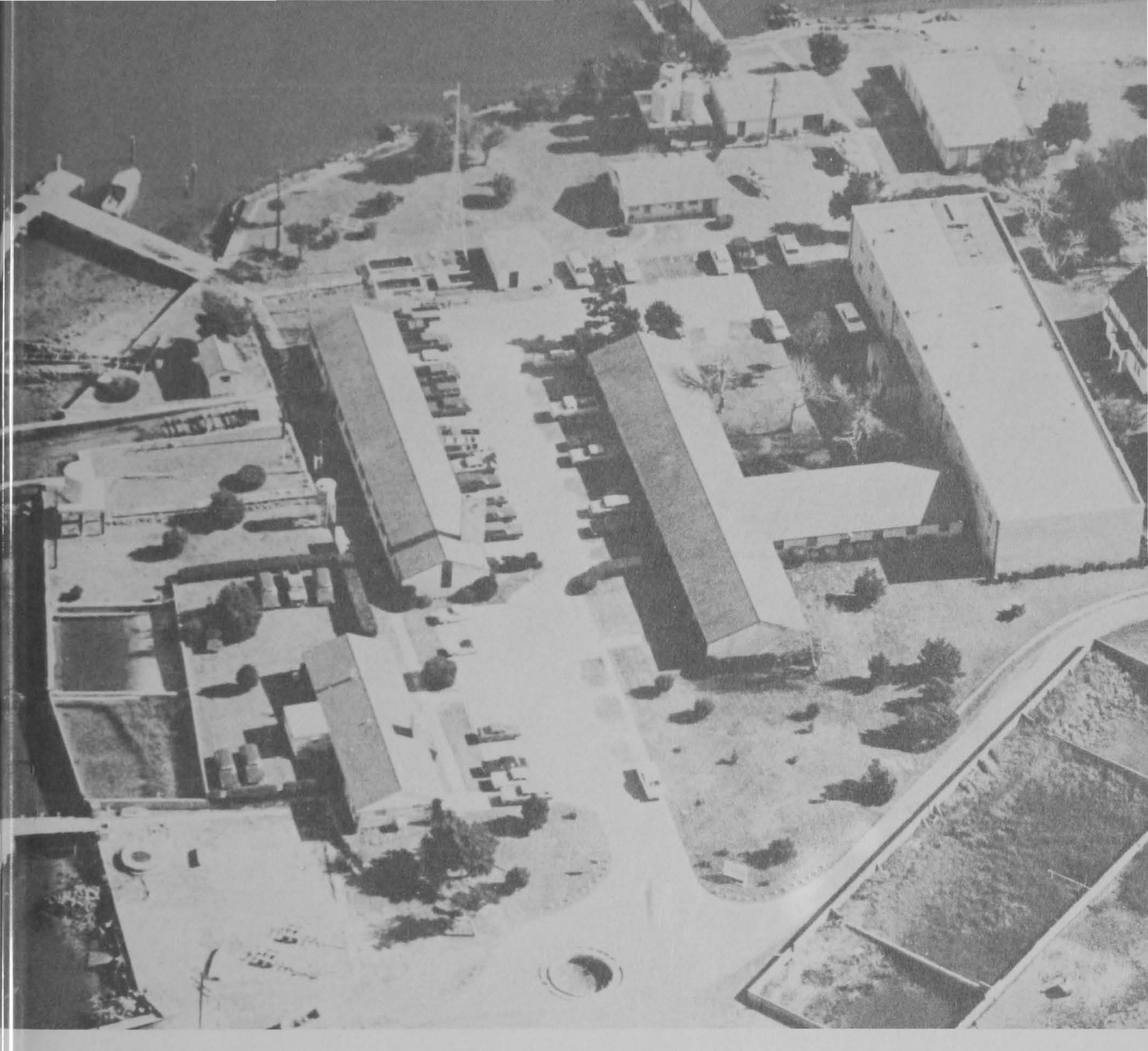

Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C. For the Fiscal Year Ending June 30, 1966

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

Circular 264

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, *Secretary*
Charles F. Luce, *Under Secretary*
Stanley A. Cain, *Assistant Secretary for Fish and Wildlife and Parks*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Harold E. Crowther, *Director*

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

For the Fiscal Year Ending June 30, 1966

Kenneth A. Henry, Director

CIRCULAR 264

Washington, D.C.

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

For the Fiscal Year Ending June 30, 1966

REPORT OF THE LABORATORY DIRECTOR

Kenneth A. Henry

Research at this laboratory is directed towards various anadromous fishes--mainly striped bass and the American shad, the blue crab, and the Atlantic and Gulf of Mexico menhadens. Additional money was received this year for tagging Atlantic menhaden.

The goals of the striped bass program, which began at this laboratory in 1955, have been achieved and, consequently, the program was not continued into this fiscal year. Using the data collected in 1955-65, we are preparing manuscripts that will be major contributions to the literature on striped bass and to the understanding of this resource. Much of the research was in conjunction with other Federal and State agencies, and its success was due mainly to the fine cooperation between the various individuals and agencies concerned, both in the field work and in the preparation of the manuscripts.

Research work in our anadromous fisheries program during the past year dealt principally with fish passage problems at various existing or proposed barriers in streams along the east coast of the United States. This research also has been a cooperative effort, with excellent results.

The main effort in our blue crab research program was to study the abundance and distribution of juvenile blue crabs in Core Sound, N.C. The purpose in obtaining a considerable quantity of biological data on these young crabs is to establish a relation between the abundance of juveniles and the subsequent abundance of marketable-size crabs. If such a relation can be established, it will be possible to predict accurately the supply of crabs that would be available to the industry when these immature crabs reach commercial size.

Since sufficient personnel were not available to staff the Green Cove Springs, Fla., field station adequately, blue crab studies in that area were terminated near the end of the fiscal year.

Because of the continuing decline in the abundance of Atlantic menhaden, the Laboratory's research on this species has consistently increased in the past few years to provide more comprehensive information on this important resource. Our research has been directed towards measuring the biological characteristics and species composition of the catch and the fishing effort, and estimating the relative abundance of each year class before it enters the fishery. Recently increased appropriations will now enable us to determine various features of the menhaden migration patterns, and to obtain estimates of the percentage of the population caught by the fishery and the number of menhaden that die naturally. These data are necessary if we are to understand the dynamics of the resource and use it effectively.

The Gulf of Mexico menhaden program is limited now to collecting various biological data from the commercial catch and measuring the magnitude of the fishery. We also are estimating the abundance of juvenile Gulf menhaden, but the estimation problems appear to be much more difficult in the Gulf of Mexico estuaries than in the western Atlantic estuaries.

RESEARCH HIGHLIGHTS

Anadromous Fish

In our studies on the use of boat locks to pass fish, the number of shad passed upstream through lock 1 of the Cape Fear River, N.C., increased 176 percent over the previous season. Lock 3, 58 miles above lock 1, was operated for fish passage in 1966 for the first time; 50 shad and 350 alewives and blueback herring were passed in one 3-hour period. This passage of fish should improve sport fishing above the dams as well as increase the available spawning area.

Young shad moved downstream at about the same time and under similar conditions as in 1965. Lock 1 and dam 1 were not deterrents to this downstream movement.

The number of shad passed upstream at the fish lift at Hadley Falls Dam, Conn., decreased 52 percent from 1965. This decrease was probably due to a late spawning season, which resulted in fewer shad reaching the dam and reduced the number of days the fish lift operated. The cumulative number of shad lifted over the dam in 1955-66 at different water temperatures showed that peak numbers were lifted at temperatures of 66° to 71° F. An estimated 7 percent of the fish lifted over the dam were observed dead or stranded when the power company drained the canal system at Hadley Falls Dam to make annual repairs. This compares with 12 percent in 1955, 15 percent in 1956, and 17 percent in 1957, the only other years when estimates were made.

We completed our study of shad in the Connecticut River by sampling the area between Hadley Falls Dam and Turners Falls Dam for shad eggs. The area in which most eggs were found was several miles farther upstream this year than in 1965. Also, about 25 shad were observed below the Turners Falls Dam. Shad probably would move farther upstream except for this barrier.

This is the final full year for the Susquehanna River cooperative shad study on the suitability of the area above the dams for shad. Collections of young shad last autumn suggested that at least some of the adult shad released above the impoundments in 1965 had spawned successfully in the upper river.

The discharge from new powerhouse units adversely affected the attraction of shad to the trap and hindered efforts to secure additional adult shad for subsequent release in the Conowingo impoundment. Only four adults were collected and released with sonic tags attached. Signals from at least one tagged shad were received about 2,200 feet upstream from the holding pen within 25 hours after release.

Eight adult shad were recaptured in the Conowingo impoundment more than 5 months after release. The good condition of these fish indicated they had found suitable food in the reservoir.

We continued our studies of the shad resource in the St. Johns River, Fla., relative to a proposal to build a ship canal and construct certain flood control devices. Preliminary data indicated that the projects could seriously threaten the resource unless measures were taken to minimize the effects.

Although the catches of shad decreased for both the commercial and sport fisheries on the St. Johns River, Fla., this river continues to be the most productive for shad on the Atlantic coast.

Blue Crab

In studies of the abundance and distribution of juvenile blue crabs, we found that the young crabs tended to congregate in certain areas within a given body of water, and that their distribution was related to size, sex, maturity, and season of the year. Immature crabs tended to begin moving out of the small, shallow, soft-bottomed creeks into the bays and sounds in the early spring.

This study also has shown that the young crabs enter the estuary, not as larvae, but at some time after metamorphosis to the first crab stage, and that young crabs continue to enter throughout the winter and into the spring. The presence of very small crabs in April indicated that some larvae may spend 5 months or more in the ocean during the winter and could be carried long distance from the hatching locality.

We completed a 2-year study on blue crab growth in the St. Johns River, Fla. Crabs kept in water salinities ranging from 6.9 to 25.8 p.p.t. (parts per thousand) had a slightly greater percentage increase in size than crabs kept in water of less than 1 p.p.t. salinity. In general, blue crabs in the St. Johns River, Fla. increased about 25 percent per molt; the time between molts increased progressively with increases in size. Also, females increased more in size per molt than males. These growth data will enable us to estimate the average time to maturity, or commercial size, of any size class of juvenile blue crabs in the St. Johns River. These data, and those on the effect of temperature on growth, can be applied to other areas.

In studies on the effect of salinity and temperature on development of megalops larvae of the blue crab, we found that at moderate temperatures (between 68° and 86° F.) the time required for the larvae to molt to the first crab stage depended mainly on the temperature over a fairly wide range of salinities. At a lower temperature (59° F.) the time required to metamorphose depended on salinity; high salinities delayed metamorphosis. Thus, larvae present in the ocean in the autumn when water temperatures are dropping could remain as larvae for an extended period and be transported for long distances.

Menhaden

Biological investigations of the Atlantic menhaden were expanded with the inception of a mark-recapture project to broaden the scope of research on menhaden migrations, growth, and mortality. A small, internal, metal tag will be used. We have concentrated on developing procedures and equipment for tagging young menhaden and for recovering the tags in the reduction plants.

The 1965 catch of Atlantic menhaden, 602 million pounds, was slightly above 1964 but was the second-smallest catch since 1944. This poor catch had been predicted on the basis of the scarcity of young menhaden in Atlantic estuaries and the absence of any strong year classes since 1958. Fishing effort on the Atlantic coast increased over the previous year, but the catch per standard vessel-day was the lowest yet recorded.

The Gulf of Mexico menhaden catch in 1965 was 1,022 million pounds, up 118,000 pounds from 1964, and only 38,000 pounds less than the record catch in 1962. Fishing effort in the Gulf of Mexico increased significantly in 1965, owing to an increase in the number of large vessels (over 200 tons). The catch per vessel-season in the Gulf was the smallest since 1958.

Because of the relative scarcity of menhaden on the Atlantic coast, it is expected that the fishing effort and competition between vessels will continue to increase in the Gulf of Mexico.

Although fishing effort on the older fish in the northern Atlantic fishing areas has decreased, fishing effort on the younger fish has remained at a high level, particularly in Chesapeake Bay where age-1 and age-2 fish normally constitute almost 90 percent of the catch. For the second year in succession, over half of the total Atlantic menhaden catch came from Chesapeake Bay.

Both the Atlantic and Gulf of Mexico menhaden landings were sampled extensively throughout the fishing season to obtain data on the length, weight, sex, and age of the fish. The 1965 Gulf catch comprised mainly fish 1 and 2 years old, with the 1 year-olds predominating. This appears to be the normal situation. There were greater numbers of age-1 fish in the 1965 Gulf catch than in the 1964 catch. This indicated that the 1964 year class was more abundant as age-1 fish than was the 1963 year class.

Under present conditions only two or three year-classes support the entire Atlantic menhaden fishery, and the occurrence of one or two poor year classes has an immediate and important effect on the catch. In 1965, 98 percent of the fish caught on the Atlantic coast were less than 4 years old. In the North Carolina fall fishery, which historically took older, mature fish, no fish older than age-4 were in the catch samples.

Based on our surveys of abundance of juvenile menhaden in the Atlantic estuaries, in which surface trawls, haul seines, and aerial census were used, the 1965 year class appeared to be one of the poorest on record. Because of this extremely poor year class in 1965 plus the lack of any strong year class since 1958, we predicted another poor catch in 1966. Very poor landings through the first 6 months of 1966 bore out this prediction. This year we greatly increased the number of Atlantic coast estuaries covered by our annual juvenile menhaden surveys. We believe this increased coverage will greatly improve the reliability of our estimates of relative abundance.

We have encountered considerably more difficulties in estimating the relative abundance of juvenile menhaden in the Gulf of Mexico than we experienced in similar studies along the Atlantic coast. The young menhaden are widely dispersed through the vast estuarine area of the Gulf, and adequate sampling was difficult. The two methods currently used are surface trawling and aerial census. The surface trawl catch had indicated that the 1965 year class would be considerably less abundant than the 1964 year class. The aerial census, however, indicated greater abundance for the 1965 year class. In view of the reduced commercial catch in 1966, it appears that the trawl catch data were more representative of the actual abundance of the 1965 year class than was the aerial census.

Surface trawl and haul seine catches in 1966 both indicated that the 1966 year class of Atlantic menhaden was more abundant than the 1965, but still a poor year class. Similar data for the Gulf also indicated an improvement over 1965, but the abundance index was still considerably below that recorded for the abundant 1964 year class. In 1965 we increased considerably the number of estuaries covered by these surveys on the Atlantic coast.

The identification of menhaden eggs and larvae is vital to our proposed studies on the early development of the species in the ocean. During the past year we acquired embryos and a good series of small yellowfin menhaden larvae, obtained embryos and small larvae from cross-fertilization of yellowfin and Gulf menhaden, and obtained unfertilized and fertilized eggs from Atlantic thread herring. These materials will greatly increase our ability to identify menhaden eggs and larvae.

New laboratory studies on the tolerance of menhaden to temperature extremes disclosed that at salinities of 4.5 to 5.4 p.p.t. small juvenile menhaden die quickly when the water reaches 95° F., a temperature that is not uncommon during the summer in menhaden nursery areas along the east coast.

ANADROMOUS FISHERIES PROGRAM

Paul R. Nichols, Chief

Our research activities included: (1) continued studies on the upstream passage of anadromous fish during their spawning migration through boat locks on the Cape Fear River, N.C., (2) continued studies on the practicability of fish passage at proposed flood control impoundments on the upper St. Johns River, Fla., (3) completion of studies for a 12-year period on the passage of American shad by the Hadley Falls Dam fish lift on the Connecticut River, Mass., and on the use of the river above the dam as shad spawning and nursery habitat, and (4) completion of field studies for a 3-year period on whether the Susquehanna River in Maryland and Pennsylvania was suitable for a restoration of the runs of American shad. Also, we reviewed reports and made comments and recommendations on 10 proposed water development projects affecting anadromous fish along the Atlantic seaboard.

CAPE FEAR RIVER

Shad Fishery--1966

The estimated total commercial catch of shad in the Cape Fear River and tributaries was 61,406 pounds, a decrease of 60 percent from 1965. Of the total catch, the commercial area produced 51,586 pounds and the inland area 9,820 pounds. From the commercial area, the Cape Fear River produced 58 percent and the North East Cape Fear River 42 percent. From the inland area, the North East Cape Fear River produced 90 percent and the Black River 10 percent. The decrease in the 1966 catch was due to extremely low water during most of the fishing season and limited fishing in the lower Cape Fear River because large numbers of Atlantic menhaden made it difficult to gill net in the fishing area.

An estimated 561 shad were caught by rod-and-reel fishermen: 383 at lock 1, 51 at lock 2, and 127 at lock 3.

Experimental Lockage of Fish at Locks and Dams--1966

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, on the use of the river as nursery grounds for anadromous fish, and on the growth of young shad (fig. 1).

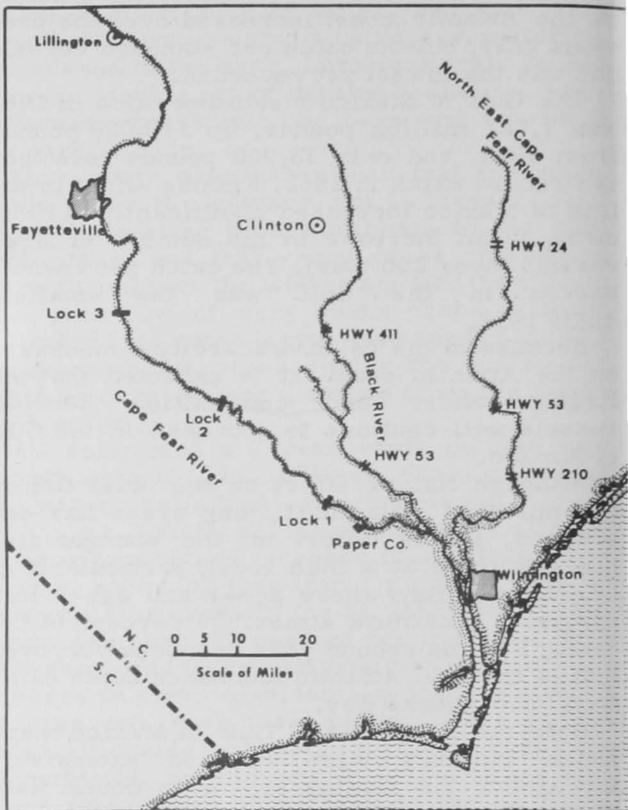

Figure 1.--Cape Fear River system - Lillington, N.C., to mouth.

To add information to that collected in 196 on the distribution and growth of young shad, we took samples of fish by the use of rotenone from August to November throughout the Cape Fear River system. Young shad were collected from river-mile 3 (32.5 miles below lock 1) to river-mile 70 (lock 2) in the Cape Fear River; from the mouth of the Black River upstream to 7 miles above Highway 53, a distance of 17 miles; and from 6 miles above the mouth of the North East Cape Fear River upstream to 5 miles above Highway 53, a distance of 30 miles. Young shad were not collected as far upstream in the Black and North East Cape Fear Rivers as in 1965.

The young shad grew well in all areas. In mid-August young shad ranged from 1.8 to 3.3 in. (average 2.4 in.) fork length in the Cape Fear River above lock 1, 2.0 to 3.3 in. (average 2.5 in.) in the Black River, and 1.7 to 3.1 in. (average 2.1 in.) in the North East Cape Fear River. In mid-August of 1964, young shad ranged from 2.1 to 3.5 in. (average 2.6 in.) in the Cape Fear River above lock 1, 1.3 to 3.1 in. (average 2.0 in.) in the Black

River, and 1.5 to 3.3 in. (average 2.0 in.) in the North East Cape Fear River.

From October 15 to 25, we observed that young shad moved downstream from above lock 1 and out of the tributaries and presumably to sea. During this interval the river had a freshet; water level in the upper pool at lock 1 increased from 16.1 to 18.2 feet and water temperature dropped from 70° to 64° F. These changes probably stimulated the young shad to move. They moved downstream at about the same time and under similar conditions as in 1964. Lock and dam 1 did not deter the young shad from moving downstream.

We examined the contents of stomachs of 739 shad, 819 blueback herring, and 68 alewives collected from July to October. Shad fed primarily on aquatic and terrestrial insects and crustaceans; insects were the dominant food. Blueback herring and alewives ate mostly crustaceans. The food of each species differed only slightly within or between rivers.

To check for possible predation on shad eggs, larvae, and young fish, we collected stomachs from 178 possible predators (longnose gar, carp, catfish, and bullhead): 52 in May and June and 126 from July to September. None had eaten shad eggs, larvae, or young.

From April 6 to May 24, we continued studies to refine our techniques for locking anadromous fish upstream during their spawning migration. On the basis of the number of fish netted in the lock chamber during periodic sampling, we estimated that 4,097 shad, 200 striped bass, and 20,296 alewives and blueback herring were passed in the 111 hours lock 1 was operated for fish passage. Exact separation of alewife and blueback herring was not attempted, but the latter dominated. Water temperature varied from 57° to 72° F., and water levels in the upper pool varied from 16.0 to 18.2 feet. The number of shad passed increased 176 percent over 1965, and the number of alewives and blueback herring passed increased 28 percent. At lock 2, 34.5 miles upstream from lock 1, an estimated 854 shad, 19 striped bass, and 11,762 alewives and blueback herring were passed in the 145 hours the lock was operated for fish passage. Water temperatures ranged from 58° to 72° F., and water levels ranged from 25.0 to 27.8 feet in the upper pool. In 1965, 92 shad, 6 striped bass, and 724 alewives and blueback herring were passed in 17 hours. At lock 3, 23.5 miles upstream from lock 2, 50 shad and 350 alewives and blueback herring were passed in 3 hours the lock was operated for fish passage (fig. 2). This was the first season lock 3 was operated for this purpose. These fish passage operations will increase the available spawning area in the river as well as make more fish available to sport fishermen in the upriver areas.

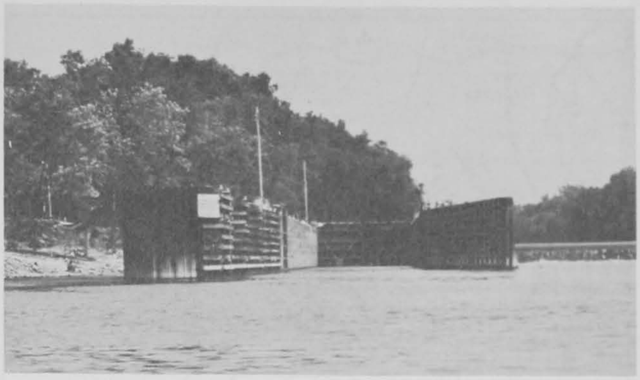

Figure 2.--Lock 3 on the Cape Fear River. N.C.

ST. JOHNS RIVER

Shad Fisheries--1966

The estimated commercial catch of shad was 587,830 pounds. Gill nets in the Mayport-Jacksonville area took 225,632 pounds, and shad nets (haul seines) in the Welaka-Palatka-Georgetown area 362,198 pounds. The commercial catch decreased about 29 percent from 1965. Data for estimating size of run were not available at the time this report was prepared.

The estimated sport catch of shad was 126,750 fish (estimated weight - 316,875 pounds) in 32,500 man-days fishing, a decrease of about 5 percent from the previous season.

The St. Johns continues to be the most productive river for shad on the Atlantic coast.

Practicability of Fish-Passage Facilities--1966

We continued cooperative studies with the Bureau of Sport Fisheries and Wildlife and the Florida Freshwater Fish and Game Commission in the upper St. Johns River to determine how the proposed Sanford-Indian River Canal and the flood control impoundments south of Lake Harney might affect the shad fisheries.

From August 10-18 we collected fish samples with rotenone from Highway 192 bridge downstream to 4 miles south of DeLand to determine if shad now used the area as nursery grounds (fig. 3). During the sampling period, water temperatures ranged from 81° to 91° F. Young shad were collected from 4 miles north of Highway 520 bridge to 4 miles south of DeLand. South of Lake Harney most shad were collected between Highway 46 bridge and Puzzle Lake (table 1). Young shad were collected about 25 miles further upstream than in previous years.

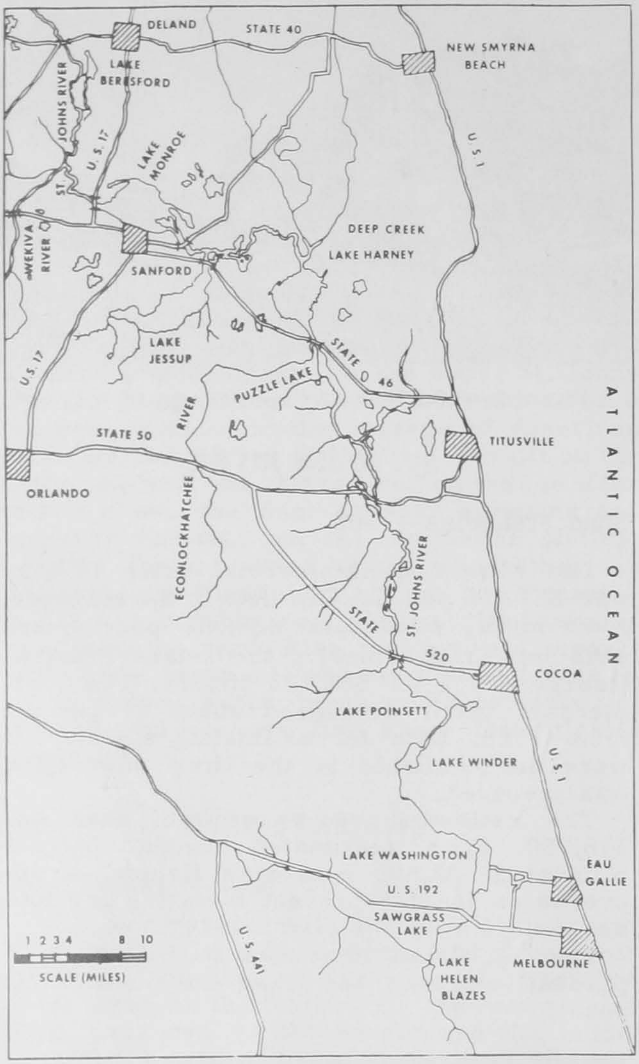

Figure 3.--St. Johns River, Fla. - DeLand to headwaters.

We sampled the Econlockhatchee River and Deep Creek March 23-26 to determine whether shad spawn in these waters. Both are outside the area that will be flooded in the proposed water development project. During the sampling period, water temperature ranged from 64° to 72° F. Shad eggs were collected at three stations in the Econlockhatchee River about 4 to 7 miles above its confluence with the main river. No eggs were collected in Deep Creek.

South of Lake Harney sport fishermen caught shad from February until the end of March. The estimated catch in this area was 7,240 shad in 1,885 man-days; 4,556 were caught in 908 man-days between Lake Harney and Highway 50 bridge, 2,634 in 920 man-days from Highway 50 to Lake Poinsett, and 50 in 27 man-days south of Lake Winder. The catch south of Lake Harney decreased about 86 percent, and the man-days of fishing decreased about 75 percent from 1965. This area produced about 6 percent of the total sport catch and accounted for about 6 percent of the total man-days of fishing, compared with 38 percent of the catch and 22 percent of the man-days in 1965.

Table 1.--Young shade collected with rotenone in upper St. Johns River, Fla., August 10-18, 1965

Sample No.	Date	Location	Water temp.	Young shad collected
			° F.	Number
1	8/10	Highway 192 - 1/2 mile south	82	0
2		Lake Washington - 1/2 mile south	84	0
3		Lake Washington	82	0
4	8/11	Lake Washington - 1 mile north	82	0
5		Lake Winder - 2 miles south	81	0
6		Lake Winder	82	0
7		Lake Winder - 2 miles north	82	0
8		Lake Poinsett - 1 mile south	82	0
9	8/12	Lake Poinsett	82	0
10		Lake Poinsett	82	0
11		Highway 520 - 4 miles north	82	1
12		Highway 520 - 10 miles north	82	0
13		Highway 50 - 6 miles south	82	1
14		Highway 50 - 1 mile south	82	0
15	8/13	Highway 50 - 3 miles north (west channel)	82	1
16		Highway 50 - 2 miles north (east channel)	84	0
17		Highway 50 - 2 miles north (west channel)	84	0
18		Highway 50 - 6 miles north (confluence of channels)	84	1
19	8/17	Highway 50 - 7 miles north	82	0
20		Puzzle Lake - south end	82	0
21		Puzzle Lake - middle	86	0
22		Between Puzzle Lake and Highway 46	88	7
23		Econlockhatchee River - 1 mile above mouth	--	4
24		Lake Harney	91	0
25	8/18	Lake Harney - 1/2 mile north	86	7
26		Lake Harney - 5 miles north	86	5
27		Lake Harney - 7 miles north	91	0
28		Lake Monroe - 4 miles south	88	1
29		Lake Jessup	90	0
30		Lake Monroe - 1 1/2 miles south	91	0
31	8/16	Lake Monroe	88	0
32		Lake Monroe - 3 miles north	84	8
33		DeLand - 4 miles south	84	5

CONNECTICUT RIVER

Operation of Hadley Falls Dam Fish Lift--1966

The Holyoke Water Power Company operated the fish lift on Hadley Falls Dam 28 days from May 24 to June 28 and recorded daily the number of fish lifted and the temperature of the water. The number of American shad passed was 16,212, a decrease of 52 percent from 1965. The marked decrease in the number passed was probably due to a late spawning season, which resulted in fewer shad reaching the South Hadley Falls Dam and limited the number of days that the fish could pass the dam. Other fish passed were 1 sturgeon, 54 alewives, 50 trout, 9 carp, 430 bass, 10 yellow perch, and 10 walleyes. Two sea lampreys were removed from the fish lift. Water temperature varied from 54° to 74° F. while the lift was operating. A peak number of 5,927 shad, or 37 percent of the total shad passed, were lifted at water temperature of 69° and 70° F. during the 3 days June 7-9 (table 2). During the lifting operations in 1965 (May 11 to June 23) the water temperature varied from 60° to 72° F.; 11,229 shad, or about 33 percent of the total shad passed, were lifted at water temperatures of 64° to 67° F. during the 4 days May 25-28. The cumulative number of shad passed (1955-66) at different water temperatures showed that peak numbers were lifted at water temperature of 66° to 71° F.

Table 2.--Shad passed by fish lift, Hadley Falls Dam, Connecticut River, Mass., 1966[1]

Date operated	Shad lifted daily	Shad lifted cumulative	8:00 a.m. water temperature	Date operated	Shad lifted daily	Shad lifted cumulative	8:00 a.m. water temperature
	Number	Number	° F.		Number	Number	° F.
May 24..	31	31	54	June 11..	661	12,288	67
26..	70	101	59	12..	98	12,386	67
27..	324	425	60	13..	416	12,802	67
31..	1,207	1,632	63	14..	587	13,389	66
June 1..	295	1,927	64	15..	962	14,351	68
2..	431	2,358	63	16..	482	14,833	69
3..	722	3,080	64	17..	372	15,205	67
4..	1,262	4,342	65	20..	238	15,443	68
5..	395	4,737	65	21..	260	15,703	70
6..	871	5,608	68	22..	214	15,917	71
7..	2,371	7,979	70	23..	127	16,044	72
8..	2,206	10,185	69	24..	110	16,154	73
9..	1,350	11,535	70	27..	42	16,196	74
10..	92	11,627	70	28..	16	16,212	74

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

Collection of Shad Eggs above Hadley Falls Dam--1966

From June 23-29, we sampled the river with 1-m. (39-inch) plankton nets from Hadley Falls Dam to Turners Falls Dam to determine the use of this 35-mile stretch of river as spawning habitat for shad. We sampled at six stations for a total of 147 net-hours. During the sampling period water temperature varied from 70° to 75° F. Shad eggs were collected from Smiths Ferry to about 2 miles below the confluence of the Connecticut and Deerfield Rivers (fig. 4). Most eggs were collected from about 3 miles below Sunderland Bridge to the spot where Whitmore Pond drains into the Connecticut River (table 3). In 1956, when the fish lift passed 7,730 shad, shad eggs were

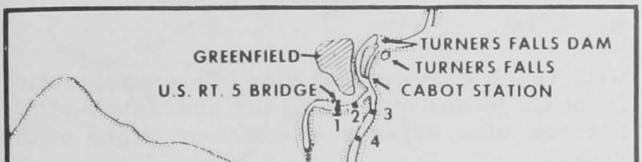

Figure 4.--Egg sampling stations, Connecticut River Holyoke to Turners Falls, Mass.

Table 3.--Shad eggs collected above Hadley Falls Dam, Connecticut and Deerfield Rivers, Mass., 1966

[Net-hour equals 1-m. (39-inch) plankton net fished for 1 hour]

River	Station number	Date	Location[1]	Sampling time	Eggs collected	Water temperature
				Net-hour	Number	° F.
Deerfield..	1	6/29	Highway 5 Bridge......	1.0	0	73
Do......	2	6/29	1/2 mile below Station 1...........	1.5	0	73
Connecticut	3	6/28	Vicinity of Deerfield River mouth.........	2.0	0	72
Do......	4	6/27	2 miles below Station 3...........	4.0	3	72
Do......	5	6/27-6/28	Vicinity of Whitmore Pond drainage.......	12.5	25	72-73
Do......	6	6/23-6/27	3 miles below Sunderland Bridge.........	39.5	32	70-72
Do......	7	6/23-6/28	Vicinity of Elwell Island..............	42.5	1	70-72
Do......	8	6/23-6/24	Vicinity of Smiths Ferry...............	46.5	1	75

[1] Locations of stations are shown in figure 4.

collected from the Oxbow to the spot where Whitmore Pond drains into the Connecticut River; most were collected near the Oxbow. We sampled two stations for 2.5 net-hours in the Deerfield River, but no shad eggs were collected.

In addition to the collection of shad eggs, observations were made below Turners Falls Dam to determine the number of shad blocked from continued upstream movement by this barrier. On June 28, we observed 25 shad in No. 1 station tailrace between the falls and Cabot Station. In 1963, when 30,052 shad were passed at Hadley Falls Dam biologist with the Massachusetts Division of Fisheries and Game observed a sizeable concentration of shad in the Cabot Station tailwaters on July 9.

Mortality of Adult Shad in the Holyoke Water Power Company Canal System--1966

On July 5, the Holyoke Water Power Company drained the canal system at Hadley Falls Dam to make annual repairs. We observed the operation to determine the number of shad stranded in the system after the drawdown was completed. An estimated 1,200 shad, or about 7 percent of the total number of fish passed by the fish lift, were counted: 200 dead and 800 stranded in the 1st-level canal, and 200 stranded in the 2d-level canal. During previous spring drawdowns that have been observed, the estimated numbers of shad observed dead or stranded in the canal system and (in parentheses) the percentage of the number of fish passed, were 420 (12) in 1955, 1,190 (15) in 1956, and 1,497 (17) in 1957.

SUSQUEHANNA RIVER

The Bureau of Commercial Fisheries, the Bureau of Sport Fisheries and Wildlife, Maryland Department of Research and Education, Pennsylvania Fish Commission, New York Conservation Department, and the four electric power companies that have dams along the

Susquehanna River have completed cooperative studies to determine if the river is suitable for restoring runs of American shad. Pennsylvania Fish Commission completed its bioassay work to determine how the eggs and larvae of shad tolerate the specific environmental factors of the river. Results of these studies are not yet available.

From October 1 to December 9, 12 young shad were collected above the Holtwood and Conowingo impoundments: 11 at Holtwood and 1 at Conowingo. They ranged from 5.8 to 6.7 in. fork length, with a mean of 6.3 in. It appears that at least some of the adult shad released above the impoundments spawned in the upper river.

From April 26 to June 16, studies of adult shad were continued to supplement information obtained in previous years on the behavior of fish released in the Conowingo impoundment after temporary confinement in holding pens (fig 5). Because of unfavorable water, few fish reached the Conowingo Dam; consequently, only four adults were collected for transplant. These fish were released in the impoundment with sonic tags attached. Signals from at least one tagged fish were received about 2,200 feet upstream from the holding pen within 24 hours after release. Eight adult shad were recaptured in the Conowingo impoundment more than 5 months after their release in the spring of 1965. Previous indications were that adult shad do not feed in fresh water; however, these fish appeared to be in good condition and evidently fed in the impoundment.

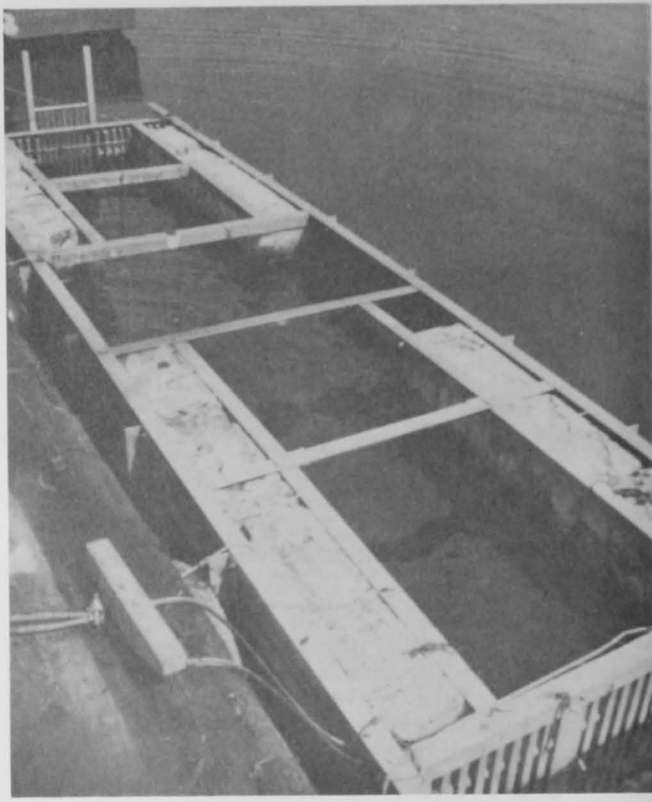

Figure 5.--Holding pen for temporary confinement of shad before release

BLUE CRAB PROGRAM

George H. Rees, Chief

The blue crab industry ranks third in value of all the seafood fisheries of the Chesapeake Bay, the South Atlantic coast, and the Gulf of Mexico. It is outranked only by the shrimp and oyster industries. During the past year work in the blue crab program has been in three general areas: abundance and distribution of juveniles, rate of growth of juveniles, and effects of environmental factors on development of the early life stages.

We are studying the abundance and distribution of juvenile crabs in Core Sound, N.C., and hope to establish a relation between the abundance of juveniles and the subsequent abundance of crabs of marketable size. If such a relation can be established, we can predict the supply of crabs that will be available to the fishery. In addition, this study is providing data on when and at what size small crabs enter the estuary, and how the sizes and sexes of these crabs are distributed within the estuary.

The studies on the St. Johns River, Fla., have provided data on the rate of growth of juvenile blue crabs that will make it possible to estimate when crabs of any particular size will reach commercial size. This information is basic to our studies of the abundance of the various size classes at different times of the year.

The survival of the early life stages of an organism is a critical factor in determining the number of individuals that will eventually reach maturity. The effects of the environment on the survival of these early stages is our third area of research. This year, in analyzing data on the megalops larva of the blue crab maintained under a variety of environmental conditions, we found that at moderate temperatures (between 68° and 86° F.) the time required for the megalops to molt to the first crab stage depends on the temperature over a fairly wide range of salinities. At a lower temperature (60° F.) the time required for metamorphosis depends on the salinity; high salinities delay development. Thus, larvae hatched in the autumn when water temperatures are dropping could remain as larvae in the ocean for an extended period and be transported long distances. This extended larval life may help explain why blue crabs are widely distributed.

ABUNDANCE AND DISTRIBUTION OF JUVENILE CRABS

Mayo H. Judy

Our present study of the blue crab resource in Core Sound, N.C., began in November 1964. This area was selected because it is small enough to be sampled intensively yet large enough to be representative of many areas that have an important production of blue crabs. The sound is about 35 miles long and averages about 2 1/2 miles wide. It connects with the ocean through Barden and Drum Inlets and opens into Pamlico Sound at its northern end and North River and Back Sound at its southern end (fig 6).

The main purpose of this study is to be able to predict the annual supply of marketable-size crabs. We propose to do this by establishing an index of abundance of juvenile crabs in various size classes in the sound, by season and by year. We will then relate this index to the catch per unit of effort in the commercial fishery, which at present is our best measure of the abundance of adult crabs. If a direct relation can be shown to exist, we should be able to predict the supply of marketable crabs from the abundance of the juveniles.

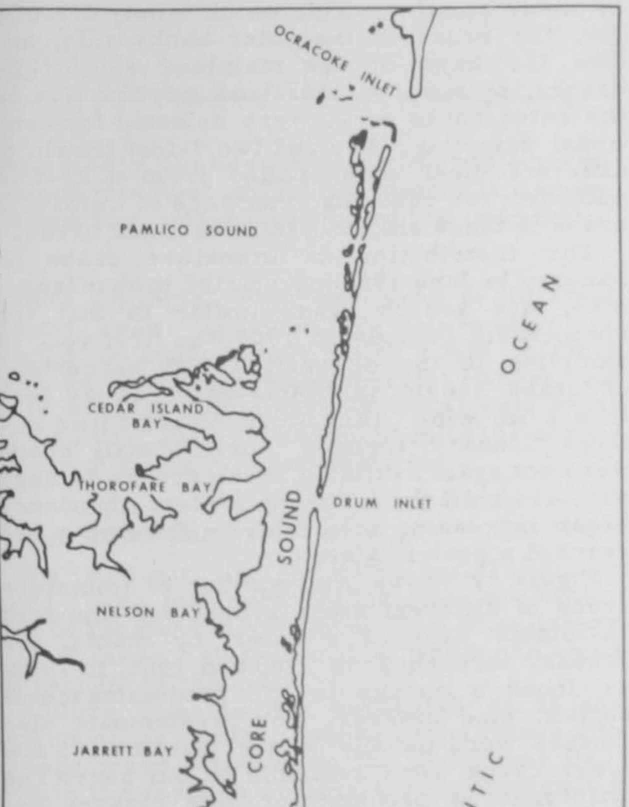

Figure 6.--Core Sound, N.C.

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

During the past 18 months, we have used three principal methods for collecting information on blue crabs: (1) trawling with our own gear, (2) taking regular samples of the commercial catch, and (3) collecting catch and effort data. We used two boats in our trawl sampling, a 26-foot trawler in the sound, bays, and inlets, and a 16-foot skiff in the small, shallow creeks.

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

Our catch of blue crabs in both the large and small nets ranged from zero to several hundred per haul. The extremes in some areas and nearly constant catches in others have directed our efforts towards finding the most effective time and place to sample. We found that blue crabs tend to congregate in certain areas within a given body of water and that their distribution is related to size, sex, sexual maturity, and season.

The Sound, Bay, and Inlet Waters

Although our prime interest when trawling was to sample the immature crabs, we also recorded data on the mature crabs collected, to check gear efficiency. Catch and effort data compiled from the commercial fishery are now the best available measure of adult abundance and this measure was the standard by which we measured the effectiveness of our trawl gear. We determined trawl efficiency by comparing our trawl catches for each month during 1965, expressed as the number of crabs per standard tow, with the commercial pot catches, expressed as pounds of crabs per pot day (fig. 7). Because the trawl catches fluctuated in much the same manner as the pot catch we concluded that the trawl was as efficient in capturing commercial size crabs as the pots. Furthermore, we assumed that the trawl was as efficient in capturing crabs of less than commercial size as it was in capturing those of commercial size, and believe that our samples are representative of the crabs available during each sampling period.

In the sound, bays, and inlets we found crabs in a wide variety of sizes; the distribution was related to the habitat and the season. We compared the number of immature and mature crabs available to our gear in the sound and bay for each month during 1965 (fig. 8). The increased catch in the bay and sound from May through September reflected the movement of immature crabs from the small, shallow, soft-bottomed creeks in the early spring. The gradual decline in numbers of immature crabs beginning in October probably was due to the maturation of many of the immature crabs. The catch of immature crabs then remained low until the following spring.

Samples taken with the 20-foot trawl in the open waters showed that immature crabs were more concentrated in the bays than in the sound during most months from May through November. Samples taken with the 9-foot trawl during warm weather in shallow, sandy, grass-bottomed areas of the sound, however, had many immature crabs. Because these shallow areas appeared to be favorable habitat for small crabs, it is highly probable that the ratio of immature to mature crabs in the bay and sound will be entirely different if we use both sizes of trawls where previously only the large trawl has been used. We need to sample more intensively in the bay and sound from May through November.

The inlet samples had about 92 percent mature females and 1 percent mature male crabs; therefore, the inlets are not very suitable for sampling immature crabs. We must sample these waters only for mature females and for larval or early crab stages, or both.

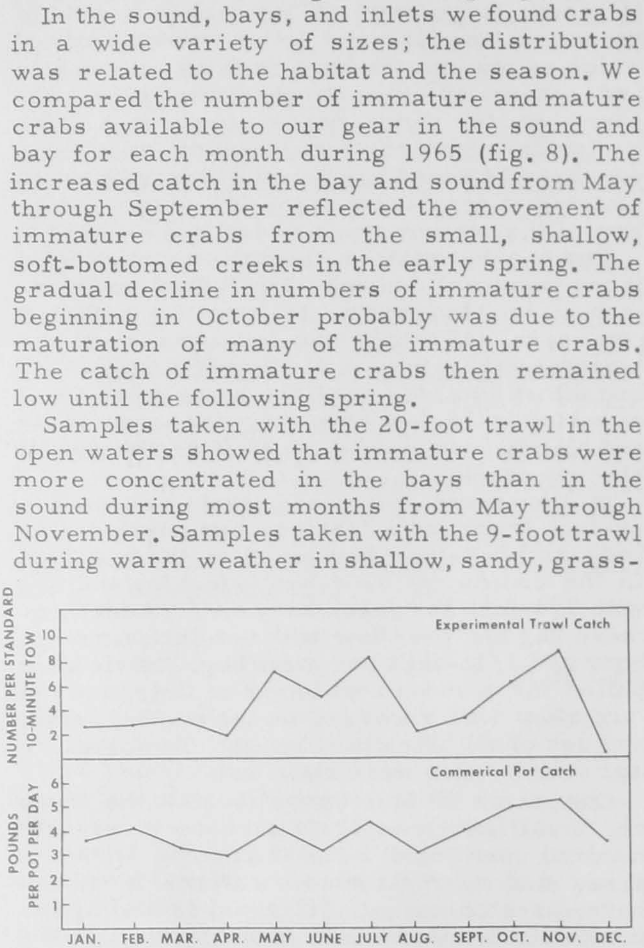

Figure 7.--Comparison of the catch of mature crabs in experimental trawls with the commercial catch in pots in Core Sound, N.C., 1965.

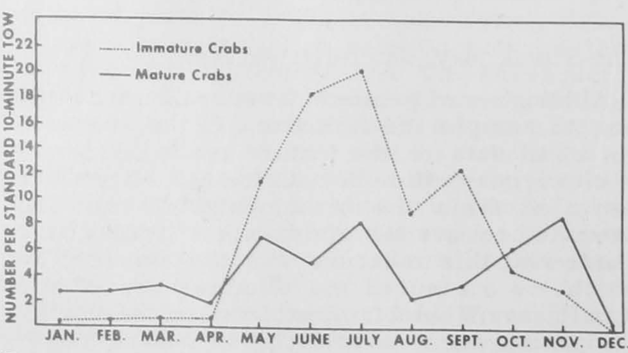

Figure 8.--Comparison of the abundance of immature and mature crabs in Core Sound, N.C., during 1965.

Creeks

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

The distribution of immature crabs in January to June 1966, as related to abundance, size, and season, was similar to that for comparable periods in 1965 (the first year of sampling in the creeks). A high percentage of crabs caught in these waters were less than 2 in. wide. They were most abundant from January through April. Small crabs were not again available in the creeks in large numbers until the following winter. Abundance began increasing noticeably in December and reached a peak in March.

Figure 9 shows the number of immature crabs of different sizes caught per standard 10-minute drag of a trawl, by month, for January through June 1965 and 1966. In 1966, we found a change in the predominance of certain size classes. The predominant size classes were usually larger than in 1965 and fewer crabs were available to our gear. The difference in predominant size classes between years might have been due to differences in the time of peak spawning, to variations in the length of time required for larval and early crab development in oceanic waters, or to a combination of these variables. We believe these size class differences from year to year indicate only natural variations.

The catch per unit of effort for both years was highest in March but decreased sharply as the weather became warmer. During this warming period the catch of immature crabs in the bays and sound increased sharply, indicating a movement of these small crabs from the creeks to more open waters.

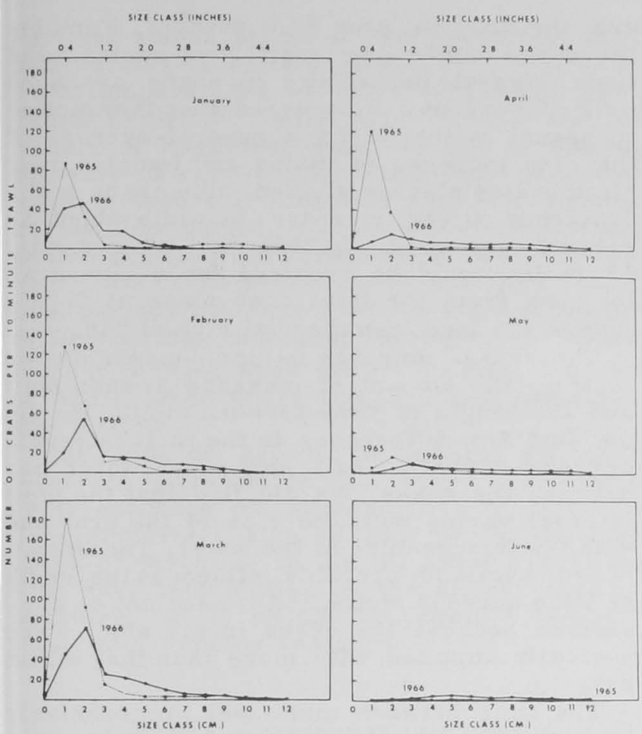

Figure 9.--The abundance of juvenile blue crabs in experimental trawl catches, Core Sound, N.C., January through June, 1965 (broken line) and 1966 (solid line).

Data collected with our gear in different habitat areas provided the information we needed to study trends which could possibly have an effect on the commercial fishery, but it is evident that many additional data must be collected before we can predict the annual supply of crabs of marketable size.

Commercial Catch

We have sampled the commercial catch in Core Sound for most months since the initiation of the study in November 1964. This fishery mainly takes mature females, which are about 90 percent of the catch.

Mature females are separated as sponge and nonsponge crabs. Sponge crabs (those with an egg mass attached to the abdominal flap) live in the sound from April through September and occasionally are found in October and early November. From April through July 1966, sponge crabs were about 42 percent of the catch. Peak spawning occurred in May and July, when sponge crabs accounted for 66 percent and 49 percent of the respective catches.

Females mate only once, but they may spawn more than once, using only a portion of the spermatozoa in the receptacles at each spawning. In commercial catch samples collected from April through July, females bearing their first sponge made up 46 percent of the catch in 1966 (43 percent in 1965), females between their first and second sponge made up 10 percent (8 percent in 1965), and those carrying their second sponge accounted for 6 percent (7 percent in 1965). Thus, the number of females spawning for the second time is either small, or females that develop beyond the first sponge are not usually available to the commercial fishermen in Core Sound.

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

The blue crab fishery in Core Sound extended over a 12-month period in 1965 and will probably cover the same period in 1966. The catch in 1965 fluctuated from month to month, with such factors as availability, price, weather, and other fisheries (mainly shrimp and oyster) affecting the blue crab fishery. The percentage of the annual blue crab catch taken in different months of 1965 ranged from a low of 3.6 percent in September to a high of 23.9 percent in November.

The blue crab catch in Core Sound during January-June was 747,761 lbs. in 1965 and 802,931 lbs. in 1966--an increase of 55,170 lbs. during the 6-month period. 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. Our average catch per unit of effort during January-June of 4.7 lbs., in 1966, and 3.6 pounds in 1965 indicated that blue crabs were more abundant during that period in 1966 than they were in 1965.

We believe that continued collection of catch and effort 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 commercial-size crabs.

GROWTH OF BLUE CRABS

Marlin E. Tagatz

We completed a 2-year study on the rate of growth of blue crabs in the St. Johns River, Fla. The crabs were maintained in individual compartments of floats anchored in the river. On alternate days, we inspected the floats, fed cut fish to the crabs, and recorded the new dimensions of the crabs that had molted. The floats held 200 crabs.

The occurrence of unusually large crabs in waters of very low salinity have suggested that crabs molting in such waters would absorb more water at the time of molt and thus increase more in size per molt than crabs molting in water of higher salinity. We tested this theory at two different locations in the river. From March 1964 to March 1965 the floats were located in the lower river where salinities ranged from 6.9 to 25.8 p.p.t. From April 1965 to April 1966 the floats were located 45 miles farther upstream where salinities were always less than 1 p.p.t.

Data from 1,372 molts in the more saline water and 1,410 molts in the fresh water did not support the theory of more increase in size per molt in fresh water. Percentage increase in size for both sexes generally was greatest in the more saline water (fig. 10). The individual percentage increase per molt varied considerably in both fresh and salt water. The smallest increase was 7.8 percent,

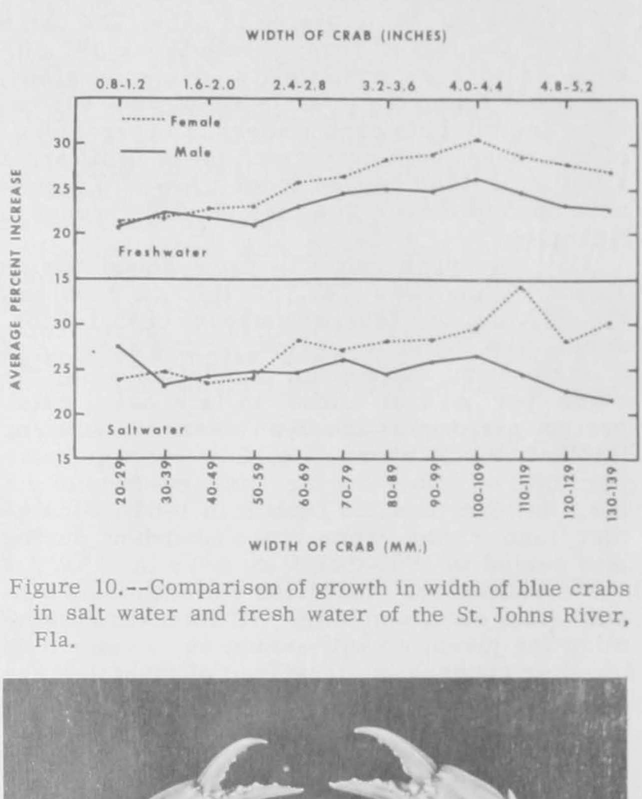

Figure 10.--Comparison of growth in width of blue crabs in salt water and fresh water of the St. Johns River, Fla.

Figure 11.--Blue crab molting. (The new shell is soft and elastic; before it hardens it will expand until it is about 25 percent larger than the old shell.)

and the largest was 50.0 percent. Females increased more per molt than males, and their largest percentage increase averaged over 30 percent and occurred when they molted to sexual maturity. As a general average of the size increase of males and females over all the size classes studied, blue crabs in the St. Johns River increase in width about 25 percent per molt. At this rate of increase, 18 molts would be required for a blue crab to grow from the first crab stage at 0.1 in. wide to the legal commercial size of 5 in.

The rate of increase in size depends on two factors, the amount of increase at each molt and the length of time between molts. We did not find any differences in the molt intervals between crabs in salt and fresh water nor between the sexes. We did find that the molt interval varies with the size of the crab and with the temperature of the water. The amount of food available probably influences the length of time between molts, but it need not be considered because the crabs in the study were normally supplied with more than they would eat.

The time between molts was progressively longer with larger crabs (table 4), so that even though the increase in size per molt remained nearly constant, the rate of increase in size in larger crabs decreased. The sizes of mesh in the floats were too small for us to keep crabs smaller than four-fifths of an inch (table 4); however, we have shown in previous laboratory experiments that crabs in the

Table 4.--Molt interval in the blue crab, by 10 mm. width groups, from April 1 to November 15, 1964 and 1965

[Salt- and fresh-water data combined]

Width		Crabs		Average molt interval (Range in parentheses)	
		Male	Female	Male	Female
Mm.	Inches	No.	No.	Days	Days
20-29	0.8-1.1	23	18...	12 (7-25)	10 (7-17)
30-39	1.2-1.5	61	77...	15 (7-34)	13 (6-27)
40-49	1.6-1.9	100	101...	17 (8-38)	18 (9-42)
50-59	2.0-2.3	101	99...	21 (9-51)	20 (9-49)
60-69	2.4-2.7	67	87...	23 (11-54)	21 (9-68)
70-79	2.8-3.1	69	51...	22 (11-64)	24 (11-59)
80-89	3.1-3.5	46	65...	28 (16-68)	26 (14-77)
90-99	3.5-3.9	52	47...	31 (20-64)	30 (17-60)
100-109	3.9-4.3	36	39...	32 (21-64)	33 (20-52)
110-119	4.3-4.7	29	38...	34 (19-53)	39 (18-61)
120-129	4.7-5.1	17	15...	43 (22-68)	43 (26-59)
130-139	5.1-5.5	13	5...	41 (27-56)	41 (35-54)

earliest stages (about 0.1 in. wide) have molt intervals as short as 2 days.

At temperatures below 60° F., which prevailed in the St. Johns River from about the middle of November until the end of March, the rate of growth decreased. Most juveniles smaller than 2 1/2 in. wide shed 2 or 3 times during this period, and we observed molting in this group at temperatures as low as 39° F. Very few crabs over 4 in. wide molted during this period, but nearly all of these large individuals that had gone through the winter without molting shed during the first 3 weeks of April, when water temperatures had risen above 60° F.

The data on growth increments and molt intervals obtained in this study will enable us to estimate the average time to maturity or commercial size of any particular size class of juveniles in the St. Johns River. We also have information on the effects of temperature, so it should be possible to apply these data to other areas.

LARVAL STUDIES OF BLUE CRAB

(Contract No. 14-17-0002-115)

John D. Costlow, Jr.
Duke University Marine Laboratory

Larvae of the blue crab were reared in water at 77° F. and 30 p.p.t. (parts per thousand) until they became megalops. The megalops were then maintained under environments that had six salinities and four temperatures in order to determine the effects of salinity, temperature, and the combined effects of salinity and temperature on survival, rate of development, and metamorphosis. Study of 505 larvae led to the following conclusions:

1. At 68° F., 77° F., and 86° F. over 70 percent of the megalops survived in salinities ranging from 10 p.p.t. to 40 p.p.t. At 59° F. survival varied from 10 percent to 50 percent in salinities ranging from 20 p.p.t. to 40 p.p.t. At 59° F., 10 p.p.t. and 68° F., 5 p.p.t., no megalops survived to metamorphosis.

2. Duration of the megalops stage varied from 5 days at 86° F. to 67 days at 59° F. Temperature was the more important factor in length of megalops life. At 68° F., 77° F., and 86° F., duration of the megalops stage was not affected by changes in salinity. At 59° F., however, an increase in salinity significantly delayed the time of metamorphosis to the first crab.

From the results of the present study we can postulate that survival and duration of the megalops stage of the blue crab in the natural environment are directly associated with the time of hatching, the time at which the megalops stage is reached in relation to seasonal changes in water temperature, and the salinity of the water in which the final zoeal molt occurs. Although some early-stage blue crab larvae may be found in waters off North Carolina for 8 months of the year, the first period of any great abundance is May when water temperatures are rising from 68° F. On the basis of the time required for development of the first seven zoeal stages, the megalops stage would be reached by about mid-June.

Of the few larvae retained within the lower salinity waters of the estuary, a large percentage would be expected to metamorphose to the first crab stage at temperature of 77° F. (in the laboratory at 77° F. and 20 p.p.t., 85 percent of the animals metamorphosed, and at 77° F. and 30 to 40 p.p.t., 100 percent metamorphosed). Larvae carried beyond the estuary to the higher salinity water of the ocean would have an even greater chance of survival to metamorphosis during the summer months. If hatching were to occur in September, when water temperatures are decreasing from 77° F., the same rate of development would result in metamorphosis during mid- to late October when water temperatures are approaching 64° F. off the coast of North Carolina. Metamorphosis of megalops in water of higher salinity would be delayed considerably by the gradual reduction in temperature, whereas those that had been carried back to the lower salinities of the estuary could metamorphose to the first crab stage. The relatively high survival of megalops at 59° F., and 35 p.p.t., accompanied by the delay in metamorphosis to the first crab stage, may have helped this species be distributed in the estuaries throughout a major portion of the Atlantic and Gulf of Mexico coasts. The extended duration of the megalops stage in colder waters of high salinity would permit the larvae to be carried relatively long distances by ocean currents. The megalops that are carried back into the estuaries could then metamorphose under conditions that favor the survival of the early crab stages.

MENHADEN PROGRAM

Joseph H. Kutkuhn

Aided by an increased budget, the Menhaden Program undertook a mark-recapture project to broaden our research on the dynamics of menhaden. On the basis of earlier trials, a numbered metallic tag, small enough to be inserted and carried harmlessly in the body cavity of a 4-inch menhaden, was selected as the standard "mark." During the new project's first year, we spent most of our effort on the development of procedures for handling and tagging young menhaden, and for recovering the tags at fish-reduction plants. This preliminary work has had encouraging results and we feel that the large-scale tagging studies, scheduled to begin in mid-1966, will increase significantly our knowledge of the Atlantic menhaden's seasonal movements, its rate of growth, and the extent of its mortality due to fishing and natural causes.

Continued surveillance of the menhaden resources in 1965 revealed no improvement in supply and production on the Atlantic coast, but a good 1964 year class and near-record landings in the Gulf of Mexico. Scarcity of fish--predicted earlier because of few juvenile menhaden in East Coast estuaries, no evidence of any strong year classes in recent years, and the generally low catch per unit of fishing effort throughout the 1965 season--plagued the Atlantic fishery for the third consecutive year. From surveys to determine the abundance of juvenile menhaden in 1966 and from data on the age composition of fish in the 1965 catch, we judged the prospects for 1966 in the Atlantic fishery to be very poor and those in the Gulf fishery to be probably not as good as for 1965.

Research on the life history and ecology of the Atlantic and Gulf menhadens proceeded at about the same rate as in the 2 previous years. We made progress on the problem of distinguishing the early growth stages of menhaden from those of the closely related herringlike fishes that reproduce in the same areas and at the same times as menhaden. Inability to identify menhaden eggs and larvae could be a real handicap in planned studies of menhaden ecology during the species' oceanic phase of development. In the process of gathering new material to resolve the problem of larval identification, we have further circumscribed when and where the important Gulf menhaden spawn, and also have determined that both the Atlantic and Gulf menhadens hybridize with other menhaden species wherever their stocks overlap during the breeding season.

Preliminary results of new laboratory work demonstrated that, with all other factors held constant, water temperatures approaching 93° F. cause considerable distress among juvenile Atlantic menhaden, and that 95° F. is lethal. Such high summer temperatures are not unusual in East Coast estuaries known to harbor young menhaden, but we must first determine if and how menhaden avoid them before we can specify temperature extremes as a probable cause of reduced survival.

CLASSIFICATION AND DISTRIBUTION OF NORTH AMERICAN MENHADEN

John W. Reintjes

The early life history of the Atlantic menhaden has been known in general terms for many years. Most of this knowledge comes from observations and deductions made by careful workers, so it is essentially correct. Unfortunately a few conclusions have been founded upon false premises, and some conclusions no longer apply because of changes in the distribution, abundance, and other features of the Atlantic menhaden resource. The uncertainty of current opinion based on other than factual information, and the lack of adequate ship facilities to properly study this matter, have handicapped somewhat our investigation of the menhaden.

Spawning of this important commercial species has never been observed, and fully ripe males or females are rarely encountered in menhaden landings. To approximate the time and place that menhaden spawn, we have used the condition of gonads in fish regularly sampled from the catch. We now believe that spawning occurs from May to October from New Jersey to Cape Cod and from October to April from New Jersey to Florida; most spawning probably occurs in the winter off the South Atlantic States.

Developing embryos and newly hatched larvae, presumed to be Atlantic menhaden, have been collected in the vicinity of Long Island and Cape Cod, off the mouth of Chesapeake Bay, and near Capes Hatteras, Lookout, and Fear. Embryos and small larvae also have been reported from Narragansett Bay and lower Chesapeake Bay, but all collection sites were near oceanic waters and within the influence of strong tidal currents. Eggs collected recently in the Patuxent River, Md., and tentatively identified as those of Atlantic menhaden, represent the first of their kind to be taken in brackish water despite many years of intensive collecting in Delaware Bay, upper Chesapeake Bay, and the sounds and bays of North Carolina.

As a result of these observations, we believe that spawning, hatching, and early larval development occur mainly in the ocean or in inshore waters with salinities similar to those of the ocean. Because the Atlantic menhaden spawns in the ocean, it follows that survival of eggs and larvae is governed in significant degree by the oceanic environment at the time of and shortly after spawning. If we are to assess the effects of the many factors that influence the distribution and abundance of Atlantic menhaden, we must be able to identify the species' eggs and larvae.

Eggs and larvae of other herringlike fishes in the family Clupeidae closely resemble those of the Atlantic menhaden. Consequently it is necessary to identify not only the early stages of the Atlantic menhaden but also those of herrings, sardines, and other species of menhaden that might be confused with them. The life history stages of the river herrings and American shad have been identified and described. Since these fishes ascend rivers to spawn and their eggs and larvae normally remain in fresh water, they offer no problem. On the other hand, the planktonic eggs and larvae of the round herring, thread herring, dwarf herring, Spanish sardine, and scaled sardine are unknown. These species are abundant along the Atlantic and Gulf of Mexico coasts, so it is reasonable to assume that to some extent they spawn and undergo early development when and where the menhaden do. Another reason for our interest in the other herringlike fishes is their potential use by the fish meal and oil industry.

We now use three procedures to identify the eggs and larvae of herringlike fishes. The preferred method is to obtain eggs and sperm from known parents, perform artificial fertilization, and produce developing embryos and larvae of known ages and species. This procedure, however, has several obstacles. Gravid adults of both sexes often cannot be obtained concurrently, artificial fertilization is not always successful, and the embryos and larvae often die before an adequate series for descriptive purposes is obtained. A second method is to obtain developing embryos or larvae from their natural habitat and rear them until they are old enough to be identified from juvenile or adult characteristics. Success in this method depends on our ability to acquire viable embryos or larvae, maintain them in a suitable environment, and provide them with adequate food. These tasks are formidable for many marine fishes, especially the herringlike species. The third method relies upon the assembly from preserved material of series of eggs and larvae that have structural affinities, and were collected within the suspected species' known geographical range just after adults with ripening gonads appeared. Some of the problems associated with this procedure are: eggs and newly hatched larvae of one species may be indistinguishable from those of another; a series may be incomplete so that identification of early stages is uncertain; and the preservative may affect the specimens in such a way that faulty conclusions are drawn.

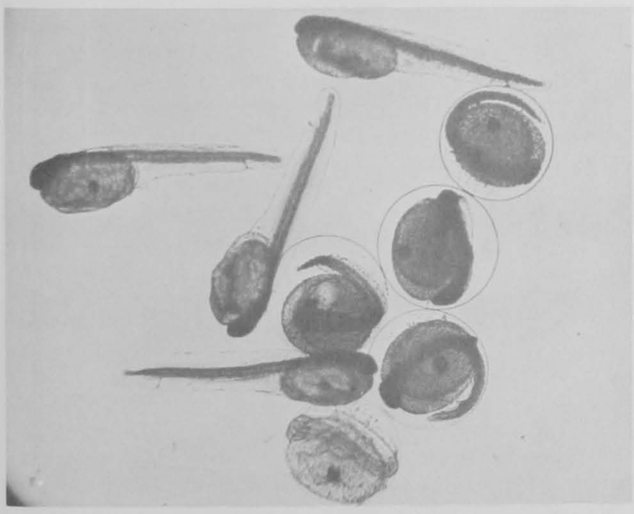

Figure 12.--Menhaden embryos and newly hatched larvae from Indian River, Fla.

To improve our ability to identify the eggs and larvae of Atlantic menhaden, we: (1) participated last winter in the exploratory fishing cruises of the Bureau of Commercial Fisheries R/V George M. Bowers along the west coast of Florida to obtain eggs and larvae for rearing studies from plankton collections and from gravid menhaden and other herringlike fishes; (2) fertilized ripe eggs with sperm from yellowfin menhaden at Indian River, Fla., in February to obtain a complete series of developing embryos and yolk-sac larvae; (3) collected gravid herringlike fishes with monofilament gill nets in the Beaufort area to obtain material for descriptive and comparative purposes; and (4) searched for clupeoid eggs and larvae in the plankton collections from the George M. Bowers cruises and from Indian River, as well as those housed at the Bureau's laboratories in Brunswick, Ga., Miami and St. Petersburg Beach, Fla., and Galveston, Tex. In the process, we acquired embryos and a good series of small larvae of yellowfin menhaden; obtained embryos and small larvae by cross-fertilizing eggs from yellowfin menhaden and sperm from the Gulf menhaden; provisionally identified embryos and larvae of the Atlantic and Gulf menhadens from plankton collections; identified postlarval finescale menhaden from collections made at Port Aransas and Arroyo Colorado, Tex.; obtained unfertilized and fertilized ova from thread herring; tentatively identified postlarvae of scaled sardine in collections from Port Aransas, Tex., and Tampa Bay, Fla.; and found eggs, larvae, and postlarvae of the bay and striped anchovies in plankton collections from the Atlantic coast.

RESPONSE OF JUVENILE MENHADEN TO TEMPERATURE AND SALINITY

Robert M. Lewis

In the spring of 1966 we began a series of laboratory experiments to determine whether high water temperatures materially affect the survival of young menhaden. Field records show that menhaden have been collected in South Carolina estuaries when the water temperature approached 97° F. Because salinity in menhaden tidal nursery areas ranges from nearly 0 p.p.t. to as high as 40 p.p.t., it was important to determine the effects of temperature under different salinity conditions. We therefore designed tests to simulate the various combinations of salinity and temperature encountered in field. In addition, we examined how acclimation time and temperature, plus the rate of temperature change, affect survival.

To be assured of an adequate supply of experimental material, we had to devise a better technique for collecting fish than used previously. As young menhaden were needed, a small pound net was set and fished overnight at Flanners Beach in nearby Croatan National Forest on the Neuse River, N.C. Some of the juvenile menhaden captured by the pound net were as small as 1 1/5 inches total length. Catches ranged from a few fish to several hundred and were always ample for experimental purposes.

The small menhaden were dipped from the pound net with a plastic bucket and poured into a small tank mounted on a truck. Care was taken to ensure that the water in the tank corresponded in temperature, salinity, and oxygen to that of the Neuse River at the time of collection. Fish were transported within 1 hour to the Laboratory where they were placed in a large acclimation tank. Few fish died enroute.

The juvenile menhaden used in the experiments described below were held in the acclimation tank for at least a week. After 3 or 4 days, mortality due to capture and handling

Figure 13.--A small pound net used to catch juvenile Atlantic menhaden.

subsided, and all surviving fish gradually became adjusted to a specific temperature and salinity. At the start of each experiment water was pumped from the acclimation tank to each of four test containers so that the experimental fish (10 in each trial) would suffer no temperature or salinity shock when introduced into the containers. The temperature gradually was increased to the various test levels at the rate of about 2° F. per hour. Compressed air bubbled through the water kept the dissolved oxygen in the experimental and control containers at about 100 percent saturation. Fish were held in these containers until 50 percent mortality occurred or at least 7 days elapsed.

Preliminary tests were run with fish acclimated at least a week to temperatures of 68° to 71° F. and salinities of 4.5 to 5.4 p.p.t. To determine at what temperature stress occurred, we performed tests at 77°, 86°, and 95° F. No significant mortality occurred at 77° or 86° F., but all fish died within a few hours after the water temperature reached 95° F.

Additional tests were run at 5 p.p.t. salinity and temperatures of 89°, 91°, and 93° F., levels commonly observed during the summer in estuarine areas known to harbor concentrations of young menhaden. No significant mortality occurred at 89° or 91° F., but in the 93° F. test, 50 percent of the fish died within 5 days.

Stress first became evident at 93° F. when the fish stopped schooling and swam so slowly that they could be touched easily with a probe. After a few days at this temperature they lost pigment and appeared whitish. By comparison, fish exposed to 95° F. were fully distressed and died within a few hours. Fish in this condition of stress swam erratically on their side with only an occasional flip of their tail. Some developed a crooked back. All finally sank to the bottom and soon died.

To determine if young menhaden have the ability to recover from heat stress, we conducted an experiment in which the water temperature was quickly raised to a high level, thereby inducing stress, and then rapidly lowered to its former level. In about 2 hours the test temperature was raised from 73° F. to 94° F. When some fish showed signs of stress at 94° F., the temperature was reduced immediately. About one-third of the fish survived after the water temperature had been lowered within an hour to 71° F.

Tests are being continued to determine the survival of juvenile menhaden at different combinations of salinity and temperature. In addition, we shall conduct experiments to check the survival of fish collected later in the summer. These fish will have been exposed to a higher temperature in their natural environment than those collected for the tests described above.

Although we have not been able to give much attention to behavior, limited observation in our other laboratory work indicated that light intensity and amount of feeding activity are major factors governing the integrity of menhaden schools. These observations will be continued in a more systematized fashion. Also, we are considering the possibility of developing experimental temperature and salinity gradients so we can determine the environment that juvenile menhaden prefer.

ABUNDANCE OF YOUNG MENHADEN

Larvae

By William F. Hettler, Jr.

In January we began regular sampling for the occurrence and abundance of larval Atlantic menhaden in entrances to local estuarine nurseries. The purpose of this project is to assess the usefulness of measures of larval abundance as indices of spawning success and year-class strength. Such indices would complement those derived from estimates of juvenile abundance and, accordingly, might yield information on the survival of each year class during its larval (oceanic) and juvenile (estuarine) phases of development.

Menhaden larvae normally occur in large numbers along the North Carolina coast from early winter until midspring. To sample them most efficiently, we needed a gear that would catch menhaden readily during daylight, that could be handled easily by one man, and that had a fixed opening so the volume of water strained could be measured with consistent accuracy.

Three types of nets were tested in the inlets and channels near Beaufort and Swansboro, N.C.

A hand-pulled beam trawl, successfully used to capture postlarval shrimp in the shallows of some inlets along the Gulf coast, was tried in the intertidal zone off the beaches of Beaufort and Bogue Inlets from mid-January until mid-March (fig. 14). This net, although very effective in catching larval Gulf menhaden incidentally when used to collect postlarval shrimp, caught only one Atlantic menhaden larva during our attempts. The clear water in the local inlets probably accounted for the poor success.

During the same period, a 1/2-meter (20-inch) plankton net towed in the inlets at about 2 knots, caught only 10 larvae in 29 tows. Several factors, including the patchy distribution of the larvae, the small volume of water strained by the net, and disturbance of the water caused by the passage of the boat, contributed to the low catches of fish of any kind.

While the catches in the beam trawl and plankton net remained poor, fixed channel nets fished at the surface from the laboratory

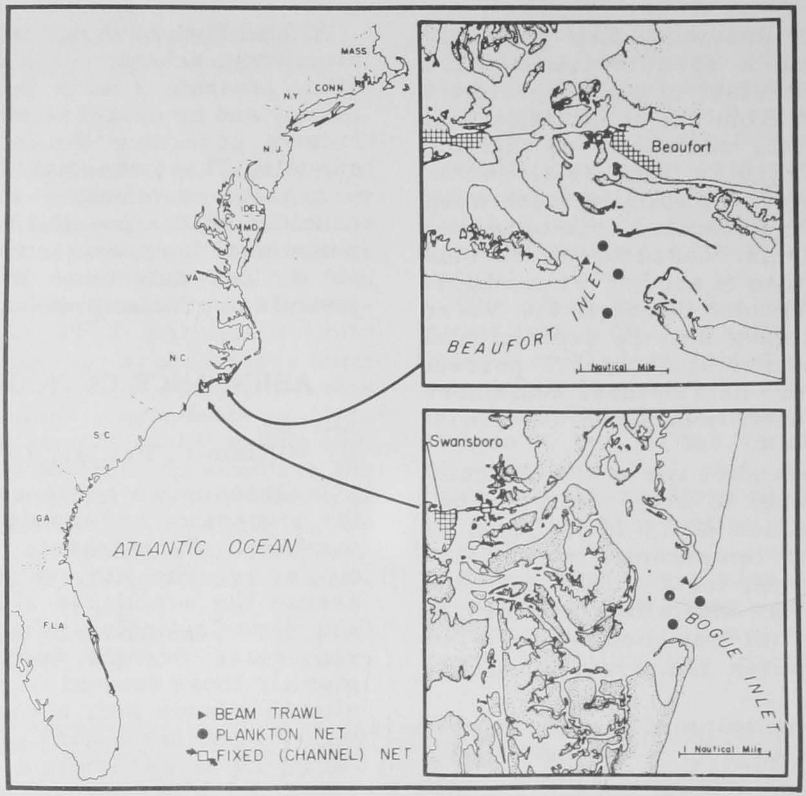

Figure 14.--The Beaufort-Swansboro, N.C. study area showing collecting sites.

bridge at Beaufort and the highway bridge at Swansboro (fig. 15) began catching large numbers of larvae. At the end of March, the use of the trawl and plankton net was discontinued, and the channel net, having undergone several modifications including the addition of a flow meter, was adopted as the standard sampling gear. We made 30-minute sets only during daylight, about 4 times a week. About 60 sets were made by the end of June. The menhaden larvae ranged in size from 4/10 to 1 1/4 inches (total length) and the mean lengths of each daily catch ranged between 3/4 and 9/10 inch. No increase in fish length was apparent during the season. Menhaden were captured at water temperatures ranging from slightly over 41° to 70° F., salinity from 25 to 36 p.p.t., and current from 2/3 to 2 feet per second. The last menhaden larvae were caught May 9.

Sampling at night on a year-round schedule is not practical so we plan to base our abundance indices on the results of daylight fishing only, assuming, until we obtain contrary evidence, that estimates of larval abundance from sampling in daylight would bear a constant relation with those from sampling after dark. It is probable that when larvae pass through the local inlets enroute to the estuaries, they exhibit diurnal differences in their vertical distribution, schooling pattern, and ability to avoid nets. This problem needs further study. Still another source of variation requiring

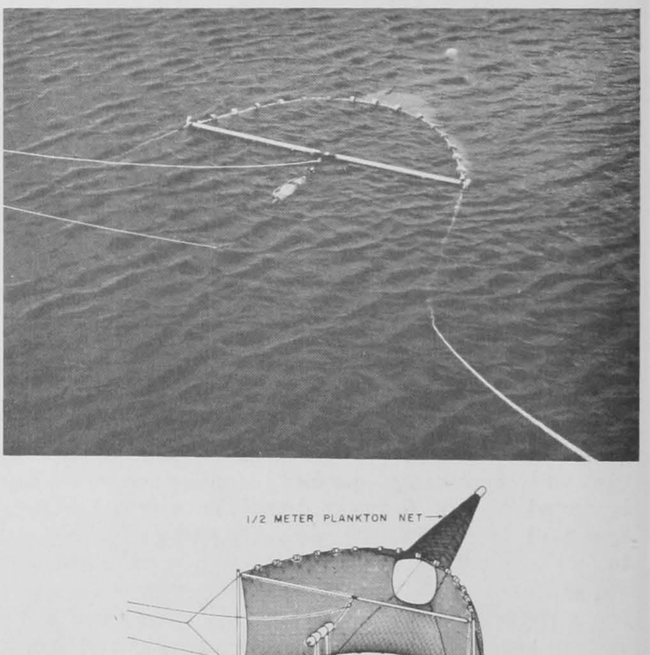

Figure 15.--Channel net in position with flow meter suspended from floats. The mouth of the net has a 20-inch diameter.

Figure 16.--Hauling aboard a surface trawl used in nursery areas to catch juvenile menhaden for determination of their abundance.

attention is the effect of current speed. A few samples collected in daylight on one occasion during the early, middle, and late stages of a tide cycle indicated that net efficiency increases with the speed of the current, probably because the net is more difficult to avoid. Differences in net efficiency during flood and ebb tides were not apparent.

Although menhaden larvae were caught in the channel net on several occasions before April 4, our failure to measure water volumes flowing through the net before that date precluded calculation of meaningful abundance indices. On March 25, for example, a 1-hour set on a late ebb tide netted an estimated 75,000 larvae. On the basis of the maximum water flow measured to date, the minimum density index in this instance would have been 686 larvae per 1,000 cubic feet of water passing through the net. It is likely that this high catch resulted from the chance capture of an unusually large concentration of larvae. Since April 4, when the flow meter was added to the net, the average indices for each week declined although individual daily catches were as high as 38 larvae per 1,000 cubic feet water:

Week beginning:	4-4	4-11	4-18	4-25	5-2	5-9
Laboratory bridge.....	14	≤1	<1	<1	<1	<1
Swansboro bridge.....	5	<1	0	0	<1	0

Juveniles

Anthony L. Pacheco

Like many commercial fishing enterprises, the menhaden fishery depends upon a resource whose magnitude characteristically fluctuates rather widely. Consequently, any knowledge of the relative success or failure of incoming year classes can be of tremendous value to the industry as it plans each season's operations. The aim of our work is to develop measures that can be used to forecast menhaden abundance and at the same time help to explain how changes in the estuarine environment govern year-class size.

Just before, or during, their first summer of life, the young of each new year class move into estuaries from oceanic spawning grounds and change from larvae into juveniles. At this period of their life history, menhaden are relatively easy to sample. Four methods of estimating their abundance (seining, trawling, marking, and aerial censusing) are used.

In 1965 we sampled in 34 tidal creeks along the Atlantic coast from northern Florida to southern Massachusetts, increasing the number of sampling areas in the South Atlantic region from 5 (in 1964) to 18 and the number in the upper Chesapeake region from 3 to 9. Aerial censusing covered the entire coast from northern Florida to Long Island. The indices we use are: (1) estimates of absolute abundance provided by mark-recapture experiments; (2) catches per 5-min. tows with two-boat surface trawls; (3) catches per standard haul in beach seines; and (4) thousands of square feet of menhaden schools sighted from aircraft (table 5).

In general, our Atlantic surveys indicated that the 1965 year class was the smallest in recent years; most of the major nursery areas had significantly fewer juvenile menhaden. Because year classes since 1958 have been relatively small and have been fished more intensively at younger ages, prospects for

Table 5.--Indices of the relative abundance of juvenile Atlantic menhaden in selected estuarine areas by method and year, 1962-65

[1962 was chosen arbitrarily as the base year]

Method and area	1962	1963	1964	1965
Mark-recapture experiments:				
Sawmill Creek, S.C.	1.00	0.57	1.61	0.26
Calabash Creek, N.C.	1	.20	--	.03
Broad Creek, N.C.	1	2.48	0.27	.10
Felgate Creek, Va.	1	1.16	.30	.24
Ball Creek, Va.	1	1.45	--	.01
White Creek, Del.	1	.82	.30	.02
Childs Creek, Mass.	1	.94	2.89	.11
Surface trawling:				
Florida to North Carolina	1	.40	0.30	.20
North Carolina (Pamlico Sound)	1	.99	5.66	1.42
Chesapeake Bay (Virginia and Delaware)	1	4.05	1.30	.12
Haul seining:				
Chesapeake Bay (Virginia and Delaware)				
Day	1	2.03	.32	.11
Night	1	2.12	.09	.06
Aerial censusing:				
South Atlantic (Charleston and Savannah)	1	.38	.01	.17
North Carolina (Albemarle and Pamlico Sounds)	1	3.27	1.86	.13
Chesapeake Bay.....				
Total	1	.88	.39	.15
Upper	1	1.28	.56	.13
Lower	1	.40	.11	.19
North Atlantic (Long Island Sound)	1	.48	.21	.25

Figure 17.--Part of a "recapture" sample of juvenile Atlantic menhaden. Two of the seven fish had been marked by clipping a portion of the tail fin at the start of a mark-recapture experiment to estimate the number of young menhaden in a tidal creek.

immediate recovery of the declining Atlantic menhaden catch are not good.

Along the Gulf coast we obtained abundance estimates by surface trawling and aerial censusing. A comparison of trawl catches from areas surveyed in 1964 and 1965 shows that fewer fish per haul were taken in 1965 (table 6). The greatest decrease in catch was in waters east of the Mississippi River Delta.

Turbidity of Gulf waters, a result of tropical storms, limited the range and general effectiveness of an aerial survey in October. A comparison of survey results for the period 1962-65 reveals (table 7) that in the eastern Gulf the quantity of fish sighted decreased in 1965 as compared with previous years in the eastern Gulf. In the western Gulf, however, more menhaden were sighted in 1965 than in 1964.

Mainly because of our greater unfamiliarity with Gulf coast estuaries in terms of their use as nurseries by young menhaden, and the generally turbid waters that reduce the value of aerial censusing, we view our survey results from the Gulf with greater reservation than we do those from the Atlantic.

Table 6.--Surface trawl catches of juvenile menhaden in Gulf of Mexico estuaries, July-August, 1964-65

[Number of hauls in parentheses]

Bayou, creek, or river	1964	1965
	Number per 5-min. haul	
West of Mississippi Delta:		
Dickinson, Tex.	4,376 (9)	553 (8)
Clear, Tex.	2,361 (8)	1,160 (9)
Johnsons, La.	7,034 (8)	992 (8)
Vermilion, La.	307 (6)	713 (9)
Shark, La.	438 (8)	29 (10)
Shaffer, La.	10 (9)	0 (9)
East of Mississippi Delta:		
Pearl, Miss.	2,419 (9)	<1 (12)
La Croix, Miss.	7,764 (6)	0 (8)
Graveline, Miss.	102 (10)	62 (6)
Magnolia, Ala.	334 (8)	9 (7)
Chico, Fla.	257 (6)	58 (5)

Table 7.--Total areas of schools of juvenile menhaden seen by aerial surveys in selected Gulf of Mexico areas, October, 1962-65

Area	1962	1963	1964	1965
	Thousands of square feet			
Eastern Gulf:				
St. Joseph Bay, Fla.	8	1	<1	2
Pensacola Bay, Fla.	38	65	73	57
Perdido Bay, Fla.	36	65	7	10
Mobile Bay, Ala.	903	215	75	35
Biloxi Bay, Miss.	17	75	25	7
Lake Pontchartrain, La.	160	113	([1])	61
Western Gulf:				
Calcasieu Lake, La.	85	13	([1])	16
Sabine Lake, Tex.	476	4	([1])	16
Gulf surf (Galveston), Tex.	14	0	0	121
Galveston Bay, Tex.	288	<1	0	119
West Bay, Tex.	163	0	0	2

[1] High turbidity.

BIOLOGY OF GULF OF MEXICO MENHADEN

William R. Turner

A major aim of the Menhaden Program is to determine the time and place of spawning by the commercially important Gulf menhaden in the Gulf of Mexico. A better understanding of this facet of its life history would improve our knowledge of this species' geographic and seasonal distribution, population structure, and movements, and of the effect of the environment on its early growth and development. Information on the density of spawning fish and on the abundance of eggs and larvae could also provide useful indices to support those now being used in comparing relative year-class strength.

During the past 2 years, laboratory personnel, in cooperation with the Bureau's Exploratory Fishing Base at Pascagoula, Miss., fished gill nets from the R/V George M. Bowers in attempts to locate winter concentrations of menhaden. These operations were centered off the Florida coast between St. Joseph Bay and Carrabelle during the winter of 1964-65, and between Tampa Bay and Cape Sable during the winter of 1965-66. Since menhadens in the

Gulf are primarily winter spawners, the Bowers' cruises afforded us an opportunity to obtain material for studies of the early life history of these fishes in the eastern Gulf of Mexico.

We obtained study material by fishing 2-5/8-inch-mesh (stretch) monofilament gill nets and by towing 1/2-meter (20-inch) plankton nets. The operations were confined within the 30-fathom contour, and most stations were at depths less than 5 fathoms. Gill net catches were examined to determine the identity, distribution, extent of gonad development, and relative abundance of menhadens and other clupeids. We also secured ripe fish and attemped artificial fertilization to obtain larvae of known identity for preparing comparative descriptions.

All told, 3,570 adult menhaden were captured during the two winters--1,817 in 1964-65 and 1,753 in 1966. The Gulf menhaden predominated in the northern area and constituted 94 percent of the menhaden catch. The yellowfin menhaden, which appeared in the catch only in December and March, made up the remaining 6 percent. In the southern area, yellowfin menhaden made up 56 percent of the catch and Gulf menhaden only 7 percent; 37 percent were menhaden with many characteristics intermediate between the two species and may possibly have been hybrids.

The thread herring was the most numerous herringlike fish in the combined catches from both areas and was followed in order of decreasing abundance by the menhadens, scaled sardine, Alabama shad, skipjack herring, and Spanish sardine. Generally, the thread herring was much more abundant in the southern area than in the northern area, whereas Alabama shad and skipjack herring were confined to the northern area. Scaled and Spanish sardines were more frequent in the southern samples. The condition of the gonads indicated that the spawning seasons of two of these species, the thread herring and scaled sardine, overlapped that of menhaden in this region. We were unable to artifically fertilize these species.

None of the menhadens taken during the 1964-65 operations were ripe, but a substantial number of ripe fish were taken in February and March 1966. The scarcity of ripe females (considerably less abundant than ripe males), however, limited the number of fertilization combinations that could be attempted. Viable eggs from one ripe female yellowfin menhaden were used in the following fertilization and cross-fertilizations: yellowfin X yellowfin; yellowfin X Gulf; and yellowfin X intermediate. All of these combinations were successful and provided developmental series of eggs and yolk-sac larvae. No larvae survived beyond the yolk-sac stage, and all apparently died of starvation. The successful cross-fertilization of yellowfin X Gulf supports the postulated occurrence of hybridization, and the success of the yellowfin X intermediate cross indicates that through backcrossing all degrees of intermediacy may be expected.

To collect menhaden eggs and larvae, we towed plankton nets at the stations where gill nets were fished. We hypothesized that the abundance and age of eggs in the collections would indicate that menhaden spawning areas were near. These samples (fig. 18) had the following number of planktonic eggs and larvae, provisionally identified as menhaden.

The frequency of eggs in the collections suggests that the peak of menhaden spawning occurred in March in the northern section of the study area off western Florida, and in February in the southern section. The warmer waters in the southern region probably accounted for the earlier spawning. Surface water temperatures were higher in February in the

Figure 18.--Sorting menhaden eggs and larvae from plankton samples.

Table 8.--The abundance of menhaden eggs and larvae from plankton samples, eastern Gulf of Mexico, 1964-66

Month	Northern section 1964-65			Southern section 1966		
	Samples	Eggs	Larvae	Samples	Eggs	Larvae
	Number	Number	Number	Number	Number	Number
December	10	2	4	--	--	--
January	13	4	5	13	74	247
February	6	0	7	11	4,373	75
March	10	30	87	11	1,855	386
April	--	--	--	9	36	26
Total	39	36	103	44	6,338	734

southern region (63° to 70° F.) than they were in March in the northern region (57° to 64° F).

Eggs and larvae were more abundant in the samples from the southern region of the study area than in those from the north. Since all of the eggs and larvae were taken relatively close to shore within the 5-fathom contour, and since yellowfin menhaden, the predominant menhaden in the southern region, is known to spawn inshore, most of the eggs are probably of that species. The scarcity of eggs in the samples from the north may reflect the small numbers of yellowfin menhaden in that region.

POPULATION DYNAMICS

CATCH SAMPLING: ATLANTIC MENHADEN FISHERY

By Stanley M. Warlen

Sampling catches of Atlantic menhaden provides essential information on the length, age, size, and sex composition of one of our largest and most important fishery resources. This information helps to describe the current status of the resource and will be used to measure population growth and assess the effects of fishing. The ultimate goal of our research is to determine the largest (average) yield that the Atlantic menhaden can sustain on a year-to-year basis.

Throughout the summer (May-October) and fall (November-December) fisheries of 1965, Bureau personnel systematically sampled commercial menhaden landings at the 16 reduction plants located from Amagansett, N.Y., to Fernandina Beach, Fla. (fig. 19). They took 985 collections of 20 fish each from purse seine landings of 301,000 tons, an average of one 20-fish sample for every 306 tons of fish landed.

Figure 19.--Fishery biologist collecting a sample of menhaden from the commercial catch.

For each fish the sampler recorded fork length, weight, sex, and stage of gonad maturity; he also took scales, mounted them between glass microslides, and sent them to the laboratory for age determination.

Fishing vessel captains and pilots cooperate by keeping daily records of their fishing in logbooks that we provide and help maintain. These records give us information on the location and number of purse seine sets for use in computing fishing effort by area. Plant managers and owners also cooperate by providing us with working space and information on vessel and plant operations.

Our sampling data showed that the age composition of Atlantic menhaden landings remained essentially unchanged in 1965 as compared with 1964 in the South Atlantic area, but revealed a greater percentage contribution of younger fish in 1965 in areas north of Cape Hatteras (table 9). The significance of these observations is discussed in another section.

A recurring problem when aging Atlantic menhaden from their scales is the proper interpretation of the first ring, particularly for fish caught in the North Carolina fall fishery. The size of Atlantic menhaden at formation of the first annulus apparently has varied considerably along the Atlantic coast. The difficulty in accurately aging fish of the 5 1/2-inch modal group led us to suspect the validity of the first ring as an annulus on the scales of these fish. Fish of this size (5 1/2 inches) from fall fishery samples in former years were usually classed as age-0 fish.

In an attempt to resolve the problem of age determination for these fish, we began regular collecting in the Neuse River, N.C., in May 1966 to obtain a series of young menhaden from the time they entered the river as larvae to the time they returned to sea as advanced juveniles or subadults. From this material we hope to determine for these local fish the time of year and general size of fish when the first annulus is completed, and to gain information on the growth of menhaden before they enter the fishery. Collecting gear includes: surface trawl, large-mesh plankton net, haul seine, gill net, and pound net.

Table 9.--Age composition of Atlantic menhaden samples, 1964-65

Port of landing	Year	Sample size	Age in years									
			0	1	2	3	4	5	6	7	8	9-10
		Number	Percent									
Amagansett, N.Y........	1964	1,793	--	--	5	23	20	25	4	4	<1	<1
	1965	1,782	--	--	12	53	18	8	6	3	<1	--
Port Monmouth, N.J.....	1964	2,054	--	<1	29	41	13	7	7	1	<1	--
	1965	1,941	--	<1	33	55	10	1	<1	1	<1	--
Lewes, Del.............	1964	728	--	13	60	25	2	--	--	--	--	--
	1965	2,720	--	33	43	21	2	<1	--	--	--	--
Reedville, Va..........	1964	3,216	20	30	45	5	<1	--	<1	--	--	--
	1965	5,991	8	70	17	5	<1	<1	<1	--	--	--
Beaufort, N.C.	1964	576	--	56	40	4	--	--	--	--	--	--
	1965	819	<1	47	48	5	--	--	--	--	--	--
Southport, N.C.........	1964	238	<1	80	17	3	--	--	--	--	--	--
	1965	373	--	39	53	8	--	--	--	--	--	--
Fernandina Beach, Fla..	1964	177	--	77	23	<1	--	--	--	--	--	--
	1965	4,172	--	66	33	1	--	--	--	--	--	--
North Carolina ports... (fall fishery)	1964	1,554	23	14	45	15	2	<1	<1	<1	--	--
	1965*	1,514	10	62	22	6	<1	--	--	--	--	--
Totals...............	1964	10,336	10	19	34	18	6	6	5	1	<1	<1
	1965	19,312	3	48	28	16	3	1	<1	<1	<1	--

*Preliminary.

CATCH SAMPLING: GULF MENHADEN FISHERY

By Robert B. Chapoton

In 1965 we systematically sampled the catch of Gulf of Mexico menhaden for the second consecutive year. The sampling techniques are designed to provide detailed information on the length, weight, sex, and age composition of the fished stocks, as well as statistics on fishing locations and daily landings. These data are being used to follow trends in menhaden supply and will serve to answer important questions regarding optimum fishing rates and the best age or size at which the harvesting of each new year class should begin.

Biological material and fishery statistics were obtained throughout the 1965 fishing season at six ports of landing, namely, Moss Point, Miss.; Empire, Morgan City, Dulac, Intracoastal City, and Cameron, La.; and Sabine Pass, Tex. The entire catch of menhaden from the Gulf of Mexico was landed at these ports in 1965, and, as in 1964, sampling was carried out by four strategically placed observers.

The scale method of aging Gulf menhaden remains to be thoroughly appraised, but we provisionally have assigned ages to all fish sampled in 1965. Scales from 15,382 Gulf menhaden were examined for year marks, and those from only 116 fish, or less than 1 percent, could not be interpreted. The age composition of the samples from the different locations in 1964 and 1965 is shown in table 10.

Although we have only two years' information for comparison, moderate changes in the age composition, especially in the contribution to the catch of 1- and 2-year-old fish, occurred in 1965. One-year-old fish contributed a higher percentage of the catch in 1965 than in 1964. In both years, 3-year-old fish were represented about equally in the catch, and fish in their 1st, 5th, 6th, and 7th year of life constituted a minor part of the catch. The greater frequency of 1-year-old fish in the 1965 landings suggests that the 1964 year class was more abundant as 1-year-old fish than the 1963 year class. If this is true, we would expect the average catch of 2-year-old fish in 1966 to exceed that of 2-year-old fish in 1965. Our samples revealed that most fish reach a fork length of at least 3 1/2 inches by the end of their first year. Fish less than 1 year old (young-of-the-year) are caught occasionally in September and October near the close of the fishing season, whereas age-1 and older fish are caught throughout the fishing season. Age-1 fish average about 5 1/2 inches, age-2 fish about 6 1/4 inches, age-3 fish about 7 inches, age-4 fish about 8 inches, and age-5 fish about 8 3/4 inches.

Table 10.--Age composition of Gulf menhaden samples, 1964-65

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

To facilitate interpretation of markings on the scales of juvenile Gulf menhaden, we examined monthly collections obtained several years ago in the Galveston, Tex., area by personnel of the Bureau of Commercial Fisheries Biological Laboratory at Galveston. The range in fork length of young-of-the-year Gulf menhaden was 1 1/8 to 2 1/8 inches (average 1 1/2 inches) in April and 2 5/8 to 4 3/8 inches (average 3 1/4 inches) in December. These observations suggest a growth rate of about 2/10 inch per month for Gulf menhaden during this period. No annuli were evident on the scales.

ANALYSIS OF 1965 MENHADEN FISHERY STATISTICS

By William R. Nicholson

Atlantic Fishery

The 1965 Atlantic menhaden catch, although slightly better than 1964, still was one of the poorest in recent years--fish were reported to be scarce in all areas. In the Middle and North Atlantic areas the number of active reduction plants decreased from six in 1964 to four in 1965, and one plant operated only a few weeks at the beginning of the season. The number of vessels landing at the three remaining plants was about one-half the number that fished in 1962-64. In the Chesapeake Bay area five plants again operated and the number of vessels remained about the same. The number of plants operating in the South Atlantic area increased by one with the reopening of a plant in Florida. Five plants again operated in the North Carolina fall fishery, but more vessels participated than in 1964.

Fishing effort, measured by the number of standard vessel days fished, remained high in the Chesapeake Bay area at about the 1963 and 1964 levels. In the Middle and North Atlantic areas it increased over the 1964 levels but remained well below the levels of previous years. Changes in fishing effort were not significant in other areas. The chief reasons for the high fishing effort in Chesapeake Bay during the past 3 years have been the addition of larger vessels and the extension of fishing into late November.

The catch per unit of fishing effort, when compared to the 10-year mean (1953-62), had the greatest decline in the Chesapeake Bay, Middle Atlantic, and North Atlantic areas. The catch per-standard-vessel day in the Chesapeake Bay, Middle Atlantic, and North Atlantic areas was 47, 33, and 23 tons, respectively, compared with the 10-year means of 84, 91, and 87 tons. These small catches per-unit-of-effort undoubtedly signify the low abundance of Atlantic menhaden in 1965.

The total Atlantic purse seine catch of 301,000 tons was the second smallest since 1944 and was only 38 percent of the record catch of 785,000 tons landed in 1956. Despite the high fishing intensity, the catch in the Chesapeake Bay area was about 9,000 tons less than in 1964. An increase in production from 39,000 to 50,500 tons in the Middle Atlantic area was at least partially due to the greater fishing effort in this area during 1965. Reduction of the catch in the North Atlantic area from 18,500 to 13,000 tons, the smallest catch since 1943, was very likely due to a scarcity of fish. The decrease in production from 51,000 to 40,500 tons in the South Atlantic area may be attributed to normal fluctuation in supply. Increased fishing effort over that in 1964 was primarily responsible for the increase from 43,000 to 58,500 tons in the North Carolina fall fishery.

In comparison with other year classes since 1958, the 1964 year class appeared relatively strong. As age-0 fish, an estimated 240 million were landed late in the 1964 season in Chesapeake Bay. As age-1 fish in 1965, this year class accounted for about 70 percent of the number of fish landed in the Chesapeake Bay area, 60 percent in the North Carolina fall fishery, 20 percent in the Middle Atlantic area, and 50 percent in the South Atlantic area. The estimated number of age-1 fish landed in the Chesapeake Bay area was about 467 million, the largest since 1959. Fishing effort in Chesapeake Bay in 1965 was much greater, however, than in any year up to 1962. In the North Carolina fall fishery, a record number of age-1 fish, about 170 million, were landed in 1965.

The menhaden fleets fished in about the same areas as in previous years. As in 1964, few fish were reported north of Cape Cod.

Two of the most significant trends in recent years have been the increase in the relative numbers of younger fish in the total catch and the decrease in the total number of fish landed. Increased fishing effort in Chesapeake Bay, where age-1 and -2 fish normally constitute almost 90 percent of the catch, and decreased fishing effort in the Middle and North Atlantic areas, where older fish normally are caught, accounted for much of the difference in age composition. In 1965, about 98 percent of the total number of fish caught were fish 0 to 3 years old. No fish older than age-4 were detected in catch samples from the North Carolina fall fishery. The trend in total number of fish caught has been downward since 1960. In 1965 the number of fish caught was about 50 percent of the number caught in 1960.

Despite the relatively good showing of the 1964 year class, the prospect for increased catches in 1966 is poor. This prediction is based on the following observations: The 1964 year class was fished heavily at ages 0 and 1; the immediately preceding year classes were poor and will contribute little to the 1966 fishery; and the incoming 1965 year class appears to be poor. On the basis of the landings through June of 1966, which were unusually poor in all major areas, the 1966 catch probably will be even poorer than we expected.

Gulf of Mexico Fishery

Continued expansion in regard to vessels, plants, and equipment marked the 1965 Gulf menhaden fishery. Eighty-five vessels, 7 more than in 1964, fished from plants in Mississippi, Louisiana, and Texas. The number of vessels of over 200 net tons increased from 28 to 40, and those of less than 200 net tons decreased from 50 to 45. All of the 85 vessels had fish pumps, 79 had power blocks, and 57 were refrigerated. Spotting planes increased from 28 to 34. Two new plants operated in 1965, increasing the total to 13. The net effect of these changes was greater fishing pressure on stocks of Gulf menhaden.

The purse seine catch of 511,000 tons was 59,000 tons larger than the 1964 catch and was only 19,000 tons less than the record high catch in 1962. The largest increase was in Louisiana, where two new plants operated. Hurricane Betsy, which struck the Mississippi Delta in early September, caused such severe damage that several plants did not reopen. Others operated at reduced capacity or were closed for several days. Fishing generally was poor immediately after the hurricane.

The mean catch per vessel-season was 5,000 tons for vessels less than 200 net tons and 7,400 tons for vessels greater than 200 net tons. For both vessel groups these figures were the smallest since 1958 and represented a decline for the fourth consecutive year. Although many vessels in 1965 fished 3 to 4 weeks less than usual because of the hurricane, catches during this period normally are smaller than they are earlier in the season.

Sampling data indicate that age-1 and -2 fish constitute the bulk of the catch each year and that age composition changes little from east to west across the Gulf. In 1964 age-1 and -2 fish accounted for over 90 percent of the catch and were present in about equal numbers. In 1965 age-1 fish predominated.

The continued decline in catch per vessel-season, paralleling an increase in fishing effort, suggests that all available stocks of Gulf menhaden are being fully harvested. Under these circumstances, greater fishing effort can be expected to increase the competition among vessels and result in decreased catches per vessel.

The Gulf menhaden fishery is dependent primarily on age-1 and -2 fish; therefore, failure of a single year class could cause a sharp decline in abundance and a decrease in the catch. The 1964 year class, as age-1 fish in the 1965 catch, appeared fairly abundant and should also contribute substantial numbers of age-2 fish to the 1966 catch. The success of the 1966 fishery will depend largely on the size of the 1965 year class. Through the first 3 months of the 1966 season the catch, containing a goodly number of age-2 fish as expected, was relatively poor in most areas, and fishermen reported menhaden to be generally less abundant than during the same period in 1964. Whether this apparent scarcity can be attributed to a poor 1965 year class or unavailability of fish because of unusually poor weather is not known at this time.

MARK-RECAPTURE EXPERIMENTS

By Robert L. Dryfoos

The purpose of this research is to broaden our knowledge of the movements, population structure, growth, and mortality of the Atlantic menhaden. This study will augment information being obtained through continuing analysis of fishery statistics. Only through direct methods such as mark-recapture experiments can the importance of specific nursery areas, seasonal migration routes, and "subpopulation" interchange positively be determined. Furthermore, knowledge of the distribution and structure of the subpopulations is essential to the proper interpretation of growth and mortality information obtained from these experiments. Information provided by this study will help us understand the causes of observed fluctuations in menhaden abundance.

The nature and lifespan of menhaden necessitate a long-term tagging study. Because menhaden are distributed along a major portion of the Atlantic coast our tagging and recovery operations must extend from New York to Florida.

Methods of Marking

Metal body-cavity tags have proved practical in large-scale tagging studies with other herringlike fishes. We believe this type of tag is least likely to influence fish behavior, is more durable, and is easier to recover than other types. Preliminary work at the Bureau's Biological Laboratory in Beaufort indicated that a tag 0.16 inch by 0.12 inch by 0.01 inch could be used in yearling and larger menhaden. These tags can be inserted easily with a special injector (fig. 20). The tag makes its own incision and is pushed forward into the body cavity by the tag behind it in the machine. Once a tag is inserted properly, the wound heals in 2 or 3 weeks, after which shedding of the tag is unlikely.

During the past year we have tried various tagging procedures to determine which one results in lowest mortality and shedding. Our aim was to find a procedure that could be used in the field to tag large numbers of fish. We found that the anesthetic MS222 in a dilution of 1:26,000 calmed the fish within 5 minutes and was not harmful to fish left in the solution for several hours. This dilution has been used under a wide range of temperature conditions with generally consistent results. Fish recover from the effects of MS222 in less than 10 minutes after they are put in untreated water, and we have noted no significant mortality attributable to the anesthetic. An antibiotic and a germicide that were tested as preventives of delayed mortality due to infection proved useless. Not only was infection not a serious problem, but the rate of healing was decreased by the agents and increased shedding of tags resulted. Several types of incisions and techniques for inserting the tags also were compared. Forward insertion of the tag into the body cavity just above and behind the pelvic fin was found to be the most satisfactory. The use of the injector was more consistent, faster, and safer than the use of scalpel and forceps. Our laboratory experiments indicate that fish in relatively good condition can be tagged with a combined loss of about 10 percent due to shedding of tags and deaths of fish from handling.

Tag-Recovery Methods

Over 90 percent of the Atlantic menhaden catch is processed in 20 operating plants between New York and Florida. The tags can be recovered from these menhaden reduction plants by means of permanent magnets strategically located in the flow of dried fish scrap through each plant. Such magnets, which are regularly serviced, will recover a high percentage of the tags entering the reduction plants. This type of equipment is being installed in all menhaden plants on the Atlantic coast.

During the past year we tested several types of permanent magnets for tag recovery. We tried two-pole and four-pole plate magnets, magnetic humps, and stationary and rotating magnetic grates. Where space does not prohibit their use, rotating grates appear to be more effective than stationary grates and magnetic humps, which clog too easily. Plate magnets can be used in restricted areas but are not as efficient as the rotating grates. The most desirable site for magnetic recovery is immediately after the drier and before the fish scrap is stored in the scrap shed. Magnets in this location are referred to as primary magnets, and they "search" all scrap, usually within 24 hours after the fish from which the scrap is produced enter the plant.

In some plants it is possible to recover tags from the last stage before the product is shipped as fish scrap or meal. Recovery at this stage results in serious time delays, however, because the scrap may be stored for varying periods of a few days to several months before shipment. Consequently, we concentrated on developing the most effective primary magnets. We evaluated tag losses and delays in the plants by tagging fish on the vessel before unloading and in the raw box while awaiting processing. We also placed tags in the dried fish scrap before it reached our magnets. Of the tags from the fish recoverd on the primary magnets, about 95 percent had entered the plant within the preceding week. In most tests loss of tags in the plant machinery did not appear to be signifi-

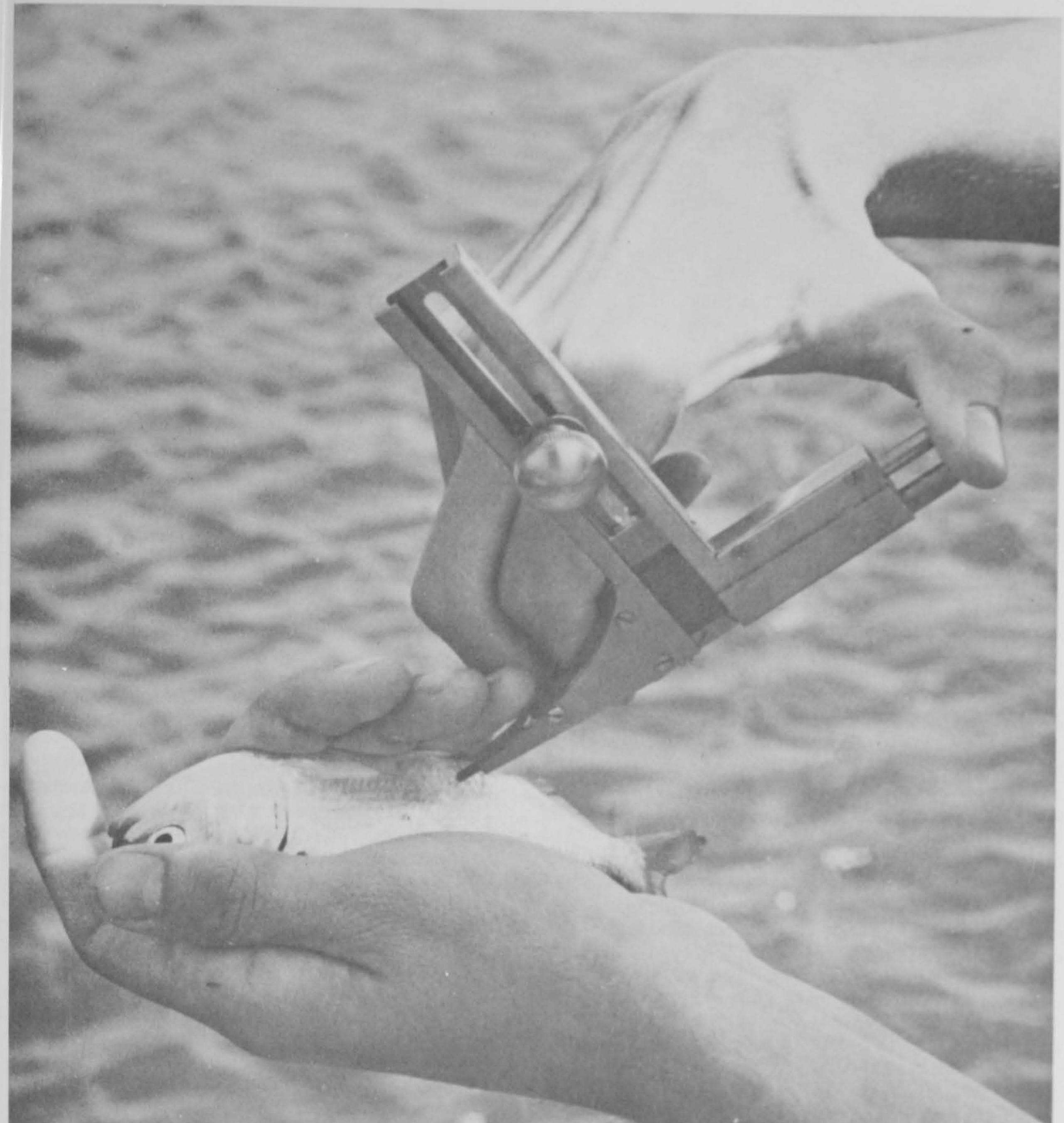

Figure 20.--Tag being inserted in fish's body cavity.

cant. Total recovery of tags placed in fish as they were being unloaded has exceeded 75 percent at five of the nine plants now outfitted with recovery equipment. Recovery rates of over 80 percent should be possible at all plants when suitable equipment is installed.

At present all plants operating in the South Atlantic area (North Carolina to Florida) are equipped with magnets, and improvements are planned. Installation of recovery equipment in the Chesapeake Bay and Middle Atlantic areas will begin soon.

Figure 21.--Tagging crew preparing to mark and release young Atlantic menhaden in Bogue Sound, N.C.

LIBRARY

Anna F. Hall

During 1965, 332 books and bound volumes of periodicals were added to the library. Seven new journals were subscribed to, bringing our total subscriptions to 67. One hundred eighty six items were received on interlibrary loan, and 7 were loaned. Cataloged reprints acquired by the library occupy about 6 additional feet of file drawers. Back issues and missing volumes of several journals were added to fill in gaps in the collection. About 100 feet of additional shelving was added to accommodate the increase in materials being received.

All materials received are cataloged and classified according to the Library of Congress Classification system, with the exception of reprints. These are assigned subject headings, and filed by accession number in fil drawers.

A list of serials available at this laborator the Duke University Marine Laboratory, an the University of North Carolina Institute Fisheries Research was revised by the librar ian and reissued. This list is prepared in format similar to the Union List of Serial and shows the holdings of each library. Thi year's list was expanded to double the previou size. It is planned to revise this list every years to incorporate the new acquisitions o the three libraries.

Preparation of the weekly list of acquisition was continued for distribution to the staff an other laboratories.

STAFF

Kenneth A. Henry, Director

ANADROMOUS FISHERIES PROGRAM

Paul R. Nichols, Chief, Beaufort, N.C.
Frank T. Carlson, Fishery Biologist, New Cumberland, Pa.
Randall P. Cheek, Fishery Biologist, Beaufort
Spencer R. Murphy, Biological Aid (temporary), Conowingo, Md.
Grady W. Phillips, Biological Aid (temporary), Beaufort
Annette E. McCoubrey, Summer Aid, 1966, Beaufort

BLUE CRAB PROGRAM (Beaufort)

George H. Rees, Chief
Donnie L. Dudley, Fishery Biologist
Mayo H. Judy, Fishery Biologist
Marlin E. Tagatz, Fishery Biologist--transferred from Green Cove Springs, Fla., fiel station 5-23-66
Ralph W. Laughinghouse, Biological Aid (temporary)
Nina I. J. Marks, Summer Aid, 1965

MENHADEN PROGRAM (Beaufort*)

oseph H. Kutkuhn, Chief & Asst. Laboratory Director
obert B. Chapoton, Fishery Biologist
illiam D. B. Davies, Fishery Biologist
obert L. Dryfoos, Fishery Biologist
harles P. Goodwin, Fishery Biologist
illiam F. Hettler, Jr., Fishery Biologist
obert M. Lewis, Fishery Biologist
illiam R. Nicholson, Fishery Biologist
nthony L. Pacheco, Fishery Biologist
aul J. Pristas, Fishery Biologist
ohn W. Reintjes, Fishery Biologist
illiam R. Turner, Fishery Biologist
anley M. Warlen, Fishery Biologist
alter C. Mann, Biological Technician
harles T. Arthur, Biological Aid
arvey M. Adams, Biological Aid
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ey D. Graham, Biological Aid
ames F. Guthrie, Biological Technician
alter P. House, Fishery Aid--Terminated 8-27-65
eorge N. Johnson, Biological Technician
ary K. Hancock, Clerk
obert F. Mackin, Biological Aid (temporary), Moss Point, Miss.
llie C. Haggans, Summer Aid, 1965
ohn L. Hatcher, Summer Aid, 1965
enneth D. Kimball, Summer Aid, 1965
eil S. Arnet, Summer Aid, 1966
homas J. Bower, Summer Aid, 1966 Morgan City, La.
inda C. Coston, Summer Aid, 1966
awrence W. Dudley, Jr., Summer Aid, 1966, Fernandina Beach, Fla.
obert G. Gould, Summer Aid, 1966, Port Monmouth, N.J.
ohn L. Hatcher, Summer Aid, 1966
teven N. Jackson, Summer Aid, 1966
bbott P. Klimley, Summer Aid, 1966, Lewes, Del.
Robert C. Milliken, Summer Aid, 1966, Amagansett, N.Y.
Gary B. Smith, Summer Aid, 1966, Cameron, La.
Leon G. Thomas, Summer Aid, Empire, La.
William D. Vermilye, Summer Aid, Reedville, Va.

STAFF SERVICES (Beaufort)

Kenneth J. Fischler, Fishery Biologist
Rita J. Fortna, Clerk-Stenographer--resigned 5-27-66
Anna F. Hall, Librarian
Mary E. Horne, Clerk-Typist
Irene D. Huff, Clerk-Typist--transferred 1-14-66
David C. Newberry, Writer-Editor
Inez J. Nierling, Clerk-Stenographer

ADMINISTRATION AND MAINTENANCE (Beaufort)

Bernard G. Allred, Administration Officer
Thelma P. Nelson, Administrative Assistant
Margaret M. Lynch, Clerk-Typist
Claude R. Guthrie, Foreman
Thomas R. Owens, Maintenanceman
Jack S. Russell, Maintenanceman
Willie S. Rainey, Mechanic Helper-Automotive
Clarence M. Roberts, Vessel Operator-Engineer
Glenshaw Henry, Sr., Caretaker--transferred 9-17-65
Jack D. Lewis, Caretaker--resigned 10-4-65
Richard L. Jones, Summer Trainee, 1965
Stephen R. Mason, Jr., Summer Trainee, 1965
Mott Hester, Summer Trainee, 1966
Burke L. Jackson, Summer Trainee, 1966

MEETINGS AND TRAINING PROGRAMS

(attendance shown in parentheses)

MEETINGS

merican Statistical Association, Philadelphia, Pa. (1)
ulf and Caribbean Fisheries Institute and International Conference on Tropical Oceanography, Miami Beach, Fla. (1)
Atlantic and Gulf States Marine Fisheries Commission, Miami, Fla. (1)
Southern Division of the American Fisheries Society, Tulsa, Okla. (1)
National Fish Meal and Oil Association, Norfolk, Va. (1)
Northeast Division American Fisheries Society, Boston, Mass. (2)
Symposium on Estuarine Ecology, Raleigh, N.C. (1)

*Except as noted.

WORK CONFERENCES

Atlantic Estuarine Research Society, Hampton, Va. (4)
Menhaden Industry, Washington, D.C. (2)
Society for Exploration of Atlantic Shelf (SEAS), Washington, D.C. (1)
Atlantic Estuarine Research Society, Morehead City, N.C. (15)

TRAINING PROGRAMS

Several governmental training programs were attended by various members of the staff. A number of films on safety were shown at the laboratory.

PUBLICATIONS

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1965. Observation on tag loss and comparative mortality in striped bass. Chesapeake Sci. 6(3): 197-198.

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1965. Annual report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C., for the fiscal year ending June 30, 1965. U.S. Fish Wildl. Serv., Circ. 240, iv 39 p.

FISCHLER, KENNETH J.
1965. The use of catch-effort, catch-sampling, and tagging data to estimate a population of blue crabs. Trans. Amer. Fish. Soc. 94(4): 287-310.

HENRY, KENNETH A., EDWIN B. JOSEPH, CHARLES M. BEARDEN, and JOHN W. REINTJES.
1965. Atlantic menhaden. Atl. States Mar. Fish. Comm., Leaflet 2, 4 p.

JUNE, FRED C.
1965. Comparison of vertebral counts of Atlantic menhaden. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 513, iii + 12 p.

LEWIS, ROBERT M.
1965. The effect of minimum temperature on the survival of larval Atlantic menhaden, Brevoortia tyrannus. Trans. Amer. Fish. Soc. 94(4): 409-412.

NICHOLS, PAUL R.
1966. Comparative study of juvenile American shad populations by fin ray and scute counts. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish 525, iii + 10 p.

NICHOLSON, WILLIAM R., and JOSEPH R. HIGHAM, JR.
1965. Age and size composition of the menhaden catch along the Atlantic coast of the United States, 1961, with a brief review of the commercial fishery. U.S. Fish Wildl., Serv. Spec. Sci. Rep. Fish. 495, iv + 28 p.
1966. Age and size composition of the menhaden catch along the Atlantic coast of the United States, 1962, with a brief review of the commercial fishery. U.S. Fish Wildl. Serv., Spec. Sci. Rep. Fish. 527, iv + 24 p.

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