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THE MENHADEN FISHERY OF THE UNITED STATES [1]

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INTRODUCTION

The menhaden fishery is the largest of all fisheries in the United States and the basis of one of the leading fishing industries in the world. A fleet of 200 carrier vessels, manned by approximately 4,000 fishermen, is employed in making the catch. Over 30 reduction plants receive and process the fish. The catch is processed into meal, oil, and condensed soluble proteins. In 1959, record landings of about one million tons of menhaden, valued in excess of $25 million to the fishermen, were taken from the waters of the western Atlantic Ocean. This catch produced 224,000 tons of meal, 21 million gallons of oil, and 102,000 tons of solubles (Power, 1960). The estimated value of these products was $75 million.

The purpose of this report is to provide a better understanding of the menhaden resource and fishery. Accordingly, there are presented a description of the resource, a review and description of the fishery, and a summary of the life history and biology of Atlantic menhaden.

THE RESOURCE

The menhaden are herringlike fishes that inhabit the coastal waters of the western Atlantic Ocean. Six closely related species are recognized (Hildebrand, 1948), four of which are known only from North America;[2] they are the Atlantic menhaden *(Brevoortia*

[1] Prepared for the International Meeting on Fish Meal, sponsored by the Food and Agricultural Organization of the United Nations, Rome, Italy, March 20-29, 1961.

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[2] Hildebrand (1948) recognized a fifth species, *B. brevicaudata*, taken in the vicinity of Noank, Conn., in 1874; however, this form appears to be a geographical variant of *B. tyrannus*, the Atlantic menhaden.

tyrannus), Gulf menhaden *(B. patronus)*, yellowfin menhaden *(B. smithi)*, and fine-scaled menhaden *(B. gunteri)*. Two species, called "lacha" or "savelha" *(B. aurea* and *B. pectinata)*, are found in South America. The Atlantic and Gulf menhadens occur in temperate waters, while the yellowfin and fine-scaled menhadens occur in tropical and subtropical waters. Little is known of the distribution of "lachas."

The United States fishery for menhaden is based solely upon the Atlantic and Gulf menhadens. Some quantities of the other North American species are caught incidentally, but the amounts are insignificant compared to the landings of the two main species. No fishery for "lachas" has been developed in South America, although the fish have been reported as abundant in certain localities.

THE FISHERY

History and Current Status

Fishing for menhaden is one of the oldest industries in the United States. Colonial writings relate that North American Indians taught the early English settlers to place a fish in each hill of Indian corn. Although menhaden probably were never widely used in this manner, this practice led to their utilization for enrichment of the soil when crops along the New England coast and on Long Island began to fail in the late 1700's. By 1820 a fishery was organized for the purpose of supplying menhaden for fertilizer. These events marked the first stage in the development of a fishery which one day was to become the largest in North America (Goode, 1879; Goode and Clark, 1887).

During the War of 1812 the use of fish oils in paints led to the utilization of menhaden for this purpose. The early menhaden oil industry was centered in New England where the large, oily fish were encountered in abundance along the coast during the summer. Despite the highly profitable market for menhaden oil, the industry grew rather slowly until about 1860 when the introduction of the mechanical screw press and the use of steam power made practical the oil-recovery process by a factory operation. During the following decade many new factories were built, and improvements in the methods of catching and processing the fish followed. Development of suitable methods of preserving the fish press cake, accumulated from the oil extraction process, also provided the basis of another phase of the menhaden oil industry that was to continue for the next 50 years--the production of fish fertilizer. By 1870 over 90 menhaden reduction plants were established from Maine to North Carolina (Goode, 1879; Goode and Clark, 1887).

Prior to 1875 the New England States accounted for the greatest part of the annual menhaden production. In 1876 the catch amounted to approximately 170,000 tons from which nearly 3 million gallons of oil and over 50,000 tons of fertilizer were produced. Maine alone accounted for nearly half the total fish production in that year (Maddocks, 1878). Several years later the fish failed to appear in waters north of Cape Cod and except for certain seasons, the fish have not been encountered in abundance in the coastal waters in that area since.

Following the collapse of the New England fishery, the industry expanded southward and by 1900 centered in New Jersey and Virginia. One factory was located in Texas, but information on the early development of the menhaden industry in the Gulf of Mexico is fragmentary. Although the occurrence of menhaden in the Gulf of Mexico was known during the early years of the oil industry on the Atlantic coast (Goode, 1879), it was apparently the collapse of the New England fishery that motivated development of the Gulf fishery. Records show that menhaden were landed on the west coast of Florida and in Texas in certain years prior to 1902, but there are no records of further landings in those States until 1918 (Stevenson, 1904; Anderson and Peterson, 1953). The first landings of menhaden in Mississippi waters were reported in 1939 and in Louisiana in 1948.

Records of menhaden landings in the first decade of the twentieth century are lacking, but in 1912 the catch amounted to 356,000 tons, the largest reported to that time. Virginia alone accounted for more than one-half of the total production in that year (Harrison, 1931). Although incomplete, records show that, except for 2 or 3 years, the total annual menhaden catch from 1912 to the beginning of World War II remained relatively stable. During the 30-year period, the catch fluctuated between 118,000 and 406,000 tons and averaged 243,000 tons. The discovery of vitamin B_{12} as an important constituent of the animal protein factor found in fish meal stimulated the demand for menhaden meal, and following World War II the catch increased markedly. Growth

of the fishery during the 10-year period, 1950 through 1959, is illustrated in figure 1. It may be seen that there was a sustained increase from 1950 through 1956; during this time the catch more than doubled. The catch declined in 1957 and 1958, but in 1959 rose to a peak of 1,097,000 tons, the largest annual catch ever recorded for a fishery in the United States. Atlantic menhaden accounted for more than 70 percent of the total menhaden catch during the 10-year period.

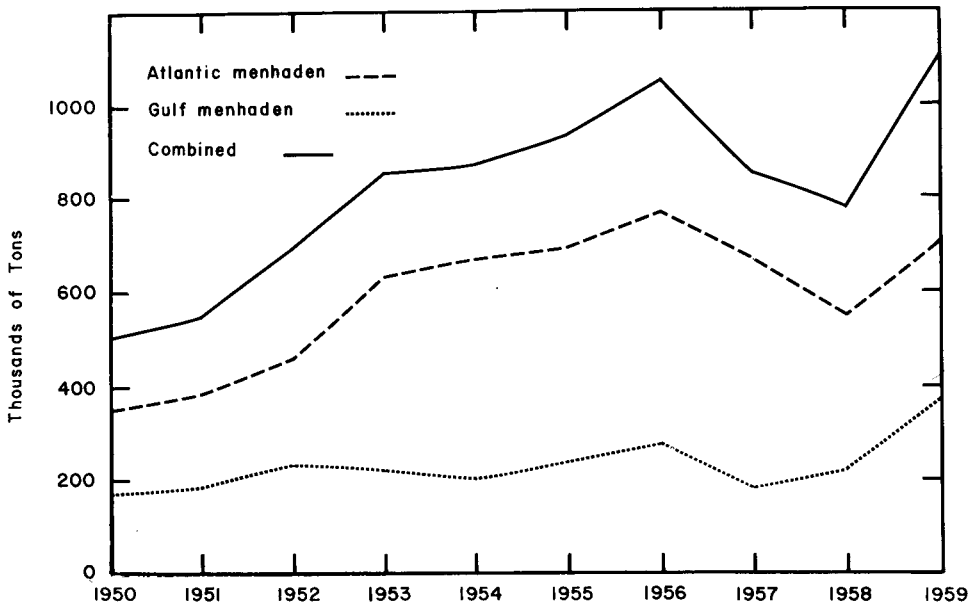

Figure 1.--Catch of Atlantic and Gulf menhadens, 1950-59.

Fishing Gear and Methods

Except for minor quantities landed in Mexico, the entire catch of menhaden for reduction is made by vessels operating from factories located in 12 coastal States bordering the Atlantic Ocean and the Gulf of Mexico (figs. 2 and 3). A highly specialized fleet of carrier vessels is employed to transport the catch from the fishing grounds to the reduction plants. Carrier vessels range from about 65 to 200 feet in length and from about 50 to 650 gross tons in weight. These vessels also carry the fishing gear to the fishing grounds and provide living accommodations for the fishermen (fig. 4). There is a large central hold for stowing the fish, and some vessels are equipped with a brine cooling system for preservation of the catch.

Menhaden are caught with purse seines as the fish swim in schools in the near-surface waters during the warmer months of the year. The seine is operated from two open seine boats. On the fishing grounds, the two seine boats are lashed together, with the seine divided equally between them, and towed behind the carrier vessel. Since about 1946, airplanes routinely have been used to locate the fish, and in recent years the practice of directing the laying of the seine around a school of menhaden from the air by radio communication between the airplane pilot and the fishing captain has been universally adopted. When a school has been selected for capture, the two seine boats approach the school. In laying the seine, the two boats separate, and the seine is laid out as each boat completes a half-circle to enclose the school. The bottom of the seine is then closed, or "pursed," confining the fish inside the seine. Power-driven blocks, one mounted in each seine boat, are used to haul in the ends and bottom of the seine until the fish are confined in the bunt (fig. 5). The catch is then pumped into the hold of the carrier vessel (fig. 6). An average purse-seine set yields from 20 to 25 tons of fish. Purse-seine fishing for menhaden is conducted during daylight hours. The vessels usually make daily trips to the fishing grounds and land the catches after dark or when the hold has been filled (fig. 7).

In some areas, such as Chesapeake Bay, fairly large numbers of menhaden are

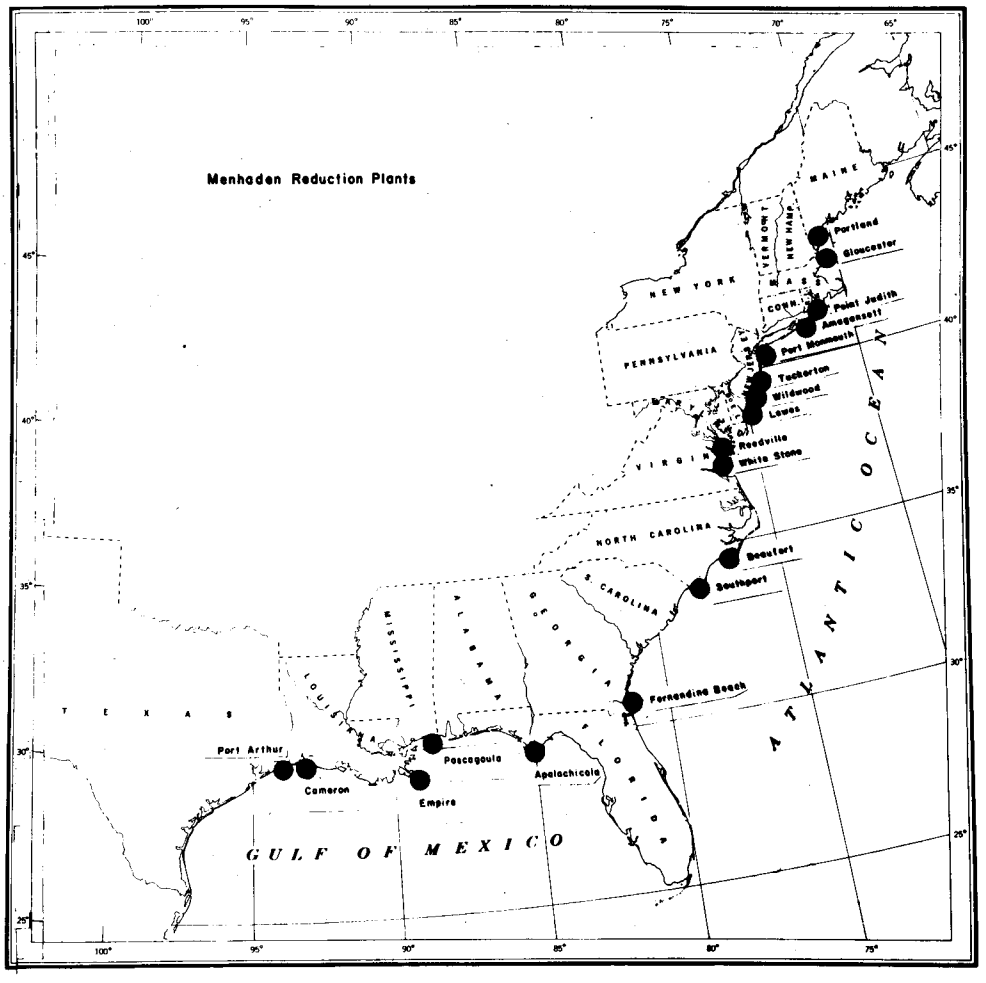

Figure 2.--Location of menhaden reduction plants.

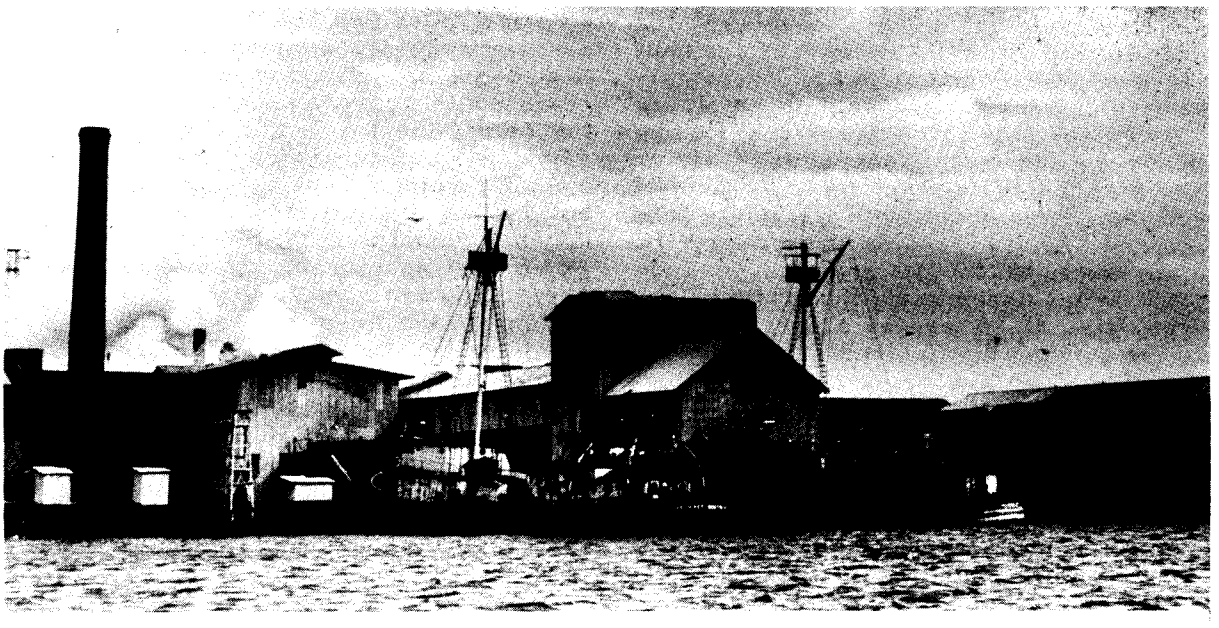

Figure 3.--A typical menhaden reduction plant.

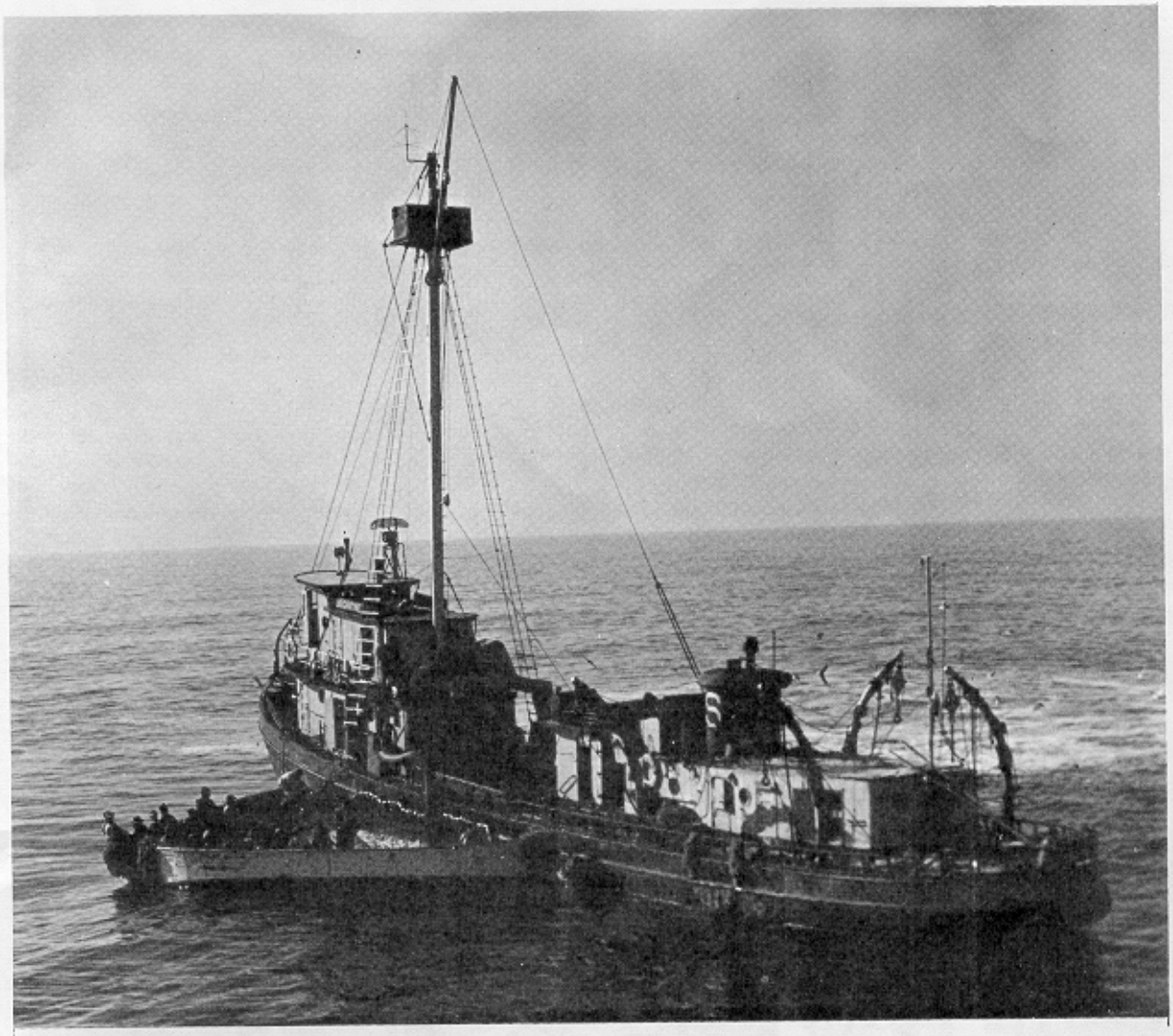

Figure 4.--Menhaden carrier vessel and seine boats.

reported as caught by pound nets (McHugh, 1960). This catch of "scrap fish" contains many other species in varying quantity, but young menhaden are dominant. This catch is used principally as bait for crab pots.

The number of carrier vessels engaged in the menhaden purse-seine fishery has remained relatively stable over the past decade. However, replacement vessels have increased in size, and steel, instead of wood, has been used in their construction. There were 201 vessels in the carrier feet in 1959 (fig. 8).

Fishing Grounds and Seasons

The purse-seine fishery for menhaden encompasses approximately 45,000 square miles of sea surface. The seasonal occurrence of schools in the surface coastal waters governs the conduct of the purse-seine fishery. On the Atlantic coast, the fishery extends from central Maine to the central east coast of Florida and is conducted from May to November over most of this range. During November and December, fishing is restricted to the coastal waters of North Carolina where the fish pass close inshore on their annual southward migration.

In the Gulf of Mexico, the purse-seine fishery is conducted from May to November and, in general, is limited to a relatively short stretch of coast in the northern Gulf. In some years, there is fishing also during the summer along the central west coast of Florida in the vicinity of Apalachicola.

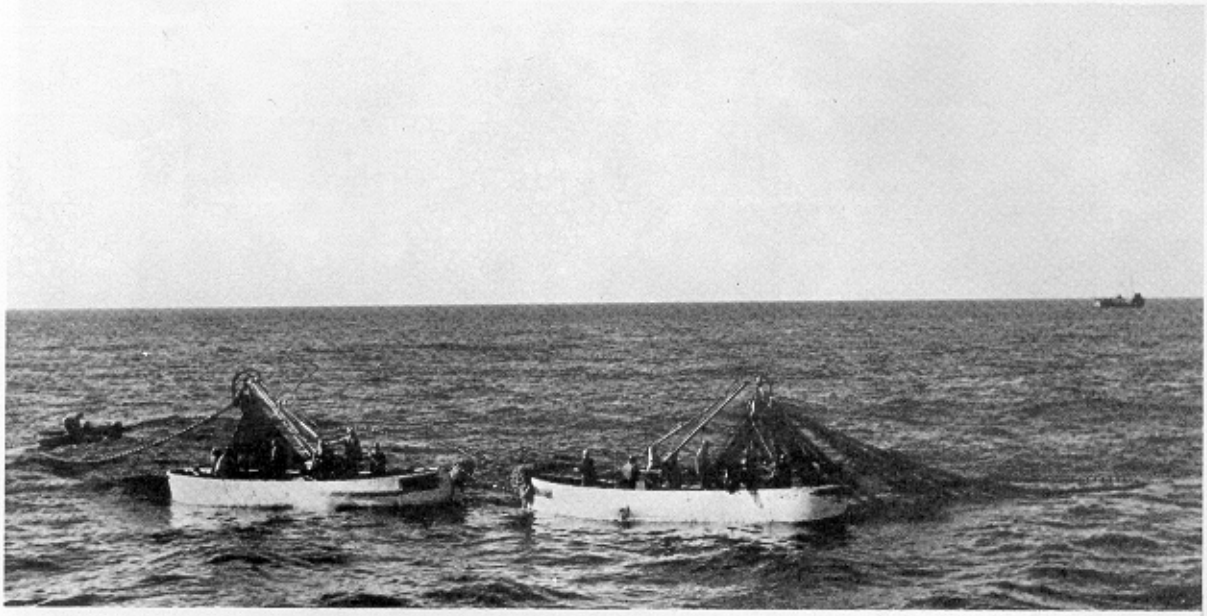

Figure 5.--Menhaden purse-seine set. The net is hauled aboard each seine boat with power-driven blocks until the fish are closely confined in the bunt.

Figure 6.--Pumping the catch from the purse seine into the hold of the carrier vessel.

Figure 7.--Unloading a day's catch of menhaden at the reduction plant.

Figure 8.--Part of the menhaden purse-seine fleet moored at Beaufort, N.C., during the fall fishing season.

BIOLOGICAL INVESTIGATIONS OF THE RESOURCE

The Bureau of Commercial Fisheries of the U.S. Fish and Wildlife Service is engaged in an investigation of the menhaden resource of the Atlantic and Gulf coasts of the United States. The object of the investigation is to obtain scientific information on the identity, life history, biology, and dynamics of the menhaden stocks and the effects of the fishery on them (June, 1957).

The research program began in 1955 and thus far has been concerned primarily with the Atlantic menhaden. At the outset, there was little knowledge of the life history and biology of menhaden, and information on the condition of the stocks was entirely lacking. Much remains to be learned, particularly about the stocks in the Gulf of Mexico, but sufficient information is being gathered on the Atlantic menhaden to permit interpretation of fluctuations in the catch and assessment of the current condition of the fishery.

Geographical Distribution of Atlantic and Gulf Menhaden

The Atlantic menhaden is found in the Atlantic coastal waters of North America from Nova Scotia to central Florida (Hildebrand, 1948). The fish do not occur in equal abundance throughout the range, but are concentrated in certain localities during certain periods of the year. During the warmer months, the fish congregate in schools in the near-surface waters overlying the inner half of the Continental Shelf. This is illustrated in figure 9 which shows the amount and distribution of fishing effort for Atlantic menhaden in 1959. While variations in the amount and distribution of fishing effort have occurred from year to year, the areas of concentration remained nearly the same over the past 5 years for which such information is available. During the colder months, the fish rarely are seen in the surface waters. In Chesapeake Bay, however, menhaden have been taken at all times of year (McHugh, Oglesby, and Pacheco, 1959). There is evidence that during this period they occur in loose aggregations in deeper water over the Continental Shelf.

The Gulf menhaden is known to occur from southern Florida to Veracruz, Mexico (Hildebrand, 1948; Reintjes and June, 1961). Seasonally it strays into the Atlantic, reaching northward to the central east coast of Florida. During the warmer months of the year, the fish occur in schools in the shallow coastal waters and are found in greatest concentrations in the northern Gulf of Mexico in the vicinity of the Mississippi River delta. The schools usually disappear from the surface waters near shore coincident with autumnal chilling. There is little information concerning the whereabouts of the main body of fish during the winter; however, large adults have been caught incidentally off southern Florida in November and December.

Life History and Biology of Atlantic Menhaden

Recent scientific studies have provided a wealth of information on the Atlantic menhaden. Some data also have been accumulated on the other North American species, but there still is little information available on those found in South America. So far as is known, however, the general features of the life history of the different species are similar. Thus a description of the Atlantic menhaden will provide some understanding of the remaining species (fig. 10).

Since Atlantic menhaden occur over some 3,000 miles of coastline, it is important to determine whether they exist as one large stock in which there is free intermingling, of whether the fish in given areas of the coast are more or less confined to those areas and possess biological characteristics and properties which make them different from fish found in adjacent areas.

Several lines of evidence have led to the conclusion that, while intermingling of Atlantic menhaden occurs, mixing is incomplete (June, 1958). The fish which contribute to the fishery along the South Atlantic coast appear to be distinct from those farther northward. However, determination of the amount and rate of mixing must await results of a tagging program.

Studies of the distribution of age and length groups in the catches, combined with information on the amount and distribution of fishing effort by the purse-seine fleet, have demonstrated that the fish undertake extensive migrations. There is a northward movement along the coast in spring. During the summer, the smaller and younger fish are found in the southern part of the range, while progressively larger and older fish occur in each more northerly latitude. Furthermore, there is a tendency for fish of similar size and age to occur together in a given locality, but remain distinct from those of overlapping

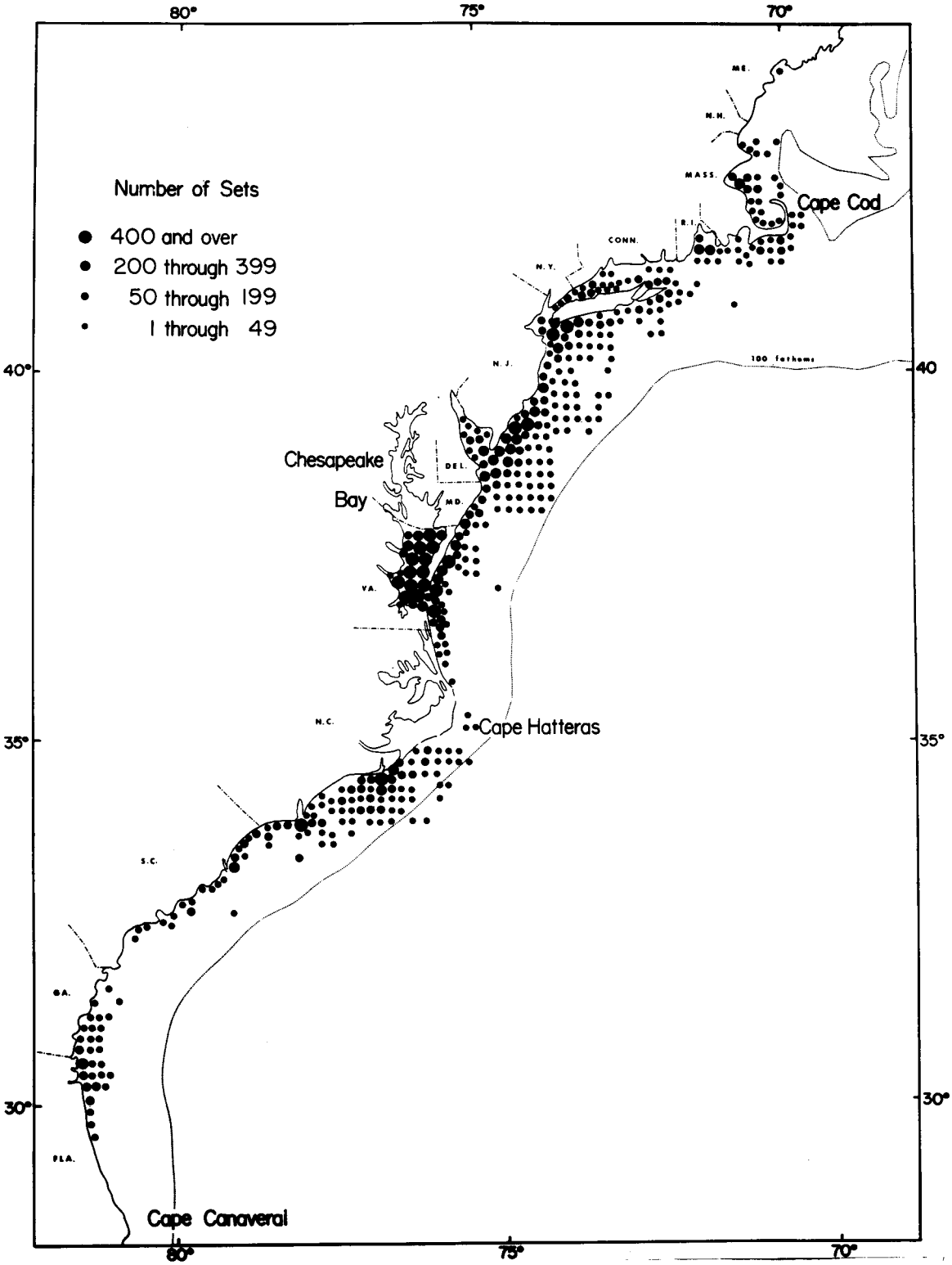

Figure 9.--Distribution of purse-seine sets for Atlantic menhaden, 1959.

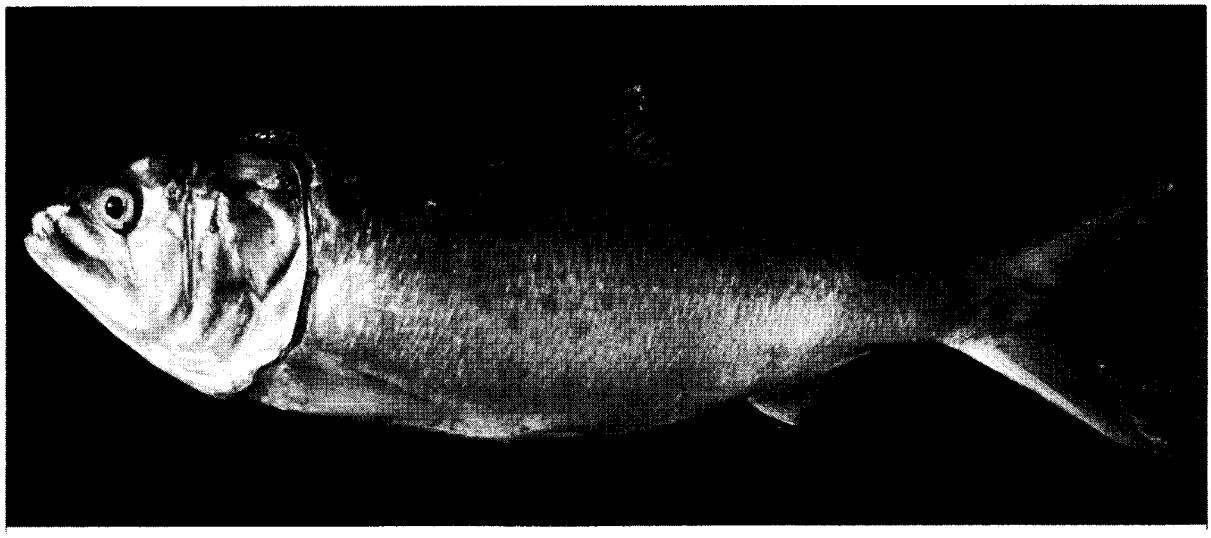

Figure 10.--An Atlantic menhaden *(Brevoortia tyrannus)*, 355 millimeters fork length.

sizes and ages in adjacent localities. Thus, a north-south gradient in size and age becomes established, with the larger and older fish found farther northward (June and Reintjes, 1959; McHugh, Oglesby, and Pacheco, 1959).

A southward withdrawal of fish from the summer grounds takes place in autumn. Prior to their southward migration, the fish congregate in large schools, which sometimes cover a surface area of many square kilometers. The fishing fleet follows the large schools as they migrate southward in October, but frequently the schools travel in deep water offshore where they cannot be caught. However, the schools are intercepted again as they pass close inshore along the coast of North Carolina in November. The large, migrating schools are last seen off the North Carolina coast in December.

Spawning of Atlantic menhaden takes place over a wide geographical range and during most of the year (Higham and Nicholson[3]). The pattern of spawning appears to be related to the coastal movements of the adult fish. In northern waters, some spawning occurs throughout the period when the adult fish occur there, but increases in intensity in autumn when they commence congregating into large schools just prior to their southward migration. Spawning occurs at successively lower latitudes concomitantly with the appearance of the large, migrating schools of sexually active fish. During the winter, spawning occurs only in southern waters, but recommences in northern waters in spring with the reappearance of the adult fish.

Atlantic menhaden spawn in the ocean, and an individual female may spawn anywhere from 40,000 to 700,000 eggs, depending on the size of the fish. Hatching of the eggs and early development of larvae also take place in the ocean. Some time after the yolk sac has been absorbed, the larvae enter estuaries and become established within.

At the time of their entry into the estuaries, the larvae are transparent and marked with black pigment spots on the lower surface of the body and about the head; they have no scales, and the fins are only partially formed. The body is slender and may range from 8 to 40 millimeters (1/3 to 1 1/2 inches) in length. The period during which larvae enter varies in different localities of the coast, but, in general, follows the pattern of spawning described previously.

Following their entry into the estuaries, the larvae congregate in greatest abundance in the shallow, brackish waters of tributaries. Here they transform into juveniles. During this transformation, the body deepens, scales appear, all of the fins become differentiated, and the fish take on the color of the adults. This transformation may begin at a body length of about 26 millimeters (1 inch) and usually is completed at body lengths of about 40 to 55 millimeters (1 1/2 to 2 inches).

[3] Higham, Joseph R., Jr., and William R. Nicholson. A study of the sexual maturation and spawning of Atlantic menhaden. Unpublished manuscript. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C.

The young fish occur in schools at the smallest sizes at which they are found in the tributaries. As the fish increases in size, the schools become more widely dispersed in the tributaries, but generally are found in greatest concentrations in those areas where food production is highest.

The juveniles spend their first summer of life in the estuarine nurseries, and in autumn congregate into larger schools and emigrate to the ocean. Generally, this emigration begins earliest in northern latitudes and takes place progressively later farther southward. After leaving the nurseries, the juveniles migrate southward along the coast and appear in large schools along the coast of North Carolina in December, following the disappearance of the larger, adult fish. The juveniles usually disappear from that locality some time in January, but during mild winters they often are seen in the sounds and bays which border the south Atlantic coastal States.

The age of Atlantic menhaden can be determined from markings on their scales (McHugh, Oglesby, and Pacheco, 1959; June and Roithmayr, 1960); therefore, the size of fish at each age can be used to estimate their growth. At the time of their departure from the estuaries, the juveniles may range from 55 to over 150 millimeters (2 to 6 inches) in fork length, depending on locality; they average about 125 millimeters (5 inches) in length and 30 grams (1/16 pound) in weight. Although subsequent growth varies considerably in different areas of the coast and in different years, in general, age-1 fish in the purse-seine catches average 192 millimeters (7 1/2 inches) in length and 133 grams (1/3 pound) in weight, age-2 fish average 243 millimeter (9 1/2 inches) and 276 grams (5/8 pound), age-3 fish average 266 millimeters (10 1/2 inches) and 366 grams (3/4 pound), and so on. By age 9, the average size is 336 millimeters (13 inches) and 693 grams (2 1/4 pounds).

Larval Atlantic menhaden are particulate feeders, that is, they pick out individual food items from the water. Studies of the stomach contents of larvae indicate that they feed predominantly on small marine crustaceans. During and following their transformation from larvae into juveniles, the gill rakers (a straining apparatus) develop, and the fish become indiscriminate filter feeders, that is, they strain out the microscopic plants and animals from the water as they swim with mouths open (Carlson[4]). There appear to be no food preferences among the larger juveniles and adults, for stomach contents reflect the food organisms peculiar to the locality in which the fish occur.

Relatively little is known about the behavior of Atlantic menhaden, or about the environmental factors that influence the behavior and distribution of the fish. It was shown previously (fig. 9) that in the ocean the fish are caught in greatest numbers in the vicinity of major estuarine systems where the microscopic plants and animals upon which they feed are in rich supply. It also has been found that entry of larvae into the estuaries is governed by water temperature at the inlets, and evidence is accumulating to show that widely fluctuating temperatures during the winter result in heavy mortalities among larvae which have become established in the tributary nurseries. But whether the larvae must enter waters of lower salinity to undergo transformation into juveniles has not been determined. The juveniles and adults can tolerate great differences in salinity, and both commonly occur in waters of salinity ranging from 5 to 36 parts per thousand. Seasonal differences in the schooling behavior of the fish already have mentioned. During the summer, individual schools may contain from less than 1 ton to over 75 tons of fish, but in autumn, the fish congregate into schools containing many thousands of tons. Furthermore, there also appear to be differences in behavior as the fish become older and larger. During the summer, the older and larger fish are not accessible to the purse-seine fishery in proportion to their abundance in the sea, while in autumn they congregate in the inshore waters prior to and during the southward migration. But it is not known why this is so. Thus many questions concerning the behavior and distribution of Atlantic menhaden remain unresolved.

The purse-seine fishery for Atlantic menhaden exploits fish of ages 1 through 8; however, fish of ages 1 through 3 usually account for somewhere between 85 and 99 percent of the catch. Fish older than age 8 are rare in the catches (June, 1961).

There is considerable variation in the survival of young fish resulting from each year's spawning, and the occurrence of unusually abundant or "dominant" year-broods

[4]Carlson, Frank T. Food and feeding habits of larval and juvenile Atlantic menhaden. Unpublished manuscript. U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C.

or year-classes in the fishery has been demonstrated. A dominant year-class influences the catch in a given locality usually for only 1 or 2 years. As the fish grew older and larger, they occur farther northward and thus influence the catch in a different locality of the coast. Fluctuations in catch in the various areas in recent years appear to have resulted primarily from variations in the relative strengths of the individual year-classes contributing to stock in those areas.

In the early 1950's, several unusually abundant year-classes appeared in succession. These, together with many older fish, representing many different age-groups, resulted in record yields during the greater part of the decade. An abundance of fish, coupled with an increased demand for fish meal, brought about the addition of new and larger carrier vessels to the fishing fleet; processing capacities of the plants were increased; and synthetic seines and other mechanical and electronic aids were introduced to increase the efficiency of fishing. The result was that the amount of fishing effort on the stock reached unprecedented levels.

The increase in fishing effort has been accompanied by a decrease in the average catch per unit of fishing effort and the usual biological symptoms of heavy fishing. There has been an increase in total mortality of the individual age-groups in the fishery. There also has been an increase in the proportion of younger fish in the catch and an increase in growth rate of older fish. During the past 6 years, the fishery has been dependent on not more than three age-groups at any time, but in most recent years, more than 90 percent of the catch has come from only two. Increased fishing effort on only two age groups--fish of ages 1 and 2--makes the fishery vulnerable to greater fluctuations in yield in the future, since poor year-classes are to be expected. Indeed, variations in the average catch per unit of fishing effort (and in total catch) during the past several years have followed more closely variations in the abundance of each new year-class entering the fishery at age 1. Concomitantly, the older age-groups have become less accessible to the fishery during the summer season, although these older fish continue to appear in abundance in the coastal waters during their southward migration in autumn and support a sustained catch off the coast of North Carolina. It appears, however, that at present stock levels, the amount of fishing may be approaching the maximum for producing a sustained catch.

POTENTIAL OF THE RESOURCE

Although menhadens account for the greatest share of the annual fish production in the United States, their yield could be increased still further. Two North American species--the yellowfin and fine-scaled menhadens--exist as virgin stocks and apparently are not being utilized because the distribution and habits of the fish are not well known. Furthermore, the adult segments of the Atlantic and Gulf menhaden stocks are not being caught in proportion to their abundance. Older Atlantic menhaden are largely unavailable to the purse-seine fishery during the summer when the schools occur in deeper water offshore. This segment of the stock is exploited during a short period in autumn when the schools approach the coast during their southward migration. The fishery in the Gulf of Mexico, at present, is restricted to a relatively short stretch of coast in the vicinity of the Mississippi River delta and is based on fish of ages 1 and 2. Older age-groups which occur in other parts of the range of this species are not being exploited. If the North American menhaden stocks were utilized more efficiently, it is estimated that the sustained catch from this resource could amount to about 1.2 million tons annually.

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