DIVISION OF FISH AND GAME OF CALIFORNIA
FISH BULLETIN No. 29
The Striped Bass of California (Roccus lineatus) [1]

By

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[1] Some discussion has arisen of late among the systematists concerning the correctness of the specific name of the striped bass—lineatus (Bloch). An effort has been made to change the present name to Roccus saxatilis (Walbaum), which some claim originated at an earlier date. Discussion has also arisen in regard to whether the present accepted generic name is based on our own form or that of a European form of some likeness. Until the systematists can reach a mutual agreement concerning the generic name of this fish, it has been decided to refer to striped bass as Roccus lineatus.

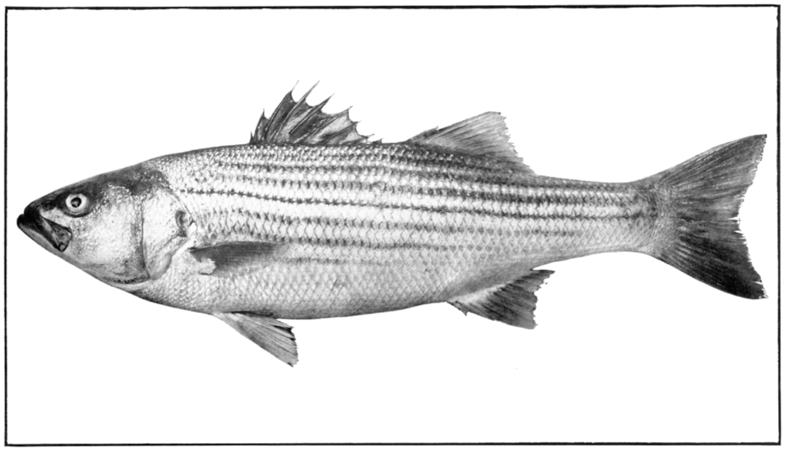

FIG. 1. The striped bass (*Roccus lineatus*).

FIG. 1. The striped bass (Roccus lineatus)

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1. INTRODUCTION

In 1879 commercial fishing was of small concern to the West; yet in this year was fostered a venture which was the pioneer of a vast new fishery which has grown to take a superior place in the interest of both commercial and sport fishermen. First in 1879 and then again in 1882 striped bass yearlings, totaling 435 in all, were planted in San Francisco Bay, California. These fish, members of the sea-bass family, Serranidae, were removed from their native waters on the Atlantic seaboard and shipped across the country in one of the early transcontinental trains. These few fish were evidently readily adapted to San Francisco Bay, for since their planting they have flourished there beyond expectation. As early as 1889, only ten years after the first plant, they were being caught in the gill nets and offered for sale in the markets. By 1895 they had formed a recognized fishery, and fishermen constructed special small-mesh nets for their capture. These commercial net men were quick to realize that a ready market awaited these new and tasty fish. During this same period the anglers began to hook these game bass and it was not long before every hook-and-line fisherman had recognized this introduced species as a new field for sport, for their gameness was discovered to be second only to the wary steelhead that migrate in and out of our coastal streams.

To illustrate the enormous and almost unbelievable increase in abundance of these fish, figures compiled by the United States Bureau of Fisheries reveal that in 1899, twenty years after their introduction, the commercial net catch alone was 1,234,000 pounds. In 1915 the greatest catch was recorded when 1,784,448 pounds were delivered to the markets. The total commercial catch continued at this high level until the close of the World War, when a general economic slump occurred throughout the country. Since then the total catch has varied between about 500,000 pounds and 1,000,000 pounds annually. [(Table 1)] .

Because the striped bass have had only fifty years of existence in this region, one might be led to believe that the annual toll of the commercial nets, as well as the increase in angling activities which are generally conceded an annual total catch of several hundred thousand pounds, will lead to the extermination of the species. The casual observer may refer to the total catch (Fig. 2) as an index to such a condition. To the contrary, however, we find the abundance of this species on the increase. A report by Craig (1928.2) bearing out this statement is based on the catch per boat over a period of years. As Craig points out, the decrease in the total catch is due to economic conditions brought about mainly by an increase in stringent conservation measures.

TABLE 1

Total Commercial Catch of Striped Bass in California for the Years 1899 to 1929

Year	Pounds	Records used
1899	1,234,000[a]	U. S. Bureau of Census
1904	1,570,000[a]	U. S. Bureau of Census
1908	1,776,000[a]	U. S. Bureau of Census
1915	1,784,448	Monthly report of dealers
1916	941,849	Monthly report of dealers
1917	1,095,856	Monthly report of dealers
1918	1,407,841	Monthly report of dealers
1919	768,934	Bureau of Commercial Fisheries of California
1920	671,747	Bureau of Commercial Fisheries of California
1921	601,614	Bureau of Commercial Fisheries of California
1922	684,198	Bureau of Commercial Fisheries of California
1923	909,573	Bureau of Commercial Fisheries of California
1924	661,777	Bureau of Commercial Fisheries of California
1925	837,773	Bureau of Commercial Fisheries of California
1926	750,801	Bureau of Commercial Fisheries of California
1927	647,594	Bureau of Commercial Fisheries of California
1928	484,113	Bureau of Commercial Fisheries of California
1929	528,981	Bureau of Commercial Fisheries of California

[a] Approximate figures.

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Total Commercial Catch of Striped Bass in California for the Years 1899 to 1929

Though the results of Craig's analysis show an increase of the striped bass from 1920 to 1928, it is not at all improbable that depletion might occur in future years. In order to prevent such an occurrence, a thorough understanding of the prime factors responsible for the yearly abundance, as well as the life history of the species, is essential. The abundance is dependent upon two factors, namely, natural and artificial conditions. Because man holds no control over the former, then the latter must be submitted to detailed study. This study may involve many problems such as commercial netting, angling, influence of obstructions such as dams and land reclamation, pollution, and others. If the fishery is doomed as a result of any or all these artificial influences, then proper regulation and conservation lie within the power of man, provided he is familiar with the life history of the species.

As the relative abundance of the striped bass has been determined by Craig, the present report deals with the next two important studies necessary in building a solid foundation upon which conservation measures may be based. These are the life history and an analysis of the commercial fishery. To simplify its comprehension, the report is divided into three sections: the first deals with a brief resume of the fishery including fishing gear and methods, the second with a detailed account of the life history of the striped bass, and the third with a study of the commercial catch including general conclusions and recommendations.

The striped bass investigation began late in 1925. From then to late in 1928, the entire program was given over to the collection of life history data, and the sampling of the commercial catch. The period from 1928 to the present time (July, 1930) has been spent in working up the available data which have culminated in the present report.

2. ACKNOWLEDGMENTS

During the course of this striped bass investigation I have become indebted to a great many friends and associates. Their assistance in gathering the material, the handling of the data, and the preparation of the manuscript, have been invaluable to me, and I wish to take this opportunity to thank them all. Certain debts, however, deserve specific mention. To Mr. N. B. Scofield, in charge of the Bureau of Commercial Fisheries of the Division of Fish and Game of California, whose farsighted policy of the conservation of our commercial fishes has been responsible for the launching of this work, I am greatly indebted, for he has given much time and thought towards the proper guidance of this investigation. I wish to thank Dr. J. O. Snyder of Stanford University, for his very kind assistance and his efforts in making it possible for me to carry on part of the work while attending that institution. I am extremely grateful to Dr. Frank W. Weymouth of the same

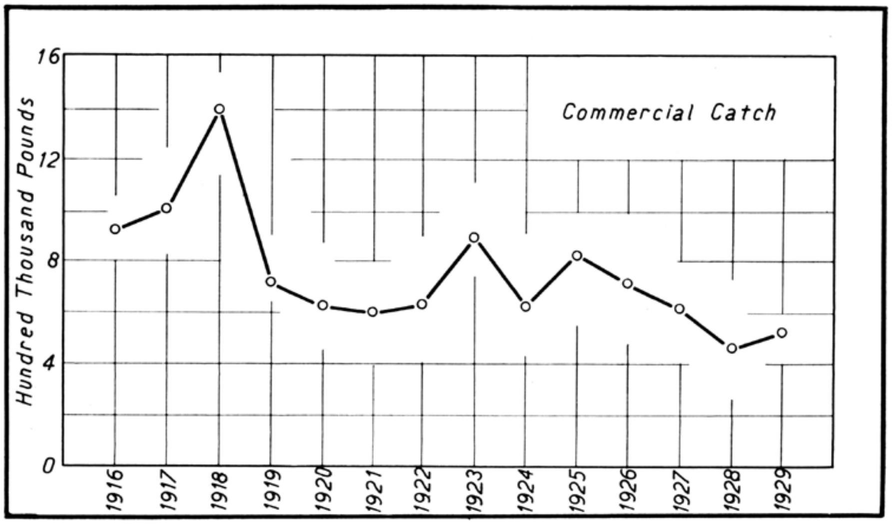

FIG. 2. The total commercial catch of striped bass since 1916. In 1918 the laws regulating the fishery were removed, thus the total catch rose very high. Since the World War, strict legislation has been enacted and the number of boats has decreased, the result being a steady drop in the commercial catch.

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institution, for his constructive criticism of certain portions of this manuscript. Mr. L. G. Van Vorhis of the Bureau of Commercial Fisheries proved invaluable to me by carrying on most of the field work during the latter part of the investigation in my absence on other duties. To Mr. W. L. Scofield, acting director of the California State Fisheries Laboratory, I am indebted for his timely advice and criticisms, which have been of great value. Dr. Frances N. Clark of the same institution, has also given considerable help since this work was first begun, as her experience in this type of work has given her a keen insight in life history studies. To all those mentioned above, as well as my wife, Marjorie Treat Scofield, I am indebteded for help in preparing this report.

A great deal of this work was carried on at the Zoology Department of Stanford University, which is headed by Dr. J. O. Snyder. The remainder of the work was done at the Hopkins Marine Station, which is directed by Dr. W. K. Fisher, and also at the California State Fisheries Laboratory, of which Mr. W. L. Scofield is in charge. Sincere thanks are extended to these three institutions and their directors for their kindness and hospitality.

The collection of material, an important part in this investigation, proved extremely successful due to the hearty support of all parties concerned. I wish particularly to thank the Bureau of Patrol of the Division of Fish and Game, since their kind cooperation made it possible to have the unlimited use of their patrol boats and nets in collecting material. Messrs. C. M. Bouton and William Armstrong (deceased) of this bureau were of great assistance, as their knowledge of the San Francisco Bay region, the rivers and sloughs, simplified the collecting to a great extent. Thanks are extended to Mr. Frank Spenger and his employees for their willingness to collect material under adverse conditions. These commercial fishermen took an intelligent interest in the work, thereby making the collection of certain material possible. I also wish to thank Messrs. Joe Grillo and Steve Belleci, commercial fishermen of Pittsburg, for their aid in collecting material.

Lastly, I wish to acknowledge the cooperation of the two main commercial fish companies at Pittsburg, the Western California Fish Company and A. Paladini, Incorporated, managed by Theodore Weissich and Frank Cardinelli, respectively. These men, because of their interest in fisheries problems, made it possible for me to secure unlimited commercial samples.

July, 1930.

3.1. PART I THE STRIPED BASS FISHERY OF CALIFORNIA

The striped bass is an excellent fresh market fish as its tasty white meat has met the favor of all Californians. The rapid development of the fishery seems startling when we consider not only the commercial catch, but the total sport catch which is probably as large as that of the commercial, though no accurate records are obtainable. On weekends and holidays thousands of admirers of this game fish rig up their rods and set out for the sloughs, bays and ocean beaches adjacent to San Francisco. Not often do they return home disappointed, for the

FIG. 3. During week-ends and holidays, sport fishermen rig up their poles and strike out for the sloughs, bays and beaches adjacent to San Francisco. Rarely do they return home disappointed, as striped bass are ever abundant. Photograph by E. C. Scofield, April, 1927.

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bass are ever abundant. Inhabitants of the inland valleys and southern areas where this species does not occur depend upon the commercial fishermen for their supply.

The total commercial catch figures since 1916 might lead one to assume that the supply is being depleted, as the catch has dropped each year since 1918, the record year, when the nets alone captured over a million pounds. (Fig. 2.) Such an assumption, however, would be false because during the late World War all legal restrictions regulating the commercial catch were removed. As a consequence the total catch mounted to unbelievable heights. After the war, restrictions were again brought into effect, and the rise of great interest in sport fishing for bass has led to more effort in increasing conservation measures. The many bass clubs which have grown up about the bay have been instrumental in promoting more stringent laws. As a result, at each session of the California State Legislature, restrictions have

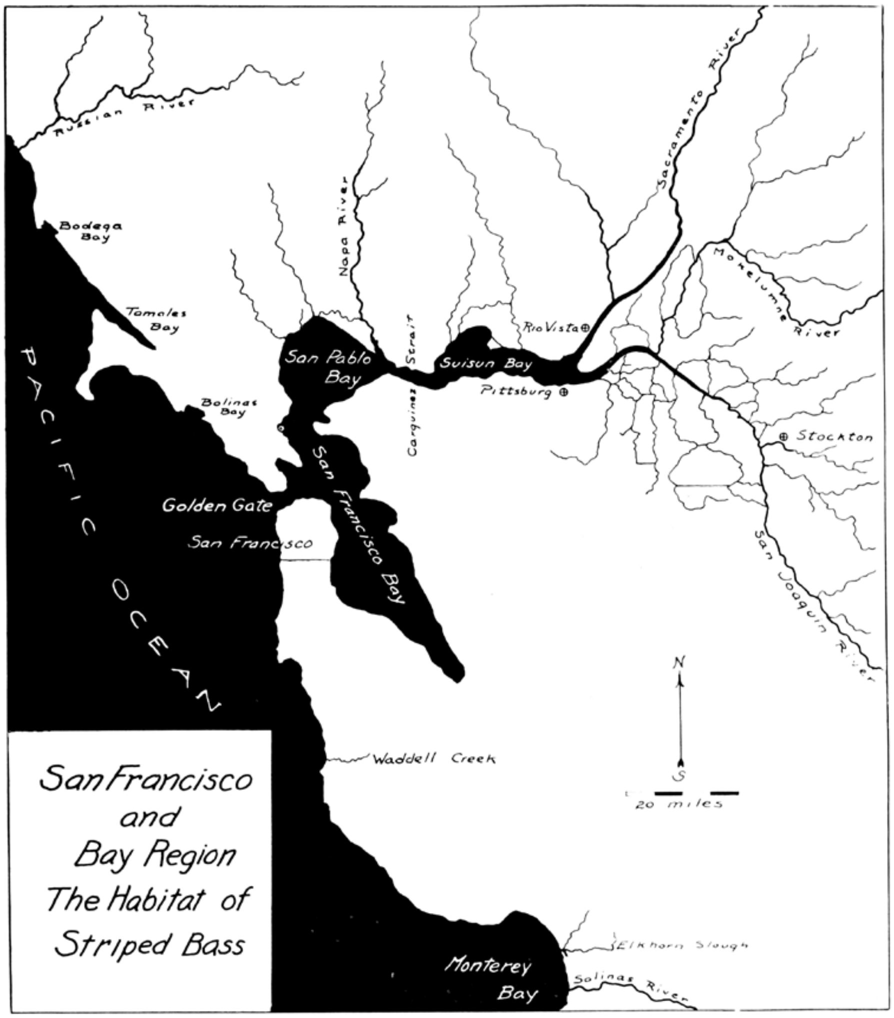

FIG. 4. Excellent hook-and-line fishing for striped bass is enjoyed as far north as the Russian River and south to Monterey Bay. The bays and sloughs inland are the main habitat of the bass. Commercial netting takes place in San Francisco, San Pablo and Suisun bays, as well as up the two large rivers—the Sacramento and San Joaquin. The numerous sloughs and flooded islands which they encircle form the main spawning grounds of these fish.

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been added, and thus many of the choicest fishing grounds for commercial fishermen have been closed in order that these areas might be reserved for sportsmen. This additional protection has therefore reduced the commercial catch from year to year, until at the present time (1930) we find only a small remnant of the once abundant group of commercial fishermen remaining to fish this species. A reduction in the number of fishermen has also been due to the depletion of the once great salmon run of the Sacramento and San Joaquin rivers, upon which all these men depended for a sizable income. Since the salmon are practically gone and the striped bass, though abundant, are so strictly protected that it no longer pays most of these men to fish for them, fishermen have left the San Francisco Bay region to pursue fisheries in other waters along the coast. The remaining fishermen have spread their interests to include the netting of other species such as catfish, shad, smelt, shrimps and anchovies. Many have opened small stores and other forms of business on a small scale in the hope of enlarging the meager income gleaned from their nets.

3.1.1. PRICE

The price of the striped bass depends upon the market conditions. At times when the markets are flooded fishermen receive as low as 10 cents a pound, and the general public can secure the same fish at retail markets for 35 cents. In periods of scarcity fishermen receive as high as 22 cents per pound, while the consumer pays 60 to 65 cents. Since this species is usually in demand during the greater part of the open season the price is fairly constant, in which case fishermen receive 12½ cents and the retailer 35 cents.

3.1.2. METHODS OF CAPTURE

The law requires that commercial netting for striped bass shall be carried on by the use of *drift gill nets* only. These nets are to be placed in the water so they may drift freely with the tide or current. The meshes are not to be less than 5½ inches when stretched. *Trammel nets, diver nets, circle* and *block nets* are legal since they are classed as *drift gill nets. Seines* and *set nets* are forbidden, and though they have been used illegally at times the efficient deputy patrol has discouraged this menacing type of violation.

As the law does not forbid a commercial fisherman from angling in the commercial fish districts and selling his catch, he sometimes takes to this mode of capturing striped bass for commercial purposes. often times this method proves of value to commercial men when their nets are being repaired or the clear water and full moon make netting useless.

3.1.3. GEAR

3.1.3.1. Surface Gill Nets

The *surface drift gill net* is most commonly used in the netting of striped bass. It is generally 250 fathoms in length and about 3½ fathoms deep. The cotton cork line, attached to the top edge of the webbing, supports a small cork every 5 feet or so. The cotton lead line bears a sufficient number of molded leads to keep the net vertical in the water. The webbing, formerly knit by hand but now almost entirely machine-made, is of the best linen twine—3-ply, numbers 40 and 20. This twine is light yet very strong and durable and can be purchased at $3.40 a pound.

3.1.3.2. Diver Nets

At times when the striped bass are running deep the fishermen submerge their nets as deeply as possible. To do this they remove many of the corks from their *surface gill net* and add a few leads on the bottom line; thus the net is caused to sink due to the excess lead weights on the bottom. As the law prevents the cork line of a net from being submerged deeper than 2 fathoms, this maximum depth is obtained by attaching buoy lines, 2 fathoms in length, every 60 feet along the net. Since these buoy lines support sizable floats, the net is buoyed up at the required depth; so the *surface gill net* becomes a *diver net*.

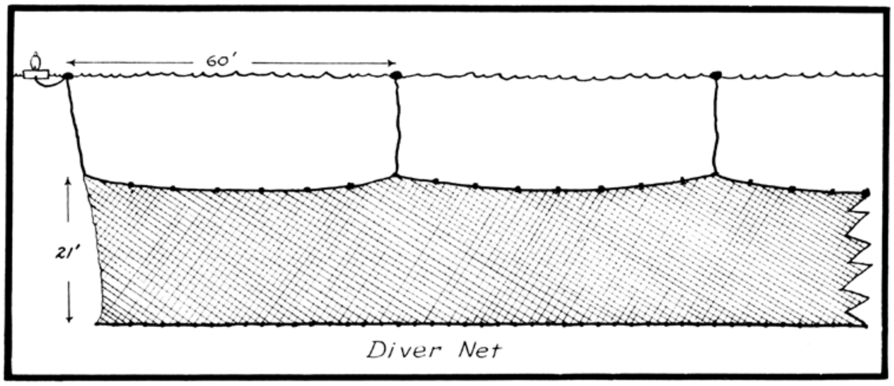

FIG. 5. Diagrammatical sketch of a diver net. This net is also used as a surface drift gill net and a semi-trammel net, depending upon the behavior of the striped bass. To float the net for use on the surface, a great many leads are removed, corks are added, and the buoy lines removed.

FIG. 5. Diagrammatical sketch of a diver net. This net is also used as a surface drift gill net and a semi-trammel net, depending upon the behavior of the striped bass. To float the net for use on the surface, a great many leads are removed, corks are added, and the buoy lines removed

The law does not prevent a *surface* or a *diver net* from extending from the surface to the bottom, yet such a net would be too bulky to handle efficiently. A deep net of this nature would also run the risk of being torn on the rugged bottom. Due to these reasons the fishermen cling to their shallow nets and add appliances which operate as successfully as a deep net. These appliances are termed "drags," for they are light rocks suspended on cords leading from the lead line. Such "drags" are attached to the nets during the colder months of the year when the bass are believed to be lying dormant in the bottom water layers. As the net drifts, the rocks drag over the bottom and the fish are frightened upward where the chance of their being gilled in the net is increased. The "drags" are often snagged, yet the light cord to which they are tied breaks readily and the net is in no way endangered.

3.1.3.3. Semi-Trammel Nets

Trammel nets, though permitted to operate in some districts, are not used for the capture of striped bass. The catches of such expensive nets have apparently not justified their use. However, fishermen have learned to use their *surface* or *diver nets* in a semi-trammel fashion. To do this they attach suspender cords every 6 feet between the lead and cork lines, and when the cords are pulled taut the webbing, because of the released weight, is permitted to sag freely. Such nets are used in the spring months when the shad are running, for they can capture the large shad as well as striped bass. The tendency of the *semitrammel nets* is to catch fish larger than a 5½-inch mesh usually does, as fish which are a little too large to gill are entangled in the loose baggy webbing.

3.1.3.4. Circle Nets

Circle gill nets are constructed so they may be operated in shallow water where the bass sometimes occur in large schools. These nets are usually 200 fathoms long and only 2 fathoms deep. Their construction is essentially the same as that of the *surface gill nets.*

3.1.3.5. Block Nets

Block nets are usually of great length, sometimes 900 fathoms long. These nets are rarely in one piece but are made up of several smaller pieces of webbing. Like the *circle nets,* they are made shallow since they are operated on mud flats which are covered with very little water. The construction of the *block nets* is quite similar to that of the *surface gill nets.*

3.1.3.6. Other Gear Used by Commercial Fishermen

Closely associated with the striped bass fishery are those of the salmon and shad. A single fisherman usually fishes all three species and is equipped with three types of nets (bass, shad and salmon). Only one type of net is used while on the fishing grounds, the fisherman's choice being regulated by the abundance of any one of the three species.

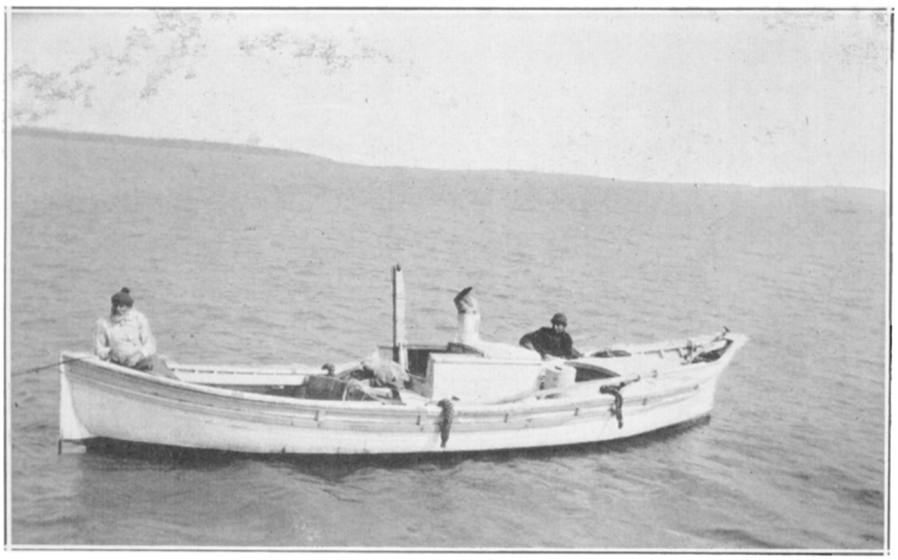

FIG. 6. A typical fishing boat used in the region above the Carquinez Strait. Note the low engine house, the forward sleeping quarters covered by a hatch and the cockpit in the stern. These men have completed laying out their drift gill net, have tied to one end of the net, and are drifting with the tide. Photograph by W. L. Scofield, September, 1926.

FIG. 6. A typical fishing boat used in the region above the Carquinez Strait. Note the low engine house, the forward sleeping quarters covered by a hatch and the cockpit in the stern. These men have completed laying out their drift gill net, have tied to one end of the net, and are drifting with the tide. Photograph by W. L. Scofield, September, 1926

The mesh of the *shad nets* ranges in size from 5½ to 6½ inches. These nets, which are constructed and handled in a manner quite similar to *striped bass nets,* are responsible for the capture of many large bass which bass nets do not take. *Salmon nets*, made of heavy webbing 6 to 9 inches to the mesh, also take some large bass. *Semi-trammel nets*, chiefly used for shad, tend to select larger bass as a rule than do the bass nets.

3.1.3.7. Boats

The strong winds in the locality above the Carquinez Strait are mainly responsible for the boats in that district being built very low and wide. The best fishing boats are perhaps 25 feet over all, with a 7-foot beam. The engine, a 1-cylinder heavy duty marine type capable of driving the craft from 6 to 7 miles per hour, is located amidships and covered by a low hatch. Located in the stern is a large cockpit in which a man can stand to lay out or pull in a net. A fish-hold with a

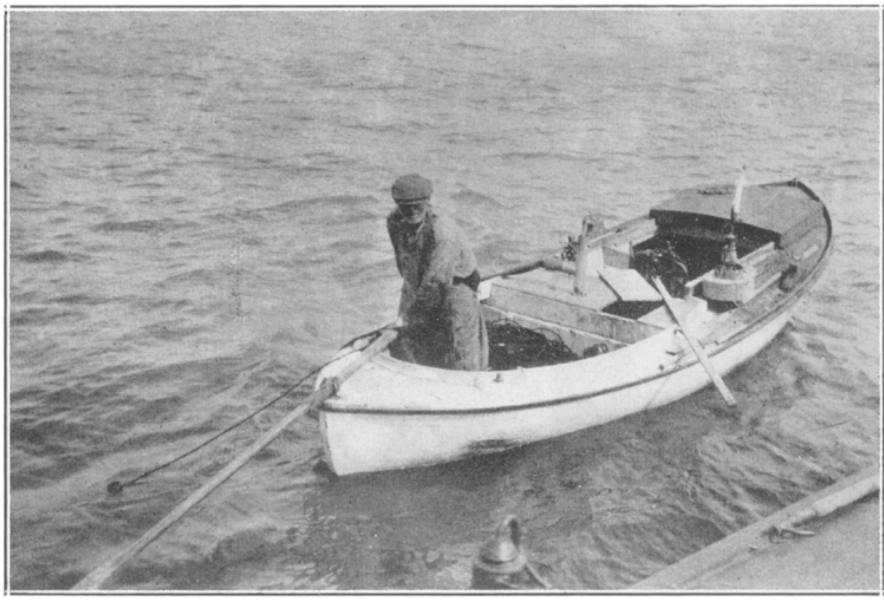

FIG. 7. Many of the fishing boats above the Carquinez Strait are not so luxurious, as is seen by the picture. These boats remain on the fishing grounds for days at a time, and to gain protection from the strong winds and cold nights the fisherman must lie in the after cockpit. Note the float and lantern on the deck which is tied on the end of the drifting net at night to warn the freight and steamer boats. Photograph by E. C. Scofield, March, 1927.

FIG. 7. Many of the fishing boats above the Carquinez Strait are not so luxurious, as is seen by the picture. These boats remain on the fishing grounds for days at a time, and to gain protection from the strong winds and cold nights the fisherman must lie in the after cockpit. Note the float and lantern on the deck which is tied on the end of the drifting net at night to warn the freight and steamer boats. Photograph by E. C. Scofield, March, 1927

capacity of about 1200 pounds lies between the cockpit and the engine. The entire forward section is decked over, allowing small sleeping quarters for two men underneath. Many of the smaller boats are not so "elegant," for their speed is perhaps 4 to 5 miles and the limited space does not allow protected sleeping quarters. The fishermen must lie in the after cockpit to gain any protection from the cold and wind.

At present there are four or five sailing craft in use in the fishing trade. These relics of fishing days of not so long ago are used by old-timers whose meager income has necessitated the reconditioning of their old style boats year after year.

Many of the recently built fishing boats are equipped to do fishing out in the ocean. During the closed fishing season in the San Francisco Bay region, many of the fishermen run their boats up the coast of California to engage in salmon trolling and other ocean fisheries. To do this they build a sturdy house over their engines and attach masts and trolling poles. A few ship their boats to San Pedro where they are converted into "jig" boats for fishing albacore, skipjack, etc. Some ship to Alaska for a few months each year to ply their trade at salmon fishing, returning in time for the striped bass and shad fisheries in the San Francisco Bay region.

In the locality below the Carquinez Strait the waters are often rough and the tides very swift. For this reason the boats in this area are built larger and made more seaworthy. They are generally 30 feet over all with an 8-foot beam. A 2-cylinder engine is placed amidships and covered by a house under which a man can stand while steering the boat. The large size of the nets *(block nets)* used require a sizable dory in which the net and fish are usually towed. The nets are generally laid out and pulled in from this dory.

3.1.4. OPERATION OF NETS

3.1.4.1. Surface, Diver and Semi-Trammel Nets

As the *surface, diver* and *semi-trammel nets* are free-floating, they are all operated in a like manner. These types of nets are only used in selected drifts or stretches of water which are fairly deep and free from snags. Such drifts are from 1 to 5 miles in length and the time

FIG. 8. A typical boat used in San Francisco and San Pablo bays for netting striped bass and other species. Note the wide beam, the house and the trailing dory. Photograph by E. C. Scofield, August, 1927.

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required to fish from one end to the other depends upon the height and speed of the tide and current.

At the upper end of a drift, one of the two men on the boat lays out the net as the other guides the craft at right angles to the current. The first end of the net to be cast into the water is buoyed up by a large float which supports a flag. At night this is replaced by a light, in accordance with regulations. These precautions warn the many freight and passenger boats which navigate through this region. Laying the net out takes from ten to twenty minutes, and once the task is accomplished the boat is made fast to one end of the cork line and the whole outfit drifts with the tide. At the end of the drift, which may take from one to three hours, the net is pulled in and the captured fish removed from the webbing. When pulling in the net the task is made easier by one man rowing the boat along the net as it is hauled in by the other. The engine is not used at this time as the risk of entangling the net in the propeller is too great. The same drift may then be repeated or the fishermen may seek another where the bass may be more abundant. During a fishing day of twenty-four hours, eight or nine of these drifts may be made, depending on the weather and the height of the tides.

3.1.4.2. Circle Nets

At times the fishermen vary their routine of drifting by occasionally running onto the mud flats at the turn of the tide and "circling" for striped bass. A keen fisherman who knows the habits of these fish is very successful at this mode of fishing. During the flood tide the bass will sometimes move upon these flats where food is more abundant and the water more calm. Here the deep drift gill nets can not be used; therefore a fisherman must employ a shallow net about 200 fathoms long. Once he detects a submerged school of bass, he runs his boat at slow speed around the entire school, and as he comes to the point where his boat lies between the bass and the direction of the tide, his partner begins casting the net which eventually comes to rest on or very close to the bottom. The boat slowly encircles the entire school again, until the whole net is paid out and the fish are trapped. The encircling of the school apparently causes the fish to cease movement, for the net when laid out completely surrounds the milling fish. The end of the net to be laid out last is brought within the circle before it is cast, thus the only opening through which the fish might escape is between the two ends. (Fig. 10). The action of overlapping the two ends is somewhat on the order of a trap, and the frightened fish going at right angles to the net

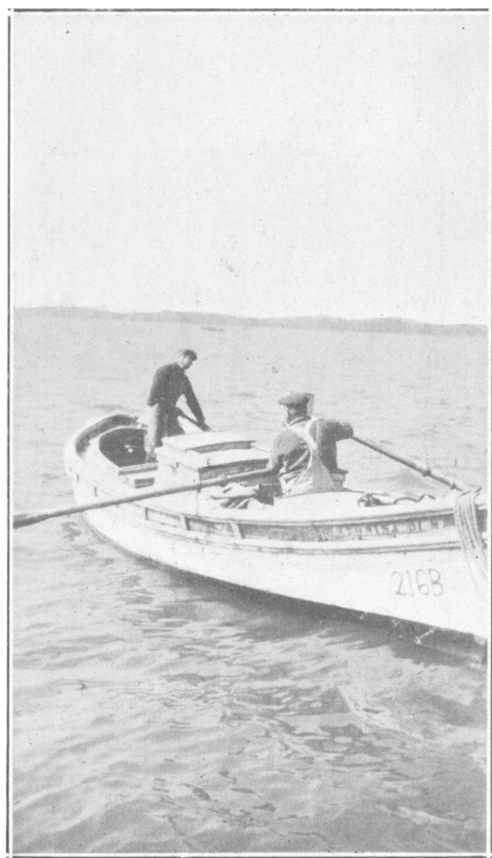

FIG. 9. At the end of a drift the fishermen pull in their nets, then repeat or try another drift. Note that the boat is rowed to relieve the labor of pulling in. The oarsman stands in the forward sleeping quarters after the hatch has been removed. Photograph by W. L. Scofield, September, 1926

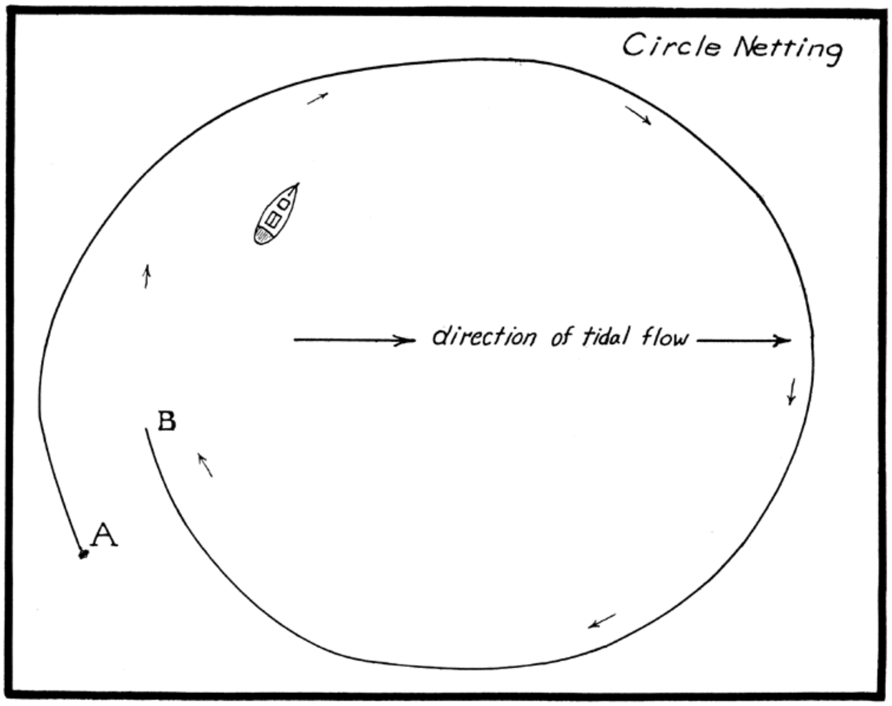

FIG. 10. The circle net is laid out in a circular fashion so as to trap an entire school of striped bass. Since the joining of the two ends is prohibited by law, the fishermen bring one end within the circle which acts as a trap. As the net is laid out slowly from left to right, as a rule, the fish are driven in that direction, thus easily missing the small opening

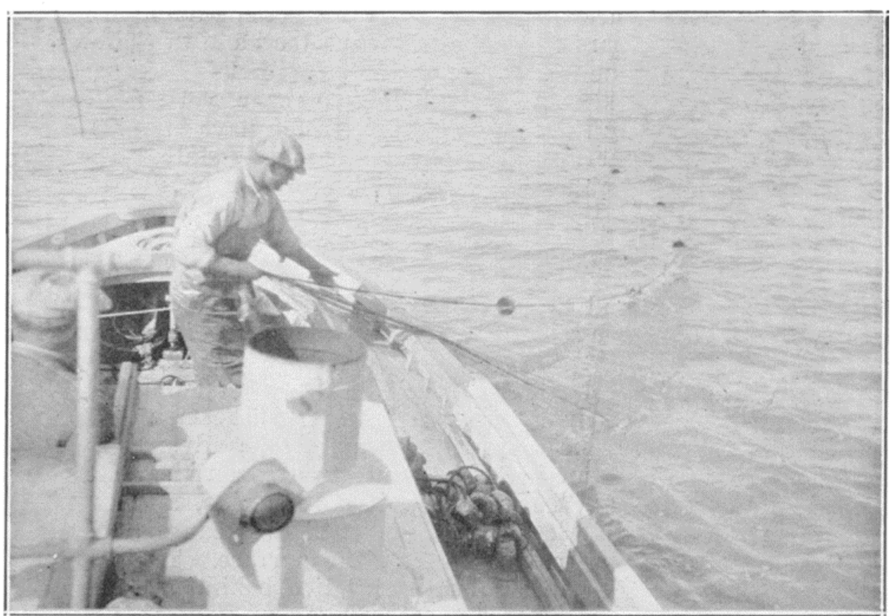

FIG. 11. Pulling in a circle net. These nets are operated on shallow flats, and a skillful fisherman is capable of detecting and encircling an entire school of striped bass at one time. Photograph by E. C. Scofield, July, 1928

would eventually gill in spite of the small opening. Fish, following the net from left to right as they often do as a result of the action of the power boat inside the net, would be very apt to pass the opening. To make quick work of their duties the fishermen will run their boat within the circle at top speed and beat the water with an oar or boat hook as the boat moves. This frightens the fish to such an extent that they scatter in all directions and some even leap clear of the surface. After several minutes of excitement during which time many bass have

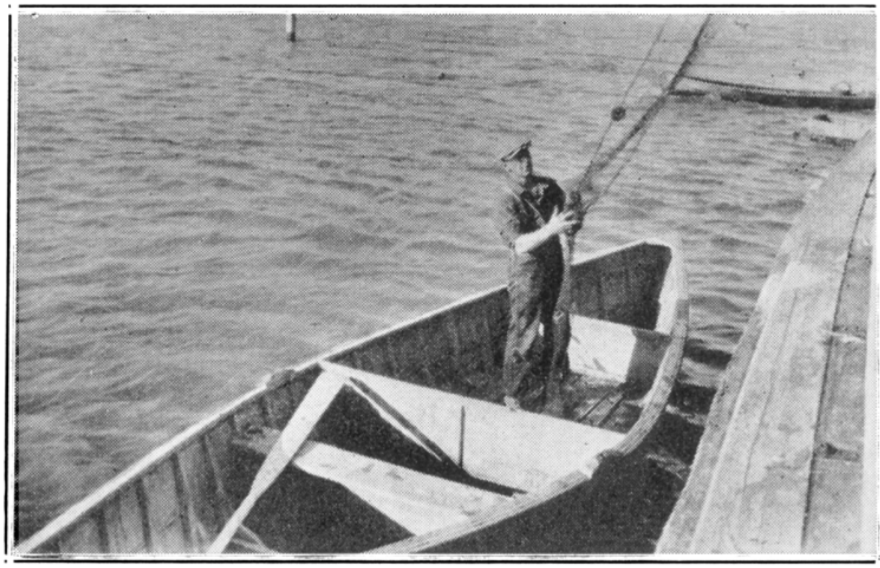

FIG. 12. The block nets, often 800 to 900 fathoms long, have to be carried in a dory which is towed behind a 30-foot launch. Because of the shallowness of the water where these nets are operated, the dory is used to lay out and pull in the nets. Photograph by E. C. Scofield, August, 1927.

FIG. 12. The block nets, often 800 to 900 fathoms long, have to be carried in a dory which is towed behind a 30-foot launch. Because of the shallowness of the water where these nets are operated, the dory is used to lay out and pull in the nets. Photograph by E. C. Scofield, August, 1927

gilled themselves, the net is pulled in. As this is done the man rowing the boat splashes his oars when the fish come too close to the opening between the boat and the free end of the net.

Many excellent catches are made in this manner, yet such catches are made so irregularly that only a few fishermen have attempted this mode of netting. Fishermen who operate these nets state that such a method takes keen judgment, skilful handling of the nets and considerable hard labor.

3.1.4.3. Block Nets

In San Francisco and San Pablo bays, *block nets* are used extensively. These bays have a great water area, most of which covers mud flats and small inlets. As the striped bass have a large amount of water in which to school and feed, it is usually found impractical to use *drift gill nets* for their capture, though many fishermen do capture bass in this manner. The majority, however, take advantage of the hordes of bass which sometimes isolate themselves on these flats and inlets in quest of food. The men await a high tide, a calm night, preferably during the dark of the moon, until they can actually hear the "skoff" of the bass as they break the surface. Their lengthy *block nets* are then piled into a large dory tied behind a comfortable 30-foot gas boat which speeds off at 7 or 8 miles an hour to a particular inlet or bay. At the first of the ebb tide the net is laid across the opening. It is cast from a dory which is rowed by hand. At the completion of this task, which takes an hour or more, the ends of the net, which are required by law to be at least 300 feet from shore, are looped around so they face the inside of the webbing. (Fig. 13). The dory is then rowed back to the launch and the men await the low water. As the water level lowers and the water recedes from the small bay, the fish within begin moving outward. As they come abreast the net, which is also slowly moving outward, they gill or follow the net to the end, where they are diverted back by the looped ends. It is then only a matter of time until they all gill if they are of the right size, but to hurry this action along the fisherman rows back to the net and splashes his oars to excite the fish as they mill back and forth. If the net has drifted into deep water the launch is sometimes brought into play by running it up and down the net at full speed. Four or five hours after the net is laid out it is pulled into the dory again and the resulting catch generally taken direct to the main fishing port at Fish Harbor, San Francisco. Another attempt may be made the following night if the tide is high and the weather good. Generally, however, several days pass before another opportunity for a good catch presents itself. This method of fishing is extremely well adapted to shallow waters and the catches as a rule are of good size, often exceeding ten tons. As the ideal periods for netting striped bass are few and far between, these fishermen make ample use of their spare time by drifting for shad, trawling for shrimps, netting smelt, anchovies and herring.

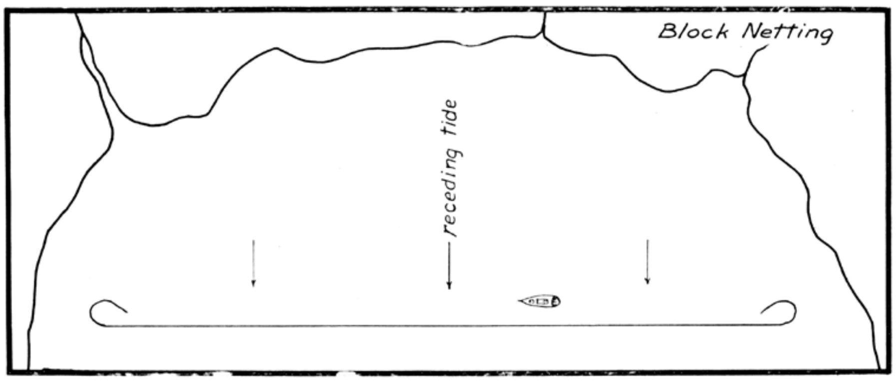

FIG. 13. Block nets are operated on the shallow mud flats that fill a small inlet or bay. The great length of the net partially blocks off the striped bass which may be schooling inside. As the tide drops the fish are forced outward until they come abreast the slowly drifting net. Those which do not gill follow the net to either end where they are diverted back by the looped ends. If they are of sufficient size they eventually gill, and to hurry this action along the fishermen beat the water with oars or run their launch along the net at high speed.

FIG. 13. Block nets are operated on the shallow mud flats that fill a small inlet or bay. The great length of the net partially blocks off the striped bass which may be schooling inside. As the tide drops the fish are forced outward until they come abreast the slowly drifting net. Those which do not gill follow the net to either end where they are diverted back by the looped ends. If they are of sufficient size they eventually gill, and to hurry this action along the fishermen beat the water with oars or run their launch along the net at high speed

3.1.5. CARE OF GEAR

Nets are greatly prized by their owners, who treat them with great care. The purchase of a new net is quite an event in the life of a fisherman, since the cost is between $250 to $400, complete. New webbing is given a twenty-four hours' tanning, which is a process of soaking it in a solution of hot water and tan bark. This treatment is supposed to stiffen the twine and protect it from the rot caused by marine microorganisms. If the net is in continual use, it is tanned about every two weeks, and every few days it is washed well and laid on prepared racks to dry. During the closed season when the nets are not in use, they are stored in ventilated sheds where they are carefully covered to ward off dust and moisture. If stored for a considerable length of time they are usually salted well. A well cared for net will last at least two seasons and often three or four seasons.

FIG. 14. Every few days the nets are given a good washing, then placed on prepared racks to dry. The fishermen take this opportunity to mend the torn meshes. Photograph by L. G. Van Vorhis, May, 1927

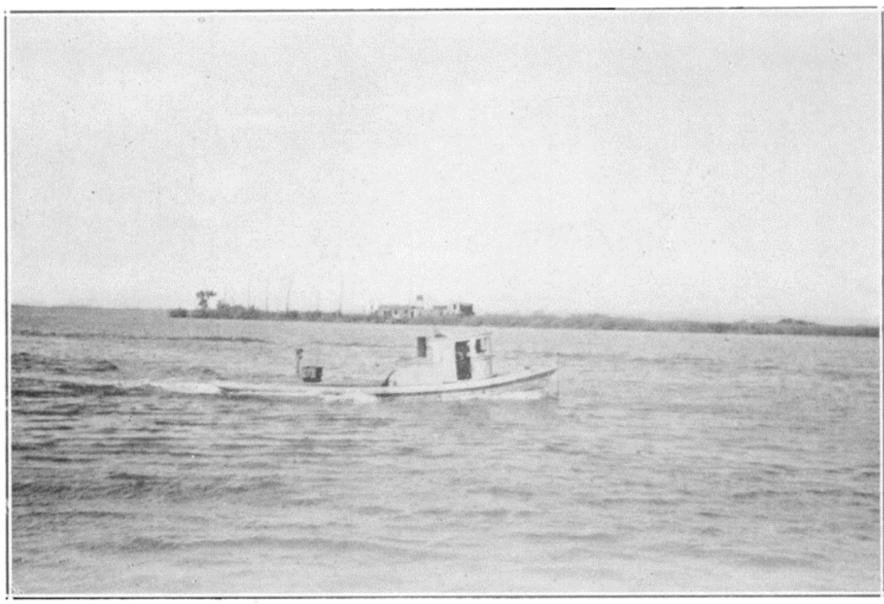

FIG. 15. Many fishing boats remain on the fishing grounds for a week at a time in which case a large "pick-up" boat owned and operated by the wholesale fish dealer runs alongside daily, receives and weighs the fish, then returns to the main plant. Photograph by E. C. Scofield, September, 1925

3.1.6. HANDLING OF CATCH

The catch of the fishermen who remain on the fishing grounds throughout the week is collected daily by large "pick-up" boats owned and operated by fish dealers. These boats have a capacity of about five tons and are capable of carrying closely packed fish in hot weather, since ice is stowed in the hold. They are equipped with scales so the fish may be weighed immediately after being received from the fishermen. Many fishing boats operate on fishing grounds close to the commercial fish plants, in which case they deliver their own catches every day or so. They run their boats alongside the dock where the fish are placed in a carrier and hoisted into the plant and weighed. For every sale of fish, a receipt provided by the Division of Fish and Game is made out in triplicate and issued to the fisherman, to the dealer and to the Division of Fish and Game. These receipts show the name of the dealer, boat making the catch and the captain, date, locality, weight and price of each species delivered. The bass are then packed in boxes in the "round," iced well and shipped immediately to all points in California.

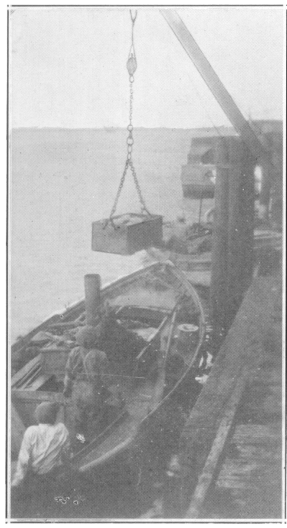

FIG. 16. Many fishermen deliver their catches to the wholesale fish plants. They run alongside the dock, and their fish, after being placed in a carrier, are hoisted into the plant where they are weighed and a receipt issued. Photograph by E. C. Scofield, May, 1927

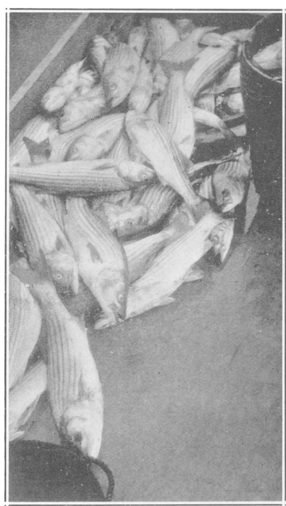

FIG. 17. A good catch of striped bass. Photograph by E. C. Scofield, May, 1927

4. PART II THE LIFE HISTORY OF THE STRIPED BASS

4.1. PART II THE LIFE HISTORY OF THE STRIPED BASS

4.1.1. AGE

The final age analysis of the striped bass was made exclusively from scale studies. This method of age determination was chosen after three years had been spent in tracing actual growth from length frequency data. These data provided a means for establishing the average lengths of the first four age groups; thus a solid foundation was laid for accurate determinations of age from scales throughout the life of the striped bass. Further age reading was done by means of opercles and otoliths, both of which aided in illustrating that the scales of the striped bass present an accurate interpretation of the age of the fish.

4.1.1.1. Scale Studies

The clearest scales for age reading lie in the midsection of the body above the lateral line. These scales, rarely deformed, show very distinct annual rings. Scales from other parts of the body were also examined. Those lying anteriorally are very small and the annual rings are very indistinct. Scales from the caudal region are oblong in shape, and the rings are crowded in such a way as to make them appear fused along either margin of the scale. The ventral region generally produces regenerated scales which lack a good center. Though all good scales were found to be readable, those lying above the lateral line between the two dorsal fins were so much superior in every respect that these scales only were removed for age-reading purposes.

The scales are very coarse and tend to curl when dry. For this reason they were mounted on slides in a preparation of glycerine jelly. In this substance they remained moist and did not curl. Once mounted they were placed under a compound microscope of comparatively low power by which their age could be determined. This method of observing scale formations was found to be excellent as it cleared up minor irregularities which would ordinarily cause confusion. With the aid of the low power lens it was easy to distinguish between true and false annuli.

Fortunately the vast majority of the scales was readable. Eight per cent of the 7430 scales examined were discarded because they lacked a good center or because they contained minor discrepancies. Those lacking a good center formed the majority of the discarded scales.

Scale growth (Fig. 20) consists of evenly spaced, arched circuli, lying between numerous radii. From 25 to 150 circuli may be formed during the course of a year, depending upon the age of the individual. The younger and faster growing fish form many more circuli than the older or slower growing. Irrespective of age it was found that in early winter the scales cease to form these arched circuli. This period of dormancy, when growth is at a standstill, continues throughout the

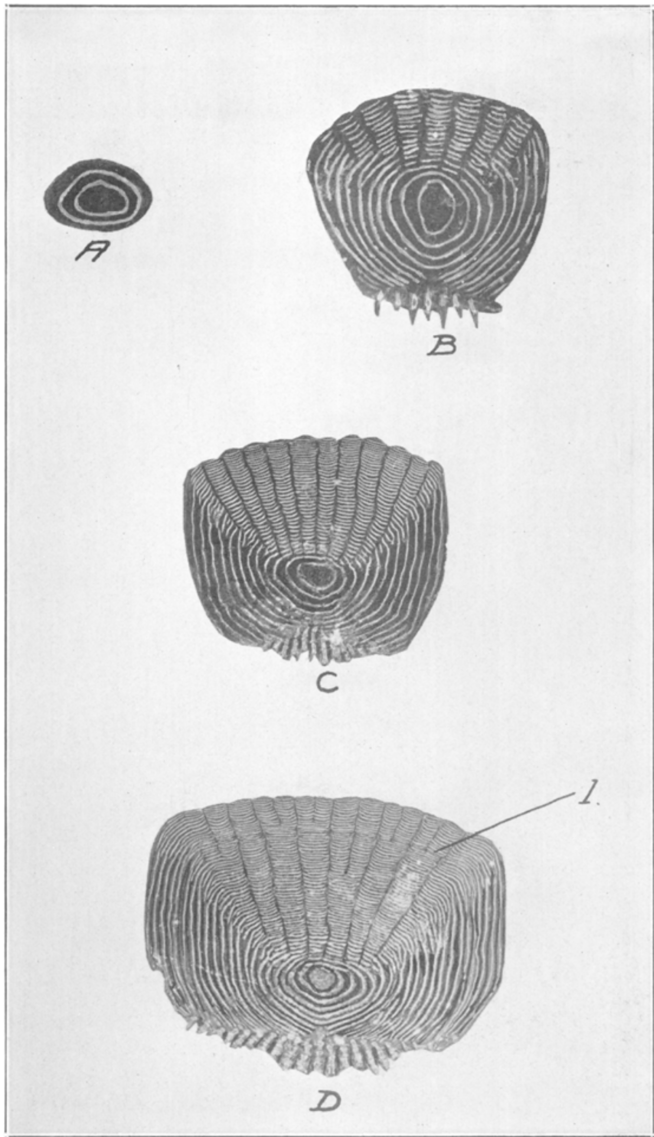

FIG. 18. This illustrates scale development through the first year. It can be seen that the radii form almost at random and that the circuli are evenly spaced through the entire year. In *D* the annulus has formed and the scale is in its second year.

(27)

FIG. 18. This illustrates scale development through the first year. It can be seen that the radii form almost at random and that the circuli are evenly spaced through the entire year. In D the annulus has formed and the scale is in its second year

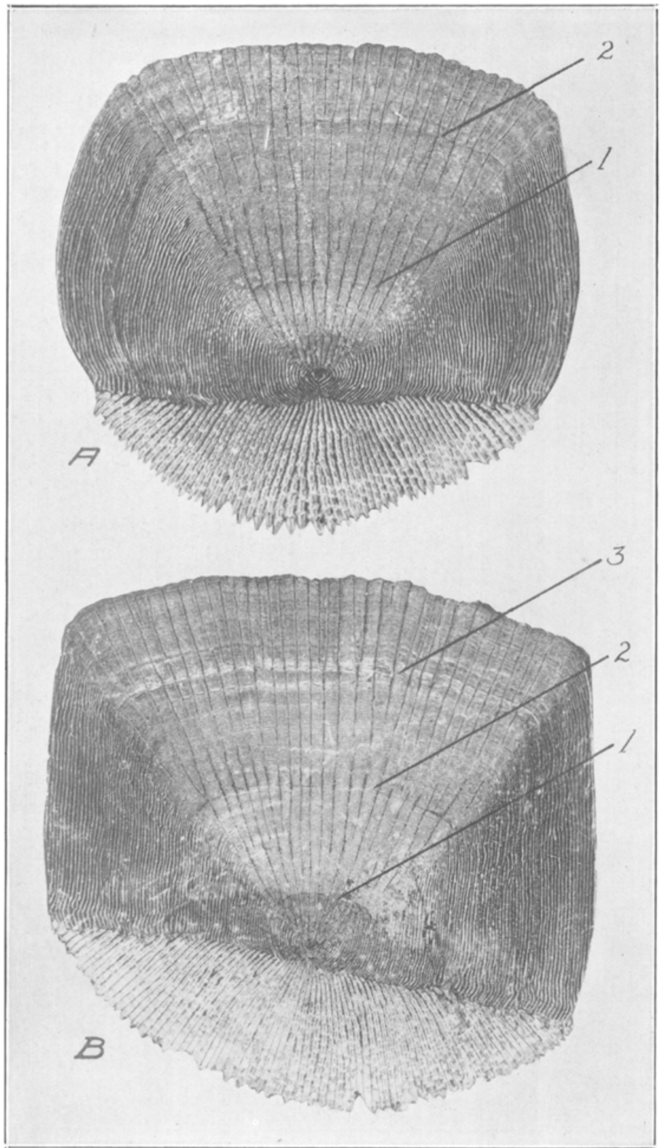

FIG. 19. *A*, a bass scale in its third year. Note the increased growth in the second year as compared to the first. *B*, a scale in its fourth year, showing that the third year's growth is comparable to the second. Note that the checks form across the entire scale and that they can also be detected down either margin.

FIG. 19. A, a bass scale in its third year. Note the increased growth in the second year as compared to the first. B, a scale in its fourth year, showing that the third year's growth is comparable to the second. Note that the checks form across the entire scale and that they can also be detected down either margin

winter and into early spring, a period of five or six months. (Figs. 30 31 32.) During this time is formed the annual ring by which the age is determined, for normal formation of circuli has ceased and in their place one or two perfectly straight circuli are formed. (Fig. 20.) Immediately after the annulus is formed, scale growth is resumed in a normal fashion.

Exceptions to normal growth, though they occur infrequently, should have a word of explanation. To the casual observer a single striped bass scale may show five annuli while in reality there are only four. Upon closer observation this "extra" annulus will appear unevenly spaced in relation to the other annuli. Such a mark on the scale is usually the result of the formation of a light or dark area. The light

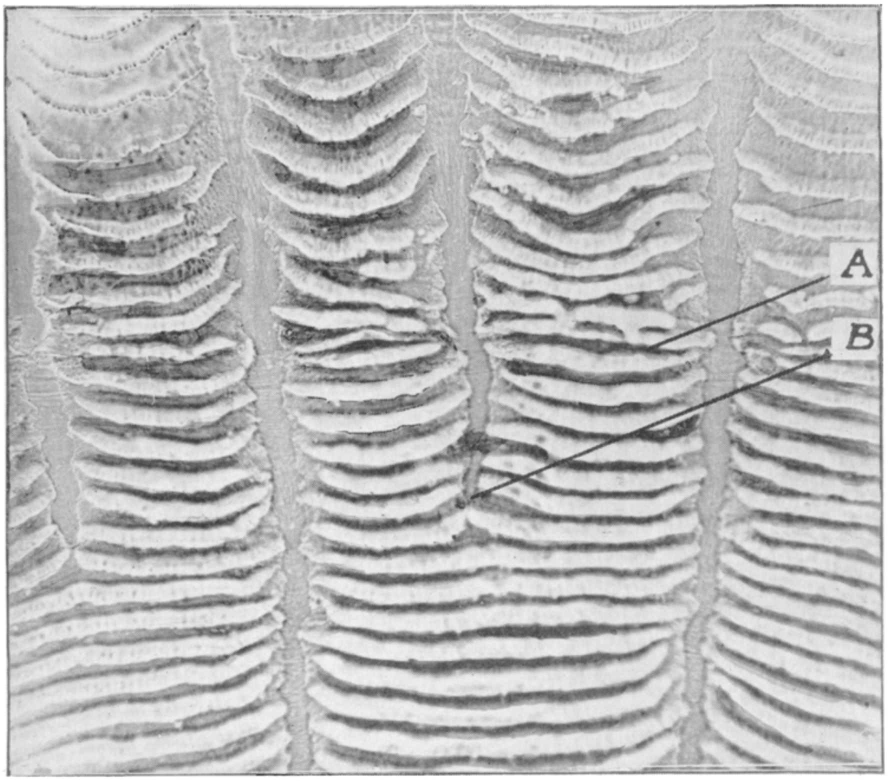

FIG. 20. Enlarged section of a scale, illustrating tpyical scale growth. *A*, the annulus composed of two irregularly formed or flattened circuli. *B*, a recently formed radius.

FIG. 20. Enlarged section of a scale, illustrating typical scale growth. A, the annulus composed of two irregularly formed or flattened circuli. B, a recently formed radius

area is caused by the presence of two or three very unevenly formed circuli, of less than normal width. The dark area is similar in formation, but the circuli are very thick thus giving the effect of an annual ring. Another discrepancy often formed on scales is the "false" annulus which generally appears on one-half of the scale only. The "false" ring is a typical annulus formation, yet it does not continue around the entire scale. A mark of this kind is easily detected because it conflicts with the normal spacing of the true annuli. Its presence on scales is not explainable as it appears on the scales of immature as well as of mature fish. Irregularity in scale growth is to be expected and it is only after considerable experience in scale reading that the observer is able to distinguish between true and false annuli. Fortunately it was possible to obtain a check on scale readings by means of length frequencies, opercles and otoliths. These methods will be discussed in later sections. With this aid little difficulty was found in the scale reading of bass up to seven or eight years of age.

Among older fish the yearly growth is lessened. The annulus is less conspicuous and the annual growth as represented by circuli is broken and irregular. New radii cease to form and many are discontinued. This jumbled condition of the scale, though more evident in the older bass, is sometimes present on scales after their fifth or sixth year. Due to a larger annual growth, such a condition is less noticeable in the younger bass, while on the scales of older fish where yearly growth is very small the irregularly formed circuli make the scales extremely difficult to read. No reason can be given for this condition on the scales of older bass. It is not believed to be a result of spawning conditions for bass feed continually at the time of spawning, and as a result growth takes place during this period. (Fig. 32.)

4.1.1.2. Otoliths

Otoliths were removed at random from the inner ear of a striped bass, and their age read to check the scale reading. Age readings, similar to those presented by the scales, were obtained in every instance. The fifty or more otoliths examined gave sufficient data to illustrate that otoliths as well as scales offer an accurate method of age reading. Growth on otoliths is represented by dark areas, while the annuli stand out as light streaks. These markings extend around the entire otolith though they are more distinct in some portions than in others. They appear very clearly at either end as here they tend to spread apart, while on both margins they lie close together and are not readily distinguishable.

4.1.1.3. Opercles

A portion of the cheek known as the opercle was also used in making checks on scale age determinations. It was first removed from the bass, then boiled to rid it of the clinging meat and

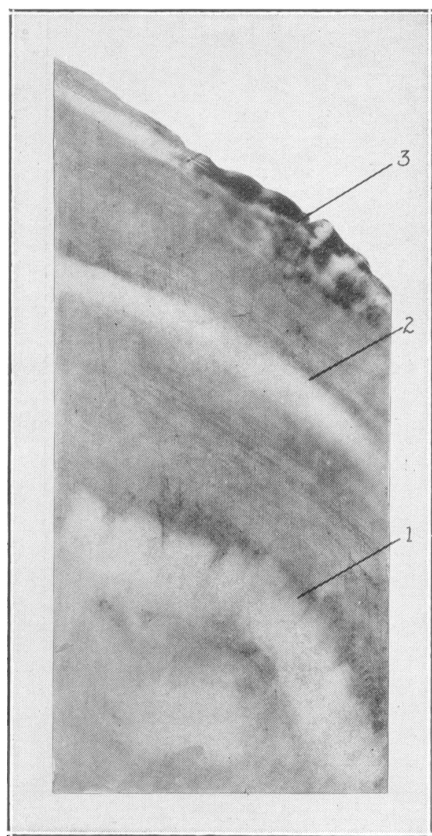

FIG. 21. A section of a striped bass otolith illustrating the possibility of aging the fish from the annuli which appear as numbered. This particular otolith was removed from a bass in its fourth year. Note the darkened areas of growth and the light streaks which form the annuli

tissues. After it was cleaned and dried it became transparent. It was then placed in water and in a few minutes the annual rings stood out as dark lines while the remaining area turned creamy color. All annuli save the first were clearly seen and, upon closer observation, the first mark could be seen near the center, though it was very inconspicuous. As on the scale, it revealed a small first year growth.

4.1.1.4. Length Frequencies

A serious study of the otoliths and opercles as a source for age determination of the striped bass was not attempted, since it was learned that the length frequencies of seine-haul samples offered a more simple and as accurate a check on the age reading from scales. The scales when first examined fortunately revealed distinct markings which were believed to be true annuli, yet to prove that these markings were representative of yearly growth it was decided that monthly seine hauls should be made in order to determine the average lengths as well as the rate of growth of the several age classes. Such seine hauls were made monthly for seventeen months commencing in September, 1925, and ending in October, 1928. During some of the months it was impossible to secure seine samples, yet these breaks in the sequence of samples in no way hindered the determination of the growth rate as well as the average lengths of the first four age classes. Take, for example, the 12 samples in figure 29. The average length of the first age class at the end of a year's growth (April) is approximately 10 centimeters. It is quite certain that the length frequency for this month is made up solely of the one-year-olds since in the sample for June the hatch of the same spring enters at a length of about 3 centimeters. By comparing figures 29 and 31, it will be seen that a normal growth progression of the length frequencies, commencing in September as shown in figure 29, would result in their reaching a length of about 25 centimeters by the following spring. Figure 31 illustrates this fact since in the sample for March the mode to the left lies at this length. Since this length frequency is made up of two-year-olds then it appears that the mode to the right should be caused by the presence of three-year-olds with an average of 34 centimeters. This assumption is further illustrated in figure 22. The graph represents the length frequencies of a single seine sample taken in June, 1927. Fortunately, there are four modes present, each of which is indicative of a single age group. Since the first mode to the left is made up of the spring hatch, then the mode to the extreme right is made up of bass at the end of their third year, their average length being 34 centimeters. Referring to figure 31 again, it will be seen that the sample for May presents a mode at 47 centimeters. Though there is no actual proof it appears that this mode is made up mainly of four-year-olds.

In summing up the average lengths of the first four age groups as obtained by length frequencies, the one-year-olds at the end of their year's growth are 10 centimeters, the two-year-olds are 25 centimeters, the three-year-olds are 34 centimeters, and the four-year-olds are 47 centimeters. The lengths of the first three age groups were definitely established, while that of the fourth was tentatively accepted as true. Having established the lengths of the first three age groups by the length frequency method it was possible to determine if they offered a specific check on the age reading by scales.

To accomplish this, the scales of a great many striped bass were read to determine their age. The markings on the scales, which were believed to be true annuli, were translated as such, and each annulus was accepted as indicative of the close of a year's growth. Under the following section on "growth," it is explained how the rate of growth of this species can be determined from the scales. Briefly this method is taken from

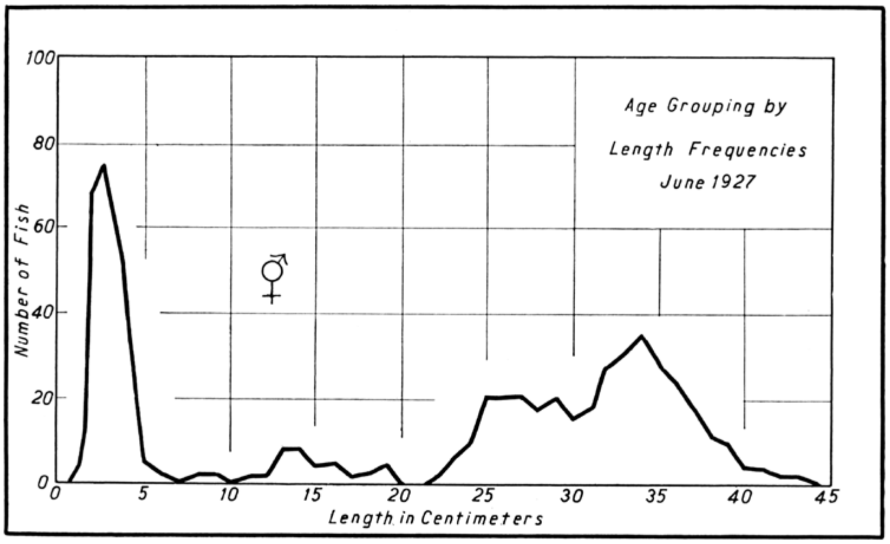

FIG. 22. A length frequency distribution of a group of striped bass taken in a seine haul in June, 1927. This illustrates the present and average size of the first four age groups. The first-year group, occurring at 3 centimeters, is the result of the same spring spawning. The second-year class has a mode at 14 centimeters, the third at 26, and the fourth at 34 centimeters.

FIG. 22. A length frequency distribution of a group of striped bass taken in a seine haul in June, 1927. This illustrates the present and average size of the first four age groups. The first-year group, occurring at 3 centimeters, is the result of the same spring spawning. The second-year class has a mode at 14 centimeters, the third at 26, and the fourth at 34 centimeters

a simple formula which is based on the fact that scale growth is indicative of fish growth since, with minor exceptions, scale growth is in direct proportion to the fish growth. In other words the percentage of growth between any two annuli on a single scale is indicative of the increase in growth of the fish that year. By this method, then, it is possible to take a single striped bass, say five years of age, and compute its length for the end of its first year, second year, third year, and so on. Many fish were treated in this manner and the average lengths for the first four age groups were determined so that they could be checked with the average lengths as obtained by the length frequencies. These average lengths in order, beginning with the one-year-olds, are: 10, 25, 37 and 46 centimeters. The average length of these age groups as established by length frequencies are: 10, 25, 34 and 47 centimeters. Since these two results are nearly identical there remains little question but what the markings which appear on the scales are true annuli. Though this check only holds for the first four age groups, these alone offered a firm foundation upon which age reading by scales could be performed with accuracy throughout the remaining years of the life of any one striped bass.

There may arise the objection that the length frequencies do not offer a specific check on the age reading by scales because the modes as presented in figure 31 are not necessarily made up of single age groups. To prove that such an argument is void in this instance, the seine samples for March, May and October were carefully analyzed; that is, each fish contained in the sample was aged, then a length frequency was arranged for each of these age groups. These in turn were plotted against the original length frequency of the total sample. In each of the three samples, results illustrated that the mode of each age group length frequency fitted nicely to the modes of the original total length frequency. An example of this is shown in figure 23, which is the sample for October, 1928. Without knowledge of the actual size of the first four age groups one would conclude that the mode to the left is made up of two-year-olds and the mode to the right contains three-year-olds. This conclusion would of course be made by one familiar with the progression of modes shown in figures 29 and 31. Such a conclusion is well

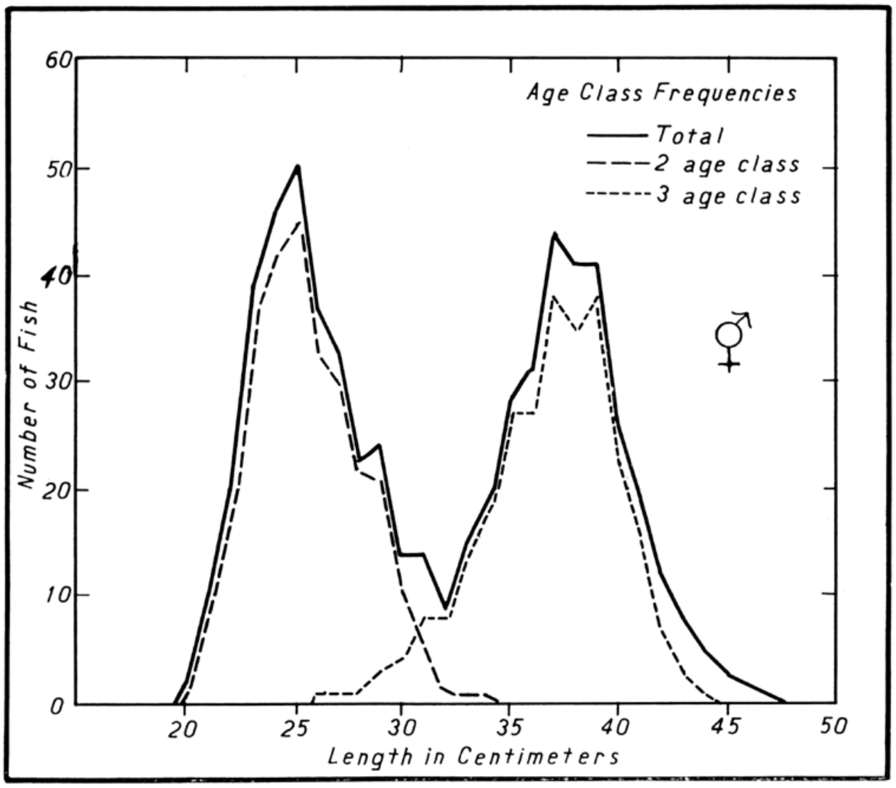

FIG. 23. The above illustrates a simple method of checking on scale age readings. The solid line represents the total frequency of a group of striped bass taken in a seine haul on October 9, 1928. Each fish in this sample was aged, thus a separate frequency was evolved for each age group, and these plotted against the total frequency. As the three curves fit nicely, the age reading was apparently correct. At points where the three curves do not fit, there occurred scales which were unreadable or missing. Between 40 to 48 centimeters the two curves do not fit since a few four-year-old striped bass were contained in the original total frequency.

FIG. 23. The above illustrates a simple method of checking on scale age readings. The solid line represents the total frequency of a group of striped bass taken in a seine haul on October 9, 1928. Each fish in this sample was aged, thus a separate frequency was evolved for each age group, and these plotted against the total frequency. As the three curves fit nicely, the age reading was apparently correct. At points where the three curves do not fit, there occurred scales which were unreadable or missing. Between 40 to 48 centimeters the two curves do not fit since a few four-year-old striped bass were contained in the original total frequency

founded for as is observed in figure 23, the modes of the two-and three-year-old age groups fit almost perfectly with the modes of the original length frequency. The same was true after an analysis of the age groups for the March and May samples of figure 31 had been made. The sample for May, however, contained a small group of three-year-olds which is not evident by any mode. The mode to the left is made up of two-year-olds while the mode to the right is composed mainly of four-year-olds, though there is a smattering of fives.

No doubt should remain that the length frequencies of seine samples formed a definite proof that the age reading by scales was correct. Once this proof was established and it was felt that age reading by scales could be carried on with utmost accuracy, the length frequencies were cast to one side and scale reading was carried on without knowledge of the length of the individuals being studied.

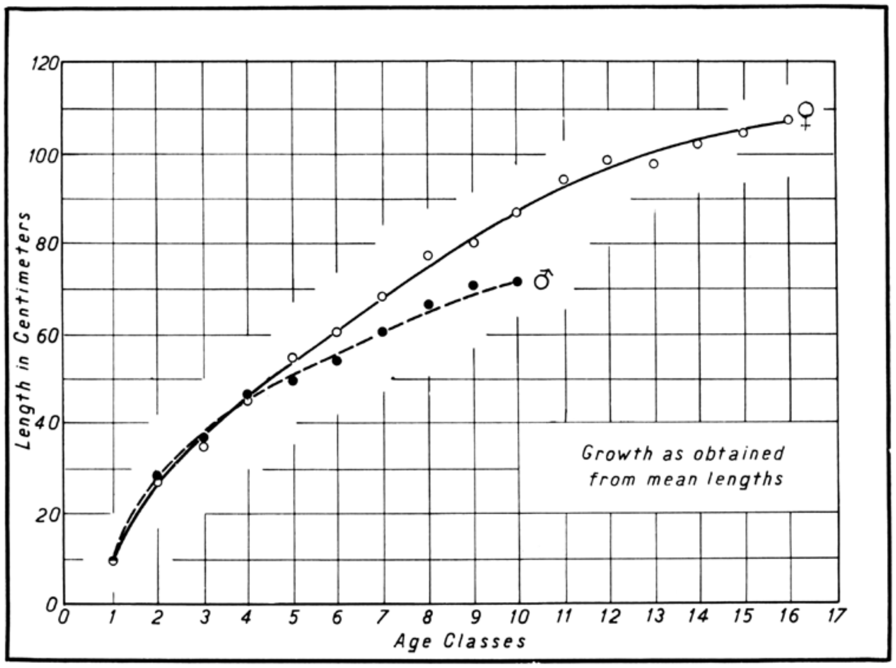

FIG. 24. The growth of striped bass as obtained from average length of all age groups. The data were collected from all material on hand which was taken during March, April or May of any one year. The points of the growth curve are somewhat irregular, yet when smoothed the resulting curve is quite similar to the formulated growth curve. (See Fig. 27.)

FIG. 24. The growth of striped bass as obtained from average length of all age groups. The data were collected from all material on hand which was taken during March, April or May of any one year. The points of the growth curve are somewhat irregular, yet when smoothed the resulting curve is quite similar to the formulated growth curve. (See Fig. 27.)

4.1.2. GROWTH

4.1.2.1. Rate

In preceding paragraphs it has been shown that growth is clearly represented on the scales of the striped bass, a fact amply proved by additional age studies on otoliths, opercles and length frequencies. Because the age is obtainable from the scales it is now possible to determine the growth rate of this species. The growth rate may be established by either of two methods: (1) average length, and (2) computed lengths. The first of these is based on massed data comprised of striped bass of all ages and sizes. By segregating each year class from this massed data, it is possible, then, to obtain the approximate length of each by selecting the mean, median or mode of its individual length frequency. In this particular study it was found that the selection of any of these three measures gave approximately the same result, since each age class presented a fairly normal frequency.

The result of such a study is illustrated in figure 24. In this instance the mean was selected from the length frequency of each class. The material comprising these data was secured during March, April and May of the years 1925 to 1928, inclusive. These spring months were selected since they mark the close of a year's growth.

An examination of figure 24 indicates the occurrence of minor irregularities due mainly to the lack of sufficient material. of the female lengths the point of the second year appears high and the points beyond the seventh year are somewhat irregular. In the curve for the males the second year point and those beyond the fifth year are also high or irregular. In averaging the lengths of similar year classes over a period of years such irregularities might be expected. However, the actual curve fitted by eye tends to iron out these discrepancies and takes on a characteristic growth curve appearance. It will be noted that both sexes grow at about the same rate during the first year. From then to the fourth year the males are larger, but beyond this point the females continue their rapid growth while the growth of the males is retarded, and at the end of the tenth year they are about seven centimeters shorter than the females. Males older than ten years are quite rare, as are females beyond the sixteenth year. (Table 2).

TABLE 2

Growth of Striped Bass Derived from Average Lengths of Various Age Groups

Age group	Females				Males			
	Number	Mean (inches)	Mean (centi-meters)	P. E. M.	Number	Mean (inches)	Mean (centi-meters)	P. E. M.
I	500	3.8	9.7	±.051	77	3.8	9.8	±.183
II	29	10.4	26.4	±.270	55	11.3	28.6	±.308
III	52	13.6	34.6	±.339	24	14.7	37.3	±.631
IV	68	18.0	45.8	±.256	49	18.2	46.3	±.318
V	62	21.1	53.5	±.281	68	19.6	49.9	±.246
VI	139	23.8	60.5	±.209	26	21.3	54.1	±.518
VII	58	27.0	68.6	±.428	4	24.0	61.0	
VIII	35	30.6	77.7	±.625	5	27.0	68.5	
IX	10	31.3	79.5	±.755	2	31.7	80.5	
X	6	34.2	87.0	±1.725	4	30.9	78.5	
XI	9	37.3	94.7					
XII	4	39.0	99.0					
XIII	1	38.6	98.0					
XIV	1	40.6	103.0					
XV	1	41.3	105.0					
XVI	1	42.5	108.0					

TABLE 2

Growth of Striped Bass Derived from Average Lengths of Various Age Groups

It is fully realized that growth as obtained by the average lengths of year classes is not strictly accurate. Variations in the growth of individual classes from year to year and the influence of dominant year classes on the average lengths are examples of the causes of possible errors. Such errors were not and could not be taken into consideration in this report. Instead, the scales of a selected group of bass were used in computing a growth curve. This study then forms the second method of establishing the growth rate of this species, the results of which served as a check on the first method based on average lengths of year classes.

Computed growth is derived from an equation which is based on the relationship between scale size and fish size. If it is assumed that the scales and fish grow proportionately from birth, then the following equation would hold for determining growth:—$L : L' = l : l'$, where L = the total length of the fish, L' = the radius of the scale, l = the unknown total length, and l' = the radius of the scale to the annulus in question. This equation may be applied for all practical purposes, but for accurate growth determinations three major factors must be considered. The first relates to the proportionate growth of all the scales on a single specimen, for it is essential in calculating growth

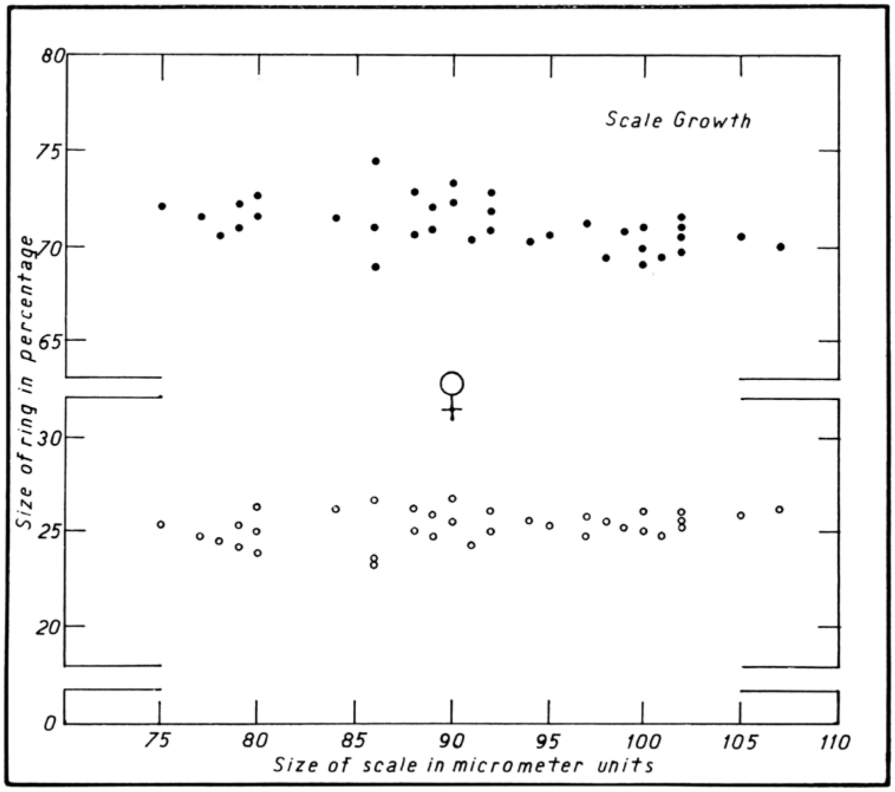

FIG. 25. The percentage of yearly scale growth as computed from 50 scales on a single striped bass. The results illustrate that all scales, whether large or small, have fairly equal percentage of growth each year.

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from scales that any scale which may be selected should be representative of the growth of that particular fish. The second involves the determination of the varying relationship between scale growth and fish growth, and the third factor to be taken in consideration is the length of the fish at the time the scales are first formed.

These factors, which may or may not have an important influence on the formula already stated, were given due consideration. First, to determine if the scales on a single striped bass grow proportionately throughout the life of the fish, fifty scales of a specimen were removed from above the lateral line between the two dorsal fins. This restricted area was chosen since in the course of this investigation scale samples were removed only from this same location. (See section entitled "Scale Studies," pp. 25–31.) Measurement was made of the radius of each scale (measurement from the center of the focus to the anterior margin). The same scale was then measured for the distance from the center of the focus to each annulus, and the results determined in percentages. Now, if these data are to illustrate that these scales, whether large or small, on a single specimen have the same percentage of growth year after year, then the radii of the fifty scales when plotted against the percentage of size of each ring should disclose a fairly level and straight line. A glance at figure 25 determines this point beyond question, for as can be observed the very nominal scatter of the points and the resulting straight line illustrate that these scales on a single striped bass grow proportionately throughout the life of the fish. As may be expected the actual variation in the percentage of ring radius is greater in the second year than in the first, the former varying 5.1 per cent and the latter 4.7 per cent.

Second, to determine the relationships between scale size and fish size, measurements were made of 362 specimens ranging from 1.5 to 110.0 centimeters in length. Each specimen was measured for its total length, and a single scale from each fish was measured for its radius (fish length from snout to tip of central caudal fin rays to the nearest centimeter; scale radius from center of the focus to the anterior

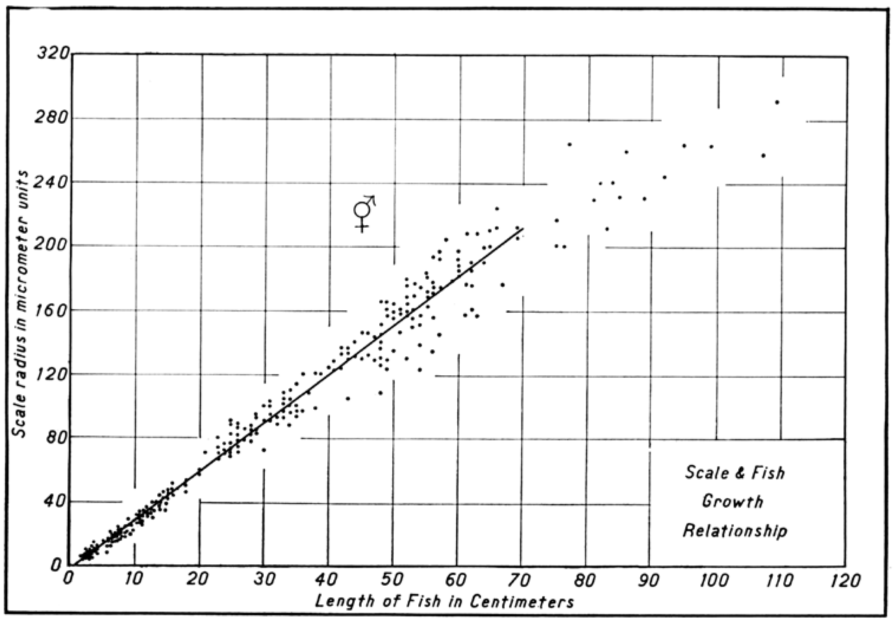

FIG. 26. The relationship between scale growth and fish growth, showing that they both have the same relative growth up to the time the fish reaches 70 centimeters in length. The data indicate that beyond this point the scales grow more rapidly in relation to the growth of the fish; however, these data are inadequate in drawing such a conclusion and were therefore excluded.

FIG. 26. The relationship between scale growth and fish growth, showing that they both have the same relative growth up to the time the fish reaches 70 centimeters in length. The data indicate that beyond this point the scales grow more rapidly in relation to the growth of the fish; however, these data are inadequate in drawing such a conclusion and were therefore excluded

margin). These data are presented graphically in figure 26. The scatter of points confine themselves to a narrow band up to the 70-centimeter mark, then they spread considerably with a tendency to lower if one were to fit a line to them. This illustrates then that the fish and the scales they bear grow proportionately up to the time the fish are 70 centimeters in length, and from this point upward the scales grow more slowly than the fish. Though the data presented produce

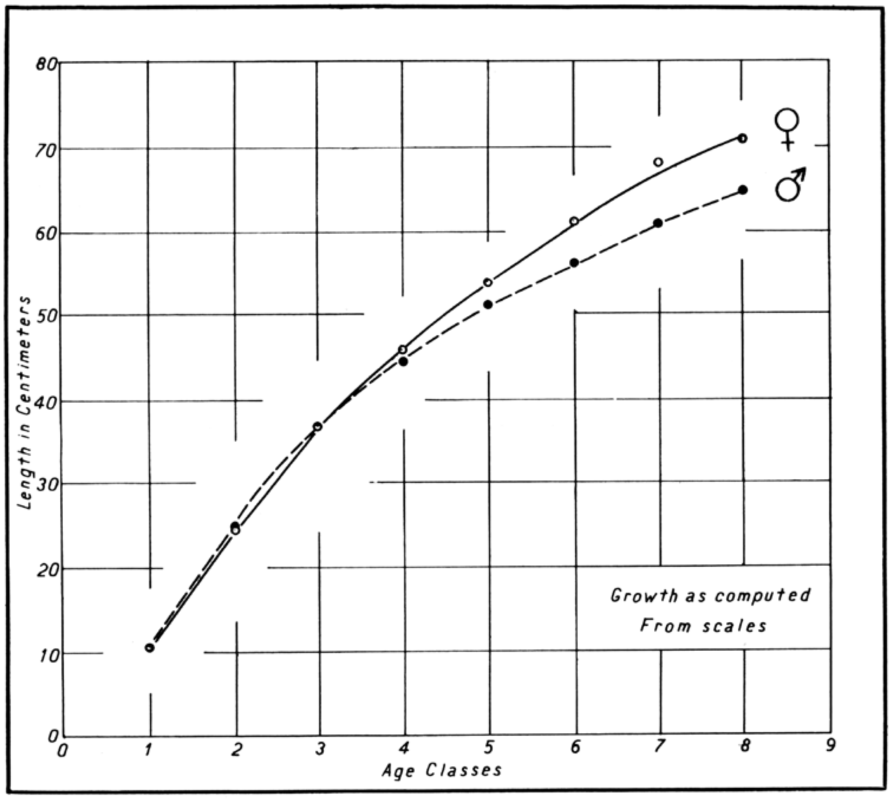

Fig. 27. The rate of growth of striped bass as computed from the scale growth, using the formula: $l = \frac{(L-1)\, l'}{L'} + 1$. This equation was applied on material up to the seventh year since it has been shown that a high degree of correlation exists between scale and fish growth up to this point.

FIG. 27. The rate of growth of striped bass as computed from the scale growth, using the formula: [l=(L-1) l'/L' + 1]. This equation was applied on material up to the seventh year since it has been shown that a high degree of correlation exists between scale and fish growth up to this point

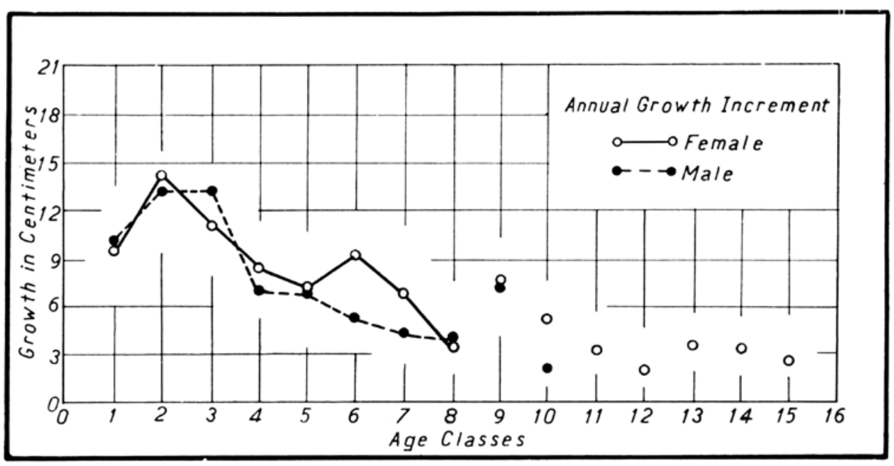

Fig. 28. The growth increment of striped bass illustrating that the greatest growth is made in the second and third years. The material beyond the seventh year was insufficient to illustrate accurate results. However, the points have been included to give some conception of the growth differential during this period.

FIG. 28. The growth increment of striped bass illustrating that the greatest growth is made in the second and third years. The material beyond the seventh year was insufficient to illustrate accurate results. However, the points have been included to give some conception of the growth differential during this period

this deduction, the sparse material beyond 70 centimeters should not justify such a definite conclusion. It was therefore considered pertinent to cast aside such data as might be thought insufficient, and which might lead to the formation of inaccurate results. All data beyond 70 centimeters were then withdrawn and as a result, conclusions were based on the remaining material. (This action was taken with the proviso that in computing growth from scales, only fish 70 centimeters or under would be used.) A line was then fitted to the remaining scattered points, and as can be observed in figure 26 a straight line resulted. This determines that the scales may be used in computing the growth of the striped bass, provided the fish from which the scales are removed do not exceed 70 centimeters in length.

The third factor to be considered, before computing growth from the scales of these fish, relates to the size of the fish when their scales first form. To determine this factor the data comprising figure 26 were used. These data were divided into two parts; those points above 35 centimeters and those below. An average point was deduced from each group and a straight line projected between the two so that it intersected the *X* axis. The point of intersection of the *X* axis corresponding to a fish length of 7.5 millimeters gave the theoretical length of a striped bass at the time the scales are first formed. This size, however, is undoubtedly too small since it is known that the scales undergo rapid growth during the first few days after their formation. Because of this discrepancy the size of the striped bass at the time the scales form was established roughly as one centimeter.

As was stated previously, the growth of striped bass can be computed from the scales from what is termed a straight formula ($L : L' = l : l'$) provided (1) that any scale which might be selected from a fish for this computation is representative of the growth of that fish; (2) that the growth of the scales is proportionate to the growth of the fish; and (3) that the scales are formed at the same time that the fish are hatched. of these three factors only the third appears to have any influence on this straight formula for fish under 70 centimeters in length. Therefore the formula for computing the growth of striped bass, taking the factor of one centimeter into consideration, reads as follows:

$$l = \frac{(L-1)\ l'}{L'} + 1$$

Since this equation holds for striped bass up to 70 centimeters in length, only such specimens were used in calculating the growth rate. The results of this study are shown in figure 27. An examination of this growth curve reveals a striking similarity to the curve derived by the first method previously discussed. This fact is interesting since it illustrates that either of the two methods of obtaining the growth rate may be used in this species. The formulated growth as calculated from

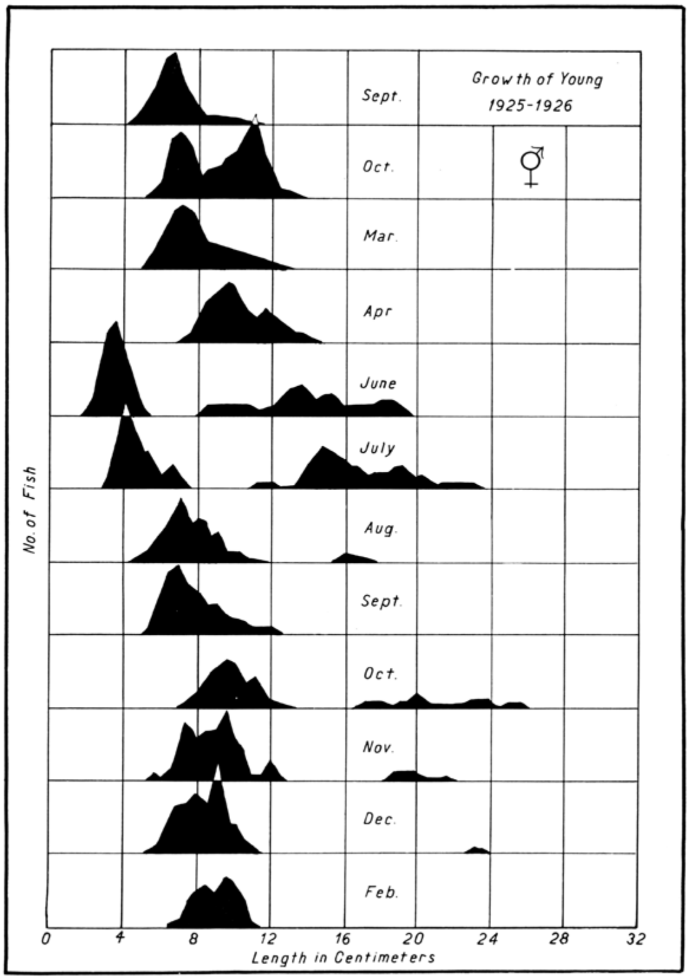

Fig. 29. The growth of young striped bass over a period of 18 months. The modes on the extreme right are composed of bass hatched the preceding spring, while the modes to the left are of individuals hatched the same year, 1926.

FIG. 29. The growth of young striped bass over a period of 18 months. The modes on the extreme right are composed of bass hatched the preceding spring, while the modes to the left are of individuals hatched the same year, 1926

the scales is however by far the more simple since it requires less data and its results are undoubtedly more accurate. (Table 3).

TABLE 3

Growth of Striped Bass as Computed from Scales

Age group	Females				Males			
	Number	Mean (centimeters)	P. E. M.	Annual growth	Number	Mean (centimeters)	P. E. M.	Annual growth
I	43	10.6	±.271	10.6	35	10.6	±.217	10.6
II	43	24.7	±.355	14.1	35	25.1	±.351	14.5
III	43	37.0	±.384	12.3	35	37.1	±.403	12.0
IV	43	46.0	±.336	9.0	35	44.5	±.430	7.4
V	43	54.2	±.312	8.2	34	51.6	±.447	6.1
VI	33	61.2	±.399	7.0	18	56.3	±.446	4.7
VII	21	68.0	±.447	6.8	12	61.2	±.804	4.9

TABLE 3

Growth of Striped Bass as Computed from Scales

4.1.2.2. Seasonal Growth of Immature Striped Bass

During the course of a single year there occurs a marked variation in the growth of striped bass, especially in the younger age classes. In determining these growth fluctuations it was necessary to secure samples

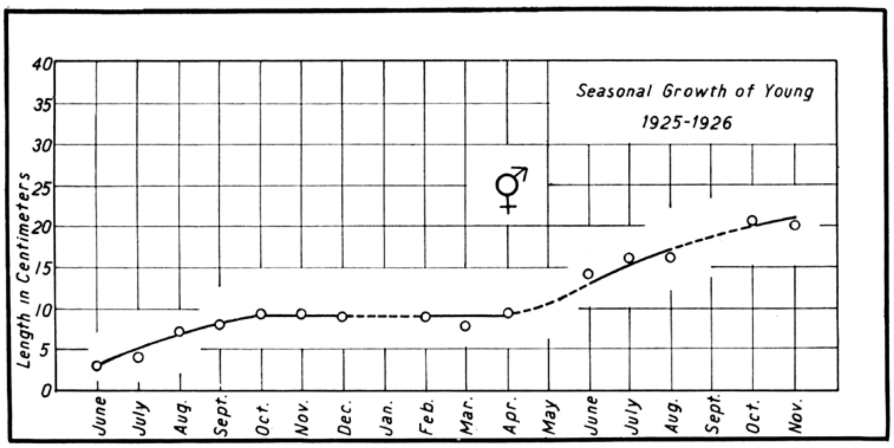

FIG. 30. The growth by months of yearling striped bass. Note the periods of rapid and slow growth.

FIG. 30. The growth by months of yearling striped bass. Note the periods of rapid and slow growth

of this species during every month of the year. In gathering this material the same collecting gear was used and the same locality was fished during the succession of months. As a result it was discovered that 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 growth. In figure 29 there is traced the growth of the youngest individuals for a period of fifteen months. These smaller sizes are quite abundant in San Francisco Bay during the warmer months of the year; consequently, no difficulty was experienced in securing material at this time. During the colder months, however, these sizes could not be found in large quantities and many of the samples were inadequate. These same data are presented

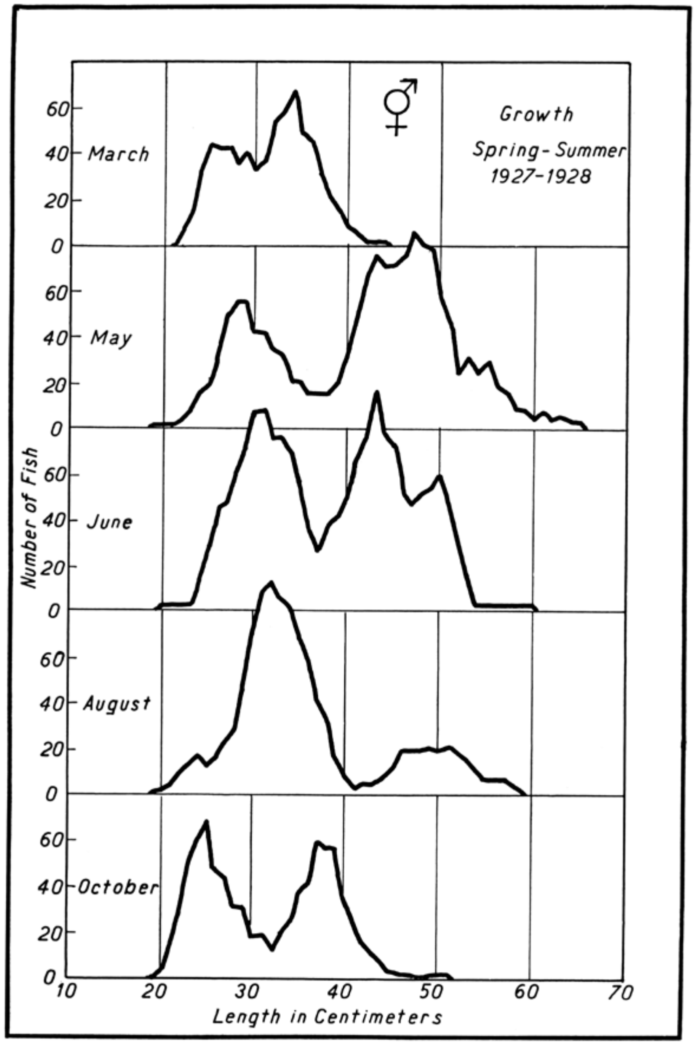

FIG. 31. The growth of the two- and three-year groups during the spring and summer, 1927–1928. Note that the two-year group in March which lies at 25 centimeters advances to 37 centimeters in length by the following October. The growth of the three-year-olds is not so marked, for during May and August the samples have included some older age groups. The fall two-year group can be seen on the 25-centimeter line.

FIG. 31. The growth of the two- and three-year groups during the spring and summer, 1927–1928. Note that the two-year group in March which lies at 25 centimeters advances to 37 centimeters in length by the following October. The growth of the three-year-olds is not so marked, for during May and August the samples have included some older age groups. The fall two-year group can be seen on the 25-centimeter line

in figure 30 which illustrates the growth by months as well as the extent of the periods of growth and of dormancy. (The monthly size was determined by the median of individual frequencies.)

An attempt was made to trace the growth of these smaller stages into their third and fourth years. Though this attempt was partially successful it had to be discontinued due to the high cost of securing such material. The results are presented in figure 31 which traces normal growth through a single spring and summer.

These studies on growth proved to be a great aid in age determinations since the progression of modes of the various age classes made it possible to determine the approximate length of the younger age classes. With this knowledge scale age studies proved to be a simple matter.

4.1.2.3. Seasonal Growth of Mature Bass

Among the immature bass there occurs a seven-month period of growth and a five-month period of dormancy. To illustrate that this condition prevails among mature bass, figure 32 has been prepared from the commercial samples of the five-, six-, and seven-year-old mature fish.

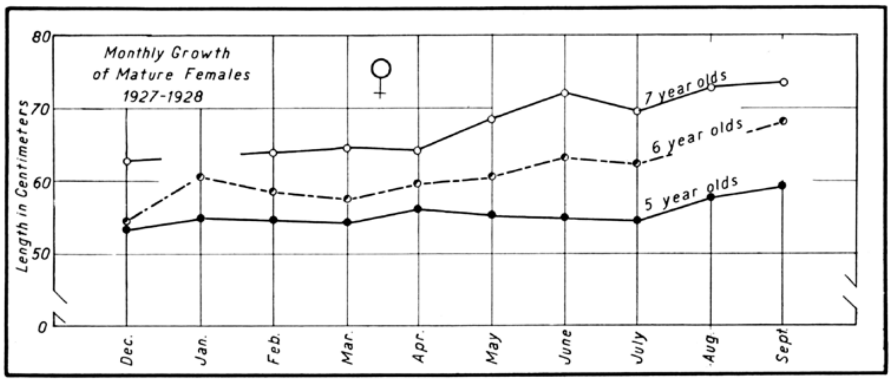

FIG. 32. The above graph illustrates the periods of dormancy and of growth among the mature striped bass of the commercial catch. From December to April growth is greatly minimized, while from April to September there is a rapid increase in length. The points represent the median length of the age groups by months.

FIG. 32. The above graph illustrates the periods of dormancy and of growth among the mature striped bass of the commercial catch. From December to April growth is greatly minimized, while from April to September there is a rapid increase in length. The points represent the median length of the age groups by months

These data are extremely interesting since they show that among these mature bass, like those of the immature group, there occurs a period of dormant growth through the winter and up until approximately April. From then through the spring and summer until September and beyond, they add considerably to their length. This period of growth is accompanied by a great deal of movement and heavy feeding among the fish. It is interesting to note that these mature fish, though spawning from March to July, continue to grow rapidly since they are feeding throughout this entire period. (See section on "Food," pp. 56–57.) The fact that they feed during their spawning is unlike a great many other species which cease feeding during such a time. It is believed that this is the direct cause for the absence of the slightest trace of a spawning mark on the scales or other parts of the body of the striped bass.

4.1.3. AGE AT MATURITY

During the striped bass spawning season of 1927, an attempt was made to determine the age at maturity by examining and recording the condition of the ovaries in the field. Observations of this nature were begun in March and continued until the following June. During this period over five hundred ovaries were examined, their condition noted as to whether they were immature, maturing, ripe or spent, and the

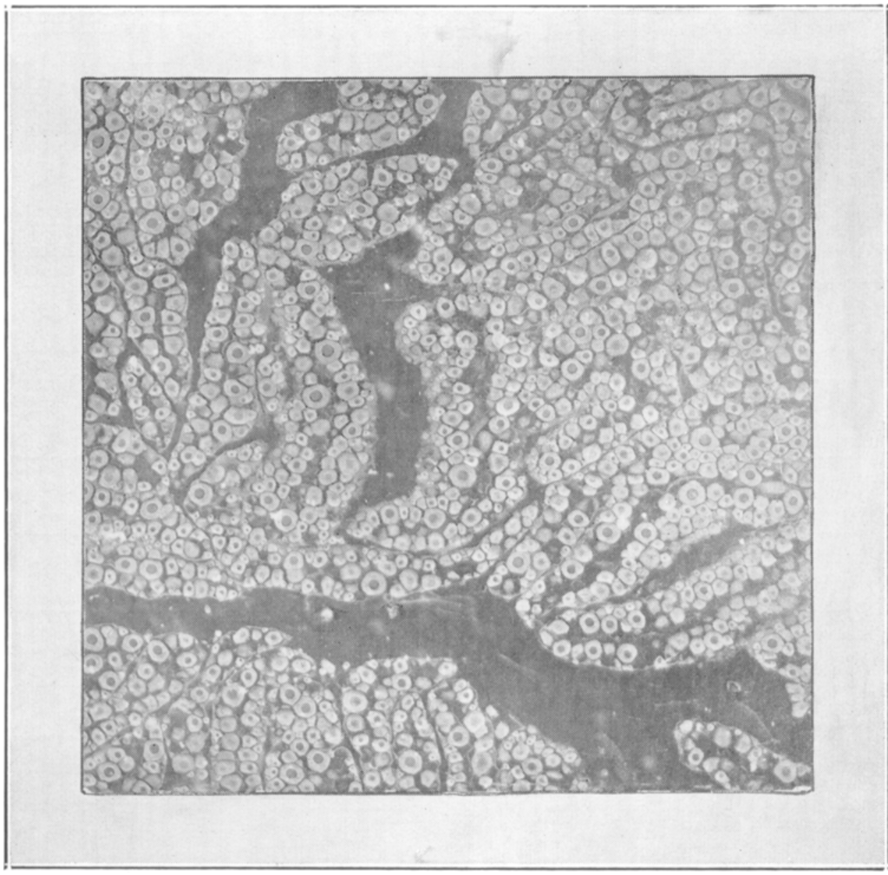

FIG. 33. A cross-section of an immature ovary. These eggs are held between tissues, and when mature they break from the tissues and become free within the ovary.

FIG. 33. A cross-section of an immature ovary. These eggs are held between tissues, and when mature they break from the tissues and become free within the ovary

length and age of each fish recorded. These field observations proved to be successful with the males as ripening testes could be readily distinguished. The females, however, offered great difficulty for the ovaries varied greatly in size and color and it was not always possible to distinguish between immature and maturing ova. This was probably due to the fact that this material was secured from San Francisco and San Pablo bays, which are some distance from the central spawning region. Here only spawning migrants were evident, the ovaries of which had not yet ripened sufficiently to make possible an accurate determination of the degree of maturity. For this reason this material had to be discarded, and the attempt to secure the age at maturity abandoned until the following spawning season of 1928.

During the 1928 spawning season an entirely different program was followed. Material was gathered from the center of the spawning region, namely Pittsburg and vicinity. From 150 to 200 females were examined monthly, and from each individual were secured the total length, the age, and an entire ovary. These ovaries were preserved in a solution of 10 per cent formaldehyde. In the laboratory the diameters of a representative group of eggs from each ovary were measured.[2] Approximately 200 eggs were contained in each group, the selection of these eggs being made from the center of the gonad where a pair of forceps was used to obtain a radial section. The selection of eggs from this position of the ovary was chosen after the diameter of several hundred eggs, which were removed from 6 different sections of 10 ovaries, had been measured. The egg diameters from any of the 6 portions of the 10 ovaries were found to have the same measurements; thereafter, eggs taken for diameter measurements were selected from the mid-section as the anterior or posterior ends sometimes were torn

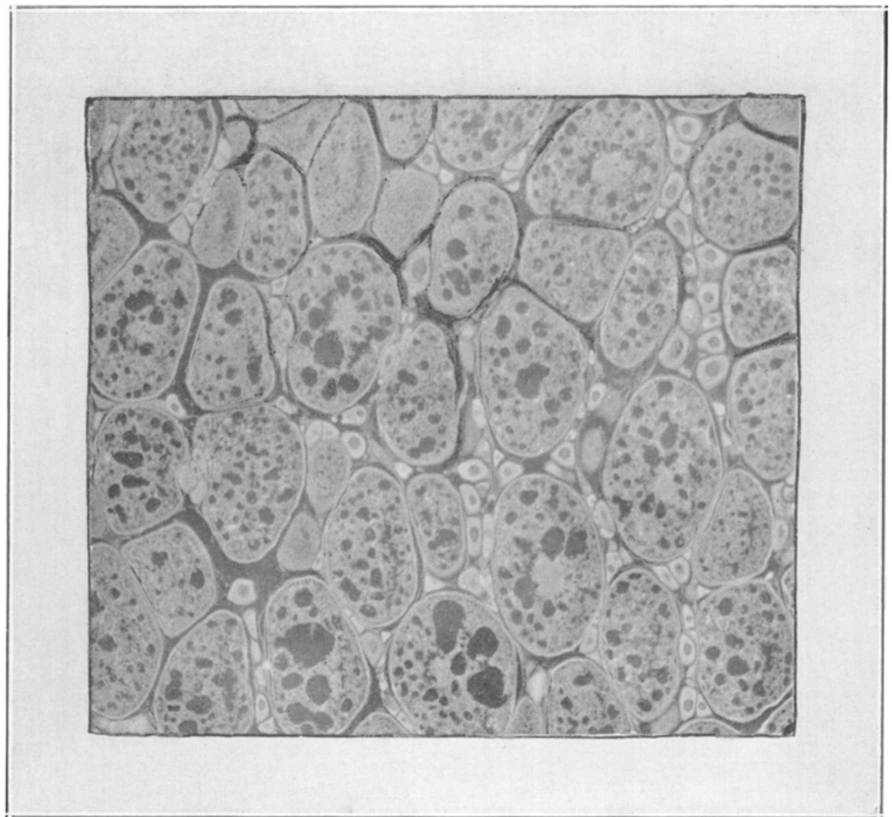

FIG. 34. Cross-section of a mature ovary. Note the two stages of ova, the mature and immature.

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[2] Since the preserved ova occurred in many distorted shapes, it was rather difficult to determine the actual diameter. To make this measurement, then, the diameter of each egg was measured regardless of whether the measurement was the long or the short diameter. Since approximately 205,000 eggs were measured in this manner the long and short diameters would tend to offset any possible error, and the resulting measurements would closely approximate the true diameter. Clark in her report (1925) made a detailed study of the possible error arising from the measuring of the long and short egg diameters of the grunion. Her results show specifically that the true diameter can be obtained by measuring all eggs regardless of their shape or chosen diameter.

away. A representative group of eggs upon being teased from the ovary were placed on a slide ruled in squares. A 10 per cent solution of formaldehyde was then added to moisten the surface, and the eggs were probed until they fell somewhat apart. The slide was then placed under a compound microscope and the diameters of approximately

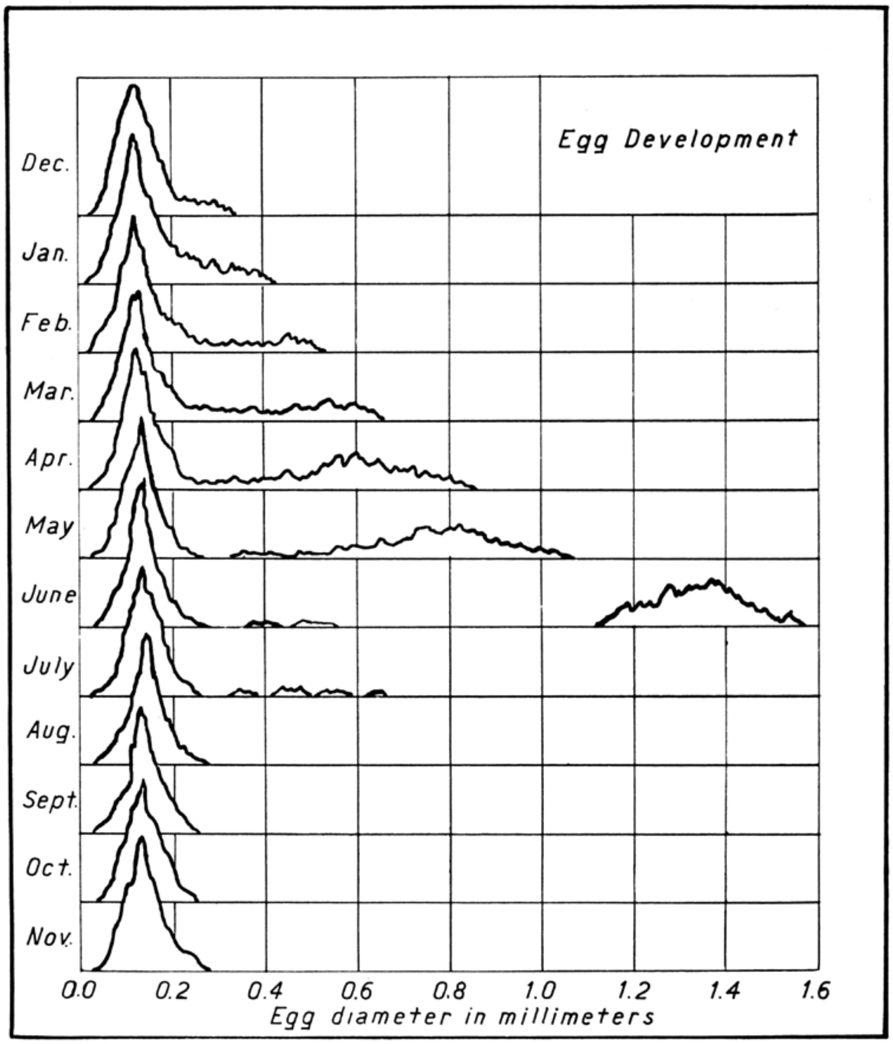

FIG. 35. Selected ova measurements to illustrate the probable development of eggs during an entire year. Note the large group of immature eggs, occurring between 0.025 and 0.25 millimeters, with a mode at 0.125. Ova begin development as early as December, and by early spring a single group has entirely split from the immature group. These ova advance to approximately 1.35 millimeters in diameter before they are spawned.

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200 eggs measured with an eyepiece micrometer. To safeguard against measuring the same egg more than once, only the eggs of one square of the slide were measured at one time, until the full quota of 200 egg measurements had been attained.

This method of measuring egg diameters was employed for 1015 ovaries. A diameter frequency was made of each specimen, and after due examination of the results it was found that each ovary whether it was immature, mature or spent, consistently contained a group of immature eggs averaging 0.125 millimeters in diameter, and no eggs of this group ever exceeded 0.29 millimeters. (Figs. 33 and 34.) This fact was of prime importance since it revealed the possibility that all ovaries which contained a group of eggs exceeding 0.29 millimeters in diameter were mature or approaching maturity. (Fig. 35). With this fact in mind all the data were classified in this manner. Then to prove the accuracy of this classification the following check was

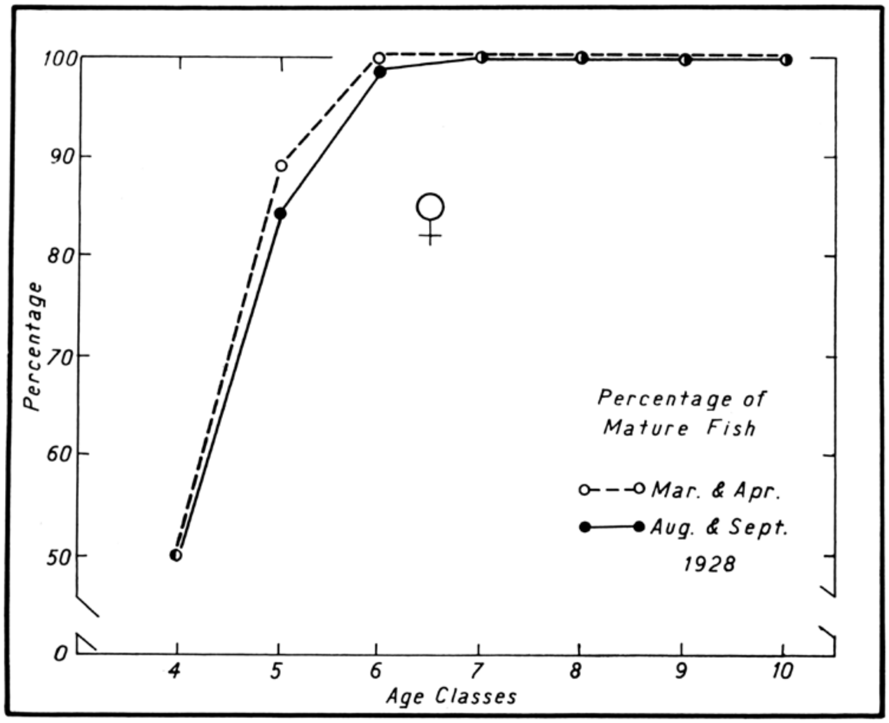

FIG. 36. To learn if the determination of a mature and immature ovary was correct, the above chart was prepared as a check reading. Since the percentage of age groups in the commercial catch illustrates that the spring and fall populations of striped bass are the same, then the percentage of immature fish in the spring samples should be the same as the percentage of immature bass in the fall samples after spawning is completed. Likewise the percentage of mature of the early season should be equal to the percentage of spent at the close of the season. The results, plotted in the above graph, show a high degree of correlation.

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made: Since the population of striped bass is the same from spring to the following fall (as illustrated on pp. 71–74, under "Age Groups in the Commercial Catch"), and since the material gathered was at all times representative of this population, it should follow that a very close or even identical relationship should exist between the percentage of mature bass in each age group during the early spawning season and the percentage of spent fish in each age group during the post-spawning season. Likewise, the percentage of immatures taken in the early season would equal that of the immatures taken after spawning was completed. These percentages were compiled and are presented graphically in figure 36, which only illustrates the percentage of mature and spent striped bass. The percentages of immatures are not shown since their figures would be the inverse of the figures for the mature and spent data. Figure 36, however, reveals a striking similarity between the percentage of mature fish in March and April and the percentage of spent fish in the following August and September.

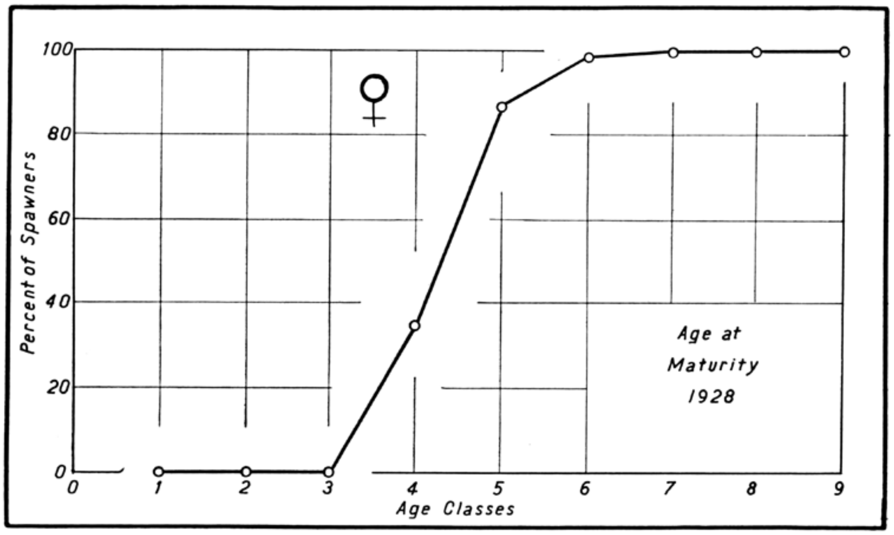

FIG. 37. Of the females, 35 per cent mature and spawn in their fourth year, 87 per cent in their fifth year, 98 per cent in their sixth year, and 100 per cent spawn thereafter. It is not known if each female spawns regularly year after year once she becomes mature; however, it has been shown that she will spawn no more than once a year.

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This information illustrates plainly that it is justifiable to call all ovaries mature which contain a group of eggs having diameters exceeding 0.29 millimeters. These results have therefore produced the following deductions: of the females 35 per cent mature and spawn in their fourth year, 87 per cent in their fifth year, 98 per cent in their sixth year, and 100 per cent spawn thereafter. Though no definite study was made of the males, field observations revealed that a great many mature and spawn in their third year and by their fifth year all are mature. The average lengths of the mature females of each age group are as follows: Four-year class, 50 centimeters; five-year class, 54 centimeters; six-year class, 61 centimeters; and seven-year class, 68 centimeters.

Spawning takes place during the spring and summer months: March to late in July. During this same period the annuli, by which the fish are aged, are laid down on the scales; thus there must be taken into account the fact that some fish spawn before the annulus is formed and others afterward. In other words a four-year-old fish may spawn late in its fourth year or it may spawn very early in its fifth year. Therefore, to avoid confusion as to the actual age at maturity set forth in the preceding paragraph, the striped bass have been classed as mature and spawning late in their respective year groups rather than early in the following year. For example, a fish which began maturing late in its fifth year, yet spawned very early in its sixth year, or just after the formation of the annulus, was classified as having matured and spawned in its fifth year.

4.1.4. SPAWNING

Spawning striped bass were found in the delta region adjacent to Suisun Bay. Here two of the largest rivers in California empty their vast amount of fresh water. In this locality the entire countryside is either flat or slightly rolling, and portions are below sea level. Years upon years of high water floods and ever-increasing silt from the rivers have honey-combed this entire area with scores of islands surrounded by narrow sloughs. Many of these islands are small, but many exceed 30,000 acres in size. The sloughs encircling the islands vary in size and depth; the largest are perhaps 200 yards in width with a depth of 10 fathoms. Many of these sloughs are natural, though a few have been dredged to aid in navigation.

The salinity of the water in this area varies according to the amount of water emptying from the rivers. During the late winter and spring

FIG. 38. A typical slough scene, the habitat of many striped bass. The entire countryside adjacent to Suisun Bay is flat or slightly rolling. Years upon years of ever increasing silt from the Sacramento and San Joaquin rivers have honey-combed this entire area into hundreds of islands, which are surrounded by narrow sloughs. Photograph of E. C. Scofield. April, 1927.

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most of Suisun Bay is all fresh water. From late spring to early winter salt water extends several miles up the rivers and into the sloughs at high tide. During the striped bass spawning season (spring) in this delta country the water is generally fresh, though on the highest tides a trace of saltiness can be detected.[Table 5] .

TABLE 4

Surface and Bottom Water Temperatures of San Francisco, San Pablo and Suisun Bays, and the Adjacent Sloughs and Rivers

Locality	Date	Time	Tide	Bottom temperature, Fahrenheit	Top temperature, Fahrenheit	Air temperature, Fahrenheit	Weather
Vallejo Light	Dec. 28, 1926	9.15 a.m.	High slack	46.5	46.0	44.0	Cold-clear
Vallejo Light	Dec. 28, 1926	2.30 p.m.	Low slack	46.5	46.0	53.0	Sunny
Vallejo Light	Dec. 28, 1926	2.45 p.m.	Low slack	46.5	46.5	47.0	Cloudy
South Hampton Bay	Dec. 28, 1926	4.20 p.m.	Ebb	46.5	46.0	....	Sunny
Benicia	Dec. 29, 1926	8.00 a.m.	Ebb	46.5	44.0	37.5	Foggy
Montezuma Slough	Dec. 29, 1926	9.35 a.m.	High	....	43.5	....	Clear
Montezuma Slough	Dec. 29, 1926	10.15 a.m.	High	43.0	43.0	49.0	Clear
Frost Slough	Dec. 29, 1926	11.15 a.m.	Ebb	....	42.0	....	Clear
Montezuma Slough	Dec. 29, 1926	6.50 p.m.	Ebb	43.5	43.5	....	Dark-clear
New York Slough	Dec. 30, 1926	7.25 a.m.	Flood	43.5	43.5	37.0	Clear
Pittsburg	Dec. 30, 1926	10.10 a.m.	Flood	43.5	43.0	....	Clear
Suisun Bay	Dec. 30, 1926	1.30 p.m.	Ebb	....	44.0	51.5	Clear
Carquinez Strait	Dec. 30, 1926	3.00 p.m.	Ebb	....	46.5	62.5	Clear
Napa River	Dec. 30, 1926	3.15 p.m.	Ebb	....	47.0	....	Clear
Point Pinole	Dec. 30, 1926	4.30 p.m.	Ebb	....	48.0	....	Clear
San Rafael Slough	Jan. 3, 1927	11.30 a.m.	High	52.0	52.5	60.0	Foggy
San Rafael Flats	Jan. 3, 1927	12.15 p.m.	Ebb	....	51.0	....	Foggy
Red Point	Jan. 3, 1927	2.20 p.m.	Ebb	50.5	50.5	78.0	Sunny
Point Pinole	Jan. 3, 1927	4.30 p.m.	Ebb	50.5	51.0	....	Foggy
Sausalito	Jan. 4, 1927	7.45 a.m.	Flood	51.0	50.0	....	Foggy
Water Spout Cove	Jan. 4, 1927	8.30 a.m.	Flood	51.0	51.5	52.5	Foggy
Richardson Bay	Jan. 4, 1927	10.20 a.m.	Flood	50.5	50.5	52.5	Foggy
Vallejo	Jan. 5, 1927	8.30 a.m.	Flood	....	47.5	....	Cloudy
Napa River—Light 1	Jan. 5, 1927	9.00 a.m.	Flood	....	48.5	53.0	Cloudy
Napa River—Light 2	Jan. 5, 1927	9.10 a.m.	Flood	....	49.5	....	Cloudy
Shoal Water Bay	Jan. 5, 1927	10.10 a.m.	Flood	50.5	49.5	58.5	Cloudy
Sonoma Creek Mouth	Jan. 5, 1927	11.30 a.m.	Flood	....	50.0	57.0	Cloudy
Point Pinole	Jan. 5, 1927	1.00 p.m.	High	50.5	50.5	....	Cloudy
Montezuma Slough	April 8, 1927	8.50 a.m.	High		54.0		
Montezuma Slough	April 8, 1927	9.50 a.m.	High		56.0		
Denverton Slough	April 8, 1927	10.00 a.m.	Ebb		57.0		
Dutch Slough	April 8, 1927	3.50 p.m.	Ebb		58.0		
Suisun Flats	April 13, 1927	10.00 a.m.	Flood		55.0		
Pittsburg	April 21, 1927	1.30 p.m.	Flood		60.0		
Mokelumne River	April 22, 1927	7.00 a.m.	High		57.0		
New Hope	April 22, 1927	8.30 a.m.	High		58.0		
Hi Wards	April 22, 1927	11.30 a.m.	Ebb		63.0		
Middle River	April 22, 1927	12.30 p.m.	Ebb		62.0		
Three Mile Slough	April 22, 1927	4.30 p.m.	Flood		60.0		
McNear's Point	May 9, 1927	10.30 p.m.	High		60.0		
Salinas River	May 26, 1927	3.30 p.m.	Low		65.0		
San Rafael Flats	June 9, 1927	8.30 p.m.	High		67.0		
McNear's Point	June 1, 1927	2.00 p.m.	High		66.0		
San Quentin Point	June 1, 1927	11.00 p.m.	Flood		63.0		
San Rafael Flats	June 9, 1927	8.00 p.m.	High		67.0		
Suisun Flats	June 14, 1927	6.00 p.m.	Ebb		73.0		
Denverton Slough	June 16, 1927	12.05 p.m.	Low		70.0		
Suisun Flats	June 16, 1927	3.00 p.m.	Flood		77.0		
Black Point	June 23, 1927	7.45 p.m.	Flood		75.0		
Feather River Mouth	July 7, 1927	2.00 p.m.	....		71.0		
Sacramento	July 8, 1927	....	....		71.0		
Shoal Water Bay	July 12, 1927	....	....		77.0		
Mokelumne River	July 18, 1927	5.00 p.m.	....		75.0		
South fork of Mokelumne River	July 18, 1927	5.30 p.m.	....		73.0		
Mokelumne Mouth	July 18, 1927	6.30 p.m.	....		75.0		
Antioch	July 19, 1927	8.00 a.m.	....		68.0		
Steamboat Slough	July 19, 1927	10.45 a.m.	....		75.0		
Cash Slough	July 19, 1927	1.00 p.m.	....		73.0		
Rio Vista	July 19, 1927	2.00 p.m.	....		74.0		
San Quentin Point	July 20, 1927	5.15 p.m.	....		65.0		
Chicken Creek	July 20, 1927	8.00 p.m.	....		68.5		
Mouth of Chicken Creek	July 20, 1927	8.00 a.m.	....		66.0		
San Rafael Flats	Aug. 3, 1927	10.00 p.m.	Low		73.0		
McNear's Point	Aug. 3, 1927	4.30 a.m.	High		66.0		
San Rafael Creek	Aug. 8, 1927	11.30 a.m.	Ebb		73.0		
San Quentin Point	Aug. 8, 1927	4.15 p.m.	Flood		67.0		
San Quentin Point	Aug. 8, 1927	5.00 p.m.	Flood		67.0		
Chicken Creek	Aug. 9, 1927	9.00 a.m.	Flood		71.0		
Vallejo	Aug. 9, 1927	2.45 p.m.	Ebb		69.0		
Glen Cove	Aug. 9, 1927	4.35 p.m.	Low		64.0		
Martinez	Aug. 9, 1927	5.00 p.m.	Flood		64.0		
Middle Grounds	Aug. 9, 1927	8.00 p.m.	Flood		66.0		
Mare Island Flats	Aug. 15, 1927	2.45 p.m.	High		67.0		
South Hampton Bay	Aug. 16, 1927	3.45 p.m.	Flood		66.0		
Martinez	Aug. 17, 1927	9.30 a.m.	Low		62.0		
Salinas River	Aug. 22, 1927	2.00 p.m.	....		70.0		

TABLE 4

Surface and Bottom Water Temperatures of San Francisco, San Pablo and Suisun Bays, and the Adjacent Sloughs and Rivers

Many of the islands in this region are under cultivation and make rich agricultural land. Because many are below sea level, their levees have been fortified to prevent the winter high waters from flooding the entire basin. In spite of these precautions many of the islands have been completely filled and it is only at considerable expense that the land can be reclaimed. The breaks responsible for the flooding of these islands are sufficiently large to allow the tides to keep up a continual circulation of water within the islands.

It is in these flooded areas that the striped bass appear to spawn in the greatest numbers. Here the special nets used in this investigation captured an abundance of ripe, flowing and spent bass, while in adjacent

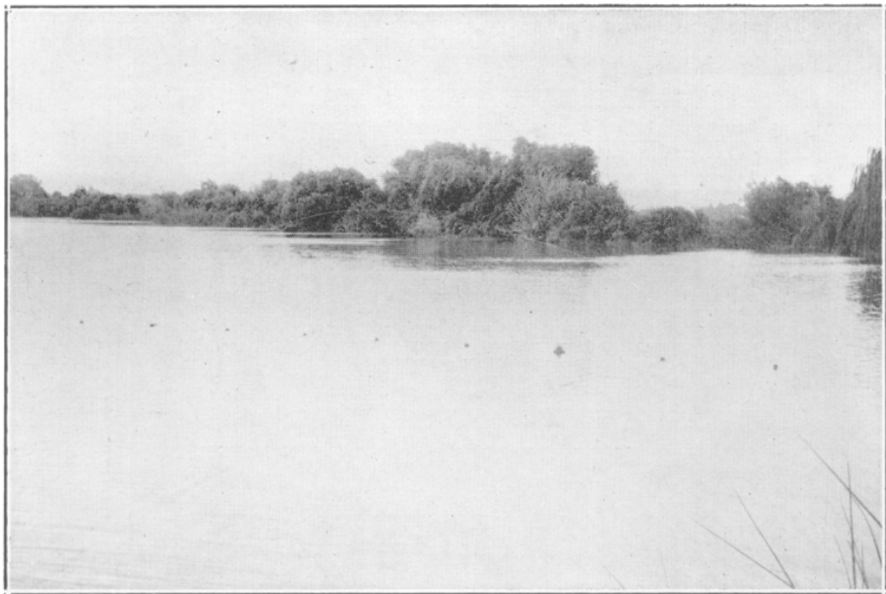

FIG. 39. A typical flooded island of the delta country where the striped bass spawn in large numbers. These large islands, which are below sea level, and save for a fortified levee around their border, are often flooded as a result of high water floods of the Sacramento and San Joaquin rivers. Photograph by E. C. Scofield, June, 1928.

FIG. 39. A typical flooded island of the delta country where the striped bass spawn in large numbers. These large islands, which are below sea level, and save for a fortified levee around their border, are often flooded as a result of high water floods of the Sacramento and San Joaquin rivers. Photograph by E. C. Scofield, June, 1928

sloughs very few were caught. The water in these islands ranges from one to twenty feet in depth, and the bottom is generally muddy though in certain places it supports a heavy vegetable growth of tules and algae. The water temperature ranges from sixty to seventy-five degrees Fahrenheit. San Pablo Bay also has many sloughs flanking its edges, the most prominent of which is Napa River. Many observers claim this to be a natural spawning ground for the striped bass. A few attempts were made to secure spawning bass in this area without success. The salinity and temperature records of this river, however, would indicate that this species may spawn there as well as in the delta country. (Table 4) .

TABLE 5

Water Salinity .n the Spawning Region of Striped Bass

Locality	Date	Tide	Water
Pittsburg	April 21, 1927	-------	Brackish
Mokelumne River	April 22, 1927	-------	Fresh
Middle River	April 22, 1927	-------	Fresh
McNear's Point*	May 9, 1927	High	Brackish
San Rafael Flats*	June 10, 1927	High	Salt
Suisun Flats	June 14, 1927	Ebb	Fresh
Denverton Slough	June 16, 1927	Low	Fresh
Suisun Flats	June 16, 1927	Flood	Fresh
Middle Grounds	June 17, 1927	-------	Fresh
Antioch Bridge	June 21, 1927	-------	Fresh
False River	June 21, 1927	-------	Fresh
Black Point*	June 23, 1927	High	Salt
McNear's Point*	June 23, 1927	High	Salt
Feather River	July 7, 1927	-------	Fresh
Sacramento	July 8, 1927	-------	Fresh
Shoal Water Bay	July 12, 1927	-------	Brackish
Mokelumne River	July 18, 1927	-------	Fresh
South fork of Mokelumne River	July 18, 1927	-------	Fresh
Mokelumne Mouth	July 18, 1927	-------	Fresh
Antioch	July 19, 1927	-------	Fresh
Steamboat Slough	July 19, 1927	-------	Fresh
Cash Slough	July 19, 1927	-------	Fresh
Rio Vista	July 19, 1927	-------	Fresh
San Quentin Point*	July 20, 1927	-------	Salt
Chicken Creek*	July 20, 1927	-------	Salt
San Rafael Flats*	Aug. 3, 1927	Low	Salt
McNear's Point*	Aug. 3, 1927	High	Salt
Middle Grounds	Aug. 9, 1927	Flood	Brackish
Mare Island Flats*	Aug. 15, 1927	High	Salt
South Hampton Bay*	Aug. 16, 1927	Flood	Salt
Martinez*	Aug. 17, 1927	Low	Salt
Salinas River*	Aug. 22, 1927	-------	Brackish
Sonoma Flats*	Nov. 22, 1927	Flood	Salt
Mokelumne River	June 25, 1928	-------	Fresh
Sycamore Slough	July 26, 1928	-------	Fresh
Deep Slough	July 5, 1928	High	Brackish
Sherman Island	July 11, 1928	Flood	Brackish
Broad Slough	July 20, 1928	High	Brackish

* Apart from spawning region.

TABLE 5

Water Salinity in the Spawning Region of Striped Bass

As far as is known the only data regarding the spawning and early life history of this fish on the Pacific coast were presented by Scofield and Coleman in a report published in 1911. During the years 1907 to 1910 these men accomplished some excellent work on artificial fertilization of the eggs and rearing of the young. They reported that the eggs upon being fertilized swell considerably, yet sink in a free condition to the bottom of the hatching jars where any slight disturbance will cause them to rise momentarily. First cleavage takes place about two hours after fertilization. The eggs hatch at the end of forty-eight hours and by the seventh day the yolk sac is completely absorbed. Considerable difficulty was experienced by Scofield and Coleman in securing females in spawning condition. Holding pens were constructed but met with failure. Several commercial fishermen were kind enough to deliver ripe females for stripping, but only a small percentage of these fish proved sufficiently mature to be spawned. Successful fertilization and hatches were recorded from females taken from sloughs and from the flooded islands. In spite of these difficulties sufficient successful hatches were made to give a clear conception of the early development of the eggs and larvae, which in itself was an excellent piece of work.

The present investigation of the spawning of this species has placed the month of May as the time when spawning is at its height. This was accomplished by a study of the maturing ova from month to month.

Eggs begin maturing as early as December, and small males ripen sometimes as early as October. At this time it is quite common to see many flowing males in the commercial catch. It is not known if they retain their milt until the following spring, though during April and May many of these small ripe males are observed. By the first of August both sexes are spent, though an exception to this was observed on August 8, 1928, when a single large mature female was captured.

The size of the ovaries, as well as the number of eggs they contain, varies with the size of the fish. The largest mature ovary recorded measured 9 inches in length and 7¾ inches in circumference. The smallest mature ovaries are approximately 5 inches long and 4 inches in circumference. According to fairly accurate estimates by several observers, the largest ovaries contain well over two million eggs; while the smaller ovaries contain only half a million or more eggs. The ovaries when ripe usually take on a yellowish green color. The main blood vessels are quite prominent, often of reddish hue. As the ovary ripens the eggs break from the inner tissues of the ovary and become free in mucus secretion. The eggs when layed are expelled from the posterior end of the ovary, through the oviduct and out the vent. The males possess testes which when ripe are of creamy-white color. The milt upon being expelled from the vent completely diffuses in the water, leaving only a trace of milkiness. Like the ovaries of the females, the size of the testes varies with the size of the fish.

Only one spawning occurs each year, during which time a single female spawns no more than once. An examination of the ova illustrated this point, since only one group of eggs matured in a single bass during any one spawning season, and no mature eggs were observed at any time other than during March to August. Growth studies have also shown that only one spawning occurs each year, for figure 29 traces growth of the new crop of bass from June throughout the remainder of the year. There is no evidence of the appearance of a new crop at any other period.

4.1.5. MIGRATIONS

Neither on the Atlantic or on the Pacific seaboard has a study ever been made of the movements of the striped bass. Unfortunately, the limited period given to this study of the life history made it impossible to carry on such an extensive investigation. However, what little information has been gleaned during the ecological study of this species may be of some interest to the readers.

In 1879 and 1882, shipments totaling 435 small striped bass were made from the eastern coast and these fish planted in San Francisco Bay. Since that time they have thrived to such an extent that small quantities have been removed from time to time and planted in other coastal regions of California. Apparently none of the plantings was as successful as the original one made in San Francisco Bay, for only a few bass have been reported from these localities to date.

At the present time the bulk of the striped bass is confined to the San Francisco Bay region and along the coast to a distance of 75 miles to the north and to the south of the Golden Gate. To the south, excellent hook-and-line fishing is enjoyed most of the year at Marina Beach, Salinas River, Elkhorn Slough (all in Monterey Bay), Waddell Creek and many unnamed beaches. To the north, Bolinas Bay, Bodega Bay and Russian River all afford fine bass fishing.

Many interested individuals contend that the striped bass which occur in the coastal waters south of the Golden Gate are of a separate race from those of the San Francisco Bay region. The bass, for instance, that inhabit Monterey Bay and its flanking sloughs and rivers, are believed to spawn there year after year. These rather serious contentions on the part of several interested sportsmen led to a study of the population of these fish occurring in this region several miles south of the Golden Gate. The results of this study seemingly disproves the theory that they are a separate population. For instance, no evidence of bass fry was obtained during the spring or summer when they should have been found in great quantities if the mature fish spawned in these southern regions. The smallest bass observed were in their second year or three inches in length and larger. The large bass examined during May, or about the time spawning was in progress in the San Francisco Bay region, contained ovaries in mature condition, but they were far from ripe. Over 95 per cent of the fish examined were females. None of the males were in ripe condition. Another fact noted as a result of seine hauls in Salinas River and Waddell Creek during May, 1927, was the complete absence of the third and fourth year classes. The second, sixth, seventh and eighth year groups were quite evident while the fifth year class was represented by only a few individuals. Samples of specimens received from anglers in this region were well over twenty inches in length, which classed them at five years of age or older. An interesting point was made when sportsmen reported that good catches of large mature bass are made in the spring until May, after which time they apparently disappear and as a consequence very few are taken. Late in July and early August these large bass again appear in Monterey Bay and are caught in considerable numbers. It is not probable that these fish refuse to take the hook during May and June, for in San Francisco Bay anglers have no difficulty in making substantial catches during this period.

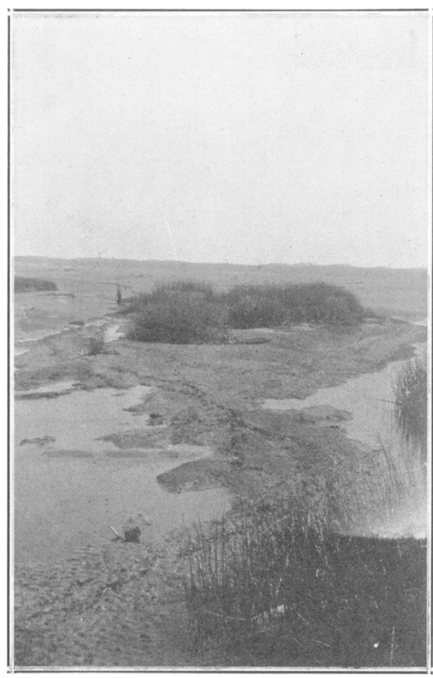

FIG. 40. The mouth of Waddell Creek as it empties into the Pacific Ocean. Here striped bass run in large numbers at times, and excellent hook-and-line fishing is enjoyed by both local and city sportsmen. Photograph by E. C. Scofield, April, 1926

The three main points determined, then, in this investigation of the striped bass found along the coast south of San Francisco Bay are as follows: (1) the absence of ripe bass during the spawning season, and the absence of small fry which would be the result of a spawning in this area; (2) the presence of only the second, fifth, sixth, seventh and eighth year classes, and the total absence of the third and fourth year classes; and (3) the scarcity of large mature bass during May, June and July as reported by anglers.

All of these points seemingly indicate that the movement of the striped bass along the southern coast of California is entirely seasonal, and the spring months reveal a migration of mature bass back to San Francisco Bay for the purpose of spawning.

In the north, however, the circumstances are quite different. A group of striped bass have apparently isolated themselves at Coos Bay, Oregon, about 400 miles north of San Francisco. This bay now affords a small bass fishery amounting to about 16,000 pounds a year or more. It was not until 1918 that the bass were noticed there in any great numbers. Since that time a good market has been established for them and the catch is increasing annually. The main run occurs during the spring of the year just prior to and during the shad run. This bass run, according to Oregon dealers, comes in from the ocean and continues up into the sloughs where the bass spawn. Though there is no actual proof, the striped bass of Coos Bay apparently have completely split from the San Francisco Bay race. The great distance lying between these two points and the fact that the yearly abundance is on the increase at Coos Bay seem to bear out this assumption.

To date two striped bass have been reported from the Columbia River which is about 600 miles north of the Golden Gate. This point is their farthest northern range, while the southernmost limit is Los Angeles County, about 250 miles south of the Golden Gate.

Movements of the striped bass inhabiting the San Francisco Bay region are characterized by two apparent features—spawning and feeding. Throughout the winter they are inactive and the commercial catch is light. During the spring the catch increases, and in May just before the commercial season is closed, some of the best net catches are made. During this time the bass are caught periodically. For several days fishermen make fine catches; then gradually the total catch drops. For the next few days fishing is poor until a few fishermen report excellent catches in lower Suisun Bay again. As these periodical catches subside the fishermen will attempt to follow the run, or what they believe to be an "ocean run," up to the upper Suisun Bay and into the rivers. Movements such as these occur each spring. When the season reopens in August and spawning is over, the fishermen go to lower Suisun Bay to net, for there they make their best catches. offhand this action would indicate that many bass move back to salt water after spawning. This theory is borne out by the fact that heavy feeding is done immediately after spawning, as has been learned from food studies. The lower bays (San Francisco and San Pablo) with their ocean water and endless mud flats undoubtedly possess a far better food supply than the delta country. A great many bass, however, remain around the spawning area and in the sloughs.

During July and August, anglers have reported excellent fishing in this vicinity and in the main rivers. Bass have been taken 250 miles up the Sacramento River and 100 miles up the San Joaquin. The flooded islands also support a great many bass at this time for crustaceans and marine worms are in abundance in these areas.

The foregoing account of the movements of striped bass is based on the few facts which are known, coupled with personal observations and assumptions of men trained in fishing for this species. A few of the author's own speculations have been added since he was able to observe carefully over a period of five years the habits of this species. It must be realized, however, that no definite conclusions can be drawn on the migrations or the causes until an accurate marking or tagging experiment can be carried out. Until then, we must be content with the knowledge now available.

4.1.6. FOOD[3]

The striped bass feed the heaviest between April and the following October. During this period they become fat and apparently lose a great deal of the vigorous activity characteristic in the fall and winter. According to fishermen, during the spring and summer these obese fish are very easily caught for once they are gilled in the net they offer little or no fight to free themselves. During the fall and winter, however, gilled bass will fight the net and many times will gain their freedom after breaking the meshes. These "fall bass," as the fishermen term them, are extremely active and difficult to catch. They are gracefully thin and their silvery colors make them very attractive.

During the spring months the bass move about in large schools on the extensive mud flats of upper San Francisco, San Pablo and Suisum bays. During the high tides when the flats are covered, these schools move upon them and feed heavily upon periwinkles, small crabs, marine worms and many small crustaceans. As the tide recedes the bass leave the flats and seek deep water just outside. Here the small shrimps form their main diet. Very often they single out the young of anchovies, herring, smelt and split-tails, as well as their own young. During the late fall and winter their diet is extremely light. Stomachs examined during this period show only traces of digested food though on one occasion a single split-tail fish was removed from the stomach of a large bass.

Spawning bass feed continually during the process of laying their eggs. Examinations of mature bass always revealed stomachs fairly well filled with crustaceans, small fishes and digested food. After spawning, feeding continues, only in a more serious manner. Some bass remain around the spawning area and feed inside the flooded islands. Some seek the sloughs and others proceed up the Sacramento and San Joaquin rivers for many miles. The majority of the bass, however, apparently return to the salt water, for the main commercial catches are made in lower Suisun and San Pablo bays at this time. It

[3] The study of the food of the striped bass was given a minor consideration in this report. Only the essential details of their feeding habits were covered, especially those governing their movements. Random examinations of stomach contents were made throughout the year. These random samples were usually made up of a dozen or more fish from the same boat-load or from the same seine-haul. No attempt was made to make a quantitative study of the variety of food contained in their stomachs.

is needless to say that this body of salt water affords far greater quantities of food than does the fresh water of the delta country.

The bass along the coast to the south and north of the Golden Gate undoubtedly find food in abundance. Only one examination was made of the stomach contents of these bass. On this occasion the fish were in the mouth of the Salinas River and just outside in the breakers. The entire school was feeding on Velella (Portuguese man-of-war). Along the beaches of this State the bass move up into the surf where they are caught by anglers who cast from the beach. Some sportsmen state that the bass are then feeding on all forms of small beach fishes, such as the perch and smelt.

Apparently the striped bass have no main diet. They feed on a great number of marine animals and usually on the species of animals most abundant at the time. Some questions regarding young chinook salmon as one of the foods of the bass have been repeatedly called to attention. During this investigation no salmon have ever been observed in the stomach of a bass. The lack of small salmon as a result of the serious depletion of this race is the probable reason none has been found in the stomachs of the voracious striped bass.

4.1.7. **SUMMARY OF THE LIFE HISTORY OF STRIPED BASS**

1. The age can be determined with accuracy from the scales.
2. Scales for aging should be taken from above the lateral line between the two dorsal fins.
3. Scale reading should be done under a low power compound microscope.
4. Scales should be moist while being aged.
5. Otoliths and opercles can be used for age reading.
6. Length frequencies afford a rough method of obtaining the age of fish up to four years of age, as well as a specific check on scale reading.
7. The rate of growth can be obtained from average lengths.
8. The rate of growth up to 70 centimeters can be obtained more accurately by computing their lengths from scales, using the formula:

$$l = \frac{(L-1)\ l'}{L'} + 1$$

since:
–a. Scales from the mid section of a striped bass are all representative of the growth of the fish.
–b. The scales and the fish grow with proportionate rapidity up to the time the fish reaches a length of 70 centimeters.
–c. The striped bass are 1 centimeter long when the scales are first formed.
9. Striped bass fry grow rapidly from June, when they first appear after hatching, until the following October. From then to April growth practically ceases.
10. Mature bass have the same periods of growth and dormancy as do the immature.
11. Of the females, 35 percent mature and spawn in their fourth year, 85 percent in their fifth year, 98 percent in their sixth year, and 100 percent spawn thereafter. Of the males, a great

many mature in their third year, and by their fifth year all are mature.
·12.Striped bass spawn in both fresh and brackish water of a temperature range of 60 to 75 degrees Fahrenheit. The spawning area is located in the region adjacent to Suisun Bay and many miles up the Sacramento and San Joaquin river country.
·13.The flooded islands appear to be the choice spawning grounds as compared to the open slough and rivers.
·14.Striped bass spawn from 500,000 to 2,500,000 eggs a season.
·15.Only one spawning season occurs during a year (March to August), and each female will spawn no more than once during this season.
·16.The eggs are demersal, thus they come to rest on or close to the bottom after they are laid and fertilized. They hatch in 48 hours and the yolk sac is absorbed after 7 days.
·17.A single population of striped bass appears to occur in the San Francisco Bay region. It is believed that the bass which occur along the coast of California are entirely migratory and are part of the San Francisco Bay population or race.
·18.Striped bass appear to be moving northward, as Coos Bay, Oregon, for the past twelve or thirteen years has had an annually increasing commercial bass fishery. Two bass have been reported as far north as the Columbia River.
·19.A knowledge of migrations is of vital importance to protect adequately a fish and fishery. No definite knowledge of the movements of striped bass can be attained until a marking or tagging experiment is launched.
·20.These fish are voracious eaters. Practically every marine form common to the San Francisco Bay region has been found in their stomachs. Their food includes fishes, such as small herring, smelt, anchovies, split-tails, striped bass, shad, gobies, carp, and perch; crustaceans and mollusks — crabs, shrimps, periwinkles, clams; and various other forms such as worms, copepods and Velella.
·21.Bass feed the heaviest during the spring and summer months. Spawning bass feed while on their spawning beds.
·22.The bass feed heavier in the salt water.

5. PART III THE COMMERCIAL CATCH OF STRIPED BASS

5.1. PART III THE COMMERCIAL CATCH OF STRIPED BASS

Although striped bass were introduced into California at a comparatively recent date, they have increased greatly in numbers and promise to grow into a major fishery if adequate protection can be guaranteed. Under the present protective measures these fish continue to increase in numbers but as the exploitation of this resource is quite likely to increase in intensity, the species deserves careful study in order that we may guard against too intensive fishing.

The essentials of a study are mainly the life history and an analysis on the effects of exploiting interests. The life history study has been completed and already presented in this report. In analyzing the effects of exploitation the commercial net has been selected as the one which should bear the closest watch. The following report, therefore, deals with the study of the commercial catch followed by a weighting of the facts of life history against an analysis of the commercial catch in order to determine whether the present laws regulating the net catch are adequate to properly conserve the striped bass.

Fortunately, a great deal was already known about the habits of the striped bass. Furthermore, the fact that commercial fishing is carried on within a very limited area, and that there is uniformity of gear employed year after year for the capture of these fish, would convince one of the possibility of completing an analysis of the commercial catch in a limited period of time. At the outset of this investigation it was realized that in analyzing the commercial catch two alternatives could be chosen—either a thorough analysis covering all phases of the problems which would undoubtedly spread over a score of years, or a general analysis covering only the major problems. The latter was chosen since, as explained, the conditions were such that a general analysis would no doubt give as accurate results as that of a technical study and in a very limited time. Furthermore, a general study was very necessary for at the time the work was begun, considerable agitation was prevalent regarding the belief that the commercial fishing gear was seriously depleting the supply. It was essential, therefore, that a study be made at once regarding the striped bass fishery as immediate results were necessary.

To arrive at general conclusions from an analysis of the commercial catch, careful consideration was given to the major problems which would most likely give such immediate results. First among these problems was to learn the percentage of the age groups that comprised the commercial catch. Not only was this to be compiled for an entire season but from month to month as well. The results of this study when associated with the already known age at maturity, would reveal the extent of the protection already being offered the mature fish by the enforcement of the present minimum 5½-inch mesh law for nets.

Closely associated with this study was that of determining if the nets catch the same size fish each year. A variation in the average lengths of striped bass from year to year would tend to complicate practically all of the problems. Length variations are not uncommon in a fishery, for there often occur dominant year groups. Perhaps a very successful spawning year resulted in an over-abundance of this single age group. As the individuals of this group become of a length readily caught in the commercial gill nets they will, because of greater numbers, outweigh the individuals of the other age groups in the catch. As long as this group remains of a size to be caught in the nets, which may be from two to three years, it will form the greatest percentage of all the age groups within that catch. If such a situation does occur one would expect that the average length of the entire catch would be largely controlled by this one age group. This is very often the case and usually reveals itself when the seasonal length frequencies are plotted and the modes are seen to shift to the right year after year as a result of the growth of this dominating age class.

The remaining problems in analyzing the commercial catch were mainly dependent on the results of the two studies stated in the preceding paragraph. of these, perhaps the most important was the study of selectiveness of the gear employed. This related to the average length of fish which the nets select from each age group. For instance, a uniform gill mesh size would perhaps select only the largest of the younger age groups and the smallest individuals of the older age groups. If such a condition were to occur it would be extremely important to determine the extent of this selectiveness. Another study of minor importance was the sex ratio. Undoubtedly the two sexes vary considerably from month to month and it was advisable to learn the exact ratio. The remaining study was that of determining the exact period of spawning in order to show the portion of the actual spawning period protected by the present closed seasons. These several problems concerning the commercial catch are presented in the following pages. Each problem is discussed separately and in each an account is given of the methods employed and results attained. In a following section, "Conclusions" (pp. 77–80), each of these results is carefully applied to the already known facts of the life history of the species.

5.1.1. METHODS OF SAMPLING

Sampling of the commercial catch of striped bass was begun in September, 1925, and ceased in October, 1928. During 1925 and 1926, only random sampling was carried on. From March, 1927, to October, 1928, samples were taken daily whenever possible, with the ultimate aim of securing approximately 200 specimens a week. Samples were taken of entire boat-loads when possible to insure against selectiveness. Generally, however, the samples had to be taken from fishing tenders or pick-up boats which combined the catch of several fishing boats. In this instance a representative group was set aside for the sample; usually a full box used in unloading the tender. Each specimen was then worked on while in a fresh condition. The total body length was measured to the nearest centimeter, this measurement being made from the tip of the snout over the body to the tip of the central caudal fin rays. The sex was then determined and the condition of the gonads or testes noted. A sample of scales was then removed from above the lateral line between the two dorsal fins and placed between two pieces of paper to dry. The captain of the fishing boat or tender was then quizzed in order to learn the approximate locality in which these fish had been captured. Under favorable conditions the weight of each fish was taken to the nearest quarter-pound. During the closed seasons when commercial nets were out of the water, fishermen were hired to operate regulation nets for the capture of specimens to fill the gap in the sequence of samples. During the entire investigation 431 samples were taken resulting in the observation of 4753 individuals. No waste of these fish was caused since the samples obtained from the commercial plants during the open season were in no way injured and dealers accepted them without hesitation. During the closed season all samples were turned over to charity.

5.1.2. EXPLANATION OF THE TERM "SEASON"

During a calendar year there are two open seasons for the netting of striped bass: August 1st to September 17th, and November 14th to May 15th of the following year. Total yearly catches such as are recorded in Table 1 are arranged by calendar years—January 1st to December 31st. However, in treating these commercial catch data statistically it has been found more logical to coin the term "season," meaning the open periods for fishing which lie between August 1st and the following May 15th. Not only does this arrangement simplify the handling of the statistical data, but it presents the desired results to the reader in a more understandable manner. In brief, the reasons for establishing such a season are twofold: (1) Because the annulus, by which the age of the striped bass is determined, is formed on the scales during the spring months, each individual fish remains the same age from August 1st to May 15th. At the close of this period they have completed a year's growth and therefore automatically pass into the ensuing year. Because all fish remain the same age during this annual season extending from August 1st to May 15th, the task of comparing and weighting the age group percentages of the commercial catch from the fall to the winter and from the winter to the spring is greatly simplified. (2) The individuals of each age group grow but very little from August 1st to May 15th, as the greater portion of their annual growth is incurred during the spring and summer months. This fact simplifies the comparison of the average lengths of the age groups selected by commercial nets from fall to winter and winter to spring.

5.1.3. COMMERCIAL CATCH SAMPLES FOR THREE SEASONS, 1926–1927 TO 1928–1929

The commercial catch samples were combined by seasons as stated in the preceding paragraph and the length frequencies plotted in figure 41. This graph illustrates clearly the selectiveness of the commercial nets. These nets are not restricted to a maximum mesh, but are required by law to have a minimum mesh of 5½ inches when stretched. Fishermen choose the minimum mesh since this gear will select from the more abundant fish comprising the younger age classes. In the spring months, however, a great many fishermen discard their bass nets for shad nets which range in size from 5# to 6½ inches. Though these nets are intended for shad alone, they do capture a great number of striped bass, and due to the large meshes these bass average longer than the fish taken in the 5½-inch mesh bass nets. This fact must be taken into consideration while examining the length frequencies of the seasonal commercial catch samples which appear in figure 41. The length frequencies of a sample selected from the catch during November, December and January form a normal distribution, as is illustrated in figure 42. During this period only striped bass are present and the customary 5½-inch mesh nets are used entirely. A normal frequency distribution results from such samples because a definite size mesh selects a fish of a certain length, but of course this selection varies somewhat in either sex according to increase or decrease in weight throughout the season. However, lengths plotted for an entire season

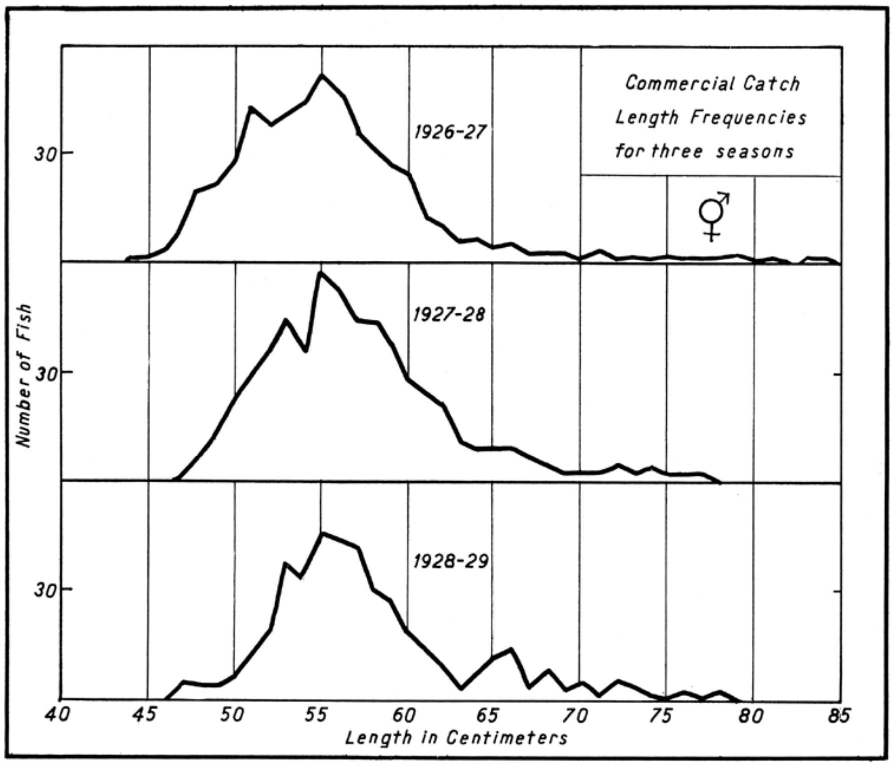

FIG. 41. Commercial catch sample frequencies for the three seasons, 1926–1927, 1927–1928, 1928–1929. A single season extends from August to May.

FIG. 41. Commercial catch sample frequencies for the three seasons, 1926–1927, 1927–1928, 1928–1929. A single season extends from August to May

establish one definite mode. The frequency distribution falling on either side of this mode is normal since a 5½-inch mesh net captures the smaller as well as larger striped bass only by chance. The smaller and larger bass do not gill in the net, but become snarled, and the two have an equal chance of becoming entangled. Referring to figure 41 again, it seems that a normal length frequency distribution is not present but that the larger mesh shad nets operated in the spring have enlarged and prolonged the distribution to the right of the mode as a result of the capture of larger striped bass.

The frequency distributions to the left of the main modes in figure 41 are normal save for the small mode occurring at about 53 centimeters. This mode is made up of males which in the commercial catch average close to 2 centimeters less in length than the females. This fact is illustrated in figure 42, which plots the length frequencies of the males from month to month. The fact that the males average smaller than the females is shown fully on pp. 67–68. As can be seen in figure 42, the nets tend to select males which average about 53 centimeters in length, whereas these same nets select females at 55 centimeters in length.

Figure 41 reveals still another fact which is of prime importance. The modes of the seasonal length frequencies occur at 55 centimeters during the three seasons from 1926–1927 to 1928–1929. The stability of the gear used in the capture of striped bass year after year is of course instrumental in bringing this about. However selective this gear may be, there may have been the possibility that the nets would have selected from dominant year groups as explained in the foregoing pages. In this instance the average lengths of the combined year groups comprising the commercial catch would have varied from year to year, depending upon the average length of the dominant year group. The variations in these average lengths would of course have revealed themselves in the position of the mode of the seasonal length frequencies. Therefore, since the modes in figure 41 remained consistently at 55 centimeters for three seasons, there is little doubt but that the gear employed in the capture of striped bass was selective to the size of the fish and not to the dominant year groups which may or may not have been present. There is a strong possibility that dominant year groups do enter into the commercial catch and that they cause the average lengths to vary less than a centimeter from year to year; but evidently they in no way affect the stability of the modes of the length frequencies. Since the error, which might arise from the presence of dominant year groups in the commercial catch, is so small it has been deemed justifiable to base all conclusions on the data collected for the two seasons 1927–1928 and 1928–1929.

5.1.4. LENGTH FREQUENCIES OF THE MONTHLY COMMERCIAL CATCH SAMPLES

The commercial catch samples secured during the seasons of 1926–1927 to 1928–1929 have been treated by months, the results of which are illustrated in figure 42. This graph reveals more clearly how the larger mesh shad nets affect the length frequency distribution in the spring months in so far as they catch larger striped bass. Note that beginning in March the normal mode occuring at 55 centimeters commences to lose its prestige, giving way to an influx of larger individuals. In April the mode, though split, has advanced approximately 3 centimeters and the distribution to the right has grown considerably due to the netting of extremely large striped bass. From May 15th to the following August 1st the season for netting is closed. In August when the shad run has vanished, only the 5½-inch mesh striped bass nets are used; thus the mode of the length frequency distribution falls back to 55 centimeters again, where it occurred the preceding winter. In September, however, the mode again shifts to the right about 2 centimeters, and the number of large bass are seen to increase. In September the heaviest salmon fishing is done, and in capturing these fish, nets ranging in mesh from 7½ inches and upward are employed. As a result the large bass caught by these salmon nets tend to overweight the mode of the length frequency distribution made up of bass caught by the

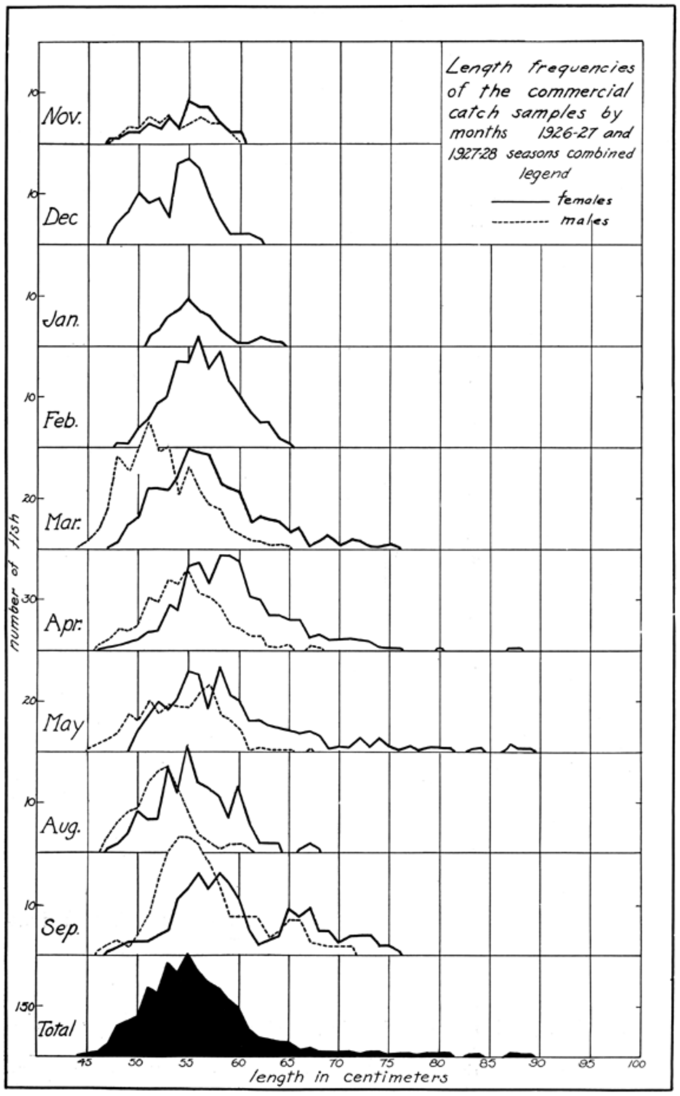

FIG. 42. Samples of the commercial striped bass catch for the two seasons, 1926–1927 and 1927–1928, combined by months. Note the shorter average length of the males. The total length frequency illustrates the selectivity of the nets. The tendency for these nets is to select fish at 55 centimeters in length, though in the spring and fall months the average length of the fish caught is increased. This is due to the employing of larger mesh nets at this time, namely, shad and salmon nets. Note that the larger mesh nets increase and prolong the frequency distribution to the right of the main modes, commencing in March and ending in September.

(66)

FIG. 42. Samples of the commercial striped bass catch for the two seasons, 1926–1927 and 1927–1928, combined by months. Note the shorter average length of the males. The total length frequency illustrates the selectivity of the nets. The tendency for these nets is to select fish at 55 centimeters in length, though in the spring and fall months the average length of the fish caught is increased. This is due to the employing of larger mesh nets at this time, namely, shad and salmon nets. Note that the larger mesh nets increase and prolong the frequency distribution to the right of the main modes, commencing in March and ending in September

5½-inch mesh nets and the mode tends to split. As is seen in figure 42, the distribution is bimodal though there is an advance of the mode on the left to 56 centimeters.

The consistency of the mode occurring at or close to 55 centimeters illustrates that the gill nets commonly used, select only striped bass which are small enough to gill or to be caught about the girth of their stomachs as they attempt to pass through the meshes. This fact then reveals why the males average approximately 2 centimeters less in length than the females in the commercial catch. The males up to 60 centimeters in length average one-half pound more than females of the

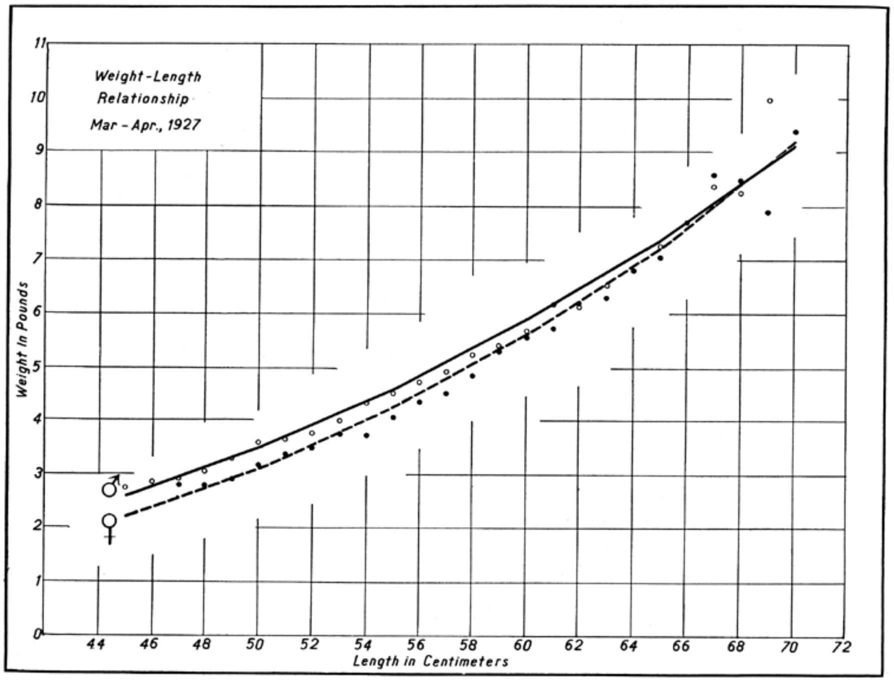

FIG. 43. The weight-length relationship of males and females of the commercial catch, March and April, 1927. Small males average close to one-half pound more than the females. The older males, however, weigh less than the females. This relationship illustrates why the males in the commercial catch average much smaller than females during the spring months. The formula used in this study $W=FL^x$; where W represents the weight; L, the length; F, the factor which differs for different species, but varies for any one species only as the weight then fluctuates in relation to the cube of the length; and $^{(x)}$ the power to which L must be raised in order to express the relation between weight and length.

FIG. 43. The weight-length relationship of males and females of the commercial catch, March and April, 1927. Small males average close to one-half pound more than the females. The older males, however, weigh less than the females. This relationship illustrates why the males in the commercial catch average much smaller than females during the spring months. The formula used in this study $W=FL^x$; where W represents the weight; L, the length; F, the factor which differs for different species, but varies for any one species only as the weight then fluctuates in relation to the cube of the length; and $^{(x)}$ the power to which L must be raised in order to express the relation between weight and length

same length. Since the males' advantage in weight is noticeably only in the stomach, the girth is enlarged sufficiently to enable the 5½-inch mesh nets to take a great number of these shorter males, hence the mode at 53 centimeters in figure 41 and the smaller average length of the males as a whole in the commercial catch.

This deduction was drawn after a detailed length-weight relationship of the two sexes had been determined. In the spring of 1927, 772 individual bass were measured for their total length and then weighed to the nearest quarter-pound. The bulk of this material was made up of bass under 70 centimeters in length, therefore the weight length relationship was established only up to that point. Material was lacking in the earlier stages since the commercial nets select bass 45 centimeters in length and longer. The weight-length relationship was then established from the formula: $W = FL^x$; where W represents the weight; L, the length; F, the factor which differs for various species but varies for any one species only as the weight fluctuates in relation to the cube of the length; and x, the power to which L must be raised in order to express the relation between weight and length. The outcome of this specific problem is presented graphically in figure 43. The points represent the average weight at each length unit as derived from the original weight-length data. The solid line and the broken line are fitted to these points from the formula: $W = FL^x$, the former being that of the male weight-length relationship and the latter that of the females. As will be seen the males from 45 to nearly 60 centimeters in length are approximately one-half pound heavier than the females. The males beyond 70 centimeters in length, however, weigh less than the females. Though this study was based on material secured in March and April, 1927, it is firmly believed that the resulting weight-length relationship exists in a like manner throughout the remainder of the year since the length frequencies of the monthly commercial samples (see figure 42) show that in each month when the males were sampled they averaged from 1 to 3 centimeters shorter than the females. ([Table 6] and [Table 7] .)

The foregoing discussion has been concerned with the causes of the shift of the modes in the length frequency distributions of the monthly commercial catch samples. In summing up this discussion there are five points which should be borne in mind. First, the 5½-inch mesh bass nets select female fish at 55 centimeters in length, and the length frequency of a sample taken from such a net would form a normal distribution, that is, the smallest bass taken are 45 centimeters in length and the largest 65 centimeters, while the mode lies at 55 centimeters. Second, the commercial gill nets select fish from a very limited length range, and as a result the modes of the length frequencies of the catch remain at one point year after year, namely, 55 centimeters. This fact eliminates the possibility that the nets might select from dominant year groups. Third, during the spring months when the shad nets are used extensively the mode tends to advance to the right somewhat while the total distribution to the right swells considerably. This is due to the use of these larger mesh shad nets which capture larger bass. Fourth, salmon nets as well as shad nets are responsible for the taking of larger striped bass. Fifth, the males selected by the commercial nets average 2 centimeters less in length than the females because they are fatter, weighing one-half pound heavier on the average.

5.1.5. SEX RATIO

During the course of sampling the commercial catch in the field, it was quite noticeable that through the winter and early spring there occurred a superabundance of males. Upon questioning fishermen it was learned that they had recognized this fact for years, their opinion being that the winter and spring run was made up of spawning migrants, and as occurs among a number of anadromous fishes the males precede the females to the spawning grounds. This fact appeared worthy of note; thus all the commercial sample data gathered from 1925 to 1928 were scrutinized to obtain the sex ratio from month to month as well as the yearly average ratio. The results as shown in figure 44 bear out the observations of fishermen. In February the

TABLE 6

The Weight-Length Relationship Data of Striped Bass for March and April, 1927
Females

Length of fish in centimeters	Weight in pounds (females)																		
	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00	6.25	6.50
45																			
46																			
47				1															
48			1		2														
49			1	2	4		1												
50					2	4	1												
51					3	9	2	1	2										
52						4	6	1	1										
53							4	3	2	1									
54						2	8	0	7	1									
55								5	12	1	2	1							
56								1	3	9	3	2	2						
57									2	10	7	4	2		1				
58									1		6	5	10	2	1				
59											1	2	7	9	5	2	2		
60												2	8	1	5	1	5	1	1
61													1	2	6	4	2	2	1
62															3	3	4	2	
63													2		2	1	3		2
64															1		2	2	3
65														1	1		1	1	
66																	1		1
67																			
68																			
69																			
70																			
Totals	---	---	2	3	11	19	22	11	30	22	19	16	32	15	25	11	20	8	8

Length of fish in centimeters	Weight in pounds (females)																					
	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75	Total number of fish
45																						---
46																						---
47																						1
48																						3
49																						8
50																						7
51																						17
52																						12
53																						10
54																						18
55																						21
56																						20
57																						26
58																						25
59																						28
60	1	1																				26
61																						18
62	1	3	1																			17
63		3			2																	15
64	5	2			2	2																19
65	1			2	2	2		1														12
66	1	2	1	2	1	3	1						1	1								15
67		1				1	1	1			1					1						6
68		2				4				2		1				1						10
69					2	1	1			1				2		1				1		9
70							1	1			1			2	1							6
Totals	9	14	2	4	9	13	4	3	---	3	2	1	1	5	1	3	---	---	---	1	---	349

TABLE 6
The Weight-Length Relationship Data of Striped Bass for March and April, 1927
Females

TABLE 7

The Weight-Length Relationship Data of Striped Bass for March and April, 1927
Males

Weight in pounds (males)

Length of fish in centimeters	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75
45				2												
46				4	4											
47			1	4	11	1										
48			1	2	15	9			1							
49					8	4	7		1	1						
50					1	6	8	4	2	1						
51					2	4	10	6	3	1	1		1			
52						2	7	2	9	2						
53							3	10	10	6	1		1			
54							1	3	6	4	7	1				
55									2	7	8	5	2	1		
56									1	3	10	4	9	1		
57										4	4	4	8	2	4	1
58											1	4	17	14	3	1
59												2	8	1	6	4
60												2	3	1	5	5
61														1	2	2
62												1			1	3
63																1
64																
65																
66																
67																
68																
69																
70																
Totals			2	12	41	26	36	25	35	29	32	23	49	21	21	17

Length of fish in centimeters	6.00	6.25	6.50	6.75	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25	9.50	9.75	10.00	10.25	10.50	10.75	Total number of fish
45																					2
46																					8
47																					17
48																					28
49																					21
50																					22
51																					28
52																					22
53																					31
54																					22
55																					25
56																					28
57																					27
58	4	1																			45
59	2																				23
60	7																				23
61	4	1	1	2	2																15
62	4	1	1		2			1													14
63	2				1				1												5
64	1	1		2					1												5
65	1		1				1		2												5
66																					0
67									2			2									4
68									1		1										2
69																	1				1
70																					0
Totals	25	4	3	4	5	0	1	1	7	0	1	2					1				423

TABLE 7
The Weight-Length Relationship Data of Striped Bass for March and April, 1927
Males

males averaged 86 per cent of the commercial catch, but in the following months they rapidly lost their superiority in numbers until in April both sexes occurred in equal abundance. During the spring months the females predominated, but in the summer commencing in August they were once more on a par with the males. The average yearly sex ratio revealed that the males predominated in the commercial catch as they averaged 56.5 per cent and the females 43.5 per cent.

5.1.6. AGE GROUPS IN THE COMMERCIAL CATCH

As pointed out in the section covering the female length frequencies of the monthly commercial samples the mode varies from month to month, especially in the spring and fall. During these two seasons the average length of the females captured is increased from one to four centimeters. As explained, this is due to the employment of larger mesh gill nets at this time, namely, shad and salmon nets. This selection on the part of the larger mesh nets would naturally include fish of greater age. This being true, it would be best to establish the percentage of the age groups within the commercial catch for three

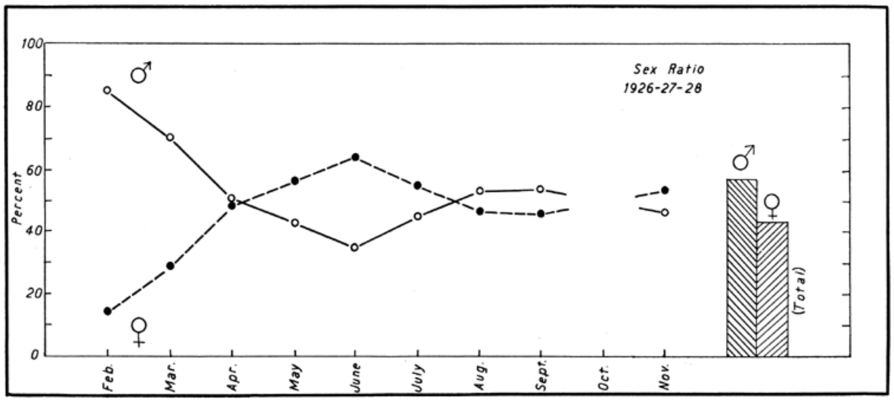

FIG. 44. The percentage of males and females in the commercial catch by months. This illustration bears out the general belief that the males precede the females on their spawning migration since spawning commences in March.

FIG. 44. The percentage of males and females in the commercial catch by months. This illustration bears out the general belief that the males precede the females on their spawning migration since spawning commences in March

separate seasons—the fall, winter and spring. As the greater portion of the summer period is closed to commercial fishing this was omitted. Data for this information were secured from the 1927–1928 season, since in this period the samples were adequate for each month of the open season.

In the spring months the bulk of the catch of females is composed of 5-year-old striped bass. The remaining age groups occurring in the catch in the order of their abundance are as follows: 6, 7, 4, and 8. (Fig. 45). Table 8 gives the percentages of each age group, showing that the 5-year-olds compose 55.9 per cent of the total catch and the 6-year olds amount to 28.5 per cent. The three remaining age groups compose about 15 per cent of the catch and are therefore of little weight. This selectiveness continues during March, April and May. During the latter part of this period the annulus by which their age is determined is formed on the scales of the fish. Therefore, in June or a little later each age group has passed into its next year. When the commercial season reopens in August, one would expect to

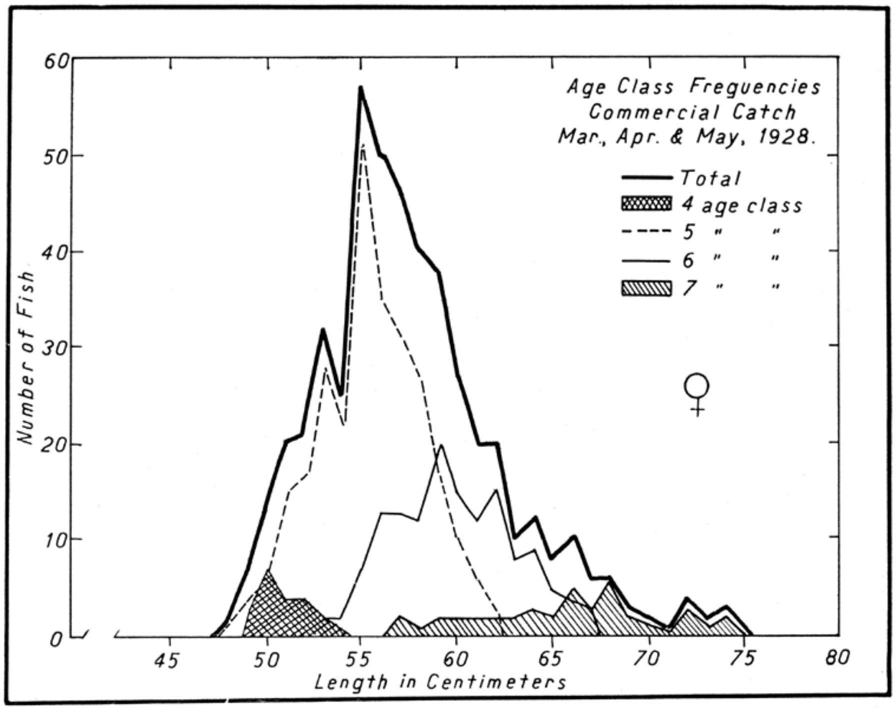

FIG. 45. The female age groups which compose the commercial catch samples for March, April and May, 1928. As a result of age determinations of the total samples, separate frequencies were drawn of each age group. The results illustrate that the nets used in the spring draw mainly on the 5-year group

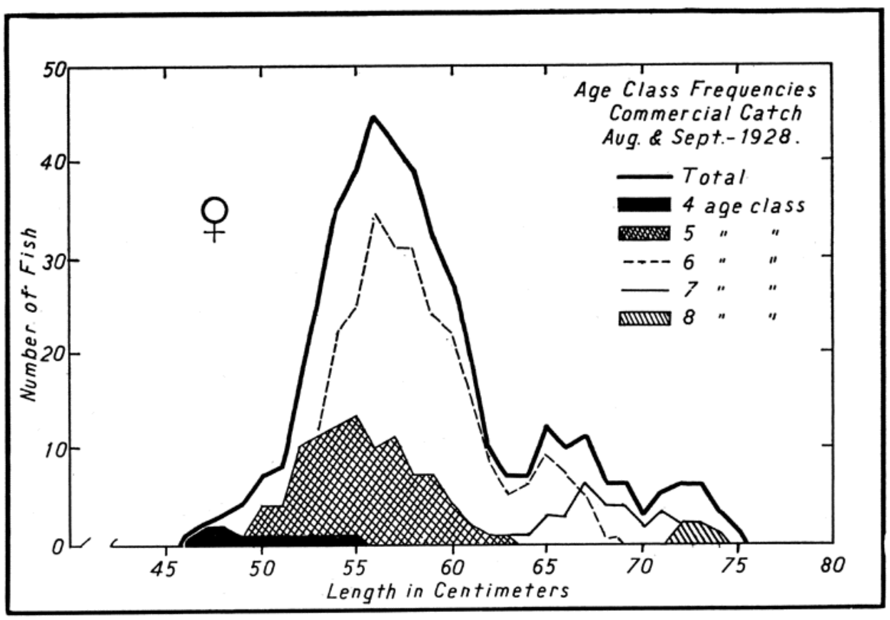

FIG. 46. The age groups which compose the commercial catch samples for August and September, 1928. By aging the striped bass in the commercial samples, separate frequencies were thus evolved for each age group. The results show the nets used in the fall draw largely on the 6-year group having a mode at 56 centimeters

find, upon analyzing the age groups in the catch, an abundance of 6-year-olds, or the age group which was the most abundant in the previous spring months. Figure 46 illustrates that such is the case. Here the 6-year-olds form 62 per cent of the commercial catch and the 5-year-olds are next in abundance, forming 22.8 per cent. The 7-year-olds, which were second in abundance the previous spring, have dwindled to 7.6 per cent. This is very interesting since it illustrates the selectiveness of the gear employed for the capture of these fish. For instance the spring catch of 4-year-olds as selected by the gill nets average 51 centimeters in length; yet the average length of the 4-year-old population is, at this time, only 46 centimeters. Thus, the commercial nets, in the months of March, April and May select 4-year-old bass which average 5 centimeters longer than the normal population. During the following fall months, however, this single age group grows to an average length of about 53 centimeters or a size which enables the gill nets to catch them in greater quantities than they did the previous spring. This point is more clearly brought out in table 8, for as will be observed the 4-year-olds in the commercial catch total 5.3 per cent in the spring months, yet during the following fall, as 5-year-olds, they total 22.8 per cent of the entire catch. From the fall to the following spring the individuals of the 5-year-old population grow very little in length. By March and April they average 54.2 centimeters and the commercial nets select a little above that length or 55 centimeters. During the next August and September these same fish, as 6-year-olds, grow to an average length of 61.2 centimeters. This increase in length of 7 centimeters from the spring to the following fall apparently does not hinder the commercial nets from capturing them during August and September with the success equal to that of the previous March, April and May, for in table 8 is shown that this age class composes 55.9 per cent of the commercial catch in the spring and 62 per cent the following fall.

TABLE 8

The Percentage of Female Striped Bass that Compose Each Age Group in the Commercial Catch for the Season, 1927-1928

Females

		Age groups					
		IV	V	VI	VII	VIII	Total
August September	Number	4	33	90	11	7	145
	Per cent	2.7	22.8	62.0	7.6	4.8	99.9
November December January February	Number	5	83	31	6	2	127
	Per cent	3.9	65.3	24.4	4.7	1.6	99.9
March April May	Number	26	274	140	46	4	490
	Per cent	5.3	55.9	28.5	9.3	0.8	99.8
Yearly average, per cent		3.97	47.97	38.30	7.17	2.40	99.8

TABLE 8 The Percentage of Female Striped Bass that Compose Each Age Group in the Commercial Catch for the Season, 1927–1928

Females

During the winter season from November to February, inclusive, the shad and salmon nets are usually removed from the water and only the standard 5 ½-inch mesh striped bass gill nets are used. This action would of course tend to lower the average lengths of the total catch which would in turn lower the average age of the fish comprising the catch. This point is brought out in table 8, which classifies the 5-year-olds as again forming the greater percentage of the age groups in the commercial catch for this period. The gear employed is not solely responsible for the shift in abundance of the age groups from the 6-year class in the fall to the 5-year group in the winter. The increase in length of these age groups from August to the following November is of significance not to be overlooked. It is estimated that 25 per cent of the annual growth of each age group is completed between August and the following November; therefore, it is reasonable to assume that from the middle of the fall to the middle of the winter period a great many of the 4-year-olds have grown to a sufficient length to be gilled in the commercial nets, and the abundant 6-year group of the fall has grown to a length too great to enable the 5 ½-inch mesh nets to capture them with the former success.

5.1.7. SELECTIVITY OF THE COMMERCIAL NETS

It has been illustrated that the nets commonly used for the capture of striped bass are highly selective in that the fish they take are restricted to a very narrow length range. The normal range is from 45 to 65 centimeters, though there is a smattering of larger fish as long as 85 centimeters. It has also been shown that the central point of selectivity is at 55 centimeters, which means that the 5-year-olds are subject to the greatest drain since their average length is a little more than 54 centimeters. There is one exception to this statement—in the fall the 6-year group (which was the 5-year group of the previous spring) is subject to the greatest strain from the commercial nets. A yearly average, however, places the catch of 5-year-olds far in excess of the 6-year group. Taking all the age groups into consideration, their order of abundance in the commercial catch is as follows: 5, 6, 7, 4, and 8. As already explained, the gill nets select at 55 centimeters on the average throughout the entire striped bass season. Since the 5-year group has an average length of 54.4 centimeters then the present size of mesh as regulated by law is selecting the very heart of the 5-year group. In considering the 4-year class it would be untrue to assume that these same nets select fish that are of the average length of this group. For instance, in the spring months it has been shown from growth studies that the average length of a 4-year-old is 46 centimeters. The average length of the 4-year-olds in the commercial catch is considerably in excess of that length, or 51 centimeters. This fact illustrates clearly that the nets are selecting the larger individuals of the 4-year class. (Table 9) . Let us now consider the 6-year group. Their actual or representative length in the spring months as determined from growth studies is 61 centimeters. The nets during this same period select 6-year-olds at an average length of 59 centimeters. The same situation arises in the case of the 7-year-olds for their average representative length is 68 centimeters and the commercial nets select individuals from this group at an average length of 67 centimeters. (See table 9 for these data.)

TABLE 9

The Mean Lengths of Age Groups of the Commercial Catch and the Actual Representative Lengths of the Same Group Derived from Growth Studies (March, April and May, 1927-1928 and 1928-1929 Seasons)

Females

Age groups	Seasonal percentage in commercial catch	Average length (growth studies) (centimeters)	Average lengths selected by commercial nets (centimeters)
IV	3.97	46.0	51.1
V	47.97	54.2	55.0
VI	38.30	61.2	59.2
VII	7.17	68.0	67.0

TABLE 9

The Mean Lengths of Age Groups of the Commercial Catch and the Actual Representative Lengths of the Same Group Derived from Growth Studies (March, April and May, 1927–1928 and 1928–1929 Seasons)

Females

5.1.8. SPAWNING PERIOD

As it is quite evident that in the spring months the commercial nets are drawing upon a spawning population, it is therefore essential to learn the length of the spawning season as well as the period when maximum spawning is underway. In securing this information the ova studies were employed as an index. The maturing, mature and spent bass were handled in a single grouping, while the immature bass were cast aside since their presence or absence during the spawning season would in no way indicate the time of spawning. In order to determine accurately the peak of spawning, the material was combined by weeks. The results of this study are presented graphically in figure 47, which indicate that maximum spawning occurs during May.

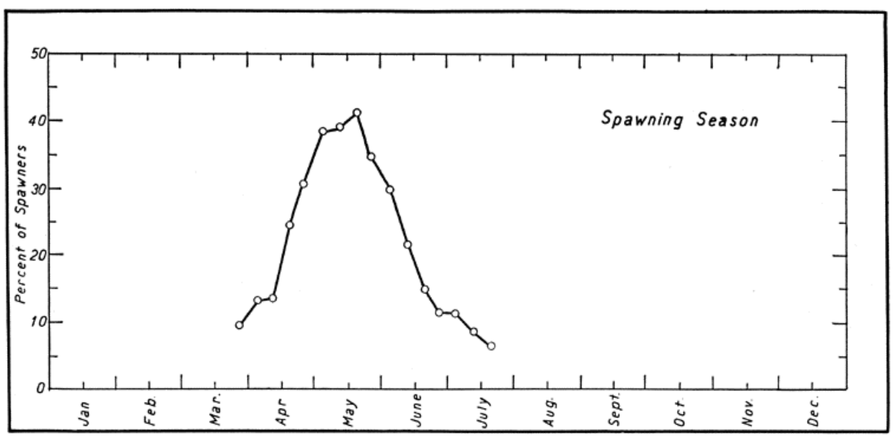

FIG. 47. The spawning season of the striped bass. As a result of ova studies, the maturing, ripe and spent bass were determined and treated as a single unit, and the percentage of mature presented by weeks. The results as illustrated above show the bass to spawn from March to July, reaching a maximum spawning in May

The percentages, obtained after being smoothed by threes twice, indicate that the actual peak occurs during the third week in May. These data however do not justify such a conclusion since no sampling was done during the last two weeks in May; therefore, it can only be stated that spawning is at its maximum during all of May. (Table 10) .

TABLE 10

The Percentage of Maturing, Mature and Spent Striped Bass During the Spawning Season of 1928

Females

Month	Weekly period	Maturing		Mature		Spent	
		Number of fish	Per cent	Number of fish	Per cent	Number of fish	Per cent
December	1						
	2						
	3	11	100.0				
	4						
January	1						
	2						
	3	15	100.0				
	4						
February	1	45	100.0				
	2	14	100.0				
	3	1	100.0				
	4						
March	1	22	100.0				
	2	38	100.0				
	3						
	4	22	91.6	2	8.3		
April	1	21	84.0	3	12.0	1	4.0
	2	42	89.3	5	10.6		
	3	30	62.5	17	35.4	1	2.0
	4	58	84.0	11	15.9		
May	1	20	36.3	28	50.9	7	12.7
	2	63	45.3	50	35.9	26	18.7
	3						
	4						
June	1	3	16.7	8	44.4	7	38.8
	2	7	21.8	1	3.1	24	75.0
	3	11	19.2	9	15.8	37	64.9
	4	5	16.6	3	10.0	22	73.3
July	1	1	7.2	2	14.2	11	78.5
	2	2	20.0			8	80.0
	3	1	2.5	2	4.8	38	92.6
	4	1	16.6			5	83.3
August	1					20	100.0
	2					15	100.0
	3					19	100.0
	4					20	100.0
September	1					17	100.0
	2					16	100.0
	3						
	4						
Totals		433		141		294	

TABLE 10

The Percentage of Maturing, Mature and Spent Striped Bass During the Spawning Season of 1928

Females

The weekly percentage of mature bass was taken as indicative of total period of spawning. These data, presented in figure 47, determine the start of spawning as the middle of March and the close during the latter part of July, or a spawning period of nearly five months. Maturing bass appear as early as December and by August all traces of maturing ova have disappeared. Spent bass appear during the latter part of March, and by the middle of August all are spawned.

5.1.9. SUMMARY OF THE STUDIES OF THE COMMERCIAL CATCH

1. The commercial nets used in the capture of striped bass select females from 45 to 85 centimeters in length, the bulk of this catch measuring close to 55 centimeters. Striped bass nets (5 ½-inch mesh)

alone select fish from 45 to 65 centimeters in length, the average being 55 centimeters.

2. Since the mode of the commercial catch remained at 55 centimeters during the three seasons, 1926–1927 to 1928–1929, there is evidence to conclude that these commercial nets always select the same size of fish and that dominant year groups would not tend to influence this normal length selection to any great extent.

3. The large mesh shad and salmon nets are responsible for the capture of larger striped bass of both sexes during the spring and fall months.

4. The males selected by the nets average 53 centimeters in length or 2 centimeters shorter than the females. This is brought about by the fact that the males of any given length are heavier and fatter than females of the same length; therefore, these shorter males will gill as readily as the longer females. The males from 45 to 60 centimeters in length are approximately one-half of a pound heavier than females of the same length.

5. The males predominate in the commercial catch, averaging 56.9 per cent of the total.

6. During the spring months (March, April and May) the commercial nets select mainly from the 5-year group, while the 6-year group is second in abundance in the catch.

7. In the fall months these same nets still select from the 5-year group, though it has passed into its sixth year. The 4-year group of the spring has risen to take second place as 5-year-olds in the fall. The number of 6-year-olds of the spring has fallen considerably in number in the fall.

8. During the winter months the nets again select from the 5-year group, while the 6-year group is second in abundance in the catch.

9. The variation in the selection by the nets of the several age groups is brought about mainly by the growth of the fish, and secondly, by the employment of larger mesh gill nets in the spring and in the fall.

10. The commercial nets select during the spring months (March, April and May) the largest individuals of the 4-year group, from all individuals of the 5-year group, and the smallest of the 6-year and 7-year classes.

11. The spawning season extends from March to August, reaching its peak during May.

5.1.10. CONCLUSIONS

The following conclusions as to the general effect of the present laws regulating the commercial nets in relation to proper conservation measures, are based on the combined results of the life history studies and the analysis of the commercial catch. In order to bring forth this general effect in a more defined manner, each major law now regulating the catch of striped bass will be taken up separately and discussed at length. In doing this it will be more readily understood whether the present laws are adequate in properly conserving the species.

5.1.10.1. 1. Effect of the Regulation Gill Nets

Since shad and salmon nets play an important part in the capture of striped bass during the seasons of the year when the greatest catch is recorded, it is essential that all the gear be treated as a single unit.

Moreover, it is only necessary to discuss the effect of the nets used in the spring months for it is at this time that the striped bass are passing through the netting area on their way to spawn. An analysis of the catch for this period is made doubly important in view of the fact that at this time the nets are drawing heaviest on the 5-year group of which 85 per cent are spawning for the first time. In the fall the nets are selecting from a 6-year-old population, 85 per cent of which spawned the previous spring.

Recalling the results of the age at maturity studies in the life history section of this paper, it was shown that 35 per cent of the 4-year class spawn each year, 87 per cent of the 5-year group spawn, 98 per cent of the 6-year group, and 100 per cent spawn thereafter. The average size of these several groups were: 4-year group at 50 centimeters, 5-year class at 54 centimeters, 6-year class at 61 centimeters, and 7-year group at 68 centimeters. Table 11 has been prepared to illustrate these data, and the actual representative lengths of each of the age groups as determined from the growth studies and the average lengths of the individuals of each group which the nets select. A close observation of table 11 will show clearly the following facts: First, that during the spring months the nets employed for the capture of striped bass, irrespective of whether they are striped bass, shad or salmon nets, select fish as soon as they become sexually mature. That is, the nets capture only the larger individuals of the 4-year class, and as has been stated, only the larger individuals of this group spawn each year. It is recalled that the average length of the mature 4-year-olds was 50 centimeters, and the average length of the same group selected by the commercial nets was 51 centimeters. The results of these data reveal then that during the open season the present size mesh net is not protecting the fish which are spawning for the first time. Second, the 5-year group, of which 85 per cent spawn each year, are exploited in their entirety during the open season. This is evidenced by the fact that the nets select 5-year-old fish at 55 centimeters in length, while the average representative length of this group, as determined by growth studies, was found to be slightly more than 54 centimeters. Since the size at maturity of this group is 54 centimeters, it is clearly illustrated why these nets exploit them in their entirety during the open season. (See table 11 .) Third, the 6-year and the 7-year classes are perhaps more protected than either of the two younger age groups. By consulting table 11, it will be seen that the size at maturity of these groups is the same as the average lengths established from growth studies. Because the nets select the smallest individuals of both age groups, the larger spawning individuals are therefore protected. Fourth, it must be borne in mind that these conclusions are meant for the commercial catch alone and that it must not be assumed that the statement, "the mature 5-year-olds are exploited in their entirety" infers that the nets are capturing every one of the mature 5-year-olds. The commercial catch is perhaps only a small fraction of the total population of striped bass. The 5-year-olds which the nets do happen to catch are for the most part mature and spawning fish.

TABLE 11

The Mean Lengths* of Individual Age Groups Compared to the Mean Lengths of Mature Fish and Commercially Caught Fish (March, April and May, 1927-1928 and 1928-1929 Seasons)

Females

Age groups	Representative mean lengths (growth studies)		Mean lengths of mature fish		Commercially selected mean lengths	
	Number of fish	Mean (centimeters)	Number of fish	Mean (centimeters)	Number of fish	Mean (centimeters)
IV	43	46.0	7	50.0	22	51.1
V	43	54.2	150	54.0	274	55.0
VI	33	61.2	92	61.0	140	59.2
VII	21	68.0	23	68.0	46	67.0

* Measurements in centimeters.

TABLE 11

The Mean Lengths of Individual Age Groups Compared to the Mean Lengths of Mature Fish and Commercially Caught Fish (March, April and May, 1927–1928 and 1928–1929 Seasons)

Females

In the fall months, however, the protection offered mature fish is far greater. As previously stated the fall commercial catch is made up of a large majority of 6-year-olds. of this same age group, 85 per cent spawned the previous spring, therefore, the nets at this time select a large percentage of spent fish. Thirty-five per cent of the 5-year group of the fall have already spawned, and as their abundance in the commercial catch amounts to 22.8 per cent at this time, then the major portion of its individuals has not spawned.

5.1.10.2. 2. Twenty-inch Limit

The minimum length of 20 inches per bass which is required by law serves only as a check on the operation of 5½-inch mesh nets or larger. This measurement (from the snout to the tip of the caudal fin) falls roughly at 47 centimeters, when the correct measurement is made from the tip of the snout over the body to the tip of the central caudal fin rays. Very often bass smaller than 47 centimeters in length are caught accidentally and delivered to the commercial markets. A catch containing too many of these small individuals would indicate the use of a net with meshes smaller than the legal 5½ inches, since this mesh has been shown to catch bass from 45 to 65 centimeters in length with the mode of the catch lying at 55 centimeters. This minimum length regulation is excellent since it discourages the use of small mesh illegal 1ets.

5.1.10.3. 3. Ten-pound Limit

A maximum weight limit of 10 pounds on each striped bass from March 1st to May 15th was primarily introduced at the request of commercial fishermen as a conservation measure to discourage others from haunting the abodes of these large fish and capturing them with large mesh salmon nets. This law has been extremely effective in its purpose. Such bass are well over 8 years of age and are capable of spawning over a million eggs annually. Though this law is generally respected as well as strictly enforced, occasionally large bass are killed in trammel or salmon nets.

5.1.10.4. 4. Closed Seasons

May 16th to July 31st: This closed period protects roughly three-fifths of the spawning period, since the peak of spawning occurs in May at which time two-fifths of the spawning period is already completed.

September 17th to November 14th: This closed period is not essential since during this time the nets would draw on a population of spent bass. However, for the protection of the fall salmon run it is necessary to have all nets removed from the water.

5.1.10.5. 5. Closed Districts

Sloughs and islands: The closing of these areas has protected the entire spawning beds of the striped bass.

San Pablo Bay flats: The closing of this region does not seem to be justified since there is no actual proof that this action has offered added protection to the striped bass. If one could prove that the bass which school upon these flats are entirely migratory, then the closure of this area would be impractical as far as conservation is concerned. On the other hand if the bass remained stationary in this area or if they spawned there, the closure would be justified.

5.1.11. RECOMMENDATIONS

In view of the work done by Craig (1928.2.) which proved the abundance of the striped bass to be on the increase since 1920, and in view of the present work on the life history and the commercial catch, it appears that the present protection given the striped bass is entirely adequate. It might be stated that the restrictions are more stringent than really are necessary in regulating the utilization of the species to prevent menacing the available supply. However, since this species has been recently introduced into this State, it is well that the present regulations are in force. Though it is felt with confidence that the commercial nets as a unit will in no way bring about depletion with the present laws in effect, it must be borne in mind that there are other exploiting interests and conditions, the combined effects of which may lead to a serious reduction in the supply. The sport catch which is fully as large as the commercial is perhaps the most serious of these menaces. It would be well to make a study of this situation in order to provide adequate limitations which are at present almost completely lacking. Another serious menace to the supply is the utilization and pollution of the bay mud flats. The increased demand for water frontage for factory sites has resulted in some of the choice habitats of this species being reclaimed. The introduction of these factories has resulted in the pollution of the nearby flats in spite of all that can be done under the present laws to prevent it. The food supply of the striped bass is endangered within the bays by the dredger operations. The silt which has been deposited on the mud flats has apparently greatly reduced the abundance of marine life upon which most young fishes depend. Other conditions believed to be affecting the abundance of striped bass are: the reclamation of many flooded islands in the delta country which are perhaps the main spawning areas; the irrigation ditches and siphons destroy young bass although a great deal of their loss has been remedied by the Division of Fish and Game; and the overflow basins, because of their great size and number, destroy a good many small bass although the Division has reduced this loss by its fish rescue work.

The increase in the abundance of the striped bass depends greatly upon the proper regulation of the above mentioned conditions. It is probably fortunate that this species is now on the increase in view of these conditions. This amply illustrates that if the striped bass are given adequate protection they will grow into a major fishery in the future. It must be remembered that the preceding paragraphs have shown that the present laws regulating the commercial catch are adequate in every respect and that other exploiting interests are the ones which should be carefully observed if we wish the supply to continue its increase during the years to come.

5.1.12. BIBLIOGRAPHY

Bryant, Harold C. 1921. A brief history of the California Fish and Game Commission. California Fish and Game, Vol. 7, No. 2, pp. 76–86.

California State Board of Fish Commissioners. 1907. Striped bass. Report, California State Board of Fish Commissioners, for 1905–1906, p. 38.

Clark, Frances N. 1925. The life history of Leuresthes tenuis, an atherine fish with tide controlled spawning habits. California Division of Fish and Game, Fish Bulletin No. 10, 51 pp.

Coleman, G. A., and Scofield, N. B. 1910. Notes on spawning and hatching of striped eggs at Bouldin Island Hatchery. 21. Biennial Report, California Board of Fish and Game Commissioner, for 1909–1910, p. 109.

Corson, R. E. 1926. Striped bass (R. lineatus). A study of weights and lengths as compared with ages. [New York] Zoological Society Bulletin, Vol. 29, No. 6. pp. 210–211.

Craig, J. A. 1928.1. Catch figures and fish supply. California Fish and Game, Vol. 14, No. 1, pp. 37–42.

1928.2. The striped bass supply of California. California Fish and Game, Vol. 14, No. 4, pp. 265–272.

1930. An analysis of the catch statistics of the striped bass (Roccus lineatus) fishery of California. California Division of Fish and Game, Fish Bulletin No. 24, 41 pp.

Creaser, Charles W. 1926. The structure and growth of the scales of fishes in relation to the interpretation of their life history, with special reference to the sun fish Eupomotis gibbosus. University of Michigan, Museum of Zoology, Miscellaneous Publications, No. 17, 82 pp.

Hubback, C. E. 1927. Striped bass as I know them. California Fish and Game, Vol. 13, No. 1, pp. 25–27.

Mason, H. W. 1882. Report of operations on the Navesink River, New Jersey, in 1879, in collecting living striped bass for transportation to California. Report, U. S. Commissioner of Fisheries, for 1879, pp. 663–666.

Scofield, E. C. 1928.1. Striped bass studies. California Fish and Game, Vol. 14, No. 1, pp. 29–37.

1928.2. Preliminary studies on the California striped bass. Transactions, American Fisheries Society, for 1928, pp. 139–145.

Scofield, N. B. 1910. Notes on the striped bass in California. 21. Biennial Report, California Board of Fish and Game Commissioners, for 1909–1910, p. 104.

Scofield, N. B., and Bryant, H. C. 1926. The striped bass in California. California Fish and Game, Vol. 12, No. 2, pp. 55–74.

Starks, E. C. 1919. The basses and bass-like fishes of California. California Fish and Game, Vol. 5, No. 2, pp. 59–68.

Shebley, W. H. 1917. History of the introduction of food and game fishes into the waters of California. California Fish and Game, Vol. 3, No. 1, pp. 3–12.

1927. History of fish planting in California. California Fish and Game, Vol. 13, No. 3, pp. 163–174.

Throckmorton, S. R. 1882. The introduction of striped bass into California. Bulletin, U. S. Fish Commission, for 1881, Vol. 1, pp. 61–62.

Weymouth, F. W. 1923. The life history and growth of the Pismo clam (Tivela stultorum Mawe). California Fish and Game Commission, Fish Bulletin No. 7, 120 pp.

Worth, S. C. 1884. Report upon the propagation of striped bass at Weldon, N. C., in the spring of 1884. Bulletin, U. S. Fish Commission, for 1884, Vol. 4, pp. 225–231.

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