REPORT OF THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, BEAUFORT, N.C.

For the Fiscal Year Ending June 30, 1967

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF COMMERCIAL FISHERIES

Circular 287

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REPORT OF THE BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY, BEAUFORT, N.C.

For the Fiscal Year Ending June 30. 1967

KENNETH A. HENRY, Director
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ABSTRACT

Results of biological research in the Anadromous Fish, Blue Crab, and Menhaden Programs are discussed. Major topics include abundance, distribution, and survival of blue crab and menhaden larvae, juveniles, and adults; results of menhaden tagging studies; and details of the 1966 menhaden fishery. Other activities of the laboratory staff, and publication for Fiscal Year 1966, are listed.

REPORT OF THE LABORATORY DIRECTOR

Kenneth A. Henry

Research at this laboratory is directed mainly towards the American shad, the blue crab, and the Atlantic and Gulf of Mexico menhadens. Our studies relating to the shad have been concerned principally with fish passage dams, whereas with the blue crab and menhaden we want to describe and examine the main features of the life history, measure the effects of certain environmental factors on survival, and develop methods for predicting future abundance to the fishery. Our menhaden studies also are aimed at defining the causes of fluctuations in abundance and determining the level of optimum utilization.

The anadromous fish program was discontinued at the end of the fiscal year. We are preparing manuscripts that will contribute greatly to the understanding of the shad resource along the Atlantic coast. Much of the research under this program was in conjunction with other Federal and State agencies, and its success was due mainly to the fine cooperation among the various individuals and agencies concerned, both in the field work and in the preparation of the manuscripts.

Our blue crab program has two major research projects. One project is to determine a relation between the abundance of juvenile blue crabs in Core Sound, N.C., and the subsequent abundance of marketable crabs. If this relation can be learned it will permit us to provide the industry with reliable predictions on the expected abundance of crabs so it can better prepare for the coming fishing season. This project also is providing considerable data on how young crabs are distributed in this estuarine area by time and size of crab. The second project is to measure how extremes of temperature, salinity, and dissolved oxygen affect the survival of blue crabs. This information is needed for evaluating the cause of mass mortalities in nature. Reductions in personnel and money for the blue crab program have considerably reduced the extent of our research.

Research on the Atlantic and Gulf of Mexico menhadens was greatly increased the past year. The budget was almost doubled, and 14 new positions were added. Most of the increased research was in our Atlantic menhaden tagging program. This year we had tagging crews in Florida, North Carolina, New York, and Chesapeake Bay. Recoveries from the tagging should provide us with the first positive data on certain aspects of the population dynamics and migrations of these fish.

Our studies on the estimation of the abundance of juvenile menhaden in the Gulf of Mexico also were expanded. Because we have had considerably more difficulty in obtaining reliable estimates in the Gulf than we have had on the Atlantic, this year we significantly increased the number of streams surveyed in the Gulf. This increased coverage should give us much more reliable estimates of abundance in our future work. We have begun studies to measure larval abundance and time of entry into the estuaries. These data will supplement our estimates of juvenile abundance.

We have not been able to expand our early life history studies, although we believe this area of study is very important in understanding the life history of the menhaden; and the size of the year class well may be determined at early stages. This work will require a suitable vessel for systematic surveys of the spawning areas.

Research is under way in the Laboratory to determine how menhaden react physiologically to the various environments through which they pass during different periods of their early life history. We also want to determine what factors govern their schooling and feeding behavior.

ANADROMOUS FISH

All the field work under this program was completed, including the cooperative studies on the Susquehanna River to determine the suitability of the area above the dams for shad, and work was concentrated on preparing manuscripts on this work. Fifteen reports were either published or submitted for publication during the year. This program was terminated at the end of fiscal year 1967.

BLUE CRAB

In our studies in Core Sound, N.C., we are attempting to establish a relation between the abundance of juvenile blue crabs and the subsequent abundance of marketable size crabs, so that we can give the industry predictions on expected abundance. We have determined that crabs less than 1-1/2 inches wide are most abundant in this area in January through March. Thus, it might be possible to establish an index of abundance by sampling only during this 3-month peak period rather than every month throughout the year. The catch per unit of effort of juvenile blue crabs was better in the creeks than in the bays and sounds; we believe the catch data for creeks should be used to establish an index of abundance for juvenile crabs.

This study also has shown that blue crabs have molted several times before they enter the estuary from the area where hatching, metamorphosis, and early development occur. This delayed entry after as long as 6 months indicates a much longer oceanic existence than we originally supposed and would permit the movement of young blue crabs long distances from where they were spawned.

Studies on how varying salinities and temperatures affect the tolerance and regulation of blood concentration of blue crabs indicate that the greatest change in their blood concentrations occurs within 6 hours after the crabs are transferred from sea water to a more dilute medium. Changes beyond 24 hours are nonsignificant. Crabs in any particular dilution of sea water generally have higher blood concentrations at decreased temperature; and the sexes exhibited no significant differences in regulatory ability.

MENHADEN

The 1966 catch of Atlantic menhaden, 483 million pounds, was the smallest since 1940; the catch has declined 62 percent in the past 5 years. Fishing was so poor in the Middle Atlantic area that two menhaden plants closed during the fishing season. Fishing intensity declined in most other Atlantic fishing areas but remained at a record high level in Chesapeake Bay. Catch per unit of fishing effort decreased in all areas except the North Carolina fall fishery in which fishing was better than expected. Because fishing had stopped earlier in the summer in the Middle Atlantic area, more fish were available to migrate southward to North Carolina during the fall spawning migration.

The catch of menhaden in the Gulf of Mexico amounted to 788 million pounds, 22 percent below the previous year and the lowest catch since 1960. The catch per vessel week, unadjusted for vessel efficiency, was the smallest since 1959, whereas the total number of vessel weeks increased 29 percent over 1965.

The catch of young-of-the-year (age-0) Atlantic menhaden was 304 million fish; 24 percent of the total landings and about three times more than in 1965. We estimate that the catch in the Chesapeake Bay area was 177 million age-0 fish. The catch of these small fish, which yield little oil, has increased significantly in the past 5 years and is attributable, at least in part, to the continuation of fishing in the bay later in the season in recent years.

In the Gulf of Mexico fishery the catch of age-1 fish appeared to be less than half as large as in the previous year. This drop probably reflects the relatively low abundance of the 1965 year class.

We completed a critical analysis of our catch sampling procedures and determined that our 20-fish sample was more than sufficient, at least for the Atlantic, although the precision of the estimates of age composition could be improved by sampling from more boats.

One of our biologists, William F. Hettler, Jr., took some excellent photomicrographs of living Atlantic menhaden embryos and larvae which he had collected and reared. In these photographs he noted protruding organs along the sides of the larvae. These organs, which form a primitive lateral line, or sensory system, have not been previously reported for menhaden and are of particular interest since older menhaden appear to lack a lateral line. The importance of these organs will be studied further.

Our preliminary tests on the response of young menhaden to certain environmental factors suggest that these fish may undergo a seasonal change in salinity preference that reflects the changing conditions they encounter in their lives. For example, juveniles in July preferred low to intermediate salinity, whereas in August their preference changed to intermediate and high salinity. This shift would correspond with their return to the sea after several weeks in nearly fresh water.

On a charter cruise aboard the Bureau of Sport Fisheries and Wildlife, Sandy Hook Marine Laboratory R.V. Dolphin in December, a large, dense concentration of live Atlantic menhaden eggs was discovered about 40 miles off New River Inlet, N.C. This discovery helps verify some of our hypotheses about the time and place of menhaden spawning.

A series of field experiments yielded evidence that the Gulf menhaden was capable of hybridizing with the less important yellowfin menhaden, and in certain areas they apparently do hybridize.

In our first year of tagging Atlantic menhaden, nearly 183,000 were tagged with an internal metal tag and released in waters off North Carolina. Actual recoveries on magnetic tag recovery equipment in the fish meal plants represent over 4-1/2 percent of the first year's releases. Preliminary analyses of the recoveries to date indicate: (1) a rather intense fishery, particularly in Chesapeake Bay, and (2) a subsequent northward movement of a considerable portion of the menhaden tagged off North Carolina in the summer and fall.

Data from our studies of the abundance of juvenile menhaden indicated that the 1965 year class of Atlantic menhaden would be one of the poorest on record. This finding was verified by subsequent catches during the 1966 fishing season. We estimate that the 1966 year class was better than 1965 but still poor. Catches to date have tended to verify these conclusions also. Preliminary estimates are that the 1967 year class will be poorer than 1966 on both the Atlantic and Gulf coasts and may be as poor as 1965.

ANADROMOUS FISH PROGRAM

Randall P. Cheek

Field studies on anadromous fish along the Atlantic coast were completed, and most of the year was spent on the preparation of reports on fish passage problems at various existing or proposed barriers along the east coast and on the analysis and reporting of data on American shad and striped bass. Fifteen reports were either submitted for publication or published during the year by program personnel. The aims of this program have been achieved, so the program was terminated at the end of the fiscal year.

BLUE CRAB PROGRAM

George H. Rees, Chief

Research on the blue crab was confined to two continuing projects. One is to develop a method for estimating juvenile abundance so that abundance of adults can be predicted, and the other is to determine how certain physical factors affect survival. Information from the latter project may help us assess the cause of mass mortalities in nature.

Each month since January 1965 we have sampled for the abundance of juvenile blue crabs in Core Sound, N.C. We have found only minor differences between the two complete years for which we now have data--differences which are possibly too small to be significant. We have shown that crabs less than 1-1/2 inches wide reach a peak of abundance in the estuary in January, February, and March. It should be possible to establish an index of abundance for a year class by sampling during their peak period rather than every month of the year. We have also shown that blue crabs enter the estuary after metamorphosis from megalops larvae and after they have gone through several molts as crabs. They do not begin to appear in the estuary in significant numbers until about 6 months after hatching has begun. This delayed entry into the estuary has considerable significance since it indicates a much longer oceanic existence than had previously been supposed and would allow the young crabs to be transported long distances from where they were hatched.

Mass mortalities of blue crabs are frequently reported in nature, and attempts made to correlate these kills with changes in the environment. The tolerance of blue crabs to extremes of temperature, salinity, and dissolved oxygen is not known; we began a series of experiments that will eventually test a large number of combinations of these variables to learn which combinations may cause mortality. With this information we will be better able to interpret observations of mass mortalities in nature and to anticipate the possible effects of extremely cold winters, extremely hot summers, or of abrupt changes in the environment.

ABUNDANCE AND DISTRIBUTION OF JUVENILE CRABS

Mayo H. Judy

Study of the blue crab resource in Core Sound, N.C., began in November 1964. This area was selected because it is small enough to be sampled intensively, yet large enough to be representative of many areas that are important in the production of blue crabs. The sound is about 35 miles long and has an average width of about 2-1/2 miles. It connects with the ocean through three inlets and opens into Pamlico Sound at its northern end and into North River and Back Sound at its southern end (fig. 1).

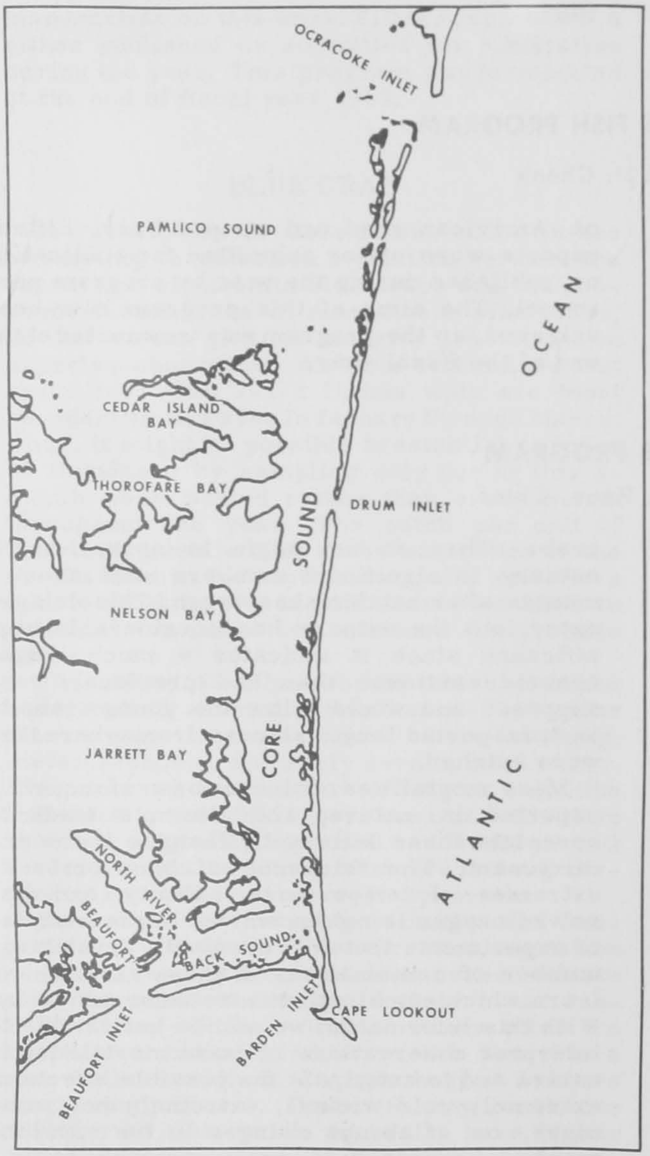

Figure 1.--Core Sound, N.C.

The main aim of this study is to be able to make reasonable predictions about the annual supply of marketable size crabs. We are approaching this objective by establishing an index of abundance of juvenile crabs in various size classes in the sound, by season and by year. We will relate this index to the catch per unit of effort in the commercial fishery, which is our best measure of adult abundance. If a direct relation can be shown to exist, we should be able to use the abundance of the juveniles to predict the supply of marketable size crabs.

This study area includes four distinct habitats: (1) the sound itself, (2) the inlets, (3) some large bays on the mainland side of the sound, and (4) many small creeks, some of which empty into the bays on the mainland side and others which empty directly into the sound on the outer banks side. After much exploratory trawling throughout the study area, we chose 14 sound and bay stations and 9 creek stations as regular sampling sites.

During this study we have used three principal methods for collecting information on blue crabs: (1) trawling with our own gear, (2) taking regular samples of the commercial catch, and (3) collecting catch and effort data from the commercial fishery. We used two boats in our trawl sampling: a small trawler in the sound, bays, and inlets, and a 16-foot skiff in the small, shallow creeks.

In the sound, bays, and inlets, we used a 20-foot trawl with 7/8-inch mesh material in the body and 5/8-inch mesh in the tail bag. In the creeks we used two 9-foot trawls, one with 7/8-inch mesh body and 1/4-inch mesh bag and the other with 1/4-inch mesh body and 1/16-inch mesh bag. Trawls were pulled for a measured length of time, and information was collected on the number, size, and sex of all blue crabs. Temperature and salinity also were recorded.

The Sound, Bay, and Inlet Waters

We have collected samples with the large trawl in open waters of the sound, bays, and inlets over a 2-year period. Our samples in the sound were composed of about equal numbers of immature and mature crabs, whereas samples in the bays contained about 80 percent immature and 20 percent mature crabs. The increased catch of immature crabs in bay and sound waters during the summer and fall seasons reflected the movement of immature crabs from the creeks in the early spring. The gradual decline in the abundance of immature crabs in these waters beginning in October probably was due to the approach of maturity of immature crabs.

Although the catch per minute of immature crabs in these open waters averaged only 0.6 crab in the sound and 1.1 in the bays and was low compared to our catch per minute of immature crabs in the small creeks which empty into the bays and sound, we believe it to be a good measure of juvenile abundance in these open waters. This belief is based on findings reported in the annual report of the Bureau of Commercial Fisheries, Biological Laboratory, Beaufort, N.C., for the fiscal year ending June 30, 1966. That report showed that our trawl catches of adult crabs fluctuated in much the same manner as pot catches of adult crabs in the commercial fishery (catch and effort in the commercial fishery is, at present, the best measure available of adult abundance; we used this standard to measure the effectiveness of our trawl gear). We assumed, therefore, that the trawl was just as efficient in capturing crabs less than commercial size as it was in capturing those of commercial size.

Trawl samples from the inlets were composed mainly of mature females, a small number of mature males, and occasionally a few immature crabs. Most females in the inlets had either a sponge (egg mass on the abdomen) or a remnant sponge (after the eggs have hatched). These waters, therefore, are not very suitable sampling areas for immature crabs.

In addition to our samples with the large trawl in the sound, we also sampled with small mesh trawls in the shallow, sandy, grass-bottomed areas at or near to the mouths of the small creeks. These areas of the sound have, at times, produced an abundance of immature crabs. The catch of immature crabs per minute in these waters is related to the movement of small crabs into and out of the small creeks. Figure 2 shows our catch of immature crabs in the shallow, grassy areas of the sound from June 1966 through May 1967. The catch per minute increases in the fall when very young crabs move from the ocean into the sound and then into the creeks. It increases again, in the spring, when the immature crabs move from the creeks into the sound. In November we have the first noticeable influx of small crabs, the catch per minute is highest by December, and in January the catch is approaching that of November. During these 3 months, early-stage crabs show major movement from the ocean into these small creeks. Crabs measuring 1-1/2 inches or less account for a very large percentage of the total catch of immatures from November through May. From June through October, when few small crabs are entering from the ocean and when growth is very rapid within the estuary, larger crabs make up a high percentage of the total catch of immature crabs.

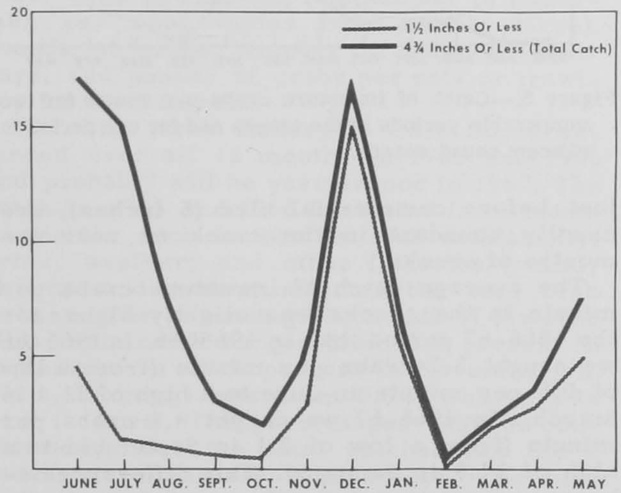

Figure 2.--Catch of juvenile blue crabs less than 1-1/2 inches wide and the total catch of juveniles per minute on the grass beds at the mouth of creeks in Core Sound, N.C., June 1966 to May 1967.

Data collected in these waters of the sound can be used to show size-class distribution by area and by season, as well as movement through these areas.

Creeks

Marshland bordering Core Sound is drained by many small creeks that empty directly into the sound on the outer banks side, and into the bays on the mainland side. Nine creeks, four on the mainland side and five on the outer banks side, were selected for repeated sampling. We used two 9-foot trawls of different mesh size, pulled from a 16-foot outboard boat, for checking abundance of immature crabs in these shallow, soft-bottomed areas.

We began sampling these creeks in January 1965, and the distribution of immature crabs as to abundance, size, and season has been closely similar for comparable periods in 1965, 1966, and 1967. A very high percentage of the crabs caught in these waters are less than 1-1/2 inches wide, and these small crabs are most abundant from late fall through early spring. Small crabs are not again available in the creeks in large numbers until the following winter.

Even though we have sampled in the small creeks over a 30-month period, data presented here cover only 24 months, from June 1965 to May 1966 and the same period in 1966-67. Each of these two time periods extends approximately from one spawning season until the beginning of the next, 1 year later. Data collected from January to May 1965 include only a portion of one complete period; this information will be used, therefore, only as a basis for comparing individual monthly catches and the catch per minute.

Comparison for two time periods in figure 3 which shows the catch of immature crabs per minute for June-May 1965-66 and June-May 1966-67. In October or November the

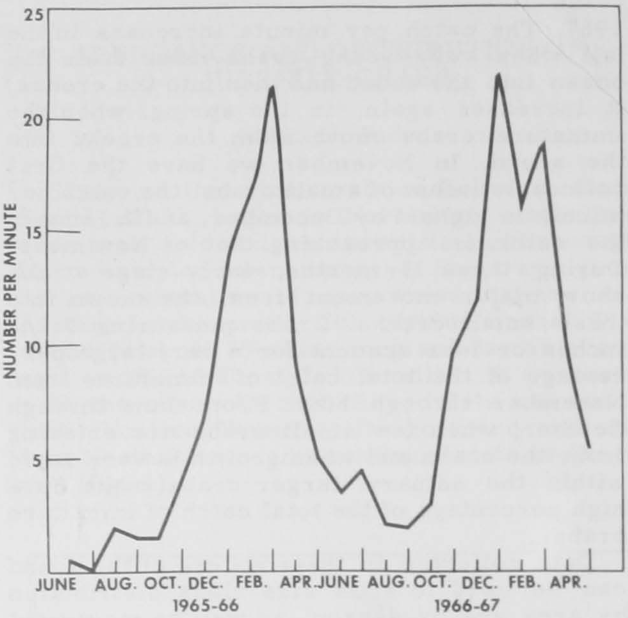

Figure 3.--Catch of immature crabs per minute in creeks of Core Sound, N.C., June 1965 to May 1967.

young-of-the-year crabs begin moving from the ocean, where the eggs are hatched, into the estuaries; this influx of crabs is evident by the increase in our catch of small crabs per minute in the creeks. This movement of crabs into the estuaries continues until a peak of abundance is reached sometime between January and March. Then, in April when the major influx from the ocean is over and small crabs begin to leave the creeks, abundance declines. The catch per minute continues low in the creeks until a new young-of-the-year group of crabs appears in October and November.

The immature crabs in our creek samples have been separated into three size groups: crabs that are 1-1/2 inches or less; those between 1-1/2 and 3 inches; and those between 3 and 4-3/4 inches. Figure 4 shows the catch per minute of each size group by monthly intervals over a 2-year period. The time of year when young-of-the-year crabs start to populate the small creeks is clearly apparent. In November, the smallest size group has the highest catch per minute, and this group continues to dominate catches through April. The catch per minute is similar for all three size groups in April through October.

The catch of immature crabs in the small creeks and the catch of immature crabs in shallow sound waters adjacent to the creeks are compared in figure 5. The pattern of movement of small crabs in these two closely associated habitats is obvious. Both areas appear to be unusually good sampling sites for immature crabs. Except for 2 to 3 months within a 12-month period, immature crabs of varying sizes, from a few tenths of an inch to

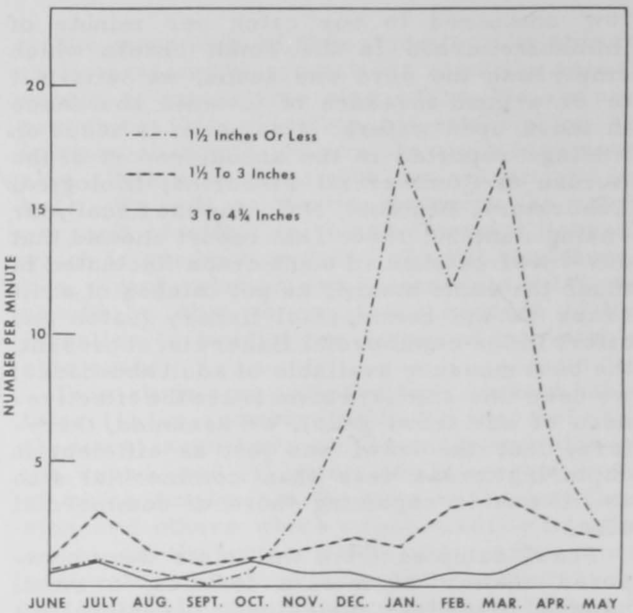

Figure 4.--Catch of immature crabs per minute in the creeks by size class. Two years of data are combined.

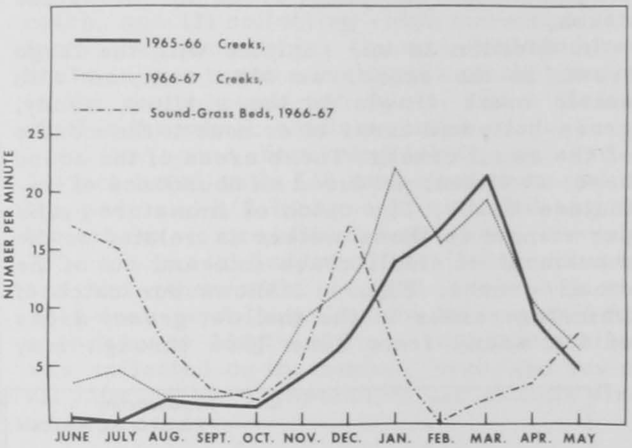

Figure 5.--Catch of immature crabs per minute for two comparable periods in the creeks and for one period in adjacent sound waters.

just before commercial size (5 inches), are usually abundant in the creek or near the mouths of creeks.

The average catch of immature crabs per minute in the creeks was slightly higher for the 1966-67 period than in 1965-66. In 1965-66 we caught 5.7 crabs per minute (from a low of 0.6 per minute in June to a high of 21.4 in March). In 1966-67 we caught 8.4 crabs per minute (from a low of 2.1 in September to a high of 21.9 in January). This difference between years is not great enough to indicate any significant changes in the abundance of juvenile crabs.

Since the catch of juvenile crabs per minute in the small creeks is considerably more than in the sound and bays, we feel that the creek data should be used in establishing our index of abundance of juveniles for the Core Sound area.

Data on immature crabs collected throughout the two time periods will be used as base data for comparison with future collections. Any changes in the abundance of juveniles in these waters could then be related with any subsequent changes that might occur in the commercial fishery. Data collected with our gear in different habitat areas, and especially in the small creeks and adjacent sound waters, provide the information we need to study trends that possibly could affect the commercial fishery, but additional information must be collected before we predict the annual supply of marketable size crabs.

Commercial Catch

Samples of the commercial catch in Core Sound have been collected for most months since the study began.

The Core Sound fishery is based almost entirely on mature females, which make up about 90 percent of the catch. Mature female crabs may be classified as sponge and nonsponge crabs. Sponge crabs (those with an egg mass attached to the abdominal flap) are present in the sound from April through September, and occasionally in October and early November. From April through July, each year, sponge crabs constituted about 40 percent of the catch. Peak spawning occurred in May and July, when the catches had more than 50 percent sponge crabs.

Catch and effort statistics have been collected for the Core Sound fishery since November 1964. We recorded data on the number of boats used in crabbing (the number of fishermen per boat varies from one to three), pounds of crabs, number of pot- or trawl-days, and pounds of crabs per pot- or trawl-day for each month.

The blue crab fishery in Core Sound extended over all 12 months in 1965 and 1966 and probably will be year around in 1967. The catch in 1965 and 1966 fluctuated from month to month; such factors as crab availability, price, weather, and other fisheries (mainly shrimp and oyster) affected the blue crab fishery. The percentage by month of the 1965 blue crab catch ranged from 3.6 percent in September to 23.9 percent in November. In 1966, the range was from 0.6 in February to 14.7 in April. The percentages differed considerably, but the total catches for the 2 years were closely comparable. The blue crab catch in Core Sound was 1,630,501 lbs. in 1965 and 1,612,893 lbs. in 1966. The catch per unit of effort has also varied somewhat between months within a year and between comparable months of the 2 years, but the catch per unit of effort was rather stable. Total catch in the 2 years differed little, and the catch per unit of effort was nearly uniform.

We believe that continued collection of catch and effort data, combined with sampling for juveniles will enable us to determine whether changes in abundance of juveniles are followed by changes in abundance of crabs of commercial size.

SURVIVAL REQUIREMENTS OF JUVENILE AND ADULT BLUE CRABS

Marlin E. Tagatz

Mass mortalities and fluctuations in numbers of blue crabs have at various times been attributed to environmental factors--unusually hot summers or cold winters, reduced salinity, or low oxygen. Generally it is difficult to ascertain when environmental factors become a threat to crabs because of the lack of knowledge of the survival requirements of the various life history stages. Our studies currently consist of a series of experiments on the tolerance of adult crabs, acclimated under varying environmental conditions, to various combinations of temperature and salinity.

The blue crab is able to tolerate a wide range of salinity by regulating the exchange of salts and water between its internal and external environment. Results of analysis of blood in a vapor pressure osmometer (fig. 6) indicated that it is the ability of this species to maintain the concentration of the blood higher than the water in which the animal lives (hyperregulate) that allows it to survive in waters of low salinity (fig. 7). Determinations of the total blood osmoconcentrations

Figure 6.--Worker using a vapor pressure osmometer to determine the total osmotic concentration of the blood of blue crabs maintained at different salinities.

Table 1.--Ability of crabs to regulate their internal environment in different salinities and at different temperatures. Averages and ranges are in osmoles per liter, and each represents 10 animals held 24 hours at selected salinity and temperature

Sea water		Male			Female (presponge)		
		50° F.	68° F.	86° F.	50° F.	68° F.	86° F.
Pct.	Os./l.	Osmoles/l.					
100	1.16	1.06 (1.00-1.12)	1.02 (0.99-1.08)	1.05 (1.02-1.10)	1.04 (0.98-1.08)	1.01 (0.98-1.06)	1.06 (1.00-1.12)
50	0.58	0.88 (0.82-0.96)	0.83 (0.82-0.86)	0.81 (0.72-0.85)	0.90 (0.86-0.95)	0.84 (0.80-0.90)	0.82 (0.76-0.84)
5	0.06	0.68 (0.60-0.76)	0.65 (0.56-0.71)	0.59 (0.49-0.65)	0.58 (0.51-0.64)	0.65 (0.61-0.73)	0.58 (0.50-0.70)

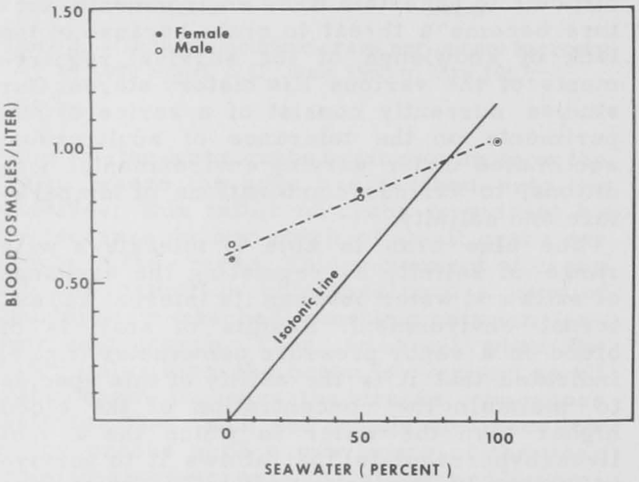

Figure 7.--The relation between the concentration of crab blood and the concentration of the medium.

after transfer of crabs from sea water to more dilute mediums indicated that the greatest change in their blood occurs within 6 hours after transfer; changes after 24 hours are not significant. We determined the concentration of the blood of mature females which had not spawned and adult males, held for 24 hours, in 5, 50, or 100 percent sea water at 50°, 68°, 86° F. (table 1). Crabs in dilutions of sea water generally maintained higher blood concentrations at decreased temperature. Although males are the dominant sex in low-salinity water and females in high-salinity water, their regulatory ability was about the same in almost all of the salinity-temperature combinations. Our continuation of the work on salinity acclimation may show that females with sponges and females who have had sponges--groups that show an even stronger preference for high salinity--differ from males and immature or newly mature females in their ability to regulate.

Table 2.--Tolerance of adult crabs to abrupt transfer between waters of different temperature, or salinity, or both

Initial environment		Receiving environment		Mortalities among 10 crabs	
Sea water	Temperature	Sea water	Temperature	Females	Males
Percent	° F.	Percent	° F.	No.	No.
50	41	50	86	1	0
50	86	50	41	0	0
10	41	50	41	0	0
10	86	50	86	0	0
10	41	50	86	0	1
10	86	50	41	0	2
10	41	10	86	4	5
10	86	10	41	8	10
50	41	10	41	6	8
50	86	10	86	3	4
50	41	10	86	6	5
50	86	10	41	10	9

To determine the effects of sudden changes on crabs, we made abrupt transfers of adults between water of different temperature, salinity, or both. Crabs were held for 3 days before transfer (initial environment), and deaths were recorded for 3 days after transfer (receiving environment). The effects of abrupt changes in temperature were salinity-dependent. Crabs were tolerant to selected temperature differences when transferred to 50 percent sea water but not when transferred to 10 percent sea water (table 2). In transfers that involved change only in salinity, crabs were not as successful in adjusting to a decrease in salinity as they were to an increase in salinity.

Resistance of crabs exposed to low or high temperatures depended on the salinity and the thermal history of the animal. Those in high-salinity water and acclimated up to 21 days at temperatures near the extremes of their tolerance survived at least 24 hours at temperatures ranging from 32° to 100° F. Resistance was less in low salinity after short acclimation. To determine when temperature acclimation is complete we are comparing the average survival times of animals acclimated for different periods and exposed to lethal temperatures. This information will enable us to conduct a series of experiments to indicate the limits of thermal tolerance of blue crabs at different levels of acclimation and salinity.

MENHADEN PROGRAM

Joseph H. Kutkuhn, Chief

Strengthened by a further increase in funding, biological research on the Gulf and Atlantic menhaden proceeded along essentially the same lines described in our two most recent annual reports.

Program personnel continued routine sampling of landings for size, age, and sex composition of the menhaden resource and concurrently obtained detailed information on catch and fishing effort.

Further analysis of statistics collected regularly along the east coast since 1955 substantiated earlier explanations of the protracted decline in annual yields of Atlantic menhaden. The major factor contributing to this downward trend is a succession of small year classes, compounded by increasingly heavy fishing on younger menhaden in the important Chesapeake Bay area.

Fishery-wide surveys, wherein we determine the comparative size of new year classes by measuring the relative abundance of juvenile menhaden in estuaries and tributary streams, indicated that incoming year classes (1966 and 1967) will not be large enough to increase production throughout the menhaden industry in the years immediately ahead.

Large-scale mark-recapture experiments, carried out simultaneously in four coastal areas, yielded preliminary but useful information--obtainable in no other way--on the seasonal movement of Atlantic menhaden in and out of major estuaries as well as up and down the eastern seaboard.

Continuing study of menhaden life history produced new information on the location and intensity of spawning by the Atlantic species, and conclusive evidence that the Gulf menhaden commonly hybridizes with another species of lesser importance. The program also began new work to determine by laboratory experimentation how menhaden react to adverse environments, how they adapt physiologically to the different environments through which they pass during their early life history, and what factors govern their schooling and feeding behavior.

DEVELOPMENT AND OCEANIC DISTRIBUTION OF LARVAL MENHADEN

John W. Reintjes

From what has been reported and what we have observed about menhaden life history, we conclude that most spawning takes place from November to March, the Atlantic species principally off Virginia and the Carolinas and the Gulf species off Mississippi and Louisiana. Hatching takes place in 42 to 54 hours at 59° to 68° F., the general range of water temperatures at that time of year. Larvae from 3/4 to 1 inch long and probably about 1 month old move from the ocean into the estuaries.

This general information about the menhaden's early life history does not provide, by itself, the understanding we seek of how each new generation of menhaden fares during the oceanic phase of its development. To answer questions about the exact times and places of spawning, the distribution and density of eggs and larvae, the best conditions for their survival, and the mechanics of their movements from the ocean into the estuaries, we must undertake studies at sea. Because we have not had our own research vessel for these studies we have had to rely on a variety of other sources for material and data. Thus, during the year covered by this report, we collected eggs and larvae from a U.S. Coast Guard light tower and from ocean-going vessels operated by various research groups, and obtained data on eggs and larvae from plankton collections generously made available by other laboratories.

Two additional sources of eggs and larvae of Atlantic menhaden, as well as those of other marine herringlike fishes, were made available to the laboratory. The first consisted of collections from 16 cruises by the R. V. Dolphin along the Atlantic coast from November 1965 through May 1967. Two technicians provided by our laboratory helped to sort these collections at the Bureau of Sport Fisheries and

Wildlife Sandy Hook Marine Laboratory (New Jersey). The preliminary sorting has been completed, and analysis of the results is underway. The second source, provided through the courtesy of Duke University's Marine Laboratory, comprises material collected during cruises of the R. V. Eastward from November 1965 to December 1966 between Cape Lookout and Oregon Inlet. This material includes the first collections of menhaden larvae ever made with opening-and-closing nets. Hence their examination offers the possibility they may yield new information on the vertical distribution of menhaden larvae.

Atlantic Menhaden (B. tyrannus)

The Coast Guard was very helpful in our first efforts to get information on the distribution of menhaden eggs and larvae along the Atlantic coast by allowing us to sample from Frying Pan Light Tower, which stands 40 miles off the North Carolina coast, more than half way to the edge of the Continental Shelf. Because it is not only in an area where we expected some menhaden spawning but also in one characterized by relatively strong wind and tidal currents, we believed we could collect eggs and larvae by regularly streaming plankton nets from the tower. One of our staff, who occupied the tower from November 30 until December 14, obtained 78 menhaden eggs, allowed them to develop at different temperatures, and took an excellent series of photomicrographs of living embryos and larvae at successive stages of growth (fig. 8). The photographs led to the discovery of protruding organs along each side of the larvae. These structures form a primitive lateral line, a sensory system used by fishes to detect currents, sound, obstacles, enemies, and perhaps other characteristics of the environment. The presence of the organs was of further interest

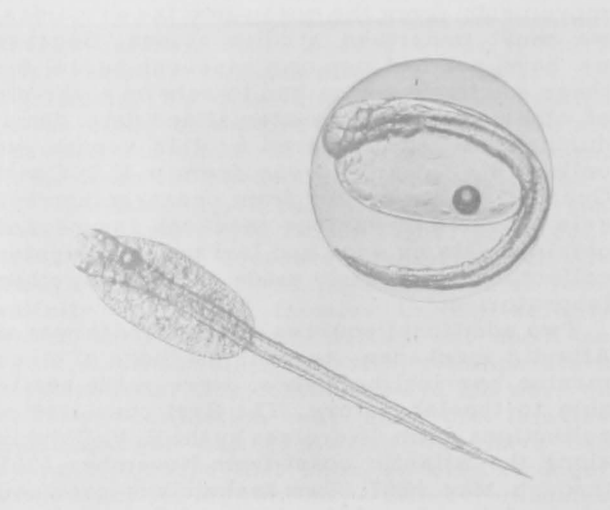

Figure 8.--Embryo and larva of Atlantic menhaden with sensory organs along the trunk.

because the trunk of older menhaden and all other herringlike fishes has no apparent lateral line.

In mid-January, another staff member spent 2 weeks on the same tower to obtain additional information on the occurrence of eggs and larvae. As in our first attempt, the Coast Guard provided transportation and facilities. During this venture, unfortunately, currents on Frying Pan Shoals were generally too weak to stream our plankton nets and only five menhaden eggs and no larvae were taken.

Besides our work on the light tower, we collected menhaden eggs and larvae by participating in three cruises of research vessels off North Carolina--one each aboard the Bureau of Sport Fisheries and Wildlife R.V. Dolphin, the Bureau of Commercial Fisheries R.V. Albatross IV, and Duke University's R.V. Eastward. In December we proceeded with the R. V. Dolphin in a systematic search for early life history stages of Atlantic menhaden, beginning on Frying Pan Shoals where earlier we had found a few eggs. Midway in the cruise, during which 87 stations were occupied, we located a dense concentration of menhaden eggs 40 miles off New River Inlet at the middle of the Continental Shelf. By crossing the area several times we found the patch to be less than 5 miles in diameter. In the center, a 10-minute haul with a Gulf-V net yielded more than 100,000 eggs. The embryos represented three age groups, estimated to be about 24 hours apart. The youngest were early blastoderm or about 8 hours old, and the oldest, about 55 hours, were ready to hatch. Spawning responsible for these eggs apparently occurred on three successive nights at about the same time each night. Elsewhere during the cruise we took 29 menhaden larvae, 1/2 to 3/4 inches long. Even though these few observations do not enable us to conclude much about spawning of the entire Atlantic menhaden stock, they are significant because they help confirm the uncertain beliefs on time and place of spawning and on distribution of eggs that had accumulated over the past few years.

Another opportunity to collect at sea came in late January when the R.V. Albatross IV made a 4-day cruise off North Carolina to compare the performance of different types of samplers for fish eggs and larvae. Thirty collections were made in an area 20 miles square northeast of Frying Pan Shoals. All fish eggs and larvae were counted and measured at our laboratory (fig. 10). Twenty-three collections contained menhaden larvae. No menhaden eggs were taken.

A 3-day cruise of the R.V. Eastward in early February presented the final opportunity of the winter. The vessel operated between Cape Lookout and Oregon Inlet, from about the middle of the Shelf to beyond its seaward edge. No menhaden eggs were taken and larvae occurred only at stations within the 40-fathom curve.

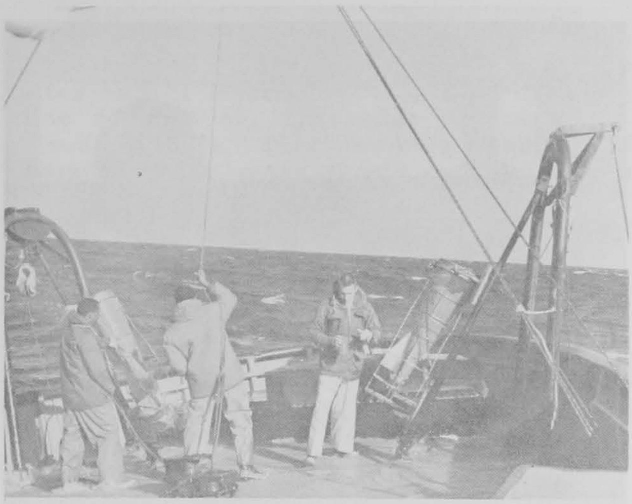

Figure 9.--Workers securing Gulf-V plankton nets after paired hauls from R.V. Dolphin.

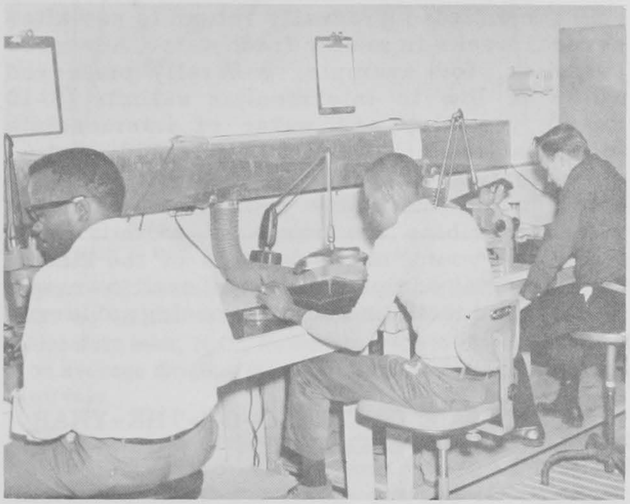

Figure 10.--Workers sorting fish eggs and larvae from plankton collected by R. V. Albatross IV.

Table 3.--Distribution of menhaden eggs and larvae collected from the eastern Gulf of Mexico, 1964-67

Month	1964-65			1965-66			1966-67		
	Port St. Joe to Carrabelle			Tampa Bay to Cape Sable			Mississippi Sound		
	Net hauls	Eggs	Larvae	Net hauls	Eggs	Larvae	Net hauls	Eggs	Larvae
	No.	No.	No.	No.	No.	No.	No.	No.	No.
Oct.---	--	--	--	--	--	--	3	0	0
Nov.---	--	--	--	--	--	--	--	--	--
Dec.---	10	28	4	--	--	--	6	23	46
Jan.---	13	173	4	13	155	247	5	8	21
Feb.---	6	0	7	11	4,376	73	--	--	--
Mar.---	10	5	104	11	0	28	--	--	--
Apr.---	--	--	--	9	0	10	--	--	--

Gulf Menhaden (B. patronus)

Our principal efforts to determine where and when Gulf menhaden spawn have been through participation in cruises aboard research vessels of the Bureau's Exploratory Fishing and Gear Research Base at Pascagoula, Mississippi. Objectives of these cruises were to locate concentrations of adult menhaden between commercial fishing seasons, to obtain gravid menhaden for fecundity studies and for artificial fertilization trials, and to collect planktonic fish eggs and larvae. Table 3 summarizes the menhaden egg and larval data that have been accumulated since the investigation began in 1964.

Some of the eggs collected in February and March are believed to be those of Atlantic thread herring (Opisthonema oglinum) and of scaled sardine (Harengula pensacolae). On the basis of their occurrence in gill net catches, it is known that gravid adults of each species were present in the collecting areas. Eggs and larvae of these species have not been described, but they probably are very similar to those of menhaden.

The only opportunity to fertilize menhaden eggs artificially came in February 1966, during a cruise of the Bureau's R.V. George M. Bowers off southwestern Florida. Ripe eggs from yellowfin menhaden (Brevoortia smithi) were fertilized with sperm of the same species and with sperm from Gulf menhaden (B. patronus). Both attempts were successful; the eggs hatched, and the larvae lived until the yolk material was absorbed. These trials provided a series of developing eggs and larvae of known age and parentage.

The information and specimens obtained from these activities have (1) given further clues regarding the time and place of menhaden spawning, (2) shown that artificial fertilization and hybridization are possible, (3) provided additional information concerning the distribution and density of eggs and larvae, and (4) resulted in large collections of embryos and larvae at different stages in their development. From these data, hypotheses may be proposed about both the sequence and the success of menhaden development and spawning in the Gulf of Mexico.

RESPONSE OF YOUNG MENHADEN TO ENVIRONMENTAL CHANGES

Richard W. Lichtenheld
William F. Hettler, Jr.

To explain variation in menhaden year-class size, which we believe is largely determined during each new generation's first year of life, we need to know much more about how changes in major environmental factors influence the survival of young menhaden.

Temperature and salinity, variables that can be handled with comparative ease in laboratory experiments with simulated aquatic environments, generally are recognized as important attributes of the environment of marine-estuarine organisms. During their first year of life, menhaden, for example, encounter wide ranges of temperature and salinity. Hatching and early development take place in the ocean during the winter at high salinities. After a month or so the larvae move inshore to the upper reaches of estuaries where the salinity is usually very low and the temperature often approaches freezing. They remain in estuaries throughout the following summer when the water temperature frequently climbs above 90° F. and the salinity fluctuates widely.

In studies at this laboratory during the past 3 years, temperatures below 39° F. killed larval menhaden. Their resistance to low temperatures was greatest at 15 p.p.t. (parts per thousand) salinity and decreased as the salinity was raised or lowered. Acclimation temperature also affected survival. In general, the lower the acclimation temperature the greater the survival of test fish.

As a logical next step in our work, we wanted to learn the relative effects of different salinities and temperatures upon survival, metamorphosis, and growth. We also wanted to find out how young menhaden react when subjected to adverse temperatures and salinities; i.e., what point in the range of each factor do they prefer when given the choice.

Focusing attention on the salinity preference of young menhaden, we constructed a test tank with four interconnecting compartments separated by incomplete partitions. The partitions allowed a different salinity to be maintained in each compartment while a shallow "water bridge" across the tops of the partitions enabled test fish to move freely between compartments. The four test salinities were 0, 10, 20, and 30 p.p.t. Temperature in the test compartments was held constant by placing the tank in a water bath. An arrangement of lights provided uniform illumination, and a mirror and overhead viewing slit facilitated observation (fig. 11).

In each test we placed 10 young menhaden in the compartment containing water of the same salinity in which they had been held. From this compartment they were free to move to any other portion of the tank. Thereafter, the number of fish in each compartment was recorded every 2 min. for 20 min.; five such observation periods--separated by 20-min. intervals--constituted each full test.

The first 20 tests yielded variable but useful information. The manner in which the test salinities were arranged in the tank, hence the inability to maintain consistently sharp salinity boundaries between adjoining compartments, appeared to be the primary source of variation among test results. Even though the results were quite variable, they did suggest a progressive seasonal change in salinity preference that may have reflected what happens as the young menhaden gradually return to sea after several weeks in nearly fresh water. Advanced juveniles, for example, generally preferred water of low to intermediate salinity (5-10 p.p.t.) in July, and water of intermediate to high salinity (10-30 p.p.t.) during August.

Figure 11.--Worker observing four-compartment tank for determining the salinity preference of larval and juvenile Atlantic menhaden.

These trials have given us a better understanding of the many problems associated with describing the range of salinity preferred by young menhaden and of the kind of experimental equipment we will need to answer important questions about the ecology of larvae and juveniles.

ABUNDANCE OF YOUNG-OF-THE-YEAR MENHADEN

Larvae

Robert M. Lewis

In January 1966, we began to sample regularly for the occurrence and abundance of larval Atlantic menhaden as they enter the local estuary. Early work concerned with testing the feasibility of different types of sampling gear had showed that a fixed "channel" net with flow meter was the most efficient. The 32-ft.^{2} net, attached to a frame that moves up and down between steel pipes, is fished from a platform on the bridge over the 20-ft.-deep channel adjacent to the Beaufort laboratory. It can be operated equally well on flood and ebb tides. All catches of menhaden larvae are reported as the number per 100 m^3 (3,530 ft.^{3}) of water passing through the net; the number of samples for each 2-week period ranged from 13 to 31.

Regular sampling began in early November 1966 and continued through May 1967. The first menhaden larvae were caught on November 14 and the last on April 28. A minor peak of abundance appeared in late November, but the main influx of larvae occurred during the latter half of March (fig. 12), about the same time as in 1966. Thereafter, the catch declined steadily. This season's results and those of future years should provide a basis for establishing yearly indices of larval abundance.

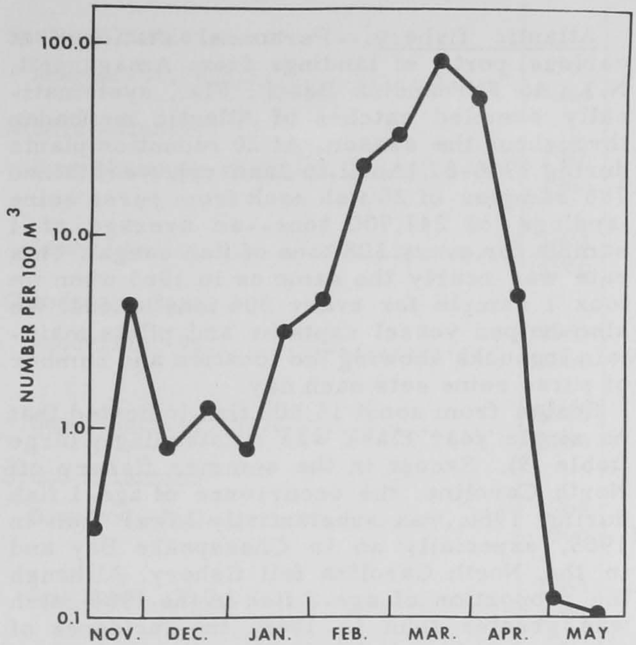

Figure 12.--Relative abundance of Atlantic menhaden larvae in channel on the north side of Pivers Island, Beaufort Inlet, N.C., November 1966 to May 1967 based on average daytime (surface) catches during 2-week intervals.

Changes in larval abundance inside Beaufort Inlet during the winter and spring of 1966-67 indicated that spawning intensity off North Carolina was greatest from January to mid-March. The sampled menhaden, none of which had metamorphosed into juveniles, ranged from 1/4 to 1-1/2 inches long. Differences in size of larvae as they entered the inlet may have reflected variable rates of transport, as well as differences in water temperature at time of spawning and in distances from spawning sites. We are trying to determine if abundance and time of movement of larvae through the inlet are related to water temperature and moon phase (as it affects the tide) but to date have been unsuccessful. The major factors influencing the abundance and movement of larvae are probably oceanic and beyond our ability to measure at this time.

Juveniles

William R. Turner

Sampling for the abundance of juvenile menhaden as an index of year-class strength continued along the Gulf and Atlantic coasts in 1966. Resulting estimates of year-class size provide indices of resource condition, and at the same time serve as a guide to the menhaden industry in planning subsequent operations.

Atlantic menhaden.--Four survey methods, developed and used over the past 5 years along the Atlantic coast from Cape Cod, Mass., to Fernandina Beach, Fla., were employed again in 1966 to estimate the abundance of juvenile menhaden before they become vulnerable to the commercial fishery. These methods were haul seining, surface trawling, and mark-recapture experiments (collectively used in our ground surveys), and aerial spotting. The ground surveys entailed sampling at 24 sites--3 in the North Atlantic area, 8 in the Middle Atlantic and Chesapeake Bay areas and 13 in the South Atlantic area. Ground and aerial surveys both showed a slight increase in menhaden reproduction in 1966 (fig. 13).

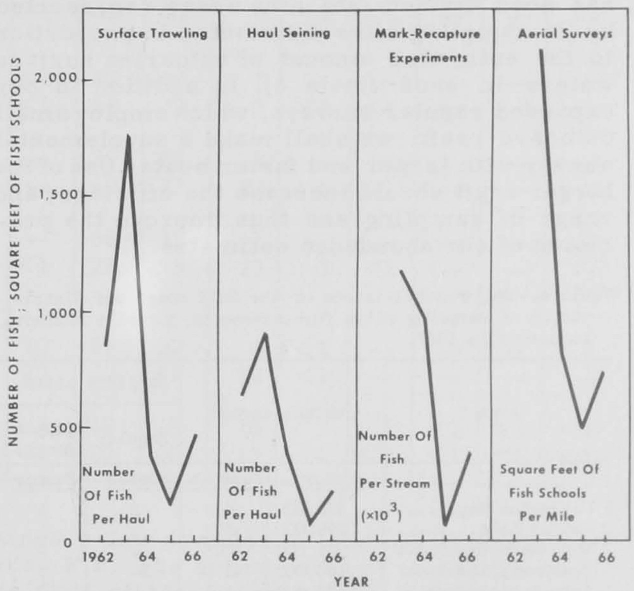

Figure 13.--Trends in abundance of juvenile menhaden derived from ground and aerial surveys along the Atlantic coast, 1962-66.

Of the three ground survey methods, surface trawling seems to be the most adaptable to the wide variety of situations encountered, provides the greatest coverage in the shortest time, and, consequently, is considered the most reliable. The following summary of year-class indices, derived from surface trawling alone in selected areas along the Atlantic coast since 1962, clearly reveals a major cause of the serious decline in Atlantic menhaden landings over the last 3 years.

Area	1962	1963	1964	1965	1966
South Atlantic . .	1.00	1.05	0.41	0.25	0.46
Middle Atlantic - Chesapeake Bay	1.00	5.77	0.90	0.08	0.50
North Atlantic . .	-	1.00	0.03	0.03	0.24

Gulf menhaden.--Surface trawls exclusively have been used in surveys to estimate menhaden year-class strength in the Gulf region since 1964 at seven sites between Apalachicola, Fla., and Galveston, Tex. As on the Atlantic coast, the 1966 survey along the Gulf coast also indicated greater menhaden reproduction than in 1965. Annual indices of relative abundance were 1.00 in 1964 (base year), 0.14 in 1965, and 0.73 in 1966.

To bridge some of the large gaps between existing sampling sites along the Gulf coast, we are increasing considerably the number of survey streams. The previously defined coastal region (Apalachicola, Fla., Galveston, Tex.) has been divided into nine areas represented by 36 sampling sites distributed in proportion to the estimated amount of estuarine surface waters in each (table 4). In addition to our expanded regular surveys, which employ small outboard craft, we shall make a supplemental survey with larger and faster boats. Use of the larger craft should increase the efficiency and range of sampling and thus improve the precision of our abundance estimates.

Table 4.--Major subdivisions of the Gulf coast and distribution of sampling sites for surveys of juvenile menhaden abundance in 1967

Area	Surface acres[1]		Sampling sites	
			Regular	Supple-mental
	Number	Percent	Number	Number
1 Galveston Bay......	336,000	6.4	2	1
2 Sabine Lake........	299,000	5.7	2	1
3 Vermilion Bay......	555,000	10.6	4	2
4 Mississippi Delta..	2,160,000	41.0	14	7
5 Lake Pontchartrain.	582,000	11.1	4	2
6 Mississippi Sound..	573,000	10.9	4	2
7 Mobile Bay.........	283,000	5.4	2	1
8 Perdido Bay........	238,000	4.5	2	1
9 St. Andrew Bay.....	229,000	4.4	2	1
Total............	5,255,000	100.0	36	18

[1] Estimates of surface area from the Office of River Basin Studies (BSFW).

POPULATION DYNAMICS

Robert B. Chapoton
Stanley M. Warlen

Catch Sampling

The Atlantic and the Gulf of Mexico menhaden resource is large, dynamic, and renewable. Through an extensive sampling program covering the menhaden fisheries, statistics on the length, weight, sex, and age composition of the fished stocks, together with records of landings and vessel operations, are gathered according to established procedures. These data constitute the basic requirements of research on the dynamics of our menhaden fisheries.

Atlantic fishery.--Personnel stationed at various ports of landings from Amagansett, N.Y., to Fernandina Beach, Fla., systematically sampled catches of Atlantic menhaden throughout the season. At 20 reduction plants during 1966-67 (April to January), we obtained 786 samples of 20 fish each from purse seine landings of 241,900 tons--an average of 1 sample for every 308 tons of fish caught. This rate was nearly the same as in 1965 when we took 1 sample for every 306 tons landed. We also helped vessel captains and pilots maintain logbooks showing the location and number of purse seine sets each day.

Scales from about 15,500 fish indicated that no single year class was outstandingly large (table 5). Except in the summer fishery off North Carolina, the occurrence of age-1 fish during 1966 was substantially lower than in 1965, especially so in Chesapeake Bay and in the North Carolina fall fishery. Although the proportion of age-2 fish in the 1966 catch was greater than in 1965, the incidence of age-3 and older fish was the same each year. Young-of-the-year (age-0) fish did not become available to the 1966 fishery until early fall, but they were harvested heavily enough to make up 24 percent of the landings, about three times more than in the 1965 fishery.

We determine the age and year class of Atlantic menhaden in our samples by counting the annular rings on their scales. For accurate aging of fish we must know if and when marks other than true annular rings are produced.

The possibility that the first mark on scales of unusually small "age-1 and -2" fish caught in the North Carolina fall fishery is not a true annulus has prompted a study to determine the time of year and size of fish when the first annulus forms on scales of young menhaden.

For a 13-month period, we have a series of biweekly collections of fish from tributaries of the local Neuse River estuary. Age-0 fish in their first spring, summer, and fall were caught with pound nets, haul seines, and surface trawls. During winter and their second spring they could only be captured with gill nets. Young-of-the-year fish first appeared in our samples on April 2, 1966, when they ranged from 0.8 to 1.4 inches long (fork length). By August 30 they were 2.3 to 3.5 inches. The average rate of growth for this period was about 0.4 inch per month. None of these fish exhibited scale marks that could be readily identified as annuli. The next collection of fish, taken September 23 and, as judged

Table 5.--Age composition of samples from Atlantic menhaden landings, 1965-66

Area and port of landing	Year	Sample size	Age in years								
			0	1	2	3	4	5	6	7	8
		Number	Percent								
North Atlantic:											
Amagansett, N.Y.	1965	1,782	--	--	12	53	18	8	6	3	<1
	1966	177	--	--	3	45	40	8	2	2	<1
Middle Atlantic:											
Port Monmouth, N.J.	1965	1,941	--	<1	33	55	10	1	<1	<1	--
	1966	1,229	--	--	15	55	27	3	<1	--	--
Lewes, Del.	1965	2,720	--	33	43	21	2	<1	--	--	--
	1966	520	--	24	52	18	6	<1	--	--	--
Chesapeake Bay:											
Reedville, Va.	1965	5,991	8	70	17	5	<1	<1	<1	--	--
	1966	5,506	21	32	39	7	<1	<1	--	--	--
Cape Charles, Va.	1965	--	--	--	--	--	--	--	--	--	--
	1966	649	7	41	43	9	<1	<1	--	--	--
South Atlantic:											
Beaufort, N.C.	1965	819	<1	47	48	5	--	--	--	--	--
	1966	1,854	<1	62	32	5	<1	<1	--	--	--
Southport, N.C.	1965	373	--	39	53	8	--	--	--	--	--
	1966	297	--	40	33	23	4	--	--	--	--
Fernandina Beach, Fla.	1965	4,172	--	66	33	1	--	--	--	--	--
	1966	3,555	<1	21	53	23	3	<1	--	--	--
North Carolina fall fishery:											
Beaufort-Morehead City	1965	1,514	10	62	22	6	<1	--	--	--	--
	1966	1,720	25	22	41	12	<1	--	--	--	--
All areas	1965	19,312	3	48	28	16	3	1	<1	<1	<1
	1966	15,507	11	29	40	15	4	<1	<1	<1	<1

from their length, presumably representing the same year class as those collected in the preceding 5 months, contained a high proportion of fish (70 percent) with scales possessing a ring resembling an annulus near their margin. Twenty-eight percent of the fish caught in October and November 1966 also had such rings near the margins of their scales. If in subsequent collections we find that scales from the same group of fish caught in the spring of 1967 have another new ring, the first mark will have to be classed as a false annulus. This study should lead to the development of improved criteria for aging Atlantic menhaden.

Gulf fishery.--We collected biological and fishery statistics throughout the 1966 fishing season (April to October) at seven ports of landing: Moss Point, Miss.; Empire, Morgan City, Dulac, Intracoastal City, and Cameron, La.; and Sabine Pass, Tex. In addition, we obtained a few samples of landings at Apalachicola, Fla. The entire catch of menhaden from the Gulf of Mexico was landed at these ports and, as in the past two seasons, four strategically placed individuals did the sampling (fig. 14).

The scale method of aging Gulf menhaden remains to be completely appraised but, in 1966 as in 1964 and 1965, ages were assigned provisionally to the fish in our samples. Comparison of the age distributions for the 3 years suggests that the age structure of the fishable stocks changed significantly (table 6). The contribution of 1-annulus fish in 1966 was about 53 percent less than the average contribution of year-old fish in 1964 and 1965. Conversely, the contribution of 2-ring fish was 21 percent greater than the average contribution of fish of the same age in the previous two seasons. Three-ring fish made up 21 percent of all individuals sampled in 1966, a significantly

Figure 14.--Close-up of catch of Gulf menhaden consisting mainly of 2-year-old fish.

Table 6.--Age composition of samples from catches of Gulf menhaden landed at major ports, 1964-66

Port of landing	Year	Sample size	Age in years						
			0	1	2	3	4	5	6
		Number	Percent						
Moss Point, Miss.	1964	3,982	<1	74	24	2	<1	--	--
	1965	6,219	<1	67	30	2	<1	<1	--
	1966	3,631	<1	12	52	32	4	--	--
Empire, La.......	1964	3,392	<1	31	44	21	4	<1	<1
	1965	3,308	<1	59	29	10	1	<1	--
	1966	2,376	--	20	52	24	4	<1	--
Morgan City, La..	1964	2,271	--	41	51	7	1	<1	--
	1965	3,030	<1	47	35	17	1	<1	<1
	1966	2,048	--	27	49	22	2	<1	--
Cameron, La......	1964	2,650	<1	46	46	7	<1	<1	<1
	1965	2,709	<1	69	28	2	1	--	--
	1966	4,211	<1	54	35	9	1	--	--
Total........	1964	12,295	<1	50	39	9	2	<1	<1
	1965	15,266	<1	62	30	7	<1	<1	<1
	1966	12,266	<1	30	46	21	2	<1	<1

greater proportion than in either of the two previous seasons. In 1966 as well as in 1964 and 1965, fish in their first, fifth, sixth, and seventh years of life contributed only small amounts to the total landings.

Particularly noteworthy was the contribution of fish of the 1964 year class of Gulf landings during the 1965 and 1966 seasons. As 1-year-old fish in 1965, they made up 62 percent of the sampled fish and as 2-year-old fish in 1966, nearly half. Equally striking was the relatively poor showing of the 1965 year class in 1966, which confirmed earlier predictions based on 1965 surveys of juvenile abundance.

During the year, we continued research aimed at verifying certain scale markings as true indicators of the age of Gulf menhaden. Part of this work is concerned with determining what part of the menhaden's body yields the best scales for age and growth studies. Statistical analysis showed that variation in the (1) relative dimensions of and (2) the number of circuli (growth rings) on scales from each of eight body areas was significant. We therefore concluded that all scales on individual Gulf menhaden can be expected to yield comparable information about age and growth and that other considerations in selecting scales should next be examined.

Additional factors that influence the selection of scales are their size, shape, clarity of markings, freedom from deformities, and ease of removal. Our studies indicated that on the average, the larger and more symmetrical scales and those with the most distinct markings are from the midlateral surface of the fish. Scales from the caudal peduncle or tail section have large cracks that make reading difficult. Scales from along the back and along the belly are comparatively small and irregularly shaped, making interpretation of the markings very difficult. We believe the midlateral area directly below the dorsal fin provides the best scales for age and growth calculations, but our final decision awaits results of other studies now in progress.

As in each of the previous two seasons, the 1966 harvest of menhaden along the Gulf coast consisted almost entirely of one species, the Gulf menhaden. Of 640 samples obtained throughout the 1966 season, only 8 were of finescale or yellowfin menhaden. These two species are so uncommon in purse seine landings that knowledge about their actual contribution is incomplete. Available data indicate that during the 1966 season, however, finescale and yellowfin menhaden constituted less than 0.1 percent of the 394,000 tons landed. Other herringlike species that were caught in small numbers were the Atlantic thread herring and scaled sardine.

Evaluation of Catch-Sampling Procedure

William D. B. Davies

Sampling the commercial purse seine landings provides information about the size, age, and sex composition of the Atlantic and Gulf menhaden resources. This information is essential to understanding the dynamics of the fisheries these resources support.

The present sampling scheme consists of "randomly" drawing a standard sample of 20 fish from the landings of as many as three vessels at each major port every workday throughout the fishing season. Each sample is taken at dockside from the top of the load, which presumably represents the catch of the vessel's last seine haul (or set) before landing. From each fish the sampler takes a scale sample and records the specimen's length, weight, sex, and stage of sexual maturity.

Sampling procedure, essentially as described above, was established at the start of Atlantic menhaden studies by the Bureau of Commercial Fisheries in 1955. The program was later (1964) expanded to include the Gulf coast fishery. Until recently no attempt had been made to evaluate the sampling plan in whole or in part; this year we undertook an exploratory study to assess its efficiency. Of immediate concern were adequacy of sample size and sampling frequency in estimating the age and size composition of menhaden landings.

At each port of landing during each week, the catch sampler, in his attempt to obtain representative samples of fish being caught by the menhaden fleet in his region, is confronted with many sources of sampling variation. They include differences in catch composition between and within fishing areas, vessels, and days--which may reflect changes in the space-time distribution of concentrations or schools of menhaden. During this study, however, we were able to consider only the variation within and between daily landings and within the last haul of fish pumped aboard the vessel.

Data with which to appraise variation in age and size composition within and between vessel landings were obtained by intensified sampling in each of two 1-week periods (early July and late August) during the regular fishing season at the major ports serving each fishery, i.e., Reedville, Va., and Moss Point, Miss. In addition, we intensively sampled for 1 week (early December) during the North Carolina fall fishery at Beaufort, N.C. Daily sampling consisted of drawing, besides our standard 20-fish sample, 10- and 40-fish samples from each of as many as nine vessels. Work was complicated frequently by the small number of (<9) landings on some days. All told, the number of 10-, 20-, and 40-fish samples collected at Reedville, Moss Point, and Beaufort were 15, 24, and 30, respectively.

For each of the five 1-week study periods, the data were grouped by age for each level of sampling and each day's landings. To assess differences in relative age distribution between levels of sampling as well as within and between daily landings, we used simple (chi-square) tests of homogeneity.

Analysis of the Atlantic menhaden data collected at Reedville and Beaufort disclosed no significant differences between age frequency distributions estimated from the 10-, 20-, and 40-fish samples, thus indicating that the fish were homogeneously distributed by age within individual schools. In contrast, differences within and between landing days proved statistically significant; this fact suggests that the appreciable variation in age composition between schools and in the day-to-day distribution of schools is a possible major source of error in estimating contributions of each year class to the total catch of menhaden.

The data collected at Moss Point revealed, as did analysis of the Reedville data, a high degree of variation in apparent age composition between schools and between landing days but, in sharp contrast with the Reedville results, it also showed that fish were distributed heterogeneously within schools. When these data were grouped by size, however, analysis showed no significant differences between the length-frequency distributions for each of the three levels of sampling, thus indicating that the fish were uniformly distributed by size within schools. Differences in relative length composition within and between daily landings remained highly significant. Possibly, the analyses suggesting a homogeneous distribution of fish within schools by size but not by age could have been influenced by errors in age determination. This possibility is particularly appealing because we have had some difficulty in obtaining consistent age readings from scales of Gulf menhaden.

The tentative conclusions of this pilot study are that our standard 20-fish sample is fully adequate, at least for the Atlantic, and that precision in estimating the age composition of the menhaden catch can be improved appreciably by sampling more vessel landings.

The 1966 Menhaden Fisheries

William R. Nicholson

Atlantic.--With the exception of the North Carolina fall fishery, the 1966 Atlantic menhaden fishery was the poorest in many years. One plant operated in the North Atlantic area from mid-June until September but processed only 2,000 tons of menhaden. Two plants that began operating in the Middle Atlantic area in May closed in July because fish were scarce. Five plants, supplied with fish caught by about the same number of vessels as in each of the previous 2 years, operated in Chesapeake Bay from late May until late November. Two others processed small quantities of fish for periods of varying length during the season. In the South Atlantic area the number of plants remained the same as in 1965--two in Florida and two in North Carolina. Five plants again operated during the North Carolina fall fishery, but fewer vessels fished than in 1965.

Fishing effort, measured by the number of standard vessel-days of fishing, remained at about the same level as in 1965 in the Chesapeake Bay area but decreased in other areas. The most significant decrease, reflecting the shutdown of nearly all plants after July, was in the Middle Atlantic area where the number of standard vessel-days was only 35 percent of the 1965 figure; the corresponding values were 81 percent in the North Atlantic area, 63 percent in the South Atlantic area, and 80 percent in the North Carolina fall fishery.

Production of Atlantic menhaden declined in every area except in North Carolina during the fall fishery. The total catch of 241,900 tons was the smallest since the end of World War II and was only 31 percent of the record catch of 1956. In that year 67 percent of the catch was landed at Middle and North Atlantic plants and 13 percent at Chesapeake Bay plants. In contrast, the 1966 figures were 4 percent and 53 percent, respectively. The South Atlantic catch of 27,000 tons was the second smallest since 1940. The North Carolina fall fishery, had a good catch--(about 79,000 tons), which was 21,000 more than 1965.

The catch per unit of effort also reflected the scarcity of fish from Chesapeake Bay northward. For the 10 years, 1956-65, the mean catches per standard vessel-day for the North Atlantic, Middle Atlantic, Chesapeake Bay, and South Atlantic areas, and the North Carolina fall fishery, were 68, 71, 60, 62, and 102 tons, respectively. For 1966, the figures were 5, 13, 42, 61, and 114 tons.

Since menhaden were too scarce to support a fishery in the Middle and North Atlantic areas, the large catch in the North Carolina fall fishery was unexpected. This catch was composed primarily of age-2 fish from the 1964 year class. An estimated 125 million were landed, as compared with about half that many age-2 fish in most previous years. Normally, age-2 fish are the dominant age group in the middle Atlantic catch. Although they probably were distributed too thinly this year to support a summer fishery in the northern areas, they became available when concentrated during the spawning season off the Carolina coast.

The decline in the catch and catch per unit of effort, the decrease in the average age of fish in the catches, and almost complete absence of fish older than 3 years indicate that the rate of exploitation is high.

Gulf.--Fishing pressure on stocks of Gulf menhaden continued to be heavy in 1966. Although the number of active plants remained at 13, the number of purse seine vessels increased from 85 to 91. Vessels of less than 200 net tons decreased from 45 to 42, whereas those of greater tonnage increased from 40 to 49. The latter group included 11 new refrigerated vessels of large capacity. Fishing effort, the number of vessel-weeks unadjusted for differences in vessel efficiency, was 1,641, an increase of 149 over 1965.

The purse seine catch of 394,000 tons was 114,000 tons less than the near-record 1965 catch, and the smallest since 1960. For the first time since 1959 the catch fell below 400,000 tons. From 1965 it decreased by 32 percent in Mississippi, 18 percent in Louisiana, and 37 percent in Texas.

The catch per vessel-week, unadjusted for differences in vessel efficiency, was 240 tons--the smallest since 1959. This figure represented a 25-percent decrease from the high of 317 tons in 1961. Except for 1965, the trend in average catch since 1961 has been steadily downward.

The downward trend in the catch, the increase in fishing effort, and the decrease in the catch per unit of effort, indicate a fully, if not overly, exploited resource. Increased fishing effort in the future will result in further competition among vessels, and probably a continued decrease in the catch per unit of effort.

Mark-Recapture Experiments

Robert L. Dryfoos
Randall P. Cheek

Mark-recapture experiments with Atlantic menhaden are designed to answer questions about the species population structure, movements, growth, and survival. In our first year of work, we tagged nearly 183,000 menhaden: 75,000 and 22,000 during the 1966 North Carolina summer and fall fisheries, respectively, and 86,000 during the spring and early summer of 1967 (March through June) from New York to Florida. Table 7 shows the distribution by State of tagged fish released this spring.

In general, tag recoveries have been adequate to indicate that our tagging and recovery techniques are satisfactory and that they can be expected to yield useful data. Tags from almost 4-1/2 percent of all marked fish released the first year have been recovered to date. Owing to the large volume, all data on tag releases and recoveries are keypunched and stored on magnetic tape. A data-processing system has been developed to maintain a master file and provide biweekly summaries.

Tag recovery.--Magnetic tag-recovery equipment has been installed in all menhaden reduction plants along the Atlantic coast. We are continuing to use either rotating-grate or stationary-plate magnets depending on the

Table 7.--Number of Atlantic menhaden tagged during the spring and early summer of 1967

State	Number
New York	1,387
New Jersey	899
Maryland	8,421
Virginia	28,682
North Carolina	20,130
Georgia	8,296
Florida	18,278
Total	86,093

space available at each plant (fig. 15). Tests of magnet efficiency are being performed regularly at each plant by tagging 100 fish when selected landings are being unloaded, and by placing 100 tags in the fish scrap before it passes over our magnets. These tests have shown that although the magnetic recovery systems are over 90 percent efficient at nearly every plant for the tags actually passing over the magnets, we can expect to recover only about 70 percent of all tags entering each plant because some tags are lost in the cookers, driers, and conveyor lines.

Tags are recovered on the primary magnets, the first magnets over which the processed fish pass, usually within 24 hours after each catch enters a plant. Tests have disclosed that only about 2 percent of tags recovered on the primary magnets take more than a week to pass through the reduction machinery before reaching the magnets. Therefore, useful comparisons of the date of landing and date of tag recovery on the primary magnets usually can be made. We are continuing to work on a system that will detect and recover tagged fish during unloading at the menhaden plants. Should this system prove feasible, it would not only improve our information about where and when tagged fish are recaptured but also would permit determination of growth rates.

Tagging methods.--Our basic method of tagging menhaden is to obtain about 2,000 menhaden by dip net from a purse seine catch before it is transferred to the carrier vessel. The fish are kept in holding nets, and a few individuals at a time are dipped out for tagging. A numbered 1/2-inch stainless steel tag is inserted into the body cavity with a tagging "gun," and then the fish is released (fig. 16). Length measurements and scale samples for

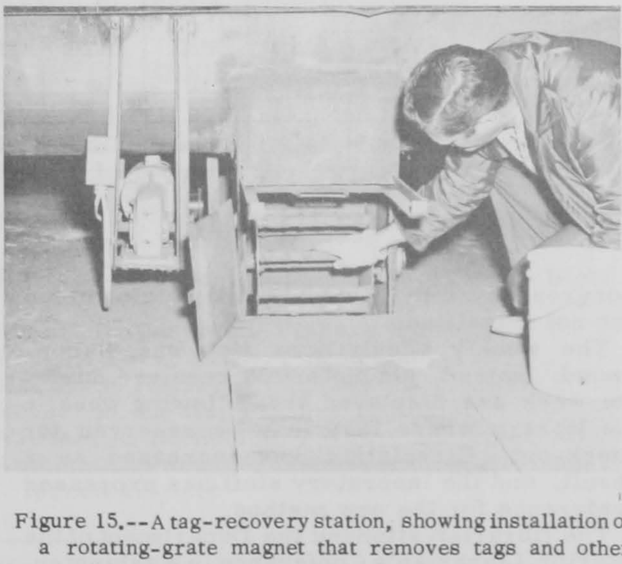

Figure 15.--A tag-recovery station, showing installation of a rotating-grate magnet that removes tags and other metal from fish scrap passing through the chute.

Figure 16.--Tagging "gun," showing tags in the magazine and one tag as it leaves the gun during insertion in the fish.

age determination are taken systematically from 5 percent of the fish tagged.

We also have developed a procedure for tagging aboard the menhaden vessels. There the fish are dipped from the purse seine and put into small tanks supplied with running sea water, from which the fish are tagged and released overboard (fig. 17). This procedure is especially useful when the fleet is fishing beyond the range of our small boats, when many sets are made each day by the menhaden vessels, or where reduced availability of fish or manpower make a smaller tagging crew desirable.

During the spring of 1967 before the commercial menhaden fishery began (March-May), we tagged and released menhaden caught in pound nets in tidal waters of North Carolina, Virginia, and Maryland. By the end of June, menhaden plants in North Carolina and Virginia had recovered tags from over 5 percent of the menhaden tagged from a pound net in the lower Neuse River, N.C. As of the same date, more than 8 percent of the tags in menhaden caught and released from pound nets in Virginia rivers tributary to Chesapeake Bay were recovered in the Virginia portion of the bay where purse seining is permitted; by comparison only 1/2 percent of the tags in menhaden released from Maryland pound nets have been recovered in the Virginia menhaden plants. We expect more of the fish tagged in Maryland to be recaptured this summer and fall if they pass through Virginia waters.

In summary, our diverse methods of obtaining fish are effective in areas that have no menhaden fishery, where fishing is limited or where fishing is relatively intense. This flexibility is especially desirable in studies of migration.

Figure 17.--Menhaden being tagged aboard a purse seiner.

Handling experiments.--We began a series of experiments in September 1966 to determine (1) the best of two methods of transferring fish from the purse seine, (2) if an anesthetic is desirable, and (3) whether fish as they are tagged should be released in a group or one by one. Nearly equal numbers of fish were subjected to each treatment; insofar as possible, all other variables were held constant during each experiment. The relative number of recoveries served as the criterion for judging success of the method (table 8).

Differences between tag returns from fish transferred from purse seine to holding net by dip netting and those from fish transferred by brailing were not significant. Anesthesia did not adversely affect the fish, and under the circumstances it was of some benefit because the fish were easier to handle. Also, fish released individually appeared to fare better than those released in groups of a hundred or more at a time, probably because of the greater amount of time the grouped fish were confined in the holding net. The recovery rate for successive groups of fish released individually from a single supply suggests that no more than 2,000 fish should be tagged from each group obtained.

Distribution of tag recoveries.--Tags from menhaden released during the 1966 summer and fall fisheries in North Carolina were recovered in Virginia, North Carolina, and Florida plants during the spring and early summer of 1967 (table 9). These data suggest considerable northward movement of fish shortly after they were tagged off North Carolina in the summer and fall. Further conclusions await more refined analysis of data adjusted for differences in (1) dates of tag release and recovery, (2) efficiency of tag-recovery systems, and (3) distribution and amount of recovery (fishing) effort.

Table 8.--Results of handling experiments with Atlantic menhaden, 1966-67

Experimental fish	Treatment	Distribution of tag recoveries			
		Summer	Fall	Spring	Total
Number		---------- Percent ------------			
,000..........	Transferred by dip net	1.6	1.6	0.3	22.1
,000..........	Transferred by brail	1.3	1.3	0.3	22.3
,283..........	Anesthetized	1.6	1.6	0.3	8.4
,304..........	Not anesthetized	1.4	1.4	0.3	8.1
,998..........	Released individually	1.8	1.8	0.3	8.6
,093..........	Released in group	1.1	1.1	0.1	5.3

Table 9.--Number of tags recovered in the spring and early summer of 1967 from marked fish released during the North Carolina summer and fall fisheries, 1966.

Tag release		Tag recoveries			
Season	Quantity	Virginia	North Carolina	Florida	Total
	Number	Number	Number	Number	Number
Summer......	74,806	158	61	12	231
Fall........	21,722	351	55	7	413
Total.......	96,528	509	116	19	644

LIBRARY

Anna F. Hall

During 1966, 400 books and bound volumes of periodicals were added to the library, an increase of 77 over the previous year. One hundred eighty-one items were received on interlibrary loan and 20 were loaned. The number borrowed declined slightly and the number loaned increased a little. About 330 periodical titles are received on subscription and through gifts and exchanges.

Periodicals are bound as volumes as completed. All books and serials are cataloged and classified according to the Library of Congress system. Reprints are cataloged but are not classified.

The weekly acquisitions list was discontinued. Instead, all materials received during the week are displayed the following week in the library where they may be reserved for check-out. Circulation has increased as a result, and the laboratory staff has expressed preference for the new method.

The librarian attended the Department of the Interior Librarian's Conference in Washington, D.C.

MEETINGS AND TRAINING PROGRAMS

(Attendance shown in parentheses)

Atlantic States and Gulf States Marine Fisheries Commissions
- Reports on the laboratory's research during the year were prepared for the two commissions.

Training Programs BioTelemetry
- Course, Washington, D.C. (1)
- Librarian's Conference, Washington, D.C. (1)

Work Conference
- Atlantic Estuarine Research Society, College Park, Md. (6)

Meetings
- American Association for the Advancement of Science, Los Angeles, Calif. (1)
- American Society of Ichthyologists and Herpetologists, San Francisco, Calif. (1)
- American Institute of Biological Sciences, College Park, Md. (1)
- National Fish Meal and Oil Association, Washington, D.C. (1)
- Atlantic States Marine Fisheries Commission, Portland, Maine (1)
- Gulf States Marine Fisheries Commission, Brownsville, Tex. (1)
- American Fisheries Advisory Committee, Irvington, Va. (1)
- International Shrimp Conference, Mexico City, Mexico (1)

STAFF

Kenneth A. Henry, Director
Joseph H. Kutkuhn, Assistant Director

ANADROMOUS FISH PROGRAM (Beaufort)

Paul R. Nichols, Chief--transferred 10-8-66
Frank T. Carlson, Fishery Biologist--transferred 12-3-66
Randall P. Cheek, Fishery Biologist--transferred to Menhaden Program 11-2-66

BLUE CRAB PROGRAM (Beaufort)

George H. Rees, Chief
Donnie L. Dudley, Fishery Biologist
Mayo H. Judy, Fishery Biologist
Marlin E. Tagatz, Fishery Biologist
James E. Bennett, Summer Aid

MENHADEN PROGRAM (Beaufort*)

Joseph H. Kutkuhn, Chief
Robert L. Dryfoos, Supervisory Fishery Biologist
Richard W. Lichtenheld, Supervisory Fishery Biologist
John W. Reintjes, Supervisory Fishery Biologist
Robert B. Chapoton, Fishery Biologist
Paul L. Fore, Fishery Biologist
Martha J. Huyler, Computer Programer
Robert M. Lewis, Fishery Biologist
William R. Nicholson, Fishery Biologist
Anthony L. Pacheco, Fishery Biologist--transferred 10-8-66
William R. Turner, Fishery Biologist
William D. B. Davies, Fishery Biologist
William F. Hettler, Jr., Fishery Biologist
Brian S. Kinnear, Fishery Biologist
Eldon J. Levi, Fishery Biologist
Richard O. Parker, Jr., Fishery Biologist
Paul J. Pristas, Fishery Biologist
Charles P. Goodwin, Fishery Biologist
Louis A. Gwartney, Fishery Biologist
Allen E. Johnson, Fishery Biologist
Richard L. Kroger, Fishery Biologist
Heyward H. Mathews, Fishery Biologist
Cleophas R. Cooke, Jr., Fishery Biologist
E. Peter H. Wilkens, Fishery Biologist
James F. Guthrie, Biological Technician
George N. Johnson, Biological Technician
Walter C. Mann, Biological Technician
Mary A. Phillips, Biological Technician
Mary K. Hancock, Clerk
Harvey M. Adams, Jr., Biological Aid
Francis D. Arthur, Biological Aid
Ronald L. Garner, Biological Aid
Ivey D. Graham, Biological Aid, resigned 10-7-66
John C. Barnes III, Summer Aid
Paul C. Baumann, Student Trainee-Biological Aid
Clisto D. Beaty, Summer Aid, Morgan City, La.
John S. Booker, Summer Aid, Reedville, Va.
Walter H. Cook III, Summer Aid, Empire, La.
Linda C. Coston, Biological Technician (temporary)
Charles S. Dietrich, Jr., Summer Aid, Port Monmouth, N.J.
Melvin W. Forbush, Summer Aid, Reedville, Va.
Correna S. Gooding, Clerk (temporary)
John P. Grady, Summer Aid

*Except as noted