarus*), annelid worms, and insects.

Food of Large Striped Bass of the Atlantic Coast. Merriman (1937a, 1941) examined the stomach contents of 550 striped bass ranging in size from 6.5 to 115 cm, of which 52% were empty. Most of them were taken from April to November 1936 and 1937 in Connecticut waters, although some came from the Massachusetts Coast and still others from Long Island and New Jersey. A majority were caught on rod and line, while others were captured in nets. Over 75% of the stomachs were from striped bass that ranged in size from 30 to 50 cm. His conclusions regarding the feeding habits were as follows: (1) The rugose lining of the stomach of the striped bass probably indicates a rapid rate of digestion. (2) The fish is not a steady feeder, since it may gorge itself in a comparatively short time and then stop feeding until its stomach is completely empty again. In this connection it is interesting to note that Webster (1943: 36) found that white perch, *Morone americana*, a relative of the striped bass, usually fed heavily early in the evening and ate little or not at all later, hence specimens taken in the morning usually had no food in the stomach. (3) There is evidence that members of a single striped bass school feed simultaneously and digest the food over essentially the same period of time. Often a high percentage of bass in one seine haul was filled with freshly eaten fish such as menhaden or silversides, while the stomach contents of bass taken in a later haul were partially or well digested. At other times most of the fish taken in the haul were entirely empty. (4) As mentioned above, 52% (286) of all the stomachs were empty. The high percentage of empty stomachs is due in part to the fact that most of the specimens were taken by anglers at the start of a feeding period whereas well fed bass were not taken since they would not feed as readily; secondly, bass caught by hook and line often regurgitate their food as they are hauled into the boat. (5) An examination of the contents of specimens larger than 25 cm confirmed the commonly held view that this species is voracious and has a fairly general choice of food. (6) It is also noteworthy that bass often take food from the bottom. Blind individuals taken in the Thames River, Connecticut, appeared to be in good condition, having apparently fed only on bottom dwelling forms. (7) The most common food item in Connecticut waters was the silverside. (8) The stomachs of bass 30 to 50 cm long taken from the Niantic River, Connecticut in 1936 and 1937 showed that adult silversides and the common prawn, *Palaemonetes vulgaris*, were the main food items from April to August. However, in August and September the bass fed on juvenile silversides to a large extent. After this change of diet in August (1936) there was a decided increase in the growth rate of two-year-old striped bass despite a drop in water temperature; the greatest growth was in October. (9) Juvenile menhaden also came into the diet of striped bass in August and was commonly eaten during the remainder of the year (1936). However, in 1937, although less juvenile menhaden were available, the growth of striped bass continued in September and October much as it had throughout the summer, despite the drop in temperature. Merriman therefore credits the availability of juvenile silversides after the middle of August as an important factor in the growth of small bass in this area. Other possible explanations of this apparently faster growth rate of striped bass in late summer and early fall (e. g., faulty sampling and "compensatory" growth) have been noted in the section on AGE AND GROWTH. (10) The following food items were found in 264 full stomachs examined by Merriman in 1936 and 1937, in Connecticut, Massachusetts, Long Island, and New Jersey.

Common types: Silversides, *Menidia menidia notata;* Menhaden, *Brevoortia tyrannus;* Shrimps or prawns, *Palaemonetes vulgaris;* Killifishes, *Fundulus heteroclitus* and *F. majalis.*

Uncommon types: Sand launce, *Ammodytes americanus;* Herring, *Clupea harengus;* Squid, *Loligo pealei;* Sand worm, *Nereis virens;* Blood worm, *Glycera dibranchiata.*

Rare types: Flounder, *Pseudopleuronectes americanus;* Eel, *Anguilla rostrata;* Tomcod, *Microgadus tomcod;* Clam, *Mya arenaria;* Crabs, *Callinectes sapidus* and *Ovalipes ocellatus;* Snails, *Littorina* sp.; Mussels, *Mytilus edulis;* White Perch, *Morone americana;* Mullet, *Mugil cephalus;* Shiner, *Notropis hudsonius amarus;* Blenny, *Pholis gunellus;* Amphipods; Isopods.

Merriman (1941: 55) also gave the following list of organisms found in 101 striped bass, yearlings to three-year-olds, taken from Albemarle Sound and Manteo, North Carolina in April 1938: Striped killifish, *Fundulus majalis;* Sea trout, *Cynoscion nebulosus;* Silver Perch, *Bairdiella chrysura;* Croaker, *Micropogon undulatus;* Gizzard Shad, *Dorosoma cepedianum;* Spotted Ling, *Phycis regius;* Anchovy, *Anchoa mitchilli;* Eel, *Anguilla rostrata;* White Perch, *Morone americana;* Glut Herring, *Pomolobus aestivalis;* Shiner, *Notropis* sp.; Shrimp, (3 species), *Penaeus, Palaemonetes, Crago;* Blue Crab, *Callinectes sapidus;* Isopod, *Aegathoa oculata.*

Hollis (1952) made a detailed analysis of the food of striped bass from material collected by Vladykov and Wallace (1952) in 1936–1938 from Chesapeake Bay. He examined the stomachs of 1,736 specimens, of which 969 or 55% contained some food. These bass were taken mostly from June 1936 to April 1937 by anglers and commercial fishermen. Those taken by the latter were captured in haul seines, gill nets, pound nets, and fyke nets. Hollis stated that the quantity and quality of food found in the stomachs varied with the different methods of fishing. Many taken by anglers were empty, presumably because it is chiefly the hungry fish that seize a hook, although the possibility of regurgitation must also be considered. In commercial catches the lapsed time between successive net hauls is obviously an important factor. Furthermore, since different types of nets are used in particular areas, the type of food available may vary according to the kind of place in which the fish was captured. For example, haul seines, pound and fyke nets are used in relatively shallow water near shore, whereas gill nets are commonly employed during cold periods of the year and are set in deeper waters near the bottom. The time at which the nets are set is also important, and the size of mesh is a further consideration, since it influences the size of fish captured. In general, larger fish tended toward a more piscivorous diet.

By weight, fish comprised 95.5% of the food of striped bass. In various areas the percentage of fish food varied from about 46 to 100% of the total stomach contents, although fishes were rather sparsely represented and totaled only 33% of the stomach contents of bass taken in fresh water of the Susquehanna River below Conowingo Dam. Twenty-six different kinds of fish were eaten by striped bass, anchovy, menhaden, spot and croaker being taken most often. During 1936 the anchovy, found schooling near the surface, was particularly abundant in Chesapeake Bay. Menhaden was also plentiful through the summer and fall of 1936, and the young of spot and croaker were abundant during the fall and winter and were generally found close to the bottom in the deeper water. Sometimes the food of individual bass consisted of only a single species, such as anchovy. On the other hand, some bass consumed anchovy, menhaden, and herring and still others menhaden, branch herring, and red drum. In Chesapeake Bay, a ten-inch herring was the longest fish found in a striped bass stomach.

Crustacea constituted the next most important category of organisms; they varied from 0 to 46.3% by occurrence, but by weight they occupied less than 2% of the total. The blue crab was found in striped bass stomachs in negligible quantities, and other crustacea were cladocerans, shrimps, mysids, copepods, and isopods. Among the miscellaneous invertebrates, polychaete worms, mollusks, and pieces of bloodworms, which in many cases had probably been used as bait, were found in bass stomachs.

A seasonal variation was noted in the food of striped bass in Chesapeake Bay. During the summer the principal food in salt water was anchovy and menhaden, whereas during the fall and winter the spot and croaker were important. In early spring the most typical food item was the white perch. Two kinds of river herring (*Pomolobus*) were found commonly in bass stomachs during spring and early summer, a period which coincides in part at least with the most active migratory period of river herring.

A regional variation in food was also noted, especially when salt and fresh water areas were compared. In fresh water, especially below Conowingo Dam, the black crappie, yellow perch, spottail shiner, blacknose dace, and bullhead were often present, as was also *Leptodora*, a crustacean usually found in lakes. The blue and mud crab, found in stomachs of bass taken in salt water, were absent in specimens captured in fresh water. It is interesting to note that Hollis found no striped bass feeding on its own young, although great numbers of young striped bass were present. No jellyfish were found in bass stomachs although medusae and ctenophores were common.

The striking difference between the results of Merriman and Hollis should be mentioned. Hollis found only seven silversides (*Menidia*) in five stomachs of the 955 that contained food. However, the silverside is a common fish in Chesapeake Bay and undoubtedly it would have been eaten if it were a preferred form; in captivity bass took the silverside readily. These facts seem to indicate that bass will feed on the silverside but that they perfer anchovy when it is present in abundance. In Chesapeake Bay top minnows are exceedingly abundant but seldom eaten, whereas in Connecticut they were the third most common fish consumed.

In Chesapeake Bay, stomach analyses indicate that there is a tendency toward cessation of feeding from mid-May to June, which corresponds with the spawning period for this species in this area; this is in accord with the findings of Woodhull (1947) in California. The number of full stomachs in Chesapeake Bay striped bass increases about 50% during the summer when the fish resume feeding shortly after spawning; the percentage remains about the same in the fall months but increases to about 70% in winter and early spring. On the other hand, Scofield (1931: 56) noted for California that the diet was light during the late fall and winter. Feeding in Chesapeake Bay is most pronounced in December and January and begins to decrease in February. Out of 29 striped bass in spawning condition taken from June 1 to 6, 1936, only two stomachs contained a trace of food.

Factors Influencing Feeding Habits. The amount and kind of food taken by striped bass clearly depends on a number of factors such as: Availability of food organisms; presence of bass in salt or fresh water; time of day, season, and temperature; physiological condition of bass; and size of bass.

Although striped bass feed on a variety of fishes and crustaceans of the preferred size in their environment, they generally take those kinds that are most abundant. However, there are some exceptions to this generalization; during the summer in Connecticut the silverside is eaten most often, while in Chesapeake Bay the anchovy is the most important item even though the silverside is present in great numbers. Practically no vegetation is eaten except incidentally when they feed on bottom dwelling animals.

It is thought that striped bass follow and feed on schools of fishes (see Scofield, 1928b), and it is true that their most important food, as determined by stomach analysis, is gregarious forms (anchovies, silversides, menhaden, spot, and killifishes). The extensive northward migrations of bass may be due in part to the movement of fishes on which they feed. The southward fall migration within Chesapeake Bay, according to Hollis (1952), results from pursuit of migrating fishes which are leaving the Bay at this time.

Fortunately the striped bass does not engulf large quantities of game or food fishes. However, in Chesapeake Bay during the winter it eats spot and croaker, both of which are important food fishes. In the spring it takes its toll of migrating shad and river herring, but this is the season when striped bass feed least. It also eats some blue crabs, which are important in the total Chesapeake Bay fishery. In Oregon and California striped bass eat some young salmon and trout, but the numbers taken are probably not critical at most localities.

The amount of feeding varies with the time of day and with the season. Bass are known to feed avidly in the evening just after dark and sometimes they also feed well just before dawn. On some occasions schooling bass take lures readily during the day. Large bass feed both day and night, but data are not available to indicate when most are captured. Hollis (1952) found seasonal differences in percentages of full and empty stomachs, the greater number of full stomachs being observed in bass taken in Chesapeake Bay from January to March when spot and croaker in deep water are their favorite foods. Bass may be taken on rod and reel in winter in localities as far north as the Thames River, Connecticut, where Al. H. Hewitt has taken specimens weighing from 4 to 40 pounds from Norwich to the New London bridge; he has had most success fishing at night with an underwater plug, but he took others with live fish bait from January to July in 1949 and 1950.

Young bass feed largely near the bottom on crustaceans and other small invertebrates. It is during the latter part of their second summer that they begin to school more extensively and then feed more heavily on schooling fishes.

AGE AND GROWTH

The chief factors which affect the growth rate of fishes are: (1) Growth capacity of the species (a genetic factor); (2) Age and attainment of maturity; (3) Availability of food and competition; and (4) Water temperature and length of growing season. In general, young striped bass are known to put on most growth in late spring and early summer, while older bass increase rapidly in length in summer and early fall but slow down markedly or cease growing in late fall (November) and winter. The most important works on this phase of the life history of the striped bass have been done by Scofield (1928b, 1931, 1932) California; Clark (1938) California; Merriman (1941) New England, Long Island; Tiller (1943, 1950) Chesapeake Bay; Calhoun (1948) California (summary from Clark, 1938); Morgan and Gerlach (1950) Oregon; Vladykov and Wallace (1952) Chesapeake Bay.

Age Determination. Methods that have been used in determining the age of striped bass are: (1) Study of the length-frequency distribution of large numbers of bass; (2) Scale analysis; (3) Study of growth bands on otoliths; (4) Study of growth bands on the opercle (gill cover).

Scofield (1931:26), who was the first to analyze the possible methods of determining age in the striped bass, observed that the first four age-groups could be determined roughly by length-frequency data. After determining the age of these younger groups, especially one- and two-year-olds, he went on to a study of scales, opercles, and otoliths. Results from all four methods indicated that age may be determined accurately at least in the first eight to ten years. As a matter of convenience the scale method has been most widely used.

Since striped bass scales are coarse and tend to curl considerably when dry, Scofield mounted scales in a preparation of glycerin jelly. However, a newer method, by which an imprint of a scale is made by stamping it in a thin celloidin film (described by Nesbit, 1934a), practically replaced the old method of mounting the scales themselves. All the delicate sculpturing on the scale is preserved and these flat films are easily manipulated, studied, and stored. Merriman (1941: 23) adopted Nesbit's method of making impressions of scales on thin sheets of transparent celluloid acetate base, and he found that: (1) The impression of the scale is easier to study than the scale itself; (2) Impressions are better for photographs; (3) The method is faster than mounting each scale in the conventional manner; (4) The cost is far less.

Description and Illustrations of Scales. Photographs of scales which illustrate the various details are given by Scofield (1928b: 31, fig. 19; 1931: 26, figs. 18, 19 and 20). Tiller (1943: figs. 1 and 2), in illustrations of striped bass scales from members of the 1939 year-class from Chesapeake Bay, showed two annuli, while Merriman (1941: 23) and Calhoun (1948: 4) have shown diagrammatic sketches of striped bass scales. The scales of striped bass are ctenoid with radii on the anterior field. Scofield (1931) found that from 25 to 150 circuli were formed during the course of a year's growth, the number depending somewhat on the age of the individual. The younger faster growing bass formed more circuli than older individuals. However, irrespective of age, he found that in early winter the scales ceased to form circuli. Scofield claimed that this period of dormancy continued throughout the winter and into early spring, a matter of five or six months. Scofield noted that in early spring, before formation of normal circuli is resumed, several more or less straight circuli are laid down, leaving a line or annular ring, called the annulus, which completely circles the scale except for its posterior edge. Scofield found that only 8% of 7,430 scales studied had to be discarded because of defects that made them unreadable, most of those being scales that lacked normal centers (regenerated scales).

Annuli, False Annuli, and Time of Formation. Occasionally false annuli may be seen on otherwise normal scales. These have the typical formation of a normal annulus except that they are incomplete. Scofield (1931) found them in both immature and mature fish scales, and he pointed out that after some experience it is not difficult to distinguish between true and false annuli. Merriman (1941: 23) did further work on the validity of the scale method and concluded that: (1) Annuli are increasingly numerous on larger striped bass; (2) The number of annuli is constant on all scales taken from a single striped bass; (3) All of the scales of 17 bass tagged in 1936 and recaptured from May to September 1937 showed the formation of an additional annulus; (4) False annuli are sometimes present on scales. Merriman

(1941: 24) also pointed out that false annuli are mainly of two types. The first is a broad accessory annulus, scarlike in appearance, frequently seen on scales of large striped bass but only rarely on scales of 2- or 3-year-old fish. This type appears just outside or in close conjunction with a true annulus. He interprets these as spawning marks, because they are formed in the spring when spawning takes place just after normal growth has been resumed. The second type looks much like a true annulus but is distinguished by the character of the circuli that border it. It occurs most commonly on scales which overlap a regenerated scale, thus suggesting that the process of regeneration may modify the scale growth in an adjacent area; Merriman (1941: 25) actually observed this type of false annulus on recaptured tagged striped bass near the area on the body where he took a scale sample on the occasion of first capture.

Tiller (1943: 6) gave the time of annulus formation as the time of resumption of rapid growth in the spring, usually early in May. According to Scofield (1931) it is early spring, but Merriman (1941: 31) found it to be winter (presumably late winter). Morgan and Gerlach (1950: 19) mentioned that some bass were taken in the spring before the annulus was formed.

The precise body length at which the scale is formed is not known. Merriman (1941: 31) found that scales were formed at 2.0 cm but not at 0.5–0.6 cm; he estimated that 1.0 cm was the length at which scales first appear.

Difficulties in Reading Scales of Older Striped Bass. Scofield (1931) found little difficulty in reading scales of bass up to seven or eight years of age, but after the eighth year, when growth slows down, the annuli tended to be less conspicuous. Also, some circuli formed more irregularly, thus making the scales of older fish much harder to read. Merriman (1941: 25) also found scales from large bass much more difficult to read than those from small individuals. He stated that the first annuli are likely to become indistinct, and since there are likely to be more false annuli, back calculations of age were limited to fish less than five years old. On scales of striped bass over eight years it was very difficult to be sure that the age reading was correct, hence the determinations made on the larger fish were only approximations. Tiller (1950: 28) concluded that the scales of Chesapeake Bay bass may be accurately determined at least until the fifth year. In Oregon, Morgan and Gerlach (1950: 19) could not determine the age accurately beyond the first ten year-classes.

As in many other fishes, the best scales for age-determination are those in the midsection of the body just above the lateral line. These scales are rarely deformed and usually show distinct annular marks.

Scales on other parts of the body also show year-marks, but often they are more difficult to read. Tiller (1950: 27) made a study of the shape of scales on several parts of the body; he noted that variation in calculated length was a function of scale size, and he used the area chosen previously by Scofield (1931) and Merriman (1941) as yielding the most symmetrical regular scales.

Back Calculations of Length from Scales. Merriman (1941: 31) went into the problem of back calculation of lengths at various ages by using scales. This method is based on the assumptions that: (1) The scales are constant in number and identity throughout life; (2) Scale growth is proportional to growth in length; (3) Annuli are formed yearly and at the same time of the year. Merriman (1941: 31) gave a graph showing a straight line relationship between scale growth and growth in length, and it is clear that the scale growth may be considered proportional to the growth of bass 10.5 to 67 cm long. Tiller (1950: 27) mentioned that scales taken from extreme areas of the body yield distorted values of calculated length.

Otoliths and Opercles. Scofield (1931) examined 50 or more otoliths and found that they yielded the same results as the scales. The rapid growth on an otolith is represented by a dark area while the annular area stands out as a light streak; these dark and light markings extend around the entire otolith, being more distinct in some areas than in others. Scofield (1931: fig. 21) gave a good illustration of annular marks on the otolith of a striped bass three years old. Merriman (1941: 25) found that the otoliths as well as the opercular and subopercular bones could be read for annular markings but that they were irregular and indistinct in fish over three years of age. He noted that the opercular bone structure could best be seen after these bones had been cleared in a 50-50 mixture of 5% glycerine and potassium hydroxide. Scofield (1931) reported that the opercle, after being boiled to remove overlying tissues, became transparent when dried; then, after being placed in water for a short time, the annular rings stood out as dark lines while the remaining area turned a creamy color. With the exception of the first annulus, which is inconspicuous, the year-marks are clear. However, because of the difficulty of obtaining and preparing otoliths and opercular bones in large numbers it is impractical to use them, especially since scales give good data.

Length-frequencies in Age Determination. Scofield (1931: 33, fig. 23) has given the method of using length-frequency distributions as a rough means of determining the age of bass in a sample. He subjected a sample of fish to analysis by both length-frequency distribution and age-class frequency based upon scale examination; the two peaks coincide for the two ages represented, although there is some overlap between the faster growing fishes of the earlier class and the slower growing fishes of the later year-class—the usual situation in the growth of fishes.

Most workers now measure striped bass to the fork of the tail, which is called the fork or median length. Total length (the over-all length) and standard length (to the base of the caudal fin) have also been used. Merriman (1941: 24) gave a conversion table so that the length of a striped bass measured by any one of the three methods may be easily transposed.

Length-Weight Relationships. Clark (1938: 177) gave a curve, modified after the earlier work of Scofield (1932), that combines age, fork-length in inches, and weight in pounds for California striped bass. Few specimens of more than 25 pounds were available for the construction of the curve, hence it may be inaccurate for heavier stripers. Calhoun (1948: 5–6) has given the same curve and has summarized the growth rate, stating that bass average four inches at the end of the first year; about 10 inches at the end of the second year; about 14 at the end of the third; and about 18 inches at the end of the fourth year. Morgan and Gerlach (1950: 24) gave a length-weight curve for fish from Coos Bay, Oregon, in which the bass cover a range from six to 47 inches (with the sexes combined).

For eastern stripers Merriman (1941: 6–7, fig. 2) gave the length-weight relations based on 526 striped bass (fork length). He also gave a table of length in centimeters and the corresponding weight in pounds. Vladykov and Wallace (1952) gave the average seasonal variation in weights of both sexes taken in Chesapeake Bay.

Growth Rate and Size. For California striped bass, Scofield (1931: 32 and 33, figs. 22 and 23) gave the length-frequency distribution of the first four year-classes taken in June 1927. He also gave graphs to show the difference in growth of males and females; males show slower growth especially after the fifth year. Morgan and Gerlach (1950: 20, fig. 13) gave a curve for Oregon bass that showed the size attained by the second to tenth year-classes.

For east coast striped bass Merriman (1941: 30, fig. 20) has shown the average growth rate derived by two methods (aging scales directly and by making back calculations from scales). The lengths of striped bass at different ages compare almost exactly with those given for Pacific fish by Scofield (1931) and Clark (1938). Pearson (1938: 839, fig. 20) gave the length-frequency distribution of 0- 1-, 2-, and 3-year-old striped bass taken principally during the summers of 1931 and 1932 in Chesapeake Bay; additional data, given by Tiller (1950:

28) for the 1940 to 1944 broods, show that dominant and subnormal broods had closely parallel rates of growth.

The possibility that a study of growth rates by back calculations of bass scales from different geographical localities may give clues as to the origin of stocks has been discussed by Merriman (1941) and Tiller (1950) and has been mentioned briefly under RACES (p. 16).

Growth increments in California striped bass, shown by graph in Scofield (1931: 38, fig. 28), indicate that the greatest growth is made in the second and third years. Merriman (1941: 32) reported that the greatest growth of striped bass taken in northern Atlantic waters in the summer of 1937 occurs in the third summer, which coincides with the period of coastal migrations. Increments fall off sharply in the fourth summer, thereafter maintaining an average of 6.5–8.0 cm each year until at least the eighth summer, when there is evidence that the rate of growth decreases markedly for succeeding years.

Merriman (1941: 32, figs. 20–23) gave data on the growth of individually tagged striped bass to confirm observations obtained by calculating the growth rate from scales. Vladykov and Wallace (1952) kept tagged and untagged juvenile fish in laboratory tanks and found that tagging did not affect the growth adversely under these conditions.

Tiller (1943: 14) observed a significant compensatory growth in the 1940 year-class from Chesapeake Bay and in the 1938 year-class of the Hudson River. In both areas those individuals that were small as yearlings showed a decidedly greater increase in growth rate during their second year than did the larger yearlings; however, a complete compensation did not occur, since the larger yearlings maintained a larger size at the end of the second year.

A graph showing the growth of the first and second year-classes of striped bass in California has been given by Scofield (1931: 40, fig. 29). Calhoun and Woodhull (1948: 180), in a table with measurements of young bass taken in California during the summer of 1947, showed that a mean length of 1.5 inches was reached by July 10. Merriman (1941: 25) reported that striped bass are about 11 to 12 cm (4.5 in.) long at the end of their first year. He also gave the length-frequency of 628 striped bass taken in the Hudson River from July 3 to September 1, 1936 and the length-frequency distribution of 104 young and juvenile striped bass taken in the Delaware River near Pennsville, New Jersey on November 8, 1937. Vladykov and Wallace (1952) measured 150 young striped bass from Chesapeake Bay in 1936 and 1937; by July these fish reached a mean size of 72 mm (2.8 in.) and a weight of 4.5 g; by October they were 92 mm (3.6 in.) and weighed 9.5 g. These authors estimate the size at one year as 110 mm (4 in.).

There is no appreciable growth in length of small bass during the winter in Chesapeake Bay (temperature 36–42° F), according to Vladykov and Wallace (1952), who also found practically no increase in length of captive juvenile bass from October through February. From records based on larger fish, there is added evidence that there is little increase in length during the winter. These authors report that bass began to grow in April and that almost 50% of the annual increase was found during the period from April 20 to July 7. Merriman (1941: 25) also stated that growth practically ceases in winter. Scofield (1931: 41) reported that in California the period of growth extends from April until October (7 months), whereas during the period from November to March there is little indication of linear growth.

Merriman (1941: 25, figs. 17–19) has given detailed data on the growth of the striped bass in New England and Long Island and has demonstrated the following main points for the 1936 and 1937 seasons. (1) Prominent peaks in samples of fish were mainly due to two-year-olds (in their third summer) in 1936 and to two- and three-year-olds in 1937. Thus it seems that the year-classes of 1934 and to a lesser extent of 1935 must have been successful. (2) Sampling errors favor the small size-groups, first because most fish were seined and smaller fishes are more easily taken, and secondly, because the smaller size-categories probably tend to school more intensively. (3) Samples from commercial fishermen's nets are in agreement with the above. Two-year-olds in 1936 comprised over 85% of the stock taken. (4) Conditions in the Niantic and Thames Rivers seem especially favorable for the smaller (two-year-old) bass. (5) The two-year-olds of 1937 (1935 year-class) were larger than the two-year-olds of 1936 (1934 year-class), and the three-year-olds of 1937 (1934 year-class) were definitely smaller than three-year-olds of 1936 (1933 year-class). Thus the members of the dominant year-class of 1934 appear to have been below average size, probably due to such factors as greater competition for food and lower water temperatures in the spring and summer of 1934, the latter factor probably affecting the time of spawning so that the 1934 group may not have had as early a start as some other year-classes. (6) A higher than expected growth rate for two- and three-year-olds in October despite a drop in temperature. This may have been due to compensatory growth (the phenomenon of the smaller fish of a single group making up a deficiency in size between themselves and the larger fish of the same age-group in a relatively short period) or to increased availability of food. (7) The two- and three-year-old stripers taken north of Cape Cod showed much greater growth than those taken south of Cape Cod (in Connecticut)—a phenomenon which might be accounted for by: differential migration, the larger stripers of both age-groups moving farther north on the average; differential growth rates in the two areas; errors due in part to sampling methods, since those fish caught north of Cape Cod were taken on rod and line; more intensive sampling in the latter part of the summer north of the Cape. However, Merriman (1941: 29) feels that there is a real difference in growth in these two areas. The growth rate of other year-classes from these regions needs to be investigated.

Pearson (1938: 838), who gave the average lengths attained during the first four summers in Chesapeake Bay, noted that the rate of growth is similar to that found by Scofield (1931) for California striped bass. Vladykov and Wallace (1952) reported two specimens at the end of their second summer as 185 and 213 mm long (75 and 126.6 g). The members of the 1934 dominant year-class averaged 13.9 inches by September 1936, were almost 15 inches long by late March 1937, and at the end of the fourth summer they averaged nearly 17 inches. Although there was little if any growth in length in late winter, there was an increase in weight due to fat storage and to the increased development of gonads. Few large bass were available in Chesapeake Bay in 1936 and 1937, hence few data from that region are available on age and growth of older fish. Tiller (1950), in his work at Chesapeake Bay, dealt with the growth of the 1940 to 1944 broods captured in pound nets and showed that the growth rate appears to be highly variable.

Scofield (1931, 1932), Clark (1938) and Calhoun (1948) summarized the known information about the growth rate of California striped bass, which appears to be similar to that in the east.

On the matter of the age and weight of large striped bass, Merriman (1941) gave the following general data: striped bass 100 cm in length (about 40 in.) average about 25 pounds and are 11 or 12 years old; those 125 cm long (nearly 50 in.) weigh approximately 50 pounds and are roughly 20 to 25 years old; a specimen 137 cm long (54 in.) weighed 65 pounds and was 29, 30 or 31 years old. Bigelow and Welsh (1925) mentioned a striped bass that lived in the New York Aquarium to an age of about 23 years. A 36-pound, 42.5-inch female from Virginia Point, Potomac River, taken on April 6, 1937, was reported by Vladykov and Wallace (1952) as being between 10 and 11 years.

Worth (1882) reported that a seine haul catch at Avoca, North Carolina on May 6, 1876 was composed of 840 fish totaling over 35,000 pounds, thus each fish averaged 41.6 pounds, and 350 were said to have averaged 65 pounds each. Smith (1907) reported that several striped bass taken in a seine near Edenton, North Carolina in 1891 weighed 125 pounds each. Bigelow and Welsh (1925: 252) mentioned a 112-pound specimen taken at Orleans, Massachusetts many years ago, and they stated also that striped bass 50 to 70 pounds are not exceptional but that the usual run of those caught is three to 30 pounds. From records compiled by Dr. John H. Cunningham at the Cuttyhunk Club the largest striped bass taken each season were 22 to 57 pounds between the years 1865 and 1907; at the Pasque Island Club, from 1866 to 1913, the largest were from 19.5 to 62 pounds, and at the Quibnocket Club they ranged from 13 to 58 pounds from 1869 to 1888. Merriman (1941: 4) summarized the weight information as follows. Those taken most commonly by sport and commercial fishermen on the Atlantic Coast weigh from one to 10 pounds, but 25 to 30 pounders are not rare; 50 to 60-plus pound fish, caught on occasion in abundance according to old records, are not common now, and 60-plus pound specimens are extremely rare. A 65-pound striped bass was taken on rod and line in Rhode Island in October 1936, and a 73-pound specimen on rod and line at Vineyard Sound, Massachusetts in 1913 (Walford, 1937). A number of large bass from 50 to 55 pounds were taken off Massachusetts in the summers of 1950 and 1951. In the St. Lawrence River, Vladykov (1947a: 197) gave the common size as five to 12 pounds. In a personal communication (June 1949) he said the largest he had seen was 24 pounds and the largest taken by a fisherman was 32 pounds.

Calhoun (1948: 5) reported that no striped bass weighing over 100 pounds appear to have been caught on the Pacific Coast. There is a record of a 78-pounder that appeared in the San Francisco fish market in 1910, and in 1911 an angler caught a 62.5 pounder near Napa.

ABUNDANCE

The abundance of striped bass is largely a relative matter, and the numbers vary greatly depending on the part of the range which is under consideration. Certainly they are not and probably never have been equally abundant in all parts of their known range. Since striped bass frequently travel in large schools, and since the migratory patterns are not necessarily identical from year to year, they may or may not appear where they have been seen previously; hence abundance or scarcity may be overemphasized. Abundance varies not only with the spawning migration in spring and early summer but with large migratory movements northward in the spring and southward in the fall. It is probable also that their abundance varies with the quantity, and possibly with the quality, of the smaller fishes available to them as food. Also, in considering abundance it is important to delimit the size categories under discussion. In certain years the young may be present at some places while scarce or absent at others, and the same thing may be true for juveniles or adults; of course it is these latter sizes which are of immediate interest since they are available to the fishery.

However, there are some fairly safe generalizations which may be made with regard to the abundance of striped bass in the Atlantic. From the available data it appears that it was once a common fish, at least throughout the more northern part of its range from North Carolina to Canada, but, as in the case of most anadromous fishes, its history has been one of decline. It is true that the long period of decline has been broken occasionally by short periods of good catches due to dominant year-classes which result from unusually successful spawning and survival and which may occur even when the population of adult fishes has reached a very low level, as in 1934 in the Chesapeake Bay area. There is considerable evidence that 1948 through 1951 produced excellent striped bass fishing over most of its Atlantic range.

Measuring Abundance. To obtain a thorough and complete appraisal of any fishery it is essential to have accurate statistics regarding the catch plus other basic data. In recent years most of the striped bass that have reached the commercial market have been summarized in the yearly Fisheries Statistics of the United States which are published as statistical digests by the U. S. Fish and Wildlife Service. Though not absolutely accurate, they provide the best data available. Only a few individual states have adequate statistical records; California publishes data on its commercial catch, and in Maryland the commercial fisheries statistics of Chesapeake Bay have been available in some detail since 1944 (see Hammer, Hensel and Tiller, 1948). Regarding the tremendous catch made by sport anglers, only a part of it reaches the market, and hence the catches by sport fishermen are unrecorded for the most part. Obviously an accurate knowledge of the catch of both commercial and sport fishermen is essential in order to provide a sane management plan for this species, but it would be an expensive proposition to establish an adequate system to obtain statistics from anglers on this or any other sport fishery. Today, as in the past, abundance or scarcity in a fishery is based mainly on generalities rather than factual data. At best the opinions are frequently biased for one reason or another, and in most cases the observations are usually too few in number to provide the basic data for a thorough study, especially when the entire range of the fish is considered.

In fisheries biology it is common practice to use the total annual catch from published records as a basis for estimating relative abundance from year to year, but such data can be misleading unless they are carefully analyzed and supplemented with other information. In using catch statistics there are a number of points to be considered. The catch may remain constant or even increase while a species is being depleted; this may occur through expanded fishing effort by more men and boats, by more effective gear, and by operations on new fishing grounds. The incentives for such an increase in fishing effort may be higher prices, a greater demand for the product, or a failure of one fishery which causes a shift to another. On the other hand, a drop in the total catch, which may occur when the supply of the species is holding its own or even increasing, may result from decreased fishing effort, legislation that prevents use of more effective gear, closed seasons which decrease fishing time, and unfavorable weather. Thus the catch in any year is dependent on several factors other than relative abundance (see Craig, 1930: 6), namely: fishing effort, legislation, shifts in fishing grounds, weather, changes in another fishery, labor, and economic conditions.

The catch as measured in terms of a unit-of-effort is likely to be more useful as an indication of relative abundance (or as an indication of availability to fishermen) provided the data are representative samples of the catch drawn from the entire fishery. Even here, however, such variables as unfavorable weather, new fishing grounds, and legislative action that affects the take per unit-of-effort have to be considered. Also, changes or variations in migrations may have a marked effect on the catch. Although an accurate measure of catch-per-unit-of-effort is recognized as an important tool in fishery management, there are relatively few species in our waters (haddock and the Pacific halibut) for which such data are available for any considerable period.

Finally, the angler is likely to overemphasize the numbers of striped bass taken by commerical fishermen, but such opinions, based on observations of only a few seine hauls or a few lifts of traps or gill nets, can be quite erroneous, since the *total* catch in the various areas along the entire coast is important in arriving at a fair appraisal.

Indications of Early Abundance. The following have given information of historical value concerning the striped bass: John Smith (see Jordan and Evermann, 1902); Wood (1635); Schoepf (1788); Mease (1815), a scientific account; Hubbard (1815); Herbert (1849); Perley (1849, 1850); Scott (1869); Adams (1873); Burns (1887); Goode (1884), an excellent survey; Atkins (1887); Endicott (1892), in American Game Fishes; Bean (1950), a scientific account; Jordan and Evermann (1902), a scientific account; Bigelow and Welsh (1925), a review of some of the above historical accounts and additional new material; Pearson (1938); Neville (1940); Merriman (1941).

The edible qualities of the striped bass were recognized by the early settlers, according to Captain John Smith and an early contemporary (see Jordan and Evermann, 1902: 374). In Massachusetts, according to Hubbard (1815), Morton (1637), and Wood (1635), the striped bass was one of the important fishes which contributed considerably to the economy of the early settlers during the year 1623. Wood (1635) gave an early account of their abundance in Boston Harbor (near Salem) and in the Merrimac River.

Indications of Decreased Abundance. Pearson (1938: 826) has noted that, within 19 years after the landing of the Pilgrims at Plymouth, the Massachusetts colonists, realizing the value of striped bass, sought to conserve the supply; thus in 1639 a general court order of the Massachusetts Bay Colony prohibited the use of either cod or bass as fertilizer for farm crops. The first public schools of the new world were made possible, at least in part, from the sale of striped bass; in 1670 the Plymouth Colony granted all income accruing annually to the colony from the bass, mackerel, or herring fisheries at Cape Cod to the establishment of a school in a town of its jurisdiction.

Until about 1885 the bass population seems to have held up well despite the great demands of those days. The records of the early bass clubs, such as that at Cuttyhunk, indicate a great decline by that year. Jordan and Evermann (1902) and Bean (1905) noted that the striped bass, though still an abundant fish, was much less common and was continuing to decrease.

As mentioned previously, the general trend in abundance of striped bass for the past 150 years has been one of gradual decline broken only by periods of abundance due to the production and survival of occasional large year-classes. In New England the abundance seems to be controlled to a large extent by the abundance in areas further to the south, such as Chesapeake Bay, for it has been shown, at least for the 1934 year-class, that striped bass undergo extensive migrations to the north in the spring and to the south in late fall. Bigelow and Welsh (1925: 253–255), in summarizing the available data for Massachusetts, pointed out that the decrease in the seemingly inexhaustible supply was first noted in the last half of the eighteenth century and that often the decreases were local. During the early 1800's bass continued to be rather plentiful in Massachusetts Bay, but by the middle of the nineteenth century the abundance of fish there had declined markedly—a general trend which was increasingly apparent over the years. According to these authors, 1897 and 1921 stand out as notable exceptions, the bass having been more common in those years than in many previous years in the waters of Massachusetts as well as New Hampshire, Maine, and at least that part of Canada that borders on the Gulf of Maine. Apparently few bass were seen in the Piscataqua after about 1792, although an occasional fish was taken there up to 1880, and, since about 1850, they have been scarce about the mouth of the Merrimac River, although a few were taken on and off until 1897. The same steady decline has been noted in Maine, so that by 1900 the commercial catch had dropped to negligible quantities. In more recent years, especially after 1936 and 1937 (1934 year-class), Maine as well as Massachusetts and New Hampshire enjoyed the best striped bass fishing known for some time.

Along the Canadian shores of the Gulf of Maine, especially in the St. John River, Nova Scotia, striped bass were rather plentiful during the first part of the nineteenth century. After a period of decline, a marked increase in the number of bass was noted in 1949 and 1950 in Nova Scotia according to Howard Scott. Considerable numbers have been taken by anglers in the Annapolis, Bass, Gaspereau, Shubenacadie, Bear and South Rivers.

In Grand Lake, New Brunswick, specimens weighing up to 50 pounds have been caught (see Vladykov and McKenzie, 1935: 91); this may well be an endemic population. The striped bass population of the St. Lawrence, which Vladykov has studied by tagging, is probably endemic and appears to be substantial enough to stand additional exploitation. There are plenty of bass available for sport anglers in the Quebec area, but economic factors, such as price and availability of markets, limit the number being taken for commercial purposes.

While statistics from a rod and line fishery obviously do not provide a very reliable index of abundance, the 1865-to-1907 catch records of the Cuttyhunk Club, which was located south of Cape Cod, showed the same steady decline with some fluctuations (see Merriman, 1941: 9). These bass clubs, of which there were three or four important ones, are said to have dissolved largely because of the absence of bass, although other economic and social conditions were also involved.

Neville (1940: 31, fig. 12), in treating the fluctuations in the annual catch of striped bass for New York showed a drop from a high yield of about 200,000 pounds in 1890 to a low of 45,000 pounds in 1908, with another high of 130,000 pounds in 1937.

For Long Island, Merriman (1941: 10) summarized the landings from pound nets set at Fort Pond Bay, Long Island, New York, from 1884 to 1937; the data were such that he was able to allow for different fishing intensities over the entire period. This fishery showed a rather gradual decline except for good years in 1894, 1906, and 1923; it also recorded a tremendous catch of striped bass in 1936 and 1937. Merriman also summarized the annual total catch of striped bass taken by seine at Point Judith, Rhode Island, from 1928 to 1937; here again he equalized the fishing intensity throughout. This index showed a relatively stable and low abundance of striped bass from 1928 to 1935, with a tremendous jump in the catch in 1936.

For Chesapeake Bay the considerable data on the catch of striped bass have been summarized by Pearson (1938), Vladykov and Wallace (1952), and Tiller (1950). As elsewhere, the trend in abundance has been downward. The general record is incomplete from 1887 to 1928 but is continuous from 1929 to 1937. The catches increased sharply in some years, recent good production years being 1925, 1936, 1937, 1942, and 1944; an extreme low was reached in 1932 and 1933. Analysis of the catch records of individual fishermen, especially of those who operate pound nets, which are the means of capturing most of the striped bass in Chesapeake Bay, has confirmed the general statistical records collected by the former U. S. Bureau of Fisheries. The marked decline in bass in the Chesapeake Bay region started about 1929 and reached its lowest point from 1931 to 1934. Vladykov and Wallace (1952) showed the striking increases in 1935, 1936, and 1937 in two pound nets at Galesville, Maryland, and they also gave a further breakdown of the catch by year-classes; they indicated a great increase in both numbers and poundage. Tiller (1950), whose data supplement and continue those noted above, has given the total catch of striped bass in Maryland for various years from 1887 to 1942; the 1940 year-class produced a tremendous catch in 1942—actually greater than the previous high in 1937. And according to the Maryland Fisheries statistics (Hammer, Hensel and Tiller, 1948: table 5), 1944 was also a good year for striped bass in Chesapeake Bay, thus indicating that the 1942 year-class was successful.

Dominant Year-Classes. The several published sources noted above indicate that the striped bass is subject to the so-called "dominant year-class" phenomenon, that is, occasional successful spawning and survival not necessarily associated with a large spawning population. In this connection it is interesting to note that recent studies (Harlan and Speaker, 1951: 102) on the white bass (*Morone chrysops*) and yellow bass (*Morone interrupta*) in the fresh waters of Iowa have shown pronounced fluctuations in population size and high survival resulting in a large year-class when the adult population was at a low level.

If Merriman (1941) is correct in his contention that a large part of the striped bass population off New York, Connecticut, and New

England is due to migrants from Chesapeake Bay, the series of successful spawnings in that area in 1934, 1940, and 1942, and possibly later, would account for the generally acknowledged good bass fishing of the past few years. However, since a small adult population may give rise to a large year-class when conditions are favorable, there is every reason to believe that other suitable spawning areas, such as the Hudson River, could at some time or other produce large broods of striped bass. The same possibility obtains for the Parker River, Massachusetts or the St. John River, New Brunswick, where large broods are known to have been produced in the past. However, without a coordinated long-term research program at a number of stations along the Atlantic Coast it is not possible to assess the contribution of the populations of the Hudson River and more northern localities to the migratory segment of the striped bass population.

There is relatively little information available on the probable conditions which are essential for the production of a good year-class in striped bass or in any other fish. In the case of the bass, it will take a detailed study of the biological, chemical, and physical conditions at a number of known spawning areas over a long period of time before this question can be answered. Russell (1932) pointed out that large dominant year-classes were produced simultaneously in the North Sea in 1904 by three different kinds of fishes, namely, herring, cod and haddock; apparently the same environmental conditions were important in determining the percentage of survival of the young of all three species. Merriman (1941: 14), in his attempt to correlate the available records of meteorological conditions with striped bass spawning, has shown that the successful production of year-classes in 1934, 1920, 1904, 1898, and 1896 took place at times of subnormal temperatures; the inverse correlation between temperature and catch record is good (minus .354), which is significant to the one per cent level. Tiller (1950) also noted that temperatures below the mean occurred during the spawning season of the dominant 1940 brood, but good broods were also produced in 1942 and 1943 when the temperature was average or above normal. Tiller has also pointed out the necessity of studying water salinity as it is affected by abnormally high or low precipitation during the spawning season. Finally, it is quite probable that there is no simple answer to this problem and that the final explanation will be found in a combination of chemical, physical, and biological factors.

Causes of Depletion and Decline. Pollution, dam building, and perhaps overfishing, are important factors that have contributed to the depletion of the stock of an andromous fish such as striped bass. There seems to be little doubt that in the past the striped bass used the lower reaches of practically all of the large rivers along the Atlantic Coast as spawning areas, but pollution and silting of these rivers as a result of increased population, industrial growth, and general destruction on the watershed has undoubtedly reduced to a great extent the spawning areas and forage grounds of young bass. The main streams which have been affected by pollution are the Roanoke, Delaware, and Connecticut Rivers as well as some of the smaller New England rivers. The Roanoke has long been known as an outstanding spawning area for striped bass, and conditions are still satisfactory for spawning in the area near Weldon, North Carolina. But severe pollution by paper mills on the lower Roanoke makes it doubtful if more than a small percentage of the fry are able to survive the trip downstream to the foraging grounds in Albemarle Sound. The lower Delaware River is an outstanding example of the destruction of a bass habitat by industrial and domestic pollution. The lower Hudson River is also severely polluted, but adult striped bass are able to make their way through the lower harbor to favorable spawning areas farther upstream where considerable natural reproduction takes place. In addition to the destruction of spawning areas and foraging grounds for young striped bass in the lower Hudson, both sport and commercial fishing are greatly reduced by sewage pollution. James R. Westman has stated (personal communication) that striped bass were plentiful in the lower Hudson River in 1948 and 1949 but that the flesh was so tainted that few were utilized effectively as human food. Some New England rivers, such as the Connecticut and Merrimac, which were undoubtedly used as spawning areas by striped bass, have been more or less cut off by dams and pollution.

It seems that some of the large tributaries of Chesapeake Bay are the only really unspoiled areas which are left for the reproduction of striped bass, and there is considerable evidence that the 1934 year-class which contributed so much to the improvement in northern bass fishing in later years was derived largely from that area. The lower Susquehanna is now blocked by a large dam which has cut off large spawning and foraging areas, but many of the other large tributaries of Chesapeake Bay have not been spoiled; at least they have not been affected to the same extent as some of the more northerly rivers.

Of course pollution also affects the organisms upon which bass feed, and thus the entire food chain of the striped bass may be upset. Considering the tremendous number of forage fishes that are necessary to bring a large population of striped bass to a size of 16 inches, it is mandatory that all of the forage areas be maintained and that pollution be curtailed as much as possible.

It is encouraging to note that some progress is being made in this direction. This is especially true in the New York City area where large structures are being built for the treatment of much of the domestic sewage. Pennsylvania is also making progress with domestic and industrial pollution, and there is some hope that in years to come the lower Delaware may once again be available as a spawning and foraging area for young striped bass as well as other game and food species. The Roanoke River should be reclaimed, but it will be necessary to stop the dumping of paper mill waste and to insure against pollution of that magnificent area by future industrial establishments.

Considering the over-all picture of depletion and destruction of spawning and foraging grounds due to pollution and dam building, it seems remarkable that the striped bass has maintained itself as well as it has. Bigelow and Welsh (1925: 255) have pointed out that the bass had dwindled nearly to the vanishing point in the St. John River, New Brunswick,[1] a stream which has been neither polluted nor dammed near its mouth; hence the scarcity of striped bass in the area can scarcely be blamed on pollution, especially since the salmon, which is also vulnerable to pollution, still maintains a bountiful run. These authors have used this as an argument, among others, to support overfishing as the major cause of depletion of striped bass. The weak point in their argument seems to lie in the lack of certainty concerning the origin of the bass that run into the St. John. At the time of Bigelow and Welsh's work it was not known that the striped bass was a highly migratory fish, and while it seems likely that part of the population is endemic, the stock in earlier years may have been augmented by bass that were produced in more southerly areas. However, conditions have been favorable for spawning at certain times in Nova Scotia rivers, and large numbers of young striped bass from there have been reported by Leim (1924).

Bigelow and Welsh (1925: 255) have stated the case for those who are inclined to consider overfishing as the main cause of the depletion of the striped bass. They pointed out that the striped bass is a vulnerable fish, is easily caught, is always close inshore, is always found in relatively shallow water, and that there is no offshore reservoir upon which to draw.

It is undeniable that the fishing intensity for striped bass has been great in the past and is so now. Vladykov and Wallace (1938) have pointed out that the fishery in Chesapeake Bay removed more than half of a single brood in the first year after members of that year-class

[1] In 1950 and 1951, bass were more common than they had been in 1925 and for a long period thereafter.

were available at legal sizes (10 inches in Virginia, 11 inches in Maryland). Tiller (1950: fig. 3) has also shown the rapid utilization of a year-class during its first two years of availability to the fishery. Merriman (1941: 15) stated that 30% of 303 striped bass (mostly three-year-olds) tagged and released at Montauk, Long Island, New York, were recovered within six months after they were tagged (October 1937), no reward having been offered for these tag returns. Though it is true that tagged fish may be more easily caught in nets, especially in gill nets, it is also probable that many of the marked fish that were caught were probably never reported, so the true percentage was probably higher than indicated. In regard to the 1934 brood, Merriman generalized that about 40% were taken during their first year in the fishery (1936) and that at least 25 to 30% of the remainder were caught in 1937. In short, an absolute minimum of about 50% of the two-year-olds which entered the fishery in the spring of 1936 had been removed by the spring of 1938; this estimate, of course, does not include natural mortality. Thus it is clear why even an outstandingly dominant year-class, such as that of 1934, causes only a temporary improvement in a fishery as intense as that for striped bass.

Neville (1942) and Wallace and Neville (1942) have outlined the persistent problems of the fishery and have focused attention on the factor of removal of the striped bass by man—the only important factor which is immediately controllable. Of course the main objective is to maintain the abundance of striped bass at a reasonably high level so as to insure stable catches over prolonged periods of time for both commercial fishermen and sport anglers. The supply of bass depends upon: the number of young which survive each year; the withdrawal of the stock by the fishery, both commercial and sport; and the diminution of the stock by natural mortality, which has to do largely with disease, predators, and age. The aim of the fisheries biologist is to determine the correct measures that are necessary to provide adequate spawning areas, to prevent overfishing to an extent where it would become unprofitable to fish, and to insure the most efficient use of the supply. Neville (1942) and Wallace and Neville (1942) feel that, under the present fishing intensity, the 16-inch legal limit, measured from the tip of snout to fork of tail, would give the most efficient use of the supply for all concerned. However, they have pointed out that in the Chesapeake Bay area the efficiency of the gear used by fishermen to take other species of importance, such as croaker and gray trout, must also be considered. Higgins, et al. (1939) and Neville (1942) have pointed out that a greater aggregate poundage of striped bass, with a higher financial return to the fishermen over a longer period, is possible in a fishery with a 16-inch limit than in one with a smaller legal size limit. But before a 16-inch limit is universally adopted, it would be necessary to prove that the undersized fish could be returned to the water without great mortality. That is, it would do little good to adopt a 16-inch limit in Chesapeake Bay if revised fishing methods resulted in the death of large numbers of undersized striped bass which had to be returned to the water.

History of Abundance on the West Coast. Commercial statistics on striped bass landings in California are complete to the year 1935, when commercial fishing was completely prohibited. The history of the abundance of bass is summarized by Shebley (1917, 1927), Scofield (1931), Craig (1930), Clark (1933), Nidever (1937) and Calhoun (1949, 1950). Striped bass, planted in California waters in the vicinity of San Francisco in 1879 and again in 1882, were first sold in San Francisco markets as early as 1889, 10 years after their first introduction. This is considered one of the most remarkable cases of the survival and commercial establishment of an introduced species. In 1899, 20 years after their introduction, over 1,200,000 pounds were landed in California, and the greatest commercial landing in any one year between 1908 and 1915 was close to 1,800,000 pounds. Nidever (1937: 56), in a graph of the landings of striped bass in California from 1916 to 1935, has shown that from about 1919 through 1935 the catch was more or less stabilized at between 500,000 and 1,000,000 pounds per year. Since 1935 it is known that some bass have been caught by more than 100,000 anglers each year; Calhoun (1948: 3) estimates that a million or more fish have been caught annually and that their aggregate weight has run well over a million pounds.

Nidever (1937: 58) has pointed out that prior to 1931, when the commercial catch of striped bass with nets was prohibited, 175 to 200 small commercial boats employing roughly 350 to 400 men were engaged in this fishery. The average yearly catch for the 10-year period 1926 to 1935 amounted to about 650,000 pounds which, at 11 cents per pound (the average price paid during this period), realized about $72,380 per year to the fishermen.

When the striped bass was first taken in California its game qualities were not generally appreciated, but in the 20 years following 1915 there were more and more anglers for bass. In 1931 the use of nets in commercial fishing was prohibited, and in 1935 the fish was taken off the commercial list entirely. In the opinion of Craig (1930) and Clark (1933), the population could support both commercial and sport fishing, provided the total yield be watched from year to year to detect significant changes.

A comprehensive report on records from the Party Boat fishery of California for the period 1938 to 1948 has been given recently by Calhoun (1949). In most of the regions of the San Francisco Bay area, characteristic seasonal patterns of fishing quality and average weight have been repeated year after year. The records also indicate that the population is maintaining itself satisfactorily; recently there has been a decline in abundance, which, judging from the considerable data available, is probably due to a normal fluctuation in abundance of a sort to be expected from time to time rather than to overfishing. Calhoun (1950b: 194) has given the trends in California striped bass angling for the years 1936 to 1948, and they show that the total yearly catch has remained surprisingly constant, with a slight downward trend in recent years. The number of anglers remained relatively constant until 1948, when there was a marked increase to 170,000 successful bass anglers (18% of all licensed anglers).

Sometime after its introduction to the San Francisco Bay area the striped bass moved northward and established itself in Coos Bay, Oregon, where a major commercial and sport fishery has developed for this species. Found first in 1914 by a gill-netter, the bass reached commercial quantities in 1922 according to Morgan and Gerlach (1950: 8). The largest catch, 263,000 pounds, was made in 1945. The bass have also become established in Umpqua River, Oregon (Anon., 1946: 56), where they first appeared in 1934; by 1941 a separate fishery was established which has expanded considerably. It is not known if the Umpqua River fish are indigenous or if they are of the same population that inhabits Coos Bay.

Other scattered populations are found along the west coast from San Diego county in southern California to the Columbia River in the north.

METHODS AND ECONOMICS OF THE FISHERY

There is little doubt that at present the striped bass is the outstanding anadromous sport fish along the Atlantic Coast from North Carolina to Massachusetts, and, as pointed out previously, it is also important commercially, especially in the Chesapeake Bay area, where it is the most valuable of all the fishes taken. Most of the essential statistics of the fishery from the standpoint of numbers and size have been discussed above; methods by which striped bass are taken by commercial fishermen and anglers are given below.

Pearson (1938: 845), who has given considerable data on the historical aspects of the fishery, has pointed out that most of the methods used in taking striped bass were frequently applicable to the fishery for other anadromous fishes such as the shad and salmon, which have also suffered depletion along the Atlantic Coast. An efficient method used by early settlers in New England consisted of stretching long seines and weirs across coastal streams so that when the water ebbed from the creeks the stranded fish were often trapped in great numbers. In those days the bass were not only eaten fresh but were salted, pickled or smoked, and pickled bass, together with salted codfish, furnished an early medium of trade with the West Indies. Wood (1635) has described the scaffolds standing in the sun with fires below so that smoke could harden and dry the striped bass laid above.

In the St. John River, New Brunswick, Indians captured bass at spawning time by dropping downstream in canoes and spearing the splashing fish (Adams, 1873). In northern waters, especially in Massachusetts, New York and New Jersey, where striped bass usually congregate during cold weather and frequently lie more or less dormant near the bottom, fishermen soon learned to capture them under the ice with large dipnets. Such a fishery in the Parker River, Massachusetts, has been described by Pearson (1933b: 16), and large catches of overwintering striped bass have been noted by other authors, especially Tenny (1795), Mease (1815) and Perley (1850).

Ever since colonial times, one of the best localities for the capture of striped bass has been the Roanoke River below Weldon, North Carolina, where the fish are taken during April and May when they are in spawning condition. The water is very swift near the falls, and at one time wooden slides were built in the rapids so that bass moving downstream were washed up against the slats of the slides whence they could be easily removed by fishermen. Pearson (1938: 846) has reported that as many as 300 fish of 30 pounds each have been removed from such a slide in a single day, but these efficient devices are now outlawed.

East Coast. Commercial fishing is still permitted in the Roanoke River below the bridge at Weldon, and striped bass are taken in large quantities at spawning time by skim nets. These are constructed of a large frame of hickory about six feet long and four feet wide to which is hung a linen net some six feet deep with a 1½ inch square mesh. The frame is lashed to a stout wooden pole at least 20 feet long. Such nets are fished from a small power boat and are kept broadside to the river current as the boat drifts downstream. Recently King (1949: 18) has given a description of the modern fishery in the Roanoke River. In North Carolina the striped bass is rated as a game fish when taken from inland waters above the bridge at Weldon, and as a commercial fish when taken from below the bridge, or in the sounds.

In commercial waters there is no creel limit and striped bass taken there may be sold in the open market. Commercially, the fish is taken by pound nets, stake and drift gill nets, seines, and bow or skim nets. In inland waters nets are unauthorized, hence the bass may be taken only by pole and line or by trolling and casting; the sale of striped bass from inland waters is prohibited and a creel limit of eight fish per day is imposed. In all of these waters it is unlawful to retain a striped bass less than 12 inches in total length regardless of where or how it is taken. The male bass that run in the Roanoke in the spring vary from one to five pounds, the females from three to 15 pounds with occasional individuals reaching 40 to 50 pounds. That any fish ever lives to reach the spawning grounds in the Roanoke is almost a miracle. At least 5,000 nets are set in Albemarle Sound alone, and the fish that go up the Roanoke must pass additional haul seines, go through several miles of polluted water, and then escape a series of skim net fishermen as well as baits and lures. After several weeks have passed and spawning is finished the stripers move back down out of the streams into the bays and sounds where they spend the summer and autumn months. Favorite angling places are deep holes near the mouths of creeks and along bridges of causeways; most fishermen use outboard motorboats and trolling gear. Some of the striped bass probably go to sea, but the percentage is not known, since no studies of tagged fish have been carried out over a long enough period of time. Apparently relatively few bass occur in the surf along the North Carolina Coast, but further north surf fishing is of some importance.

Vladykov and Wallace (1952) have pointed out that the Chesapeake contributed more than half of the entire catch for 1936, and they also stated that Maryland yields about 75% of the Chesapeake Bay catch. Among Maryland's commercial fisheries, striped bass ranks third in quantity after the herring and croaker, but it ranks first on the basis of dollar value. Sport fishing, mainly by trolling, is also a major industry. According to Truitt and Vladykov (1937), some 200,000 anglers fish yearly in Chesapeake waters for striped bass with a resultant $500,000 income to watermen from that source.

Commercial fishing operations in Chesapeake Bay make extensive use of pound nets, gill nets, and haul seines. For the year 1936 there were some 529 to 721 pound nets in Maryland waters and about 2,000 pound nets in Virginia waters, a total of about 2,600 for the Bay. In Maryland about 4,000 gill nets were used. In the lower Bay there were about 135 haul seines in use in both Maryland and Virginia. During 1937 Virginia employed 6,189 gill nets, Maryland 3,652.

Pound-net fishing takes place in Maryland from March 1 until mid-November except for about 10 days in the middle of June when the nets are taken out for preservation treatment, and the best catches with these nets are made from late September to mid-November. Pound nets capture from 40 to 75% of the striped bass taken commercially in Maryland, and haul seines rate next in efficiency with 21.5% of the commercial catch of bass from 1931 to 1934. Haul seines, used in waters eight to 12 feet deep, are usually employed during the summer months when there is a shoreward concentration of striped bass. Occasionally tremendous catches are made with haul seines. Vladykov and Wallace (1952) have stated that in July 1936, at the mouth of the Patuxent River, one haul of a 240-yard seine produced 16,000 pounds of legal striped bass. While tremendous catches are made occasionally with haul seines, fishing with such gear is a matter of feast or famine, since huge catches are exceptional.

Sunken drift nets of the gill net type are used from mid-December to midwinter in water ranging from 60 to 100 feet, but this fishery is influenced from year to year by variations in water temperature; the best catch in the period 1936–1937 was made in January, but in the following season the peak of capture was in December. The anchor net, a modification of the sunken drift net, is employed where the bottom is rough and is operated from mid-December to midwinter. Still another type of gill net, the stake net, is employed in water approximately eight feet deep during the period from late January to the end of April. The drifting gill net is the most efficient of the three, the stake net ranks next, and the anchor net is the least effective of all. Purse seines, formerly used to take schooling striped bass in Chesapeake Bay, are now outlawed. Tiller (1950) has given the total catch of striped bass in Maryland for various years from 1887 to 1942. According to the U. S. Fish and Wildlife Service records, Maryland produced in 1940 approximately 40% of the total catch of striped bass in the United States.

The commercial fishery in states to the north (Delaware to Massachusetts) also employs a variety of gear, with haul seines and various modifications of the pound net predominating. Table IV gives information on the relative quantities of striped bass taken commercially from different areas on the Atlantic and Gulf Coasts. The sport fishery from New Jersey to Massachusetts is extraordinarily heavy and involves every conceivable means—still fishing, trolling, surf-casting, fly fishing, etc. There are no reliable figures of the catch by states or of the financial return to boatmen and others who cater to the needs of the sportsmen.

West Coast. Commercial fishing for striped bass has been prohibited in California since 1935, but Calhoun (1950b; 194) has given the total yearly catch by anglers during the period from 1936 to 1948. He has also given the trends in the sport fishery, including the number of bass fishermen and the catch per angler. Additional data for 1949, from a statewide angling estimate through a postal card survey, has been reported by Calhoun (1951). Calhoun (1948: 1), in discussing the types of fishing tackle and boats used in central California, has pointed out that bait fishing, the type indulged in by most anglers, requires that the bait be kept close to the bottom and that considerable weight be used because of the strong tidal currents usually present on striped bass grounds. The universal bait is sardine, either fresh or frozen, used either in chunk or fillet. In certain seasons, especially summer, considerable trolling is carried on with many types of plugs, jigs, and spoons, frequently in double combinations.

Large numbers of party-boat operators in the San Francisco Bay area make a business of taking anglers out by the day or half day, and an excellent account of this industry has been published by Calhoun (1949: 211). In the more sheltered fishing grounds, such as the Napa River, many persons fish from rowboats, but an outboard motor is almost a necessity because of strong tidal currents. During the height of the season some establishments furnish towing service to haul the rowboats to the fishing grounds. At certain times shore fishing is good, but in general it is much less productive than boat fishing and is practiced by fewer anglers.

Fishing changes considerably with the season. It reaches a peak during the autumn bait-fishing period, which normally extends from about mid-August to the end of October. When the bass move up into fresh water in large numbers in late autumn the quality of fishing declines for the winter months, although netting operations for tagging purposes have shown that many fish are present even though few are caught on the hook at this time. As the water warms during March, April and May, fishing in the sloughs and rivers of the Delta reaches a climax; the main Sacramento and San Joaquin Rivers are also favorite fishing areas at this season. After the end of May there are few bass of any size in the fresh water of the Delta and fishing activity drops back into the bays. During the summer months there is a great deal of trolling, usually during the late afternoon. At this time of the year many fishermen use bait until midafternoon and then troll in San Pablo Bay or in the Carquinez Straits. The results of trolling are variable from day to day, and in general fishing is not as dependable during the summer as it is in autumn. Trolling is discontinued in August as soon as the bait-fishing improves to the point where good catches can be made with some regularity.

The considerable sport and commercial fishery in Coos Bay, Oregon, has been described in detail by Morgan and Gerlach (1950). The sport fishery is good in July and August. It is estimated that from December 1949 to November 1950 4,979 anglers fished 23,851 hours to catch 2,563 bass weighing approximately 14,931 pounds. The over-all average of sport-caught bass was 5.8 pounds, and most fishing was pursued from skiffs, although additional angling was done from the bank. Frozen pilchard, herring, or other small fishes were used as bait. An attempted evaluation of the sport fishery estimates that $65,722 was spent in 1950. The cost per fish was $25.64, or $4.42 per pound for the average 5.8-pound specimen caught. The average angler took 2.1 fish per year.

The commercial fishery in Oregon first took bass in quantity in 1922, although it is reported that gill netters captured the first as early as 1914. From statistics that are available since 1931, the largest catch was made in 1945 when 263,000 pounds were landed. In Oregon no fishermen fish solely for striped bass; rather, it is caught incidental to the gill net fishery for shad during April through June. The average weight of commercial bass has varied over the years from 6.6 to 9.1 pounds.

PARASITES, DISEASES AND ABNORMALITIES

Merriman (1941: 55) has summarized the literature and has given additional new data on parasites of the striped bass.

Monogenetic trematodes. *Lepidotes collinsi, Aristocleidus hastatus, Epibdella melleni, Microcotyle acanthophallus, M. eueides,* and *M. macroura;* see Mueller (1936).

Digenetic trematodes. *Distoma rufoviride, Distoma tornatum,* and *D. galactosomum;* see Linton (1898, 1901).

Cestodes. *Rhynchobothrium bulbifer,* as plerocereoids in the intestine and *R. speciosum* as cysts in the viscera; see Linton (1901, 1924).

Endoparasitic nematodes. *Goezia annulata,* not common in striped bass; found in stomach mucosa where, according to MacCallum (1921: 261), it may interfere materially with the function of the stomach, since it burrows under the mucous membrane and often restricts the cavity in the host's stomach. *Dicheilonema rubrum,* very common in striped bass; found in the peritoneal cavity, usually associated with gonads, but it does not seem to seriously harm its host; see Railliet (1918), Linton (1901), and Merriman (1941). *Ascaris* sp.; see Linton (1901).

Acanthocephalans or roundworms. *Echinorhynchus gadi* and *Pomphorhynchus laevis;* see Linton (1901).

TABLE IV. CATCH OF STRIPED BASS ON THE EASTERN SEABOARD OF THE UNITED STATES AS REPORTED BY THE U. S. FISH AND WILDLIFE SERVICE IN FISHERY STATISTICS OF THE UNITED STATES.* QUANTITY (FIRST COLUMN) EXPRESSED IN THOUSANDS OF POUNDS, VALUE IN THOUSANDS OF DOLLARS

	New England		*Middle Atlantic*		*Chesapeake*		*South Atlantic and Gulf*	
	Quantity	*Value ($)*	*Quantity*	*Value ($)*	*Quantity*	*Value ($)*	*Quantity*	*Value ($)*
1948	151	27	758	205	5102	821	—	—
1947	119	23	413	111	4063	773	—	—
1946	—	—	—	—	3699	656	—	—
1945	317	83	782	203	3664	677	610	121
1944	341	61	799	166	4545	687	540	59
1943	216	49	514	121	3286	325	540	59
1942	219	31	419	87	3286	325	540	59
1941	147	19	382	54	2089	185	540	59
1940	147	19	382	54	1839	175	540	59
1939	301	29	311	37	2869	232	523	49
1938	450	36	405	47	3016	220	713	70
1937	22	3	62	8	2383	176	768	61
1936	22	3	62	8	1302	118	362	36
1935	61	7	40	6	642	66	362	36
1934	61	7	40	6	833	101	507	54
1933	42	7	52	8	1028	128	507	55

* For Chesapeake Bay, see Hammer, Hensel and Tiller (1948), Tiller (1950), and Vladykov and Wallace (1952). Pearson (1938: fig. 26) has given the detailed commercial catch for Maryland, Virginia, North Carolina and the Middle Atlantic States from 1887 to 1935. For other eastern states, see the annual reports of the several Conservation Departments. For California the data on the commercial catch have been summarized by Craig (1930), Nidever (1937) and Calhoun (1949, 1950); Calhoun has also given a summary of the party-boat fishery from 1938 to 1948. Morgan and Gerlach (1950: 10) gave the annual landings from 1931 to 1950 for Coos Bay, Oregon, where commercial fishing is limited to the shad season and is more or less incidental to that fishery.

Ectoparasites. Copepods: *Caligus rapax,* found on many marine fishes including striped bass; see Wilson (1905, 1932). *Argulus alosae* Gould, found on three striped bass in the Niantic River, Connecticut, by Merriman (1941); see Wilson (1903). Lernaeopodid: *Achtheres lacae;* see Wilson (1915). Ergasilid: *Ergasilus labracis;* see Wilson (1911, 1932). Mollusca: glochidia, found on a high percentage of juvenile striped bass from western Albemarle Sound; see Merriman (1941).

A large number of striped bass taken by Merriman (1941: 56) in the Thames and Niantic Rivers, Connecticut, had cataracts of the eye. Sometimes 10% of the seine haul was thus affected, the opacity of the lens ranging in all degrees from slightly cloudy to dead white. The cataract was almost always bilateral, was rare in two-year-old bass and more common in larger sizes. The cataracts may be due to a dietary deficiency.

An outbreak of skin erruption, designated as lymphocytis by Ross Nigrelli of the New York Zoological Society, was noted on bass in the Thames and Niantic River areas during June 1951 (Salt Water Sportsman, June 22, 1951).

Disease may on occasion seriously deplete a population of striped bass, as indicated by Smith (1833: 13) who referred to a serious epidemic in Boston harbor that killed large numbers of fish.

A pug-headed striped bass is illustrated by Gudger (1930: pl. 1), who also gave other references to similar specimens mentioned in print (see Sutton, 1913). This abnormality is not unusual in other species.

STUDIES IN PROGRESS

In an effort to obtain additional knowledge of the migrations of striped bass, a tagging program was initiated in October 1948 by Henry Lyman. With the cooperation of both commercial and sport fishermen, tags were inserted on undersized bass. After a modest beginning with indications of success, the program was expanded in the summer of 1949 as the Schaefer—*Salt Water Soprtsman* Striped Bass Tagging Program, which has continued to operate until the present time. Significant numbers of bass were tagged in 1950, 1951 and 1952, the program operating on a coastwise basis from Maine to South Carolina. In the fall of 1951 the Massachusetts Division of Marine Fisheries cooperated by tagging large bass. The returns have not yet been analyzed.

During the summers of 1948 and 1949 the New York State Conservation Department made a survey of young shad and striped bass in the Hudson River, and in 1952 this work was continued after an interruption of two years. The program has been directed by John R. Greeley and supervised by Cecil Heacox.

In New Jersey a relatively small number of bass have been tagged recently by James R. Westman, and returns to date have been few.

The most active and comprehensive research program that has been undertaken to date is under way in California, where, according to Alexander J. Calhoun, the Division of Fish and Game is investigating the following items: (1) A tagging program to determine fishing mortality with a view to evaluating the adequacy of current regulations; about 2,000 bass from 12 to 40 inches are being tagged annually; (2) Annual determination of year-class strength from abundance of small fish; (3) Physiological studies; an attempt to work out the effects of changes in salinity and/or temperature upon bass. (4) Habitat studies; a study of forage fishes and invertebrate populations, and a broad study of the effects of pollution upon the ecology of San Francisco Bay. California also maintains an extensive system of catch records.

The Oregon State Fish Commission is continuing the studies of bass at Coos Bay, Oregon, reported by Morgan and Gerlach (1950).

SUGGESTIONS FOR RESEARCH

Many phases of the biology of the striped bass populations of the east coast have been investigated during the last decade, but many problems remain partially or totally unsolved. If the information for proper management is to be made available, a continuous coastwise research program is necessary for striped bass as well as other important game and food fishes such as bluefish, weakfish, and channel bass. Investigations on the striped bass should be started at once while the population is at a high level of abundance, and most of the studies should be set up on a long term basis.

In this report many problems which should be investigated have been given some consideration, and the more important matters are listed below for convenience, though they do not necessarily appear in order of importance.

(1) What is the source of the migratory components of the striped bass population of the east coast? It has been assumed that a large percentage of the New England bass have originated in southern waters, mainly in Chesapeake Bay, an assumption that has been based largely on movements of tagged bass (mostly two- and three-year-olds) of the 1934 year-class. Intensive tagging programs at critical areas are needed immediately, especially in New England, as soon as funds can be made available. Striped bass are now abundant in the waters of Connecticut, New York and New Jersey and it would be possible to seine and tag large numbers of adult specimens. Thus data may be obtained from such an undertaking which will aid in the solution of the following problems. (a) The sources of migratory schools of different sizes and ages and sex; (b) the local movements undertaken by schools of different sized bass during the summer in the north; (c) the geographic origin of striped bass that overwinter at various places in the north, and the percentage of each school that overwinters; (d) the rate of exploitation of schools of striped bass; special efforts should be made to obtain the cooperation of commercial fishermen in securing tag returns in this connection; (e) the percentage of striped bass which escape from Chesapeake Bay and the Delaware and

Hudson Rivers from year to year; young and yearling bass should be marked in this connection; (f) the migration of the schools of large bass that are noted yearly off Cape Hatteras, North Carolina in February; (g) Is there any northward migration of bass spawned in tributaries of North Carolina sounds?

(2) What is the sex ratio within various striped bass schools and what is its relation to migratory behavior? (a) A high percentage of females has been found in northern waters, and it should be determined if possible whether females found in the north are usually nonspawners in spite of the fact that they have reached maturity. Since few ripe females have been found in the north, they should be looked for in known spawning areas like the Parker River during May and June. Since there is evidence that female striped bass do not spawn every year, it should be determined whether they migrate in nonspawning years and stay south during spawning years. (b) Efforts should be made to study other phases of schooling behavior, but special attention should be devoted to sex and age composition.

(3) The growth rate is well established for only the first six years. (a) Sex differences in growth rate need more intensive study. (b) Additional data on the age of larger bass are needed; otoliths and other structures should be studied in large specimens. (c) A reinvestigation of the growth rate of two- and three-year-old bass north and south of Cape Cod would be significant.

(4) Are there different populations of striped bass? (a) Reinvestigate by tagging the presence of slow growing (migratory) and fast growing (nonmigratory) populations within Chesapeake Bay. Schools should be tagged at different times and at different locations. (b) Is the James River population significantly different (on a level of speciation lower than subspecies) from the Chesapeake Bay striped bass? (c) Do the North Carolina striped bass constitute a different race? Further effort is needed to find a method by which the origin of a bass may be determined in order to reduce costly and difficult tagging operations. (d) A study of the meristic characters of the populations from all major areas, west and east, would be of scientific interest.

(5) What is the effect of a large dominant year-class of striped bass on other fishes and invertebrates in the environment? (a) Since other important food and game fishes (alewife, shad, weakfish, croaker, and spot) and invertebrates (blue crab) live in the same habitat as the bass, to what extent is the whole fishery in an area like Chesapeake Bay affected by a large bass population? (b) Since the food of young and yearling striped bass is not well known, there should be a study of its variation with locality and season. Are there weak points in

the food chain which may result in poor survival even though spawning has been successful? (c) Restudy the diet of adults to note the importance of various fishes such as silversides, menhaden, and anchovy at different localities.

(6) Accurate catch records are necessary for the management of the striped bass. Since the commercial catch passes through the various established markets, the data on it are probably fairly accurate, but for areas where the sport fishing is highly developed it would be desirable to set up a system for obtaining catch data from party boats and other sport fishermen. The Hudson River is one of the areas where such data could be obtained, and it would be interesting to compare the present sport angler catch in the Hudson with the former commercial catch, which ran about 50,000 pounds annually.

(7) Pollution. (a) Study the effects of different types of pollution on the eggs and young of striped bass and on the various components of the food chain in the spawning and nursery areas. The Roanoke River, Delaware Bay and the lower Hudson River are areas where such studies might be undertaken. (b) What degree of pollution "taints" the flesh of a striped bass or other species? This is an important problem in setting up state and federal standards for the control of pollution.

(8) What are the fundamental factors that influence the production and survival of large year-classes such as those of 1934, 1940 and 1942? The solution of this problem would make it possible to provide predictions of economic value to sport and commercial fishermen. (a) The investigation of this problem should be set up on a long-term basis, and it would seem that permanent stations such as the Virginia Fisheries Laboratory at Gloucester Point, Virginia and the Chesapeake Biological Laboratory at Solomons, Maryland could best handle the work, since both are located close to successful spawning grounds where data may easily be obtained. This investigation calls for regular and complete records of meteorological data, such as wind direction and force, precipitation, temperature, etc., as well as oceanographic data, both physical and chemical, such as temperature, turbidity, current, salinity, oxygen, carbon dioxide, and pH; also needed are data on the biological phenomena, such as the dominant forms and cycles of plankton, the egg production and fry survival of all fishes in the area, and an ecological study of the young, including a study of predation. (b) Since a successful spawning and survival may occur when the adult population is relatively low in numbers, is it probable that a more successful spawning will occur with a larger population of adults? (c) It has been assumed that year-class dominance has resulted largely from a successful spawning, but there are few data to

prove that spawning is not usually successful (at least in the Chesapeake region), since populations are not adequately sampled until they reach the fishery at an age of two years or older. Hence, a method of obtaining a quantitative estimate of small bass on the nursery grounds should be developed, and yearly investigations of egg production and survival of young and yearlings in all major eastern rivers should be established. A more intensive study should be made at Cos Cob Harbor, Connecticut, in the Parker River, Massachusetts, and at other northern localities where successful reproduction may take place.

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APPENDIX A

A chronological list of the more important papers dealing with the striped bass on the Atlantic Coast from 1878 to date.

1878	Abbott
1882	Mason; Worth
1883	Worth; Jordan and Gilbert
1884	Goode; Worth
1885	Abbott
1888	Goode
1889	Worth
1902	Jordan and Evermann
1903	Worth; Fearing; Henshall
1904	Worth
1905	Bean
1907	Smith
1910, 1912	Worth
1914	Snyder
1924	Leim
1925	Bigelow and Welsh
1926	Corson; LeCompte
1928	Hildebrand and Schroeder
1930	Jordan, Evermann, and Clark
1933	Pearson; Gowanloch
1936	Truitt and Vladykov
1937	Curran and Ries; Townes; Greeley; Merriman; Truitt
1938	Merriman; Pearson; Vladykov and Wallace
1939	Greeley
1940	Neville
1941	Merriman
1943	Tiller
1947	Vladykov
1948	Hammer, Hensel and Tiller; DeArmon; Merriman
1949	King
1950	Tiller
1952	Hollis; Tresselt; Vladykov and Wallace; Jackson and Tiller

A chronological list of the most important contributions on the striped bass on the Pacific Coast, including papers on its introduction and acclimitization.

1882	Throckmorton
1889	Dunn
1896	Smith
1910	Coleman and Scofield; Scofield
1917	Shebley
1926	Scofield and Bryant
1927	Hubback; Shebley
1928	Craig; Scofield
1930	Cole; Craig; Clark
1931	Scofield
1932	Clark; Scofield
1933	Clark
1934	Clark
1936	Clark; Shapovalov
1937	Nidever; Walford
1938	Clark
1940	Hatton
1942	Hatton; Hatton and Clark
1945	Van Cleve
1946	Anonymous
1947	Woodhull
1948	Calhoun and Woodhull
1949	Calhoun
1950a and b	Calhoun; Calhoun, Woodhull and Johnson
1950	Morgan and Gerlach; Erkkila, et al.
1952	Calhoun; Johnson and Calhoun

APPENDIX B

Literature of the striped bass of eastern United States and Canada listed by region from north to south.

St. Lawrence and Eastern Canada
- Perley (1849, 1850)
- Knight (1866)
- Adams (1873)
- Leim (1924)
- Vladykov (1947a and b)

Maine, New Hampshire, Massachusetts
- Belknap (1792) New Hampshire
- Smith (1833) Massachusetts
- Atkins (1887) Maine
- McFarland (1911)
- Bigelow and Welsh (1925) Gulf of Maine
- Bigelow and Schroeder (1936) Gulf of Maine
- Pearson (1938) Massachusetts
- Merriman (1941)
- Towne (1941) Maine

Connecticut
- Caulkins (1852)
- Merriman (1937, 1938, 1941)

New York, New Jersey and Delaware
- Mitchill (1815)
- DeKay (1842)
- Ayres (1842) Long Island
- Abbott (1878, 1885) New Jersey
- Mason (1882) New Jersey
- Bean (1891) Long Island
- Bean (1903) New York
- Corson (1926) New York
- Curran and Ries (1937) Hudson River, New York
- Greeley (1937, 1939) New York
- Townes (1937) Hudson River
- Neville (1940) New York
- Merriman (1941) Long Island

Maryland and Virginia (Chesapeake Bay)
- Snyder (1914, 1918, 1919)
- Hildebrand and Schroeder (1928)
- Truitt, Bean and Fowler (1929)
- Haddaway (1930)
- Pearson (1933)
- Truitt and Vladykov (1936, 1937)
- Truitt (1937, 1938)
- Wallace and Truitt (1938)
- Pearson (1938)
- Vladykov and Wallace (1938)
- Merriman (1941)
- Wallace and Neville (1942)
- Tiller (1943, 1944)
- Hammer, Hensel and Tiller (1948)
- Tiller (1950)
- Hollis; Tresselt; Vladykov and Wallace; Jackson and Tiller (1952)

North Carolina
- Worth (1882, 1883, 1884, 1889, 1903, 1904, 1910, 1912)
- Smith (1907)
- Merriman (1941)
- King (1949)
- Vladykov and Wallace (1952)

South Carolina
- Burns (1887)

Gulf Coast
- Bean (1884) lower Mississippi River
- Jordan and Eigenmann (1890)
- Jordan (1929)
- Gowanloch (1933) Louisiana

SPAWNING GROUNDS OF THE STRIPED BASS OR ROCK, *ROCCUS SAXATILIS* (WALBAUM), IN VIRGINIA[1]

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ABSTRACT

During April and May 1950, the Pamunkey, Mattaponi, Chickahominy, James and Rappahannock Rivers were surveyed to determine the location of striped bass spawning grounds. Starting in brackish water (5 °/₀₀), stations were made at three to five mile intervals upstream far into fresh water; large plankton nets were anchored in the current at the surface and on the bottom at each station. Striped bass eggs were collected in all of the rivers surveyed. Most eggs were found within the first 25 miles of fresh water. On the Pamunkey, Mattaponi, and Chickahominy Rivers, the largest numbers of eggs were collected in areas where fishermen make the best spring catches of bass; this relationship was not apparent in the James and Rappahannock Rivers.

INTRODUCTION

Since the early settlement of the country, the spring migration of striped bass up rivers along the Atlantic Coast has been assumed to be a spawning movement (see Pearson, 1938). Though such a

[1] Contributions from the Virginia Fisheries Laboratory, No. 41.

general assumption has prevailed, only one spawning ground is well known, that at Weldon, North Carolina on the Roanoke River, where a hatchery for the artificial propagation of striped bass eggs has been operated at irregular intervals since 1874. The Roanoke River at this point is some 100 miles from tide-water, is roughly 100 yards wide, and has a swift erratic current of about four miles per hour. Both Pearson (1938) and Merriman (1941) have described the river at Weldon and have presented illustrations of various developmental stages of eggs and larvae from material observed there.

In the Chesapeake Bay region there have been few studies that gave direct evidence of striped bass spawning activities. Pearson (1938) collected eggs during May and June 1932 in the Susquehanna River at Garrett Island, about 12 miles below the Conowingo Dam, in a swift section of the stream. Vladykov and Wallace (1952), on the basis of collections of ripe females, stated that spawning grounds are located in the upper tidal reaches of rivers where the water is almost fresh, where the current is 2½ to 3 miles per hour, and where the bottom is usually mud or sand. Raney (1952) collected young striped bass in the lower James and Chickahominy Rivers, in Virginia, and concluded that spawning took place there.

From other areas along the Atlantic Coast the data are equally fragmentary. Leim (1924) found larvae near the head of the tidal zone in the Shubenacadie River, Nova Scotia; in 1937 Merriman (1941) found three juvenile bass in the Parker River, Massachusetts; and in 1936 and 1937 Curran and Ries (1937) reported juvenile bass from the Hudson River in water of low salinity. Studying the occurrence of ripe fish in the commercial fishery and the distribution of young in summer, Wallace and Neville (1942) concluded that the principal spawning and nursery areas of striped bass on the Atlantic Coast are found in the Hudson River around Newburgh and in Delaware Bay, Chesapeake Bay, Pamlico Sound, and their tributaries. Records of juvenile bass from many coastwise rivers led Merriman (1941) to suggest that in early times bass probably entered and spawned in every river of any size, where suitable conditions existed, along the greater part of the Atlantic Coast. In California, where the striped bass was successfully introduced in 1879, spawning has been observed in the San Joaquin River, about 60 miles above the Golden Gate, where the river is tidal, swift, and fresh (Woodhull, 1947). In addition, eggs and larvae have been taken in various rivers of the Sacramento-San Joaquin River system (Calhoun and Woodhull, 1948; Calhoun, Woodhull, and Johnson, 1950). Though many of the above studies have lacked specific information on spawning habitats, sometimes even omitting comments as to whether the water was fresh or brackish, there is evidence of a wide variation in type of spawning environment. Thus Merriman (1941) concluded that, in addition to spawning in fresh water, it is possible that bass may at times spawn in brackish or even saline waters.

The present study, based on egg collections, may be described briefly as a survey to determine where and under what conditions striped bass spawn in Virginia rivers. Sampling stations were established at the upper brackish region of each stream, where the salinity was about 5.0°/₀₀ or less, and were continued upstream until navigational or other difficulties made it necessary to discontinue operations. The sampling schedule was set up to correspond to the spawning season, which in this area extends from April through June (Merriman, 1941).

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Nelson Marshall, Willard Van Engel, and other members of the staff of the Virginia Fisheries Laboratory for their cooperation and help in the preparation of the manuscript; to William H. Massmann of the Virginia Fisheries Laboratory, who designed most of the equipment used in this survey, and James B. Sykes of the U. S. Fish and Wildife Service, co-workers in the field, are due much of the credit for the success of the sampling.

RIVERS STUDIED

The following rivers were sampled (Fig. 1): the Pamunkey, a branch of the York River; the Mattaponi, a branch of the York River; the Chickahominy, a branch of the James River; the James River; and the Rappahannock River. All of these rivers have a number of characteristics in common. They are tributaries of Chesapeake Bay or of rivers entering the Bay. They are under tidal influence in the areas considered in this study. In the lower portions they are brackish. There is no fixed point at which any of the rivers become fresh; rather, the salinity varies over a considerable area under the influence of tidal and river flow conditions. The upper reaches have a high turbidity due to silt; this is less true of the more saline areas nearer the Bay. The most turbid waters are located in the areas where brackish water is first encountered. Channels and flats are fairly well defined. Bottom conditions vary considerably over all the rivers, ranging from mud to sand.

APPARATUS AND METHODS

Large nets, similar in design to simple plankton nets, were made of nylon marquisette, a fine material having about 25 meshes per inch. Six nets were used: four with a diameter of 1 m at the mouth,

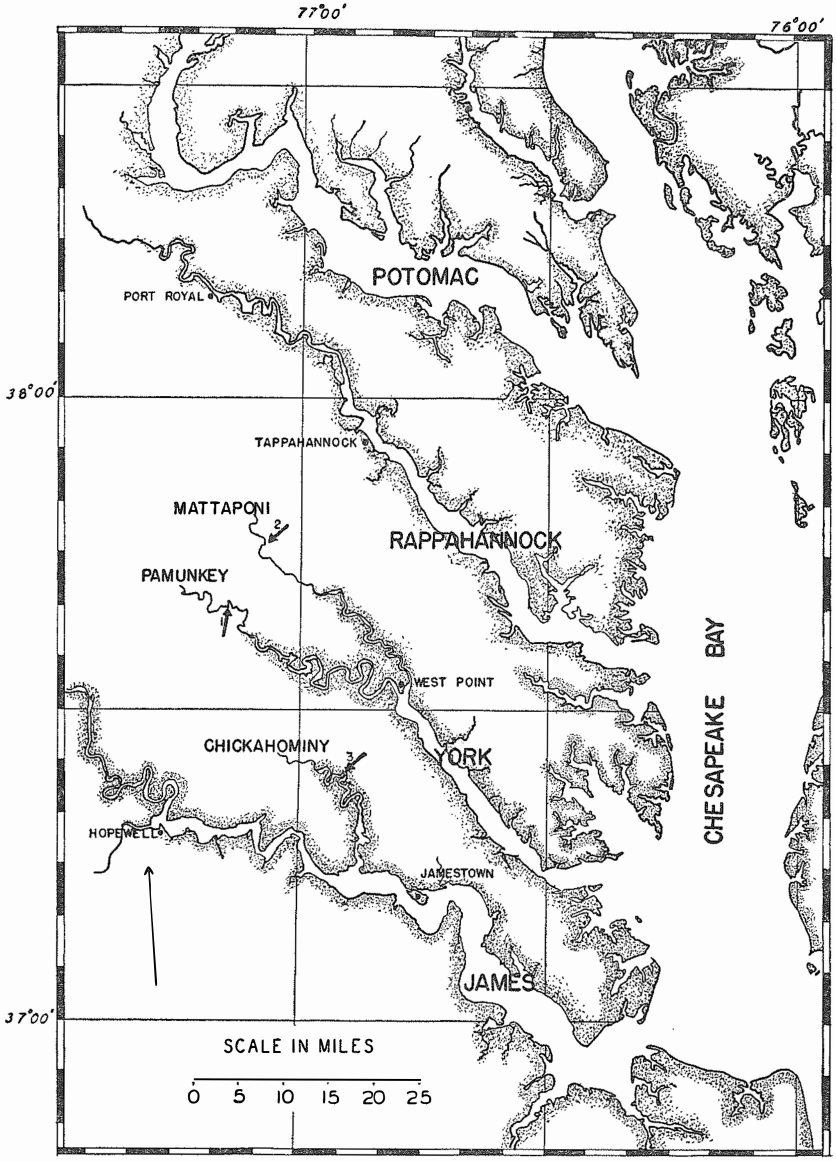

FIGURE 1. Virginia rivers in which striped bass eggs were collected. The upper and lower limits of the sampling areas are indicated. Numbers refer to the following stations: 1—Bassett's Bar; 2—Pointer's Landing; 3—Walker's Dam.

one with a diameter of ½ m, and one with a sled-type net in the shape of a semicircle which had a radius of ¼ meter. A quart mason jar was attached at the apex of each net.

These nets were set in the current, not towed. They could be operated on the surface or bottom in almost any part of the stream where there was sufficient current. Sampling stations were planned at approximately 3-mile[2] intervals on the short rivers and at approximately 5-mile intervals on the longer rivers so that sampling could be completed in the time available.

Since the survey was exploratory in nature, with shad and herring spawning grounds being surveyed concurrently, some variation was necessary in the number of surface and bottom samples taken at each station. Previous experience in collecting shad eggs by the method described here showed that most of the eggs of that species were collected on the bottom. Both shad and striped bass eggs are described in the literature as semibuoyant, and hence bottom sampling was stressed at first, with only one surface net being set at each station. Experience soon indicated that more bass eggs were taken in surface samples; thereafter more surface nets were set at each station. Nets were set for approximately one hour.

Samples were preserved in formalin and stored in quart jars until sorted. Eggs were separated from the other organisms and debris as soon as possible. Additional samples were sometimes taken on the return trip as a check on the adequacy of sampling.

HYDROGRAPHIC DATA

At each station field measurements were made of the salinity, surface current, depth, and temperature; in addition, water samples were taken for laboratory analysis of salinity and turbidity. Density measurements were made with a hydrometer (float), the readings then being converted to salinity at 15° C. These readings afforded a rapid approximate estimate of salinity as the field work progressed, and it was fortunate that these determinations were available, since many of the water samples were lost in transit. The remaining samples were titrated, and the salinity value was compared with those calculated from hydrometer readings at the same stations. A rather constant relationship was indicated, the hydrometer salinities exceeding those based on chemical analysis by about 1 °/₀₀. Stations having values of 1 °/₀₀ or lower, as calculated from hydrometer readings, were considered to be located in fresh water.

Most surface current measurements were made by timing a float over a measured course. An Ekman current meter was also used and the readings were converted to feet per second.

[2] All mileage distances used are nautical miles.

Temperature measurements were taken at both surface and bottom from samples collected with a Kemmerer water bottle. A bathythermograph was also used in deep water (50 to 80 feet). Practically no difference in temperature between surface and bottom was noted, even in the deepest water.

LOCATION OF STRIPED BASS SPAWNING GROUNDS

Pamunkey River (Table I).—Samples were taken at approximately 5-mile intervals from West Point to Bassett's Bar (1, in Fig.1), a distance of about 45 miles upstream. Beyond this point navigation became difficult and no samples were taken. Eggs were collected only in the vicinity of Morgan's Landing (Island Reach), about 17 miles above West Point, on April 6 and 13. Fishermen questioned during the survey indicated that the largest spring catches of striped bass are made in this area each year. The river at Morgan's Landing was fresh during the sampling period.

Mattaponi River (Table II).—Sampling was started at West Point and was continued at approximately 3-mile intervals upstream to Pointer's Landing (2, in Fig.1), about 25 miles from West Point. Navigation became difficult beyond this point and no samples were taken. On April 26 and 27 eggs were collected from all but one of the stations between Boardley and Rickahock, Boardley being about 8 miles from West Point and Rickahock about 19 miles. On April 30, on the downstream trip, many eggs were collected between Mattaponi and Muddy Point, where the last sample was taken. Although spawning was probably taking place over a fairly wide section of the stream, the peak activity was in the vicinity of Foxes, about 9 miles above West Point. The river at this point was fresh and relatively turbid. Fishermen on the river indicated that each year the largest spring catches of bass are made in the region of Foxes.

Large numbers of eggs were also taken on the downstream trip in the Muddy Point samples, about 3 miles above West Point, where the salinity was about $1°/_{oo}$. These were collected toward the end of an ebb tide, indicating that they could have been carried to this point by the current. Since no eggs were collected here on the upstream trip it seems questionable whether spawning was occurring this far downstream.

Chickahominy River (Table III).—Samples were taken at 3-mile intervals from Barret's Point, at the mouth of the River, to Walker's Dam (3, in Fig. 1), about 19 miles upstream. A few eggs were collected on May 5 at Nettle's Greek, Watt's Point, and below Big Marsh Point. Fishermen make the best catches of bass during

TABLE 1. STRIPED BASS EGG COLLECTIONS FROM PAMUNKEY RIVER IN APRIL 1950 (U. S. COAST AND GEODETIC SURVEY CHART NO. 504)

Station	*Date*	*Time sampling started*	*Tide*	*Surface current (feet/sec.)*	*Surface temp; (°C)*	*Salinity °/₀₀ (Hydrometer)* *Surf.*	*Bot.*	*Depth of water at nets (ft.)*	*No of nets set* *Surf.*	*Bot.*	*No. of eggs collected* *Surf.*	*Bot.*
A—West Point	4	1120	Flood	2.9	12.2	7.5	9.2	23	0	2	–	0
"	4	1230	Flood	2.0	12.6	7.5	9.6	25	0	2	–	0
B—Lee Marsh	4	1550	Ebb	1.5	13.3	3.3	5.1	20–32	0	4	–	0
"	4	1700	Ebb	1.7	13.0	2.5	4.6	20–32	0	4	–	0
"	4	1800	Ebb	—	13.2	1.7	2.4	20–32	0	4	–	0
C—Devils Reach	5	1200	Flood	2.0	13.6	0.5	1.1	18–26	1	5	0	0
"	5	1300	Flood	2.0	13.6	0.9	0.7	18–26	0	5	–	0
"	5	1400	Flood	1.7	13.5	0.8	0.4	18–26	0	4	–	0
D—Island Reach	5	1800	Ebb	—	13.2	—	—	22	1	0	0	–
"	6	0630	Ebb	1.7	13.2	0.3	1.2	16–22	1	4	8	1
"	6	0745	Ebb	2.9	13.4	0.3	0.3	16–22	0	4	–	0
"	6	0850	Ebb	2.5	13.6	0.5	0.5	16–22	0	4	–	0
E—Lester Manor	6	1345	Flood	1.4	14.0	—	—	20	0	4	–	0
"	6	1445	Flood	1.3	14.3	—	—	20	0	4	–	0
"	11	1145	Ebb	2.2	13.2	—	—	13–20	1	3	0	0
F—Rockahock	10	1750	Flood	1.7	13.2	—	—	20	1	5	0	0
"	10	1900	Flood	1.4	12.5	—	—	18–20	0	3	–	0
"	10	2000	Flood	1.4	12.6	—	—	20	0	4	–	0
G—Gregory's Bar	11	1500	Ebb	1.8	14.4	—	—	5–6	1	2	0	0
"	11	1600	Ebb	1.7	13.6	—	—	5	0	4	–	0
H—Hogan Bar	12	1600	Ebb	1.7	13.4	—	—	9	0	4	–	0
I—Bassett's Bar	12	1330	Ebb	0.9	13.9	—	—	10	1	3	0	0
D—Island Reach	13	0915	Flood	—	13.0	0.8	0.5	25	3	2	63	0
								Total	10	80	71	1

TABLE II. STRIPED BASS EGG COLLECTIONS FROM MATTAPONI RIVER IN APRIL 1950 (U. S. COAST AND GEODETIC SURVEY CHART NO. 504)

Station	*Date*	*Time sampling started*	*Tide*	*Surface current (feet/sec.)*	*Surface temp; (°C)*	*Salinity °/oo (Hydrometer)*		*Depth of water at nets (ft.)*	*No of nets set*		*No. of eggs collected*	
						Surf.	*Bot.*		*Surf.*	*Bot.*	*Surf.*	*Bot.*
A—West Point	13	1420	Ebb	1.0	12.6	6.6	7.2	30	0	4	–	0
B—Below Muddy Point	25	1430	Flood	1.0	15.8	3.9	7.2	12–28	1	4	0	0
C—Chelsea	25	1615	Flood	1.7	14.6	2.9	2.8	31–35	1	4	0	0
D—Boardley	25	1745	Flood	0.6	13.9	1.1	1.5	31	1	4	16	44
E—Foxes	25	2115	Ebb	1.3	14.0	0.5	0.7	25–30	1	4	0*	1
F—Courthouse Ldg.	26	0900	Ebb	1.4	14.9	1.0	1.0	29–30	1	4	5	2
G—Mattaponi	26	1100	Ebb	1.4	15.2	0.8	0.8	15–20	1	4	0	0
"	26	1630	Flood	1.7	15.2	—	—	15–30	1	4	0	0
H—Sandy Point	26	1300	Ebb	0.8	15.2	—	—	20–30	5	1	0	0
"	27	0630	Flood	1.0	15.7	—	—	15–28	1	4	0	1
I—Rickahock	27	0955	Ebb	1.3	16.4	—	—	20	1	4	0	0
"	27	0930	Slack	15 minute surface tow in shallows—no. 20 plankton net							3	–
J—Peavine Island	27	1145	Ebb	0.8	16.2	—	—	10	0	4	–	0
K—Line Tree Bar	28	0800	Flood	0.8	17.0	—	—	10–14	1	4	0	0
L—Pointer Landing	27	2000	Flood	0.3	17.4	—	—	9	0	4	–	0
Downstream Trip												
I—Rickahock	29	1715	Ebb	0.4	20.5	—	—	15	1**	1**	0	0
H—Sandy Point	29	1830	Flood	1.4	19.1	—	—	15–20	2	2	0	0
G—Mattaponi	30	0710	Flood	1.0	19.0	—	—	11–18	1	4	1	2
F—Courthouse Ldg.	30	0915	Flood	1.7	17.7	—	—	10–20	2	3	40	90
E_1—Below Foxes	30	1215	Ebb	1.1	16.8	—	—	21–30	3	2	5600	1700
D_1—Above Clifton	30	1400	Ebb	2.0	16.8	1.2	1.2	18–25	3	2	5100	236
B_1—Muddy Point	30	1530	Ebb	—	16.6	2.0	2.2	25	3**	0	800	–
								Total	30	67	11,565	2,076

* 30 eggs were collected here in an all-night surface sample.

** Nets set for about 30 minutes.

the spring in the region of the last two stations. Nettle's Creek is 3 miles and Big Marsh Point about 11 miles above the mouth of the Chickahominy. The whole river was fresh and appeared less turbid than the other streams. Brackish water was encountered in the James River below Jamestown, a point about 10 miles downstream from the mouth of the Chickahominy River.

Since so few eggs were collected in the river, it was impossible to locate the region of peak spawning; however, interviews with fishermen indicate that a spawning ground is probably located between Watt's Point and Big Marsh Point.

James River (Table IV).—Samples were taken at approximately 5-mile intervals from Jamestown to the west side of Turkey Island cutoff, above Hopewell, Va., above which no samples were taken. Some eggs were collected on May 9 and 10 at almost every station between these limits. Evidently eggs were being spawned over a relatively wide area, possibly extending upstream from the last sampling station. The eggs from the Jamestown sample and from the one taken above that were almost ready to hatch, indicating that they may have been spawned further upstream. The largest numbers of eggs were taken from the area between Dunmore and Jordan Point, which are 16 and 27 miles, respectively, above Jamestown. Turkey Island cutoff is about 32 miles above Jamestown. The whole river was turbid during the sampling period. A few fishermen were questioned but no indication was obtained as to the location of the largest catches.

Rappahannock River (Table V).—Samples were taken from Tappahannock to Port Royal at approximately 3-mile intervals, from May 17 to May 21. Sampling conditions were very poor because of a heavy concentration of fine filamentous algae in the water, which clogged nets and made sorting of samples difficult. A few eggs were collected from Layton, Ketch Point, Wilmot, and Portobago Bay. These localities are 13, 17, 22, and 28 miles, respectively, from Tappahannock. Fresh water was first encountered in the vicinity of Tappahannock. The whole area studied was very turbid, a Secchi disc disappearing 12 to 16 inches under the surface. The fishermen questioned gave no clear picture of the location of the best commercial fishing grounds.

In the above descriptions of spawning grounds no attempt has been made to interpret the significance of the number of eggs per sample because of limitations inherent in the method of sampling. At best the apparatus is semiquantitative, since it is difficult to measure currents accurately, to compensate for variable clogging of

TABLE III. STRIPED BASS EGG COLLECTIONS FROM CHICKAHOMINY RIVER IN MAY 1950 (U. S. COAST AND GEODETIC SURVEY CHART NO. 530)

Station	*Date*	*Time sampling started*	*Tide*	*Surface current (feet/sec.)*	*Surface temp; (°C)*	*Salinity °/oo (Hydrometer) Surf.*	*Salinity °/oo (Hydrometer) Bot.*	*Depth of water at nets (ft.)*	*No of nets set Surf.*	*No of nets set Bot.*	*No. of eggs collected Surf.*	*No. of eggs collected Bot.*
A—Barret's Point	5	0915	Ebb	1.2	18.3	1.1	0.8	25–30	1	4	0	0
B—Nettle's Creek	5	1230	Flood	1.6	18.7	—	—	19	1	4	0	1
C—Shipyard Landing	5	1430	Flood	1.1	19.0	—	—	38	2	3	0	0
D—SE Watt's Point	6	1315	Flood	1.5	21.1	—	—	15–20	2	3	0	1
E—Big Marsh Point	6	1450	Flood	1.2	20.4	—	—	14–20	2	3	0	1
F—Lanexa	7	0800	—	—	20.4	—	—	15	2*	0	0	–
H—Walker's Dam	8	0640	—	—	20.2	—	—	13	0	3	–	0
								Total	10	20	0	3

* Nets towed for ½ hour.

TABLE IV. STRIPED BASS EGG COLLECTIONS FROM JAMES RIVER IN MAY 1950 (U. S. COAST AND GEODETIC SURVEY CHARTS NO. 530 AND 531)

Station	*Date*	*Time sampling started*	*Tide*	*Surface current (feet/sec.)*	*Surface temp; (°C)*	*Salinity °/oo (Hydrometer) Surf.*	*Salinity °/oo (Hydrometer) Bot.*	*Depth of water at nets (ft.)*	*No of nets set Surf.*	*No of nets set Bot.*	*No. of eggs collected Surf.*	*No. of eggs collected Bot.*
A—Deep Water Shoals	4	2000–0515	—	—	—	—	—	All Night Sample			0	–
B—Jamestown Island	9	0900	Ebb	1.1	19.0	1.4	1.4	10–15	3	2	1	0
C—Dancing Point	9	1110	Ebb	0.7	20.0	0.9	1.3	25–30	3	2	5	1
D—Dunmore	9	1340	Ebb	1.2	20.6	1.4	—	25–32	3	2	7	1
E—Windmill Point	9	1710	Flood	0.9	20.8	—	—	20–28	3	2	13	3
F—Jordan Point	10	0710	Flood	1.4	20.2	—	—	30	3	2	13	6
G—City Point	10	0905	Flood	—	20.4	—	—	15	1	2	0	0
H—Turkey Island Cutoff:												
West End	10	1145	Ebb	—	21.1	—	—	10–35	3	2	6	1
East End	10	1400	Ebb	—	20.8	—	—	12–15	3	2	0	0
								Total	22	16	45	12

TABLE V. STRIPED BASS EGG COLLECTIONS FROM RAPPAHANNOCK RIVER IN MAY 1950 (U. S. COAST AND GEODETIC SURVEY CHARTS NO. 535 AND 536)

Station	*Date*	*Time sampling started*	*Tide*	*Surface current (feet/sec.)*	*Surface temp; (°C)*	*Salinity °/oo (Hydrometer)*		*Depth of water at nets (ft.)*	*No of nets set*		*No. of eggs collected*	
						Surf.	*Bot.*		*Surf.*	*Bot.*	*Surf.*	*Bot.*
A—Mallory's Point	17	1115	Ebb	0.8	19.0	0.7	0.7	15–18	2	4	0	0
B—Island Point	17	1400	Flood	1.3	19.4	—	—	25	1	3	0	0
D—Layton*	17	1620	Flood	0.8	20.4	—	—	22–25	2	4	2**	0
E—Ketch Point	18	0815	Ebb	1.3	20.0	—	—	20–35	2	4	0	1
F—Owl Hollow	18	1130	Ebb	1.3	20.3	—	—	15–22	2	4	0	0
G—Wilmot	21	0900	Ebb	1.3	18.1	—	—	15–25	2	4	1**	0
H—Portobago Bay	20	1800	Flood	0.6	17.9	—	—	11–16	2	4	1	0
I—Port Royal	20	1500	Ebb	0.5	16.7	—	—	15–25	2	4	0	0
A_1—Tappahannock	21	1500	Flood	1.3	20.4	1.4	1.4	12–16	2	2	0	0
								Total	17	33	4	1

* Skipped station "C" because it was too near the previous station.

** Because of a heavy concentration of algae, only about one-eighth of each sample was taken.

nets, and to make allowances for similar factors. The short time spent on each river allows no comparison of the importance of spawning grounds since spawning is not carried on throughout the season with equal intensity.

DISCUSSION

Though eggs were taken in every river surveyed, only in the Mattaponi River were they collected in appreciable numbers. On the Pamunkey, Mattaponi, and Chickahominy Rivers the regions of largest commercial catch approximately coincide with those in which eggs were collected in greatest abundance. This suggests that the peak spawning activity on these rivers takes place in the same limited areas from year to year. These areas are apparently located within about the first 25 miles of fresh water and usually have high turbidity during the spawning season.

In the James and Rappahannock Rivers no good indication of the region of best commercial catch of bass was obtained. Only a few eggs were collected over a wide section of these rivers; thus no region of peak spawning activity could be located. The greater dispersal of eggs may have indicated a wider range of spawning activity, or it may simply have been the result of little spawning activity when the river was surveyed.

No eggs were collected in the last upstream samples except in the James River. Fishermen on the rivers reported that few bass were taken at or above the upstream limits of the survey areas. These two observations seem to indicate that spawning does not take place as far upstream as the fall line in Virginia Rivers.

Spawning grounds described by Vladykov and Wallace (1952) and by Pearson (1938) in the Chesapeake Bay region, and by Woodhull (1947) in California, appear to be similar in most respects to those described here. By contrast, the spawning ground at Weldon, North Carolina, is distinctly different. It is much farther from brackish water and is located at the fall line where the bottom is rocky and the current erratic.

The contrast between the Weldon spawning ground and those in Virginia raises many questions regarding the nature of this difference. Possibly the fish that spawn in this river belong to a physiologically different race. Since practically nothing is known about striped bass spawning activities in other parts of the Roanoke or in other North Carolina rivers, further studies are necessary for the clarification of the problem.

SUMMARY

1. During April and May 1950, the Pamunkey, Mattaponi, Chickahominy, James and Rappahannock Rivers were surveyed to de-

termine the location of striped bass spawning grounds by sampling for planktonic eggs.

2. Large nets similar in design to simple plankton nets were anchored in the current both on the bottom and at the surface. Samples were taken from brackish water (about 5°/₀₀) and were continued upstream until navigation became difficult or scheduled demands required that sampling be stopped.

3. In all of the rivers surveyed, most of the spawning activity occurs within the first 25 miles of fresh water. On the Pamunkey, Mattaponi and Chickahominy most eggs were collected where fishermen made the best spring catches of bass. However, on the James and Rappahannock no such relationship was apparent.

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VARIATIONS IN THE FEEDING HABITS OF THE STRIPED BASS, *ROCCUS SAXATILIS* (WALBAUM), IN CHESAPEAKE BAY[1]

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ABSTRACT

The stomachs of 1,736 striped bass, *Roccus saxatilis* (Walbaum), from Chesapeake Bay, taken from June 1936 to April 1937, were examined for contents. The most

[1] This report is based in part on a thesis submitted by the author to the Graduate School, University of Maryland, May 1937, in partial fulfillment of the requirements for the degree of Master of Science.

common foods present were anchovy (*Anchoa mitchilli*) and menhaden (*Brevoortia tyrannus*), but young spot (*Leiostomus xanthurus*) and croaker (*Micropogon undulatus*) were prominent foods also. Crustaceans were secondary to fishes as food items both in number and weight. A distinct seasonal and regional variation in food composition was found. Anchovy and menhaden, dominant forms in summer and fall, were replaced by spot and croaker in the winter. White perch (*Morone americana*) and herrings (*Pomolobus*) were common in spring and early summer. Fresh-water organisms were dominant in samples taken from the Head of Chesapeake Bay. There was a tendency toward reduction of feeding in late May and early June, a period corresponding to the spawning season.

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INTRODUCTION

As a part of the investigations of the life history of the rock or striped bass, *Roccus saxatilis* (Walbaum), in Chesapeake Bay waters from 1936 to 1938, the contents of 1,736 stomachs were examined to determine the percentage that contained food and the kinds of organisms eaten by season and by locality. Although striped bass are reputed to be voracious feeders, published information on their food is scant.

Hildebrand and Schroeder (1928) examined the stomachs from 48 striped bass from Chesapeake Bay and LeCompte (1926) and Haddaway (1930) published popular accounts in which they mentioned its feeding behavior in Chesapeake Bay waters. The food of this species has been discussed briefly by Bigelow and Welsh (1924: 255) for the Gulf of Maine, by Smith (1907: 273) for North Carolina waters, and by Verrill (1873: 514), who reported on a few stomachs examined at Great Egg Harbor, New Jersey and at Woods Hole, Massachusetts. Merriman (1937: 32–33) reported on his examination of about 250 stomachs, most of which were from Con-

TABLE I. DATA ON THE NUMBER AND PER CENT OF STRIPED BASS STOMACHS WHICH CONTAINED FOOD

Date	*Locality*	*Fishing Gear*	*Number Examined*	*Number*		*Per Cent*	
				Full	*Empty*	*Full*	*Empty*
VI/1 to IX/30, 1936*	Head of Chesapeake Bay	Mainly hook and line	263	175	88	66.5	33.5
VII/21–22, 1936	Rock Hall, Maryland	Pound nets	420	152	268	36.2	63.8
IX/10 to XI/11, 1936	Rock Hall, Maryland	Hook and line; pound nets	100	43	57	43.0	57.0
XII/4–28, 1936	Vicinity, Rock Hall, Md.	Gill nets	124	54	70	43.6	56.4
X/25–29, 1936	Tilghman Island, Md.	Hook and line; pound nets	18	8	10	44.4	55.6
II/10, 1937	Tilghman Island, Md.	Gill nets	124	107	17	86.3	13.7
III/18–19, 1937	Tilghman Island, Md.	Haul seine	6	3	3	50.0	50.0
I/4–18, 1937	Hooper Island	Gill nets	148	110	38	74.3	25.7
VIII/21–25, 1936	Galesville, Maryland	Pound nets	205	112	93	54.6	45.4
X/8 to XI/12, 1936	Galesville, Maryland	Pound nets	7	5	2	71.4	28.6
VI/20 to VIII/ 18, 1936	Solomons Island, Md.	Hook and line	135	64	71	47.4	52.6
IX/16 to X/ 6, 1936**	Solomons Island, Md.	Hook and line	60	39	21	65.0	35.0
X/6, 1936	Potomac River near Colonial Beach, Va.	Pound nets	4	4	0	100.0	0
III/12, 1937	Potomac River, Virginia	Gill nets	2	2	0	100.0	0
XII/3/1936– I/22/1937	James River, Virginia	Fyke nets	74	53	21	71.6	28.4
III/20, 1937	James River, Virginia	Fyke nets	45	37	8	82.2	17.8
		Total	1735	968	767	55.8	44.2

* One group of 79 stomachs, of which 56 contained food, were collected from anglers during August and September and preserved in a single container. Exact dates were not available.

** One stomach was examined from Solomons April 22, 1937. It was from an 11-pound female, 725 mm long. The contents were 3 menhaden, 2 glut herring, 1 branch herring, and 2 isopods, totaling 473 g.

necticut waters. On the Pacific Coast, where this species was introduced, Scofield and Bryant (1926: 66–67), Scofield (1928: 37; 1931: 56–57) and Shapovalov (1936) have noted its feeding behavior. Most of the literature indicates that fishes constitute the dominant food for striped bass.

The stomachs examined in this study were obtained from fish used by Vladykov and Wallace for morphometric studies, the fish having been obtained from both commercial and sports fisheries. Immediately upon capture, or as soon thereafter as possible, the stomachs were removed and preserved in individual bottles containing about 4% formalin solution. Data on size, weight, sex, and stage of maturity were recorded for each sample. A summary of the collections is given in Table I.

TABLE II. List of Fish Species Found in the Stomachs of Striped Bass Caught During the Period 1936–1937 in Chesapeake Bay

Common Name	*Scientific Name*	*Conowingo*	*Rock Hall*	*Tilghman Is.*	*Hooper Is.*	*Galesville*	*Solomons Is.*	*Potomac R., Va.*	*James R., Va.*
Anchovy	*Anchoa mitchilli*	—	×	×	—	×	×	—	×
Bullhead	*Ameiurus* sp.	×	—	—	—	—	—	—	—
Butterfish	*Poronotus triacanthus*	—	—	—	—	×	—	—	—
Crappie	*Pomoxis* sp.	×	—	—	—	—	—	—	—
Croaker	*Micropogon undulatus*	—	×	×	×	—	×	—	×
Dace, Blacknose	*Rhinichthys atratulus*	×	—	—	—	—	—	—	—
Eel	*Anguilla rostrata*	×	—	—	—	—	×	—	—
Flounder	*Etropus crossotus*	—	—	—	×	—	—	—	—
Goby	*Gobidae*	—	—	—	—	—	×	—	—
Gray trout	*Cynoscion regalis*	—	×	—	—	—	×	—	—
Herring, Branch	*Pomolobus pseudoharengus*	—	×	×	—	—	×	×	×
Glut	*Pomolobus aestivalis*	—	—	×	—	—	×	—	×
Menhaden	*Brevoortia tyrannus*	—	×	×	×	×	×	×	×
Mud Shad	*Dorosoma cepedianum*	—	—	—	—	—	—	×	×
Red drum	*Sciaenops ocellatus*	—	—	—	—	—	—	—	×
Shad	*Alosa sapidissima*	—	×	—	—	—	—	—	×
Silversides									
Common	*Menidia menidia*	—	×	—	—	×	—	—	×
Rough	*Membras vagrans*	—	×	—	—	—	×	—	—
Spot	*Leiostomus xanthurus*	—	×	×	×	×	×	—	×
Spot-tail Shiner	*Notropis hudsonius*	×	—	—	—	—	—	—	—
Ten pounder	*Elops saurus*	—	—	—	—	—	—	—	×
White perch	*Morone americana*	—	×	×	—	—	—	×	×
Yellow perch	*Perca flavescens*	×	—	—	—	—	—	—	—

ANALYSES OF STOMACH CONTENTS

First the stomachs were classified as either "full" or "empty," a stomach containing any material whatsoever being called full. In samples taken with hook and line, no distinction was made between a stomach containing bait and one with natural food, since the fish was feeding in either case. In the laboratory, each stomach was split and all of the contained material was washed into a glass dish; this material was then examined with a low power binocular dissecting microscope. Food organisms were separated, identified, counted, and weighed, and lengths of ingested fish were measured or estimated on the basis of undigested fragments. Of the 1,736 stomachs which were obtained for analysis, 969 contained food and the data acquired from these observations are summarized in Tables I to VII.

Frequencies of food types were obtained by counting all stomachs that contained the same types of food regardless of the quantities of individual organisms. Thus a stomach containing a single organism and a stomach containing many of the same organism were given the same tally inasmuch as each of them possessed the same type of food. Since some stomachs contained more than one food species, the total number of occurrences of food organisms was higher than the number of full stomachs present in many samples.

Fishes, because they constituted the predominant food group, received special attention and were identified to species whenever possible. Table II presents the common and scientific names of the species found in the striped bass stomachs by localities, and to avoid repetition, only the common names will be used in subsequent parts of this paper. The identification of partially digested fish was determined by means of otoliths, scales, structure of distinctive bones, number and type of gill rakers, and other known characters that were checked against a reference collection. In some instances the shape, size, and color of the stomach and other viscera of the ingested fish served as means of identification. The invertebrate groups were identified to orders.

FOOD GROUPS

Fish. The total weight of food in 969 full stomachs was at least 8,945 g, or about 20 pounds. Of this weight, fish comprised about 95%.

The occurrence of forage fishes (32.9%) was lowest in the stomach samples taken from the Head of Chesapeake Bay (Table III). This was in sharp contrast with all other samples, where the occurrence of fishes was much higher, ranging from 46.2 to 100% in some of the smaller samples. The most important forage fishes were the anchovy, menhaden, spot, and croaker. Frequently one species constituted the principal food, but in many instances individual bass fed on several species. One striped bass taken on September 10, 1936 at Rock Hall, Maryland had in its stomach 26 anchovies and four herrings that weighed a total of 59 g. Even more diversified was the food found in a bass from the James River, Virginia, taken on March 29, 1937; this fish, 363 mm long, had eaten 55 anchovies, one menhaden, and three herrings, giving a total weight of 54 g.

Crustaceans. Crustaceans were of secondary importance as food, their percentage of occurrence varying from 0 to 46.3 (Table III). By weight, they amounted to less than 2% of all food examined.

TABLE III. FOOD ITEMS AND THEIR FREQUENCY OF OCCURRENCE IN NUMBERS AND PER CENT IN STRIPED BASS STOMACHS BY SEASON AND REGION

	SUMMER				FALL					WINTER				SPRING		
Food Items	*Head of Chesapeake Bay*	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
	Number															
Fishes	81	151	105	52	43	8	5	25	4	53	107	98	44	3	2	37
Copepods	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Cladocerans	61	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	—	—	8	12	2	—	1	10	—	3	2	—	5	—	—	2
Mysids	—	—	—	3	—	—	—	12	—	1	—	—	—	—	—	—
Amphipods	—	—	2	2	—	—	—	—	—	—	—	—	—	1	—	1
Shrimps	—	5	—	2	3	—	—	1	—	2	1	24	6	—	—	3
Mud crabs	—	1	2	—	2	—	—	1	—	—	—	—	—	—	—	—
Blue crabs	—	—	—	1	—	—	—	—	—	—	—	2	11	—	—	3
Other crustacea	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lamellibranchs	—	—	2	—	—	—	—	2	—	—	—	—	—	—	—	—
Mineral	—	—	1	2	—	—	—	1	—	—	—	—	—	—	—	—
Polychaetes	—	1	—	—	—	—	—	—	—	—	—	10	—	—	—	1
Algae	1	—	—	—	—	1	—	1	—	—	—	1	—	1	—	—
Bait	89	—	—	8	—	—	—	—	—	—	—	—	—	—	—	—
Fish scales	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	5	1	1	2	—	—	—	—	—	—	—	—	—	—	—	—
Total	246	159	121	84	50	9	6	54	4	59	110	135	66	5	2	47

TABLE III.—*Continued*

Food Items	SUMMER				FALL					WINTER				SPRING		
	Head of Chesapeake Bay	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
	Per Cent															
Fishes	32.9	95.1	86.8	61.7	86.0	88.9	83.3	46.2	100	89.8	97.3	72.6	66.7	60.0	100	78.8
Copepods	—	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—
Cladocerans	24.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Isopods	—	—	6.6	14.4	4.0	—	16.7	18.4	—	5.1	1.8	—	7.5	—	—	4.2
Mysids	—	—	—	3.6	—	—	—	22.2	—	1.7	—	—	—	—	—	—
Amphipods	—	—	1.7	2.4	—	—	—	—	—	—	—	—	—	20.0	—	2.1
Shrimps	—	3.1	—	2.4	6.0	—	—	1.9	—	3.4	0.9	17.8	9.1	—	—	6.4
Mud crabs	—	0.6	1.7	—	4.0	—	—	1.9	—	—	—	—	—	—	—	—
Blue crabs	—	—	—	1.2	—	—	—	—	—	—	—	1.5	16.7	—	—	6.4
Other crustacea	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lamellibranchs	—	—	1.7	—	—	—	—	3.7	—	—	—	—	—	—	—	—
Mineral	—	—	0.8	2.4	—	—	—	1.9	—	—	—	—	—	—	—	—
Polychaetes	—	0.6	—	—	—	—	—	—	—	—	—	7.4	—	—	—	2.1
Algae	0.4	—	—	—	—	11.1	—	1.9	—	—	—	0.7	—	20.0	—	—
Bait	36.3	—	—	9.5	—	—	—	—	—	—	—	—	—	—	—	—
Fish scales	2.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	2.0	0.6	0.8	2.4	—	—	—	—	—	—	—	—	—	—	—	—
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Although crustaceans comprised the only food in some instances, in only a few stomachs did their occurrence and weight suggest that they were of significant importance as food for striped bass of the sizes reported herein.

Shrimp were relatively abundant in samples taken January 18, 1937 in the vicinity of Hooper Island. One fish 195 mm long had eaten 16 shrimp weighing 11 g; another, 320 mm in length, contained 10 shrimp weighing five g in addition to two small croakers, 65 and 75 mm long, weighing six g.

Cladocerans of the genus *Leptodora* were rather abundant in the stomachs of fish taken at Conowingo. A bass 195 mm in length taken there during the summer of 1936 had about three g of *Leptodora* in its stomach in addition to a blacknose dace which weighed one g.

Crabs were found occasionally in stomachs of bass taken in more saline waters. Eight blue crabs measuring 22–24 mm from tip of spine to tip of spine and weighing a total of 53 g were found in the stomach of a 620 mm male taken on June 28, 1936 off Solomons, Maryland. Single mud crabs were found in the stomachs of two bass caught at Galesville, Maryland in August 1936. Small crabs were found more often along with other food groups.

Much of the invertebrate material examined was badly digested or broken, but some of the better specimens were saved and forwarded to the U. S. National Museum for identification. J. O. Maloney identified the isopods: the parasitic *Aegathoa oculata* (Say) and *Olencira praegustator* (Latrobe) were most numerous in the specimens submitted, but one nonparasitic form, *Erichsonella attenuata* (Harger), was identified from the stomach of a bass taken at Solomons. Waldo L. Schmitt identified the prawns and shrimp: *Crago septemspinosus* (Say) occurred in samples from Solomons, Rock Hall, Tilghman, and James River; *Palaemonetes vulgaris* (Say) and *Palaemonetes carolinus* Stimpson were identified in James River samples; and *Neomysis americana* Smith was found in samples from Rock Hall, Solomons, and Tilghman. From specimens found in the stomachs collected at Conowingo July 2–20, 1936, Chancey Juday identified *Leptodora kindtii* (Focke). C. B. Wilson examined the copepods and found one of the genus *Cyclops* in material from Conowingo taken July 2–20, 1936; he also found a parasitic copepod, *Argulus stizostethii* Kellicott, in a sample taken at Rock Hall July 21, 1936. The stomach from which the latter was taken contained two fish, one of which was an anchovy and the other an unidentified clupeoid. Mary J. Rathbun identified six samples of mud crabs from fish taken at Rock Hall and Solomons as *Rhithropanopeus harrisii* (Gould).

Isopods were found frequently in these analyses. There is the possibility, however, that not all of these were ingested as a result of direct feeding, since some of them are known to be parasitic and may have been ingested along with their fish hosts. Thus *Aegathoa oculata* and *Olencira praegustator*, both parasitic, were identified from stomach contents. Although most of these were found in the same stomach with forage fish, there were some exceptions. In the stomach of a bass 325 mm long taken on October 14, 1936 at Solomons, Maryland, 29 parasitic isopods were found together with a grass shrimp, but there was no trace of a fish host. At the same locality on October 16, one fish contained 19 isopods, 10 of which were relatively whole and were identified as *Aegathoa oculata.*

Small quantities of other crustaceans such as amphipods, mysids, and copepods were found occasionally in stomachs, but they were never present in large quantities.

Other Invertebrates and Miscellanea. Other invertebrate groups such as polychaete worms and mollusks were found less frequently in bass stomachs. Pieces of the bloodworm (*Nereis*), used as bait, were common during the summer season, particularly at Conowingo. Some annelids from the stomachs were examined by A. L. Treadwell, but they were in such poor condition that specific identification was impossible; samples taken from Tilghman, Solomons, and Rock Hall in the summer were placed in the family *Spionidae,* while a sample taken from the vicinity of Hooper Island during winter was placed in the genus *Glycera;* and one sample taken at Solomons during the summer belonged to the family *Aphroditidae.* Paul Bartsch identified the small bivalve mollusk, *Mulinia lateralis* Say, in samples taken at Galesville during August and at Solomons during October.

Some of the items found in the stomachs were unusual and could hardly be classified as food. Stones were found in the stomach contents of at least five specimens. One bass 785 mm in length and weighing 11½ pounds, taken near Solomons on August 1, 1936, had ingested two stones weighing 13.2 g, in addition to an eel and some unidentified material. Glass and an unidentified fish were found in the stomach of a bass 250 mm in length taken at Galesville August 24, 1936. Scales of shad, herring and striped bass of a size too large to be from fishes taken for food were found occasionally in the stomach samples taken at Conowingo, and it seems likely that these were thrown in the water by sportsmen while cleaning fish. Such undigestible items were probably taken accidentally while the striped bass were striking at food organisms.

REGIONAL VARIATION IN FOOD COMPOSITION

These data have been grouped in Tables III, IV, and V by seasons defined as follows: Summer, June through August; Fall, September through November; Winter, December through February; and Spring, March and April. Because of limited funds it was impossible to purchase samples at regular intervals from all localities, but the samples seem sufficient to show some seasonal variations in food composition. The areas from which samples were obtained were either salt or brackish, with the exception of the Head of the Bay, where the water is fresh.

Head of Chesapeake Bay. The data from this locality were collected from 263 bass, of which 175 had full stomachs. Most of them were caught by anglers during the summer months just below the Conowingo Dam on the Susquehanna River, where the water is fresh, and the food organisms were typical fresh water forms. Seasonal variations in food composition were observed during the several months of sampling. No *Leptodora* were found in stomachs of fish caught in June, but during July and August-September they were very frequent in occurrence, amounting to 40.2% in July and 25.6% in August-September samples.

There was a less pronounced seasonal difference among the food fishes. Eels were more common (55.6%) in June than in other months, while crappie appeared more frequently (38%) during August-September.

Rock Hall, Maryland. The fish examined from Rock Hall were caught by pounds nets, gill nets, and hook and line over three seasons (Tables III, IV, and V) and ranged in length from 180 to 485 mm. Food was found in 249 stomachs. Anchovy constituted about 50% of the food fish occurrences during the summer and fall seasons but was not found at all during the winter sampling. Menhaden was of little importance as a food item in July (3.8%), but it was found frequently in fall samples (35.3%) and then less frequently in December (27.2%). The herrings were found also as food items in all three seasons of sampling at Rock Hall, but they were found most frequently during the summer, their occurrence at this season amounting to 23%. Croaker, trout, spot, and white perch were found only during winter months. The small croaker and trout were fed upon to the extent of 17.1 and 22.9% respectively, and together they were important food items in the winter. In this locality there was a pronounced variation in food composition from season to season. Invertebrate food items ranged from about 3–14% in the three seasons of sampling, and of this food group the shrimp was found in each season of sampling.

Tilghman Island, Maryland. Fish taken from this area were captured by gill nets, pound nets, and haul seines over three seasons. Altogether, 118 bass between 280 and 425 mm with full stomachs were examined. During late fall the anchovy was a dominant food item, occurring in 55.6% of the feeding fish, but it was entirely absent during winter and early spring (Tables IV and V). Menhaden and herrings, present only in the winter samples, constituted only a very small percentage of the stomach contents. During the fall, the croaker and spot were present in small amounts, but during the winter they increased tremendously, together comprising 89.0% of food fish occurrences. Only three full stomachs were obtained during the spring, and the principal food during that period appeared to be white perch.

Solomons Island, Maryland. The fish from this locality were collected over two seasons and were obtained almost exclusively by means of hook and line. A total of 104 stomachs contained food. Anchovy was the main diet during the summer and fall months, varying from 82.4 to 51.9%. Only one full stomach was obtained during the spring and it contained herrings and menhaden. Spot was found during the summer and fall in small quantities, and croaker was present only in the fall. Other species of fish were represented in small numbers. The seasonal difference between summer and fall was slight.

James River, Virginia. Two samples of fish, one in winter with 53 full stomachs and one in spring with 37 full stomachs, were obtained from fyke nets in the lower James River just above Newport News. The two samples showed similarities in types of food; menhaden, herrings, and anchovy were the most important items, but young croakers were found during the spring.

SEASONAL VARIATIONS IN FOOD COMPOSITION

Data presented thus far show the extent of variation of bass food composition for certain localities from season to season. Differences in feeding were also observed in different regions during the same season.

Summer. Food of bass taken during this season in the fresh water immediately below Conowingo Dam consisted exclusively of fresh-water species. Spottail shiner, dace, bullhead, crappie, and yellow perch were the typical species found most often in stomach contents and these species were not present in bass taken from any other region. By contrast, the anchovy was the most typical food species in stomachs of striped bass taken from salt waters during this season. The

TABLE IV. FORAGE FISH AND THE NUMBER OF STRIPED BASS STOMACHS IN WHICH THEY OCCURRED BY SEASON AND REGION

	SUMMER				*FALL*					*WINTER*				*SPRING*		
	Head of Chesapeake Bay	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
Anchovy	—	83	23	47	24	5	—	14	—	—	—	—	5	—	—	17
Bullhead	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Butterfish	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Crappie	17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Croaker	—	—	—	—	—	1	—	3	—	12	52	45	—	—	—	11
Dace, blacknose	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eel	19	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—
Flounder	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Goby	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Herring (sp?)	—	28	—	—	4	—	—	—	1	1	2	—	—	—	—	10
Branch	—	10	—	—	—	—	—	—	—	1	—	—	11	—	—	4
Glut	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Menhaden	—	6	12	6	17	—	5	2	3	19	6	3	8	—	1	20
Mud Shad	—	—	—	—	—	—	—	—	1	—	—	—	2	—	—	1
Red Drum	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—
Shad	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—	2
Silversides																
Common	—	—	3	—	1	—	—	—	—	—	—	—	3	—	—	2
Rough	—	1	—	—	—	—	—	1	—	—	—	—	—	—	—	—
Spot	—	—	2	2	—	1	—	1	—	4	77	47	1	—	—	—
Spottail Shiner	16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ten pounder	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—
Trout, Gray	—	—	—	—	—	—	—	—	—	5	—	—	—	—	—	—
Trout (sp?)	—	—	—	—	—	—	—	1	—	11	—	—	—	—	—	—
White perch	—	—	—	—	—	—	—	—	—	7	2	—	4	2	1	6
Yellow perch	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	32	33	66	1	2	2	—	4	—	10	6	15	11	1	—	2
Total	95	162	107	57	48	9	5	27	5	70	145	111	50	3	2	77

TABLE V. FORAGE FISH AND THE PER CENT OF STRIPED BASS STOMACHS IN WHICH THEY OCCURRED BY SEASON AND REGION

	SUMMER				FALL					WINTER				SPRING		
	Head of Chesapeake Bay	*Rock Hall, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Galesville, Md.*	*Solomons, Md.*	*Potomac River near Colonial Beach, Va.*	*Rock Hall, Md.*	*Tilghman, Md.*	*Hooper, Md.*	*James River, Va.*	*Tilghman, Md.*	*Potomac River, Va.*	*James River, Va.*
Anchovy	—	51.3	21.5	82.4	50.0	55.6	—	51.9	—	—	—	—	10.0	—	—	22.2
Bullhead	4.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Butterfish	—	—	0.9	—	—	—	—	—	—	—	—	—	—	—	—	—
Crappie	17.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Croaker	—	—	—	—	—	11.1	—	11.1	—	17.1	35.9	40.6	—	—	—	14.1
Dace, Blacknose	2.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Eel	20.0	—	—	1.8	—	—	—	—	—	—	—	—	—	—	—	—
Flounder	—	—	—	—	—	—	—	—	—	—	—	0.9	—	—	—	—
Goby	—	—	—	—	—	—	—	3.7	—	—	—	—	—	—	—	—
Herring (sp.?)	—	17.2	—	—	8.4	—	—	—	20.0	1.4	1.4	—	—	—	—	13.0
Branch	—	6.2	—	—	—	—	—	—	—	1.4	—	—	22.0	—	—	5.2
Glut	—	—	—	—	—	—	—	—	—	—	—	—	2.0	—	—	2.6
Menhaden	—	3.8	11.2	10.5	35.3	—	100	7.4	60.0	27.2	4.1	2.7	16.0	—	50.0	26.0
Mud Shad	—	—	—	—	—	—	—	—	20.0	—	—	—	4.0	—	—	1.3
Red Drum	—	—	—	—	—	—	—	—	—	—	—	—	4.0	—	—	—
Shad	—	0.6	—	—	—	—	—	—	—	—	—	—	2.0	—	—	2.6
Silversides																
Common	—	—	2.8	—	2.1	—	—	—	—	—	—	—	6.0	—	—	2.6
Rough	—	0.6	—	—	—	—	—	3.7	—	—	—	—	—	—	—	—
Spot	—	—	1.9	3.5	—	11.1	—	3.7	—	5.7	53.1	42.3	2.0	—	—	—
Spottail Shiner	16.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ten Pounder	—	—	—	—	—	—	—	—	—	—	—	—	2.0	—	—	—
Trout, Gray	—	—	—	—	—	—	—	—	—	7.1	—	—	—	—	—	—
Trout (sp.?)	—	—	—	—	—	—	—	3.7	—	15.8	—	—	—	—	—	—
White Perch	—	—	—	—	—	—	—	—	—	10.0	1.4	—	8.0	66.7	50.0	7.8
Yellow Perch	5.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Unidentified	33.7	20.2	61.7	1.8	4.2	22.2	—	14.8	—	14.3	4.1	13.5	22.0	33.3	—	2.6
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

low frequency of anchovy (21.5%) from the Galesville area is probably explained by the fact that approximately 60% of the fishes in the stomachs could not be identified because of decay due to inadequate preservation; hence it is probable that anchovies were actually fed upon in larger quantities than shown. Menhaden was found at Galesville and at Solomons in greater abundance than at Rock Hall, while herrings were present only in the latter locality. Blue crabs had been eaten in the vicinity of Solomons while mud crabs were present in stomachs taken at Rock Hall and Galesville.

Fall. No material was collected from the fresh-water area during this season, and samples from Galesville, Potomac River, and Tilghman Island were limited. However, comparisons can be made between the Rock Hall and Solomons Island areas. Again anchovy was dominant, with menhaden numerous (35.3%) at Rock Hall and rather scarce at Solomons Island (7.4%). At Solomons and Tilghman the croaker was present, but it was absent from the Rock Hall samples. The number of species of forage fish was greater at Solomons than in the other areas (Table IV). A similarity between the Rock Hall and Solomons areas was found in the presence of mud crabs, but they were absent from other regions during this period. The fish at Solomons apparently fed to a greater extent on invertebrates than those in other areas.

Winter. During this season, material was collected from Rock Hall, Tilghman and Hooper Islands, and the James River. The only area in which anchovy appeared as food was the James River, but even there it was not the dominant form (Table V). Although menhaden was a principal food at Rock Hall (27.2%) and was prominent also in the James River (16%), in both of these areas a great variety of forage fish was utilized and their combined frequency of occurrence exceeded that of menhaden. During December, croaker and spot were particularly abundant in stomachs of bass taken in deep water off Tilghman and Hooper Islands. The young of these commercially important fish were also present in Rock Hall samples but in the James River only small numbers of spot were found. White perch was found at Rock Hall and the James River in about equal quantities. The James River material showed the greatest variety of fish species and a larger quantity of blue crabs. Crabs were present, but in lesser amount, in samples from Hooper Island.

Spring. The collection of stomachs during the spring was limited except for the lower James River, where anchovy was found with about the same frequency as menhaden and herrings. The trend of feeding upon a great variety of fish and invertebrate species observed in winter continued on into spring, but it was only in the spring samples that the small croaker appeared as an item of food.

VARIATION IN NUMBER OF FULL AND EMPTY STOMACHS

Although the percentages of empty and full stomachs examined throughout the year were nearly equal (44.2 to 55.8% respectively) there was considerable variation among the samples. When the data were grouped according to the method of capture (Table VI), fish taken with gill nets, fyke nets, and hook and line showed the highest numbers of full stomachs, varying from about 65 to 80%,

TABLE VI. Variations with Gear in the Number of Feeding Striped Bass, as Shown by Full and Empty Stomachs in Samples Where Method of Capture Was Known in Chesapeake Bay, 1936–37

Gear	*Number*			*Percentage*	
	Full	*Empty*	*Total*	*Full*	*Empty*
Gill Net	218	55	273	79.9	20.1
Fyke Net	87	29	116	75.0	25.0
Hook and Line	274	151	425	64.5	35.5
Haul Seine	10	14	24	41.7	58.3
Pound Net	298	437	735	40.5	59.5
Total	887	686	1573	56.4	43.6

while the numbers of feeding fish taken with haul seines and pound nets were lower, about 41%. On a seasonal basis, about 50% of the stomachs were full during the summer-fall period, about 70% during winter and spring.

DISCUSSION

The data show regional and seasonal variation in the food composition of striped bass in Chesapeake Bay as well as a variation in the intensity of feeding by region and season. Although the samples were obtained from eight localities, there are two main contrasting areas: the waters at the Head of the Bay, which are entirely fresh, and the remaining seven localities, which are salt and brackish.

The Conowingo Dam, impassable to the ascent of fish, impounds the Susquehanna River and thus forms a large lake, and all types of food found in samples from below this dam are typical fresh-water organisms. Most striking was the occurrence of large quantities of *Leptodora* in samples collected during July, August, and September. It seems reasonable to assume that these typical lake crustaceans floated down from the lake through the turbine gates of the dam. Many of the food fishes found in the Conowingo samples were of small size, due apparently to the generally smaller size of the striped bass themselves. Most of the samples from this region were donated by sportsmen, and a large number of them consisted of bass smaller than the lower legal size limit of 11 inches. Observations on the stomach contents from this fresh-water area disclosed the absence of young herrings and shad, although these forms were taken there by seine in August 1936. The greater portion of the stomach contents of the samples taken at the Head of the Bay (Table III) consisted of bait, the small bass undoubtedly nibbling bait from many hooks before being captured. Also, since a large number of anglers fish at the Conowingo Dam during the summer months, it is probable that discarded bait, consisting of nonindigenous bloodworms, shrimp, and fish, contributes to the diet of young bass. Merriman (1937: 33) has pointed out that bloodworms and sandworms constitute part of the food for bass in Connecticut waters.

The hydrographic conditions of the seven other regions generally are similar. Salinities range from about 9–20 $^{\circ}/_{\circ\circ}$, the James River, located near the entrance to Chesapeake Bay, probably having the highest salinity of any area sampled. Most of the forage fish found in the James River samples were also found elsewhere in the Bay, but not all of them were observed at the same place during any one season. The food in brackish water was distinctly different from that at the Head of the Bay.

It is of interest to note that exotic food species were not found in any of the areas sampled. No brackish water species were taken in the samples from the Head of the Bay, despite the fact that they are known to occur in abundance within 20 miles of the Conowingo Dam, nor were any typical fresh-water species found in samples from brackish waters. These two observations point either to an extremely rapid rate of digestion or to a slow rate of migration between fresh and brackish waters.

During summer and fall, the most common types of food in the salt-water areas of Chesapeake Bay were anchovy and menhaden, ranging from 33 to 100% in occurrence. Field observations indicated that the anchovy was abundant in Chesapeake Bay during 1936. In practically every Maryland tidal river, from the Chester to the Potomac, thousands of sea gulls were observed flying near the surface in places where bass were pursuing anchovy for food. Haddaway (1930: 8) described this phenomenon for the season of 1930, and it probably occurs every year; in particular areas the feeding activity of sea gulls serves as an indicator to fishermen in locating schools of bass.

The many schools of young menhaden seen repeatedly during the summer around the Chesapeake Bay shores suggest that this fish was abundant enough to be consumed by bass in the same quantities as anchovy. However, stomach samples indicate that this did not occur, a possible manifestation of selective feeding.

One of the fishing methods employed by Maryland anglers during the summer months is that of "chumming" with grass shrimp. This type of fishing is based on the belief that larger rock prefer shrimps to the other food which is available at that time of the year. In the material for this study, only a few stomachs of fish larger than 500 mm were available, but they did not show any marked differences from those of the smaller bass which fed almost exclusively on fish.

From the end of November to about the end of April, no anchovy was found in the upper Chesapeake Bay samples, and in samples from Maryland waters during the winter months menhaden was found only occasionally in samples from Tilghman and Hooper Islands. However, these two species were frequent in stomachs of bass taken in the James River during winter and spring (December 3, 1936 to March 29, 1937). During the cooler periods of the year the spot and croaker were the most common food items for striped bass. Winter samples from the deep water off Tilghman and Hooper Islands showed that spot and croaker comprised almost 90% of the food fish occurrences. Although spring samples were limited, white perch appeared to constitute a typical early spring food in the waters of Tilghman Island and the Potomac River. During early winter in the Rock Hall area, croaker and trout were eaten in abundance along with menhaden. Other species of fish occurred rarely. Blue crabs were present in winter and spring samples from the James River and in summer samples from Solomons Island. This feeding upon crabs parallels the distribution of crabs as established by tagging studies carried on by the Chesapeake Biological Laboratory (Truitt, 1937).

There is a possibility that the seasonal movements of fish consumed by striped bass influence the migration of this species in Chesapeake Bay. Tagging experiments by Vladykov and Wallace (1937) showed that bass move from the upper to the lower Bay in the fall and from the lower to the upper Bay during the spring. The southerly migration may be due to the pursuit of migrating food forms which are leaving the upper Bay in the fall, and the return northward in the spring may be due to the pursuit of young croakers, trout, and spot that ascend the Bay at that time.

In California waters, according to Scofield (1928: 37) and Shapovalov (1936), the striped bass commonly feeds on its own young in great quantities, but in the material from Chesapeake Bay, no small striped bass were found in the stomachs of the larger fish. Also, it has been reported that California bass feed on the jellyfish, *Velella,* but no comparable food was found in the stomachs of Chesapeake fish, although medusae and ctenophores are at times extremely common in these waters.

It is of interest to compare Merriman's (1937) observations on about 150 full stomachs from the Connecticut area with those derived from the present study. The most common food items during the winter months in Chesapeake Bay, spot and croaker, are not mentioned for Connecticut. Although the croaker is seldom found that far north, the spot ranges from Massachusetts southward. It is especially interesting to note that Merriman did not find anchovy in his material, since this form, according to Bigelow and Welsh (1925: 125), is abundant around Woods Hole and southward; and as pointed out previously, it is the most typical summer food in Chesapeake Bay. Merriman listed the silverside (*Menidia menidia notata*), as one of the most common food items of striped bass in the Connecticut area. Although silversides are abundant in Chesapeake Bay, according to Hildebrand and Schroeder (1928: 187–192), only nine specimens were found in 1,736 stomachs. It appears that bass from Chesapeake Bay, although they may feed on silversides, show a preference for anchovies. Probably for the same reason, killifishes (*Fundulus*) were not found in the local striped bass even though they are extremely abundant in the area studied; two species of *Fundulus* were mentioned by Merriman as common types of food. From these facts it would seem that bass exhibit food preferences and, at least to some degree, actively seek specific foods. During the summer months menhaden was next to anchovy in importance as bass food. Menhaden was also reported by Merriman (1937) as one of the most common food items in Connecticut.

Table VII shows the number of full and empty stomachs by season. The greater part of the material, collected from June to October, was obtained by hook and line, and the stomachs from fish taken by this method of capture probably do not reflect the same ratio between full and empty stomachs that might be expected in a more random sample, since only feeding fish would be expected to bite. No doubt stomachs secured from fish taken with nets would be more representative and indicative of the normal feeding intensity. According to Table VI, fish taken by haul seines and pound nets show about the same ratio between full and empty stomachs, whereas those taken with gill and fyke nets during winter give the highest percentage of full stomachs. From these data it appears that the number of full stomachs increased to about 80% by early spring. To some extent, this observed increase in the percentage of full stomachs may reflect a slower rate of digestion during cold weather, but local fishermen have observed that during December and January the rock do feed extensively and may be taken by deep trolling. This abundant feeding during the colder period of the year, the prespawning season, may be due to the physiological demands of sexual maturation. The spawning period for bass at the Head of Chesapeake Bay is probably protracted,

TABLE VII. Variations with Season in the Number of Feeding Striped Bass as Shown by Full and Empty Stomachs

Season	*Number*			*Percentage*	
	Full	*Empty*	*Total*	*Full*	*Empty*
Summer	503	520	1023	49.2	50.8
Fall	99	90	189	52.4	47.6
Winter	324	146	470	68.9	31.1
Spring	43	11	54	79.6	20.4
Total	969	767	1736	55.8	44.2

with the major spawning starting in May and continuing on into June. During the period from June 1–6, 1936, Vlakykov collected 29 bass (205–710 mm) in pound nets at Turkey Point, Maryland, all of which were sexually ripe and some showed running spawn; of the 29 stomachs, only two contained a trace of food—a fact which suggests that mature bass do not feed heavily in the Chesapeake Bay during spawning. That bass cannot be caught in appreciable numbers with hook and line by anglers during late spring is a further indication of the partial cessation of feeding during the period of spawning. Toward the last of June angling improves, which may indicate another period of active feeding.

Although these data probably represent the trend of feeding of striped bass, observations made since the completion of the study point out some of the limitations of sampling. Two factors make it difficult to obtain representative samples: first, this species can regurgitate its food, and second, food may be more concentrated in the capturing gear than in nature. Presumably regurgitation is linked with the stress of capture, which would tend to increase the percentage of empty stomachs in a sample. On the other hand, there is a strong possibility that bass taken in pound nets, fykes, and to a more limited extent in haul seines, may gorge while in the nets just before they are landed. Although the mesh-size of pound nets is usually large enough to permit the escape of many forage fish, including anchovies and smaller menhaden, it is a matter of common observation that these species tend to concentrate in the pound pockets and remain there until the net is nearly out of the water. Presumably the forage fish behave similarly in other impounding gear. Furthermore, while impounded, bass sometimes "break," a typical concomitant of feeding. Thus it is entirely possible that the method of capture does influence the pattern of feeding as observed from stomach-content analyses. Within Chesapeake Bay proper, it would be difficult to explore this problem unless it were approached experimentally, since more than one form of gear is seldom fished at the same time and place. However, in some of the rivers, small pound-nets, stake gill-nets, and haul seines are fished in close proximity, and a comparative study of striped bass stomachs taken simultaneously in the same area by the different types of gear might be of interest.

SUMMARY

1. The present study is based on an examination of 1,736 stomachs removed from striped bass taken in Chesapeake Bay from June 1936 to April 1937. Of the stomachs studied, 55% contained food which weighed 8,945 g, or about 20 pounds.

2. The following food-groups were found in the bass stomachs: fishes, crustaceans, mollusks, polychaete worms, and fragments of algae. Undigestible materials such as sand, pebbles, pieces of glass, and fish scales were occasionally present.

3. Fish constituted the dominant food-group, amounting to 95.5% by weight of the total food content of the stomachs examined. This food-group occurred in 32 to 100% of the stomachs, depending on season and area.

4. Within the fish group, anchovy and menhaden ranked first, varying in occurrence from 55 to 100%. Spot and croaker were the next most important food fishes, varying from about 30 to 90%.

5. Next to the fish in importance were crustaceans, which ranged in occurrence from about 4 to 46% by frequency but less than 2% of the total by weight. Remaining invertebrate groups were a negligible part of the food.

6. There was a distinct seasonal variation in food composition. During the summer and fall seasons of 1936, the principal food in salt-water regions were anchovy and menhaden, while during the winter months spot and croaker were dominant. Early in the spring the most typical food was the white perch. Two species of herring were common during the spring and early summer.

7. There was a regional variation in food between fresh-water and salt-water areas. In the former, a number of fresh-water species,

including crappie, yellow perch, spottail shiner, dace, and bullhead were commonly present; there was also an abundance of *Leptodora*, a crustacean. The above species were lacking in salt-water regions, where anchovy, menhaden, spot, and croaker were the principal foods. Blue and mud crabs were present in stomachs from salt-water areas, but they were absent in samples obtained from fresh water.

8. There was a tendency toward reduction of feeding during late May and early June, a period which corresponds with the spawning period for this species.

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STUDIES OF THE STRIPED BASS, *ROCCUS SAXATILIS* (WALBAUM), WITH SPECIAL REFERENCE TO THE CHESAPEAKE BAY REGION DURING 1936–1938

BY

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INTRODUCTION

This study of the life history and habits of the striped bass or rock within Chesapeake Bay was prompted by the extremely poor catches of bass in Maryland waters from 1931 to 1934. Field collections were made from May 1936 through April 1938, and efforts were made to determine the factors that influence fluctuations in abundance.

The present account is a revision of a previous interim report submitted by the senior author on August 20, 1938 when it became

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necessary for him to terminate this study to return to his former position. In later years, certain phases of the study were completed by the junior author. Since there has always been considerable interest in these findings, they are now made available for other workers in published form.

ACKNOWLEDGMENTS

Financial responsibility for the work reported herein was assumed by the Maryland Conservation Department. Commissioners Duer, McComas and Northam, and the entire personnel of the Department offered cordial assistance throughout. Officers on the Department's fleet of vessels also helped greatly with the field work.

The Chesapeake Biological Laboratory sponsored the striped bass research program, and its Director, R. V. Truitt, and his assistant, C. L. Newcombe, gave valued advice and suggestions to further the work. Needed working space, equipment, and facilities were provided by the Laboratory. E. H. Hollis of that Laboratory, under the supervision of the senior author, made a comprehensive analysis of the food of the rock. Certain equipment was made available through the offices of Elmer Higgins, then Chief of the Division of Scientific Inquiry, U. S. Bureau of Fisheries, while R. A. Nesbit, of the same Bureau, offered valuable criticisms of the work when it was in progress. Laboratory space was provided during the winter months by the University of Maryland, and W. B. Kemp of that institution supervised the statistical treatment of the commercial fish records.

Many fish dealers and fishermen were cooperative in furthering the field work, contributing much time and effort as well as the use of their boats and fish for tagging and analysis. The following were especially helpful: Woodfield Brothers, Bernard Hallock, Noah and Warren Hazard of Galesville, Buck Richardson of Flagpond, George T. Harrison, Bane Bradshaw, Carroll Jackson and Nathan Parks of Tilghman. Harrison Woolford of Annapolis and Upshaw Stevenson of Oxford cooperated in the collection of extensive data on sport as well as commercial fishing. Commissioners W. G. Mapp of Virginia and G. B. Chalk of North Carolina helped materially with tagging operations in their respective states. The contributions of the persons and institutions named are gratefully acknowledged and appreciated.

In addition, the authors express their appreciation to Miss G. Bernier of the Department of Zoology in the University of Montreal and to Mrs. Vadim D. Vladykov, who assisted greatly in the preparation of the data, tables, and graphs.

LITERATURE,[3] DISTRIBUTION, AND SIZE

Very little previous study had been given to striped bass in Chesapeake Bay. Hildebrand and Schroeder (1928) gave some notes on the life history, the growth of young fish, and the commercial importance within this area. Pearson (1933a) first studied the migration of bass within Chesapeake Bay by tagging 408 fish which had been caught by hook and line at Annapolis, Maryland. Truitt and Vladykov (1937) presented some information on the importance of this fish as a sport species in the area, and Vladykov and Wallace (1938) studied the movement of striped bass within Chesapeake Bay, basing their results on over 1,500 fish tagged.

On the Atlantic Coast the striped bass ranges from the Gulf of St. Lawrence to Florida and the northeastern section of the Gulf of Mexico. On the Pacific Coast in 1879, and then again in 1882, a total of 435 bass yearlings was planted in San Francisco Bay, California (Mason, 1882; Scofield and Bryant, 1926). In 1899 the commercial net catch was 1,234,000 pounds, and at present it constitutes an important fishery not only in California but also in Oregon.

Striped bass are captured principally in brackish waters; however, they are also taken regularly in salt and fresh waters. Details on the distribution of this species within Chesapeake Bay are given in the section on METHODS OF FISHING.

Striped bass attain a considerable size and age, the heaviest described in the literature weighing about 125 pounds each; these were taken at Edenton, North Carolina in April 1891 (Smith, 1907). However, W. Spencer of Darlington, Maryland has informed us that his father took five bass weighing a total of 900 pounds from the Susquehanna River during the spring, about 1898. Large bass are still found within Chesapeake Bay; it has been reported that one weighing 76 pounds was taken from the Susquehanna River near Conowingo Dam in July 1934; when this fish was killed it contained 14 hooks with leaders. The world's record striped bass taken by rod and reel was caught in 1913 and weighed 73 pounds. The largest bass examined by us was a female of 36 pounds and 41½ inches taken in the Potomac River at Virginia Point on April 6, 1937; the age of this fish, as determined by scales, was between 10 and 11 years old. It is well known that striped bass can live a long time. In the authors' possession are scales[4] removed from a 20-inch fish

[3] The complete references to the literature cited in this paper will be found in the bibliography of Raney, pp. 86–95 in this volume.

[4] Made available through the courtesy of Leonard P. Schultz, Curator of Fishes, U. S. National Museum, Washington, D. C.

TABLE I. CATCHES OF STRIPED BASS IN VARIOUS STATES DURING 1935

States	*Catch (Lb)*	*Value ($)*
Chesapeake Bay		
Maryland	927,700	78,644
Virginia	374,800	39,310
Total	1,302,500	117,954
New England		
Massachusetts	5,100	537
Rhode Island	16,200	2,094
Connecticut	400	55
Total	21,700	2,686
Middle Atlantic		
New York	37,100	4,781
New Jersey	7,700	1,247
Delaware	16,700	2,207
Total	61,500	8,235
South Atlantic		
North Carolina	362,000	35,675
Pacific		
Oregon	27,800	1,890
California	502,100	41,300
Total	529,900	43,190
Grand Total	2,277,600	207,740

weighing 10 pounds which had been kept for 12 years in the New York Aquarium; another individual in the New York Aquarium lived to the age of about 23 years (Bigelow and Welsh, 1925).

ECONOMIC IMPORTANCE

The striped bass or rock is one of Maryland's most valuable fish and has been held in high esteem by the state's residents since colonial times. Its likeness is prominent on the Maryland state crest on the Great Seal. The quality of its flesh is excellent, especially when baked, and it is a good market fish, shipping well and always commanding a fair price. In the middle 1930's the wholesale price varied between 5 and 20 cents per pound depending on the season and size of fish. Table I shows that in 1935 Chesapeake Bay led all other sections of the Atlantic Coast in the catch of this species, and in 1937 and 1938 the Chesapeake produced almost 70% of the entire production of 4,250,000 pounds. In Maryland waters the striped bass fishery occupied third place in quantity for the two-year period 1935–1936; only alewives (*Pomolobus aestivalis* and *Pomolobus pseudoharengus*) and croaker (*Micropogon undulatus*) exceeded the striped bass. However, from the viewpoint of financial return the bass ranked first with an average yearly yield of $110,000 (Table II).

TABLE II. Average Yearly Catches of the Most Important Commercial Fishes in Maryland during the Two-Year Period 1935–1936

Species	*Quantity* (*Lb.*)	*Value* (*$*)
Alewives	3,799,050	44,770
Croaker	3,106,350	37,459
Rock	1,395,900	109,992
Sea Trout	1,326,800	67,539
Shad	685,100	70,096

The striped bass is an excellent sport fish on both the Atlantic and Pacific Coasts. There are many angling centers in Maryland, a large number of party boats sailing from Solomons, Rock Hall, and Tilghman. According to Truitt and Vladykov (1937), about 200,000 anglers fish annually in Chesapeake waters, and each year the Bay attracts more and more nonresident sport-fishermen, large numbers coming from Pennsylvania and the District of Columbia.

METHODS OF FISHING

Commercial Fishing

Pound Nets. This type of net, as fished in Maryland waters, typically consists of several parts: a *leader* directs fish into one of two *hearts* or *forebays*, from which the fish pass through a funnel to a *crib* or *head* or *pocket*. When the net is hauled, the funnel is closed and the fish are removed with dip nets from the crib, which is raised by pulling the bottom and part of the sidewall over the side of the fishing boat. The crib is squarish in shape, the size varying from 24x24 to 36x48 feet; its depth corresponds to the depth of water, usually from 20 to 30 feet. All sections of a pound net are held in position by wooden poles driven into the bottom; the net is weighted with chain and is lashed to the poles or fastened with pulleys. Heavy twine is used in making this gear. The size of the mesh[5] varies in different parts of the net: 2½-inch mesh or slightly smaller for the

[5] Throughout the paper, size of mesh refers to stretched mesh.

crib, 4-inch for hearts, and from 4- to 18-inch mesh in the leader. The length of the leader varies from 300 to 500 yards. The nets are usually set at right angles to the shore, and occasionally two cribs are attached to the same leader, one on each end. Of course there are several modifications of pound nets along the Atlantic Coast.

TABLE III. Monthly Variation in Striped Bass Catches Made in Two Pound Nets at Galesville, Maryland during the Eight-year Period 1930–1937; Expressed in Per Cent

Month	*Catches* Pound net A	*Catches* Pound net B
January	0.0	0.0
February	0.0	0.0
March	0.5	0.1
April	0.9	0.3
May	2.5	1.6
June	1.2	0.5
July	5.4	1.4
August	13.1	10.6
September	16.6	17.0
October	46.6	49.0
November	13.2	19.5
December	0.0	0.0
Total	100.0	100.0

The number of pound nets used in Maryland waters has fluctuated from 450 to 700 per year. In Virginia the number has been much greater, being around 2,000 in 1938. In Maryland waters no fishing with pound nets is done during the winter months from December to February. During the spring season, from about March 1st to June 10th, alewives and shad constitute the principal catch, although there are occasional good catches of large bass of 4–70 pounds around the Susquehanna flats and in the lower parts of the Potomac and Choptank Rivers. At the end of May, pound nets are overhauled and many of them are removed as the take of shad diminishes. As the so-called "fall" season gets under way fishermen then set new rigs or reset some spring nets in new localities; the chief species taken then are sea trout, *Cynoscion regalis*, and striped bass. The summer-fall season extends from about the middle of June to the end of November, and the best catches of bass are made from the middle of September to November 15th. About 50% of the yearly catch of striped bass made with pound nets in the upper Chesapeake

Bay (Table III) are taken during the month of October, single catches up to 5,000 pounds being made on occasion. The greater catches in the fall may be explained by the fact that fish are larger (see GROWTH) and that they school and begin to migrate. According to official statistics for 1931–1934, pound nets caught 41% of all striped bass taken by commercial fishermen in Maryland; during 1935 and 1936 the catch with pound nets increased to about 52%.

Gill Nets. Three modifications are used: drift, anchor, and stake nets, all of which are manufactured of fine twine. The fish are "gilled" when they run their heads through the meshes. There were from 3,500 to 4,000 gill nets of all types used in Maryland yearly from 1931–1936—a total surface of from 500,000 to 700,000 square yards. In Virginia from 5,000 to 7,000 gill nets were fished in the same period.

The drift nets are usually about 1,000 feet long and six feet deep (18 or 20 meshes in height). For winter fishing near the bottom, six-inch galvanized iron rings with one pound sand bags are attached to the bottom line and corks are used on the top line so that the net is held in an upright position. Of course the size of the mesh, varying from three to five inches, determines the size of the fish taken. The most common size used during 1936–1937 was 3½- and 3¾-inch mesh; during the winter season of 1937–1938, nets of larger mesh (5-inch) were commonly employed. Individual nets are often tied together in a "string" of two to four, these being left to drift with the tide. The season for gill netting is from about mid-December to the end of February. To the authors' knowledge, the largest catch during the period covered by this report was 4,600 pounds in a single haul with a gill net 1,000 feet long. Winter gill netting is pursued in the deeper parts of the Bay, from Barren Island to Hoppers Island Light and in the vicinity of Cove Point, Maryland. However, during the mild winters of 1936–1937 and 1937–1938, when there was no formation of ice, bass were taken with gill nets in several places in rather shallow water. During the severe winter of 1935–1936 large catches with gill nets were made under the ice around Rock Hall.

The anchor net is similar to the drift net, except that it is held stationary by several anchors. Ordinarily, a string consisting of 10 to 12 nets, each 125 feet long, is employed. In some years this method of fishing is very profitable, especially when heavy ice prevents the use of drift nets.

Stake nets are gill nets lashed to a line of poles extending out from the shore line. Individual nets are about eight feet deep and from 75 to 100 feet long; from 8–15 of these panels are fished in each string.

These nets are placed close to shore in shallow water and are fished from the end of January to the end of April. This type of net is widely used in the tributaries and upper Bay. In some years, for example 1938, the catch by this gear was particularly profitable.

Haul Seines. In Maryland waters seines as long as two miles or more were used in the past (Willis, 1882). At present the length of net employed varies from 600 to 1,800 feet, the depth from 9–11 feet, and the mesh size from three to four inches. From 400 to 500 haul seines are operated yearly in the entire Chesapeake Bay. The most profitable catches are made during the summer months when even large bass approach close to shore and are found in shallow waters. Occasionally very good catches are made by this method of fishing. During the period under consideration, the best catch to the authors' knowledge was made on July 22, 1936 at Cedar Point in the estuary of the Patuxent River, when 16,000 pounds of rock were taken in a single haul by a 240-yard seine.

Relationship between Method of Fishing and Size of Fish. Frequently there is a direct relationship between the size of fish taken and the method of fishing. Thus gill nets are clearly selective and catch bass of a size proportionate to the size of mesh employed; smaller fish pass through the meshes while large specimens are unable to enter the meshes sufficiently to be gilled.

In general, pound nets take fish ranging from four inches up to a weight of 70 pounds. Pound-netters get their largest fish in the spring, but during June some nets are filled with small bass 6–8 inches in length, occasionally to such an extent that the fishermen are forced to "bail" them out of the crib or lower the top lines to permit them to escape. By the end of August the average size of the bass taken with pound nets gradually increases. During October 1936, fish weighing 1½ to 2 pounds were taken, and during the same month in 1937 the average weight was 3 pounds. In November, at the end of the season, pound-netters again take bass of a smaller size—a pound or less. Although the size of bass taken with pound nets is variable, the bulk of the catch is composed of small and medium fish from 11 to 16 inches in length.

The haul seines catch bass of varying sizes, and large ones are often taken by this method. The quantity of smaller bass depends to some extent on the size of mesh used. In general it appears that the haul seine is selective for larger sizes, since the bulk of the catch with this gear during the period covered by this report consisted of fish over two pounds.

Sport Fishing

During the summer and fall of 1936 and 1937 exceptionally large numbers of bass were observed to be schooling throughout the Upper and Middle Chesapeake Bay. These fish were a great attraction for anglers; the principal method of fishing was by trolling, with the "Barracuda feather" considered the best lure.

A few bass can be taken with hook and line as early as April, but regular fishing begins about the end of May; the best months are September and October. During 1936 the predominant size was 1½ to 2 pounds, while in 1937 large numbers of 3- or 4-pounders were taken. In 1938 the sizes taken were still larger, but a smaller quantity was caught. Occasionally, during the summer months, sportsmen take large fish from 6 to 15 pounds around Rock Hall and Tilghman by "chumming" with live shrimp. The estuary of the Potomac River around St. George Island is famed for its large bass, which are taken by using the whole peeler crab (*Callinectes sapidus*) or spot (*Leiostomus xanthurus*) as bait; fish up to 25 and 30 pounds have been taken here by this method.

FLUCTUATIONS OF THE FISHERY

The striped bass fishery fluctuates by season and by year. The quantities of bass taken for various years in Chesapeake Bay are summarized in Table IV. The data given are from published statistics; unfortunately, figures for some years are not available because the surveys of the commercial catches were not continuous.

Maryland. An unusually large catch in Maryland waters was reported for 1925, when almost 1,500,000 pounds were taken. There is also evidence to show that exceptionally large quantities of bass were taken along the eastern shore with gill nets during the winter season of 1927–1928. At that time the fishermen of one of the eastern shore communities caught so many bass that during two weeks they deposited $90,000 in the local bank; if they received an average price of 15 cents per pound, then some 600,000 pounds of rock were taken in this period.

Unfortunately, statistical data for 1926 through 1928 are missing because no surveys were made. Both 1929 and 1930 yielded approximately 1,250,000 pounds, but from 1931 through 1934 the catches suddenly dropped and remained at a very low level, some 635,000, 434,000, 314,000, and 332,700 pounds respectively being taken. In 1935, however, the striped bass fishery commenced to improve, the yield being 927,000 pounds, almost three times as high as the catch for 1934. For 1936 the catch was at least twice as high as

TABLE IV. Yearly Quantities (Pounds) of Striped Bass Taken in Chesapeake Bay

Year	*Maryland*	*Virginia*	*Totals*
1887	1,140,000	505,000	1,645,000
1888	1,123,000	779,000	1,902,000
....	....	......	....
1890	1,366,000	529,000	1,895,000
1891	1,265,000	483,000	1,748,000
....	....	......	....
1897	935,000	576,000	1,511,000
....	....	......	....
1901	824,000	528,000	1,352,000
....	....	......	....
1904	721,000	451,000	1,172,000
....	....	......	....
1908	640,000	504,000	1,144,000
....	....	......	....
1920	1,040,000	380,000	1,420,000
....	....	......	....
1925	1,414,000	821,000	2,235,000
....	....	......	....
1929	1,292,000	290,000	1,582,000
1930	1,228,000	425,000	1,653,000
1931	635,000	481,000	1,116,000
1932	434,000	594,000	1,028,000
1933	314,000	519,000	833,000
1934	332,700	309,800	642,500
1935	927,700	374,800	1,302,500
1936	1,864,100	519,500	2,383,600
1937	2,011,300	1,004,500	3,015,800

TABLE V. Quantities of Striped Bass Taken Principally with Pound Nets by a Limited Number of Fishermen around Galesville and Rock Hall during the Nine-year Period 1929–1937

Year	*No. of men*	*No. of days fished*	*Catches (lb.)*	
			Total	*Average per man-day*
1929	3	416	4,715	294.7*
1930	7	446	7,157	16.0
1931	8	448	1,870	4.2
1932	10	504	1,100	2.2
1933	10	488	1,023	2.1
1934	9	494	1,372	2.8
1935	10	759	151,269	199.3
1936	9	766	596,470	517.6
1937	11	902	135,666	150.4

* For November only.

that for 1934. In 1937 the highest catch ever recorded for Maryland was taken—2,011,300 pounds. Production in Maryland in 1938 amounted to 1,714,000 pounds, which was only slightly less than the catch for 1936.

Fishing records of individuals also reflect the fluctuations in abundance of striped bass during 1930–1937. The average catch of pound-netters dropped from a high in 1929 to a low in the five successive years. The average catches per man-day during 1931–1934 are remarkably similar. The figures for 1936 are probably the highest records for pound nets in the whole history of the Maryland fisheries (see Tables V, VI).

TABLE VI. Yearly Catches of Striped Bass (in lb.) in Two Pound Nets at Galesville during the Eight-Year Period 1930–1937

Year	*Fisherman A*	*Fisherman B*	*Total*
1930–1934	2,834	38	2,872
1935	64,230	54,826	119,056
1936	193,957	136,750	330,707
1937	41,759	89,195	90,954

Virginia. The amount of bass caught in Maryland is usually much higher than that taken in Virginia waters. During recent years the highest catch in Virginia, 600,000 pounds, was reported for 1932, while in Maryland that year the catch was only 434,000 pounds. On the other hand, one of the highest catches in Maryland, nearly 2,000,000 pounds, was made during 1936, whereas the Virginia catch for the same year was only 520,000 pounds. Our tagging has shown some intermingling of the bass populations of Maryland and Virginia.

POPULATION STUDIES

The composition of the striped bass population was explored by analyses of the commercial catches and by studies of racial characters. Data pertaining to the age of fish are based on the length-frequencies of the fish examined (*length-class*) rather than on grouping according to age (*year-class*). The lengths of fish are expressed in inches.

Composition of Commercial Catches. In Chesapeake Bay, bass caught commercially are usually marketed in size groups called *small, medium,* and *large. Small* fish weigh from ¾ to 1¼ pounds, *medium* from 1½ to about 2 pounds, and *large* from 3 pounds up. *Small* bass range from 11 to 15 inches in length, the size that was particularly abundant within Chesapeake Bay during the season of 1936 (Fig. 1).

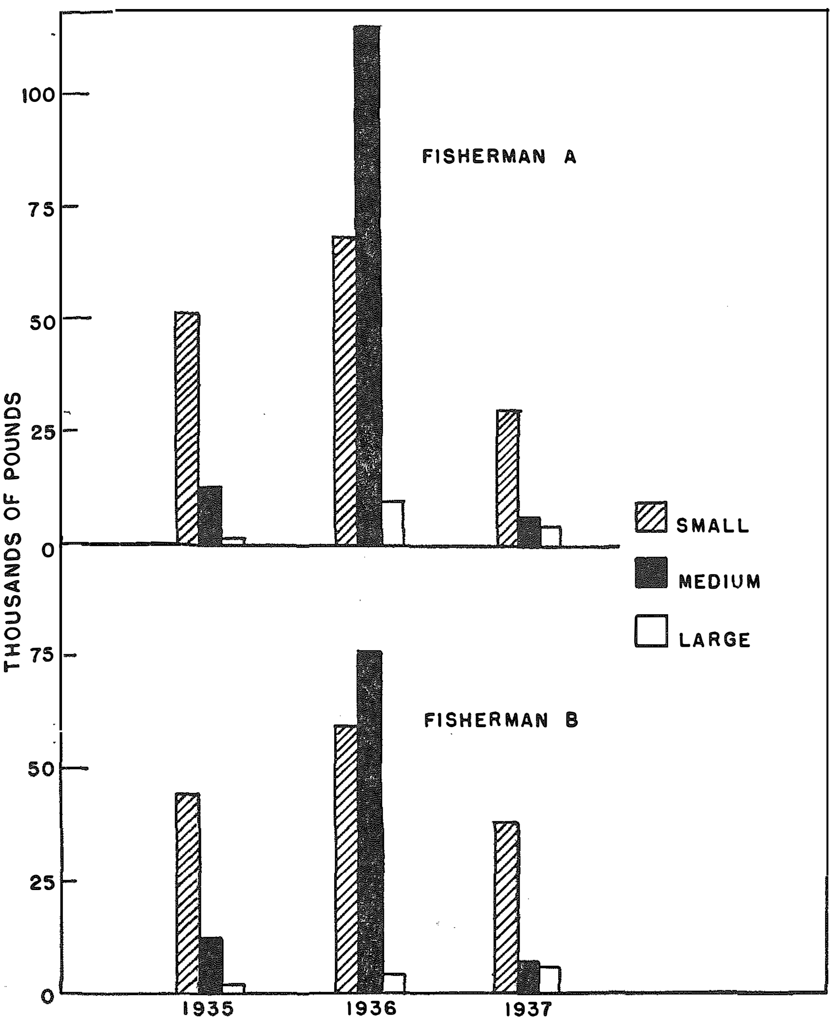

Figure 1. Yearly catch of small, medium and large striped bass by two pound-netters (A and B) at Galesville, Md., during the period 1935–1937.

Extensive fishing records for striped bass taken at Galesville have been a valuable source of information on the population in Chesapeake Bay. From Fig. 2 it is evident that the catch of bass in 1936 was almost three times as high as that in 1935 and four times that in 1937. The distribution of sizes throughout these three years was also very different (Tables VII, VIII, IX). During 1935 the

TABLE VII. MONTHLY CATCHES OF STRIPED BASS (EXPRESSED IN POUNDS) OF THREE DIFFERENT SIZES TAKEN BY TWO POUND-NET FISHERMEN (A AND B) AT GALESVILLE, MD. DURING 1935

	Small			*Medium*			*Large*			*Grand Totals*		
Month	*A*	*B*	*Total*	*A*	*B*	*Total*	*A*	*B*	*Total*	*A*	*B*	*Total*
January	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0
March	0	0	0	0	0	0	127	18	145	127	18	145
April	0	0	0	3	0	3	98	7	105	101	7	108
May	0	0	0	1	0	1	39	0	39	40	0	40
June	0	0	0	0	0	0	29	0	29	29	0	29
July	5,861	311	6,172	2	0	2	0	11	11	5,863	322	6,185
August	3,586	2,513	6,099	0	0	0	0	87	87	3,586	2,600	6,186
September	11,401	7,470	18,871	651	773	1,424	0	0	0	12,052	8,243	20,295
October	23,202	25,543	48,745	8,311	8,424	16,735	97	0	97	31,610	33,967	65,577
November	7,013	7,178	14,191	3,668	2,492	6,160	42	0	42	10,723	9,670	20,393
December	0	0	0	0	0	0	0	0	0	0	0	0
Total	51,163	43,015	94,178	12,636	11,689	24,325	432	123	555	64,231	54,827	119,058

TABLE VIII. MONTHLY CATCHES OF STRIPED BASS (IN POUNDS) OF THREE DIFFERENT SIZES TAKEN BY TWO POUND-NET FISHERMEN (A AND B) AT GALESVILLE, MD. DURING 1936.

	Small			*Medium*			*Large*			*Grand Totals*		
Month	*A*	*B*	*Total*	*A*	*B*	*Total*	*A*	*B*	*Total*	*A*	*B*	*Total*
January	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0
March	318	97	415	67	0	67	49	27	76	434	124	558
April	542	190	732	0	9	9	199	90	289	741	289	1,030
May	5,150	2,992	8,142	454	131	585	199	61	260	5,803	3,184	8,987
June	2,109	938	3,047	259	13	272	18	0	18	2,386	951	3,337
July	5,285	1,071	6,356	2,137	221	2,358	0	0	0	7,422	1,292	8,714
August	18,978	11,060	30,038	12,224	7,419	19,643	3	3	3	31,205	18,482	49,687
September	13,336	11,562	24,898	17,778	16,510	34,288	45	62	107	31,159	28,134	59,293
October	17,688	18,226	35,914	65,954	38,403	104,357	7,124	3,201	10,325	90,766	59,830	150,596
November	8,281	11,711	19,992	15,172	12,172	27,344	588	581	1,169	24,041	24,464	48,505
December	0	0	0	0	0	0	0	0	0	0	0	0
Total	71,687	57,847	129,534	114,045	74,878	188,923	8,225	4,025	12,250	193,957	136,750	330,707

TABLE IX. MONTHLY CATCHES OF STRIPED BASS (IN POUNDS) OF THREE DIFFERENT SIZES TAKEN BY TWO POUND-NET FISHERMEN (A AND B) AT GALESVILLE, MD. DURING 1937

	Small			*Medium*			*Large*			*Grand Totals*		
Month	*A*	*B*	*Total*	*A*	*B*	*Total*	*A*	*B*	*Total*	*A*	*B*	*Total*
January	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0
March	216	19	235	169	61	230	0	6	6	385	86	471
April	784	227	1,011	388	82	470	33	31	64	1,205	340	1,545
May	1,428	228	1,656	331	23	354	146	59	205	1,905	310	2,215
June	474	96	570	39	0	39	13	0	13	526	96	622
July	987	895	1,882	777	397	1,174	9	26	35	1,773	1,318	3,091
August	3,847	3,731	7,578	1,239	894	2,133	4	0	4	5,090	4,625	9,715
September	2,734	1,732	4,466	1,642	2,068	3,710	2,758	532	3,290	7,134	4,332	11,466
October	15,436	17,933	33,369	2,038	2,452	4,490	868	4,309	5,177	18,342	24,694	43,036
November	4,414	12,114	16,528	169	555	724	95	225	320	4,678	12,894	17,572
December	0	0	0	0	0	0	0	0	0	0	0	0
Total	30,320	36,975	67,295	6,792	6,532	13,324	3,926	5,188	9,114	41,038	48,695	89,733

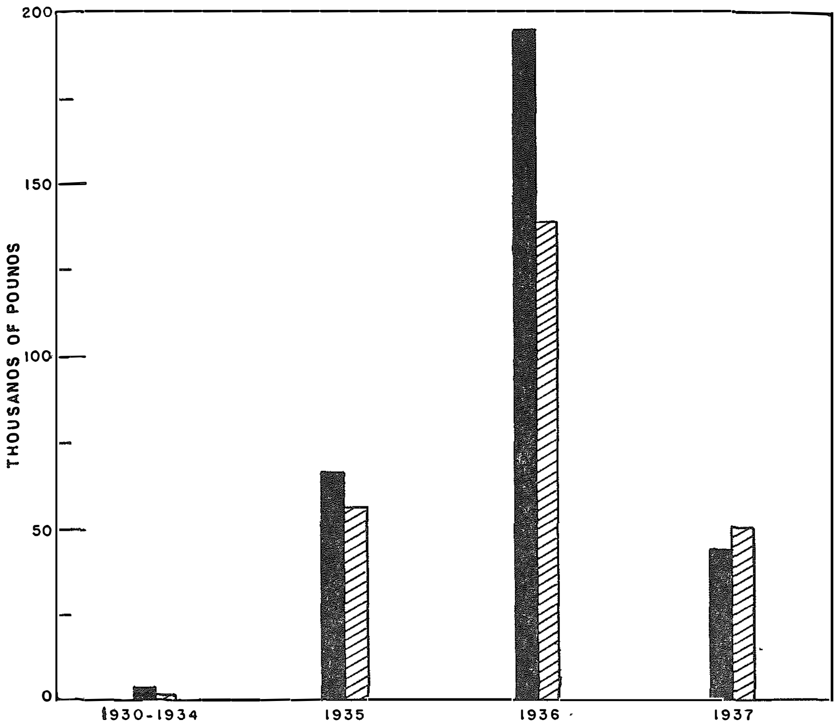

Figure 2. Catches of striped bass by two pound-netters at Galesville, Md. during 1930–1937. Black bars, Fisherman A; Hatched bars, Fisherman B.

small fish were most abundant, making up 79% of the catch, while medium fish represented only 20%. In 1936 the picture was reversed, the medium fish (57%) dominating over the small (39%) and large (4%) grades. Conditions in 1937 were quite similar to those in 1935, the main bulk of the fishery being made up of small fish (75%). The distribution of different sizes may be interpreted as follows. The decline of small fish during 1936, the increase of medium fish during the same year, and the increase of large fish in the 1937 catch suggest that these striped bass were of the same brood which entered the commercial catch as small fish in 1935, as medium grade the next year, and as large fish the year after. These observations fit with other observations that the brood of 1934 (and possibly of 1933) was responsible for the tremendous increase of bass along the entire Atlantic seaboard from Virginia to Maine (Vladykov and Wallace, 1938). In Connecticut Merriman (1937a) found that two-year-old fish (1934 brood) made up 65% of the total number of fish measured by him in 1936.

TABLE X. Relationship between the Lengths of Striped Bass and Number of Well Developed Gill Rakers on the First Branchial Arch

Locality	*Date*	*No. of fish*	*Average length (mm)*	*No. of gill rakers Total*	*Upper limb*	*Lower limb*
		Potomac River, Va.				
Colonial Beach	X/14/37	77	217.8	23.69	9.61	13.06
Colonial Beach	IX/23/37	25	254.1	23.58	9.50	13.07
		James River, Va.				
Wreck Shoal	XI/13/37	103	237.7	23.47	9.49	12.89
Newport News	III/29/37	45	370.7	23.32	9.77	12.45
		Middle Chesapeake Bay, Maryland				
Galesville	X/7/37	34	305.3	23.50	9.65	12.82
Hoopers Island	XII/11/37	94	349.5	23.48	9.57	12.94
Secretary	III/30/38	31	379.2	23.00	9.39	12.61
		North Carolina				
Croatan Sound	XII/13/37	101		23.40	9.69	12.72
Albemarle Sound	III/17/37	100	357.1	23.32	9.53	12.74

Racial Characters. In view of the fact that the striped bass fishery showed a pronounced increase over a wide area of the Atlantic Coast during 1936 and 1937, it became necessary to determine whether or not these fish had a common origin. Hence, an effort was made to determine whether or not more than one population or race existed. Counts of the vertebrae, the rays in the dorsal, anal and pectoral fins, and the number of gill-rakers on the first left branchial arch were made, since these characters may be affected by the environment (Vladykov, 1934) and may be useful in the separation of fish populations.

The results of this study showed conclusively that vertebrae, spines in the first dorsal fin, and gill-rakers are not useful characters for the determination of racial differences in striped bass. More than 2,500 specimens were examined and the number of vertebrae (including the urostyle) was found to be 25 in all except one fish, which had two fused vertebrae to make the count 24. Also, there were invariably nine spines in the first dorsal fin. The gill-rakers varied inversely with length and presumably with the age of the fish (Table X). That is, small bass had a relatively higher number of gill-rakers than larger ones; since this character apparently changes with age it does not appear to be helpful in separating races.

The number of rays in the pectoral fins and of soft rays in the second dorsal and anal fins exhibited the most pronounced regional variations (Table XI). Numerous counts were made in the field

TABLE XI. AVERAGE NUMBER OF RAYS IN DIFFERENT FINS OF STRIPED BASS FROM SEVERAL LOCALITIES

Locality	*Date*	*No. of fish*	*No. of soft rays 2nd dorsal*	*No. of soft rays anal*	*Pectoral fin*
		Season of 1936			
Susquehanna R. Region	VI/1–IX/30	346	11.87	10.95	—
Galesville, Md.	VIII/20–25	287	11.92	10.94	—
Rock Hall, Md.	VII/21–X/30	556	11.91	10.94	—
Solomons, Md.	VI/28–X/15	215	11.92	10.93	—
		Season of 1937–1938			
Galesville, Md.	X/7/37	35	11.86	10.83	16.79
Solomons, Md.	I/17/37	130	11.94	11.92	—
Choptank River, Md.	III/30/38	72	11.91	10.96	16.71
Hooper Island, Md.	XII/11/37	98	11.84	10.88	16.78
Potomac River, Va.	IX/23 37	30	11.66	10.86	16.76
" " "	X/14/37	81	11.83	10.90	16.68
" " "	X/16/37	96	—	10.87	16.63
James River, Va.	I/22/37	71	11.66	10.72	16.41
" " "	III/29/37	45	11.89	10.87	16.78
" " "	XI/13/37	103	11.77	10.82	16.75
" " "	XI/22/37	57	11.82	10.81	—
Croatan Sound, N. C.	XII/13/37	105	11.88	10.93	16.51
Albemarle Sound, N. C.	III/17/38	99	11.89	10.93	16.61

and probably these were less accurate than those made in the laboratory. Also, samples obtained during the late fall from Virginia probably contained some fish from the Upper Chesapeake Bay, which tended to obscure any racial distinction between these areas. In spite of these handicaps, however, the bass populations of Upper Chesapeake Bay, of the Potomac and James Rivers, and of North Carolina, showed certain differences in the above-mentioned characters. Upper Chesapeake bass exhibited the highest values and James River fish the smallest. A sample of 71 bass taken on January 22, 1937 in the James River had the smallest number of soft rays in the dorsal and anal fins, 11.66 and 10.72 respectively. Counts on specimens from the Potomac River and from North Carolina were intermediate between those of Upper Chesapeake Bay and the James River. Several collections from Conowingo Dam to Solomons Island showed no significant variation in the number of soft rays of either dorsal or anal fins, the counts averaging 11.91 and 10.94 respectively. On the basis of these analyses, we believe that the North Carolina striped bass represent a distinct and separate population from the fish of the Chesapeake Bay region. Within Chesapeake Bay there are probably at least three distinct schools

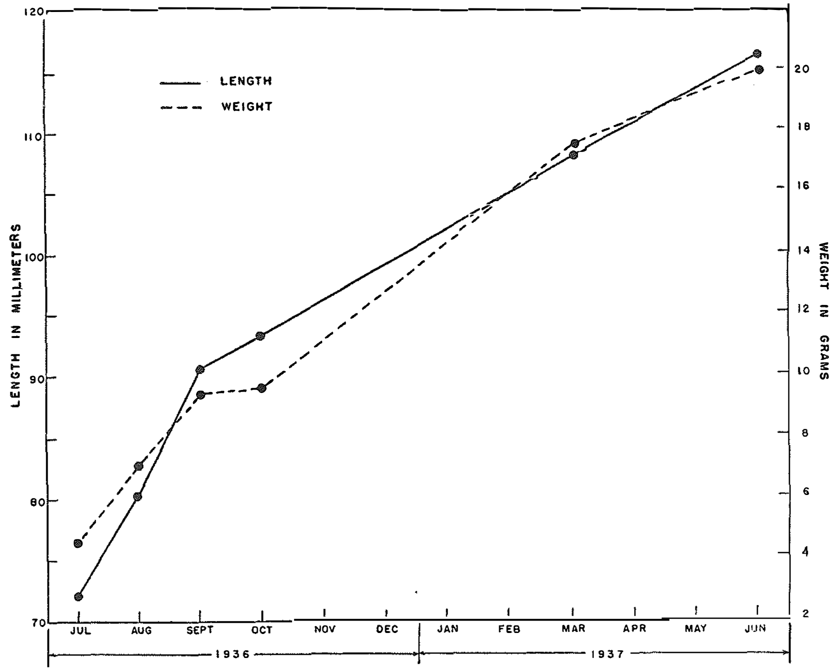

Figure 3. Growth of young striped bass hatched in 1936 during the period 1936–1937.

or races: one is found during the summer months from Conowingo to the Patuxent River, the *Upper Chesapeake school;* another population originates in the *Potomac;* and the third population is in the *James River.* Tagging experiments lend support to these conclusions (see MIGRATIONS).

GROWTH

Available information shows that the growth rate of striped bass in Chesapeake Bay differs from that reported previously for fish from other regions. The following records are based on an examination of 13,174 specimens collected in Maryland (10,360), Virginia (2,056) and North Carolina (758).

Chesapeake Bay. Since it is desirable to ascertain the rate of growth for all sizes from the fry to the largest, efforts were made to collect all sizes, but the youngest juveniles obtained were already about 2½ months old. Data bearing on the rate of growth of juvenile striped bass are based on 150 specimens of less than one year of age, these having been collected throughout 1936 and 1937 in the regions

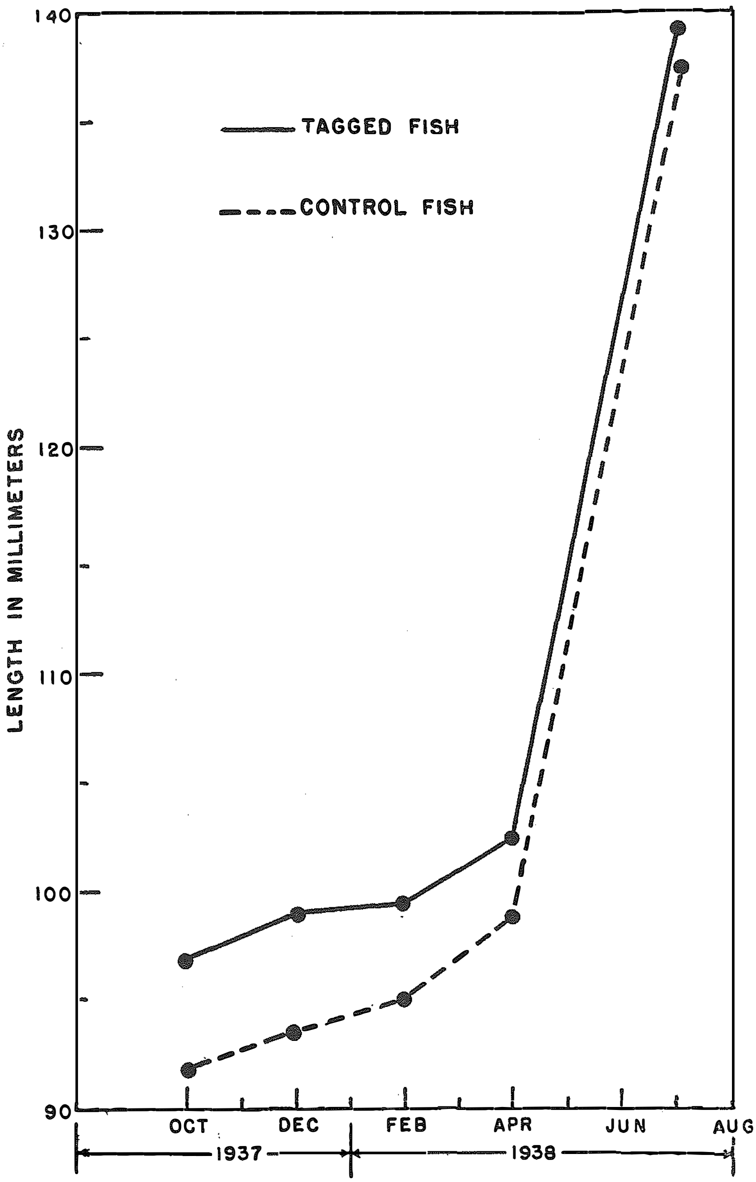

Figure 4. Comparative growth of two lots of young striped bass kept in an experimental tank during the period October 9, 1937–July 7, 1938.

TABLE XII. LENGTH-FREQUENCIES OF STRIPED BASS IN THE MIDDLE CHESAPEAKE BAY FROM AUGUST 1936 TO MARCH 1938, EXPRESSED IN PER CENT

Length-Class	*1936*					*1937*					*1938*
(in.)	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*Mar.*	*Oct.*	*Dec.*	*Mar.*
10–11.9	61.2	17.3	14.5	11.1	5.4	9.2	16.3	0	38.7	1.5	15.5
12–13.9	35.6	51.3	47.1	50.0	66.4	76.2	59.3	24.3	26.0	40.9	12.7
14–15.9	2.8	27.5	33.6	29.2	25.9	13.1	23.6	54.5	8.8	18.2	11.3
16–17.9	.3	3.4	4.1	7.2	2.1	1.5	.8	18.2	16.3	24.8	25.4
18–19.9	.1	.5	.3	2.0	.1	0	0	3.0	9.4	13.1	29.5
20–21.9	0	0	.3	.5	.1	0	0	0	.8	1.5	2.8
22–23.9	0	0	.1	0	0	0	0	0	0	0	1.4
24–25.9	0	0	0	0	0	0	0	0	0	0	1.4
Total No. of Fish	893	1,452	2,976	888	730	130	123	33	783	198	71

of Rock Hall, Tilghman Island, and Solomons, Maryland. It appears that fish hatched in April and May attain a total length of about 72 mm (4.5 g) by July and of about 92 mm (9.5 g) by fall; thus they double their weight during the period from November 1936 through February 1937; in view of the low temperatures of the bottom waters in which bass live during winter (3.55°–6°C), it is not likely that an appreciable amount of growth takes place during this season.

TABLE XIII. Average Seasonal Variations in Weight of Striped Bass of Both Sexes Taken in the Middle Chesapeake Bay during 1936 and 1937

Average weight (g)

Length	*August, 1936*		*December, 1936*		*February, 1937*	
(in.)	*Weight*	*No.*	*Weight*	*No.*	*Weight*	*No.*
9	169.0	29	0	0	0	0
10	204.0	53	0	0	0	0
11	268.0	3	325.0	15	360.6	20
12	352.0	18	406.0	31	446.0	34
13	399.0	13	443.0	41	580.0	39
14	465.0	29	643.0	10	677.0	22
15	550.0	7	850.0	4	874.0	7
16	0	0	950.0	1	1,056.0	1

In order to obtain further information on the rate of growth of juveniles, two lots of fish, eight in each, were held under laboratory conditions in an experimental tank containing brackish water from October 1937 to July 1938. These fish were taken at the end of September 1937 in the Chester River, and one lot was marked with celluloid tags. Fig. 4 shows that there was practically no increase in size from October to February inclusive, that growth was resumed in April and was rapid during the period from April 20 to July 7. There was no appreciable difference in the rate of growth of the two lots of fish.

Assuming that the peak of hatching in Chesapeake Bay occurs during May, it appears that striped bass at the end of the first year (at the end of the second May) reach an average length of 110 mm (about 4 in.). By the beginning of the second winter (age 1½ years) these fish probably average about 227 mm (9 in.). Two specimens hatched in 1935 and taken on March 19, 1937 at Tilghman Island were 185 and 213 mm long and weighed 75 and 126.6 g, respectively.

Further information on growth is limited to fish over 11 inches measured to the posterior end of the caudal fin. Measurements indicate that fish increase rapidly in length during summer and early fall, cease growing during late fall and winter, and commence to

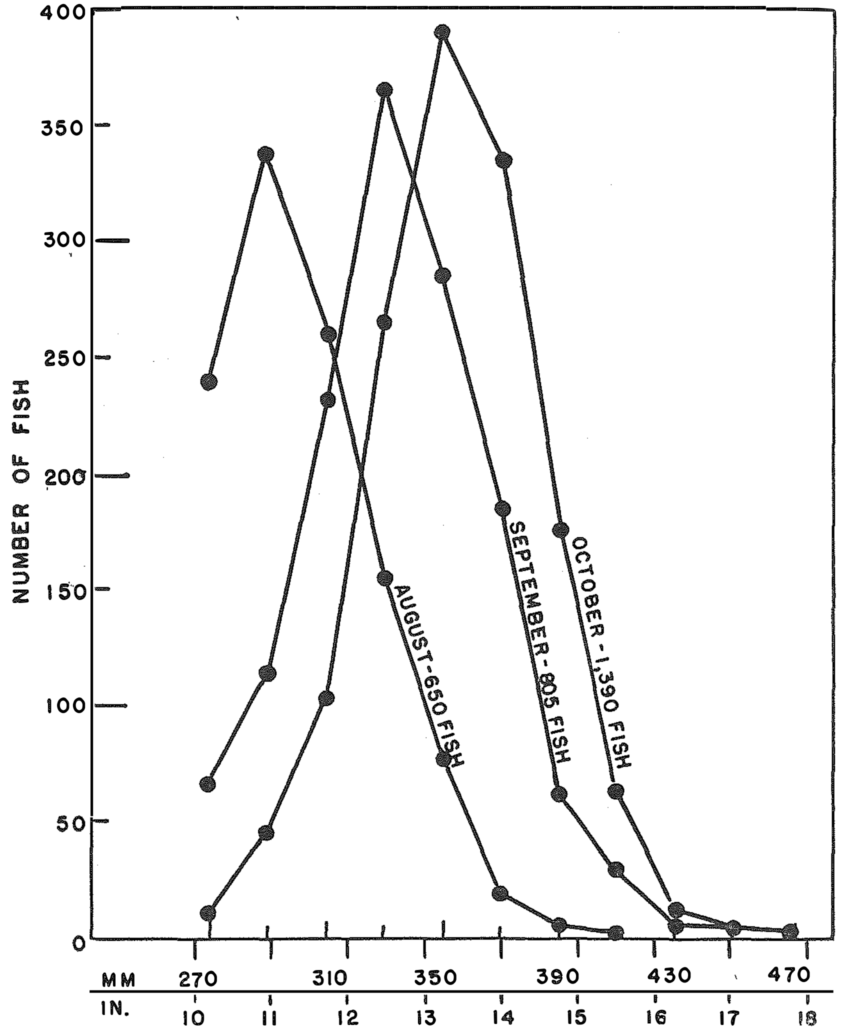

Figure 5. Monthly increase in length of striped bass as shown by analysis of commercial catches in upper Chesapeake Bay during 1936.

grow again the following spring (Table XII). In August 1936 the group from 10 to 11.9 inches (1934 year-brood) composed 61.2% of the population. By September 1936 these fish had grown so that the dominant group was 12–13.9 inches (Table XII, Fig. 5). During late fall and winter the population did not increase in length,

TABLE XIV. Large Striped Bass, Weighing More than Three Pounds, Taken with Pound Nets Near Galesville, Md. during the Seven-Year Period 1930–1936

Year	*No. of days fished*	*No. of fish*	*Total weight (lb.)*	*Average weight (lb.)*	*No. of fish per hundred man-days*
1930	446	37	329.5	8.91	8.3
1931	448	65	607	9.34	14.5
1932	524	45	154	3.42	8.6
1933	488	67	396	5.91	13.7
1934	494	55	365.5	6.65	11.1
1935	759	63	568	9.06	8.3
1936	766	120	1,211	10.10	15.7

but by March 29, 1937 the peak in a small sample had moved up to 14–15.9 inches, which suggests the possibility of early spring growth.

It is of considerable interest that there was a marked increase in weight (Table XIII), although there was practically no increase in length during the December–February period. By the fall of

TABLE XV. Comparison of Average Weights of Large Male and Female Striped Bass Taken in Chesapeake Bay 1936–1938

	Male			*Female*			*Total*		
Length	*Weight*		*No.*	*Weight*		*No.*	*Weight*		*No.*
(in.)	*(g)*	*(lb.)*		*(g)*	*(lb.)*		*(g)*	*(lb.)*	
17–17.9	1,170	2½	9	1,260	2¾	3	1,192.5	2¾	12
18–18.9	1,335	3	18	1,300	3	5	1,327.4	3	23
19–19.9	1,477	3¼	5	1,630	3½	2	1,520.7	3½	7
20–20.9	1,830	4	2	1,600	3½	1	1,753.3	3¾	3
21–21.9	2,190	4¾	2	2,120	4¾	3	2,148.0	4¾	5
22–22.9	0	0	0	2,870	6¼	3	2,870.0	6¼	3
23–23.9	2,268	5	1	0	0	0	2,268.0	5	1
24–24.9	0	0	0	3,050	6¾	1	3,050	6¾	1
25–25.5	0	0	0	3,500	7¾	1	3,500	7¾	1
26–26.9	4,050	9	1	0	0	0	4,050	9	1
27–27.9	5,220	11½	1	4,380	9¾	2	4,660	10½	3
28–28.9	0	0	0	4,390	9¾	2	4,390	9¾	2
29–29.9	0	0	0	5,500	12	1	5,500	12	1
30–30.9	0	0	0	6,750	15	1	6,750	15	1
31–31.9	7,580	16½	1	5,800	13	3	6,245	13¾	4
32–32.9	0	0	0	0	0	0	0	0	0
33–33.9	0	0	0	0	0	0	0	0	0
34–34.9	0	0	0	0	0	0	0	0	0
35–35.9	0	0	0	8,165	18	1	8,165	18	1
....	....	....	..	....	....	..	......	....	..
41–41.9	0	0	0	16,329	36	1	16,329	36	1

1937 the dominant class was 16–17.9 inches.[5] Again the three-year-old group of fish did not grow appreciably during late fall and early winter, but by March 1938 the fish were 18–19.9 inches in length. These data indicate that striped bass 2½ years old in October increased about four inches in length by the time they were 3½ years of age. Linear growth was quite rapid from July through October but the increase in weight over the same period was relatively small.

TABLE XVI. Difference in Average Weights (Expressed in g) between Male and Female Striped Bass Taken in the Middle Chesapeake Bay during 1936 and 1937

	August 1936			*December 1936*			*February 1937*		
Length (in.)	♂	♀	*Difference*	♂	♀	*Difference*	♂	♀	*Difference*
9	168.5	171.0	− 2.5	0	0	0	0	0	0
10	207.0	202.0	+ 5.0	0	0	0	0	0	0
11	290.7	222.2	+68.5	320.0	338.0	−18.0	370.0	362.0	− 8.0
12	359.0	347.5	+11.5	415.0	400.0	+15.0	477.0	426.0	+ 51.0
13	407.0	383.0	+24.0	495.0	460.0	+35.0	590.0	556.0	+ 34.0
14	473.0	460.0	+13.0	680.0	606.0	+74.0	690.0	657.8	+ 32.2
15	546.0	560.0	−14.0	875.0	825.0	+50.0	900.0	707.0	+193.0
16	0	0	0	950.0	0	0	1,056.0	0	0

Supplementary data on the growth was afforded by tagging experiments. A specimen 12.6 inches in length, tagged at Tilghman Island on October 29, 1936, was recaptured at Flagpond, Maryland a year later, during which time it had grown 3.6 inches. Another specimen 14.2 inches long, tagged at the same time and recaptured at Lower Bank, New Jersey, had grown 4.7 inches in 418 days.

Since a Maryland law prohibits the capture of fish weighing more than 15 pounds, it was difficult to get a sufficient number of large fish for analysis. Moreover, this size group apparently occurred only in small numbers in the Bay in the period from 1930 to 1936 (Table XIV).

With regard to the length-weight relationship of striped bass from different localities, only a part of the data dealing with this subject has been analyzed (Tables XIII, XV). From this material it is evident that bass taken during the winter, particularly in February, are much heavier than those of the same length taken in August. This weight increase is apparently due to the condition of the fish, for those taken during the winter and early spring are fatter than

[5] By that time another year-class at 10–11.9 inches appeared in the commercial catches.

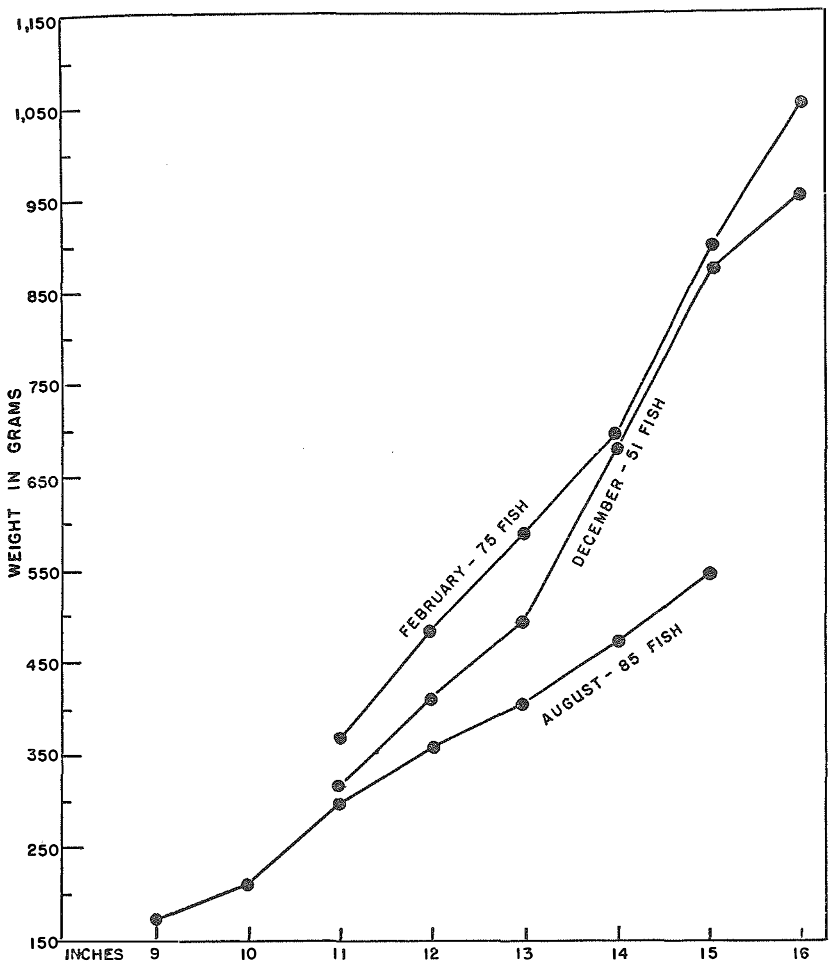

Figure 6. Monthly increase in weight of male striped bass taken in the Middle Chesapeake Bay from August 1936–February 1937.

those caught in the summer months, layers of fat being apparent in the mesenteries of the body cavity.

The variations in the weight of bass of the same sex and same length throughout several seasons are summarizrd in Table XVI and Fig. 6. Fish of both sexes, but particularly males, have more highly developed gonads during the winter, and it seems probable that the ripening of the gonads during the winter months necessitates more active feeding, with the result that fish of the same length will weigh more in winter than in summer (see also FEEDING HABITS).

TABLE XVII. REPRODUCTIVE CYCLES OF MALE STRIPED BASS IN CHESAPEAKE BAY

Date	*Locality*	*Range (mm)*	*Resting*	*Pre-spawning*	*Spawning*	*Spent*	*Total number*
June 1–6, 1936	Conowingo Dam, Md.	180–345	4	0	25	48	77
June 4, 1937	Conowingo Dam, Md.	310–440	4	4	3	7	18
June 28, 1936	Solomons, Md.	230–590	6	0	1	2	9
Total		180–590	14	4	29	57	104
July 15–17, 1936	Conowingo Dam, Md.	205–360	6	0	0	2	8
July 1–9, 1936	Solomons, Md.	225–290	10	0	0	5	15
July 21, 1936	Rock Hall, Md.	180–260	148	0	0	0	148
Total		180–360	164	0	0	7	171
Aug. 1–30, 1936	Conowingo Dam, Md.	180–270	53	0	0	0	53
Aug. 24–25, 1936	Galesville, Md.	215–375	102	0	0	0	102
Total		180–375	155	0	0	0	155
Sept. 10, 1936	Rock Hall, Md.	300–380	34	0	0	0	34
Sept. 23, 1937	Colonial Beach, Va.	180–338	79	0	0	0	79
Total		180–380	113	0	0	0	113
Oct. 29, 1936	Rock Hall, Md.	310–480	16	0	0	0	16
Oct. 18–24, 1937	Solomons, Md.	240–505	36	0	0	0	36
Oct. 14–16, 1937	Colonial Beach, Va.	190–445	93	0	0	0	93
Total		190–505	145	0	0	0	145
Nov. 11–13, 1937	James R., Va.	190–305	54	5	0	0	59
Dec. 28, 1936	Rock Hall, Md.	280–415	32	29	0	0	61
Dec. 11, 1937	Barren Is., Md.	295–440	32	25	0	0	57
Total		280–440	64	54	0	0	118
Jan. 17, 1937	Barren Is., Md.	280–430	10	77	0	0	87
Jan. 22, 1937	James R., Va.	275–515	14	30	0	0	44
Total		275–515	24	107	0	0	131
Feb. 10, 1937	Rock Hall, Md.	280–415	14	61	0	0	75
March 30, 1938	Choptank R., Md.	260–490	4	30	26	0	60
May 21, 1937	North East, Md.	222–450	0	0	0	11	11

Other Regions. In Gulf of Maine waters, according to Bigelow and Welsh (1925), young striped bass fry are two to three inches long by the autumn. For Connecticut, Merriman (1938) stated that juveniles "are 5–6 inches long in the early summer just after their first birthday." According to the same author (1937a), the two-year old fish in Connecticut averaged 28 or 29 cm (about 12 in.) long in the spring and early summer and were approximately 38 cm (about 16 in.) long by late October. Although all of our data have not been analyzed, there is evidence that striped bass in Chesapeake Bay grow slower than those in Connecticut waters. According to Scofield (1928), the rate of growth of California fish is similar to that of fish in Chesapeake Bay, and the seasonal trends are also comparable. Scofield (1931) has stated, "The period of growth extends from April until October, a duration of seven months. During the remaining period from November to March, the bass show no indications of linear growth."

SEX AND MATURITY

Internal examination of 1,211 striped bass in Maryland during 1936 and 1937 indicated that 55% of the entire population was composed of male fish (Table XVIII). A similar ratio was observed for samples taken in Virginia and North Carolina.

However, this relationship did not hold through all seasons of the year; from August through November there was approximately the same number of females and males, whereas males composed the greater part of the commercial catch through the winter and spring seasons. Males started to dominate in early December 1937; by the middle of that month they made up 58% of the catch and the increase continued until late March 1938, when males constituted 83.4% of the catch. This predominance of male fish then dropped off to establish the summer ratio in which the sexes were approximately even (Table XIX). No positive explanation was found for the excess of male striped bass in the commercial catch in late winter and spring, but it seems likely that males are attracted to the breeding grounds ahead of the females and that such concentrations make the males more susceptible to capture by the various types of fishing gear employed at that season than the far-spread females.

Gonad development in striped bass was observed through the period 1936–1938. As the striped bass ripen, the gonads become much larger. Thus the ratio of fish weight to gonad weight for males changed from 1:80 in those with resting gonads, to 1:20 at the prespawning stage, and to 1:16 at the time of spawning (Table XX). In the females the change was even more striking. Immature

TABLE XVIII. VARIATION IN NUMBERS OF MALE AND FEMALE STRIPED BASS TAKEN THROUGHOUT THE YEAR IN THE MIDDLE CHESAPEAKE BAY DURING 1936–1937

Date	*Locality*	*Range (mm)*	*No. of fish*			*Sex ratio (%)*	
			♂	♀	*Total*	♂	♀
VIII/21–XI/12/36	Galesville, Md.	200–895	117	97	214	54.6	45.4
VII/21–XII/28/36	Rock Hall, Md.	180–480	337	280	617	54.6	45.4
VI/28/36–I/17/37	Patuxent R., Md.	220–785	206	174	380	54.2	45.8
	Totals	180–895	660	541	1,211	54.5	45.5

TABLE XIX. RELATIONSHIP BETWEEN NUMBERS OF MALE AND FEMALE STRIPED BASS TAKEN THROUGHOUT THE YEAR IN NORTH CAROLINA, VIRGINIA. AND MARYLAND DURING 1936–1938

Date	*Locality*	*Range (mm)*	*No. of fish*			*Sex ratio (%)*	
			♂	♀	*Total*	♂	♀
VIII/25/36	Galesville, Md.	215–330	68	71	139	49.0	51.0
IX/23–X/16/37	Potomac R., Va.	165–445	172	177	349	49.4	50.6
XI/10–13/37	James R., Va.	185–340	59	60	119	49.6	50.4
XII/11/37	Hooper Is., Md.	295–445	57	41	98	58.0	42.0
XII/13/37	Croatan Sound, N. C.	215–455	61	43	104	58.5	41.5
XII/3/36–I/22/37	James R., Va.	275–630	45	29	74	60.8	30.2
I/17/37	Barren Is., Md.	280–430	87	41	128	68.0	32.0
III/30/38	Choptank R., Md.	260–610	60	12	72	83.4	16.8
	Totals	165–630	609	474	1,083	56.5	43.5

TABLE XX. Relationship between Body Size and Gonad Size in Male Striped Bass. Data in Averages

No.	Fish Length (mm)	Fish Weight (g)	Testis Length (mm)	Testis Width (mm)	Testis Weight (g)	Ratio Testis weight: Fish weight	Stage of maturity
12	350	613	54.7	9.0	7.6	1 : 80	Resting
16	340	550	84.4	19.4	27.1	1 : 20	Prespawning
11	442	1,461	115.0	30.7	89.9	1 : 16	Spawning

females having an average weight of 930 g (two obs.) had ovaries weighing only 6.5 g, a ratio of 1:143; however, as the females started to mature the ratio changed from 1:21 at the prespawning stage to 1:12 at spawning time. In three fish averaging 832 mm (32⅞ in.) in length and 19 pounds in weight, the ovaries weighed at least 1½ pounds. Immediately after spawning, when the ovaries were empty, the ratio was 1:80 (Table XXI).

The testes of 413 male fish examined during August, September, and October were in a resting stage (Table XXII). In November the testes had started to develop, and by January 81% of the fish were in the prespawning stage. By the end of March practically all of the males had developed milt, and about 43% had matured to the spawning stage. Although comprehensive data were not secured for April and May, it was established by field observations that the males were ready to spawn in April. Of the fish examined on spawning areas June 1–6, 1936, many of the males were not yet completely spawned out; this was also true of the females. Observations made on both males and females from the identical areas on the same date a year later indicated that spawning was about at an end; the fact that the preceding winter had been slightly milder than average may be significant. A few stragglers of both sexes in the breeding areas were still unspent in late June and July.

TABLE XXI. Relationship between Body Size and Gonad Size in Female Striped Bass. Data in Averages

No.	Fish Length (mm)	Fish Weight (g)	Ovaries Length (mm)	Ovaries Width (mm)	Ovaries Weight (g)	Ratio Ovary weight: Fish weight	Stage of maturity
17	405	930	51.2	9.9	6.5	1 : 143	Immature
4	511	1,650	72.5	19.2	28.5	1 : 58	Maturing
4	565	2,500	131.0	32.0	120.0	1 : 21	Prespawning
3	832	8,670	228.0	61.4	755.0	1 : 12	Spawning
1	785	5,897	109.0	24.0	73.9	1 : 80	Spent

The smallest mature males observed in these studies (four fish) ranged from 7¼ to 7¾ inches in length; they were taken at Conowingo Dam during the first week in June 1936 and were estimated to be two years old. The accumulated data indicate that practically all males above 10 inches in length are able to spawn. To what size male fish may grow and continue to spawn has not been established, although one spawning male was examined which measured

TABLE XXII. MONTHLY VARIATION IN STAGES OF MATURITY OF MALE STRIPED BASS IN CHESAPEAKE BAY DURING 1936–1938, EXPRESSED IN PER CENT

Month	*Stages of Maturity*				*No. of fish*
	Resting	*Prespawning*	*Spawning*	*Spent*	
June	13.5	3.9	27.9	54.7	104
July	96.0	0.0	0.0	4.0	171
August	100.0	0.0	0.0	0.0	155
September	100.0	0.0	0.0	0.0	113
October	100.0	0.0	0.0	0.0	145
November	91.5	8.5	0.0	0.0	59
December	54.3	45.7	0.0	0.0	118
January	18.5	81.5	0.0	0.0	131
February	18.5	81.5	0.0	0.0	75
March	6.6	50.0	43.4	0.0	60

34 inches in length and weighed 15½ pounds. A female 41½ inches in length, 36 pounds in weight, and 11 years old was found to be ripening.

In this study the work on gonad development in female striped bass was not as comprehensive as that on the males because of the smaller numbers in the catch; also, the females did not mature until they were of a larger size, a factor that limited the number which could be purchased with funds available. All females less than 17 inches in length which we examined had arrested gonad development. Only one 17-inch fish was found to be sexually mature. Of the 17–18-inch class of females, two of the eight examined were sexually mature, while five of the six 20–22-inch fish examined were mature. No mature females were observed among fish younger than the fourth year-class, but it is probable that females become sexually mature in their fourth year. Scofield (1931) found that 87% of the Pacific Coast females are mature in their fifth year. There is reason to believe that nearly all females in Chesapeake Bay reach maturity in the fifth year.

MIGRATIONS

In the extensive tagging operations undertaken during 1936 and 1937, the Nesbit modification of the Peterson disc was used. The tagging procedure and part of the results have already been published by Vladykov and Wallace (1938). The tagged fish were measured to the nearest half centimeter, the length was recorded on a scale envelope, and a sample of approximately ten scales was removed from the left side just below the area of tag attachment. The whole operation, performed by two men, took about a minute and did not appear to weaken the fish appreciably. The suitability of this type of tag was checked by preliminary observations on striped bass kept in laboratory tanks; also, fish recaptured several months after tagging appeared healthy. Contrary to expectations, some tags remained on the fish a surprisingly long time. Three fish from a lot tagged on November 23, 1937 in the James River were recovered over two years later. One tagged at Flagpond on October 25, 1937 was recaptured in the Choptank River on April 3, 1940. Another fish, 12¾ inches long when tagged at Tilghman on October 29, 1936 was recovered on June 3, 1939 in the Baltimore Fish Market after a period of two years and seven months. And one small bass tagged in late October 1936 at Tilghman was recovered in the Choptank River in February 1940 three years and three months after its release. This was the longest tag retention by a bass of which we have record. It is possible, of course, that some of these returns may have been the result of delays in reporting tags, but evidence from the size at recapture indicated relatively prompt return.

Exactly 3,500 fish were tagged, 483 fish in North Carolina waters and 3,017 in Chesapeake Bay. Table XXIII gives data on the size and number of fish tagged at the principal localities; in addition, the following small taggings were also made: 65 fish, June 2–3, 1937, at the head of the Chesapeake Bay about five miles south of Havre de Grace; 67 fish, October 8 to November 12, 1936, at Solomons, Maryland; six fish, August 15, 1937, at Solomons, Maryland; six fish, March 18 to April 20, 1937, off Tilghman; and four fish, April 14, 1938, in Chesapeake Bay near the mouth of Lynnhaven Bay, Virginia.

Recaptures were high, but the returns were by no means complete. Unfortunately, during the winter of 1936–1937, certain groups in Maryland advocated the prohibition of gill nets (the principal method of fishing during this season), and consequently some of the commercial netters became suspicious of these studies and were uncooperative about reporting the capture of tagged fish. Moreover, rewards were not given for the return of tags. In spite of these handicaps, the number of recaptures was sufficient to indicate in a general way the migratory peculiarities of this species; however, an analysis of fishing intensity was not possible.

For convenience in presentation, the localities of recapture are referred to general areas designated by roman numerals, as shown in Fig. 7. In certain cases the recaptures have been grouped by season rather than by individual months in the following manner: *fall,* September–November; *winter,* December–February; *spring,* March–May; and *summer*, June–August.

TABLE XXIII. Number and Size of Striped Bass Tagged in Principal Localities during 1936–1937

Length Class		*Tagging Localities*						
(*in.*)	(*mm*)	*Tilghman X/25–29/36*	*Galesville X/8–22/36*	*Flagpond X/21–26/37*	*Potomac R. X/12–16/37*	*James R. I/6 and XI/ 11–24/37*	*N. Carolina XI/15–19/37*	*Total 1936–1937*
5–10	140–259	13	2	10	281	82	68	456
10–15	260–379	449	657	290	340	199	283	2,218
15–20	380–499	50	210	174	39	52	96	621
20–25	500–619	—	2	6	2	40	29	43
25–30	620–739	—	—	2	—	1	7	10
30–35	740–859	—	—	4	—	—	—	4
Total		512	871	486	662	338	483	3,352

During the fall of 1936 and of 1937 the principal concentration of striped bass in Maryland waters (as observed by commercial fishing operations) was in Middle Chesapeake Bay around Galesville, Rock Hall, and Tilghman Island. A second center of fishing was the lower Potomac River as well as the James River between Jamestown Island and Newport News. To understand the movements of fish in these important areas tagging experiments were undertaken.

Middle Chesapeake Bay. Two large lots of fish were tagged in Maryland waters. In the first lot 1,383 bass were tagged: 512 at Tilghman Island on the eastern shore from October 25–29, 1936, and 871 off Galesville on the western shore from October 8–22, 1936. The second lot of 486 fish was tagged about 30 miles south of Galesville, at Flagpond, from October 21-26, 1937. In these experiments bass caught in pound nets were transferred to a large tank half full of water on the boat. The tagging was then done en route from one net to another, and the fish were released immediately. Most of the tagged fish were of the 1934 brood.

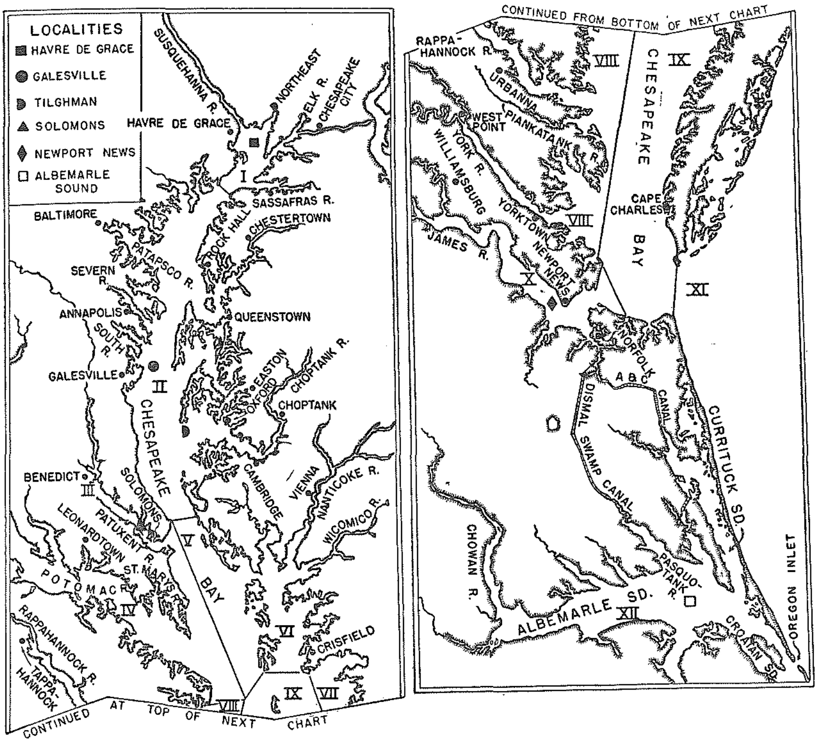

Figure 7.

All returns from tagging done in the Galesville, Flagpond, and Tilghman areas from October 1936 to April 1940 are summarized in Table XXIV (see also Fig. 7). The individual data on these taggings are given in Tables XXV–XXVIII. It is evident that the returns of bass tagged at these localities are essentially the same. Fish tagged in Middle Chesapeake Bay remained during the late summer and fall months in the localities where they had been released. For example, one fish tagged at Galesville on October 13 was recaptured locally five times during the period from October 17 to November 11, 1936; another fish tagged on October 12 was recaptured six times in nearby waters from October 14 to November 3, 1936.

About the end of October the bass from all three tagging localities started to move southward. The Galesville and Flagpond fish moved principally along the western shore, and apparently they were joined by the Tilghman bass from the eastern shore, since six Tilghman fish were taken at Flagpond November 11–19, 1936, while

TABLE XXIV. Recaptures of Upper Chesapeake Bay Striped Bass by Principal Regions during the Period October 1936–April 1940

No.	*Area of recaptures Name of subdivision*	*Season of recaptures*	*Tagging localities*		
			Tilghman	*Galesville*	*Flagpond*
I	Sassafras River at Turkey Pt.	Spring	4	5	—
II	Baltimore	Fall-Spring	8	27	1
	Galesville	Fall-Spring	9	289	6
	Choptank River	Fall-Spring	25	15	10
III	Patuxent River, above Solomons	Winter-Spring	—	4	2
IV	Estuary of Potomac River	Fall-Spring	1	15	4
	Potomac River above Mundy Pt.	Spring	8	15	3
V	Barren Island, Hooper Is. Light	Winter-Spring	11	9	5
VI	Fishing Bay and Tangier Sound	Spring	6*	8	2
	Nanticoke and Wicomico Rivers	Winter-Spring	9	14	—
VII	Pocomoke Sound	Spring	3	5	1
	Smiths Pt.–Windmill Pt.	Fall	2	6	7
VIII	Rappahannock-Piankatank River	Winter-Spring	1	5	2
	Mobjack Bay	Spring	1	1	1
X	James River	Winter-Spring	4	18	

* One fish recaptured during July 1938.

two more were recaptured with Galesville bass farther south off the Rappahanock River on November 17, 1936. It appears that bass do not move swiftly in their southward migration in the Bay, since there were definite concentrations of tagged fish around the mouths of large rivers for periods of one to three weeks. The first Galesville fish were taken at the mouth of the Potomac River on November 3 and another 10 tags were obtained from bass in this vicinity by November 24, 1936. On December 7, 1936 the first Galesville fish were taken in the James River; tagged fish from the Tilghman school appeared here one week later. During the winters of 1936–1937 and 1937–1938, several tagged fish from the three localities were

TABLE XXV. REGIONAL RECAPTURES DURING 1936–1940 OF BASS TAGGED IN DIFFERENT LOCALITIES

Area of recapture	*Tilghman (512)**	*Galesville (871)**	*Flagpond (486)**	*Potomac R. (662)**	*James R. (338)**	*N. Carolina (483)**	*Total (3,352)**
	Number of recaptures of fish tagged in localities						
I	4	5	—	—	—	—	9
II	61	380	41	1	—	—	483
III	—	5	6	—	—	—	11
IV	9	30	7	109	1	—	156
V	12	11	5	—	—	—	28
VI	15	22	2	—	—	—	39
VII	3	5	1	—	—	—	9
VIII	4	12	10	2	—	—	28
IX	—	2	—	—	—	—	2
X	4	18	—	—	77	—	99
XI	11	13	4	2	—	1	31
XII	—	—	—	—	1	123	124
Fish Market	5	13	5	5	5	13	46
Total	128	516	81	119	84	137	1,065
Percentage	24.8	59.2	16.7	18.0	24.8	38.4	31.9

* Figures in brackets refer to number of fish tagged in respective localities.

TABLE XXVI. REGIONAL RECAPTURES IN DIFFERENT YEARS OF BASS TAGGED AT GALESVILLE, MARYLAND

Area of recapture	*Year of recaptures*					
	1936	*1937*	*1938*	*1939*	*1940*	*Total*
I	—	5	—	—	—	5
II	344	32	—	—	4	380
III	1	4	—	—	—	5
IV	12	17	—	1	—	30
V	—	8	—	—	3	11
VI	—	22	—	—	—	22
VII	—	5	—	—	—	5
VIII	6	6	—	—	—	12
IX	—	2	—	—	—	2
X	8	8	—	1	1	18
XI	—	12	1	—	—	13
Fish Markets	6	7	—	—	—	13
Total	377	128	1	2	8	516
Percentage	73.0	24.8	0.2	0.4	1.6	100.0

TABLE XXVII. Regional Recaptures in Different Years of Bass Tagged at Flagpond, Maryland

Area of recapture	*Year of recaptures* 1937	1938	1939	1940	*Total*
II	21	17	2	1	41
III	3	3	—	—	6
IV	2	4	2	—	7
V	—	5	—	—	5
VI	—	2	—	—	2
VII	—	1	—	—	1
VIII	8	1	1	—	10
XI	—	1	3	—	4
Fish Markets	—	4	1	—	5
Total	34	38	8	1	81
Percentage	42.0	47.0	10.0	1.0	100.0

caught with gill nets in the deeper water between Barren Island and Hooper Island Light. Some tags from the deeper waters of large rivers such as the Choptank, Patuxent, Potomac, and James were also turned in; the temperatures of bottom waters here were probably warmer than those in more saline regions.

From February to April numerous bass were taken with stake gill nets close to shore. During the spring months, the fish from the three tagging localities mentioned above showed a tendency to con-

TABLE XXVIII. Regional Recaptures in Different Years of Bass Tagged at Tilghman, Maryland

Area of recapture	*Year of recaptures* 1936	1937	1938	1939	1940	*Total*
I	—	4	—	—	—	4
II	36	22	—	2	1	61
III	—	—	—	—	—	
IV	—	8	—	1	—	9
V	3	7	1	—	1	12
VI	—	14	1	—	—	15
VII	—	3	—	—	—	3
VIII	3	1	—	—	—	4
IX	—	—	—	—	—	
X	3	1	—	—	—	4
XI	—	10	1	—	—	11
Fish Markets	2	2	—	1	—	5
Total	47	72	3	4	2	128
Percentage	36.8	56.2	2.3	3.1	1.6	100.0

gregate in areas of low salinity or even fresh water, these shallow places probably warming up more rapidly than the Bay. There is also the possibility that abundance of food was responsible for the concentration of bass in these areas at this season. However, the chief reason for such a congregation is probably associated with spawning, and it seems likely that these areas may be the approaches to spawning grounds, although present knowledge does not permit definite conclusions. The concentration of fish in the James River was such as to lead to eight tag returns in February. A similar concentration was noticeable in Tangier Sound (Fishing Bay, Nanticoke, and Wicomico Rivers) during February and was even more conspicuous during March. Another concentration, greater than that in Tangier Sound, was observed at this time in the upper part of the Potomac River, where 26 tags were recovered in the area of Port Tobacco Creek and Maryland Point (upper part of Area IV, not shown on map). These results agree with earlier tagging experiments by Pearson (1933). During the spring months several tagged fish were also recaptured in the upper portion of Area II. Some marked fish were taken in the Choptank River, others apparently while they were en route to the Susquehanna River; eight fish were caught around the Sassafras River and one was recovered at Turkey Point (Area I). The Choptank and Susquehanna Rivers would thus appear to be spawning grounds for bass tagged at the Galesville, Flagpond and Tilghman areas in Middle Chesapeake Bay.

In the hope of gaining information concerning the length of time spent by rock on these spawning grounds and their migratory pattern after spawning, 65 fish were tagged on June 2–3, 1937 off Spesutie Island in Area I. But only four tags were recovered, two in the spring of 1938 in the same area and two from Rock Hall in July 1937 and June 1938. The Spesutie Island tagging seems to indicate that some bass, after spawning in the area of the Susquehanna Flats in the Upper Chesapeake, move to the same feeding grounds which are frequented by the Galesville and Tilghman fish (Area II). It is quite possible that some fish from the principal tagging areas may spawn in other rivers, and it seems likely that schools which visit the summer feeding grounds around Tilghman, Rock Hall, and Galesville[6] may be rather heterogeneous. This tentative explanation may explain why fish tagged in the Middle Bay were recovered in so many different localities.

Some additional tagging is highly desirable to settle this problem.

[6] Flagpond is not regarded as an important summer feeding ground. The fishery there is profitable only during the spring and fall months, as it is located in the migration path of the Galesville fish up and and down the Bay.

Only one difference in the migrations of fish tagged at Galesville and Flagpond was apparent—no Flagpond tags were returned from the James River. The Tilghman fish differ from the two other groups in that they were not recaptured in the Patuxent River. However, since these differences are insignificant, the bass tagged in the three localities can be considered as members of the same population. Further evidence of this is found in the fact that bass from the whole Upper and Middle Chesapeake, from Conowingo to the Patuxent River, exhibit the same number of fin rays (see *Racial Characters*).

TABLE XXIX. Regional Recaptures in Different Years of Striped Bass Tagged in The Potomac River

Area of recapture	*Year of recaptures* 1937	1938	1939	1940	*Total*
II	—	1	—	—	1
IV	79	25	4	1	109
VIII	1	1	—	—	2
XI	1	1	—	—	2
Fish Markets	3	2	—	—	5
Total	84	30	4	1	119
Percentage	70.6	25.2	3.4	0.8	100.0

The concentration of tag returns in the spring of 1937 from the upper Potomac River indicated the likelihood of a mixture of Chesapeake and Potomac River fish. In order to better understand this relationship, 662 fish of varying sizes were tagged October 12–16, 1937 off Colonial Beach, Virginia. The tagging was done at this season because returns from the previous year's tagging indicated that the Chesapeake fish would still be absent from the Potomac. Of the fish marked, 51.5% were of the 1935 brood, 43.5% were of the 1936 brood, and the remaining 5.0% were of the 1934 brood as well as older broods. In spite of the variety in sizes, the Potomac bass exhibited a remarkable uniformity of movement. Of 119 returns, only five fish, or 4.2% of the total recaptures, were taken outside the Potomac River.

Details of this experiment are presented in Table XXIX and may be summarized as follows. During October 1937, 50 fish were recaptured in the area of release, and in November an additional 25 bass were recovered there, the last bass caught in this area being taken on December 3, 1937. From the beginning of December to March there was no commercial fishing in the Potomac River, since the use of gill nets was prohibited by law and since stormy weather and ice made the operation of pound nets impossible; therefore, no more tags were recovered until spring. During March and April 1938, five fish were taken, again in the Colonial Beach area. At the same time, nine other Potomac fish were recaptured in the upper section of the river between Riverside and Indian Head. In this section of the Potomac (Port Tobacco Creek and Maryland Point) several bass from the Middle Chesapeake Bay tagging were recovered in the spring of 1937, 1938, and 1939. This would indicate that a mixed population of Chesapeake fish, as well as local Potomac stock, migrate to the spawning grounds further up the river where there is little fishing. Following the completion of spawning, the local population returns to its summer feeding grounds, and from July to November 1938, tags from nine Potomac rock were recovered in the Colonial Beach area. The last recaptures in the area of original release in the Potomac were made in November 1939, when four fish were taken.

Since only a small portion of the Potomac fish emigrated from the river, it appears that many of the Potomac bass spend the entire year in this river and do not make extensive migrations. Some of these apparently undertook a coastal migration, since two Potomac tagged fish were recaptured along the Atlantic Coast. Others reported from outside the river were: one from the mouth of the Potomac, one between Smith and Windmill Points, and another off the mouth of the Rappahannock, all during the period from November 8–14, 1937; two were taken at the mouth of the Potomac in April 1938. Thus it appears that Potomac bass are relatively stationary. The few recaptures of fish tagged originally at Colonial Beach from outside the river need not necessarily be considered contradictory, for bass from Middle Chesapeake Bay visit the Potomac River every year, and it is quite possible that some of the tagged fish were from this migratory stock.

Lower Chesapeake Bay. In the James River off Rescue, Virginia, 42 fish taken in fyke nets were tagged on January 6, 1937, and some 296 fish, taken in pound nets, were tagged from November 11–24, 1937. The recaptures are treated as a single unit (Table XXX).

Two recaptures, one from each tagging, were exceptions to the normal migratory pattern. One was the recapture of a 12½-inch bass (released January 6) at Liverpool Point, Maryland in the upper Potomac River on April 13, 1937. This fish was taken in a section of the Potomac River where numerous recaptures of both Middle Bay and Potomac fish were made in the spring months, and it may

TABLE XXX. Regional Recaptures in Different Years of Striped Bass Tagged in the James River, Virginia

Area of recapture	*Year of recaptures* 1937	1938	1939	1940	*Total*
IV	1	—	—	—	1
X	48	19	5	5	77
XII	1	—	—	—	1
Fish Markets	—	5	—	—	5
Total	50	24	5	5	84
Percentage	59.5	28.5	6.0	6.0	100.0

have been a Middle Chesapeake migrant; indeed other tagging experiments showed Middle Chesapeake fish in the James River in midwinter. The other was an unusual recapture of a James River fish (tagged in November) in Albemarle Sound, North Carolina. Outside of recoveries from fish markets, all other tags came from the James River—91.5% of all the returns. The results of the James River tagging showed clearly that this stock is even more stationary than that of the Potomac River. The relatively static nature of the bass populations from both of these rivers contrasts greatly to the active movements of bass from the Middle Chesapeake.

Outside Chesapeake Bay. Some of the bass tagged during this study migrated out of Chesapeake Bay (Table XXXI). It is evident that a limited number of fish, tagged originally at Galesville and Tilghman, migrated northward along the Atlantic Coast from February to May 1937. In June three fish were recovered in New England waters, and from July to September only one recovery was made, that being a Tilghman bass caught in Massachusetts. Merriman (1937) observed that striped bass made only limited local migrations during the summer months, and this pattern may also be typical for fish from Chesapeake Bay which move northward in the spring; it is certainly true of those stocks which remain in Chesapeake Bay.

In the fall of 1937 a southern migration along the Atlantic Coast began. On October 1 a tagged fish was taken south of Cape Cod in Buzzard's Bay, and another was recovered on October 13, 1937 from Newark, New Jersey. On October 31 another was taken in Gardiners Bay, Long Island, on November 2 one off Westerly, Rhode Island, and on November 19 still another was taken in Moriches Bay, Long Island. From December on, these coastal migrants were taken in brackish waters in various places along the coast between the Hudson River and Delaware Bay. On March 11 and May 7,

TABLE XXXI. Details of Recapture of Striped Bass Outside Chesapeake Bay

Date of tagging 1936	*Place of tagging Md.*	*Length of fish (mm)*	*Date of recapture*	*Days fish were out*	*Distance in nautical miles*	*Place of recapture*	*Method of capture*
X–14	Galesville	355	II/1/37	110	370	Toms River, N. J.	Hook and Line
X–12	Galesville	400	III/22/37	161	270	Cape May, N. J.	Drift Net
X–8	Galesville	385	IV/14/37	188	570	Pt. Judith, R. I.	Fish Trap
X–28	Tilghman	335	IV/22/37	177	300	Bowers Beach, Del.	—
X–14	Galesville	350	IV/28/37	196	570	Pt. Judith, R. I.	Fish Trap
X–19	Galesville	355	V/5/37	199	580	Connecticut R., Conn.	Drift Net
X–29	Tilghman	335	V/5/37	189	600	Newport, R. I.	Pound Net
X–29	Tilghman	295	V/5/37	189	600	Newport, R. I.	Pound Net
X–16	Galesville	355	V/10/37	206	600	Prices Neck, R. I.	Pound Net
X–28	Tilghman	285	V/11/37	195	580	Connecticut R., Conn.	Gill Net
X–28	Tilghman	205	V/24/37	208	570	Pt. Judith, R. I.	Fish Trap
X–28	Tilghman	330	V/27/37	211	600	Mt. Hope Bay, Mass.	Hook and Line
X–8	Galesville	395	VI/3/37	236	900	Cape Ann, Mass.	Fish Trap
X–19	Galesville	335	VI/4/37	224	570	Connecticut R., Conn.	Drift Net
X–14	Galesville	385	VI/30/37	258	850	Saddle Rock, Mass.	—
X–28	Tilghman	375	VIII/2/37	278	820	Barnstable Bay, Mass.	Mackerel Seine
X–21	Galesville	365	X/1/37	345	600	Buzzards Bay, Mass.	—
X–28	Tilghman	425	X/13/37	350	450	Newark, N. J.	—
X–28	Tilghman	310	X/31/37	369	435	Gardiners Bay, N. Y.	Pound Net
X–9	Galesville	340	XI/3/37	391	483	Westerly, R. I.	Drag Seine
X–13	Galesville	350	XI/29/37	413	403	Moriches Bay, L. I.	Set Net
X–29	Tilghman	360	XII/18/37	416	236	Mullica R., N. J.	—
X–29	Tilghman	385	III/11/38	499	332	Hudson R., N. Y. (Verplanck)	Gill Net
X–12	Galesville	395	V/7/38	573	326	Hudson R., N. Y. (Croton)	Stake Gill Net
1937							
X–25	Flagpond	320	IV/27/38	185	188	Ocean City, Maryland	Pound Net
X–26	Flagpond	400	II/25/39	122	261	Great Bay, N. J.	Gill Net
X–26	Flagpond	390	V/31/39	487	452	Warwick, R. I.	Hand Line
X–21	Flagpond	295	VII/7/39	625	335	Sandy Hook, N. J.	—
X–13	Potomac R.	350	XII/18/37	67	330	Bayonne, N. J.	Hook and Line
X–14	Potomac R.	400	VI/14/38	224	462	Onset Bay, Mass.	—
XI–18	*N. C.* Croatan Sd.	555	IV/22/38	156	285	Great Bay, N. J.	Gill Net

1938 two fish were recovered in the Hudson River, and it seems possible that this is a wintering ground for some of the Chesapeake migrants.

In general the bass tagged in 1937 within Chesapeake Bay showed the same migratory pattern as those marked in 1936; the first fish from the 1936 tagging that was recaptured outside the Bay was taken in Toms River, New Jersey on February 1, 1937, 110 days after release; the earliest outside recapture from 1937 tagging was on December 18, 1937 off Bayonne Light, New Jersey, 67 days after release. These dates seem to indicate that the outward migration is a continuation of the down-Bay migration in late fall.

It seems clear that bass from Middle Chesapeake Bay tend to undertake more distant migrations than those from the Potomac or James Rivers. Of 1,869 fish tagged during 1936 and 1937 in the Middle Chesapeake, 28 (1.5%) were recaptured along the Atlantic; on the other hand, only two (0.3%) of the 662 bass marked in the Potomac were taken outside of the Bay; and on the basis of two tagging experiments in 1937, the James River population did not contribute at all to the stragglers along the Atlantic north of the Chesapeake area.

The above percentage estimates of Chesapeake migrants to northern waters are based on the *total* number of fish tagged. Actually, at any given period from 1936–1938, the ratio between the number of outside recoveries and the tagged fish in the water at that time was higher. Bass did not start to leave Chesapeake Bay until late fall, when the number of tagged fish had been considerably reduced by intensive fall fisheries; perhaps as much as half of the tagged fish were removed during the fall and winter fisheries within the Bay, thus making the percentage of outside recaptures higher. However, even under these conditions the quantity of stragglers along the Atlantic would only amount to about 30 fish out of every 1000. This would result in only a small reduction in the total number of individuals in the Bay, but it does contribute materially to the stocks of fish found to the north of the Chesapeake Bay.

Judging by lengths, no fish under two years of age migrated out of Chesapeake Bay. Among 30 fish recaptured along the Atlantic, the smallest was 205 mm or 2½ years old when tagged and released; it was recaptured almost seven months later at Point Judith, Rhode Island. Merriman's (1937) data have indicated that there may be a differential migration by sexes, with a predominance of females in northern populations. The data for Chesapeake Bay show a decrease in the percentage of females after the down-Bay migration had taken place in the fall.

During November 1937, 483 fish were tagged in North Carolina as follows: November 15, Popular Branch, Currituck Sound, 179 fish, caught with a haul seine; November 17–18, Manns Harbor, Croatan Sound, 298 fish, taken with pound nets; November 16 and 19, Kitty Hawk in the Atlantic Ocean, six fish (19–26 in.), taken with a haul seine. A total of 123 tags, or 90% of all of the recaptures, came from North Carolina, and another 13 tags, recovered from various fish markets, were no doubt taken also from fish caught in local waters. Only one fish tagged in Croatan Sound was caught outside of the state—at Leeds Point, New Jersey. Judging by these results, the contribution of the North Carolina stock to northern waters does not seem to be extensive. However, from tagging results by Merriman (1937a) it seems that there may be more interrelation between the bass populations of North Carolina and northern waters than these tagging experiments showed, especially since most of the fish tagged by us in November 1937 were below 20 inches and were subjected to an intensive fishery immediately after their release. None of the North Carolina fish tagged during this investigation were recovered in Chesapeake Bay, and no Upper Chesapeake or Potomac fish were found in North Carolina waters. One James River fish, 20 inches long when tagged, was taken on December 18, 1937 in Albemarle Sound off the Alligator River. This bass was caught 24 days after release, and the geography of the area as well as the brief time interval between tagging and recapture suggest that it reached Albemarle Sound through one of the branches of the Albemarle and Chesapeake Canal rather than by the Atlantic.

The results of tagging experiments within Chesapeake and North Carolina waters show that each of these areas maintains its own bass populations, which, as a rule, do not intermingle. Both areas are self-supporting. North Carolina, Virginia, and Maryland have the most productive fisheries for striped bass on the Atlantic Coast. During certain years some Chesapeake and North Carolina bass may vacate their respective native waters and undertake northward coastal migrations. These stragglers from the southern stocks probably add to the fisheries in the more northern states during years of great abundance, but the usual striped bass catch to the north represents only a fraction of the quantity taken in either Chesapeake Bay or North Carolina.

DISCUSSION AND SUMMARY

A study of the history of the fishery for striped bass in Chesapeake Bay reveals that the abundance of this species has fluctuated widely over the years. Unfortunately, records of the commercial catch in past years have given no indication of the annual size composition. However, observations over the limited period of this study show that the size composition was not the same from year to year, and that, in periods of abundance, most of the fish comprising the catch were of a single year-class. Growth studies show that the 1934 year-class entered the commercial fishery in Chesapeake Bay a little over a year after hatching and that it was dominant through 1938. Precisely what caused the appearance of such an outstanding year-class is not known, but it can be stated definitely that factors of the natural environment, not human efforts, were responsible. Despite the intensive fishery for striped bass in Chesapeake Bay, a highly favorable combination of numerous factors, such as the conditions for spawning, development, and feeding, were such as to produce this successful or dominant year-class.

In 1934, when this prominent year-class was born, the smallest catch of striped bass ever reported for Chesapeake Bay was made, and the catch in 1933 was almost as small. In fact, the entire four year period from 1931–1934 was extremely low. Thus all the evidence points to the fact that the highly successful 1934 brood was produced when the adult spawning stock was low. This span of poor years (1931–1934) separates 1930 and 1935, years of relatively good catches. An analysis of the Galesville pound net records (Table V) reveals interesting details pertinent to the period under discussion. During the period from 1930–1936, two year-classes of large fish dominated the catch—one during 1930 and 1931 consisting of relatively old fish weighing an average of 8.91 and 9.34 pounds respectively, and the other, probably the 1929 brood, which averaged 3.4 pounds in 1932. The 1929 year-class reached a weight of 6.7 pounds in 1934, and a certain number of the 1929 brood were captured even as late as 1935 and 1936. Probably the main bulk of the 1934 brood was derived from the eggs deposited by 1929 fish. Judging from the low catch for 1934 and from certain private fishing records, it seems quite certain that the number of spawners of both sexes was not higher in 1934 than it was in 1933 or 1932. In short, relatively small numbers of mature fish produced an unusually large quantity of young ones. There is some indication that this phenomenon occurs in other fishes, for instance the mackerel (*Scomber scombrus*), about which Bigelow and Welsh (1925) wrote: "Study of the composition of the stock of fish in periods of high and low production also suggests that there is a very definite correlation between the number of adult mackerel existing in the sea at any time and the success with which they breed, years of great production always falling when fish are both scarce and average very large." The relatively large size of the striped bass spawners during 1934 was probably also a favorable factor, for this prolific species produces a greater and greater number of eggs the older it grows.

The increased catch of striped bass along the Atlantic Coast north of Chesapeake Bay was concurrent with the increased production in the Bay. However, the returns from tagged fish show that although there are seasonal migrations of the several populations within the Bay itself, most of the fish remain within the Bay.

Fluctuations in the striped bass population of Chesapeake Bay are undoubtedly caused by unusually successful broods, which, so far as the evidence goes, are not dependent on a large quantity of brood stock. This suggests that the highly successful survival of eggs deposited in any year is associated with a fairly narrow threshold of hydrographic or meteorological conditions. Even if the resulting environmental conditions were known, they could not be controlled by man to the advantage of the fishery.

The tagging experiments carried out during this study suggest that the fishing rate in Chesapeake Bay is high and that any dominant year-class is decimated rather quickly. Therefore, it seems that it would be wise to reduce the catch of small striped bass to achieve the optimal utilization of this population. Only a small percentage of the total stock of bass appears to leave the Bay; those that remain grow rapidly and would be available to the fishery for long periods.