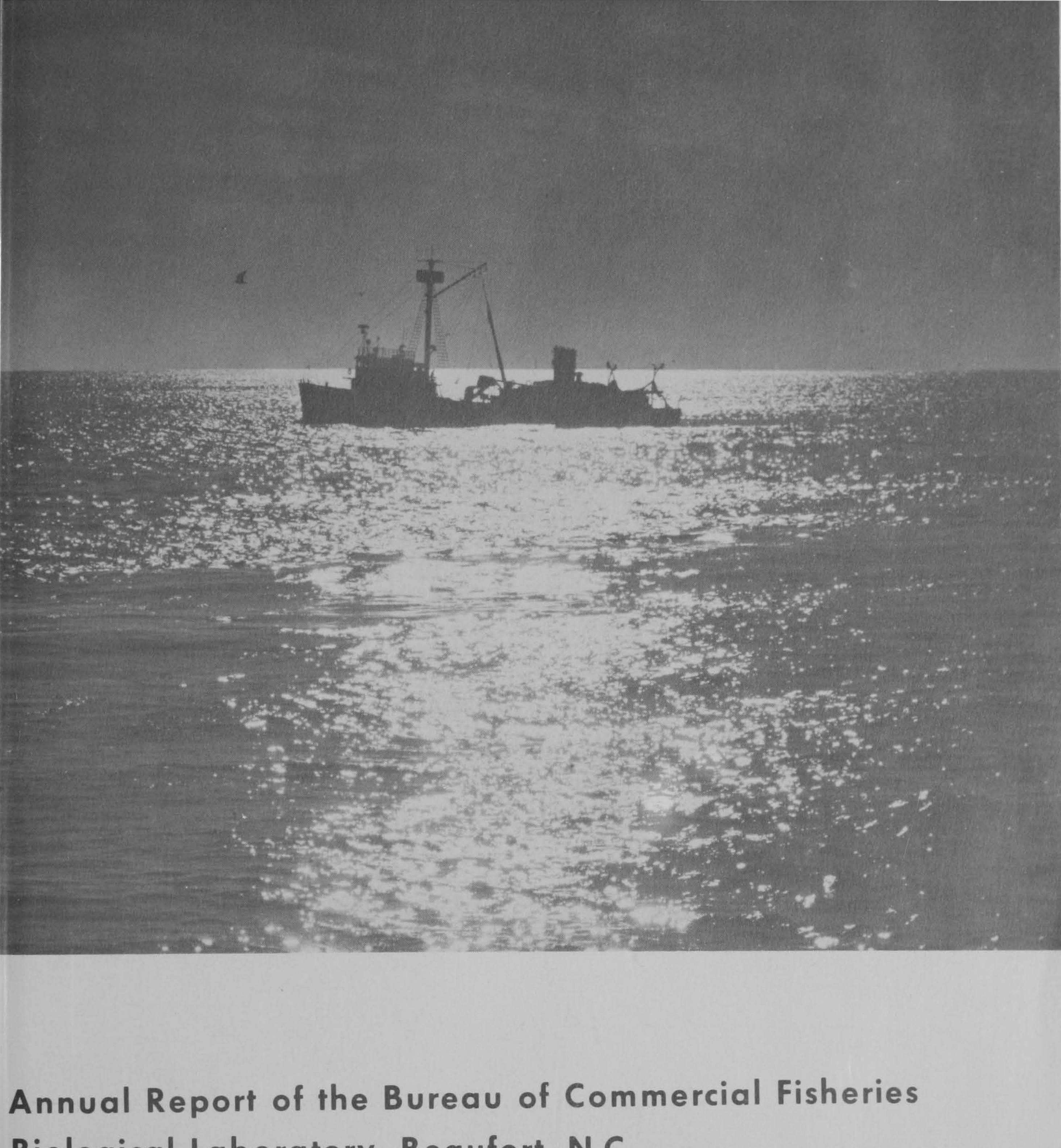

Annual Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. For the Fiscal Year Ending June 30, 1965

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

BUREAU OF COMMERCIAL FISHERIES

Circular 240

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Annual Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C.

For the Fiscal Year Ending June 30, 1965

REPORT OF THE LABORATORY DIRECTOR

Kenneth A. Henry

Research at the Bureau's biological laboratory in Beaufort, N.C., is concerned with the Atlantic and Gulf of Mexico menhadens, the blue crab, and various anadromous fishes--principally the American shad and striped bass. Increased emphasis is being placed on the menhaden studies in view of the continued decline in the Atlantic menhaden catch. Because of the increase in personnel, however, space at the laboratory is at a premium.

In our menhaden studies, which were begun in 1955 on the Atlantic coast and expanded to the Gulf of Mexico in 1964, we primarily want to: (1) describe the main features of menhaden life history and ecology; (2) evaluate the effect of the environment on survival; (3) define the causes of fluctuations in menhaden abundance and develop techniques for predicting future abundance in the fishery; and (4) obtain measures of population characteristics (such as growth and mortality) for use in assessing the condition of stocks and establishing the most favorable levels for harvesting them. In pursuing these objectives, program personnel: (1) establish criteria to identify species, particularly at larval growth stages; (2) investigate ways of delineating subpopulations on the basis of anatomical differences; (3) study the location, time, and intensity of spawning; (4) evaluate the effect of environment on the survival of larvae; (5) measure the relative size of year classes prior to their entry into the commercial fishery; and (6) determine the age, size, and sex composition of the catches and estimate annual fishing intensity. Funds obtained near the end of the fiscal year enabled us to obtain some of the initial equipment needed to begin a mark-recapture project with Atlantic menhaden, which will be tagged with internal ferromagnetic tags. We anticipate that we will need at least the first year for field studies to establish the necessary techniques for a large-scale tagging program. These efforts will be expanded when we have additional funds and personnel. Results of this work will aid in the study of menhaden populations--their structure, movements, growth, and mortality.

The decision to locate the Gulf menhaden studies at Beaufort rather than to establish a field station has proven very satisfactory. This arrangement has permitted a flexible interchange of people, ideas, and equipment between the Gulf and Atlantic studies.

Although our blue crab research has been somewhat restricted by personnel limitations, the basic objectives still are to (1) describe the main features of the biology and life history and (2) determine the causes of fluctuations in abundance of marketable blue crabs. To achieve these aims, we are studying the growth and mortality of crabs confined at different salinities and seasons and the effects of various environmental factors on survival of larvae (contract with Duke University). We also are studying the crab population in Core Sound, N.C., to try to relate abundance of precommercial size crabs with the subsequent commercial catch; this investigation involves systematic sampling of the young crabs before they are taken by the commercial fishery.

Research in the anadromous fisheries program is mostly cooperative with Federal and State agencies; it is aimed at helping solve biological problems in connection with fish passage at existing and proposed barriers along the Atlantic coast and obtaining biological and fishery catch data on which to base management recommendations. We assisted in several tagging studies to measure migrations and fishing rates, and, in a study on the Cape Fear River, N.C., to determine the feasibility of using boat locks as a fish-passage facility.

RESEARCH HIGHLIGHTS

Our growth studies with blue crabs in the St. Johns River, Fla., indicate that virtually all crabs can be expected to be of commercial size within 1 year after hatching.

Under contract with Duke University Marine Laboratory a satisfactory micro-method has been worked out for determining the nitrogen content of blue crab larvae at all stages of development. Although this contract was terminated at the end of this fiscal year, the analysis of data will continue until the results of the experimental work over the past 5 years have been published.

In our species studies of menhaden, preliminary attempts at gel electrophoresis, in cooperation with personnel at the Bureau of Commercial Fisheries California Current Resources Laboratory at La Jolla, Calif., yielded distinct test patterns for each species. Tests on six fish believed to be hybrids of Atlantic and yellowfin menhaden gave patterns indistinguishable from those produced by fish positively identified as yellowfin menhaden.

Results of laboratory experiments on menhaden larvae acclimated at 10° and 15° C. and a salinity of 25 to 30 p.p.t. (parts per thousand) suggest that when larvae enter the estuaries they probably will survive if the water temperature does not drop below 4° C. and the salinity remains between 10 and 20 p.p.t.

Our 1964 surveys of abundance of juvenile menhaden in estuaries indicate that prospects for the Atlantic fishery remain poor. Abundance of juveniles in Atlantic estuaries was well below the average established over the past 3 years and nearly matched the low levels reached by the poor 1960 and 1961 year classes.

In racial studies of Gulf menhaden, we were unable to detect any differences on the basis of vertebral counts. Additional data collected over a number of years will be needed to resolve this problem.

The 1964 Atlantic menhaden catch was the smallest since 1944. Sample data indicate that age-2 fish contributed a larger portion than usual of the Chesapeake Bay catch and age-0 fish were more numerous than in any previous year. Age-3 fish rather than age-2 fish dominated the Port Monmouth catches, and the catches from the North Carolina fall fishery contained a larger than usual portion of age-0 fish. Although fishing intensity was reduced in some areas, more vessels operated from Chesapeake Bay plants than in any previous year of record.

The 1964 Gulf menhaden catch was about 7 percent less than in 1963. Most of the catch appeared to consist of age-1 and age-2 fish.

In the Cape Fear River, N.C., young shad from the 1964 spawning were distributed throughout the area between locks 1 and 2, a distance of about 35 miles. Preliminary findings indicate that the growth of young fish above lock 1 was somewhat greater than in the other tributaries of the Cape Fear River, although little difference in water quality in the areas could be detected. Observations showed that lock 1 and dam 1 were not deterrents to the downstream movement of the young shad. The use of these locks for fish passage has opened up considerably more area for spawning.

Based on our studies in April and May 196 it was estimated that the number of sha passed per hour of operation of lock 1 in creased 80 percent over the previous seaso and the number of alewives and blueba herring passed per hour increased about 2 percent.

Preliminary findings indicate that propose water development projects on the St. John River, Fla., could eliminate established spawn ing grounds and possibly eliminate the con tribution of that section of the River to th run unless certain measures are taken t minimize these effects.

In the Susquehanna River shad studie studies of scales from young shad indicate that some of the young fish hatched in th spring of 1963 had wintered in the impound ments. Collections of young shad at the lower most dam showed that some fish had move downstream successfully through the fou impoundments into the lower River, a dis tance of about 196 miles.

Sonic tags were used on some of the adul shad in the Susquehanna River to trace thei movements after release above the impound ments. Analysis of the tracking tapes o recording devices has not been completed.

The total number of shad passed at th Hadley Falls Dam fish lift, Connecticut River decreased about 2 percent from the previou year, although the number passed per day' operation of the fish lift increased 4 percent The mean growth of fish hatched above the Dan was significantly greater than the growth o those from below the Dam.

Results from cooperative tagging studie on striped bass in the Maryland portion o Chesapeake Bay indicate that few Marylan fish move into Virginia waters and few of th younger fish of catchable size move to outsid waters. As a part of this tagging study, at tempts were made to determine the sex o some of the tagged fish by biopsy. Althoug preliminary observations indicate that onl 41 percent of the samples were actuall material from the sex organs and the res was fat or connective tissue, perfecting thi technique for determining the sex of live fis would add a much-needed tool for biologica studies.

MEETINGS AND TRAINING PROGRAMS

Atlantic States Marine Fisheries Commission

A report on menhaden research was give at the 23d annual meeting of the Commissio in Atlantic City, N.J., in September. Researc reports on blue crab, shad, striped bass, an menhaden also were prepared for the minute of the meeting.

Training Programs

Laboratory personnel attended various Civil Service Commission and General Services Administration training courses during the year.

Work Conferences (attendance shown in parentheses.)

Industrial Products Division, National Fisheries Institute, Morehead City, N.C. (1)
Atlantic Estuarine Research Society, Baltimore, Md., and Newark, Del. (10)
Northeastern Division of the American Fisheries Society, Harrisburg, Pa. (2)
Southern Division of the American Fisheries Society, Clearwater Beach, Fla. (3)

Meetings (attendance shown in parentheses.)

North American Wildlife Conference, Washington, D.C. (1)
National Menhaden Association Meeting, Old Point Comfort, Va. (1)
American Fisheries Society, Atlantic City, N.J. (4)
American Institute of Biological Sciences, Boulder, Colo. (2)
Atlantic States Marine Fisheries Commission, Atlantic City, N.J. (1)
Gulf States Marine Fisheries Commission, Brownsville, Tex. (1)

STAFF

Kenneth A. Henry, Director

BLUE CRAB PROGRAM

George H. Rees	Chief	Beaufort, N.C.
Donnie L. Dudley	Fishery Biologist	Do.
Mayo H. Judy	do.	Do.
Marlin E. Tagatz	do.	Green Cove Springs, Fla.

ANADROMOUS FISHERIES PROGRAM

Paul R. Nichols	Chief	Beaufort, N.C.
Frank T. Carlson	Fishery Biologist	New Cumberland, Pa.
Randall P. Cheek	do.	Beaufort, N.C.
Charles P. Goodwin	Fishery Biologist (temporary)	New Cumberland, Pa.
Marc A. Jackman	do.	Do.
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Douglas A. Trent	Fishery Aid (temporary)	Weldon, N.C.

MENHADEN PROGRAM

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William F. Hettler, Jr.	do.	Do.
Joseph R. Higham, Jr.	do. (transferred 10-10-64)	Do.
Robert M. Lewis	Fishery Biologist	Do.
William R. Nicholson	do.	Do.
Anthony L. Pacheco	do.	Do.
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Charles T. Arthur	Fishery Aid	Do.
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Ronald L. Garner	Fishery Aid	Do.
Ivey D. Graham	do.	Do.

James F. Guthrie	Fishery Aid	Beaufort, N.C.
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George N. Johnson	do.	Do.
John T. Smith	do. (resigned 9-4-64)	Do.
Mary K. Hancock	Clerk	Do.
Lawrence Dudley	Summer Aid	Fernandina Beach, Fla.
Edward E. Gallaher	do.	Morgan City, La.
Ronald J. Faust	do.	Empire, La.
Robert F. Mackin	do.	Moss Point, Miss.
Ottawa R. Pullen, Jr.	do.	Amagansett, N.Y.
Donald M. Rush	do.	Lewes, Del.
Robert W. Ryder	do.	Reedville, Va.
James A. Supej	do.	Cameron, La.
Stephen D. Treacy	do.	Amagansett, N.Y.
John W. Wood, Jr.	do.	Port Monmouth, N.J.

STAFF SERVICES

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Irene D. Huff	Clerk-Typist	Do.
David C. Newberry	Writer-Editor	Do.
Inez J. Nierling	Clerk-Stenographer	Do.
Margaret L. Rose	do. (transferred 1-3-65)	Do.
Daisy S. Sterlen	Clerk-Stenographer (resigned 6-2-65)	Do.
Celeste P. Walt	Clerk-Typist (temporary)	Do.

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Thelma P. Nelson	do.	Do.
Margaret M. Lynch	Clerk-Typist	Do.
Claude R. Guthrie	Foreman (Repair and Maintenance)	Do.
Glenshaw Henry, Sr.	Caretaker	Do.
Jack D. Lewis	do.	Do.
Clarence M. Roberts	Vessel Operator-Engineer	Do.
Willie S. Rainey	Mechanic Helper-Automotive	Do.
Thomas R. Owens	Maintenanceman	Do.

BLUE CRAB PROGRAM

George H. Rees, Chief

Fluctuations in the abundance of blue crabs, usually occurring abruptly and without advance indications, have been a serious problem to the industry. This year we began a study in North Carolina designed to provide data on the abundance of juvenile crabs. These data can then be used to predict the supply of marketable-size crabs.

One of the factors governing yield in a fishery is the rate of growth of the animals. We studied growth rate this year on the St. Johns River, Fla., and found that the percentage increase in size at the time of each molt is nearly constant throughout the life of the crab, but that the length of time between molts depends, among other thing on the temperature of the water and the siz of the crab. Small crabs are apparently abl to molt at lower temperatures than large crabs. In the lower St. Johns River virtuall all crabs can be expected to be of com mercial size within 1 year after hatching.

The experimental work on blue crab larva being conducted under contract at the Duk University Marine Laboratory is nearly com plete. The contract was terminated at the en of fiscal year 1965, but analysis of data wi continue until the results have been publishe At least seven manuscripts based on thi study are now being prepared.

NORTH CAROLINA STUDIES

Mayo H. Judy and Donnie L. Dudley

We began a study this year of the blue crab resource of Core Sound, N.C. Core Sound was selected as being small enough to sample intensively, yet large enough to be representative of many areas that are important to the production of crabs. The area is about 35 miles long and averages about $2\frac{1}{2}$ miles wide; it communicates with the ocean through three inlets and opens into Pamlico Sound at its northern end and into the North River at its southern end (fig. 1).

This study has two basic aims. The first is to measure the abundance of juvenile crabs in various size classes to determine if a relation exists between the abundance of small crabs, as we can measure it, and the subsequent marketable crab population. If there is a direct relation, it should be possible to predict the supply of crabs. The second objective is to measure the abundance of spawning females to see if there is any clear-cut relation between the size of the spawning stock and the subsequent marketable crab population. A direct relation would mean that the spawning stock should be protected.

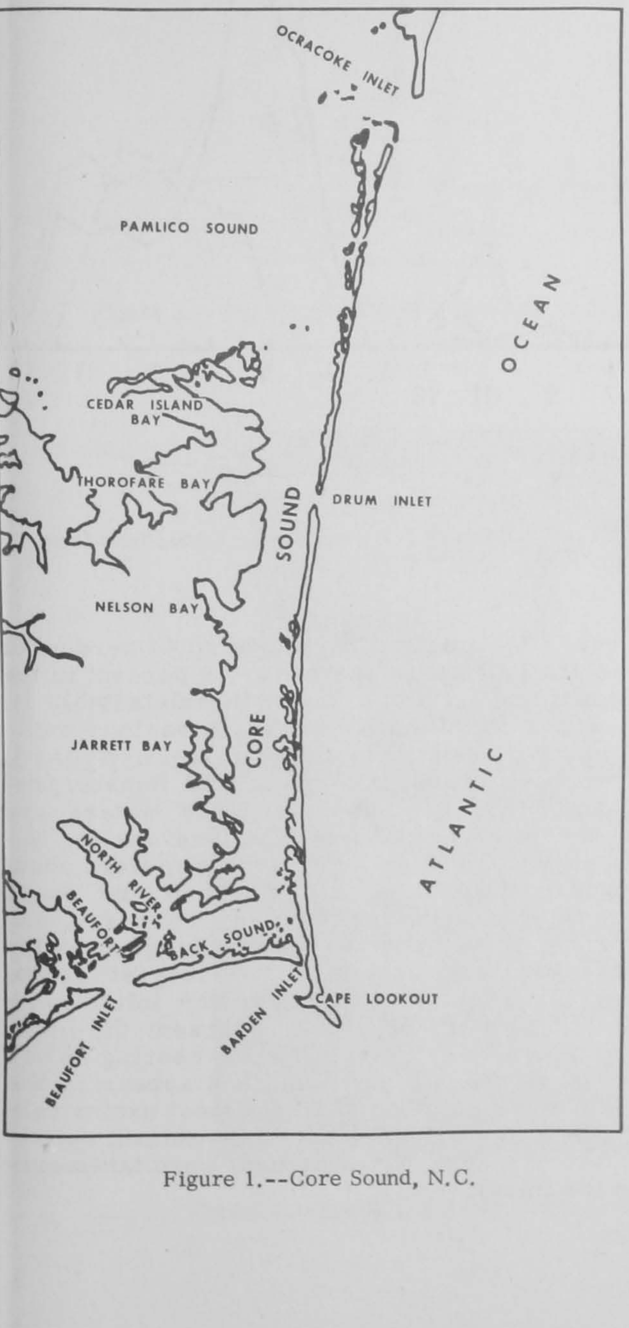

Figure 1.--Core Sound, N.C.

There are four distinct habitats in the Core Sound area: (1) the Sound itself, (2) the inlets where the Sound communicates with the ocean, (3) some large bays on the mainland side of the Sound, and (4) many small creeks which empty into the bays on the mainland side and directly into the Sound on the outer banks side.

There are so many possible sampling stations in the Core Sound area that much of our work has been exploratory, to determine the distribution of crabs in the area and to locate the best places for permanent sampling stations. Within a body of water, blue crabs tend to congregate in certain areas, which are the logical areas for sampling, if they can be located. The crabs also tend to be distributed according to size and to sex.

We began sampling for juvenile crabs in the Sound, bays, and inlets in October by pulling a 20-foot trawl for a measured length of time. During extended periods of cold weather, when crabs were buried in the mud and not available to the trawl, samples were taken with a 4-foot dredge. In January we collected samples in the creeks by using a 9-foot trawl pulled from an outboard boat.

The abundance of marketable-size crabs was measured by collecting catch and effort statistics from the commercial fishery.

The Sound, Bay, and Inlet Waters

We found a pattern of distribution of crabs in the Sound, bay, and inlet waters related to size and season (fig. 2). In October, November, and December, crabs in the precommercial size classes (below 127 mm. wide) were concentrated in the bays; a few in this size range were in the Sound, and virtually none in the inlets. During January, February, and March we found very few precommercial size crabs in the Sound, bays, or inlets. It is possible that the small crabs were absent from these waters during that period, but more likely that because of the cold weather they were buried too deeply to be available to our sampling gear. With the coming of warmer weather in April, May, and June there were increases in the number of crabs in the larger size classes and a movement of crabs from the bays into the Sound and inlet.

We also found a pattern of distribution related to sex and stage of sexual maturity.

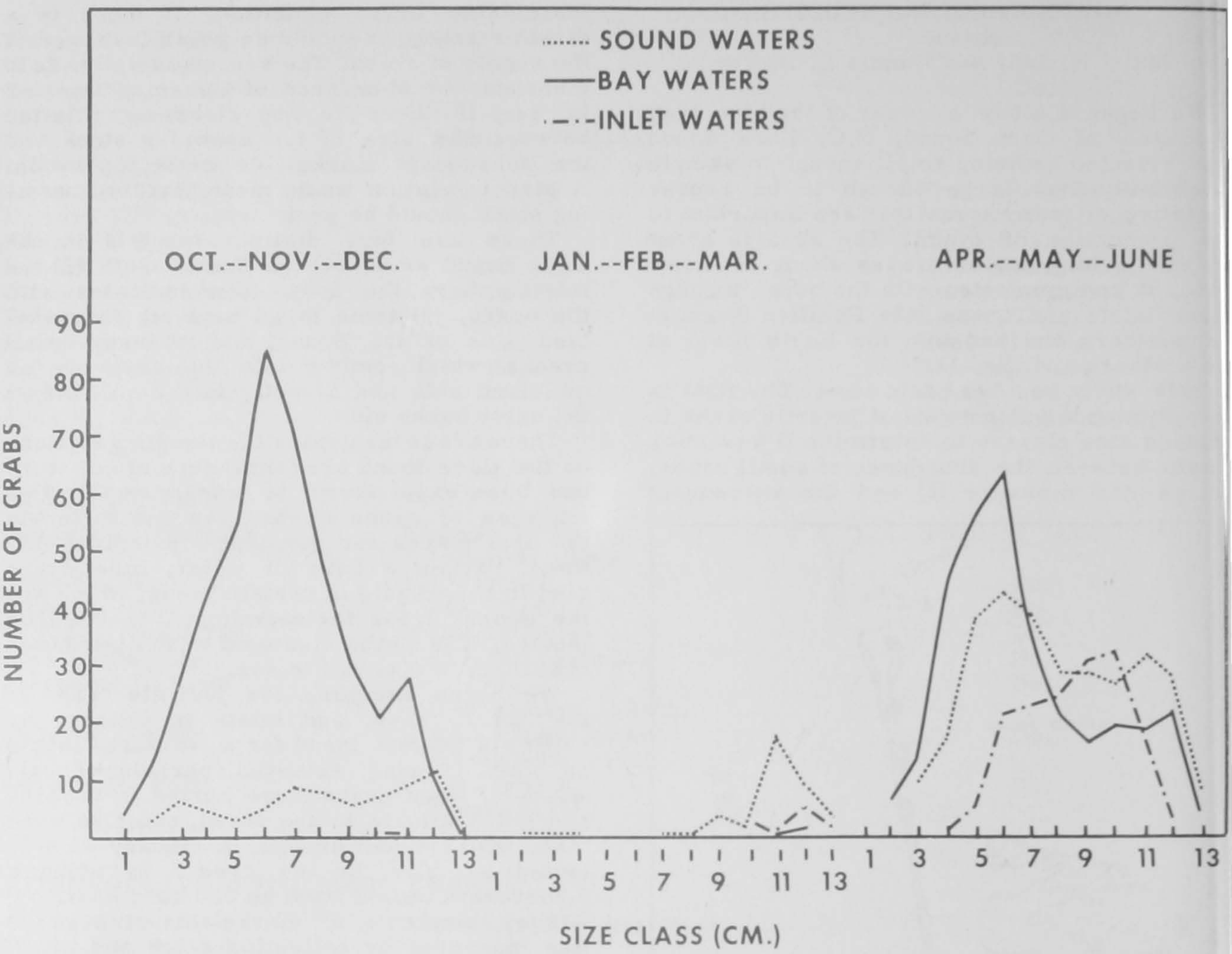

Figure 2.--The distribution of blue crabs by size in the waters of Core Sound, N.C., and its bays and inlets from October 1964 to June 1965.

Table 1.--Composition of the total crab catch by sex and stage of maturity for different water areas from October 1964 to June 1965

Area	Male		Female	
	Immature	Mature	Immature	Mature
	Percent	Percent	Percent	Percent
Bays	44	10	39	7
Sound	15	11	28	46
Inlets	3	1	4	92

Mature females have a broadly oval abdomen, and as immature females have a triangular abdomen. Males were considered to be mature if they were over 12 cm. wide. Immature males were found in greatest numbers in the bays and in decreasing numbers from the bays toward the inlets. They made up 44 percent of the total catch in the bays, 15 percent in the Sound, and only 3 percent in the inlets (table 1).

The distribution of crabs in various water masses as related to sex is shown in figure 3. Immature crabs, both male and female, frequent the bays and Sound; bay waters are more strongly favored. Mature males, the smallest group in total numbers, were about equally distributed between bay and Sound areas except during January, February, and March, when they were more frequent in the bays. Mature females, the largest group, are the main inhabitants of the inlets; only small numbers of crabs represent the other groups. Sponge crabs (females bearing an egg mass on the abdomen) did not appear in the catch until April, and then almost exclusively in the inlets. Females with a remnant sponge (after the eggs have hatched) were taken only in the inlets.

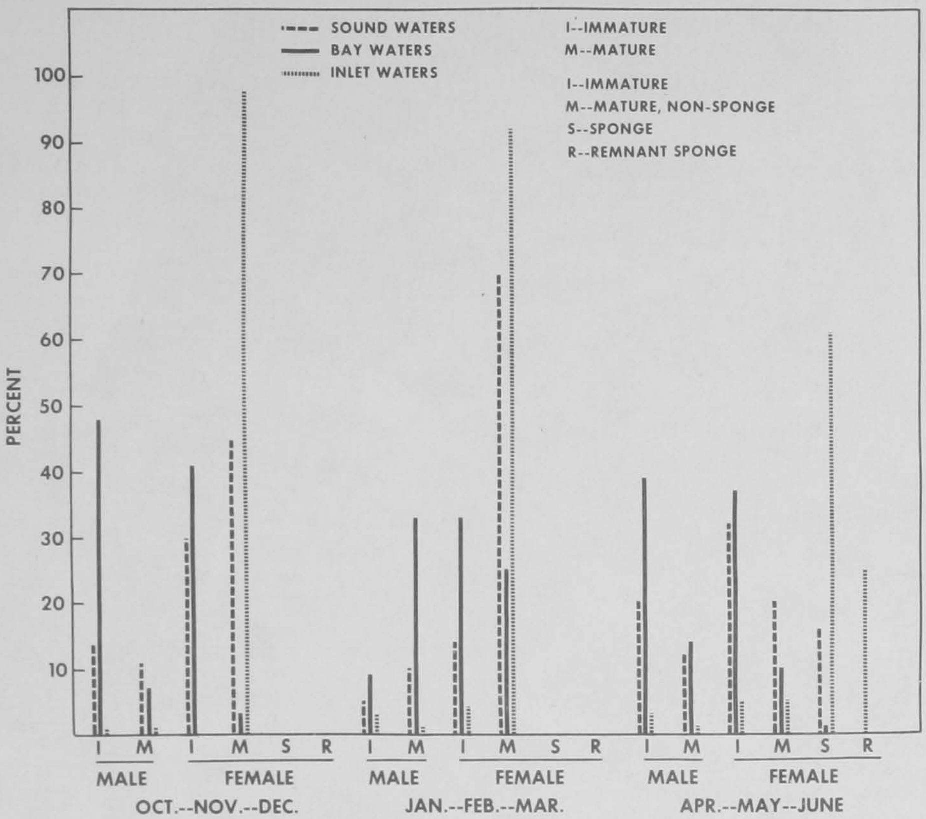

Figure 3.--The distribution of blue crabs by sex and stage of sexual maturity in the Core Sound, N.C., area from October 1964 to June 1965.

Figure 4.--Sampling for blue crabs at Drum Inlet, N.C. The 20-foot trawl is being taken aboard after a 10-minute drag.

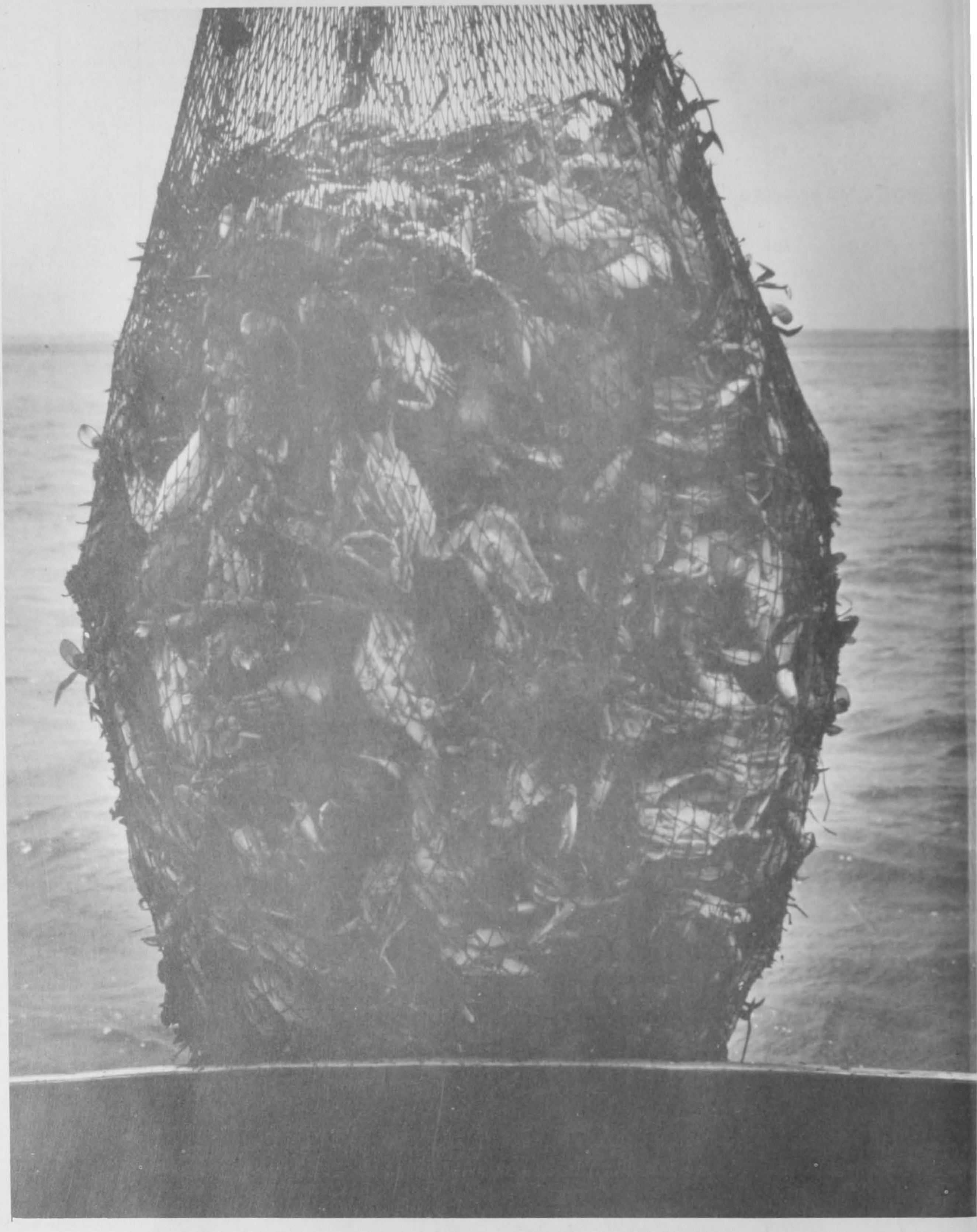

Figure 5.--The results of a 10-minute trawl haul at Drum Inlet, N.C.--more than a thousand female crabs.

Creeks

The marshes bordering Core Sound are drained by many small creeks. These creeks empty directly into the Sound on the outer banks side, and into the bays on the mainland side. We began sampling in these creeks in January, using a 9-foot, small-mesh trawl pulled from a 16-foot outboard. Eventually, eight creeks were selected for continued sampling, four on each side of the Sound.

The crabs caught in these creeks were virtually all less than 4 cm. wide and appeared to be rather abundant in January, February, and March. During this period our catch averaged 25 crabs per minute for the outer banks creeks, and 15.4 crabs per minute for the mainland creeks. Crabs less than 1 cm. wide were the most abundant size at this time and were the result of the previous fall's spawning.

In April, May, and June, abundance in the creeks fell sharply; catch rates were seven crabs per minute in the outer banks creeks and 1.6 per minute in the mainland creeks. During this period the most abundant size class of crabs was between 3 and 5 cm. wide. That the small crabs had moved from the creeks into the Sound as they became larger and the weather became warmer was shown by the appearance of crabs in the 1- to 4-cm. size classes in samples taken in the Sound near the mouth of the creeks. During the winter no appreciable number of these small crabs had been in the Sound.

Our work during the past year has shown that few juvenile crabs are collected at sampling stations in the Sound. These stations will probably be discontinued so that the bays and creeks can be sampled more intensively. We believe that it will be necessary to sample the creeks and bays with trawls of a variety of mesh sizes. A trawl with mesh small enough to retain crabs less than 4 cm. wide probably cannot be pulled fast enough to capture larger crabs effectively.

Commercial Catch

Samples of the commercial catch taken monthly from January through June showed that the Core Sound fishery is based almost entirely on mature females. Catches for the period averaged 89 percent females and ranged from 70 to 100 percent. Our own catches of mature crabs averaged 92.3 percent females.

Sponge crabs first appeared in the catch in April, and in April, May, and June made up 50.8 percent of the commercial catches. Females bearing their first sponge made up 43.4 percent of the catches sampled, females between their first and second sponge made up 8 percent, and those carrying their second sponge accounted for 7.4 percent.

Catch and effort data have been collected for the Core Sound fishery since November 1964. In the absence of a method of estimating population size, the catch per unit of effort (in this case, catch per pot per day) is the best means of detecting fluctuations in abundance. We believe that continued collection of these data, combined with intensified sampling for juveniles, will enable us to determine whether changes in abundance of juveniles are followed by changes in abundance of marketable crabs.

FLORIDA STUDIES

Marlin E. Tagatz

We conducted a study on the rate of growth of blue crabs in the St. Johns River, Fla., from March 1964 through March 1965. The crabs were maintained in individual compartments in floats anchored in the lower River, where salinities ranged from 6.9 to 25.8 p.p.t. The compartments were numbered, and a record was kept of the length and width of each crab. On alternate days, we inspected the floats, fed cut fish to the crabs, and made a record of the crabs that had molted and of their new dimensions. The floats had a total capacity of 200 crabs.

A total of 1,375 molts were recorded during the study. There was considerable individual variation in the amount of growth per molt and the time between molts in crabs of the same size and during the same period of time. The largest percentage increases in size per molt always occurred in summer. Crabs less than 60 mm. wide increased more per molt in winter than in spring. In crabs wider than 60 mm. the reverse was generally true--spring molts resulted in a larger percentage increase than winter molts (table 2).

In the size classes over 60 mm. wide, females increased more in width per molt than males. The average increase in width per molt throughout the year was 25.3 percent for females and 22.9 percent for males. Females in the 110-119 mm. size class showed the greatest average increase in size at a single molt (36.1 percent). For most females this is the last or next-to-the-last molt.

Although males may increase less in size per molt than females, they do not cease to

Table 2.--Percent increase in width of blue crabs, by size, sex, and season, St. Johns River, Fla.

Width	Males	Increase in width			Females	Increase in width		
	W[1] S[2] S[3]	Winter	Spring	Summer	W[1] S[2] S[3]	Winter	Spring	Summer
Mm.	Number	Percent	Percent	Percent	Number	Percent	Percent	Percent
20-29	10 7 9	26.7 (17.2(35.7)	25.9 (15.4-38.1)	29.0 (22.2-38.5)	11 4 9	25.5 (15.4-32.1)	17.0 (10.3-24.0)	26.8 (19.0-39.1)
30-39	15 19 20	25.6 (17.6-37.5)	18.6 (10.2-37.8)	27.8 (17.1-34.4)	28 24 18	23.7 (12.9-36.1)	21.1 (12.8-31.6)	29.5 (18.8-35.9)
40-49	24 43 31	24.6 (15.2-31.7)	19.5 (11.4-28.9)	30.8 (14.9-41.9)	24 38 26	25.5 (14.3-36.4)	20.0 (11.1-30.4)	28.6 (15.6-44.2)
50-59	21 35 38	22.9 (16.4-28.0)	19.7 (11.3-29.6)	28.6 (14.3-40.0)	21 40 37	24.6 (13.8-31.6)	21.3 (11.9-28.8)	27.4 (11.5-36.4)
60-69	16 27 38	19.1 (6.7-29.5)	20.4 (8.3-30.0)	27.3 (9.1-39.3)	25 29 46	22.7 (13.8-29.0)	23.6 (16.7-33.3)	31.1 (13.6-44.1)
70-79	15 19 47	20.6 (15.5-30.4)	18.8 (8.1-21.7)	29.2 (11.1-39.7)	20 32 30	22.3 (16.0-36.6)	23.0 (13.5-36.0)	31.4 (19.7-43.0)
80-89	14 22 36	17.3 (12.4-25.0)	20.2 (15.0-27.0)	27.0 (8.4-37.6)	18 31 43	19.9 (12.8-27.9)	23.2 (13.8-31.0)	31.7 (20.5-44.8)
90-99	8 10 42	19.0 (15.5-22.6)	21.0 (13.3-33.7)	27.1 (12.6-41.0)	5 20 35	16.2 (13.5-21.3)	23.8 (11.7-48.9)	30.7 (20.2-48.4)
100-109	2 7 36	18.0 (15.7-20.2)	22.5 (19.8-29.8)	27.1 (9.7-36.1)	3 11 28	22.0 (13.3-27.9)	27.1 (16.0-33.3)	30.4 (21.2-45.7)
110-119	3 2 28	18.1 (15.8-20.0)	22.3 (19.8-24.8)	24.6 (13.4-30.4)	3 5 25	19.7 (15.3-27.4)	24.6 (14.8-30.4)	36.1 (18.0-50.0)
120-129	0 1 15	- -	9.4 (9.4)	23.4 (15.4-31.4)	1 3 3	11.0 (11.0)	24.8 (23.4-26.0)	31.2 (28.4-32.8)
130-139	0 0 13	- -	- -	21.6 (14.1-33.6)	0 1 1	- -	28.8 (28.8)	31.6 (31.6)

[1] Winter, November 15 to March 31, average temperature 59° F.
[2] Spring, April 1 to May 31, average temperature 76° F.
[3] Summer, June 1 to September 15, average temperature 83° F.

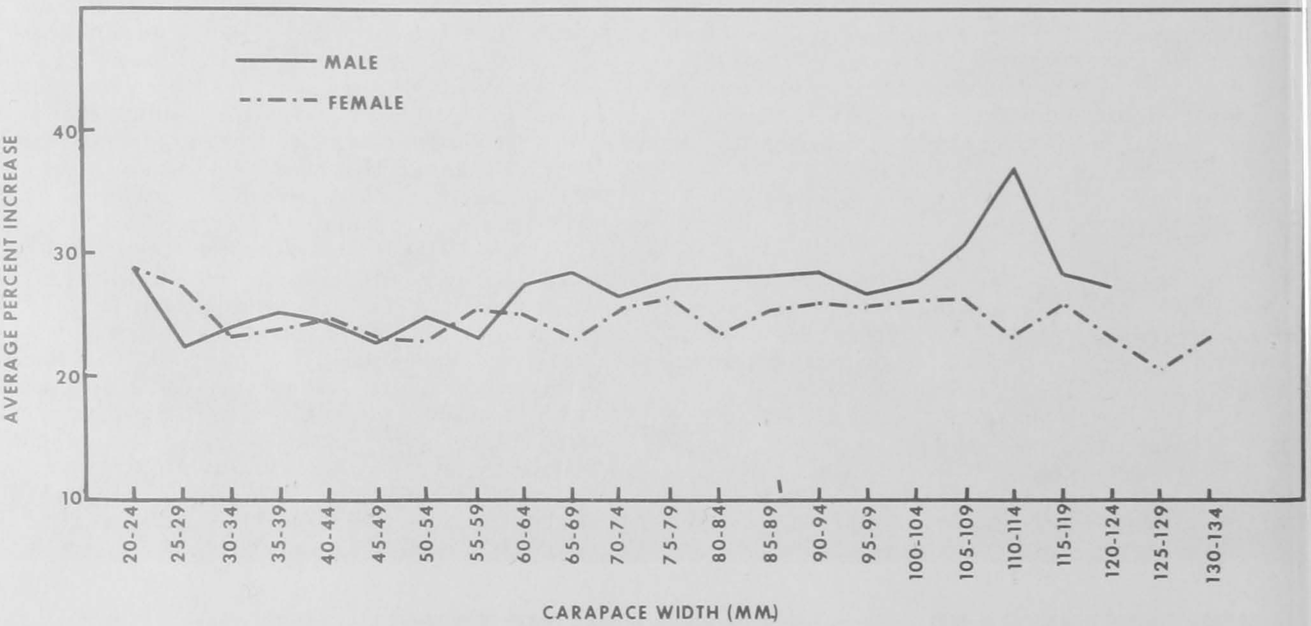

Figure 6.--Increase in width of blue crabs per molt in the St. Johns River, Fla., March-September 1965.

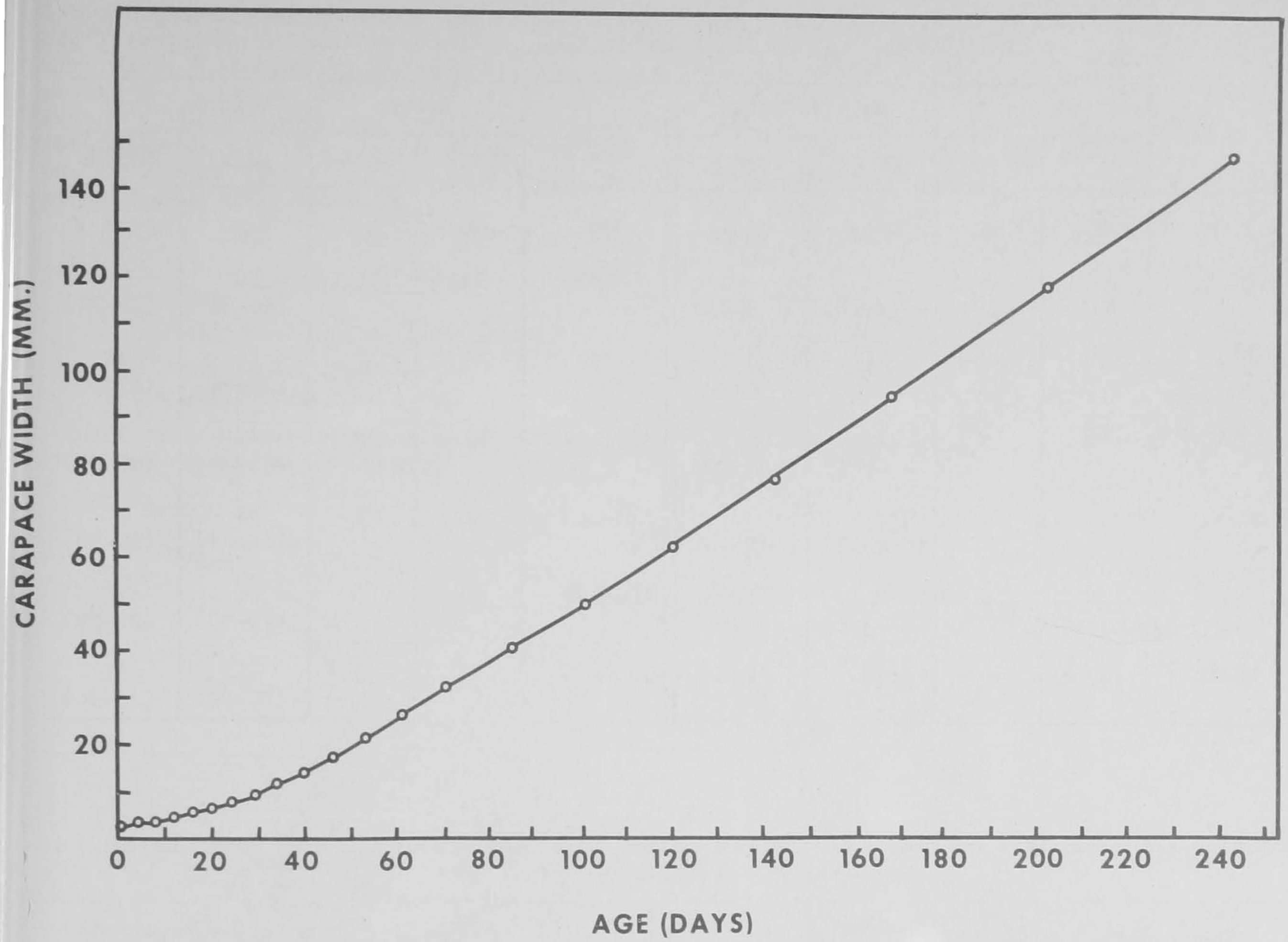

Figure 7.--Theoretical growth curve for the blue crab in the St. Johns River, Fla.

molt at sexual maturity. Males become sexually mature before they are fully grown and continue to molt after females of the same age have become sexually mature and stopped molting. Thus, males eventually reach a larger size than females.

In the few published reports on growth in crustaceans, the percentage increase per molt decreased as the size of the animals increased. This does not seem to hold true for blue crabs (fig. 6). On the contrary, females tend to increase more per molt with increasing size.

The time between molts was progressively longer with increased size (table 3), so that even though the increase per molt did not decline, the rate of growth was slower in larger crabs. Sex appeared to have no effect on the interval between molts.

The time between molts was greatest in winter. This effect of low temperatures on the molting period was more pronounced in the larger crabs. During the winter, all of the 150 crabs less than 90 mm. wide, molted, usually more than once, and 27 of them shed 3 times. In this period only 25 of the 44 crabs wider than 89 mm. molted, and none more than once.

The time required for crabs of various sizes at certain seasons to attain commercial size is shown in table 6. The main point to be made from this table is that crabs in a wide range of sizes in spring and summer can be expected to be of commercial size by about September.

By using the data from this study and data from laboratory experiments on growth of the first 10 postlarval molts, it is possible to calculate the length of time and the number of molts that a blue crab in the lower St. Johns River needs to reach commercial size. Assuming an average increase in width per molt of 24 percent and averaging the time between molts for the various sizes over the entire year, we get the growth curve shown in figure 7. The curve shows that it is theoretically possible for a blue crab in the St. Johns River to grow from the first crab stage at about 2 mm. wide to commercial size in about

Table 3.--Molt interval of blue crabs, by width and sex, in spring and summer, St. Johns River, Fla.

Width	Crabs		Molt interval		Width	Crabs		Molt interval	
	Male	Female	Male	Female		Male	Female	Male	Female
Mm.	No.	No.	Days	Days	Mm.	No.	No.	Days	Days
20-29	4	3	8 (7-10)	10 (9-11)	80-89	37	45	28 (16-68)	26 (16-77)
30-39	13	17	14 (7-24)	13 (6-23)	90-99	41	36	31 (20-64)	31 (19-60)
40-49	40	29	16 (8-25)	16 (9-25)	100-109	35	32	32 (21-64)	33 (20-50)
50-59	51	54	20 (9-51)	18 (9-44)	110-119	26	23	34 (19-53)	37 (28-58)
60-69	52	59	23 (11-52)	22 (11-68)	120-129	13	5	44 (29-68)	48 (35-59)
70-79	53	34	23 (13-64)	25 (14-59)	130-139	11	2	40 (27-56)	44 (35-54)

Table 4.--Time required for crabs of different sizes to attain commercial size (over 120 mm.) in the lower St. Johns River, Fla., 1964

Month and initial width	Crabs	Months in which commercial size attained	Molts	Size range	Time required	
					Range	Average
Mm.	No.		No.	Mm.	Days	Days
April-May						
30-39............	6	Aug.-Sept.	5-6	121-142	125-153	137.5
40-49............	12	July-Aug.	4-5	123-152	74-147	121.5
50-59............	16	June-Sept.	3-5	121-148	56-165	107.0
60-69............	5	June-July	3	122-139	73-100	84.2
70-79............	4	June-Aug.	2-3	126-149	58-125	93.5
80-89............	5	June-July	2	130-144	56-80	68.6
90-99............	12	May -July	1-2	123-163	30-78	54.2
June-July						
30-39............	3	Sept.	5-6	139-166	92-99	95.7
40-49............	9	Aug. -Sept.	3-4	121-161	40-84	68.1
50-59............	13	July -Sept.	3-4	121-153	50-85	65.0
60-69............	8	Aug. -Sept.	3	126-160	55-77	67.6
70-79............	12	Aug. -Sept.	2	121-153	40-51	45.2
80-89............	6	Aug. -Sept.	2	137-163	50-56	53.2
90-99............	2	July -Aug.	1	123-136	21-24	22.5

8 months and after 20 molts. Since the larval life is between 1 and 2 months long, the total time from hatching to commerical size is about 10 months. The curve is based on a number of assumptions, but it is probably accurate to say that most blue crabs in the St. Johns River reach commercial size within 1 year after hatching.

LARVAL STUDIES

(Contract No. 14-17-0002-60)

John D. Costlow, Jr.
Duke University Marine Laboratory

Blue crab larvae were hatched to provide additional material for experiments on the effect of salinity on larval respiration, the relation between nitrogen changes and larval development, and studies to determine if "sterilization" of the eggs at the time of removal from the female would increase the percentage survival of the larvae.

Survival of the larvae was generally good, and although there was some variability in development, producing the "mixed stages," it has been possible to complete the study of effect of salinity on rate of oxygen consumption of larvae. Data are available on the rate of oxygen consumption of larvae from each day of development within each stage at three different salinities. Replications from different series of larvae have been completed, primarily during the later stages. The data will be analyzed statistically.

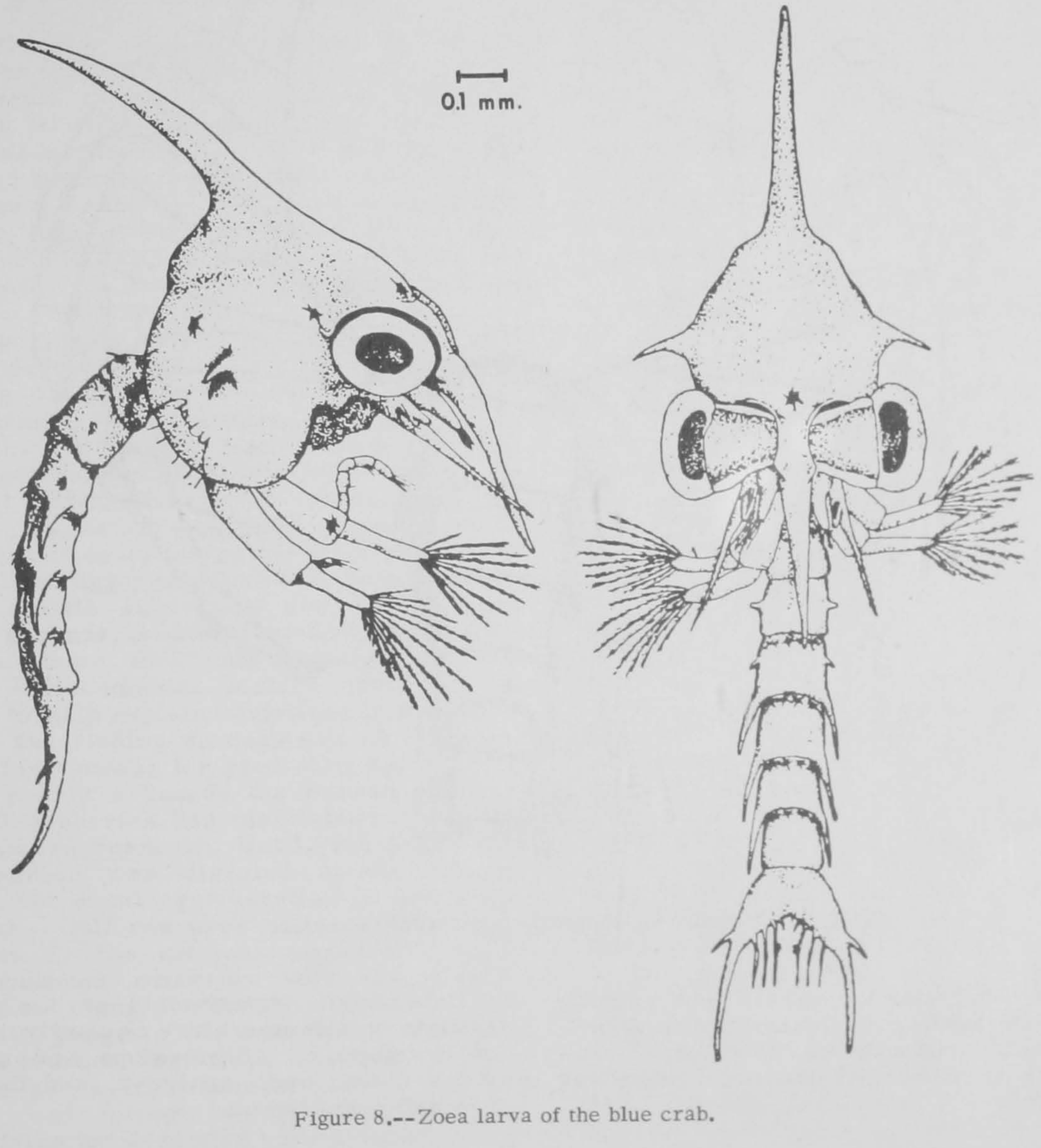

Figure 8.--Zoea larva of the blue crab.

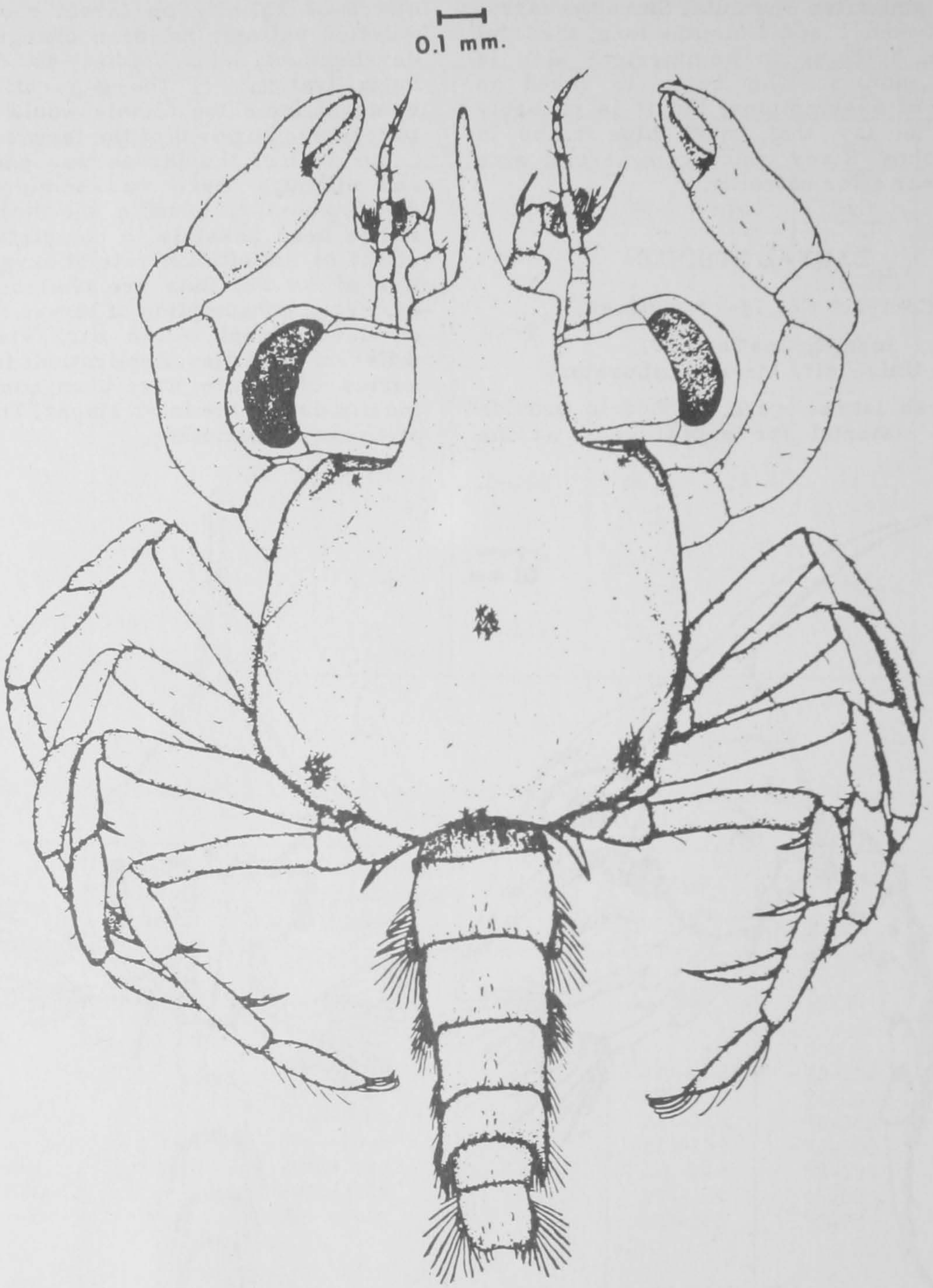

Figure 9.--Megalops larva of the blue crab.

Nitrogen determinations of all larvae during all stages of development and at three salinities are being continued. A satisfactory micromethod has been worked out for these determinations.

Data from experiments on the effect of salinity and temperature on survival and rate of development of megalops and postlarval stages have been analyzed, and the results are being written up.

This contract has ended, but the analysis of data will continue until the results of our experimental work over the last 5 years have been published. The following manuscripts are now in preparation:

Free amino-acids in developing larvae of the blue crab, Callinectes sapidus Rathbun.

The relation between diet and survival in developing larvae of the blue crab, Callinectes sapidus Rathbun.

The effect of salinity and temperature on survival and development of megalops of the blue crab, Callinectes sapidus Rathbun.

Post-larval growth and molting of the blue crab, Callinectes sapidus, in relation to salinity and temperature.

Oxygen consumption of larvae of the blue crab, Callinectes sapidus.

The effect of salinity on metabolic rate of larvae of the blue crab, Callinectes sapidus Rathbun.

Nitrogen changes during development of larvae of the blue crab, Callinectes sapidus Rathbun.

One manuscript was published this year:

Variability in larval stages of the blue crab, Callinectes sapidus. Biol. Bull. 128 (1): 58-56.

MENHADEN PROGRAM

Joseph H. Kutkuhn, Chief

In 1962 the Atlantic and Gulf of Mexico menhaden fisheries produced a record 2.3 billion pounds of fish: the domestic fish meal and oil industry prospered. By 1964--only two seasons later--the yield had fallen to about 1.5 billion pounds, a remarkable drop of 35 percent. Although the decline along the Atlantic coast proved far more drastic than that along the Gulf coast, the impact was felt throughout the industry and prompted the question: What happened?

To provide an answer and perhaps forestall further decline requires a fairly broad understanding of resource ecology and dynamics. For example, an evaluation of how year-to-year changes in the environment influence each species' reproductive potential and its survival during the critical oceanic and estuarine phases of early development is as important as determining the effects of fishing itself. Since egg production and early survival jointly dictate subsequent abundance on the fishing grounds, it naturally follows that knowledge of their functional relationship with major environmental factors could be expected to help explain variations in menhaden supply and fishing success and at the same time offer a means for predicting the harvest.

For nearly a decade the Bureau of Commercial Fisheries has maintained a program of menhaden research. Until 1964 practically all attention was directed at the Atlantic stocks, but equal consideration is now being given the Gulf resource whose relative importance in the national menhaden picture has increased markedly with the drop in production along the Atlantic coast. In general, the program for both the Atlantic and Gulf resources is divided into two comprehensive areas of research: (1) studying the biology and ecology of the menhadens and (2) studying the dynamics of the fished portions of their stocks.

Initial concern is with menhaden identification, especially in areas such as south Florida where two or more species overlap in occurrence, and hybridization is a distinct possibility. It is self-evident that inability to circumscribe each species and define its component populations would greatly limit not only the effectiveness of our research but also the likelihood of ever being able to develop meaningful programs of resource management.

Of no less importance than this basic work on the classification of American menhadens are studies through which we hope to learn more about the life history and ecology of menhaden. In several projects involving both Atlantic and Gulf species we are seeking information on such critical items as the location, time, and intensity of spawning in sea; the joint role of environmental factors that control the survival of young menhaden in estuaries; and, finally, the year-to-year abundance of juveniles as it is conditioned by the environment. Rounding out the program is a rather full slate of activities in the area of resource dynamics. To be resolved here are such matters as the possible existence of subpopulations (or "races") in the Atlantic and Gulf menhadens; the assessment of population characteristics, particularly growth and mortality; the questions of whether Atlantic and Gulf stocks are currently being overfished, or whether they are being harvested at too young an age; and the likelihood of being able to place both fisheries on a "sustained-yield" basis. During the year covered by this report, program personnel shed new light on the long-standing issue of population heterogeneity in the Gulf menhaden. Through an extensive sampling operation they also accumulated the catch and related biostatistics needed to appraise present trends in both fisheries and made preliminary arrangements for mark-recapture experiments with juvenile menhaden.

CLASSIFICATION AND DISTRIBUTION OF NORTH AMERICAN MENHADENS

John W. Reintjes

Most menhaden caught with purse seines in U.S. waters are of two species: Brevoortia tyrannus and B. patronus. Each supports a sizable fishery: the former along the Atlantic coast from Cape Cod to northern Florida, the latter in the Gulf of Mexico from western Florida to eastern Texas. In the autumn, their stocks apparently migrate into deeper water and toward Florida--the Atlantic species southward, the Gulf species eastward. These movements are inferred from changes in the dispersion of menhaden schools as determined by aerial observation, shifts in fishing fleet distribution, and the winter occurrence of menhaden in otter trawl and gill net catches. Although both species and their fisheries are separated geographically by the Florida peninsula during the main fishing season from April to November, stocks of the two menhadens may mingle during the remainder of the year.

In the southern United States two other species, the yellowfin menhaden, B. smithi, and the finescale menhaden, B. gunteri, occur uncommonly and probably contributed less than 0.1 percent to the total catch in the past 2 years. The yellowfin menhaden ranges from Cape Hatteras, N.C., around Florida to the Mississippi Delta. This species is caught by gill nets in south Florida for use as blue crab and catfish bait. Less than 500,000 pounds are landed annually because of the limited demand for bait. The finescale menhaden ranges from the Mississippi Delta to the Gulf of Campeche. No commercial fishery for this species has developed in the United States, and less than 100,000 pounds annually (1959-63) are landed and sold for bait at Veracruz, Mexico.

Continued advancement of knowledge about the distribution, biology, and abundance of North American menhadens depends largely on the degree to which we can improve our ability to identify them accurately, whether they be observed as eggs and larvae in the ocean, transforming larvae and juveniles in the estuarine nurseries, or yearlings and adults in the commercial catch. Measures of recruitment, growth, and mortality in menhaden populations are urgently needed to meet program objectives that rely on the proper definition of each species making up the resource.

Generally, species are distinguished by dissimilarities in general appearance and structure. The characters more commonly used are color, body proportions, and counts of scales, fin rays, scutes, gill rakers, and vertebrae. Before species can be compared, expected variation within each character must be known. Assessment of these attributes assumes that all the fish from a given locality that have similar characters are of the same species. Other criteria used to support or refute this assumption are relative size, age at sexual maturity, behavior, and habitat.

Project objectives range from classifying the menhadens--which entails bringing together descriptive material for identifying eggs, larvae, juveniles, and adults and thereby facilitating the study of menhaden life history and distribution--to determining the structure of populations composing the resource. Stated briefly, the following problems are being resolved in the manner indicated:

> Difficulty in positively identifying North American menhadens in commercial landings and scientific collections has prompted construction of a field guide and key to the various species (juveniles and adults only) and, for comparative purposes, preparation of a definitive series of growth stages reared from fertilized eggs of known parentage. To date, reference collections of the young and adults of all species have been assembled; a series of larval yellowfin menhaden has been obtained from eggs hatched in captivity; and eggs as well as larvae of the Atlantic and Gulf menhadens have been sorted for morphological study from plankton collections.
>
> Uncertainty about the distribution in space and time of each species' larvae, juveniles, and adults is gradually being lessened through continual examination of commercial catch statistics, reports of exploratory fishing operations, and records of the occurrence of menhaden in a large number of scientific collections.
>
> Questionable speciation in regions where the geographical ranges of two or more menhadens overlap has led to comparative analyses of body proportions, counts of body parts, blood composition, chemical makeup, and host-parasite relations. By such methods we hope to settle the matter of apparent intergradation of what are now recognized as valid species. Thus far, representative samples of all species have yielded measurements of body proportions and counts of body structures that suggest crossbreeding in the Indian River (Fla.) area, and population heterogeneity in the Atlantic menhaden. Preliminary attempts at gel electrophoresis of Atlantic, Gulf, and yellowfin menhaden yielded distinct test patterns for each species. The test patterns of six menhaden believed to be Atlantic X yellowfin hybrids were indistinguishable from those produced by fish positively identified as yellowfin menhaden. In performing these checks, we have been assisted by personnel of the Bureau of Commercial Fisheries Biological Laboratory at La Jolla, Calif.

Figure 10.--Comparison of juvenile Gulf menhaden (upper and lower) and yellowfin menhaden (center pair), each about 6 months old. Note the characteristic secondary spots, coarser scales, and black-edged tail on the Gulf menhaden.

ESTUARINE SURVIVAL OF YOUNG MENHADEN

Robert M. Lewis

After hatching at sea, larvae of Atlantic menhaden enter inshore waters and move into the nursery areas where they develop into juveniles. As juveniles, they are found in most of the bays and sounds from Maine to Florida. In the area from Delaware to North Carolina, larvae may be exposed to near-freezing temperatures as they move into estuaries during January or February. In the area of Long Island Sound and north, most spawning occurs from May to October, and the resulting larvae are not subjected to such low temperatures. From the time of hatching until they reach their nursery areas, larvae run the gamut of salinity from 100 percent sea water to nearly fresh water.

Laboratory Studies

From January to April 1964, experiments were conducted to determine the low-temperature tolerance of Atlantic menhaden larvae conditioned at different temperatures. Additional work in the year covered by this report yielded complementary information on the capacity of larvae to endure various combinations of salinity and temperature after being held at two specific acclimation temperatures. Larvae were first acclimated to 10° C. and salinity of 25 to 30 p.p.t. for 12 hours or longer, then tested at temperatures ranging from 2° to 6° C. by 1° intervals, and at salinities from 0 to 30 by intervals of 5. A similar series of tests was conducted for larvae acclimated to 15° C. and salinity of 25 to 30. Each test lasted until 50 percent of the larvae died or 96 hours elapsed.

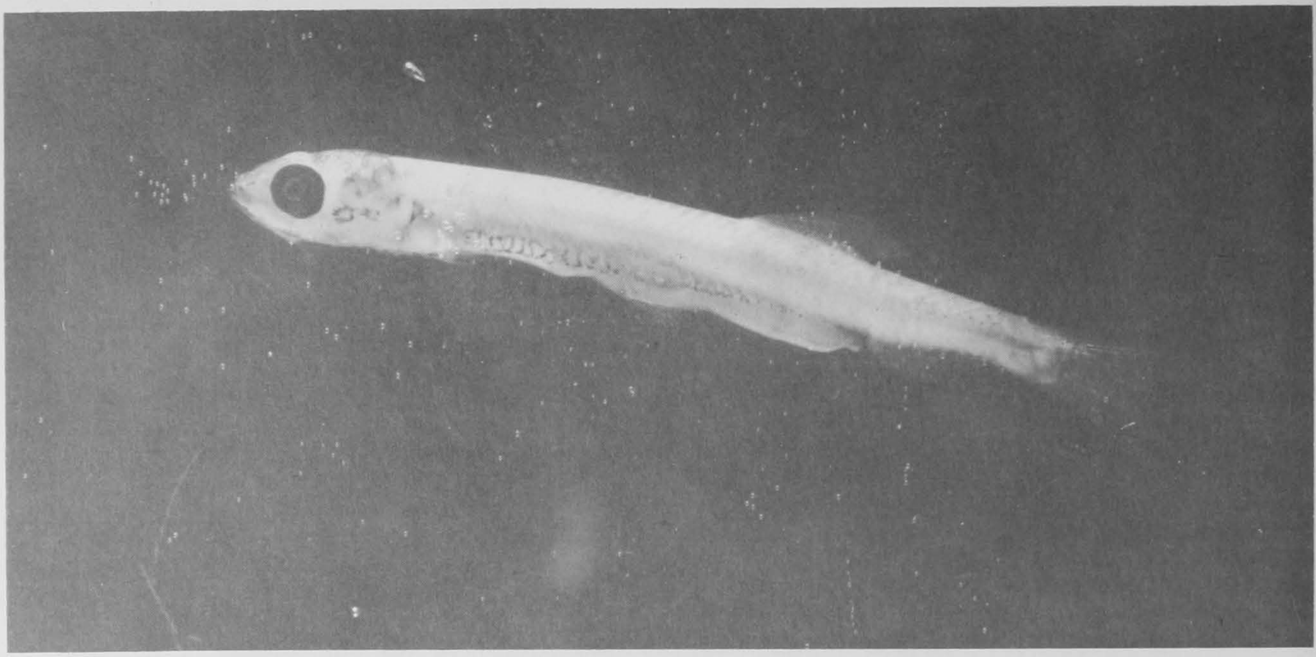

Figure 11.--A larval Atlantic menhaden, 1 inch long, about the size at which the species enters estuarine nurseries.

Results of the tests with fish acclimated at 10° C. and salinity of 25 to 30 (table 5) indicated that these larvae can be expected to survive for about 1½ days at 2° C. and salinity of 15. At this temperature and other test salinities, survival time was shorter. The longest survival time for larvae tested at 3° C. was about 3 days at a salinity of 15. The best survival time in the series was generally achieved by larvae tested at 4° C. and greater, and salinity of 5 and greater.

In the test series in which larvae were acclimated at 15° C. and salinity of 25 to 30 (table 6), the best survival time at a test temperature of 3° C. was slightly more than 2 days. As in the 10° C. acclimation series, larvae survived longest at 4° C. and above. Regardless of acclimation and test temperature, larvae survived only a short time in fresh water. Results of both acclimation series show that, in most instances, as the test temperature increased, larvae survived longer at all test salinities.

Results of both acclimation series suggest that if larvae enter an estuary during the winter or early spring (when the water cools appreciably) they will likely survive if the temperature does not drop below 4° C. and the salinity remains between 10 and 20.

Field Studies

Bath Creek, N.C., a tributary of the Pamlico River, was surveyed biweekly from December through May to determine when menhaden larvae enter this nursery area. Several recording thermometers provided a continuous picture of water temperature; salinity was determined on a biweekly basis. From March 15 when larvae were first observed in Bath Creek until late May when sampling ended, the creek's salinity ranged from 1 to 8 and its temperature

Table 5.--Number of hours to 50 percent mortality of menhaden larvae acclimated at 10° C.

Test temperature	Salinity (p.p.t.)						
	0	5	10	15	20	25	30
°C.	Hours	Hours	Hours	Hours	Hours	Hours	Hours
2.............	4.2	14.2	27.5	34.0	25.0	21.5	15.2
3.............	4.2	33.0	59.0	77.6	53.2	40.0	26.5
4.............	7.0	>96.0	>96.0	>96.0	>96.0	>96.0	35.0
5.............	7.8	>96.0	>96.0	>96.0	>96.0	>96.0	>96.0
6.............	13.0	>96.0	>96.0	>96.0	>96.0	>96.0	>96.0

Table 6.--Number of hours to 50 percent mortality of menhaden larvae acclimated at 15° C.

Test temperature	Salinity (p.p.t.)						
	0	5	10	15	20	25	30
°C.	Hours	Hours	Hours	Hours	Hours	Hours	Hours
2............	4.5	15.8	46.0	26.8	16.2	14.0	10.2
3............	6.0	44.5	53.0	56.0	51.2	27.0	10.5
4............	4.5	26.2	>96.0	>96.0	>96.0	39.5	14.0
5............	7.2	50.2	>96.0	>96.0	>96.0	>96.0	48.0
6............	8.8	>96.0	>96.0	>96.0	>96.0	>96.0	>96.0

varied between 9° and 25° C. At these temperature levels the low salinities probably did not cause undue loss of larvae.

ABUNDANCE OF JUVENILE MENHADEN

Anthony L. Pacheco

Since 1961 we have estimated annually, by means of standardized sampling techniques, the relative and absolute abundance of juvenile menhaden in selected nursery areas along the Atlantic coast. Similar work along the Gulf coast began this year. The intensity and frequency of sampling and the improvement of estimation techniques have undergone continued evaluation in both areas. Results of this work are of considerable interest because they promise to be useful indicators of future menhaden abundance, thus minimizing the problems associated with unanticipated fluctuations in abundance that have troubled the industry for at least a decade. Forecasts of menhaden abundance and fishing success would help the industry to plan its labor requirements and market commitments more realistically.

Our sampling and projection techniques have been developed from many observations of the distribution and behavior of larval and juvenile menhaden. The sequence of events during the early life history is as follows. The larvae move into estuaries shortly after hatching in the ocean. This influx is believed to be complete in most areas by early June. The young fish then invade the upper reaches of estuarine nursery areas where the water is nearly fresh. Thereafter, they gradually move downstream and by late August may range over the entire estuary.

The later growth stages in the estuary, therefore, represent the ultimate point in the development of a menhaden year class at which its relative size can be readily determined before its members are recruited to the fishable stock. Entering the fishery the following spring, yearlings may contribute significantly to the commercial catch, as in the Chesapeake Bay and South Atlantic summer fisheries. A noteworthy advantage of estimating year class size at this growth stage is that the highly variable oceanic and estuarine environments have already exerted their modifying effects. Hence, if we can develop methods for estimating the relative abundance of juvenile menhaden in selected tidewater estuaries, we should be able to forecast trends in fishery production with reasonable accuracy.

Along the Atlantic coast, the abundance of juvenile menhaden is estimated by four methods--trawling index, haul-seining index, mark-recapture experiments, and aerial measurement--in a sequence of ground and aerial surveys. Because estuarine areas differ greatly in such features as configuration, tidal amplitude, and turbidity, no single technique is equally effective at all points along the coast. In any one area, however, abundance trends generally can be confirmed by at least two methods. Our first estimate is derived during late June from sample catches by a surface trawl. At this time fish are small, usually concentrated well up in the tributaries, and probably most vulnerable to the trawl. This method has proved particularly useful in the Chesapeake and South Atlantic areas. In July and August, we conduct small-scale mark-recapture experiments. The fish are captured by seining, marked (fin-clipped) and released, and then recovered by trawling. By this technique we not only obtain estimates of absolute density as computed from the returns of marked fish but also indices of relative abundance in terms of catch per seine haul and catch per trawl haul. The fourth technique is used during September-October and entails a series of flights over the nursery areas when young fish are moving back to sea. Counts of fish schools and estimates of their mass are made along flight tracts transecting the major estuarine systems.

Results of our 1964 survey indicate that prospects for the Atlantic fishery remain poor. Abundance of juveniles was well below the average established over the previous 3 years and nearly matched the low levels reached by

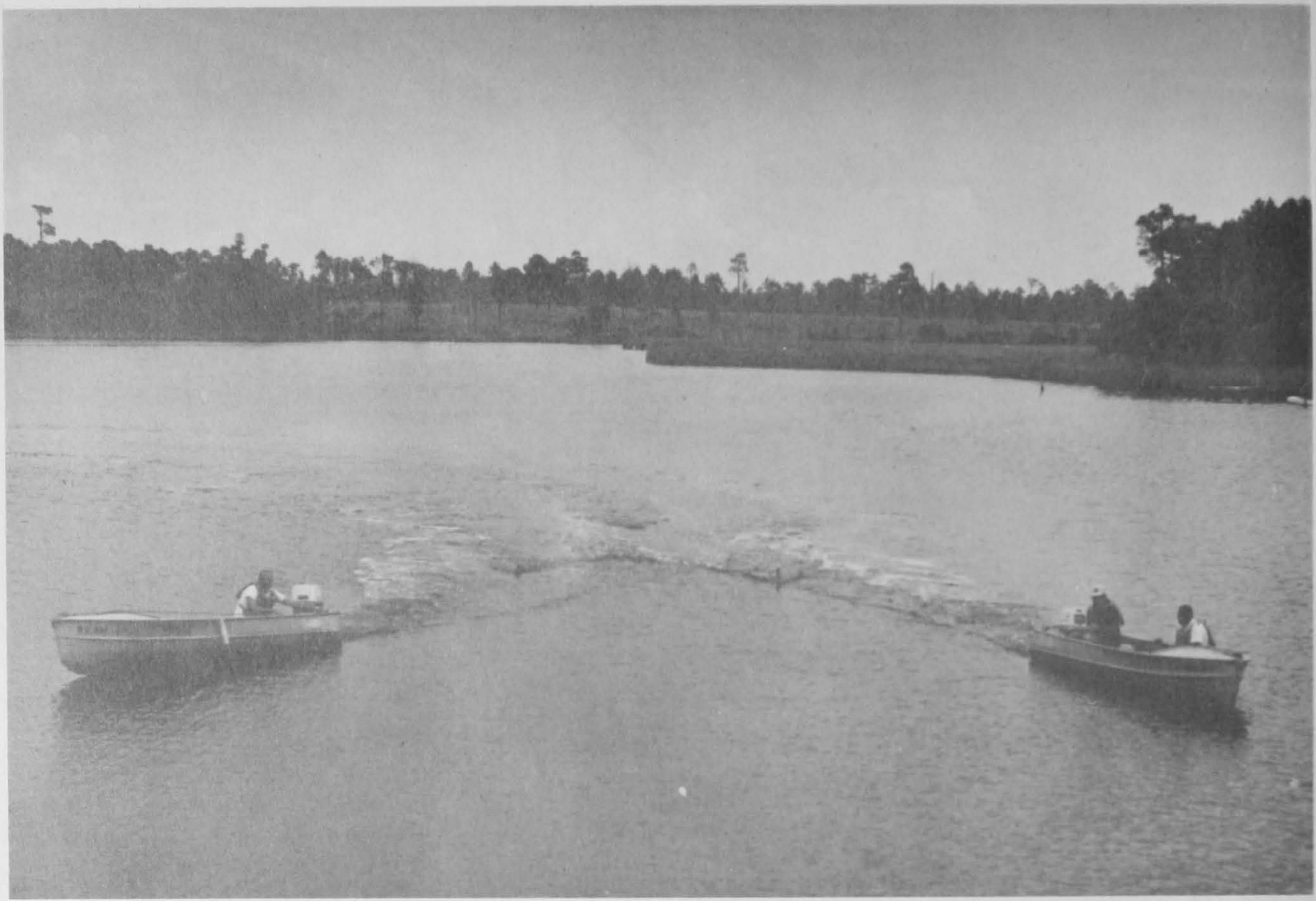

Figure 12.--Use of surface trawl to sample for abundance of juvenile menhaden.

the poor 1960 and 1961 year classes. The greatest reduction was in the Chesapeake Bay area, but generally reduced levels were evident along the entire middle and south Atlantic coasts. In the following table some 1964 sampling results are compared with those of 1963:

Area	Estimated population		Abundance index	
	1964	1963	1964	1963
	Number of fish	Number of fish		
Sawmill Creek, S.C.	29,800	10,500	9.3	16.2
Calabash Creek, N.C.	$<$1,000	489,000	2.2	27.8
Broad Creek, N.C.	183,000	1,797,000	1.6	275.8
Felgate Creek, Va.	79,500	1,319,000	6.7	57.6
Ball Creek, Va.	$<$1,000	273,000	1.3	390.4
White Creek, Del.	620,900	1,738,500	4.8	120.9

Just prior to the year covered by this report, we expanded our operations to include Gulf coast estuaries. Data for abundance estimates in the Gulf area are obtained with the surface trawl during the summer, and from an aerial survey of schools in the fall. Although our netting technique is efficient in bayous, we may have to develop new methods for sampling in such menhaden environments as moderately saline lagoons and low-salinity bays. In these habitats, which characterize some extensive Gulf coast areas, turbidity is highly variable and menhaden seem to be widely scattered. Both factors markedly affect the efficiency of our sampling gear. Under such conditions measures of larval rather than juvenile abundance may represent more efficient criteria for assessing differences in the size of successive year classes.

Impressive catches of juveniles were made in tributaries of Galveston Bay, Tex.; Sabine Lake, La.; and in the Pearl River, La., but because we have not studied these areas long enough to establish a basis for comparison, we can provide no indication of their relative significance. During the aerial survey in October excessive turbidity from tropical storms precluded reliable counting of fish schools in many Gulf coast estuaries.

In summary, we view the forecasting function as a valuable byproduct of our ecological studies rather than as a primary project mission. As we gain technical competence and statistical confidence in the measurement of annual menhaden reproduction, we can better evaluate our tidal wetlands in terms of their suitability and use as menhaden nursery grounds.

STRUCTURE AND BIOLOGY OF GULF MENHADEN STOCKS

William R. Turner

Racial Studies

A study of variation in the number of vertebrae for Gulf menhaden was initiated to determine whether this important segment of the menhaden resource comprises two or more distinguishable subpopulations. Although we recognize that other body characters promise additional means for checking this hypothesis, our analysis was purposely limited to vertebral counts, which in studies elsewhere have apparently proved to be a valuable means of distinguishing subpopulations.

Figure 13.--Counting vertebrae, ventral scutes, and anal-fin rays from X-ray photographs of 1-year-old Gulf menhaden.

Samples totaling 2,358 juveniles were obtained in selected estuaries from Apalachicola Bay, Fla., to Galveston Bay, Tex. Sample size ranged from 58 to 126 fish. The sex of each fish was determined by microscopic examination of the gonads, and its vertebrae were counted from radiographs. Differences in vertebral counts between sexes and year classes as well as among and within localities were then tested by analysis of variance.

Only three-fourths (1,775) of the fish sampled--all of those belonging to the 1963 year class and about one-third of those from the 1964 year class--were identified as to sex, but this number provided adequate evidence that sexes do not differ significantly in number of vertebrae. The mean number of vertebrae in fish of the 1963 year class was 44.42 for 712 males and 44.38 for 706 females; the means for the 1964 year class were 44.50 for 193 males and 44.52 for 164 females. Since sexual dimorphism could not be demonstrated, sex was not considered a factor in subsequent analyses.

Vertebral counts in fishes representing the two year classes ranged from 42 to 46 and were distributed as follows:

Year class	Number of fish	Number of vertebrae					
		42	43	44	45	46	Mean
1963	1,418	-	28	802	577	11	44.40
1964	940	1	15	476	435	13	44.47
Total	2,358	1	43	1,278	1,012	24	44.43

Generally, the only consistent pattern indicated by the 2 years of data was that juveniles from the Louisiana coast had more vertebrae. In 1963, fish from Lake Pontchartrain averaged 44.60 vertebrae, while those taken from Lake Pontchartrain and Atchafalaya Bay in 1964 averaged 44.58 and 44.62, respectively. The mean vertebral number was lower in samples collected to the east and west of this area during both years.

Despite the higher number of vertebrae in menhaden from the Louisiana coast, inconsistencies in counts from adjoining areas suggest that more data are needed to resolve the question of population homogeneity. To disclose the possible existence of racial differences, a fairly large volume of material collected over several successive years is required. In addition, other body characters should be studied to substantiate any findings based solely on analysis of vertebral number.

Life History

Project personnel participated in four monthly cruises of the R/V George M. Bowers during the winter of 1964-65 to collect menhaden eggs and larvae. Operations were confined to shelf waters off Florida between Panama City and Carabelle. The collection of only 6 eggs and 16 larvae indicated minimal spawning activity during December, January, and February. In March, the capture of 30 eggs and 87 larvae signaled an upswing in spawning. In the interval between the third and final cruises, the average surface temperature in the collection areas rose from 12.7° to 16.8° C. Besides the eggs and larvae taken with plankton nets, 1,645 adult Gulf menhaden and 107 adult yellowfin menhaden were captured by gill nets during the four cruises. None of these fish was sexually ripe.

POPULATION DYNAMICS

Efficient management of any fishery resource presupposes an adequate understanding of its ecology and dynamics. Thus, before prescribing realistic measures to improve the use and maintenance of our menhaden stocks, we must know something about their collective ability to reproduce, their capacity for growth, and their susceptibility to attrition by fishing as well as by a number of natural causes. Each of these factors is largely influenced by the environment, which varies seasonally and annually. At present their assessment is feasible only by either or both of two techniques: (1) collection and analysis of fishery statistics and (2) mark-recapture experiments. In situations where both methods can be applied, corroboration of the results of one by those of the other greatly strengthens all the information obtained. To date we have relied exclusively on the collection and analysis of fishery statistics, the general features and current results of which are described below. Although not yet yielding the kinds of information mentioned above, this method has nonetheless provided a description of resource age structure that has permitted a tentative explanation for the Atlantic fishery's present difficulty. The mark-recapture technique, on the other hand, awaits further adaptation to the peculiar features of the menhaden that make its application here somewhat more uncertain than might ordinarily be the case in other species. Increased activity with this research tool is scheduled for fiscal year 1966.

Atlantic Menhaden Fishery

By William R. Nicholson

Strategically located personnel collected statistics of the Atlantic menhaden fishery in

1964 in the same manner as in previous years. Daily landings of individual vessels were obtained from plant records, information on the location and number of purse seine sets was taken from logbooks kept by vessel captains or pilots, and estimates of the length, weight, sex, and age composition of catches were based on daily samples at the major ports.

The menhaden catch again declined for the third consecutive year, dropping from 632,000 tons in 1962 to only 307,000 tons last year. The 1964 harvest was the smallest since 1944 (catch records date to 1940) and was but 38 percent of the largest (809,000 tons), which was made in 1956. The 65,000-ton catch made north of Cape Charles, Va., was the smallest recorded in 25 years. The Chesapeake Bay catch amounted to 148,000 tons, 31,000 tons more than in 1963, but fishing effort also increased. A relatively good catch of 51,000 tons was made in the summer fishery between Cape Hatteras, N.C., and Daytona Beach, Fla., but landings in the North Carolina fall fishery (November-December) were poor because the fish were scarce.

Because of the general lack of fish north of Cape Charles, processing plants either closed or operated at partial capacity. None operated at Gloucester, Mass., or Point Judith, R.I. The number of vessels supplying plants at Amagansett, N.Y., Port Monmouth and Tuckerton, N.J., and Lewes, Del., diminished as the season progressed. In early July both plants at Lewes closed, but one reopened and operated from late August to mid-September. Vessels at Wildwood, N.J., were shifted to Chesapeake Bay in early June and, except for brief periods in late summer, did not return to Wildwood during the rest of the season. With one exception, all plants closed by the end of September, nearly 4 weeks earlier than usual.

By contrast, more vessels operated from Chesapeake Bay plants than in any previous year of record. Many continued fishing until late November, 3 to 4 weeks longer than usual.

Figure 14.--Setting purse seines for menhaden off the Middle Atlantic coast.

Fishing occurred in the same areas as in previous years, but because small numbers of fish compelled fishermen to reduce their effort, fewer sets were made in coastal waters north of Virginia. In these waters, the number of fish caught per set also decreased. Elsewhere, the number of sets and the average catch per set remained about the same as in other years.

Examination of samples from landings at Fernandina Beach, Fla.; Southport and Beaufort, N.C.; Lewes, Del.; and Amagansett indicated little change from previous years in the age composition of fished stocks (table 7). These sample data indicated that age-2 fish contributed a larger than usual proportion of the catch in Chesapeake Bay, and age-0 fish were more numerous than in any previous year. Also, age-3 rather than age-2 fish dominated catches landed at Port Monmouth. Production in the North Carolina fall fishery contained a large proportion of age-0 fish.

The most significant aspects of the 1964 season were the dearth of fish in outside waters north of Cape Charles, the relatively small numbers of age-1 fish in samples from areas north of Cape Charles, and the large proportion of age-0 fish in catches from Chesapeake Bay and the North Carolina fall fishery.

The absence of any large or even moderate-size year class in the past 6 years is a major factor contributing to the relative scarcity of fish in waters from Chesapeake Bay northward. The unusually large 1958 year class supported the fishery off Cape Charles and northward from 1959 to 1962. With the depletion of this year class, the catch plummeted to a 25-year low in 1964. The catch in Chesapeake Bay, where the fishery depends primarily on age-1 and age-2 fish, remained fairly good over the past 3 years only because of increased fishing effort. The boats increased in number (from about 29 in 1961 to between 37 and 40 in the ensuing years) and they fished longer seasons. In 1964 many vessels continued fishing through November.

The relatively small percentage of age-1 fish in the Chesapeake Bay and Lewes catches suggests no more than a small to moderate-size 1963 year class. Because of the increased number of vessels in Chesapeake Bay, this year class was subjected to greater fishing pressure at age-1 than were corresponding year classes of previous years.

Catches of age-0 fish from Chesapeake Bay and off North Carolina in the autumn were sizable only in relation to harvests of the less abundant older fish and are not believed indicative of a strong, incoming year class. Lack of oil, poor meal quality, and excessive gilling of fish generally deter the harvest of these fish if older age groups are available. Because of the few old fish in the fall fishery off North Carolina, many vessels returned to Chesapeake Bay in November to fish for the more abundant age-0 fish that appeared in northern Virginia waters. When older fish became very scarce in December, vessels remaining in North Carolina waters fished age-0 fish more heavily than in previous years.

Prospects for increased catches do not appear good. High-level harvesting of the moderate-size 1963 year class as age-1 fish may preclude any chance for greater yields in 1965. Expectations for larger catches in future years are extremely poor unless a series of exceptionally big year classes appears. Early season catches in 1965 tend to confirm this speculation. In the North Carolina region, fish were sparse through June. In Chesapeake Bay, catches were large during the first week of the season but declined thereafter. One plant at Lewes and the plant at Tuckerton did not open. Vessels at Wildwood were transferred to Chesapeake Bay soon after the season began. In the remaining areas, fewer vessels fished than in previous years and catches were small.

Table 7.--Number of fish by age and port of landing in samples of Atlantic menhaden catches, 1964

Port of landing	Size of sample	Age									
		0	1	2	3	4	5	6	7	8	9-10
Amagansett, N.Y.	1,793	--	--	94	419	359	457	383	72	8	1
Port Monmouth, N.J.	2,054	--	12	592	845	275	151	146	26	7	--
Lewes, Del.	728	--	97	436	183	12	--	--	--	--	--
Chesapeake Bay	3,216	651	963	1,443	153	5	--	1	--	--	--
Beaufort, N.C.	576	--	321	230	25	--	--	--	--	--	--
Southport, N.C.	238	1	190	40	7	--	--	--	--	--	--
Fernandina Beach, Fla.	177	--	136	40	1	--	--	--	--	--	--
North Carolina unspecified (fall fishery)	1,554	365	212	695	233	38	7	3	1	--	--

Gulf Menhaden Fishery

By Robert B. Chapoton

The techniques we employ in the Gulf menhaden fishery to obtain data on the amount and distribution of fishing effort and on the volume and composition of landings are patterned after those developed over the past 10 years on the Atlantic coast. They entail collecting statistics of purse seine operations from vessel personnel via logbooks, and systematically sampling the catch to determine the length, weight, sex, and age composition of the fished stocks. Data on landings are transcribed from records maintained by processing plants.

Beginning in the year covered by this report, we obtained biological material and fishery data throughout the fishing season at six ports of landing, namely, Moss Point, Miss.; Empire, Morgan City, Cameron, and Dulac, La.; and Sabine Pass, Tex.

The 1964 harvest of menhaden from the Gulf of Mexico consisted almost entirely of Gulf menhaden. Of 631 catch samples obtained throughout the season, only 4 contained finescale menhaden and none contained yellowfin menhaden. Other herringlike fishes occasionally represented in the catches were threadfin shad, *Dorosoma petenense*; Atlantic thread herring, *Opisthonema oglinum*; and scaled sardine, *Harengula pensacolae*.

As part of a thorough investigation of the use of scales to determine the age of Gulf menhaden, the length attained by this species at the time it first becomes fully scaled was determined. This and additional information on scale characteristics during early life history stages were provided by juveniles collected from Florida to Texas in 1963 and 1964. Findings to date indicate that scales begin to form on the Gulf menhaden at a fork length of about 20 mm. Fully scaled fish less than 25 mm. long have not been observed. A reliable aging technique will yield needed information about the relative contribution of the different year classes or broods that support the fishery, together with a means of assessing growth and mortality in the fished stocks. We anticipate that 1 or 2 years of additional sampling will be required before we accumulate enough material to develop a satisfactory aging method.

Ages have been provisionally assigned, however, to about five thousand Gulf menhaden sampled systematically during the 1964 fishing season.

Port of landing	Size of sample	Number of annuli						
		0	1	2	3	4	5	6
Moss Point........	2,513	6	1,695	781	30	1	--	--
Empire............	2,046	33	712	855	359	79	7	1
Morgan City.......	259	2	137	98	18	--	4	--
Cameron...........	438	1	218	170	40	9	--	--
Total..........	5,256	42	2,762	1,904	447	89	11	1

These data indicate that about half the catch consisted of fish in their second year of life and almost 90 percent of fish in their second and third years. Fish caught near and landed at Empire were generally larger and older than those taken near other ports.

Information on fishing intensity is entered routinely in logbooks kept aboard the fishing vessels. Such data, recorded daily, show the number and location of sets. Sets in which no fish are caught are also indicated. This information is important because fishing intensity seldom remains the same from season to season. Some measurement of the effort exerted to catch whatever fish are landed is, therefore, essential if changes in apparent menhaden abundance are to be properly interpreted. Although they have not yet been completely processed, logbook data obtained during the 1964 season reveal that fishing in the Gulf ranged from Apalachicola, Fla. (long. 85° W.), to Sabine Pass, Tex. (long. 94° W.), a 540-mile stretch of coast. Most activity, however, was concentrated in Mississippi, Breton, and Chandeleur Sounds east of the Mississippi River Delta, and within 10 miles of the coast west of the Delta to long. 93° W.

The Gulf menhaden catch in 1964 totaled about 452,000 tons, a 7-percent drop from the 1963 catch of 485,000 tons and 15 percent less than the record catch of 530,000 tons landed in 1962. Of this total, Mississippi, Louisiana, and Texas landings represented 26, 67, and 7 percent, respectively. Adverse weather late in the 1964 season contributed significantly to the decline.

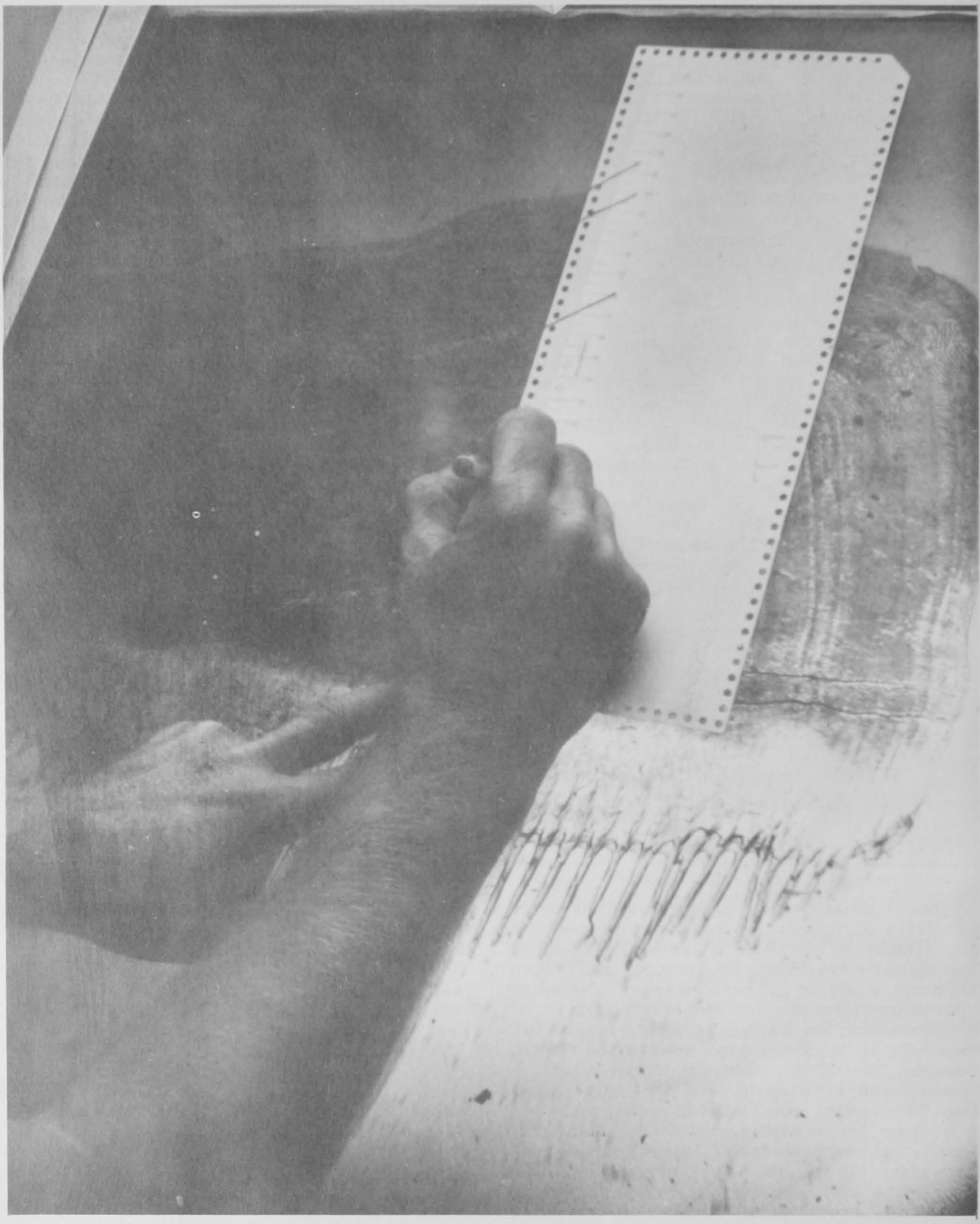

Figure 15.--Determining the age and growth of a Gulf menhaden by counting the number of and measuring the distance between annular marks on an enlarged image of its scale.

ANADROMOUS FISHERIES PROGRAM

Paul R. Nichols, Chief

The problems of fish passage at existing and proposed barriers and the effects of water developments on the runs of anadromous fish have become more acute along the Atlantic coast; therefore, most of our research efforts were shifted to these areas. We continued obtaining and making available to State agencies biological data and fishery catch statistics on which to base management measures. Methods and procedures developed in our studies of fish populations are being turned over to the States for continued annual inventories of the fisheries.

AMERICAN SHAD, ALOSA SAPIDISSIMA (WILSON), STUDIES

Paul R. Nichols

With State and Federal agencies, we continued cooperative studies of biological problems encountered in restoring runs of anadromous fish, particularly American shad, above dams and encountered in conservation of the runs in areas of proposed water developments. The studies included: (1) experimental lockage of fish at navigation locks on the Cape Fear River, N.C.; (2) suitability of the Susquehanna River for restoring runs of shad; (3) practicability of fish passage facilities for proposed impoundments on the St. Johns River, Fla.; and (4) passage of shad at the Hadley Falls Dam fish lift on the Connecticut River, Mass. We collected shad catch data on the Cape Fear and St. Johns Rivers. Also, we reviewed reports, mainly from the Bureau of Sport Fisheries and Wildlife, for comments and recommendations on 14 proposed water development projects affecting anadromous fish.

Cape Fear River

Shad fishery--1965: The estimated total commercial catch in the Cape Fear River and tributaries was 153,555 pounds, of which the commercial area produced 133,080 pounds and the inland area 20,475 pounds. From the commercial area, the Cape Fear River produced 74 percent of the catch and the North East Cape Fear River 26 percent. From the inland area, the North East Cape Fear produced 88 percent and the Black River 12 percent. Of the total catch, drift gill nets employed throughout the Cape Fear and Black Rivers and the lower North East Cape Fear took about 88 percent, anchor gill nets in the upper North East Cape Fear 11 percent, and haul seines operated in the upper North East Cape Fear 1 percent.

A few shad were caught by rod-and-reel fishermen above lock 1, but no estimate was made of the number taken.

Although the total North Carolina shad commercial catch increased from 639,900 pounds in 1964 to 1,068,300 pounds in 1965, the Cape Fear River catch decreased 28 percent from the previous season. This decrease was probably due to unfavorable fishing conditions caused by high waters during the peak of the run.

Experimental lockage of fish at locks and dams--1965: We continued joint studies with the North Carolina Wildlife Resources Commission, the North Carolina Division of Commercial Fisheries, and the U.S. Army Corps of Engineers on the practicability of locking anadromous fish upstream during their spawning migration, use of the Cape Fear River system for nursery grounds by the young fish, and the growth of young shad hatched above lock 1 in the Cape Fear River with the growth of shad hatched in the Black and the North East Cape Fear Rivers.

In July and August, we sampled these areas for water quality and distribution of young herringlike fishes. This is the first year of these observations. In the Cape Fear River, young shad and blueback herring (Alosa aestivalis) were distributed from river mile 3 (32.5 miles below lock 1) to river mile 70 (lock 2), and alewives (A. pseudoharengus) were collected only in the vicinity of river mile 3. During the sampling period, water temperature ranged from 25.0° to 26.6° C., carbon dioxide 5.0-15.0 p.p.m., total alkalinity 7.0-18.0 p.p.m., dissolved oxygen 3.8-5.8 p.p.m., and pH 6.6-6.7. In mid-August, young shad collected above lock 1 ranged from 53 to 88 mm. (average 65.6 mm.) fork length.

In the Black River, young shad and blueback herring were distributed from the River mouth to Highway 411 bridge, a distance of about 15 miles. No alewives were collected. During the sampling period, water temperature ranged from 25.5° to 27.8° C., carbon dioxide 7.0-20.0 p.p.m., total alkalinity 5.0-11.0 p.p.m., dissolved oxygen 2.8-7.0 p.p.m., and pH 5.0-6.5. In mid-August, young shad ranged from 33 to 78 mm. (average 52.4 mm.) fork length.

In the North East Cape Fear River, young shad were distributed from 10 miles above the River mouth to Highway 24 bridge, a distance of about 35 miles, and alewives and

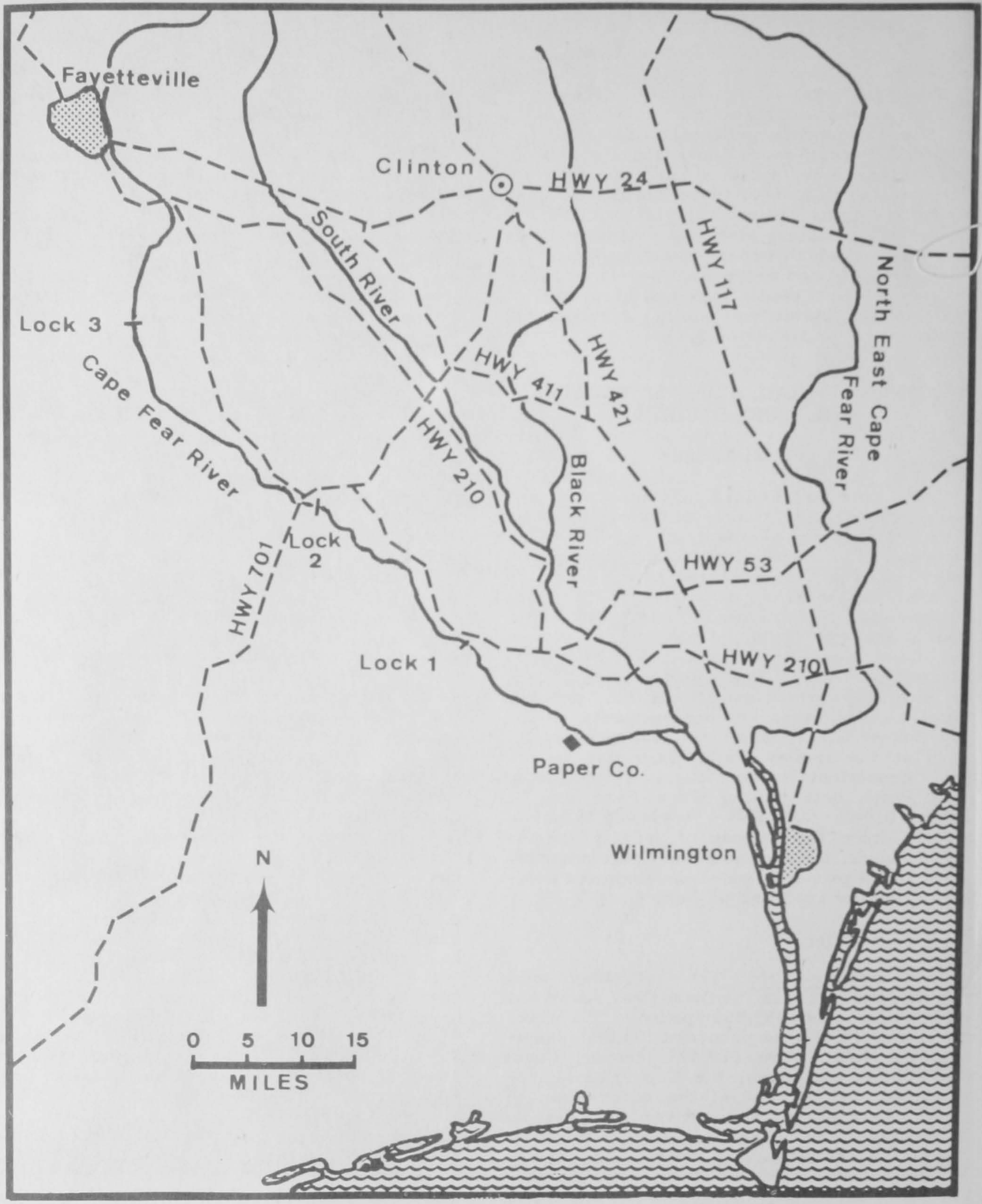

Figure 16.--Cape Fear River study area.

blueback herring were distributed from the River mouth to 10 miles upstream. During the sampling period, water temperature ranged from 25.5° to 28.9° C., carbon dioxide 8.0-14.0 p.p.m., total alkalinity 7.0-22.0 p.p.m., dissolved oxygen 3.0-6.4 p.p.m., and pH 6.2-6.6. In mid-August, young shad ranged from 38 to 83 mm. (average 53.3 mm.) fork length.

Preliminary findings indicated that growth of young shad was excellent in all areas, with growth of those hatched above lock 1 greater than in the Black River or the North East Cape Fear River. There was little difference in water quality in the areas.

From October 2-14, we observed that young shad moved downstream from above lock 1 and out of the tributaries and presumably to sea. During this interval there was a freshet in the River; water level in the upper pool at lock 1 increased from 17.5 to 25.0 feet and water temperature dropped from 22.8° to 15.6° C. These changes probably incited the movement of the young shad. Observations showed that lock and dam 1 were not deterrents to the downstream movement of young shad.

Periodic sampling of fish to determine movement through lock 1 began April 17 and continued through May 6. During this interval, we observed 13 lockages requiring 22 hours. The Corps of Engineers operated the lock for fish passage for an additional 77 hours. Based on the number of fish netted in the lock chamber during periodic sampling with a haul seine, an estimated 1,485 shad, 400 immature striped bass (Roccus saxatilis), and 15,818 alewives and blueback herring were passed. Most of the fish called alewives and blueback herring were the latter, but exact separation of the two species was not attempted. During lockage for fish passage, water temperature ranged from 17.8° to 20.0° C., and the upper pool level varied from 16.1 to 18.1 feet. The number of shad passed per hour increased 50 percent over the previous season, and the number of alewives and blueback

Figure 17.--Lock 1 on the Cape Fear River, N.C.

herring passed per hour increased about 250 percent. Striped bass movement through the lock was probably a feeding migration, because all fish sampled were young of the year.

Lock 2, 34.5 miles upstream from lock 1, was sampled from April 21 to May 26 to estimate fish movement through the lock. During this interval, we made 7 lockages requiring 17 hours. A total of 92 shad, 6 young-of-the-year striped bass, and 724 alewives and blueback herring were passed. In the previous season, lock 2 was operated 9 hours for fish passage and during this interval 164 shad, 45 blueback herring, and 3 young-of-the-year striped bass were passed. Although more shad were passed at lock 1 and less were passed per hour at lock 2 than in the previous season, lock 2 was operated too few hours to attach any significance to the number of shad passed. The sampling indicated, however, that at least a portion of the fish passed at lock 1 continued the migration upstream beyond lock 2.

In an effort to determine the efficiency of lock 1 for upstream fish passage, we tagged 80 shad below the lock and 122 in the lock. Of the fish tagged below the lock, 36 were recaptured by the commercial fishery in the vicinity of release, 2 were recaptured during periodic sampling of lock 1, and 1 was recaptured in lock 2. These recoveries were made 1 to 28 days after release. Of the 122 shad tagged in lock 1 (an estimated 8.2 percent of the total number of shad passed) 9 tagged fish were recaptured in lock 2 (9.7 percent of the total number of tagged shad passed) within 2 to 23 days after release. No conclusions were made concerning the efficiency of lock 1 because of the small number of tagged fish recovered.

Preliminary indications are that anadromous fish will use navigation locks to pass upstream and that locks may be used to restore, at least in part, spawning runs above such barriers. The locks provide a much needed outdoor laboratory for the study of fish passage, and application of the findings can be accepted in the planning of water developments in the St. Johns River, Fla., and elsewhere. Continued studies are needed, however, to refine techniques for locking fish upstream and to consider modifications in the structures compatible with their primary use to assure maximum efficiency.

Susquehanna River

Cooperative fishway studies--1965: We continued cooperative studies with the Bureau of Sport Fisheries and Wildlife, Maryland Department of Research and Education, Pennsylvania Fish Commission, New York Conservation Department, and four electric power companies that have dams along the Susquehanna River, to determine if the River is suitable for restoring runs of American shad. It is highly probable that findings relative to the suitability of the River for shad will apply to other anadromous fish.

Sufficient numbers of young resulted from the 20 million fertilized shad eggs transplanted to the upper Susquehanna River, the North Branch of the Susquehanna, and the Juniata River in the spring of 1964 to complete our observations on the downstream movement of fish through the impoundments. From August to mid-October, several thousand young shad, 60 to 95 mm. fork length, were observed throughout the hatching sites and the York Haven impoundment. During this period, water temperature ranged from 24° to 19° C. Many young fish started their downstream movement in mid-October when water temperature suddenly dropped from 19° to about 10° C. From mid-October to late November, these fish were distributed throughout a 50-mile stretch of river from the York Haven impoundment to Conowingo Dam. Fish collected in late November ranged from 82 to 195 mm. fork length. Minimal water temperature was 2° C. at York Haven Dam and 8° C. at Conowingo Dam. In December, 63 young shad, 110 to 208 mm. fork length, were collected in Safe Harbor and Holtwood impoundments, and 25 young shad, 111 to 210 mm. fork length, were collected in Conowingo tailrace. Water temperature ranged from 1° to 4° C. in the Conowingo tailrace. Transverse groove count on scales from young shad more than 175 mm. fork length indicated that some young hatched in spring of 1963 had wintered in the impoundments. Collections of young shad in Conowingo tailrace showed that some fish had successfully moved downstream through the four impoundments into the lower River, a maximum distance of about 196 miles.

From April 23 to June 4, we continued studies to determine the extent and nature of the movement by adult shad transported from below Conowingo Dam and released from holding facilities in the Conowingo impoundment and the River at Harrisburg, Pa., above the impoundments. Of 1,330 adult shad taken from pound nets in the Susquehanna Flats, 1,045 survived transport and orientation in the holding pens. Ultimately, 771 adult shad were released in the Conowingo impoundment--465 untagged, 25 tagged with sonic tags and 281 with Petersen tags; and 274 were released at Harrisburg--164 untagged, 35 tagged with sonic tags and 75 with Petersen tags. From the Conowingo impoundment releases, limited recoveries (2.5 percent) of the Petersen tags indicated a downstream movement after release. Direction of movement of fish released with sonic tags will not be known until tracking tapes have been interpreted. Observations at Harrisburg showed that fish released from

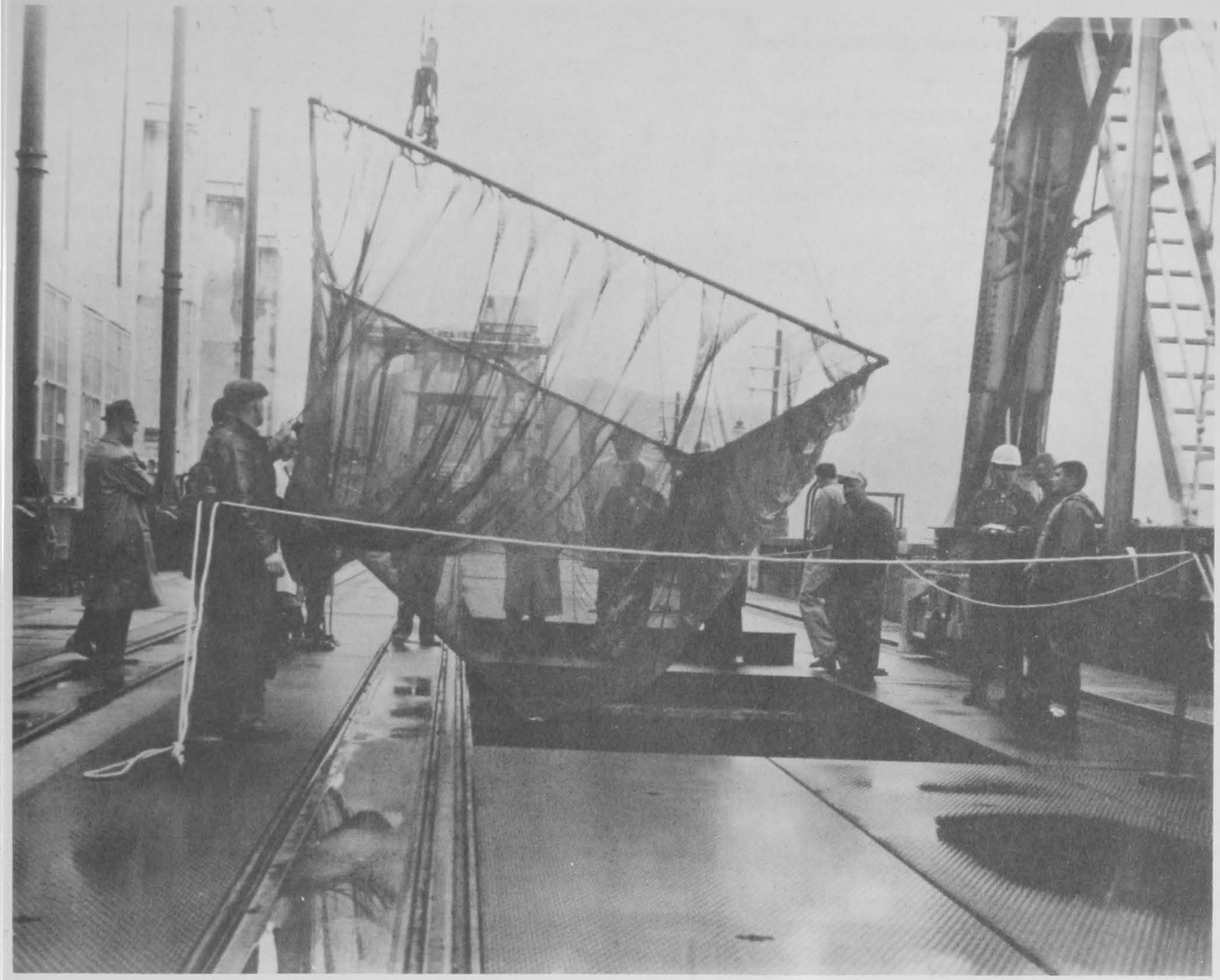

Figure 18.--Dip net, 16 by 11 feet with 3/4-inch stretched mesh, used to capture young shad in gate wells in Safe Harbor Dam on Susquehanna River.

holding pens initially moved upstream. Tracking tapes on monitors above Harrisburg revealed traces most likely due to upstream passage of shad; however, a definite decision has not yet been made.

We transported 42 adult shad from trapping devices below Conowingo Dam and released them in the Conowingo impoundment. Before release 10 of these were marked with sonic tags. Preliminary examination of tracking tapes from monitors 3 miles upstream from the release site showed no traces of marked shad having passed upstream. In the spring of 1966, we plan to continue studies on movement of adult shad, transported from the trap below Conowingo Dam and released in the impoundment, by electronic tracking equipment.

St. Johns River

Shad fisheries--1965: The estimated commercial catch of shad was 825,860 pounds, of which gill nets in the Mayport-Jacksonville area took 322,240 pounds and shad nets (haul seines) in the Welaka-Palatka-Georgetown area 503,620 pounds. Based on catch-effort statistics, the estimated population weight was 3,695,000 pounds and the commercial fishing rate was 22 percent. The commercial catch increased about 50 percent over the previous 5-year average annual catch and the estimated weight of the population increased 30 percent (table 8).

The estimated sport catch of shad was 132,860 fish (estimated weight, 332,150 pounds) in 32,855 man-days of fishing. The sport catch

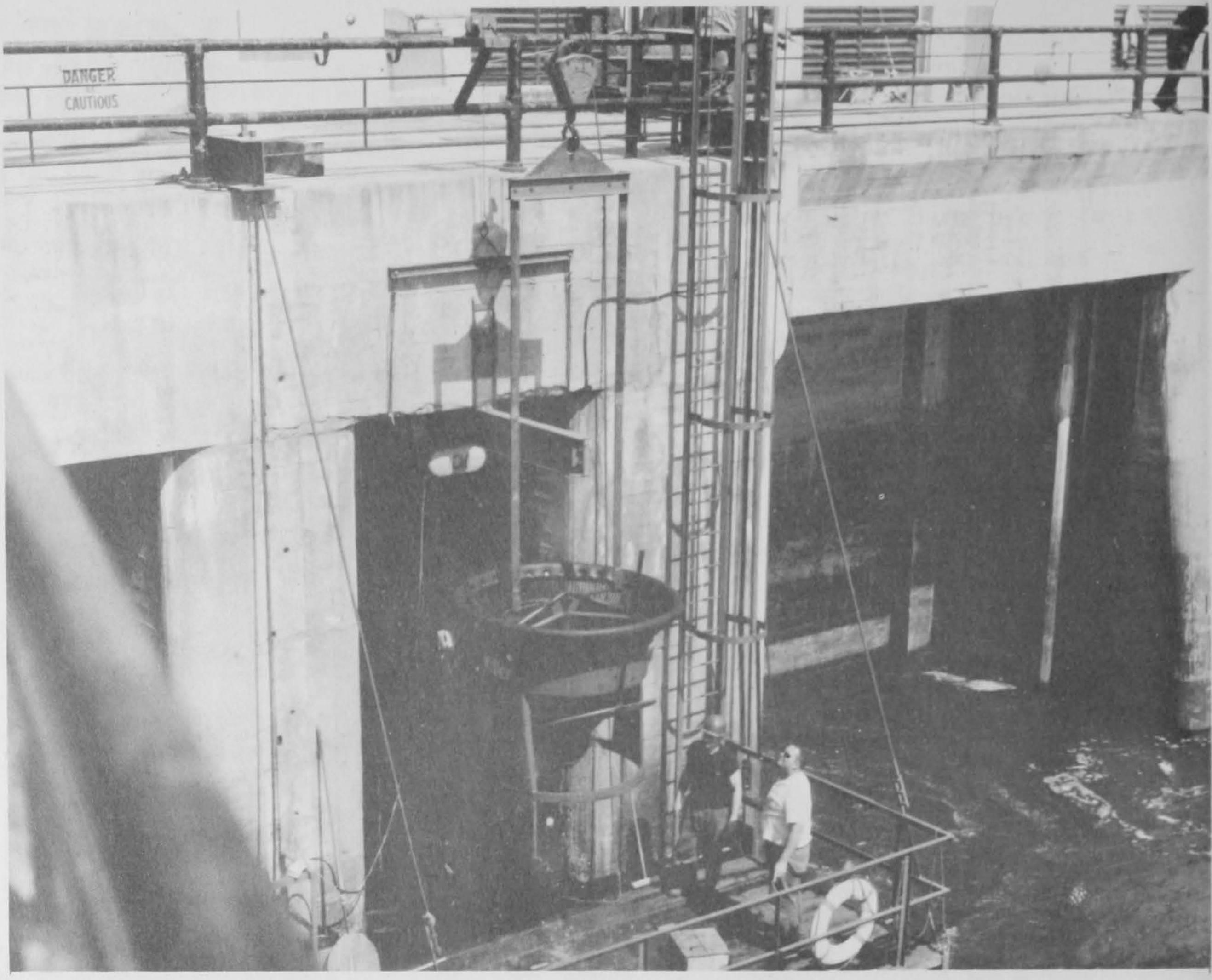

Figure 19.--Lifting trap brail at Conowingo Dam on Susquehanna River.

Table 8.--Shad catch and effort statistics for St. Johns River, 1960-65

Season	Commercial catch	Sport catch	Total catch	Fishing rate	Calculated size of run
	Thousand pounds	Thousand pounds	Thousand pounds	Percent	Thousand pounds
1960.........	505	198	703	32	2,199
1961.........	443	166	609	24	2,563
1962.........	621	174	795	24	3,362
1963.........	716	194	910	31	2,940
1964.........	484	212	696	22	3,106
1965.........	826	332	1,158	31	3,695

increased about 56 percent over the previous season and was the best catch of record.

The total shad catch of about 1,158,000 pounds makes the St. Johns River the most productive for shad on the Atlantic coast.

Practicability of fish-passage facilities--1965: We continued cooperative studies with the Bureau of Sport Fisheries and Wildlife in the upper St. Johns River to determine possible effects of proposed navigation canal and flood control impoundment projects on shad fisheries.

From March 23 to April 1, we sampled the River with 1-m. plankton nets from Lake Beresford near DeLand, Fla., to Highway 192 bridge to determine the extent of the area used by shad for spawning. We sampled at 12 stations for a total of 2,804 net-hours. During the sampling period, water temperature ranged from 19.0° to 27.2° C. Shad eggs were collected from Highway 520 bridge north of Lake Poinsett to Osteen Bridge near Lake Monroe inlet (table 9). South of Lake Harney, most eggs were collected from Highway 520 bridge to Puzzle Lake. Those findings were similar to those of previous years. North of Lake Harney, most eggs were collected from Lemon Bluffs to Marina Isle near Lake Jessup outlet. No eggs were collected north of Lake Monroe. Preliminary findings indicate that proposed water development projects south of Lake Harney could eliminate established spawning grounds and possibly eliminate the runs contributed by that section of the River unless measures are taken to minimize adverse effects of the proposed projects on the fisheries.

The estimated total sport catch of shad in the River was 132,860 fish in 32,855 man-days of fishing. South of Lake Harney the shad sport fishery began in early January and continued until the end of March. The estimated catch in this area was 51,225 shad in 7,402 man-days; 15,393 were caught in 2,199 man-days between Lake Harney and Highway 50 bridge, 32,018 in 4,574 man-days from Highway 50 bridge to Lake Poinsett, 2,814 in 402 man-days from Lake Poinsett to Lake Winder, and 1,000 in 227 man-days south of Lake Winder. The catch south of Lake Harney increased about 200 percent, and catch per man-day increased about two fish over the previous season. This area produced about 38 percent of the total River catch and accounted for 22 percent of the total man-days of fishing, compared with 26 percent of the catch and 18 percent of the man-days in the previous season. Preliminary findings indicate that the proposed water developments south of Lake Harney could eliminate a significant part of the sport fishery.

Connecticut River

Operation of Hadley Falls Dam fish lift--1965: The Holyoke Water Power Company operated the fish lift on Hadley Falls Dam 35 days (May 11 to June 23) for passage of fish. The number of American shad passed was 33,896, a decrease of about 2 percent from 1964. The decrease in the number passed was probably due to lower water flows during a part of the lifting period, which prevented operation on most weekends and limited the number of operating hours on week days. The number passed per day of operation, however, increased 4 percent over the previous season. The number of fish of other species passed

Table 9.--American shad eggs collected per net-hour, upper St. Johns River, Fla., March 23 to April 1, 1965

[Net-hour equals 1-m. plankton net fished for 1 hour]

Station number	Location	Date	Sampling time	Eggs collected	Eggs collected per net-hour	Water temperature
			Net-hours	Number	Number	°C.
1.......	Vicinity of Highway 192 bridge	3/23	37.0	0	0	20.5
2.......	South of Lake Winder	3/24-3/25	83.0	0	0	23.3-25.0
3.......	South of Lake Poinsett	3/26-3/31	178.0	0	0	23.3-25.0
4.......	Vicinity of Highway 520 bridge	3/23-4/1	341.5	965	2.8	20.5-27.2
5.......	Vicinity of Highway 50 bridge	3/23-4/1	360.0	2,215	6.2	20.5-26.1
6.......	South of Puzzle Lake	3/29-4/1	159.0	3,658	23.0	21.1-25.5
7.......	Vicinity of Highway 46 bridge	3/24-4/1	275.5	217	0.8	19.0-26.7
8.......	Vicinity of Lemon Bluff	3/24-4/1	285.5	940	3.3	22.2-25.0
9.......	Vicinity of Marina Isle	3/24-4/1	283.5	2,672	9.4	20.7-25.0
10......	Vicinicy of Osteen bridge	3/24-4/1	304.0	466	1.5	20.7-25.0
11......	Vicinity of Wekiva River mouth	3/23-3/31	321.0	0	0	20.5-26.7
12......	South of Lake Beresford	3/23-3/26	175.5	0	0	20.5-23.9

were 2 sturgeon, Acipenser sp.; 53 alewives; 48 trout, Salmo sp.; 17 carp, Cyprinus carpio; 657 bass, Micropterus sp.; 118 yellow perch, Perca flavescens; 18 northern pike, Esox lucius; 5 pickerel, Esox sp.; 35 walleyes, Stizostedion vitreum; 5 white perch, Roccus americanus; 1 catfish, Ictalurus sp.; and 18 bullheads, Ictalurus sp. Twenty-six sea lampreys, Petromyzon marinus, were removed from the fish lift. Water temperature varied from 60° to 72° F. while the lift was in operation; a peak number of 11,229 shad, or about 33 percent of the total shad passed, were lifted at water temperatures of 64° to 67° F. during a 4-day period from June 25-28 (table 10). During the lifting operations in the previous season (May 12 to June 25) the water temperature varied from 60° to 77° F.; 11,118 shad, or about 31 percent of the total shad passed, were lifted at water temperatures of 67° to 70° F. during a 4-day period from June 9-12. The cumulative number of shad passed (1955-65) at different water temperatures showed that peak numbers were lifted at water temperatures of 66° to 71° F.

Table 10.--Shad passed by fish lift, Hadley Falls Dam, Connecticut River, 1965[1]

Date operated	Daily lift	Cumulative total	8:00 a.m. water temperature
	Number	Number	°F.
May 11....	404	404	61
12....	376	780	61
13....	679	1,459	62
14....	141	1,600	60
15....	1,064	2,664	62
16....	1,872	4,536	62
17....	1,705	6,241	64
18....	1,309	7,550	65
19....	1,144	8,694	63
20....	2,202	10,896	64
21....	1,303	12,199	64
24....	931	13,130	64
25....	3,280	16,410	65
26....	2,715	19,125	66
27....	2,725	21,850	68
28....	2,509	24,359	67
29....	257	24,616	67
June 1....	192	24,808	66
2....	1,492	26,300	66
3....	934	27,234	63
4....	1,107	28,341	65
7....	1,211	29,552	66
8....	717	30,269	70
9....	1,034	31,303	73
10....	603	31,906	74
11....	787	32,693	74
12....	21	32,714	72
14....	506	33,220	71
15....	66	33,286	66
16....	89	33,375	68
17....	139	33,514	68
18....	190	33,704	68
21....	114	33,818	72
22....	64	33,882	71
23....	14	33,896	72

[1] Data supplied by Holyoke Water Power Company, Holyoke, Mass.

Collection of young shad--1965: In October, we collected 314 young shad from above the Hadley Falls Dam and 292 from below the Dam to continue comparisons of growth and to determine if shad hatched above the Dam can be differentiated from those hatched below the Dam by such factors as the number of fin rays, gill rakers, or vertebrae. If this can be done, it would be possible to distinguish the contribution made to the returning runs by the fish hatched above or below the Dam, and, therefore, to estimate the value of fish passage to the run. Young shad hatched above the Dam ranged from 107 to 155 mm. in fork length, with a mean of 129.8 mm.; those hatched below the Dam ranged from 96 to 146 mm., with a mean of 123.1 mm. The mean growth of young shad was significantly greater above the Dam than below the Dam. Analyses of the meristic counts are incomplete.

STRIPED BASS, ROCCUS SAXATILIS (WALBAUM), STUDIES

Randall P. Cheek

We completed cooperative studies on striped bass in Chesapeake Bay, Md., with the Chesapeake Biological Laboratory, Solomons, Md., and in Albermarle Sound and Roanoke River, N.C., with William W. Hassler of North Carolina State University, Raleigh.

Chesapeake Bay Cooperative Studies

In a joint effort with the Chesapeake Biological Laboratory we completed: (1) tagging studies to determine Maryland's contribution to striped bass stocks occurring along the Northeast Atlantic coast; (2) analyses of tagging data to determine utilization of Chesapeake Bay striped bass stocks; and (3) observations on seasonal movement of striped bass, tagged and released in the Potomac River.

Origin of striped bass stocks of the Northeast Atlantic coast--1965: Tagging in Maryland waters to determine the origin of striped bass stocks along the Northeast Atlantic coast was completed. From April through June, we tagged and released 329 striped bass in the Patuxent, Elk, and Sassafrass Rivers, making a total of 16,149 fish tagged and released in the Maryland part of Chesapeake Bay and tributaries from 1959 to 1965. To date, recaptures have totaled about 5,325, or 33 percent of the tagged fish.

Preliminary findings indicate that although most of the recaptures were made near the release site, some tagged fish traveled great distances within the Bay and tributaries, and a small number traveled even greater distances outside Maryland waters. Less than 1 percent of the tagged fish were recaptured in the Virginia part of Chesapeake Bay and its tributaries. About 1.5 percent of the recaptures were outside Chesapeake Bay, from Delaware Bay to Nova Scotia. None was recaptured south of Chesapeake Bay. Observations showed that striped bass in the tributaries and extreme northern part of the Bay remain in the vicinity up to 2 years and that coastal migrants are mostly 2-, 3-, and 4-year-old fish. In general, there is little movement of Maryland fish into Virginia waters and little loss to the outside waters of the younger fish of catchable size.

One significant part of the study was an attempt to determine sex of a part of the tagged fish by biopsy. This technique has proved satisfactory in large-scale sexing of commerical catches without affecting the market quality; however, sexing live striped bass, other than running-ripe fish, is extremely difficult. The possible effects of the biopsy on live fish is under observation. Of 2,375 fish tagged in 1964-65, 800 were sexed by extrusion of sex products and 970 were biopsied. To date, 451 of the biopsied materials have been examined. Preliminary observations indicate that only 41 percent of the samples were gonadal tissue; the others were fatty or connective tissue. Perfecting this technique would add a much-needed tool for studies on the movement and biology, by sex, of striped bass. The technique may be applicable to other species where determination of sex by external inspection is difficult or impossible.

Utilization of Chesapeake Bay striped bass stocks: Analyses of data from a 2-year tagging study on the winter gill net fishery for striped bass in Chesapeake Bay were completed. In 1962-63, the estimated annual average weight of the striped bass stocks available to the fishery was 1,500,000 pounds; the fishing rate was 19 percent, and the catch was 249,500 pounds. The catch was composed of about 84 percent age-group 2 fish, 15 percent age-group 3 fish, and 1 percent age groups older than 3. Tag returns showed that the fish were active during the winter and moved as much as several miles a day.

Preparation of a report is in progress so that findings and techniques and procedures developed will be available for continued monitoring of the winter stocks of striped bass in the Bay. Knowledge of the weight of stocks present at the start of the fishing season would be of enormous value to management authorities.

Seasonal movement of Potomac River striped bass: We completed analyses of data on 3,348 recaptures from 8,973 striped bass tagged during the wintering, spawning, and feeding seasons. In addition to the seasonal movement of the tagged fish reported in the 1964 Annual Report, recaptures indicated: (1) during winter there is an intermingling in the Potomac River of striped bass stocks from the Rappahannock and Mattaponi Rivers in Virginia and from the

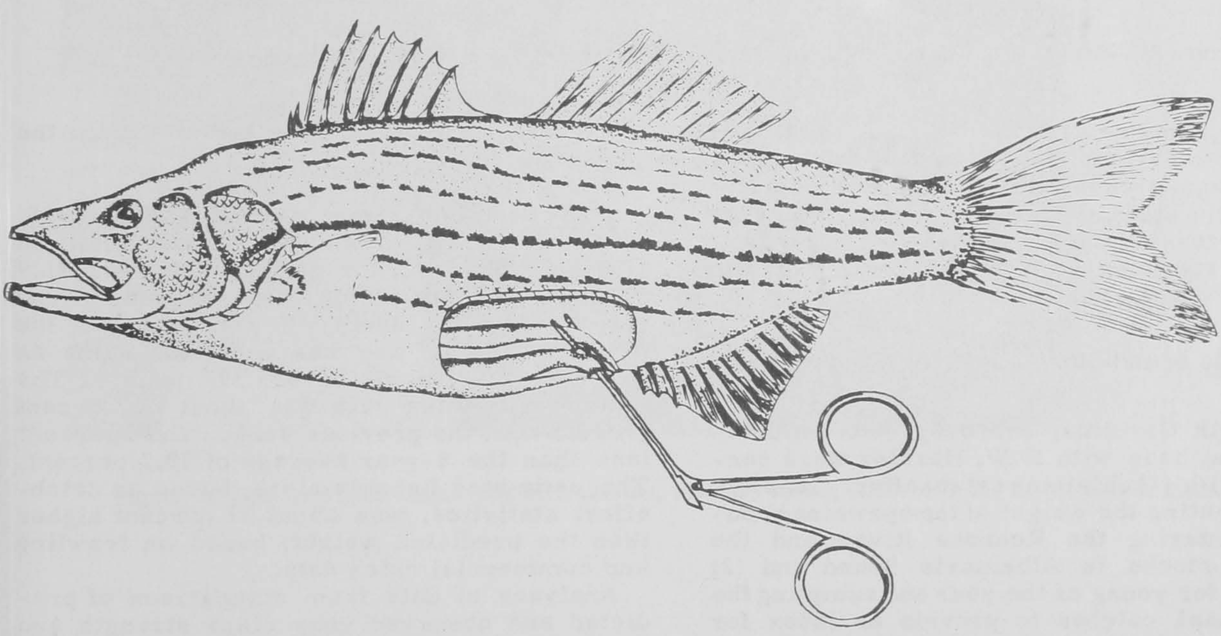

Figure 20.--Use of forceps in sexing striped bass. Forceps are inserted in the vent and through intestinal wall to grasp gonad.

Figure 21.--Sampling the striped bass commercial catch for length and weight, and scale samples for aging the fish, Chesapeake Bay.

Choptank, Patuxent, Potomac, and Nanticoke Rivers in Maryland; (2) Potomac River striped bass, in age-groups 2 and 3, contribute significantly to the stock occurring along the Northeast Atlantic coast during summer and early fall; and (3) spawning striped bass return to the same spawning area each year.

Albemarle Sound-Roanoke River Cooperative Studies

In North Carolina, our cooperative studies of striped bass with W.W. Hassler were concerned with (1) obtaining catch-effort statistics for estimating the weight of the spawning population entering the Roanoke River and the fishable stocks in Albemarle Sound and (2) trawling for young of the year and sampling the commercial catches to provide an index for predicting relative year class strength and weight of stocks available to the commercial fishery 1 year in advance of exploitation in the Sound.

Utilization of Albemarle Sound stocks--1965: The estimated fishable stocks weighed 1,906,125 pounds, the fishing rate was 26.9 percent, and the catch 513,150 pounds. The catch increased about 35 percent over the previous season and was about the same as the 8-year average of 513,326 pounds. The estimated fishing rate was about 20 percent greater than the previous season and 5 percent less than the 8-year average of 28.2 percent. The estimated fishable stock, based on catch-effort statistics, was about 27 percent higher than the predicted weight, based on trawling and commercial catch data.

Analyses of data from comparison of predicted and observed year class strength and for predicting the weight of the fishable stocks available to the 1966 fishery are incomplete.

Figure 22.--Striped bass caught in a drift gill net, Roanoke River, N.C. Note tag on the fish at right.

Roanoke River studies--1965: In April and May, we tagged and released 560 striped bass during the spawning migration into Roanoke River. Tagged fish ranged from about 1 to 10 pounds in weight and from 10 to 25 inches in fork length. To date, 111 tags have been returned, which indicates a fishing rate of about 20 percent--an increase of 50 percent over the previous season. Analyses of catch-effort statistics for estimating the weight of the spawning population are continuing.

This completes our 9-year cooperative tagging studies on striped bass in the Roanoke River. Analyses of the data are continuing for preparation of a report so that our findings are available to State agencies concerned with management of the fishery.

LIBRARY

Anna F. Hall

The library was expanded in 1964. The collection was brought together in a central location, additional shelving was obtained to increase the capacity by about one-third, and an office was built for the librarian. Two Microcard readers were purchased, one for microfiche and one for micro-opaque cards. We bought 1,053 micro-opaque cards to fill in missing volumes of journals and to add one journal which was new to the library. Relatively few microfiche cards have been received as yet.

Included in library acquisitions during the year were 186 books and 119 bound volumes of periodicals. Through gifts, exchanges, and subscriptions, the library received 318 serials. Reprints acquired during the year occupy about 4 feet of file drawers. All publications have been processed and are available for use.

Publications borrowed on interlibrary loan increased from 197 items last year to 267. An estimated 2,800 library items were used, about 500 for periods longer than overnight.

Preparation of the weekly list of acquisitions was continued for distribution to the staff and other laboratories.

The librarian attended the Department-wide Librarians Conference held in Washington, D.C.

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