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

For the Fiscal Year Ending June 30, 1968

UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. FISH AND WILDLIFE SERVICE

BUREAU OF COMMERCIAL FISHERIES

Circular 341

UNITED STATES DEPARTMENT OF THE INTERIOR
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U.S. FISH AND WILDLIFE SERVICE
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Report of the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C.

For the Fiscal Year Ending June 30, 1968

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ABSTRACT

Results of biological research in the blue crab and menhaden programs are discussed. Major topics include abundance, distribution, and survival of blue crab and menhaden larvae, juveniles, and adults; results of menhaden tagging studies; and details of the 1967 menhaden fishery. Other activities of the laboratory staff, and publications for fiscal year 1968, are listed.

INTRODUCTION BY THE LABORATORY DIRECTOR

Research at this laboratory is directed toward the blue crab (Callinectes sapidus) and the Atlantic and Gulf of Mexico menhadens (Brevoortia spp.) Because of decreased funds for research on blue crabs, the laboratory expects that this program will be phased out within the next year. In our menhaden studies we principally want to describe and examine the main features of the life history, define the causes of fluctuations in abundance, and determine the level of optimum utilization.

We have not been able to expand our early life history studies of menhaden materially, although we believe this area of research is very important in understanding the biology of menhaden and possible causes of fluctuations in abundance. This work requires a suitable vessel for systematic ocean surveys of the spawning areas.

Blue Crab

Studies were continued in Core Sound, N.C., to establish a relation between the abundance of juvenile blue crabs and the subsequent abundance of marketable-size crabs. For the fourth year in succession, young blue crabs did not appear in Core Sound in significant numbers until about 6 months after spawning started and after they had gone through several postlarval molts. Unfortunately, our index of juvenile abundance was not proportional to the commercial catch per unit of effort; we must reevaluate our methods and data.

Since blue crabs, depending on their sex and stage of sexual development, prefer certain areas of the estuary, we made laboratory studies of their blood osmoconcentrations. The differential distribution of crabs could not be explained by differences in their osmoregulatory abilities.

Laboratory studies also were undertaken to provide estimates of the upper and lower lethal thermal limits for blue crabs. Acclimation time clearly affected survival; as acclimation time increased, survival time increased. Also, adult female and juvenile blue crabs were less tolerant to temperature extremes at low than at high salinity; and as acclimation temperature increased the upper and lower tolerance limits increased.

Menhaden

The 1967 catch of Atlantic menhaden (Brevoortia tyrannus), 427 million pounds, was the smallest since 1942; the catch has declined 64 percent since 1962 and in 1967 was 12 percent below the 1966 landings. Two of the reduction plants that had operated in 1966 did not open for the 1967 season. Total fishing effort declined from the previous year but remained at near record levels in Chesapeake Bay. Catch per unit of fishing effort increased in the South Atlantic, Middle Atlantic, and North Atlantic areas, but decreased in Chesapeake Bay and the North Carolina fall fishery.

The 1967 catch of Gulf menhaden (Brevoortia patronus) in the Gulf of Mexico was 719 million pounds, 12 percent below the 1966 landings and 34 percent below the record catch in 1962. The unadjusted catch per vessel week was the second lowest in 9 years. Vessel week is our present measure of fishing effort in the Gulf. We are trying, however, to develop a unit of effort based on vessel-ton-day that we believe will be a better measure.

Very few young-of-the-year (age 0) Atlantic menhaden were caught in 1967. Age-3 fish were predominant in the Middle Atlantic fishery, age-1 fish in Florida, and age-1 and age-2 fish about equally abundant in the remaining areas. Fish over 3 years of age continued to be very scarce.

The R/V Dolphin from the Bureau of Sport Fisheries and Wildlife laboratory at Sandy Hook, N.J. made a series of cruises along the Atlantic coast in 1965-66. Their samples indicated that menhaden larvae were more abundant from September through February than during the other times of the year.

We also examined samples collected in 1963 by the R/V Gus III from the Bureau's Biological Laboratory in Galveston, Tex. These samples indicated that the spawning season in the northern and western Gulf of Mexico extended from mid-October through March. Egg collections indicated that Gulf menhaden spawned over the Continental Shelf between Sabine Pass, Tex. and Alabama, and were restricted to waters between the 4- and 40-fathom contours, at least off Texas and Louisiana. Spawning was concentrated near the Mississippi Delta, but the seaward margin east of the Delta could not be determined because no samples were taken beyond the 40-fathom contour.

Data from our studies of the abundance of juvenile menhaden indicated that the 1966 year class would be better than 1965, but still poor. This view was subsequently verified by the poor landings in 1967. Indices developed for the 1967 year class indicate that it will be the poorest since the surveys began in 1962 on the Atlantic. It will also be very poor in the Gulf--only slightly better than the 1965 year class.

Since we started tagging Atlantic menhaden in 1966, over 650,000 have been tagged and almost 10 percent of them have been recovered. Tag recoveries are confirming the general hypothesis that Atlantic menhaden move northward in the spring and southward in the fall. Fish tagged in Florida have been recovered the following year as far north as New Jersey.

SURVIVAL REQUIREMENTS OF JUVENILE AND ADULT BLUE CRABS

Marlin E. Tagatz

To survive the varying salinities to which it is exposed, the blue crab must actively absorb ions to replace those lost by outward diffusion and excretion. The differential distribution of crabs within an estuary, both by sex and stage of sexual development, might be explained by differences in their ability to regulate their internal salinities in different environments. For any salinity, the concentration of dissolved salts in the blood (osmoconcentration) would be higher in crabs preferring that environment than in crabs usually found in waters of other salinities. To explore this possibility, a vapor pressure osmometer was used to determine the osmotic concentration of the blood of adult males and immature-, mature-, and ovigerous-females for various combinations of salinity (5, 50, 100 percent sea water) and temperature (50°, 68°, 86° F.). Ten crabs were acclimated for 24 hours at each selected combination of salinity and temperature.

In general differences in the physiological capabilities between the sexes or among stages of development of female crabs could not explain differential distribution (table 1). An analysis of variance showed no significant difference in osmoconcentration in each salinity at 86° F. Differences were significant at 50° and 68° F., but they were not consistent with the preferred salinities of the crabs in nature. Some were due to particularly low osmoconcentrations in ovigerous females. The osmoregulatory ability of ovigerous females in dilute salinities was obviously impaired at low temperature. When the regulative abilities of adult males and mature females were compared, the only significant difference between sexes was in 5 percent sea water at 50° F.

In another series of experiments, adult female blue crabs and juveniles of both sexes (1.6 - 2.4 inches wide) were exposed to selected water temperatures to determine the upper and lower limits of their thermal tolerance. Studies were made in 20 and 100 percent sea water to uncover any effect of salinity on these limits. For each of four acclimation temperatures (43°, 57°, 72°, or 86° F.), the 48-hour median tolerance limit (temperature at which 50 percent survived for 48 hours) was estimated by graphical interpolation of data for temperatures that killed more than one-half and less than one-half of the animals. Each experiment had 10 crabs.

Previous experiments revealed that blue crabs required a longer acclimation time (21 days) than the few days generally reported for fish. Tests of adult females at both low and high temperatures (32°, 100°, or 102° F.) showed that acclimation time affected survival; as the acclimation time (3, 7, 14, or 21 days) increased, survival time increased.

Adult female and juvenile blue crabs were less tolerant to temperature extremes at the lower salinity, and as the acclimation temperature increased the upper and lower tolerance limits increased (table 2). The thermal limits for adult females and juveniles generally were similar (within 1° F.).

Table 1.--Total blood osmoconcentrations of various categories of blue crabs in different salinities and at different temperatures

[Each mean represents 10 animals.]

Sea water, crab category, and F[1]	Osmoconcentration					
	50° F.		68° F.		86° F.	
	Mean	Range	Mean	Range	Mean	Range
Percent	Osmoles/liter		Osmoles/liter		Osmoles/liter	
100						
Immature females	0.95	0.88-1.00	0.99	0.92-1.04	1.06	0.99-1.18
Mature females	1.04	0.98-1.08	1.01	0.98-1.06	1.06	1.00-1.12
Ovigerous females	0.98	0.93-1.03	1.07	1.02-1.13	1.06	1.02-1.14
Adult males	1.06	1.00-1.12	1.02	0.99-1.08	1.05	1.02-1.10
F	**21.19	--	**11.62	--	0.11 N.S.	--
50						
Immature females	0.85	0.81-0.88	0.78	0.72-0.83	0.80	0.79-0.83
Mature females	0.90	0.86-0.95	0.84	0.80-0.90	0.82	0.76-0.84
Ovigerous females	0.73	0.64-0.82	0.79	0.73-0.84	0.80	0.73-0.86
Adult males	0.88	0.82-0.96	0.83	0.82-0.86	0.81	0.72-0.85
F	**42.28	--	**8.66	--	0.55 N.S.	--
5						
Immature females	0.65	0.55-0.73	0.63	0.55-0.71	0.63	0.56-0.69
Mature females	0.58	0.51-0.64	0.65	0.61-0.73	0.58	0.50-0.70
Ovigerous females	0.49	0.42-0.56	0.58	0.47-0.73	0.55	0.46-0.75
Adult males	0.68	0.60-0.76	0.65	0.56-0.71	0.59	0.49-0.65
F	**25.27	--	*2.92	--	2.52 N.S.	--

[1]Analysis of variance: * significant at 5 percent level, ** significant at 1 percent level, N.S. nonsignificant.

Table 2.--Estimated thermal tolerance limits of adult female and juvenile (1.6-2.4 inches wide) blue crabs in relation to salinity and preceding acclimation temperature

Sea water	Acclimation temperature	Estimated 48-hr. median tolerance limits			
		Adult females		Juveniles	
		Upper	Lower	Upper	Lower
Percent	° F.	° F.	° F.	° F.	° F.
100	86	101.7	40.3	102.2	40.8
100	72	98.4	[1] 36.3	102.2	[1] 36.9
100	57	94.5	32.0	95.5	32.0
100	43	91.6	[1] 32.0	91.4	[1] 32.0
20	86	98.6	42.8	99.0	41.5
20	72	98.4	37.2	98.6	37.2
20	57	94.1	32.4	95.0	33.3
20	43	88.7	[1] 32.0	88.5	32.4

[1]32° F. was the lowest temperature tested.

ABUNDANCE AND DISTRIBUTION OF JUVENILE BLUE CRABS

Donnie L. Dudley

We began a study in November 1964 to determine the relative abundance of juvenile blue crabs in Core Sound, N.C. The primary aim was to find the relation of juvenile abundance to the subsequent abundance of adults; we hoped to establish a basis for reasonable predictions of the annual supply of commercial size crabs.

Core Sound was selected because it is small enough to be sampled intensively, yet large enough to be representative of the types of habitats that are important to the production of blue crabs. The sound is about 35 miles long and averages 2-1/2 miles wide. It connects with the ocean through Barden and Drum Inlets and has Pamlico Sound at its northern end and Back Sound at its southern end (fig. 1). The sound proper generally has a hard sandy bottom with only a few areas of soft mud, whereas

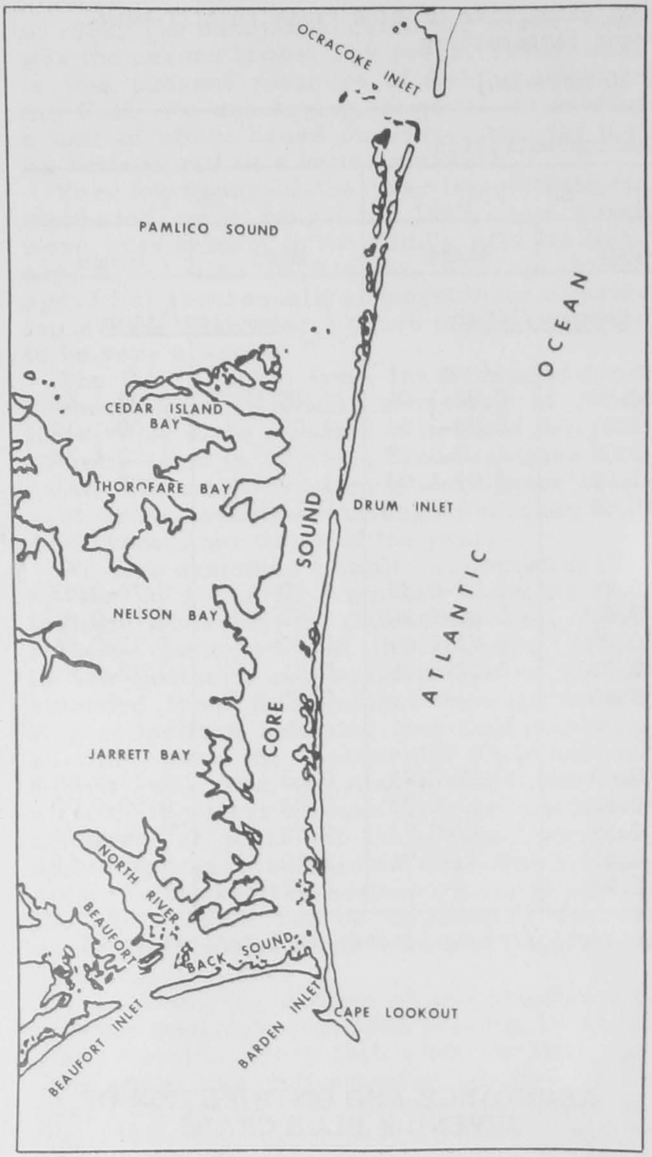

Figure 1.--Blue crab study area in Core Sound, N.C.

the marshes that border the sound have soft muddy bottoms. The study area contains four general habitats: (1) the sound proper; (2) the inlets; (3) the bays (on the mainland side of the sound); and (4) the many small marsh creeks that empty directly into the bays on the mainland side and into the sound on the outer banks side.

We have used three principal methods for collecting information on blue crabs: (1) trawling with our own gear; (2) taking systematic samples from the commercial pot fishery; and (3) collecting catch and effort data from the commercial fishery.

In the sound, bays, and inlets, we used a 20-foot otter trawl with 7/8-inch bar mesh in the body and 5/8-inch bar mesh in the cod end. In the creeks we used two 9-foot otter trawls, one with 7/8-inch bar mesh in the body and 1/4-inch bar mesh for the cod end, and the other with 1/4-inch bar mesh for the body and 1/16-inch bar mesh for the cod end. Both 9-foot nets were pulled at each sampling station. Trawl hauls were pulled for a measured length of time, and the number, size, and sex of all blue crabs caught were recorded together with the temperature and salinity of the water.

We collected samples in the sound, bay, and inlet waters with a 20-foot otter trawl in 1965 and 1966. The samples contained mostly mature crabs. Only a few juveniles were taken in the bays during the summer. We felt that the numbers captured were not sufficient for estimating the abundance of the juvenile population. Because our prime interest was to sample immature crabs (information on commercial-size crabs could be obtained from catch and effort records from the commercial pot fishermen), we discontinued sampling these waters.

Our trawl samples in the sound showed that the catch of mature crabs fluctuates in about the same manner as the catch per unit of effort in the pot fishery for the same time periods. The findings for our 20-foot trawl work were previously reported in the Annual Reports for 1966 (U.S. Fish Wildl. Serv. Serv., Circ. 264) and 1967 (U.S. Fish Wildl. Serv., Circ. 287).

Juveniles were abundant in the many small creeks that drain marshlands bordering Core Sound. These creeks empty directly into the sound on the outer banks side and into the bays on the mainland side. Nine creeks, four on the mainland and five on the outer banks, were selected for systematic quantitative sampling.

We began to sample these creeks for immature crabs on a regular basis in January 1965. We were interested in their distribution by season, abundance, and size. Our catch per minute by month and year has been similar during the 3-1/2 years of study.

Crabs caught in these creeks are mostly less than 2 inches wide and are most numerous from December through March. A reduction during late spring and summer signals the end of recruitment of the young-of-the-year crabs.

Juvenile abundance during different spawning seasons was compared for the time period from June through May, the approximate start of one year's spawning to the start of spawning the following year. Comparable data may be reviewed from the Bureau of Commercial Fisheries Annual Report, Biological Laboratory, Beaufort, N.C., for the fiscal years ending June 30, 1966 and June 30, 1967. Our catch per minute was about the same for all years studied.

Comparison of catch per minute in June 1966 to May 1967 with June 1967 to May 1968 (fig. 2) indicated, as in previous years, that the influx of juveniles increased rapidly during November and their numbers reached a peak during March. During the winter of 1968, February catches of juveniles dropped to our lowest production indices. This low yield was attributed to behavior caused by lower water temperatures rather than a slump in production.

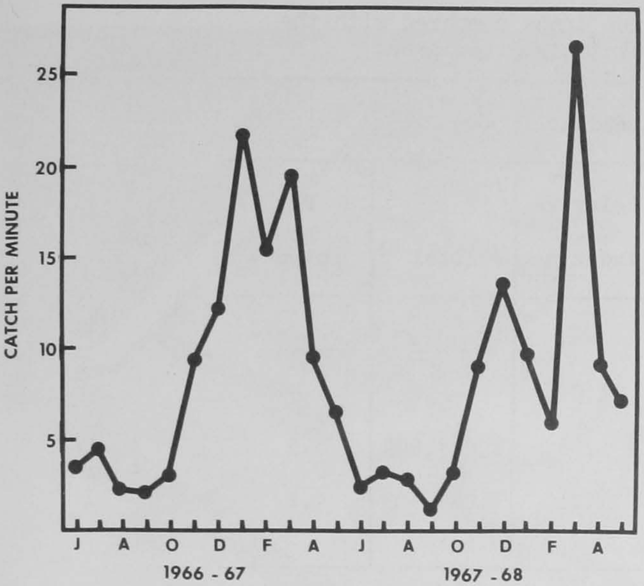

Figure 2.--Catch of immature crabs per minute in creeks of Core Sound, N.C., June 1966 to May 1968.

During extreme cold (water temperatures below 43° F.), small crabs burrow in the substrate and are not caught by our trawl gear. Temperatures during January and February 1968 were below the average of previous years. During February 1968, the average water temperature was 41° F. as opposed to February readings of 56° F., 55° F., and 53° F. during 1965, 1966, and 1967, respectively.

The relative abundance of juvenile crabs on a catch-per-minute basis from 1965 through 1968 and the average monthly temperatures are tabulated in table 3. Generally, the monthly abundance of juvenile blue crabs varied among the 3-1/2 years studied.

Hatching of blue crab larvae begins in June and continues through October. The larvae metamorphose in the ocean (or very near, in high salinity waters) and begin to make their way back to the estuaries in late fall, where they seek favorable bottom and hydrographic conditions.

Since juvenile crabs are relatively abundant in the marsh creeks of Core Sound, the catch data for the creeks should provide a reliable criterion for establishing an index of juvenile abundance for the Core Sound area. Any changes in the abundance of juveniles in these waters could then be examined in relation to subsequent change that might occur in the commercial fishery.

Table 3.--Mean number of juvenile crabs caught per-minute of trawling in nine marsh creeks and monthly average temperatures

Month	1965		1966		1967		1968	
	No.	°F.	No.	°F.	No.	°F.	No.	°F.
Jan. ---	15.6	55	14.0	47	21.9	53	9.8	46
Feb. ---	24.1	56	15.7	55	15.3	53	5.9	41
Mar. ---	31.4	55	21.4	60	19.3	62	26.7	54
Apr. ---	17.4	66	9.0	65	9.6	70	9.7	64
May ---	4.2	70	5.2	72	6.7	69	7.2	72
June ---	.6	80	3.6	74	2.4	82	3.2	81
July ---	--	--	4.6	85	3.3	81	--	--
Aug. ---	1.9	84	2.3	85	3.0	82	--	--
Sept.---	1.3	83	2.1	79	1.4	75	--	--
Oct. ---	1.5	65	3.0	69	3.2	70	--	--
Nov. ---	3.9	57	9.4	58	9.2	54	--	--
Dec. ---	7.1	46	12.1	49	13.8	54	--	--

Table 4.--Catch of juvenile blue crabs compared with the commercial catch of marketable sized crabs[1]

Time	Catch of juveniles		Commercial catch	
	Catch per minute	Relative index no.	Total	Per pot-day
	Number		Pounds	Pounds
June 1965 - May 1966	81.6	1.0	-	-
June 1966 - May 1967	109.9	1.35	1,617,605	5.5
June 1967 - May 1968	98.8	1.21	2,057,523	4.2

[1]Young crabs first occur in numbers in June and enter the fishery about 1 year later.

We have collected catch and effort statistics for the Core Sound commercial fishery since November 1964. Data on number of boats used in crabbing (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 are recorded for each month. The fishery extends over the entire year, but major landings are made during spring and late fall.

The abundance (catch per minute) of juvenile blue crabs is compared with the commercial catch of blue crabs 1 year later in table 4. A 35-percent increase in the catch of juveniles per minute for June 1966 through May 1967 is not reflected in the catch per unit of effort in the commercial fishery 1 year later (pounds per pot-day decreased 24 percent). The total catch in pounds, however, did increase about 27 percent. We will be in better position to evaluate the reliability of our methods and data as they relate to Core Sound after collecting catch and effort records of the commercial fishery for another year. On the basis of our relative index of juvenile abundance in 1967-68 and assuming that fishing effort remains about the same, we can project a figure of 1,844,000 pounds as an estimate of the catch of blue crabs in Core Sound in 1968-69.

MENHADEN TAGGING

Robert L. Dryfoos
Randall P. Cheek

Mark-recapture experiments with Atlantic menhaden were designed to answer questions about population structure, movements, growth, and survival. They were begun in the vicinity of Beaufort, N.C., during the summer and fall of 1966, when nearly 97,000 menhaden were each tagged with a numbered, internal, ferromagnetic tag. In 1967 the tagging and tag-recovery program was expanded to encompass the range of the commercial fishery, from New York to Florida. Since the program's start, over 650,000 menhaden have been tagged and released along the Atlantic coast, and tags have been recovered at every menhaden plant. Recovery of most tags is accomplished when the fish are reduced to meal, from which magnets remove the tags and "tramp" iron (ferrous contamination) before the meal is used in animal feeds (fig. 3). At one plant whole tagged fish can be recovered by an electronic detector system (fig. 4). Nearly 63,000 tags or almost 10 percent of the tags released have been recovered. Although detailed analysis of our tagging data awaits the return of additional tags, some preliminary results can be described.

Population structure

In the Annual Report for 1962 (U.S. Fish Wildl. Serv., Circ. 184) Reintjes has suggested that a natural subdivision of the menhaden population exists in the Atlantic south of Cape Hatteras. Thus far, the results from tagging have not resolved this question but they cast some doubt on the existence of more than one stock. Few tagged fish released off Georgia and Florida in 1967 were recaptured north of there in 1967. This spring, however, four of every five tagged fish recaptured from last year's releases in Georgia and Florida have been recovered in North Carolina, Virginia, and New Jersey. It is still possible that a

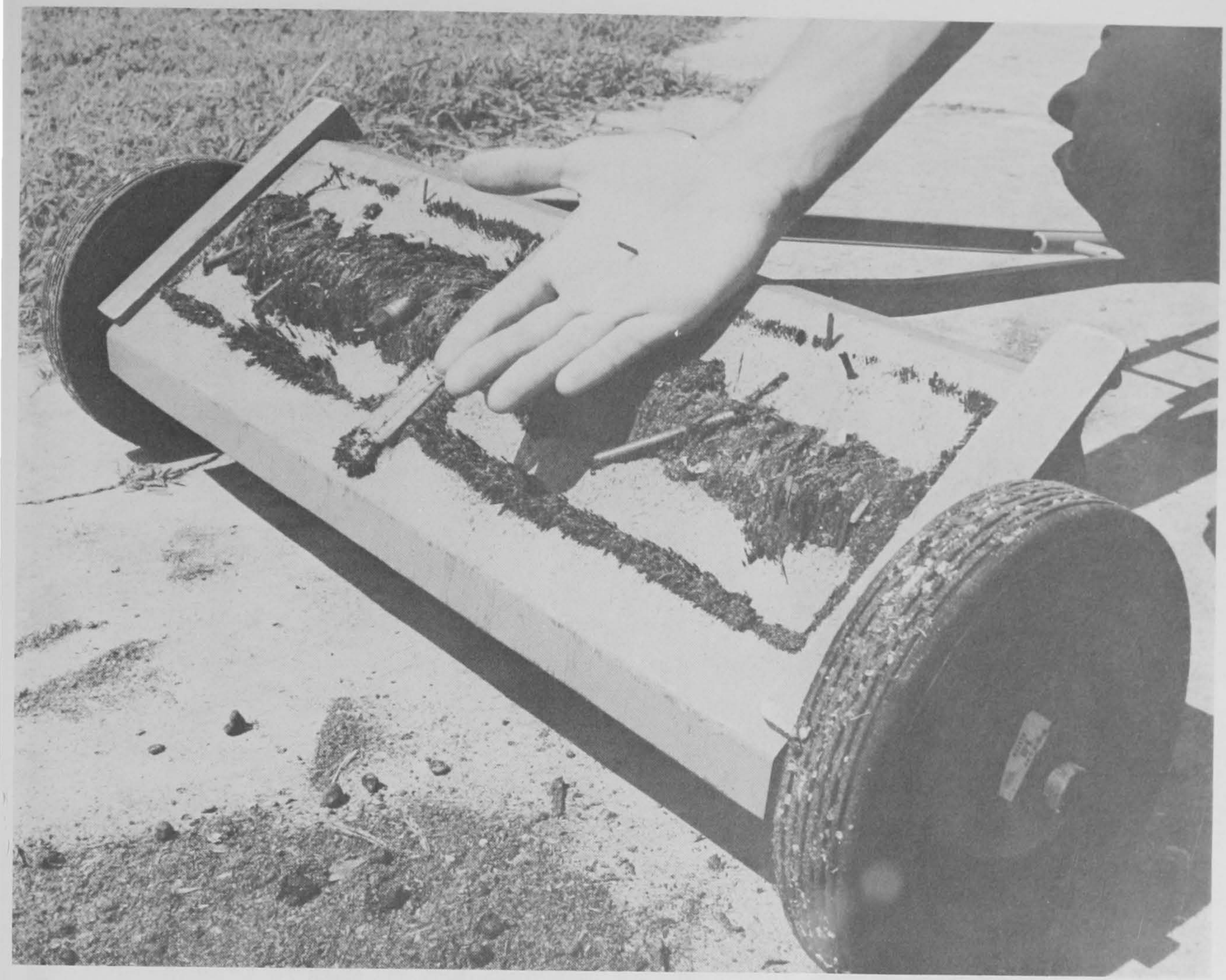

Figure 3.--Menhaden tags, along with "tramp" iron, are removed from fish meal by magnets.

separate stock of menhaden exists in the South Atlantic, but these tag recoveries show a considerable amount of intermixing of "northern" and "southern" fish in the Carolina, Chesapeake Bay, and even the Middle Atlantic areas the summer following the year of release.

Movements

Tag recoveries are confirming the general hypothesis that Atlantic menhaden move northward in the spring and southward in the fall. Fish tagged in Florida in the spring have been recovered as far north as Chesapeake Bay the summer of the same year. Also, fish tagged in North Carolina in the spring have been recovered as far north as New Jersey in the summer. There has been no evidence of any southward movement during the spring or summer (tables 5 and 6).

In October 1967 and 1968 the first recoveries were obtained of tagged fish moving south. Then the fall fishery began and tags from many fish released the previous summer in the North Atlantic, Middle Atlantic, Chesapeake Bay, and the Carolinas were recovered in the North Carolina fall fishery (table 7). The results from tagging also supported the generally accepted hypothesis of a coastwise, rather than an inshore-offshore, migration for menhaden.

Growth

Determination of how much a tagged fish grows during a given time period is possible when whole tagged fish can be isolated from the catch. Our prototype electronic fish detector system has this capability, although the tagged fish so recovered to date have been of limited value for growth studies or age verification. In 1966, length data were obtained for 20 fish representative of each set from which fish were tagged. In 1967, we measured and

Figure 4.--Prototype electronic detector system at Seashore Packing Co., Beaufort, N.C. A portion of the catch being conveyed to the plant by a dragline (right) is diverted onto a high-speed belt conveyor. As a tagged fish passes through the detector, a door is activated to push the fish off the belt into a tub. The remaining fish pass up the screw conveyor and are returned to the dragline.

Table 5.--Number of tags recovered through October 15, 1967, from fish released between March 10 and October 14, 1967

Area of recovery	Area and number of tag releases					
	New York	New Jersey	Chesapeake Bay	North Carolina	Georgia and Florida	Total
	2,093	13,660	90,053	97,666	93,932	297,404
	Number Recovered					
New Jersey	200	846	146	17	0	1,209
Virginia	0	0	8,241	708	1	8,950
North Carolina	0	0	0	9,970	[1] 149	10,119
Florida	0	0	0	0	2,528	2,528
Total	200	846	8,387	10,695	2,678	22,806

[1]As many as 143 of the fish containing these tags may have been recaptured off Georgia and transported back to North Carolina.

Table 6.--Number of tags recovered through June 30, 1968, from fish released between February 29 and June 30, 1968

Area of recovery	Area and number of tag releases				
	New Jersey	Chesapeake Bay	North Carolina	Georgia and Florida	Total
	6,141	63,524	55,677	66,711	192,053
	Number Recovered				
New Jersey	363	5	1	0	369
Virginia	[1] 2	2,494	47	0	2,543
North Carolina	0	0	2,973	137	3,110
Florida	0	0	0	2,358	2,358
Total	365	2,499	3,021	2,495	8,380

[1]Fishing records suggest fish containing these tags were recaptured in New Jersey and transported back to Virginia where they were landed.

took scales for age determination from 5 percent of all fish tagged. This year (1968) we have taken length and scale samples from 10 percent of the released fish. Also, plans were made to install a more efficient electronic detector system at another local plant; therefore, more tagged fish should be recovered for growth studies during the 1968 North Carolina fall fishery. The 79 fish recovered to date by our present system have provided, in addition to data on growth, useful information on final tag position in the abdomen following the release of tagged fish and on rates of healing at the site of tag insertion.

Survival

Since tagging began, sufficient time has not elapsed for us to accumulate enough data for calculation of reliable survival rates. The best

Table 7.--Number of tags recovered October 16, 1967, through March 31, 1968 from fish released between March 10, and October 28, 1967

Area of recovery	Area and number of tag releases					
	New York 2,093	New Jersey 13,660	Chesapeake Bay 95,330	North Carolina 110,629	Georgia and Florida 95,832	Total 317,544
	- - - - - - - -	- - - - - - - -	- - - Number	Recovered - - -	- - - - - - - -	- - - - - -
New Jersey	30	110	55	5	0	200
Virginia	0	122	1,733	121	0	1,976
North Carolina	40	663	2,193	7,386	4	10,286
Florida	0	0	0	0	645	645
Total	70	895	3,981	7,512	649	13,107

we can do at present is make an estimate based on recoveries in the spring and summer of 1967 and 1968 from 96,626 tagged fish released during the summer and fall of 1966 in North Carolina. In the spring and summer of 1967 and 1968 we recovered 1,687 and 623 tags, respectively. Before definite estimates of survival are made returns must be adjusted for differences in the efficiency of recovery and in the age and size composition of the catch; however, use of these unadjusted tag recoveries suggests a survival rate for the tagged population of about 37 percent during the period from 1967 to 1968. These data will be refined and the estimates improved as tags are recovered over a longer time span. In addition, estimates of fishing mortality will be made after adjustments for tag loss, tagging mortality, inefficiency of recovery, and changes in recruitment and emigration. The development of a mathematical model for predicting yields of the valuable menhaden resource will not be possible without the kind of information expected from our tagging work and from other population studies.

MENHADEN LIFE HISTORY AND BIOLOGY

Several biological studies on menhaden were continued, including investigations of the distributions of eggs and early stages, the abundance of juveniles and larvae, rearing the larvae, and schooling behavior.

Oceanic Distribution

John W. Reintjes

Larvae of the Atlantic menhaden.--Spawning and early larval development of Atlantic menhaden take place in the ocean and to a limited extent in the larger bays and sounds along the Atlantic coast of the United States. The time and place of spawning, the rate of larval development, the distribution of larvae in the ocean, and their movement into estuaries have perplexed biologists since the first inquiries were made into menhaden biology nearly a century ago. The lack of systematic collections from the ocean has been the main obstacle to progress in subsequent studies.

In 1965-66 the R/V Dolphin, based at the Sandy Hook, N.J., laboratory of the Bureau of Sport Fisheries and Wildlife, made a series of cruises along the coast from Martha's Vineyard, Mass. to Cape Lookout, N.C. to collect fish eggs and larvae. The track of each cruise included 92 stations along 14 transects perpendicular to the coast and extending to the edge of the Continental Shelf. Two oblique tows, a shallow one from 50 ft. to the surface and a deep one from 110 to 60 ft., were made at each station. Larvae of Atlantic menhaden as well as those of other herring-like fishes were sorted, counted, and measured from the collections. This work was accomplished by the staff of the Sandy Hook Marine Laboratory assisted by several technicians provided by our laboratory.

Menhaden larvae were more abundant from September to early February than during the other times of the year (table 8). No collections were made in late February and March, a period when larvae are known to move from the ocean into estuaries. Collections during October contained three times as many menhaden as did collections from all other cruises combined. More menhaden were taken over the middle of the Shelf than near shore or along the outer edge, and more were taken in the shallow than in the deep tows. These findings

Table 8.--Atlantic menhaden larvae collected during _Dolphin_ cruises from Cape Cod, Mass. to Cape Lookout, N.C., 1965-66

Dates	Area of occurrence	Total menhaden larvae	Tows with menhaden larvae
1965-66		Number	Number
Dec. 3-15	Northern N. J. to Cape Lookout, N.C.	906	37
Jan. 26 - Feb. 9	Chinoteauge, Va. to Cape Lookout, N.C.	304	25
Apr. 6-22	Vicinity of Cape Hatteras, N.C.	34	9
Mar. 6-26	Near Cape Henry, Va.	3	3
June 16-19	Offing of Delaware Bay	14	3
Aug. 4-10;20-28	Western Long Island to northern N.J.	7	4
Sept. 28 - Oct. 5;11-15	Block Island Sound to Cape Henry, Va.	5,334	53
Nov. 9-19; Dec. 1-7	Northern N.J. to Cape Lookout, N.C.	306	33

provide additional evidence that Atlantic menhaden spawn principally during their fall and winter migrations. The abundance of larvae in the Middle Atlantic Bight was unexpected even though some spawning was known to occur during the early autumn.

Anchovies, the next most abundant group among the clupeoid larvae, were taken principally during August, September, and October. The distribution and abundance of anchovies are being watched closely because this species may represent an alternate resource for the fish meal and oil industry. Nor can we discount the possibility that they may thrive and replace the declining menhaden stocks.

Paul L. Fore

Eggs and larvae of the Gulf menhaden.--From 1964 to 1967, Bureau biologists investigated the time and place of Gulf menhaden spawning in the Gulf of Mexico by participating in some cruises during the winter aboard the Bureau's R/V _George M. Bowers_. Although they provided useful information on spawning in the areas of Mississippi Sound and along the coast of Florida, these cruises did not cover offshore waters in the northern and western Gulf of Mexico.

This year, we had the opportunity to examine plankton collections obtained in 1963 during 12 cruises of the R/V _Gus III_. The primary aim of these cruises, made by personnel of the Bureau's Biological Laboratory at Galveston, Tex., was to obtain plankton for use in studies of distribution of larval shrimp. The cruise track, which consisted of 51 stations, covered the area between southern Texas and Alabama. Plankton was sampled at the 41 stations west of the Mississippi Delta during each of the 12 cruises, whereas the 10 sampling sites east of the Delta were visited on alternate cruises. All collections were made with a Gulf-V sampler hauled obliquely in stepwise fashion from the bottom to the surface over a 20-minute period. The sampler was fitted with a meter for calculation of filtered water volumes.

Menhaden spawn offshore, the pelagic eggs hatch in 2 or 3 days, and the larvae move inshore to estuarine nursery areas. Knowledge of this inshore movement is important. Accordingly, menhaden larvae moving through Galveston Entrance and Sabine Pass, Tex., were sampled biweekly and weekly, respectively. A standard "pass" collection was obtained with a Renfro beam trawl over a 5-minute period. Subsequent examination of 192 pass collections for menhaden larvae and 518 oceanic collections for eggs and larvae provided data on the time of spawning as well as on the location of the main spawning grounds.

Although the 1963 cruises overlapped portions of two spawning seasons, the distribution of eggs revealed that the spawning season in the northern and western Gulf of Mexico extended from mid-October through March, an inferred duration of 5-1/2 months. Figure 5 shows the monthly distribution of eggs per 3,530 cubic feet of water strained per sample.

Menhaden eggs were first collected in mid-October, reached a peak in December, decreased in January and February, and tapered off in March. Mean values of environmental variables associated with the egg collections were: water temperature, 66° F.; salinity, 34 p.p.t. (parts per thousand); station depth, 14 fathoms (1 fathom equals 6 feet); and distance to the nearest continual shoreline, 18 miles.

The schedule of menhaden larvae entering the passes corroborated the time of spawning offshore. At Galveston Entrance, larvae moved through this inlet from late October until April 5, whereas individuals entered Sabine Pass from November 6 through April 24. Interestingly, oceanic menhaden larvae were collected in the northern Gulf of Mexico from October 20 through April 25.

The location of spawning areas of Gulf menhaden was determined solely from the distribution and abundance of eggs. Egg collections revealed that Gulf menhaden spawned mainly over the Continental Shelf between Sabine Pass and Alabama (fig. 6). They also indicated that spawning was restricted to waters between the 4- and 40-fathom contours

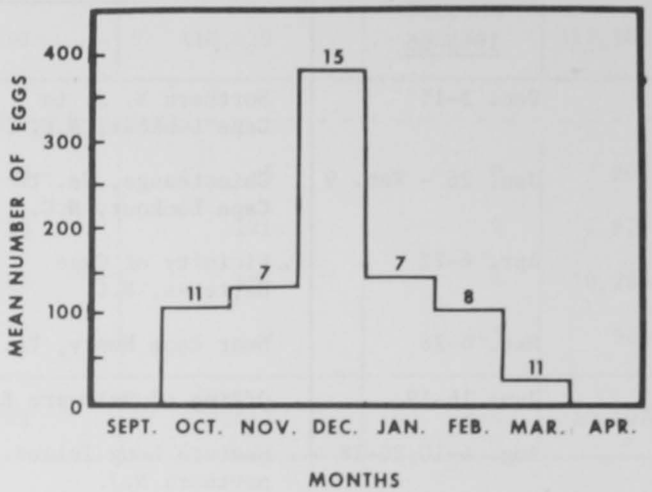

Figure 5.--Distribution of menhaden eggs in the northern and western Gulf of Mexico, 1963. The numerals represent the number of collections containing eggs.

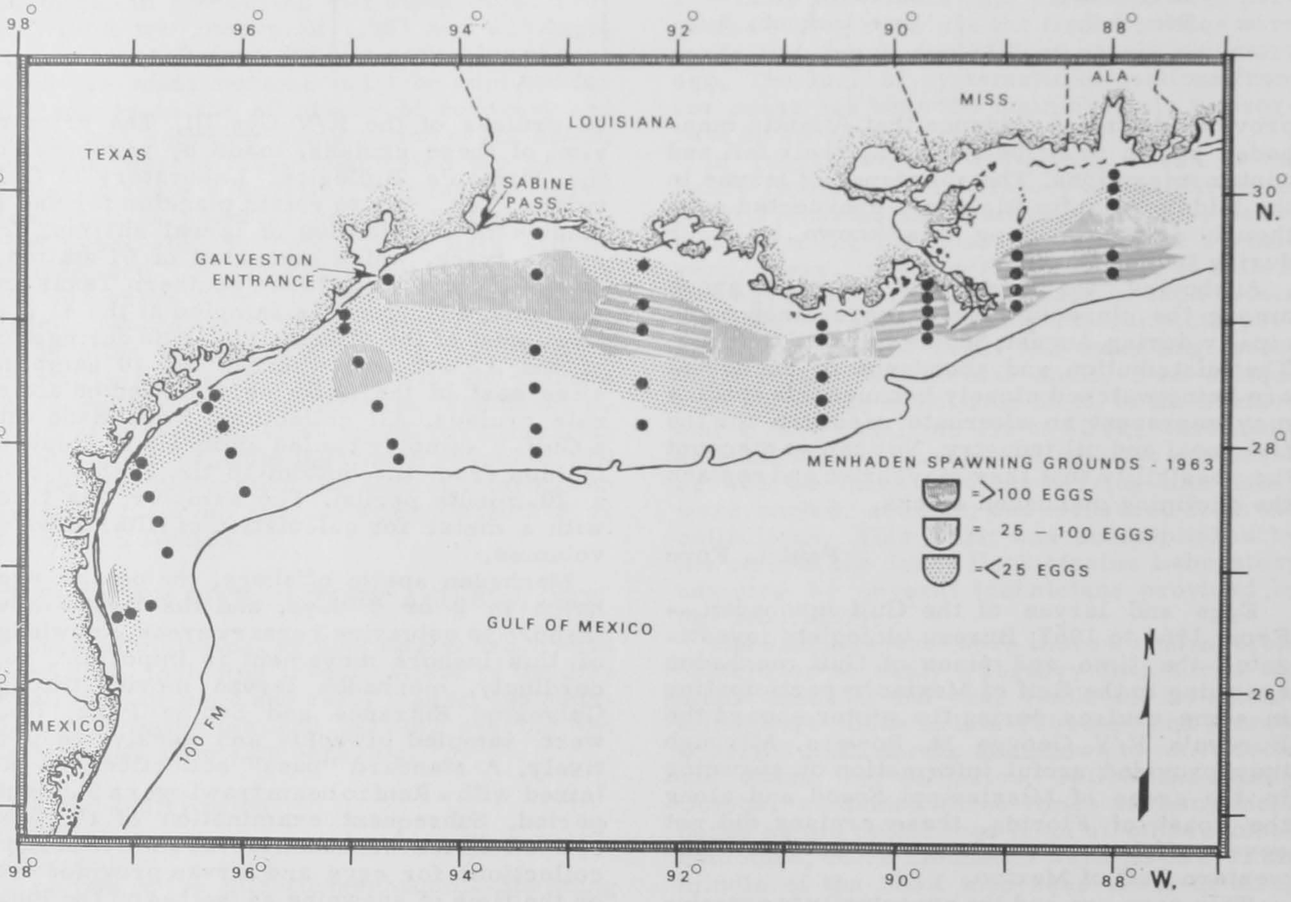

Figure 6.--The winter spawning grounds of the Gulf menhaden.

off Texas and Louisiana, and that it was concentrated near the Mississippi Delta. Because no stations were occupied beyond the 40-fathom contour east of the Delta, the seaward spawning range in this area could not be delineated.

The data from the Gus III cruises also establish the winter location of adult Gulf menhaden in relation to the summer commercial fishing grounds. The summer fishery in Louisiana and Mississippi coastal waters generally extends from mid-April through September. When the temperature of the water cools to 77° F. and below in October, some spawning commences about the same time that the fishery ceases. It now appears that the adult menhaden leave the coastal surface waters and gradually move out into the Gulf as the spawning season progresses. Spawning ceases with warming waters and increasing day length in the spring, the adults return to coastal and estuarine areas, and a new fishing season begins.

In summary, these findings for the first time: (1) delimit the length of the Gulf menhaden's spawning season; (2) establish the location of its main spawning grounds in the northern Gulf of Mexico; (3) document the oceanic phase of the species' early life history; (4) provide data on the physical environment during spawning; and (5) furnish indirect evidence on the winter distribution of adult fish. This information will serve as a basis for future oceanographic work to expand our knowledge about the Gulf menhaden's early life history.

Estimated Abundance

William R. Turner

Juvenile menhaden.--Estimates of abundance of juvenile menhaden in 1967 were obtained by sampling with two-boat surface trawls (fig. 7) and by aerial surveys of the size and number of schools on the nursery grounds. The elimination of haul seining and mark-recapture trials as insufficiently effective methods of

Figure 7.--Beginning a surface-trawl haul to capture juveniles for the estimation of menhaden abundance.

determining abundance, made it possible to include a greater number of streams than heretofore in our surveys. Last year the number of sampling sites in the Gulf was increased by allocating survey streams in proportion to the amount of estuarine surface area. The same procedure is being used on the Atlantic coast in 1968 to provide more adequate coverage of potential nursery areas. These surveys could serve the industry as a means of forecasting fishing success and prove useful in helping to manage the menhaden resource.

Surveys of Atlantic menhaden have indicated a declining resource since 1963. They have also shown that the 1967 year class is the poorest encountered since this work began in 1962 (table 9). Indices based upon 10 streams surveyed regularly since 1962 signified a weaker year class in 1967 in all three major regions along the coast.

Because estimates of the strength of Atlantic menhaden year classes now are based on a relatively small number of samples, we plan to increase the number of survey sites. The coastal region between Cape Cod, Mass., and Fernandina Beach, Fla., has been divided into 11 areas represented by 60 sampling sites (table 10). Juvenile menhaden will be sampled at the indicated number of sites in each of these areas in 1968.

Estimates of the relative abundance of juvenile Gulf menhaden have been derived from

Table 9.--Indices of relative abundance of juvenile Atlantic menhaden, 1962-67

Region	1962	1963	1964	1965	1966	1967
North Atlantic States	1.00	6.77	0.17	0.17	1.64	0.47
Middle Atlantic States	1.00	5.77	0.90	0.08	0.50	0.02
South Atlantic States	1.00	1.05	0.41	0.25	0.46	0.17
Entire Atlantic coast[1]	1.00	2.06	0.45	0.22	0.55	0.18

[1]Means for the entire coast were computed by dividing the total catch by the total number of samples.

Table 10.--Major subdivisions of the Atlantic coast and distribution of sampling sites for surveys of juvenile menhaden abundance in 1968

Area and designation	Surface acres[1]		Sampling sites
	Number	Percent	Number
1. Long Island Sound	1,320,000	15.3	9
2. Delaware Bay	931,000	10.7	6
3. Chesapeake Bay	3,076,200	35.7	21
4. Albemarle Sound	690,000	7.9	5
5. Pamlico Sound	1,423,800	16.5	9
6. Long Bay	130,500	1.5	1
7. St. Helena Sound	229,900	2.7	2
8. Port Royal Sound	100,000	1.2	1
9. Savannah River	247,000	2.9	2
10. Altamaha Sound	249,000	2.9	2
11. Cumberland Sound	230,000	2.7	2
Total - - - - - -	8,627,400	100.0	60

[1]Estimates of surface area from the Office of River Basin Studies, Bureau of Sport Fisheries and Wildlife.

seven streams surveyed regularly since 1964. The 1967 surveys indicated a year class that was considerably weaker than that of 1966 and about equivalent to the 1965 year class (table 11). The number of survey sites along the Gulf coast was increased in 1967, although information obtained from this expanded coverage will not serve as a base for estimating relative juvenile abundance until data are available for one more year.

In 1964, large catches of juvenile Gulf menhaden from the muddy waters of Pearl River and Bayou la Croix, Miss., indicated that eastern Gulf estuaries also serve as nurseries. Since that time the clarity of the waters in most of the streams east of the Delta has made our gear ineffective in sampling for the abundance of menhaden. Accordingly, we tried sampling at night in three selected streams during August 1967. This work demonstrated that juvenile menhaden could be taken at night in clear water (table 12). Sampling in darkness as a means of obtaining more useful measures of the abundance of young menhaden in clear streams of the eastern Gulf will be further explored in 1968.

Estimates of abundance of juvenile menhadens obtained from the 1967 aerial surveys generally substantiated findings of the 1967 trawl surveys along both coasts (table 13). Counts on the Atlantic coast were the lowest since the surveys began. Counts in the Gulf also decreased and were nearly as low as those of 1965. The 1964 counts in the Gulf, as well as the 1963 counts in the Atlantic, were influenced by adverse spotting conditions in some areas.

Table 11.--Catches of juvenile menhaden in selected Gulf coast estuaries, 1964-67

Stream	1964	1965	1966	1967
	Number per 5-minute haul (No. of hauls)			
Dickinson Bayou, Tex.	4,376 (7)	553 (8)	9,244 (9)	829 (9)
Clear Creek, Tex.	2,361 (8)	1,160 (9)	1,019 (8)	2,173 (9)
Johnson Bayou, La.	7,034 (8)	992 (8)	250 (8)	0 (8)
Vermilion River, La.	307 (6)	713 (9)	2,455 (7)	1,294 (7)
Pearl River, Miss.	2,419 (9)	0 (9)	0 (8)	0 (8)
Bayou la Croix, Miss.	7,764 (6)	0 (8)	1 (8)	0 (9)
Bayou Chico, Fla.	257 (6)	58 (5)	49 (5)	1 (5)
Relative index - - -	1.00	0.14	0.53	0.18

Table 12.--Day-night catches of juvenile menhaden in three clear-water streams of the eastern Gulf, 1967

Sampling site	Water transparency	Catch per 5-minute haul			
		Day	(Hauls)	Night	(Hauls)
	In.	Number			
Fish River, Ala.	>24	0	(6)	99	(6)
Pearl River, Miss.	>24	0	(8)	732	(5)
Tchefuncta River, La.	>40	0	(7)	238	(7)

Table 13.--Summary of aerial surveys of juvenile menhaden along the Atlantic and Gulf coasts, 1962-67

Year	Atlantic coast			Gulf coast		
	Flight Track	Surface area of schools sighted	Relative index	Flight track	Surface area of schools sighted	Relative index
	Miles	Square feet/mile		Miles	Square feet/mile	
1962	807	2,737	1.00	-	-	-
1963	1,121	2,176	0.80	-	-	-
1964	942	922	0.34	835	306	1.00
1965	1,096	439	0.16	753	346	1.13
1966	1,267	839	0.31	774	413	1.35
1967	1,497	164	0.06	739	379	1.24

Robert M. Lewis

Larval menhaden.--During 1967-68, we sampled regularly with our standardized channel nets that were hung from bridges in the lower reaches of the estuaries within Beaufort and Bogue Inlets. The purpose of this sampling was to determine the occurrence and abundance of larval Atlantic menhaden. We chose these locations to obtain comparable information on larvae at adjacent inlets. Larvae entering Bogue Inlet and moving on into the nursery area as juveniles are restricted to the White Oak River complex. This area provides an excellent opportunity to show the relation between abundance of larval and juvenile Atlantic menhaden. Menhaden larvae enter the two inlets from November to the end of April after hatching off the North Carolina coast. Our basic unit of measurement, the larval index, is the number of larvae per 3,530 cubic feet of water.

The number of larvae caught inside Beaufort Inlet indicated that the relative abundance in 1966-67 was about 10 times that in 1967-68. A comparison between samples taken at Beaufort laboratory bridge and east Swansboro bridge during 1967-68 showed that the abundance of larvae at Bogue Inlet was slightly more than half that moving through Beaufort Inlet but the timing of movements through the two inlets was essentially the same (fig. 8).

Water temperatures were lower during the past winter (1967-68) than in the previous one. Earlier laboratory experiments with larval menhaden showed that temperatures that approach 40° F. can have a pronounced effect on survival. Water temperatures near the laboratory generally remained below 50° F. from the end of December 1967 through February 1968; these low temperatures may have contributed to the reduction in larval abundance this past year.

To determine if tidal currents or stages affected the presence or movement of larvae during daylight at different depths at the laboratory site, we randomized the surface and bottom sets during the 1967-68 season. Tidal cycles were divided into three stages of about 2 hours each. On the average, the surface sets had higher larval indices. Patchiness of larval distribution was illustrated by the fact that the highest and lowest mean index values from the bottom sets were recorded during two successive stages of flood tide. No relation was detected between larval index and current velocity.

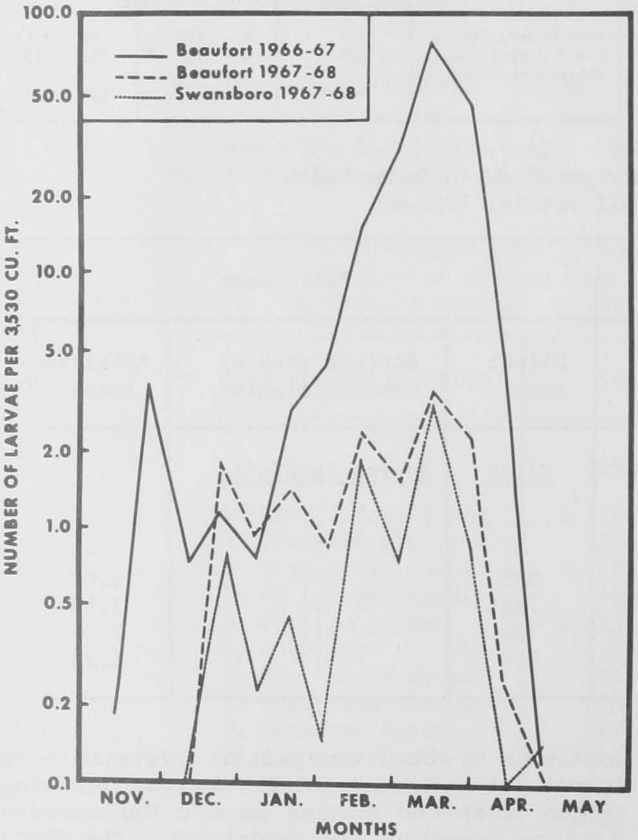

Figure 8.--Relative abundance of Atlantic menhaden larvae in the channel on the north side of Pivers Island, Beaufort, N.C., 1966-67 and 1967-68, and in White Oak River near the east bridge at Swansboro, N.C., 1967-68, based on average daytime catches during 2-week intervals.

Once during March when the probability of obtaining high indices of larval abundance was greatest, we sampled continuously for 24 hours to determine if changes in tidal and light conditions affected the numbers of larvae taken. Variation due to depth was examined by sampling simultaneously at the surface and bottom. Daytime indices from surface and bottom sets followed similar trends except during the afternoon ebbing tide when we took a few more larvae at the surface. The greatest difference between indices from surface and bottom sets came during flood tide after dark. As the velocity of the tidal currents increased, the indices from surface and bottom sets became markedly different; more larvae were being caught at the bottom. It appeared that in darkness when currents were fast in the upper layers, menhaden larvae sought the bottom where the currents were slower.

Rearing Larval Menhaden

William F. Hettler, Jr.

In attempting to comprehend the phenomenon of year-class strength, we assume that the size of any year class is established in the 6-month periods that precede and follow fertilization. During these critical 12 months, we hypothesize that observed fluctuations in year-class size begin with the quality of the gametes in maturing adults. The release of these sex products in turn subjects them to the rigors of the environment. During the early stages of life, the critical factors that dictate year-class success or failure are the behavior of larvae, their food-capturing ability, and the behavior and quality of their food organisms. It is important, therefore, that we understand the interrelation among larvae and their biotic and abiotic environments so that we can construct and predict the survivorship curve of these animals.

Requisite to experimental studies of larval behavior is the ability to rear menhaden from the egg in the laboratory. It is nearly impossible at sea to collect undamaged prolarvae and young postlarvae for experimental work. Equally important, many experiments would be meaningless without a record of the environmental history of the test animals. Therefore, a pilot study to rear menhaden from artificially fertilized eggs was made last February.

Figure 9.--Fatal gas bubbles in coelomic cavity of a 0.55-inch yellowfin menhaden larva caused by supersaturation of water with air in rearing tanks.

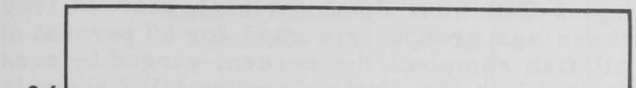

Figure 10.--Growth of yellowfin menhaden at 68° F. in a pilot rearing experiment.

Eggs and sperm of yellowfin menhaden (Brevoortia smithi) were mixed at the collecting site in Indian River, near Melbourne, Fla. This species was used instead of the commercially more important Atlantic menhaden because sexually mature Atlantic menhaden are unavailable in the winter.

The fertilized eggs of the yellowfin menhaden were transported to the laboratory and reared under controlled conditions of temperature, light, and food. The resulting larvae fed first on fertilized sea urchin eggs and possibly on unicellular flagellated algae, and later on brine shrimp nauplii. The postlarvae were reared at 68° F. for 35 days, after which time insufficient food and supersaturation of the laboratory sea water with air caused the death of the last larva. Figure 9 shows fatal gas bubbles in the posterior portion of a 0.55-inch larva. The largest specimens grew to 0.59 inch (total length). Figure 10 shows the growth of a few larvae preserved during the study. Techniques learned in this study were applied in the design of a better rearing system for use when viable gametes become available. Subsequent attempts during the spring to collect Atlantic menhaden eggs and sperm from upper Chesapeake Bay were not successful, although ripe males and several nearly ripe females were collected in Wye River, Md. in late April.

Schooling Behavior of Young Menhaden

Richard W. Lichtenheld

In a world where survival requires successful reproduction, natural selection should favor the evolution of behavioral systems that allow for the nonrandom dispersal of organisms to maximize their chances for survival. In menhaden, this distribution is characterized by schooling and migration behavior. Why and how fish school and migrate have whetted the curiosities of scientists and evaded explanation for centuries. The fact that answers to these questions are piecemeal at best for any species is curious in view of their fundamental importance in the strategies of fishing and of resource management. For example, without the tendency to school, menhaden, like many other commercially important pelagic species, would be extremely difficult--perhaps prohibitively uneconomical--to catch. Unfortunately, very little is known about schooling behavior and nothing about the mechanisms that underlie the formation and maintenance of menhaden schools.

One of the factors directly affecting the formation and size of a school is the three-dimensional character or extension of the habitat. For example, restrictions in any plane will limit the size of the school in that dimension. Shallow waters, for example, restrict the depth of a school to a thin layer.

To determine the influence of space on the schooling tendency and behavior of menhaden larvae, we placed different numbers of fish (10, 20, and 40) in three identical 22-inch cuboid tanks. After 10 days, each group was then introduced independently into a circular (6.5-ft. diameter) 500-gallon tank. Comparisons among these test groups and environments showed that the behavior of a group in a given space is largely dictated by the size of the group.

In the confined area of the small tanks, for example, 40 larvae formed a mill or rotating "wheel", but individual fish in the group of 10 generally moved independently of one another. This meandering and random orientation was interrupted occasionally by the formation of small groups of three to five fish. When placed in the large tank, all groups initially formed a tight school that gradually thinned to or toward a rotating wheel. The differential behavior among these groups and the observed changes over time within each group suggest that menhaden possess the perceptual framework for determining at least the minimum number of individuals to associate with as a school in a given space, and that the tendency to school is, in part, a function of the animal's familiarity with its environment.

MENHADEN POPULATION DYNAMICS

The studies of population dynamics involved sampling the catches of fish in the Atlantic and Gulf of Mexico, assessing the sampling procedures, and observing the 1967 fishery.

Catch Sampling

Mayo H. Judy

Atlantic fishery.--Atlantic menhaden catches were systematically sampled throughout the season by personnel stationed at various ports along the Atlantic coast from Port Monmouth, N.J., to Fernandina Beach, Fla. At 14 of 17 reduction plants that reported landings during 1967 (April through December), we obtained 771 samples of 20 fish each from total purse seine landings of 215,200 tons--an average of one sample for every 279 tons of fish caught. Over the comparable period in 1966, landings at 20 reduction plants totaled 241,900 tons. They yielded 786 samples--an average of one sample for every 306 tons landed. In addition to regular samples from menhaden landings by purse seiners, we collected menhaden samples from pound nets in Chesapeake Bay and samples of Atlantic thread herring (Opisthonema oglinum) from purse seine landings at three ports along the South Atlantic coast. We also obtained data on daily vessel activity through personal observation by catch samplers and through logbooks maintained by vessel personnel. The number of menhaden purse seiners operating in Atlantic waters has declined gradually over the past few years; 83 boats landed menhaden at various ports along the Atlantic coast in 1965, 73 in 1966, 64 in 1967, and 59 in 1968.

Scales from 14,495 fish indicated that no single year class made an exceptional contribution in 1967 (table 14). In 1966 and 1967, 3-year-old fish predominated in catches from Port Monmouth, N.J.; for all areas combined, 3-year-old fish made up only 16 percent of the catch. Since 3-year-old fish accounted for about 60 percent of the Port Monmouth, N.J., catches, and 4- and 5-year-old fish were less plentiful than in 1966, the trend is toward a Middle Atlantic fishery producing 3-year-old and younger fish. In Chesapeake Bay and throughout the South Atlantic area, age-1 and age-2 fish were dominant each year. In 1966 these age groups accounted for 69 percent of all fish sampled; the percent ranged by area from 63 in the North Carolina fall fishery to 94 in the North Carolina summer fishery. In 1967 they accounted for an even higher percentage (81 percent) and ranged from 75 percent in the North Carolina fall fishery to 94 percent at Fernandina Beach, Fla. The contribution of age-3 fish was the same during both years. In 1967 our samples contained very few age-4 and older fish.

Robert B. Chapoton

Gulf fishery.--To meet the continuing requirements of our research on the population dynamics of Gulf menhaden, we compiled fishery statistics and sampled catches for biological data throughout the 1967 fishing season. Four samplers, one each at Moss Point, Miss., and Empire, Morgan City-Dulac, and Cameron, La., regularly gathered information for each menhaden purse seiner on when and where it fished and how much it caught. By systematic sampling, they also recorded detailed information on the size and sex composition of catches, and collected scales for data on age composition.

Comparison of 4 years' (1964-67) data on age composition indicates that the age structure of the fishable stocks changed significantly (table 15). In 1967, age-1 fish made up about 60 percent of the sample fish, whereas in 1966 fish of this age made up only 30 percent. The age structure throughout 1967 was in fact closely similar to that in the 1965 season. The combined-sample data also affirm that age-0 and age-4 and older fish are rare and contribute little to Gulf menhaden landings.

In 1967, as in the past, the catch of menhaden in the Gulf was almost entirely of one species, the Gulf menhaden. Other species appeared in the landings only occasionally. These fishes included, as in the other seasons,

Table 14.--Age composition of Atlantic menhaden samples, 1966-67

Area and port	Year	Sample size	Number of annuli 0	1	2	3	4	5	6
		Number	- - - - - - -	-	-	Percent	-	-	- - - - - -
Middle Atlantic:									
Port Monmouth, N.J....	1966	1,229	-	-	15	55	27	3	<1
	1967	1,667	-	3	27	61	8	1	<1
Chesapeake Bay:									
Reedville, Va.........	1966	5,506	21	32	39	7	<1	<1	
	1967	5,634	2	49	37	12	<1	<1	
South Atlantic:									
Beaufort, N.C.									
Summer..............	1966	1,854	<1	62	32	5	<1	<1	
	1967	1,125	5	43	43	8	<1		
Fall................	1966	1,720	24	22	41	12	<1		
	1967	1,444	3	43	32	21	1	<1	
Southport, N.C........	1966	297		40	33	23	4		
	1967	222	<1	42	46	12			
Fernandina Beach, Fla.	1966	3,555	<1	21	53	23	3	<1	
	1967	4,403	<1	60	34	5	<1		
Total...................	1966	14,161	11	29	40	16	4	<1	<1
	1967	14,495	1	46	35	16	1	<1	<1

the yellowfish menhaden, the finescale menhaden (Brevoortia gunteri), and the scaled sardine (Harengula pensacolae). Atlantic thread herring, although uncommon, were observed in catches landed at Cameron in June and at Morgan City in July and August. The true contribution of these and other uncommon species to the total landings is not known. Of interest, however, in view of the numerous reports on the commercial potential of Atlantic thread herring, are limited observations of this species in the menhaden landings.

A preliminary analysis of the scales from 100 thread herring showed that 47 were in their second year of life, 32 in their third, 17 in their fourth, and 4 in their fifth. At comparable ages, these fish are roughly the same length as are Gulf menhaden; they also occur in surface schools, but are reportedly more difficult to catch in a purse seine than are the Gulf and Atlantic menhadens.

Among the kinds of information needed in our study of the Gulf menhaden resource and fishery is that showing the distribution as well as quantity of fishing effort. As mentioned earlier, a duty of our catch-sampling personnel is the maintenance of fishing logbooks, in which vessel personnel enter data on fishing locations and the number of sets, or times the purse seine is played out to catch menhaden. Table 16, which summarizes those logbook data, indicates how menhaden fishing was distributed along the Gulf coast over the past four seasons (1964-67). These data are neither measures of true fishing effort nor do they necessarily indicate the origin of all landings along the coast, but they probably represent the best information on where most menhaden fishing takes place in the Gulf. The easternmost grounds are near Apalachicola, Fla.; the area between the 87th and 89th meridians includes most of Mississippi Sound; that between 89° and 91° covers the rich waters around the Mississippi River Delta; and that from 92° to 95° identifies the grounds off western Louisiana and eastern Texas.

Other studies on the Gulf menhaden include determination of the change in weight of a fish as its length (and age) increase. The data thus far summarized (fig. 11) indicate, as expected, that fish weight increases roughly as the cube

Table 15.--Age composition of samples from catches of Gulf menhaden landed at major ports, 1964-67

Port of landing	Year	Sample size	Number of annuli						
			0	1	2	3	4	5	6
		Number	Percent						
Moss Point, Miss.	1964	3,982	<1	74	24	2	<1	--	--
	1965	6,219	<1	67	30	2	<1	<1	--
	1966	3,631	<1	12	52	32	4	--	--
	1967	5,069	<1	63	31	5	1	<1	--
Empire, La.......	1964	3,392	<1	31	44	21	4	<1	<1
	1965	3,308	<1	59	29	10	1	<1	--
	1966	2,376	--	20	52	24	4	<1	--
	1967	3,141	<1	48	43	8	<1	--	--
Morgan City, La..	1964	2,271	--	41	51	7	1	<1	<1
	1965	3,030	<1	47	35	17	1	<1	<1
	1966	2,048	--	27	49	22	2	<1	--
	1967	2,848	<1	57	37	6	<1	<1	--
Cameron, La......	1964	2,650	<1	46	46	7	<1	<1	<1
	1965	2,709	<1	69	28	2	1	--	--
	1966	4,211	<1	54	35	9	1	--	--
	1967	2,951	<1	69	29	2	<1	<1	--
Total.........	1964	12,295	<1	50	39	9	2	<1	<1
	1965	15,266	<1	62	30	7	<1	<1	<1
	1966	12,266	<1	30	46	21	2	<1	--
	1967	14,009	<1	59	34	5	1	<1	--

Table 16.--Distribution of recorded purse seine sets by Gulf of Mexico menhaden vessels, 1964-67

Year	Vessels reporting		Recorded sets	Fishing position by degrees of longitude (West)										
				94	93	92	91	90	89	88	87	86	85	84
	Number	Percent	Number	Percent of recorded sets										
1964	74	95	9,950	2	15	10	20	3	34	15	<1	<1	1	-
1965	58	67	10,472	2	9	6	26	6	31	18	<1	<1	<1	1
1966	58	63	6,936	1	9	6	26	3	34	17	<1	-	2	1
1967	45	53	6,970	1	9	10	36	3	27	14	-	<1	<1	-

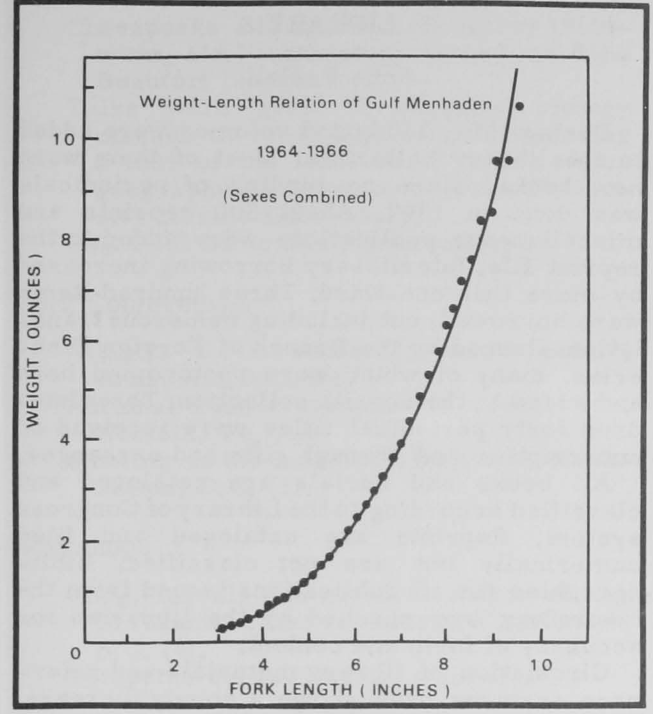

Figure 11.--Weight-length relation of Gulf menhaden, 1964-66 (sexes combined).

of the length. This generalized relation characterizes a fish having an unchanging body form. In the Gulf menhaden, male and female fish show a nearly identical weight-length relation and have been combined in this presentation. Knowledge of this relation is useful for (1) describing weight and length as functions of each other, (2) converting length to weight or vice versa whenever one is not known, (3) converting to weight the average lengths of fish back-calculated from scale annuli, and (4) calculating instantaneous growth in weight of individual fish as well as of the fished stocks.

Statistical Assessment of Sampling Procedure

Gene R. Huntsman

Reliable estimates of the age structure of the menhaden populations are essential to understanding the population dynamics of menhaden. Though we have calculated estimates of numbers of menhaden by age for each port each week in the fishery, we have not previously assessed the quality of these estimates. This quality is directly related to the variance of the estimate. Knowing the variance for each estimate allows evaluation of the estimates and distribution of future sampling effort so that the best possible estimates are obtained with available manpower and funds.

Our work during the last year has been directed toward determining the best method of estimating the numbers of fish by age and the variances of those estimates. Because the key to our estimates is the ratio of the number of fish of the age of interest in a sample to the total weight of that sample, we are able to use the theory and techniques of ratio estimators. By modifying the general formulas for ratio estimators and their variances, we have created statistical procedures appropriate to the menhaden fishery. Douglas S. Robson of Cornell University provided valuable assistance in the development of these procedures.

Preliminary results indicate that since the amount of variability (with respect to age) between schools is greater than that within schools, it is more efficient to sample a large percentage of the landings than it is to take large samples of fish from each landing. For example, age 2's represented an estimated 22 percent (by number) of the catch at Port Monmouth, N.J., in each of the weeks July 23-29 and July 30 to August 5, 1967. But the variance (19,195,651,176) of the estimated number of 2's (228,582) in the second week, when only 4 out of 14 landings were sampled, is almost 95 times as great as the variance (203,697,383) of the estimated number of 2's (47,976) for the first week when we sampled 7 of 11 landings.

Also, the greater the relative abundance of a given age in a week's landings, the better will be the estimate of the number of that age taken. In the week July 23-29, 1967, at Port Monmouth, N.J., age-4 fish constituted only an estimated 12 percent of the week's catch, and the variance of the estimated number of 4's is relatively much greater than the variance of the estimated number of 2's in the same week. Possibly the greater relative variance for the 4's is the result of a less satisfactory number-to-weight ratio for the 4's than for the 2's, but it most likely resulted from the lesser abundance of the 4's.

The 1967 Menhaden Fisheries

William R. Nicholson
Stanley M. Warlen

The Atlantic menhaden fishery experienced another poor season in 1967. No plants operated in the North Atlantic area. In the Middle Atlantic area the Port Monmouth, N.J., plant operated with only five vessels, the Wildwood, N.J., plant intermittently from July to October, and the Tuckerton, N.J., and Lewes, Del., plants remained closed. Six plants again operaged in Chesapeake Bay from late May until late November, although one did not process any fish after July. In the South Atlantic area two plants processed fish in Florida and two in North Carolina, the same number as in the previous year. Five plants operated in the North Carolina fall fishery.

The amount of vessel activity remained about the same as in 1966. In the Middle Atlantic area, five vessels fished at Port Monmouth and eight fished intermittently at Wildwood, but at the latter port only four vessels on the average fished at any one time.

Although 43 vessels fished from Chesapeake Bay plants, only some 35 fished at one time. Eight of these spent part of the season at Wildwood, some fished in the Gulf until September or October, and others fished off and on at Southport, N.C. In the South Atlantic area, five boats fished at Fernandina Beach, Fla., seven intermittently at Southport, N.C., and eight at Beaufort, N.C. The North Carolina fall fishery had 45 vessels, about the same number as in previous years.

The total catch of 213,300 tons was 88 percent of the 1966 catch, which, in turn, had been the smallest since the end of World War II. No fish were landed at North Atlantic ports. At Middle Atlantic ports the catch was up from 6,600 tons in 1966 to 18,900 tons, mainly as the result of full-season operation of the plant at Port Monmouth, N.J., and the availability of fish to Wildwood-based vessels in Delaware Bay in midsummer. In Chesapeake Bay, despite the continuation of fishing until late November and about the same amount of fishing effort, the catch dropped 21 percent, from 127,300 to 100,400 tons. The South Atlantic catch increased from 27,000 to 36,700 tons, mainly because of increases at Fernandina Beach, Fla., and Southport, N.C. The catch in the North Carolina fall fishery dropped from 79,000 to 56,400 tons.

Although fishing pressure declined slightly in the Gulf of Mexico from 1966, it was still heavy. The Apalachicola, Fla., plant did not open, but a new plant began operations at Cameron, La., keeping the total at 13, the same number as in 1966. The number of menhaden vessels dropped from 92 to 85 and the number of vessel-weeks, which we now feel is our best measure of fishing effort, dropped from 1,641 to 1,545. Some of this decrease was the result of difficulty in retaining crews, and some was due to the start of several plants later in the year and their quitting earlier than usual. Several small vessels were replaced by larger and more modern ones.

The purse seine catch of 348,000 tons was the smallest in 9 years (1959-67) and was only 66 percent of the record catch in 1962. Except for an increase to 508,000 tons in 1965, the catch has declined steadily since 1962.

The unadjusted catch-per-vessel-week of 225 tons was the second lowest in 9 years-- only 13 tons above the previous low in 1959, and 92 tons below the record high in 1961. The trend in catch-per-vessel-week has been downward since 1961.

The estimated number of Gulf menhaden caught annually has remained relatively stable since catch sampling began in 1964. Except for an estimated 6,054 million landed in 1965, the number has fluctuated between 4,235 and 4,594 million. Age-1 and age-2 fish constituted over 90 percent of the number landed each year; ages 1 to 3 over 98 percent. The remaining percentages were divided among ages 0, 4, 5, and 6.

LIBRARY

Anna F. Hall

During 1967, 200 bound volumes were added to the library collection. Most of them were new books, since no binding of periodicals was done in 1967. About 500 reprints and miscellaneous publications were added to the reprint file. Interlibrary borrowing increased by more than one-third. Three hundred items were borrowed, not including numerous translations loaned by the Branch of Foreign Fisheries, many of which were photocopied here and added to the reprint collection. Three hundred forty periodical titles were received on subscription and through gifts and exchanges.

All books and serials are cataloged and classified according to the Library of Congress system. Reprints are cataloged and filed numerically but are not classified. Bibliographies for all publications issued from the laboratory are checked by the librarian for accuracy of form and content.

Circulation of library materials and reference services have shown a steady increase. Particular emphasis is given to assisting staff members to maintain a current awareness of publications relating to their field of research. All incoming materials are displayed in the library for 1 week, and selected items are routed to call special attention to them.

In addition to the Biological Laboratory staff, the library serves the Radiobiological Laboratory, the staff and students of the Duke University Marine Laboratory, the University of North Carolina Institute of Marine Sciences, other state and educational organizations, and individuals.

MEETINGS AND TRAINING PROGRAMS

(Attendance shown in parentheses)

Meetings

- 97th American Fisheries Society meeting, Toronto, Canada (2).
- BCF Laboratory Directors, Woods Hole, Mass. (1).
- American Society of Ichthyologists and Herpetologists, Ann Arbor, Mich. (2).
- Atlantic Estuarine Research Society, Hampton, Va. (4).
- Atlantic States Marine Fisheries Commission, Virginia Beach, Va. (1).
- Atlantic States Marine Fisheries Commission, Menhaden Subcommittee, Washington, D.C. (1).
- Gulf States Marine Fisheries Commission, Montgomery, Ala. (1).

Training

- Duke University Marine Laboratory summer courses (3).

Chesapeake Biological Laboratory (Solomons, Md.) ichthyology class toured the Beaufort laboratory.

Talks were given to advanced biology classes at local high schools including a tour of the laboratory; and to a biogeography symposium at Duke University Marine Laboratory.

CSC PPB home study course (3).

Work Conferences

Atlantic Estuarine Research Society, Annapolis, Md. (5).

National Fish Meal and Oil Association, Norfolk, Va. (1).

Meeting of the menhaden industry, Washington, D.C. (1).

Workshops

"Egg, larval, and juvenile stages of fish in Atlantic coast estuaries," Charleston, S.C. (4).

Computer usage, Dayton, Ohio (1).

STAFF*

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

Blue Crab Program

Fishery Biologists:

Donnie L. Dudley
Mayo H. Judy
George H. Rees--transferred 09-26-67
Marlin E. Tagatz

Menhaden Program

Fishery Biologists:

Robert B. Chapoton
Randall P. Cheek
Cleophas R. Cooke, Jr.--resigned 05-03-68
William D. B. Davies--resigned 09-01-67
Robert L. Dryfoos
Paul L. Fore
Charles P. Goodwin
Louis A. Gwartney--resigned 04-19-68
William F. Hettler, Jr.
Gene R. Huntsman
Allan E. Johnson--resigned 07-21-67
Brian S. Kinnear
Richard L. Kroger
Eldon J. Levi
Robert M. Lewis
Richard W. Lichtenheld
Walter C. Mann--transferred 06-30-68
Heyward H. Mathews--resigned 07-28-67
William R. Nicholson
Richard O. Parker, Jr.
Paul J. Pristas
John W. Reintjes
Glenn B. Sekavec
William R. Turner
Stanley M. Warlen
E. Peter H. Wilkens

Biological Technicians:

Linda C. Coston
James F. Guthrie
George N. Johnson
Jacqueline E. Moss--resigned 12-15-67
Judith K. Parker
Mary P. Reyes

Biological Aids:

Harvey M. Adams, Jr.
Francis D. Arthur
Ronald L. Garner--resigned 04-05-68
Donald W. Norman--military furlough 05-20-68
James N. Walker
Thurman D. Willis

Summer Temporary Aids and Technicians:

Biological Aids:

Charles W. Boardman
John S. Booker, Reedville, Va.
Clifford F. Cloutier, Jr., Morgan City, La.
Milford F. Crandall, Amagansett, N.Y.
Robert F. Daugherty, Wildwood, N.J.
Charles S. Dietrich, Jr., Port Monmouth, N.J.
Charles H. Fields, Wicomico, Va.
Doris M. Finan, Highlands, N.J.
Melvin W. Forbush, Reedville, Va.
Robert G. Gould
John P. Grady
Daniel W. Griffin, Jr., Fernandina Beach, Fla.
John L. Hatcher
Richard L. Jane, Fernandina Beach, Fla.
Richard E. Jett, Reedville, Va.
Katheryn L. Jones, Reedville, Va.
G. Otis Kirkham, Reedville, Va.
Lewis B. Lawrence
Bennie H. Moore
William H. Moore, III, Reedville, Va.
Michael N. Morris, Cameron, La.
Robert W. Murdoch
Jon S. Palmintier, Intracoastal City, La.
John R. Richardson, Cape Charles, Va.
Harold C. Rittenhouse, Reedville, Va.
William E. Skipper, Fernandina Beach, Fla.
Kenneth E. Smith, Southport, N.C.
Murphy Smith, Jr., Empire, La.
John L. Snipes
John B. Spotswood, Wicomico, Va.
Joseph F. Stahl, Jr., Port Monmouth, N.J.

*All personnel located at Beaufort, N.C., except as noted.

Jackie A. Sterling, Crisfield, Md.
Thomas A. Theobald, Fernandina Beach, Fla.
Joseph F. Ustach

Conservation Aids:

James E. Bennett
Arthur J. Drewyor
Clarence M. Innis
James D. McHoney
John D. Phillips

Technicians:

Andrew C. Conlyn, Reedville, Va.
John F. Hassell, Moss Point, Miss.
Marcus M. Sherman, Student Aid
Bonnie W. Tobin, Student Aid

Staff Services

Linda C. Antwine, Clerk-Stenographer
Virginia M. Evans, Biological Aid
Beverly A. Ferrier, Clerk-Stenographer--resigned 08-11-67
Kenneth J. Fischler, Fishery Biologist (Biometrics)
Correna S. Gooding, Clerk (Part-time)
Anna F. Hall, Librarian
Mary K. Hancock, Clerk
Suzanne R. Hill, Illustrator
Mary E. Horne, Clerk-Typist
Martha J. Huyler, Computer Programer--resigned 01-26-68
Inez J. Nierling, Clerk-Stenographer

Administration and Maintenance

Bernard G. Allred, Administrative Officer
Robert L. Carter, Laborer--terminated 12-28-67
Larry D. Collins, Student Aid
Claude R. Guthrie, Foreman (Repair and Maintenance)
Margaret M. Lynch, Clerk-Typist
Thelma P. Nelson, Administrative Assistant
Thomas R. Owens, Building Repairman
Willie S. Rainey, Mechanic Helper, Automotive
Clarence M. Roberts, Fishery Methods and Equipment Specialist
Jack S. Russell, Building Repairman
George J. Stamps, Student Aid

PUBLICATIONS

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NICHOLS, PAUL R.
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WALBURG, CHARLES H., and PAUL R. NICHOLS.
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