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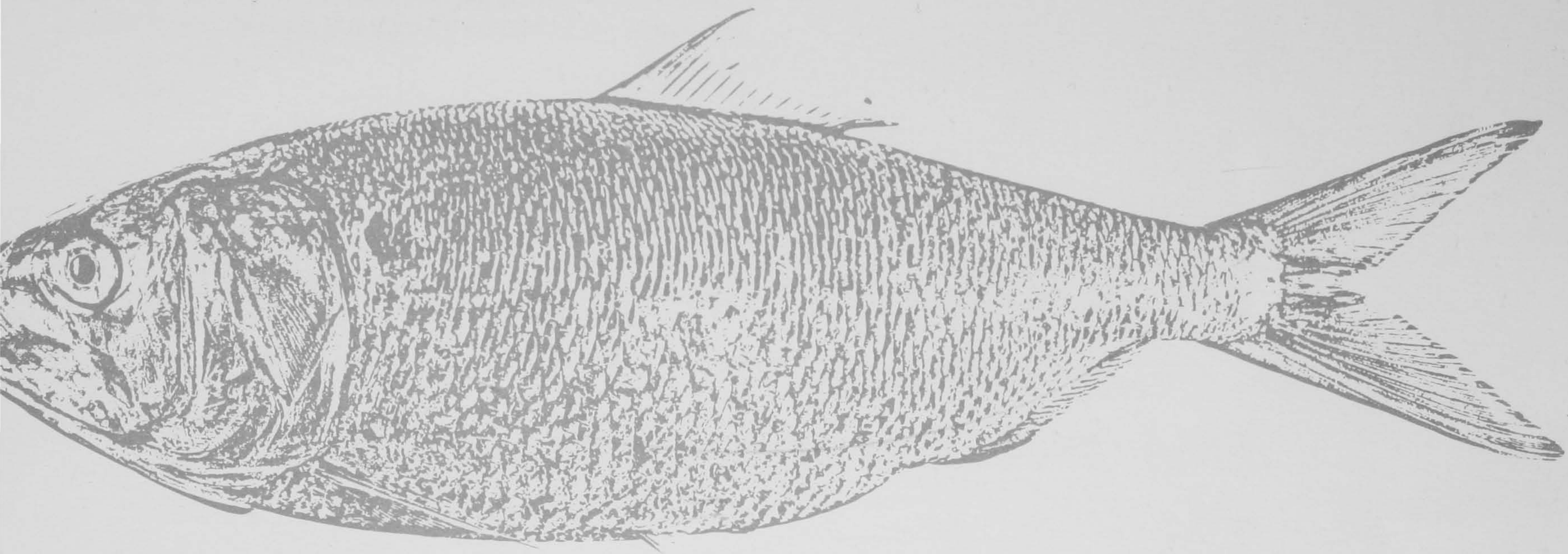

Research in Fiscal Year 1969 at the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.(

UNITED STATES DEPARTMENT OF THE INTERIOR
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Fred J. Russell, *Under Secretary*
Leslie L. Glasgow, *Assistant Secretary for Fish and Wildlife and Parks*
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Research in Fiscal Year 1969 at the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N.C.

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

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ABSTRACT

Research on blue crab, conducted for thirteen years at the Laboratory, is summarized briefly. Progress of research in the menhaden investigation–the life history, ecology, behavior-physiology, tagging, and population dynamics programs–is reported. Research in the Industrial Schoolfishes Program is reviewed.

REPORT OF THE LABORATORY DIRECTOR

In an attempt to provide a better balance between resource needs and State-Federal agency capabilities, the research at our Laboratory in fiscal year 1969 was shifted from blue crab to menhaden and thread herring.

The Laboratory's *Blue Crab Program,* which began in 1957 and ended this past fiscal year, contributed 26 scientific reports that we feel added significantly to man's understanding of this important resource. During this period we studied blue crab *(Callinectes sapidus)* migrations, distribution and abundance; food habits; and the age, size, species composition of crab populations from North Carolina to Florida. Knowledge obtained on the extent of blue crab development in the ocean and on the degree of intermixing of adult stocks will help concerned agencies develop management measures for an estuary or coastal region.

For more than a decade BCF (Bureau of Commercial Fisheries) has had a program of menhaden research at this Laboratory. Until 1964, practically all attention was directed at the Atlantic stocks. Since then, consideration has been given the Gulf resource, whose relative importance in the national menhaden fishery has increased with the marked drop in catches along the Atlantic coast.

In our menhaden studies, which are directed towards developing management guidelines, we need to determine the factors regulating the distribution and abundance of menhaden. To do this, program personnel: (1) study the location, time, and intensity of spawning, (2) evaluate how the environment affects the survival of eggs and larvae, (3) measure the relative size of year classes as larvae and as juveniles, (4) investigate schooling behavior, (5) identify migratory patterns, (6) define population characteristics, such as growth and mortality, (7) determine the age, size, and sex composition of the catches in order to estimate annual fishing intensity, and (8) assess the condition of stocks and establish the most favorable fishing rates.

During the year, our *Life History Program* used the collections of other organizations to obtain information on the distribution of eggs and larvae along the Atlantic and Gulf coasts. Spawning and the early development of Atlantic menhaden, *Brevoortia tyrannus,* occur in the ocean along the major portion of the Atlantic coast; some spawning occurs in every month in some locality from Cape Cod to Cape Kennedy. Most spawning apparently is off the middle Atlantic States from October to March. The eggs hatch about 2 days after spawning, and the young larvae are planktonic over the Continental Shelf for about 1 month before they enter estuaries.

In the northern Gulf of Mexico, data from 22 monthly cruises of the R/V *Gus III* and from 10 years of continuous sampling at Galveston Entrance provided the basis for establishing the precise time and place of spawning by the Gulf menhaden, *B. patronus.* Unlike the Atlantic menhaden, the Gulf menhaden is strictly a winter spawner, spawning from mid-October through late March. The main spawning grounds are in the offshore waters of Mississippi and eastern Louisiana between the 4- and 40-fathom depths.

Collections of larval Gulf menhaden at Galveston from 1959 to 1969 also provided information on the relative abundance of each year class during this period. The observed larval index consistently paralleled subsequent commercial landings. This year's index indicates that the 1968-69 year class is not as strong as the 1967-68 year class.

Our *Ecology Program* has as its subjects the movements of larvae from the ocean into estuaries and the use of estuaries by the developing year class of larvae and juveniles. This year, in the White Oak River, N. C., estuary, we measured a 68-fold increase over last year in the number of larvae immigrating from the ocean. This rise could possibly herald the development of a strong year class. Our annual juvenile-abundance estimates, which were expanded recently to cover 60 streams along the Atlantic and 36 streams along the Gulf, measure the numbers of young fish at a time closer to their entry into the commercial fishery and over a much greater geographical area than previous estimates. Collection of data for the 1969 year class estimates is still in progress, but along the Atlantic, the mean relative index of abundance of juvenile menhaden was more than three times greater in 1968 than in 1967. Compared to 1967, Gulf menhaden juveniles were twice as abundant in the western Gulf in 1967 and 68 times as abundant in the eastern Gulf.

The *Behavior and Physiology Program* began laboratory studies on rearing menhaden and developed approaches for studying the schooling behavior and migrations of menhaden in the natural environment. In the laboratory, considerable time was spent on the design and construction of a reliable open-flow sea-water system. When the system is completed, it will provide filtered, temperature- and salinity-controlled water to our rearing and behavior tanks.

We made a major advancement in our rearing-behavior studies when, for the first time, Atlantic menhaden were reared beyond the critical yolksac stage. Eggs, collected in the ocean off Beaufort, were hatched in the laboratory, and the larvae fed sea urchin blastulae and brine shrimp nauplii. The larvae were reared for more than 1 month–the largest was almost ½-inch long.

In an attempt to assess the role of salinity as a factor underlying the movement of larvae into and through estuaries, we exposed groups of larvae to either high or low salinity. The larvae, collected in the channel north of Pivers Island, were divided into two groups, high or low salinity, and reared into juveniles. Although growth was considerably better at high salinities, we suspect that experimental temperatures, which were higher than those in the upper estuary, inhibited growth of larvae in our fresh-water tank. Studies designed to separate the interactions of temperature and salinity should clarify this assumption.

In our studies of schooling and migratory behavior, we used a somewhat novel approach to obtaining information about these phenomena. Professional spotter pilots were interviewed and given logbooks to provide answers to the questions: What are the ideal conditions for seeing a school of Fish? Where is the school? What are the fish doing? Spotters stated that schools are most visible in the morning and evening and at slack water, and that not only are schools seen more often in certain areas, but larger menhaden occupy different areas than smaller ones. The suggestion that menhaden actively select habitats raises several questions that need to be answered experimentally.

Because the "swimways" (migration routes), spawning sites, and wintering areas of Atlantic menhaden are not known, we began joint studies with NASA-Wallops Island in December 1968 to obtain certain information about these aspects. Remote measurements of sea-surface temperatures from aircraft along the North Carolina-South Carolina coast during the winter revealed that whereas the major portion of Raleigh Bay was unfavorable for adult menhaden during 1 to 2 months, the surface waters of Onslow and Long Bays had large areas of favorable temperatures seaward of the 10-fathom line throughout the winter. The apparent absence of menhaden schools at the surface in the winter, together with observations of the success of Soviet vessels fishing on subsurface concentrations of coastal species similar to menhaden (Atlantic herring and Atlantic mackerel) during the winter, indicate that menhaden school at the surface in the summer and at depths in the winter.

In our *Tagging Program* we are determining patterns of migration and rates of dispersion, growth, and mortality. Since July 1966, our biologists tagged and released 913,000 Atlantic menhaden with internal metallic tags from New York to Florida. Over 124,000 of these tags were physically recovered on magnets in the menhaden plants. Our studies have reinforced previous assumptions and data on the general migration pattern of menhaden in the Atlantic. Recoveries to date clearly show that menhaden move north along the Atlantic coast in the spring and summer, and south in the fall. This migration is exemplified by recoveries in North Carolina, Virginia, and New Jersey of fish tagged in Florida, and by recoveries in North Carolina of fish tagged in New York, New Jersey, Delaware, Maryland, Virginia, Georgia, and Florida.

Estimates of fishing mortality from our studies indicate that the Atlantic menhaden resource is being subjected to an intense fishery in several States. For example, over 25 percent of the 322,342 menhaden tagged in 1967, including 42 percent of those tagged in Chesapeake Bay the same year, were recaptured by the end of 1968. It is evident that interstate regulation of the fishery will be necessary to produce the optimum annual harvest from the resource.

This year we began our mark-recapture studies of the Gulf menhaden in April with the release of over 27,000 fish in three different areas along the Gulf. Tag recovery magnets, which recovered nearly 600 tags by the end of this fiscal year, have been installed in all but one active plant. Preliminary results from our recoveries, which will continue throughout the fishing season, indicate that we shall have a sufficient number of tags to gain some insight to the migration and fishing mortality of Gulf menhaden.

Our *Population Dynamics Program* has two principal functions: (1) monitoring the Atlantic and Gulf menhaden fisheries, and (2) using the information gathered to form management recommendations for those fisheries. The 1968 Atlantic catch (259,000 tons) was slightly (20 percent) better than in 1967 but was still only 45 percent of the 1958-67 average. The number of vessels (59) and amount of effort (1,215 vessel weeks) both decreased in 1968. In 1968 the catch per vessel-week increased in most areas over 1967. The 1967 year class (1-year-old fish) appeared distressingly small, and in 1968 less than 5 percent of the fish caught were older than 3 years, whereas formerly even 6-year-old fish were fairly common in the catch.

The 1968 Gulf menhaden catch (410,000 tons) was 18 percent greater than in 1967. Though the fleet decreased by 7 vessels (to 78) from 1967 to 1968, the number of vessel weeks (1,520) remained about the same. The catch per vessel-week increased from 225 tons in 1967 to 270 tons in 1968. The catch was, as usual, made up principally of 1- and 2-year-old fish.

In general the Atlantic fishery has, over the past few years, shown greatly decreased total catches, decreased catch per unit of effort, and a decreased average age of fish caught. All of these trends indicate excessive fishing pressure. It is obvious that some action must be taken to protect the Atlantic menhaden and the industry it supports.

Although the Gulf fishery appears much healthier than the Atlantic fishery, we cannot afford to be complacent regarding its future.

The biology of *Industrial Schoolfishes Program* was administratively transferred from the BCF Biological Laboratory, St. Petersburg Beach, Fla., to the Beaufort Laboratory on January 3, 1969. Program personnel will continue to operate from the St. Petersburg Beach Laboratory.

As a result of 18 months of sampling with gill nets from our own vessel and of inspecting the commercial catches, we are beginning to understand basic migratory patterns and some of the life history of the Atlantic thread herring, *Opisthonema oglinum,* in the eastern Gulf of Mexico. Thread herring schools appear to move south in the fall, concentrate into larger schools during the winter, and move north and break up into smaller bodies in the spring as the water warms. Experimental catches were greatest in water between 81° and 84° F. Preliminary stomach analyses disclosed that thread herring have a diet primarily of copepods, supplemented by planktonic forms of clams, snails, and barnacles. Studies on gonad development revealed that spawning in the Fort Myers, Fla., area begins around March, peaks in June, and continues through August. Preliminary fecundity studies indicate that female thread herring produce from 19,000 to 50,000 ova. Mature ova are about 0.02 inch in diameter.

In August 1968, IBM installed an 1130 computer at the Laboratory, which provides services for both the biological and radiobiological laboratories. In addition to operating as a stand-alone computer, our new system also is linked by telephone to the Geological Survey's IBM 360/65 computer in Washington, D. C.

STAFF

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

BLUE CRAB PROGRAM

Donnie L. Dudley — Fishery Biologist (transferred to Menhaden Tagging Program 01-12-69)

Marlin E. Tagatz — Fishery Biologist (transferred to Menhaden Life History Program 01-12-69)

MENHADEN LIFE HISTORY PROGRAM

Fishery Biologists
- Paul L. Fore
- Thomas W. McKenney
- John W. Reintjes, Chief
- Marlin E. Tagatz

MENHADEN ECOLOGY PROGRAM

Fishery Biologists
- Brian S. Kinnear
- Robert M. Lewis
- William R. Turner
- E. Peter H. Wilkens

Biological Aid
- James N. Walker

MENHADEN BEHAVIOR AND PHYSIOLOGY PROGRAM

Fishery Biologists
- William F. Hettler, Jr.
- Richard W. Lichtenheld, Chief

MENHADEN TAGGING PROGRAM

Fishery Biologists
- Randall P. Cheek
- Linda C. Coston
- Robert L. Dryfoos, Chief
- Donnie L. Dudley
- Richard L. Kroger
- Eldon J. Levi
- Richard O. Parker, Jr.
- Paul J. Pristas
- Glenn B. Sekavec
- Roger H. Vopelak – Terminated 01-24-69

Biological Technicians
- Herbert R. Gordy
- Thurman D. Willis

Biological Aids
- Richard E. Jett – Terminated 01-31-69
- Henry D. MacFarlane
- John L. Snipes
- Jack G. Willis
- Willie H. Willis, Jr. – Terminated 12-27-68

MENHADEN POPULATION DYNAMICS PROGRAM

Fishery Biologists
- Robert B. Chapoton
- Charles P. Goodwin
- Gene R. Huntsman, Chief
- Mayo H. Judy
- William R. Nicholson

Biological Technicians
James F. Guthrie
George N. Johnson
Judith K. Parker – Resigned 02-14-69
Mary P. Reyes – Terminated 02-07-69

Biological Aids
Harvey M. Adams, Jr.
Francis D. Arthur
Ethel A. Hall
Robert R. Rankin – Resigned 12-06-68

BIOLOGY OF SCHOOLFISHES

Fishery Biologist
Charles M. Fuss, Jr.

Twenty-four temporary summer aids and technicians were employed in support of the above programs.

STAFF SERVICES

Automatic Data Processing
Kenneth J. Fischler, Fishery Biologist (Biometrics) – Resigned 01-27-69
William E. Schaaf, Biologist
Stanley M. Warlen, Fishery Biologist
John E. Hollingsworth, Computer Programmer
Cheryl H. Harris, Computer Technician
Mary K. Hancock, Clerk
Virginia M. Evans, Biological Aid
Correna S. Gooding, Clerk – Resigned 02-14-69

Clerical
Inez J. Nierling, Clerk-Stenographer
Linda C. Antwine, Clerk-Stenographer
Lynda C. Kauth, Clerk-Typist

Librarian
Anna F. Hall

Illustrator
Suzanne R. Hill – Resigned 06-03-69

ADMINISTRATION

Bernard G. Allred, Administrative Officer
Thelma P. Nelson, Administrative Assistant
Mary E. Horne, Clerk-Typist
Margaret M. Lynch, Clerk-Typist

MAINTENANCE

Claude R. Guthrie, Foreman (Repair and Maintenance)
Thomas R. Owens, Building Repairman
Jack S. Russell, Building Repairman
Willie S. Rainey, Maintenanceman
Clarence M. Roberts, Fishery Methods and Equipment Specialist – Retired 12-09-68
Glenwood P. Montgomery, Helper General

MEETINGS AND TRAINING PROGRAMS

American Institute of Biological Sciences, Columbus, Ohio - Robert L. Dryfoos, September 3-7, 1968.

IBM System 360 OS Language Interface Course, Washington, D. C. - Kenneth J. Fischler, John E. Hollingsworth, Stanley M. Warlen, September 23-27, 1968.

I.C.E.S. 56th Meeting, Pelagic Fish (Southern) Committee and Symposium On Early Life History of Herring and Recruitment, Copenhagen, Denmark - Kenneth A. Henry, October 1-4, 1968.

Atlantic Estuarine Research Society Workshop, Morehead City, N. C. - most of the staff, October 3-5, 1968.

American Fisheries Society, Southern Division Meeting, Baltimore, Md. - Mayo H. Judy, Brian S. Kinnear, Marlin E. Tagatz, and William R. Turner, October 21-23, 1968

Atlantic States Marine Fisheries Commission, Durham, N. C. - Kenneth A. Henry, October 28-30, 1968.

U.S. International Biological Program Thermal Workshop, Solomons, Md. - William F. Hettler, Jr., Gene R. Huntsman, and Robert M. Lewis, November 4-7, 1968.

Gulf and Caribbean Fisheries Institute, Miami, Fla. - Paul L. Fore, November 17-21, 1968.

BCF Acoustical Workshop, Seattle, Wash. - Brian S. Kinnear, November 25-27, 1968.

Scientific Exploration of the Atlantic Shelf Workshop, Annapolis, Md. - William R. Turner, December 16-17, 1968.

Earth Observations from Balloons Symposium, Washington, D. C. - Richard W. Lichtenheld, February 3-8, 1969.

American Fisheries Society, Northeast Fish and Wildlife Conference, White Sulphur Spring, W. Va. - Eldon J. Levi, Paul J. Pristas, and Glenn B. Sekavec, February 9-12, 1969.

North Carolina Fishery Biologists, Raleigh, N. C. - Robert B. Chapoton, Randall P. Cheek, William F. Hettler, Jr., Gene R. Huntsman, Brian S. Kinnear, Richard L. Kroger, William R. Nicholson, Richard O. Parker, Jr., and John W. Reintjes, February 20, 1969.

National Fish Meal and Oil Association Meeting, Old Point Comfort, Va. - Robert L. Dryfoos and Kenneth A. Henry, February 23-24, 1969.

North American Wildlife and Natural Resources Conference, Washington, D. C. - William R. Nicholson, March 3-5, 1969.

Regional Administrative Workshop, St. Petersburg, Fla. - Bernard G. Allred, March 11-13, 1969.

Computer 1130 Executive Course, Poughkeepsie, N. Y. - Kenneth A. Henry, March 18-21, 1969.

Geological Society of America Southeastern Section, Columbia, S. C. - Marlin E. Tagatz, April 9-12, 1969.

Regional Staff Conference, St. Petersburg Beach, Fla. - Kenneth A. Henry, April 15, 1959.

Atlantic Estuarine Research Society, Ocean City, Md. - Linda C. Coston, Marlin E. Tagatz, and Stanley M. Warlen, April 25-26, 1969.

North Carolina Academy of Science Meeting, Wilmington, N. C. - Robert B. Chapoton, Randall P. Cheek, Richard L. Kroger, and John W. Reintjes, May 2-3, 1969.

Population Dynamics Workshop, Seattle, Wash. - Robert L. Dryfoos, Kenneth A. Henry, and Gene R. Huntsman, May 5-9, 1969.

Florida Senate Natural Resources Committee at State Capitol, Tallahassee, Fla. - Charles M. Fuss, Jr., June 2, 1969.

PUBLICATIONS

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1968. The American shad. U.S. Fish Wild. Serv. Fish. Leafl. 614, 13 pp.

FUSS, CHARLES M., JR., JOHN A. KELLY, JR., AND KENNETH W. PREST, JR.

1968. Gulf thread herring: Aspects of the developing fishery and biological research. Proc. Gulf Carib. Fish. Inst. 21st Annu. Sess., pp. 111-125.

LEWIS, ROBERT M., and WILLIAM F. HETTLER, JR.

1968. Effect of temperature and salinity on the survival of young Atlantic menhaden, *Brevoortia tyrannus.* Trans. Amer. Fish. Soc. 97: 344-349.

TAGATZ, MARLIN E.

1968. Growth of juvenile blue crabs, *Callinectes sapidus* Rathbun, in the St. Johns River, Florida. U.S. Fish Wildl. Serv., Fish. Bull. 67: 281-288.

TURNER, WILLIAM R.

1969. Life history of menhadens in the eastern Gulf of Mexico. Trans. Amer. Fish. Soc. 98: 216-224.

WARLEN, STANLEY M.

1969. Additional records of pugheaded Atlantic menhaden, *Brevoortia tyrannus.* Chesapeake Sci. 10: 67-68.

BLUE CRAB PROGRAM

Marlin E. Tagatz and Donnie L. Dudley

This report summarizes the major areas of work and some of the findings of the blue crab program, which began in 1957 and ended early in 1969. Funds for blue crab research at Beaufort were reduced in 1967 and again in 1968. Because reduced funds in FY 1969 permitted no research, the two remaining staff members prepared summary reports of past studies and an annotated bibliography on the commercial fishery and the biology of blue crabs. The program resulted in 26 scientific reports either published or recently submitted for publication.

BCF began its studies on the blue crab at the Beaufort Laboratory in 1957 by giving a contract to the Oyster Institute of North America for a study of larval growth and development. Before the contract expired in 1958, J. D. Costlow, Jr. and C. G. Bookhout at the Duke University Marine Laboratory succeeded in rearing crabs from the egg to the adult. This work was of particular value, because for the first time, all stages of the crab could be recognized when caught. With the curtailment of the shad program at Beaufort, new, though limited, research on blue crab was initiated and conducted at our Laboratory from 1957 to 1960. Studies of movement and population size were carried out in the Neuse and Newport Rivers of North Carolina and, in cooperation with the Bears Bluff Laboratory, in several rivers of South Carolina. The population size of blue crabs in the Neuse River was estimated by the use of data on catch-effort, catch-sampling, and tagging. Tagging in South Carolina indicated that adult crabs undertook little movement between estuaries and that management measures can probably be confined to individual estuarine systems rather than large coastal regions.

In 1960, additional funds and personnel made possible a long-range investigation of the blue crab. The research included a contract with Duke University (1960-65), and work in Florida (1961-66) and in North Carolina (1960-68).

A contract with the Duke University Marine Laboratory provided for an experimental study of how the environment affects survival of young crabs. Factors investigated were the variations in the anatomy of each larval stage, oxygen consumption, amino acid content, nitrogen content (used to compare metabolic rates), and the effects of salinity, temperature, and diet on growth and development.

To study the biology of the blue crab in the St. Johns River, Fla., a field laboratory was established at Green Cove Springs. An intensive 2-year survey on catch and effort of the commercial fishery revealed that market conditions, migrations, and population size are the main factors that determine the size of the catch. Recaptures of crabs tagged in the ocean and river indicated that both sexes make considerable movements and also that large numbers of females from the ocean return to estuaries to spawn a second or third time. Blue crabs over ½-inch wide congregated where food was plentiful and generally ate the same types of food regardless of crab size, area, and season. The effects of season and salinity on growth were studied to provide an estimate of the time required for crabs of any particular size to reach harvestable size.

Work in the inland and offshore waters near Beaufort, N. C., and much of the work in the St. Johns River involved all life history stages. Larval crabs of the genus *Callinectes* (includes the blue crab and some noncommercial species) were sorted from the ocean plankton collections of *Theodore N. Gill* cruises, 1953-54, and from our collections obtained near the mouths of estuaries. Early-stage zoeae (larval stages consist of seven zoeal forms and one megalops) were abundant in the estuaries and near the beaches, advanced stages and megalops were more common offshore, and mixed larval stages were in the greatest numbers 20 miles offshore. Collections in blue crab nursery areas revealed that small postlarval crabs do not begin to appear in the

Figure 1.—Adult male blue crab.

estuary in significant numbers until about 6 months after hatching has begun. They enter in large groups after metamorphosis from megalops larvae and several molts as crabs, and the influx may continue as late as December. This delayed entry into the estuary is significant because it indicates a much longer oceanic existence than was previously supposed. The protracted period of oceanic life would allow the young crabs to be transported long distances from where they were hatched.

Three years of sampling (1965-67) for the relative abundance of juvenile blue crabs in Core Sound, N. C., indicated that crabs less than 1½ inches wide reach a peak abundance in the estuary in January, February, and March. The observed regularity of the influx suggests that it should be possible to establish an index of abundance for a year class by sampling only during these 3 months. The methods developed to estimate juvenile abundance, together with knowledge we hoped to obtain on the factors that influence the time and the size of the influx of young crabs into the estuary, were to be used to predict future fishing success.

Tagging studies (1960-65) in two rivers, two sounds, and two ocean areas showed that in North Carolina the adult blue crabs do not have the type of migrations that would make any particular stock available to a succession of fisheries along the coast. Migrations are primarily limited to the random movements of males within the estuary and the movement of females between the estuary and the immediately adjacent ocean areas. In North Carolina, the fishery for crabs in a particular system depends for its success on the number of crabs that reach maturity within that system.

Laboratory experiments were made (1966-68) at Beaufort on the survival requirements of juvenile and adult blue crabs. Blue crabs, depending on their sex and stage of sexual development, display preferences for certain portions of estuaries. Determinations of blood osmotic concentrations over a range of salinities indicated that the distribution of the crabs within an estuary generally was not determined by varying ability to adapt (by adjusting their internal chemistry) to different salinities. Results of other experiments, which provided estimates of the upper and lower lethal thermal limits of adults and juveniles, should be correlated with field observations (1) to develop guidelines to judge effects of powerplants, and (2) to determine when a specific temperature in nature reaches or has reached lethal levels.

Figure 2.—Commercial blue crab fishery boat loaded with crab pots, Marshallberg, N.C.

MENHADEN LIFE HISTORY PROGRAM

John W. Reintjes, Chief

The life history program is concerned with reproduction, development, and growth of Atlantic and Gulf menhadens in the ocean and in estuaries. Spawning, hatching, and early development take place in the ocean. Metamorphosis into juveniles and their development and growth into subadults occur in estuaries. A critical period in the life cycle of menhaden is the interval from hatching until the larvae establish themselves in the estuary. Another begins with transformation into juveniles and their survival during the first summer of life. It is these early developmental stages that our program seeks to understand more fully.

Our two projects are directed toward (1) determining the times and places of spawning along the Atlantic and the Gulf, and (2) detailing the developmental changes in the early life stages.

LIFE HISTORY OF ATLANTIC MENHADEN

Thomas W. McKenney

The early phases of the life of the Atlantic menhaden are spent at sea along the Atlantic coast of the United States. Spawning takes place in late spring and summer off New England, in fall, winter, and early spring off the Middle Atlantic and Southern States, and probably in winter off Florida. The eggs hatch about 2 days after spawning. Newly hatched larvae are between 1/8-and 1/4-inch long. They probably spend about a month in the waters over the Continental Shelf and then enter the estuarine nurseries. Beyond these broad features, we know little about the spawning and the early days of menhaden life.

Systematic collections for spawning adults, eggs, and early larvae over large areas during several years would provide much important information about this part of menhaden life. Until this material is available, however, we can make use of whatever collections and opportunities to collect that we have. This year we participated in three cruises.

In December (9-12) we were allowed to use the *Advance II,* the training vessel of the Cape Fear Technical Institute, Wilmington, N.C., along with its crew and 75 students. We collected 80 plankton samples between Cape Fear and Cape Lookout, N.C., along a track between the 12-fathom curve and the edge of the Continental Shelf, but took no menhaden larvae or eggs.

In mid-January (13-17) we used the *Advance II* for a similar cruise between Cape Fear and Cape Romain, S.C. A few infertile eggs taken about 80 miles south of Cape Fear on the 50-fathom curve may be menhaden eggs. Menhaden larvae were taken at 24 of 91 stations, but no great concentrations were encountered. Of 466 menhaden larvae, 337 were from three stations on the 18-fathom curve.

In March (18-22) we participated in an operation involving the USCG cutter *Chilula* and the NASA vessel *Range Recoverer.* We got two plankton samples from each of 58 stations between the 12- and 100-fathom curves. The northernmost station was about 20 miles east of Cape Hatteras; the southernmost, about 60 miles east of Charleston, S.C. No menhaden eggs were found in these samples, but 19 of the stations yielded a total of 349 menhaden larvae. The southernmost station provided the most–103. This station also provided more larvae of other fish species than other stations of the cruise. The most likely explanation is that this station was the only one of the cruise that was occupied at a time after sunset when more fish larvae are commonly taken by plankton nets than during daylight.

In general the data from these cruises tend to confirm those from past cruises and strengthen our faith in the meager knowledge that we have of the early life history of the Atlantic menhaden.

LIFE HISTORY OF GULF MENHADEN

Paul L. Fore

An understanding of the early phases of the life history of the Gulf menhaden was improved by three studies during the past year that were directed toward (1) determining the temporal and spatial distribution of Gulf menhaden eggs and larvae in 1965, (2) delimiting the time of entry and abundance of larval menhaden that were moving to estuarine nursery areas at Galveston Entrance from 1959 through 1969, and (3) describing the oceanic approach of menhaden larvae within a 20-mile radius of Galveston Entrance. Biological material for these studies consisted of plankton samples from the northwestern Gulf of Mexico that were collected by the BCF Biological Laboratory at Galveston, Tex., during various investigations of larval shrimp.

Time and Place of Spawning

In 1965, the R/V *Gus-III* sampled plankton at 41 stations on each of 10 monthly cruises. There were no cruises in July and November. The station pattern, in eight tiers or rows of three to six stations each, were established in relation to bottom depths. The first station of each tier was at a water depth of 24 feet, whereas the other stations progressed seaward to depths of 45, 90, 150, 240 feet, and, at two stations to 360 feet. Because of the abrupt slope of the ocean floor at the edge of the Continental Shelf, the outermost sampling sites were only a short distance from the 600-foot curve. This station pattern gave a wide coverage of the area over the Continental Shelf from the Mississippi Delta to the United States/Mexico boundary. All collections were taken with a Gulf-V plankton net that was hauled for 20 minutes in step-oblique tows extending from near the bottom to the surface.

Altogether 361 samples were sorted for menhaden eggs and larvae. Table 1 summarizes the results of the 1965 cruises. During the entire year, 18.6 percent of the samples contained either eggs or larvae, or both stages. During the spawning season, 46.2 percent of the samples contained the early stages of the Gulf menhaden.

The oceanic distribution of eggs and larvae revealed that most spawning had occurred in offshore waters near the Mississippi River Delta. It was not possible to determine the exact beginning of the spawning season from these data, because no stations were occupied in November (table 1). The presence of larvae in the early December samples, however, and the capture of larvae at Galveston Entrance in November justified the inference that spawning began in October and continued through March. The 1965 cruise data essentially verified previous observations that were obtained from the 12 *Gus-III* cruises in 1963. Because the 1963 data were reported in last year's annual report and closely resemble the 1965 data, no further analyses are given here.

Movements of Larvae Through Galveston Entrance

Semiweekly plankton samples were taken from one of two sites at Galveston Entrance from 1959 to 1969. The first site was near the south jetty on the sand flats of Galveston Island. Following the

Table 1.--Distribution of eggs and larvae of Gulf menhaden in the northwestern Gulf of Mexico, 1965

Month	Galveston, Tex., to Mexico				Galveston, Tex., to Mississippi River Delta			
	Stations occupied	Positive samples	Eggs	Larvae	Stations occupied	Positive samples	Eggs	Larvae
	Number	Number	Number	Number	Number	Number	Number	Number
Jan.	19	4	6	6	20	12	460	405
Feb.	20	8	4	84	11	7	54	388
Mar.	19	7	36	218	21	15	26,306	162
Apr.	20	0	0	0	21	0	0	0
May	20	0	0	0	21	0	0	0
June	20	0	0	0	21	0	0	0
July	--	--	--	--	--	--	--	--
Aug.	20	0	0	0	21	0	0	0
Sept.	14	0	0	0	19	0	0	0
Oct.	--	--	--	--	19	0	0	0
Nov.	--	--	--	--	--	--	--	--
Dec.	19	7	414	170	16	7	50	72

destruction of this site by Hurricane Carla in 1961, all subsequent samples were obtained at a second site between the north jetty and the Fort Travis ruins on Bolivar Peninsula.

The sampling gear was a 5-foot wide, hand-drawn beam trawl. It had a plankton net at its cod end and wings constructed of nylon netting.

A standard procedure was followed during each collection. One end of a 150-foot line was tied to a stake driven into the sand at the edge of the water. The collector held the bitter end of the line in one hand and the bridle of the trawl in the other. The gear was then pulled along the bottom in a semicircular arc from the shoreline. An average tow of 5 minutes strained 2,477 cubic feet of water. All tows were made in daylight.

A total of 883 plankton samples from Galveston Entrance was sorted for menhaden larvae. Table 2 gives the mean number of larval menhaden captured per month and the number of tows for 1959-69.

The period that menhaden larvae migrate through passes and inlets to nursery areas serves as a dependable indication of the length of the spawning season. Because newly spawned larval menhaden require about 4 to 5 weeks to move from the spawning areas to the inlets, we may infer that spawning in the northern Gulf of Mexico is about 1 month before the first larvae are captured and ceases 1 month earlier than the last date of capture in the spring. The data in table 2, which were collected during 10 consecutive spawning seasons, show that menhaden larvae consistently migrate through Galveston Entrance during a 6-month period. Generally, menhaden larvae were first captured in November. Their numbers increased from December to February and usually reached a peak in March and April. The presence of migrating larvae in Galveston Entrance during the cold months showed that the annual spawning season of the Gulf menhaden was the same in the northwestern Gulf of Mexico from 1959 through 1969.

The lengths of the spawning seasons, interpreted from the dates of collection, are listed in table 3. The date that larvae first entered the estuary in 1959, 1967 and 1968 is not known because of the lack of sampling in November and December (table 1). Disregarding these 3 biological years, we find that menhaden larvae were captured during an average duration of 25.3 weeks over seven spawning seasons.

The mean total lengths of larval menhaden from Galveston Entrance for each month were nearly 0.3 inch shorter in November and December than those collected later in the winter. Generally, size varied little among the larvae in a given month. The gradual monthly increase in the size of the larvae suggests that adult menhaden spawn close to shore in October and then gradually move out into the Gulf as the spawning season progresses. The prevailing currents off the Texas coast flow northwesterly at this time of year, thus, 0.6-inch menhaden larvae moving through Galveston Entrance in November apparently travel a shorter distance from the main spawning grounds in Louisiana waters than do the 1.1-inch fish that are captured from January through April.

Table 2.--Mean number of Gulf menhaden larvae per standard tow per month at Galveston Entrance, 1959-69

[Number of tows in parentheses]

Month	Years									
	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69
	Number									
Aug.	-	0 (9)	0 (6)	0 (9)	0 (9)	0 (8)	0 (9)	0 (9)	0 (9)	0 (9)
Sept.	-	0 (9)	0 (4)	0 (8)	0 (8)	0 (9)	0 (8)	0 (9)	0 (9)	0 (9)
Oct.	-	0 (9)	3 (10)	0 (9)	<1 (9)	<1 (9)	0 (9)	0 (9)	0 (9)	0 (9)
Nov.	0 (2)	20 (8)	3 (9)	<1 (9)	10 (7)	2 (8)	9 (9)	<1 (7)	0 (3)	0 (2)
Dec.	17 (4)	121 (9)	25 (8)	21 (9)	17 (8)	5 (9)	6 (9)	8 (9)	-	0 (1)
Jan.	90 (7)	180 (9)	36 (9)	11 (9)	29 (9)	8 (8)	46 (8)	19 (9)	68 (3)	149 (3)
Feb.	27 (6)	252 (7)	19 (8)	10 (8)	477 (8)	68 (8)	696 (8)	16 (8)	54 (9)	128 (7)
Mar.	186 (6)	51 (8)	58 (9)	73 (8)	64 (9)	115 (9)	73 (10)	59 (10)	319 (7)	71 (7)
Apr.	12 (8)	12 (7)	80 (8)	11 (8)	198 (6)	<1 (9)	61 (9)	259 (8)	4 (9)	64 (9)
May	0 (5)	0 (2)	0 (9)	0 (9)	2 (9)	0 (8)	<1 (9)	<1 (9)	<1 (9)	1 (9)
June	0 (8)	-	0 (9)	0 (8)	0 (9)	0 (9)	0 (9)	0 (9)	0 (8)	-
July	0 (8)	-	0 (9)	0 (7)	0 (7)	0 (9)	0 (8)	0 (8)	0 (9)	0

Table 3.--Duration of movement of larval Gulf menhaden through Galveston Entrance, 1959-69

Spawning season	Inclusive dates of collection[1/]	Inclusive number of weeks
1959-60	-- - 4/15	--
1960-61	11/7 - 4/21	24
1961-62	10/16 - 4/23	27
1962-63	11/13 - 4/5	21
1963-64	10/15 - 5/7	29
1964-65	10/30 - 4/16	24
1965-66	11/12 - 5/10	26
1966-67	11/1 - 5/1	26
1967-68	-- - 5/6	--
1968-69	-- - 5/8	--

1/ Initial dates of entry were missed in 1959, 1968, and 1969 because of no sampling.

The spatial distribution of menhaden eggs in the northwestern Gulf in 1963 and 1965 supports this conclusion that the adults spawn further offshore as the season progresses.

Annual indexes of larval abundance were obtained by taking the mean of the monthly means from November through April during 10 seasons, 1959-69. Figure 3 shows the relative indexes of abundance. Collections in October and May were not included because of the sporadic capture of larvae during these 2 months.

The data indicated that the strongest year classes developed during the 1960-61, 1963-64, 1965-66, and 1967-68 spawning seasons. The commercial catch of menhaden from the Gulf reflected these findings since 1-year-old fish constituted the dominant age group in the landings in 1965, 1967, and 1969. Information on the age composition of the landings before 1964 was not available. The larval index of abundance suggested that the 1969 year class was smaller than the 1968 year class and that 1-year-old-fish probably will not dominate the catch and the

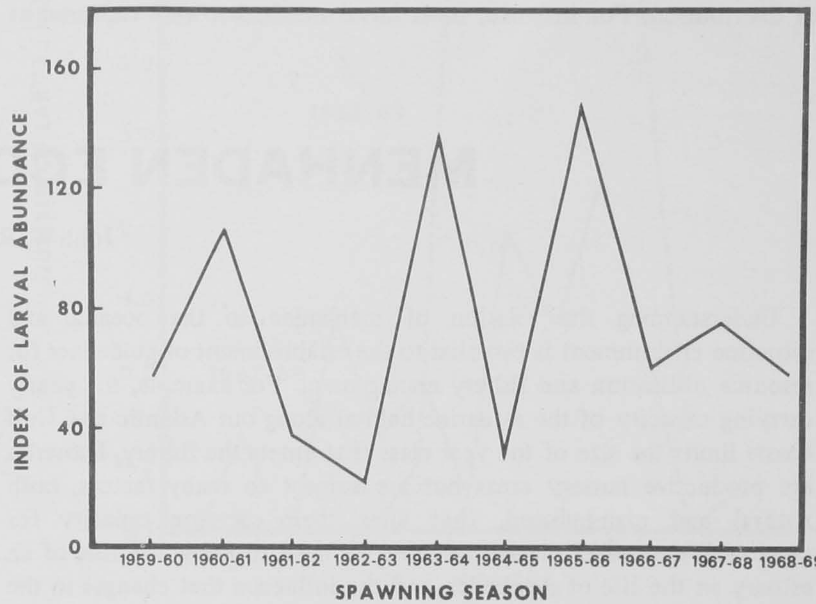

Figure 3.—Annual index of relative abundance of Gulf menhaden larvae at Galveston Entrance, 1959-69.

1970 fishing season. The fact that trends in year-class strength may be obtained by systematically sampling the abundance of larval menhaden in the passes warrants further investigation to increase the reliability of this technique.

Approach of Larvae to a Coastal Inlet

From March 1959 through March 1960, about 900 plankton samples were obtained in the Gulf within a 20-mile radius of Galveston Entrance and examined for menhaden larvae. These collections were from 16 offshore stations arranged in four tiers of four stations each extending seaward from the inlet. Metered plankton tows were made with a Gulf-V net at three depths—5 feet, 20 feet, and occasionally, on the bottom. About 1,500 concurrent samples from six stations within Galveston Entrance remain to be sorted for menhaden larvae.

Preliminary analysis of the Gulf samples indicated distinct patterns of distribution. For instance, most larval menhaden were captured at the intermediate depth, some specimens were taken at the surface, but only a few were obtained near the bottom. Thus, a preferred depth was evident during daylight.

We anticipate that these radial and entrance collections will supply data on the oceanic approach of larval menhaden, on their movement through this inlet into Galveston Bay, and on some of the environmental factors that may influence their entrance behavior.

Most important points in the new information now available on the oceanic and estuarine phases of the early life history of the Gulf menhaden are: (1) the main spawning grounds are in the offshore waters near the Mississippi River Delta, (2) corroboration from oceanographic and inlet collections establishes that this species normally spawns from October through March in the northwestern Gulf of Mexico, and (3) the collection of larvae at selected inlets may be used to obtain an early estimate of the relative size of the incoming year class. Knowledge of these biological aspects of this commercial species contributes to an understanding of success of spawning survival of larvae, and the subsequent strength of individual year classes.

MENHADEN ECOLOGY PROGRAM

John W. Reintjes, Chief

Understanding the relation of menhaden to the oceanic and estuarine environment is essential to the establishment of guidelines for resource utilization and fishery management. For example, the yearly carrying capacity of the estuarine habitat along our Atlantic and Gulf coasts limits the size of the year class that enters the fishery. Estuaries are productive nursery areas but are subject to many factors, both natural and man-induced, that alter their carrying capacity for menhaden and other marine animals. We need to know the role of an estuary in the life of menhaden and the influence that changes in the estuarine habitat exert on the menhaden resource. To advance our understanding, we must first estimate the numbers of young menhaden entering and leaving estuaries, and record the environmental conditions at various levels of population.

Our larval abundance project (1) estimates the number of larvae that enter a specific estuary and (2) determines the time of entry and movement pattern of larvae in this selected estuary. Our juvenile abundance project makes trawl and aerial surveys in 60 streams along the Atlantic and in 36 streams along the Gulf to (1) estimate the relative numbers of juveniles and (2) develop indexes of year-class strength. These studies should furnish guidelines for better use of the resources and estuaries.

ESTIMATION OF LARVAL ABUNDANCE

Robert M. Lewis and E. Peter H. Wilkens

During the year, we concentrated our sampling for young menhaden on the Bogue Inlet-White Oak River system in eastern North Carolina. Our aims were to assess the relative abundance, movements, and growth rates of young menhaden in the estuary. Sampling from our Beaufort Laboratory bridge in the Newport River estuary was discontinued because a new bridge was built.

Menhaden enter Bogue Inlet as larvae and then, as they grow, gradually move from the lower estuary to the nursery grounds upstream. By the time they reach fresh water they have transformed into juveniles.

We sampled regularly, November through April, during the time of larval immigration to the White Oak River. Our sampling site was at the Swansboro, N.C., bridge, about 3 miles from the inlet. Collections were made with our standard channel net once or twice a week; four to six sets were made on a sampling day. The abundance of menhaden was expressed as a larval index–the number of larvae per 3,530 cubic feet of water. We also measured water velocity, temperature, and salinity.

The number of larvae caught inside Bogue Inlet this year indicated that relative abundance was much greater than during the previous year (fig. 4). The sum of the biweekly mean larval indexes for the present season, 1968-69, was 570.9 as compared with 8.4 for 1967-68–about a 68-fold increase in abundance. The highest catches of larvae were made during March of both years. The peak index for 1968-69 was 3,582.0 as compared with 20.7 for 1967-68.

Atlantic menhaden larvae may take a few days to several weeks to reach a specific ocean inlet from the offshore spawning grounds. During this time, many biological and environmental factors affect their abundance. Once the young menhaden reach the inlet and enter the lower estuary, temperature, particularly when it is less than 50° F., has an important effect on the survival of larvae. Water temperatures at the Swansboro bridge during the two sampling seasons showed a similar trend each year, except for December. The mean water temperature in December 1968 was 46.5° F., whereas that for December 1967 was

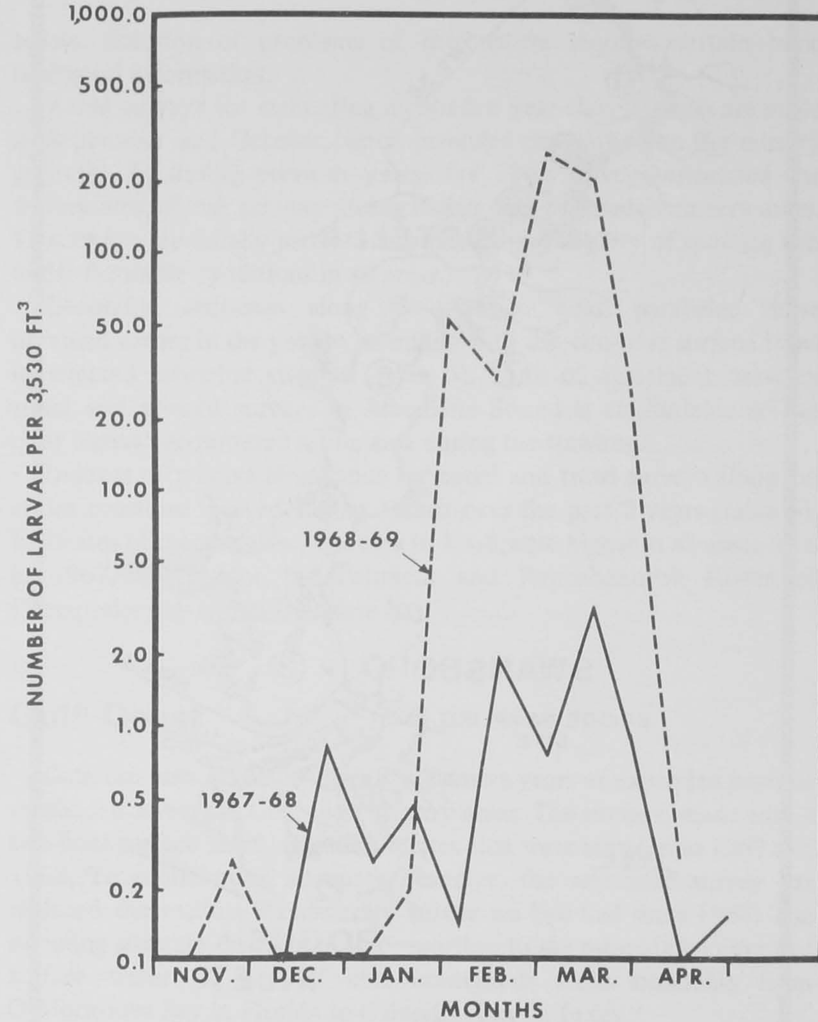

Figure 4.–Relative abundance of Atlantic menhaden larvae in the White Oak River near bridge at Swansboro, N.C., 1967-68 and 1968-69, based on average daytime catches during 2-week intervals.

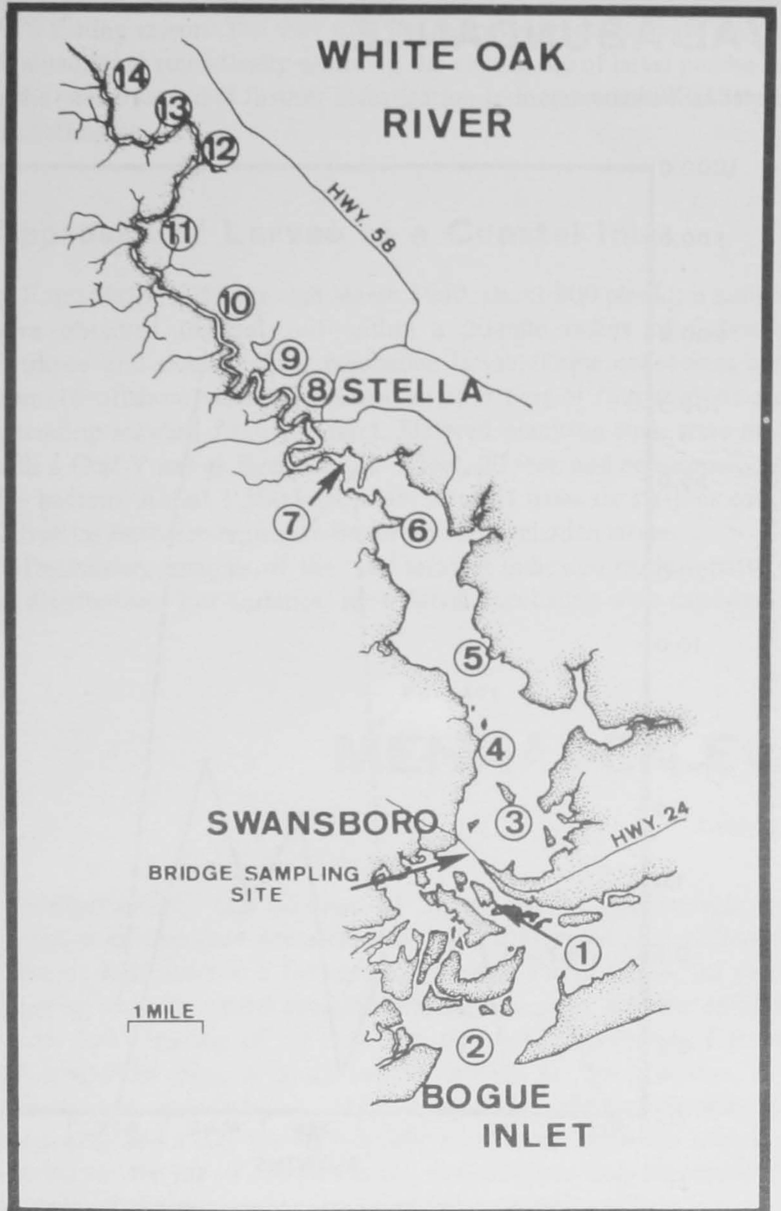

Figure 5.—White Oak River, N.C., with sampling locations.

54.8° F. The colder water may have caused the low level of abundance of menhaden larvae in December 1968.

We also studied growth and distribution of young manhaden in the White Oak River. Starting at the end of February, we established additional stations throughout the White Oak River. These new stations covered an area from the inlet to about 28 miles upstream (fig. 5). We chose stations so that samples of fish would be obtained from each salinity and fresh-water zone. The net at the Swansboro bridge was stationary, but at the other stations within the river, we towed our standard channel net between two boats. Water velocity, temperature, and salinity were recorded at each station.

We found young menhaden as far as 22 miles upstream from Bogue Inlet, about 7 miles into the fresh-water zone. Menhaden were most abundant at stations 6 through 9; our effort accordingly concentrated at these areas.

By comparing the numbers and developmental stages of young menhaden in our catches with the salinity at each sampling site, we found that (1) young menhaden concentrate at the interface of the fresh water and salt water and (2) these fish are distributed by developmental stage within the salinity gradient. The highest catches of menhaden, made in the zone of this interface, generally consisted of several thousand fish. The width of the interface varies because of the influence of tide and weather. Upstream from this zone, we usually caught less than 100 fish, and as the distance from the interface increased, the catch decreased. Young menhaden apparently seek a specific salinity zone depending on their developmental stage. The larger, more advanced menhaden were found in the more saline water of the interface. Young menhaden found in the less saline and fresh waters were generally smaller and in an earlier stage of metamorphosis.

ESTIMATION OF JUVENILE ABUNDANCE

William R. Turner and Brian S. Kinnear

Numbers of juvenile menhaden are estimated annually along the Atlantic and Gulf coasts to provide indexes of abundance and to guide the industry in planning fishing operations. We obtain the estimates by sampling with a two-boat surface trawl in estuarine nursery areas during the summer and by surveying fish schools from the air as menhaden emigrate from estuaries in the fall.

Atlantic Coast

Estimates of juvenile menhaden abundance on the Atlantic coast have been based upon a 10-stream survey since 1962. Indexes of abundance derived from sampling in these 10 streams in 1968 indicated an increase in the number of juveniles over 1967, but the small number of survey sites and the scarcity of fish in the samples lessens the reliability of the estimates (table 4). In 1968, the sampling base was strengthened considerably by increasing the number of survey sites to 60. These sites were distributed in proportion to the estimated amount of estuarine surface waters in the same geographic area previously covered by the 10-stream survey, i.e. from Cape Cod, Mass., to Fernandina Beach, Fla. Catches from the expanded surveys will be reported after we have 2 years of data.

Although the increased sample size added some productive sites, catches still were small in many streams. In accordance with our observations in the Gulf, most of the small catches were associated with clear waters. This relation constitutes a sampling problem that must be overcome to satisfy a basic assumption underlying surveys of this nature; catches from each stream must be representative of the population density within that stream. The effectiveness of sampling during darkness in clear-water streams of the Gulf already has been established and should be studied in certain areas of the Atlantic. In addition to water clarity, other factors influencing the distribution of menhaden within nursery areas continue to be perplexing along both coasts. Solution of problems of this nature requires certain basic ecological information.

Aerial surveys for estimating menhaden year-class strength are made in September and October, when juveniles emigrate from the nursery grounds. As during previous years, the 1968 surveys estimated the surface area of fish schools during flights over menhaden nursery areas. Two flights are usually made to improve the probability of spotting fish under favorable conditions in all areas.

Generally, estimates along the Atlantic coast paralleled those obtained earlier in the year by sampling with the two-boat surface trawl in selected estuarine streams (table 5). Lack of agreement between aerial and ground surveys in Albemarle Sound is attributable to the clear waters encountered in the area during the trawling.

Indexes of relative abundance for aerial and trawl surveys along the entire coastline showed similar trends over the past 2 years (table 6). Estimates of menhaden school area in 1968 were higher in all areas than in 1967, except for the Patuxent and Rappahannock Rivers of Chesapeake Bay and in Delaware Bay.

Gulf Coast

Data are now available from 2 successive years of expanded juvenile menhaden surveys in Gulf coast nursery areas. The surveys, made with a two-boat surface trawl, include 28 sites that were sampled in 1967 and 1968. To assure more adequate coverage, the expanded survey has replaced the routine seven-stream survey we had had since 1964. The sampling sites are distributed in proportion to the estimated amount of surface water in each of nine contiguous areas extending from Ochlockonee Bay in Florida to Galveston Bay in Texas.

Relative indexes obtained from the 1968 surveys showed a substantial increase in the numbers of juvenile menhaden over the base year,

Table 4.--Summary of juvenile Atlantic menhaden surveys, 1962-68

[Number of tows in parentheses]

Sampling site	Mean catch per 5-minute tow													
	1962		1963		1964		1965		1966		1967		1968	
	Number of fish													
North Atlantic														
Childs River, Mass.	0	(3)	443	(4)	111	(4)	54	(6)	331	(13)	220	(3)	27	(3)
Duck River, Conn.	306	(6)	3,757	(6)	1	(6)	3	(6)	14	(4)	93	(3)	156	(3)
Old Ferry Creek, Conn.	367	(4)	348	(7)	1	(6)	58	(7)	757	(6)	1	(3)	1,336	(3)
Mean catch per stream	224		1,516		38		38		367		105		506	
Relative index	1.00		6.77		0.17		0.17		1.64		0.47		2.26	
Middle Atlantic														
White Creek, Del.	705	(4)	176	(11)	387	(12)	1	(6)	0	(6)	8	(5)	0	(4)
Ball Creek, Va.	229	(3)	721	(6)	9	(6)	1	(7)	12	(6)	0	(3)	92	(3)
Felgate Creek, Va.	81	(4)	4,949	(4)	519	(8)	82	(13)	492	(13)	11	(4)	2,878	(4)
Mean catch per stream	338		1,949		305		28		168		6		990	
Relative index	1.00		5.77		0.90		0.08		0.50		0.02		2.93	
South Atlantic														
Broad Creek, N.C.	201	(14)	3,111	(4)	30	(5)	112	(6)	1,012	(13)	528	(3)	10	(3)
Calabash Creek, N.C.	2,382	(6)	1,828	(5)	1,392	(5)	14	(4)	934	(4)	587	(4)	1,301	(4)
Meggetts Creek, S.C.	3,955	(10)	758	(12)	814	(12)	1,417	(5)	1,075	(5)	63	(3)	10	(3)
Sawmill Creek, S.C.	328	(6)	1,485	(6)	582	(6)	173	(5)	110	(6)	0	(4)	7	(4)
Mean catch per stream	1,717		1,795		705		429		783		295		332	
Relative index	1.00		1.05		0.41		0.25		0.46		0.17		0.19	
Entire Atlantic														
Mean catch per stream	855		1,758		385		191		474		151		582	
Relative index	1.00		2.06		0.45		0.22		0.55		0.18		0.68	

Table 5.--Comparison of menhaden estimates obtained by the expanded two-boat surface trawl surveys and aerial surveys in 1968

Area	Trawl survey		Aerial survey	
	Mean catch[1/] of fish per stream	Rank	School area	Rank
	Number		Ft.^{2} per mile	
Long Island Sound	2,074	1	1,788	1
Delaware Bay	13	6	0	6
Chesapeake Bay	726	3	218	5
Albemarle Sound	92	5	1,029	2
Pamlico Sound	2,018	2	930	3
South Atlantic[2/]	224	4	590	4

1/ Based upon standard 5-minute tows.

2/ Area extends from Cape Lookout, N.C., to Fernandina Beach, Fla.

1967 (table 7). Catches in the western Gulf were twice as great in 1968 as in 1967; those in the eastern Gulf were 68 times greater. Most of the increase in the eastern Gulf, however, was due to the influence of one stream, Dog River. Catches were nil in 10 of 13 streams sampled east of the Delta in 1967 and in 11 of these streams in 1968, whereas menhaden were taken in every stream sampled in the western Gulf, and in many, the catches were large. Consequently, we have greater confidence in surveys in the western waters.

By sampling during darkness in 1967, we demonstrated that clear water was responsible for the preponderance of zero catches in the eastern Gulf. Although the effects of water clarity on fish distribution and schooling behavior are poorly understood, this work verified that young menhaden use eastern Gulf estuaries, and provided the basis for sampling at night in clear-water nursery areas. In 1968, seven streams were sampled in the eastern Gulf to compare day-night catches and to establish a base year for the future (table 8). Sampling during darkness provided useful measures of menhaden abundance in clear streams (fig. 6).

Table 6.--Relative abundance of juvenile Atlantic menhaden estimated by surface trawl and aerial surveys in 1967 and 1968

Year	Trawl survey			Aerial survey		
	Mean catch of fish per stream	Streams	Relative[1/] index	School area	Miles	Relative[1/] index
	Number	Number		Ft.^{2} per mile	Number	
1967	151	10	0.18	164	1,497	0.06
1968	582	10	.68	948	1,410	0.35

1/ Computed from base year 1962 (= 1.00).

Aerial surveys for Gulf menhaden are not practical in the turbid waters that prevail to the west of the Delta, and consequently flights are confined to the eastern Gulf. Military restrictions on airspace in the eastern Gulf further impede fish spotting in the Gulf, so our estimates of the areas of Gulf menhaden schools are based upon limited observations. Nevertheless, estimates obtained from the 1968 aerial surveys indicated an increase in juvenile menhaden over 1967 in the eastern Gulf.

Table 7.--Summary of expanded Gulf menhaden surveys, 1967-68

[Number of tows in parentheses]

Area	Sampling site[1]	Catch of menhaden per 5-min. tow			
		1967		1968	
Western Gulf		Number		Number	
Calveston Bay	Dickinson Bayou, Tex.	14,040	(11)	4,922	(11)
	Double Bayou, Tex.	6,068	(8)	5,240	(9)
Sabine	Johnsons Bayou, La.	0	(7)	14,477	(7)
Vermilion	Vermilion River, La.	1,294	(7)	1,173	(7)
	Weeks Bayou, La.	2,046	(8)	23,974	(8)
	Hog Bayou, La.	1	(9)	9	(9)
Delta	Bayou du Large, La.	11	(8)	1,645	(8)
	Bayou Grand Caillou, La.	1,297	(10)	1,312	(10)
	Bayou Petit Caillou, La.	3,774	(8)	5,045	(8)
	Bayou Terrebonne, La.	101	(8)	2,667	(8)
	Bayou Pointe au Chien, La.	1,910	(5)	5,113	(5)
	Bayou Blue, La.	4,206	(8)	1,504	(7)
	Bayou Barataria, La.	72	(11)	2,435	(11)
	Bayou Dupont, La.	77	(7)	1,943	(7)
	River aux Chenes, La.	239	(10)	66	(10)
Mean catch per stream	- - - - - - - - - - - -	2,342	-	4,768	-
Relative index - - -	- - - - - - - - - - - -	1.00	-	2.04	-
Eastern Gulf					
Pontchartrain	Bayou Lacombe, La.	0	(7)	0	(7)
	Bayou Bonfouca, La.	260	(6)	936	(6)
	Pearl River, Miss.	0	(9)	0	(9)
	Mulatto Bayou, Miss.	0	(7)	0	(7)
Mississippi Sound	Bayou Caddy, Miss.	0	(5)	0	(5)
	Bernard Bayou, Miss.	4	(8)	0	(8)
	Bayou la Croix, Miss.	0	(8)	0	(8)
	McInnis Bayou, Miss.	0	(7)	75	(7)
Mobile Bay	Dog River, Ala.	5	(10)	17,658	(10)
	Magnolia River, Ala.	0	(6)	0	(6)
Perdido Bay	Boggy Bayou, Fla.	0	(5)	0	(5)
St. Andrew	Burnt Mill Creek, Fla.	0	(5)	0	(5)
	Whisky George Creek, Fla.	0	(6)	0	(6)
Mean catch per stream	- - - - - - - - - - - -	21	-	1,436	-
Relative index - - -	- - - - - - - - - - - -	1.00	-	68.38	-
Entire Gulf					
Mean catch per stream	- - - - - - - - - - - -	1,264	-	3,221	-
Relative index - - -	- - - - - - - - - - - -	1.00	-	2.55	-

[1] Stream names are taken from the most recent U.S. Geological Survey Topographic Maps available, Scale = 1:250,000.

Figure 6.—Juvenile menhaden taken at night during a 5-minute surface trawl tow in a clear-water stream of the eastern Gulf of Mexico.

Table 8.--Day-night menhaden catches in the eastern Gulf during 1968

[Number of tows in parentheses]

Area	Sampling site	Water transparency range	Catch per 5-minute tow		Area	Sampling site	Water transparency range	Catch per 5-minute tow	
			Day	Night				Day	Night
		Inches	-------Number------				Inches	-------Number------	
Lake Pontchartrain	Tchefuncta River, La.	33 - >40	2 (7)	69 (7)	Mobile Bay	Fish River, Ala.	29 - >40	0 (6)	1,380 (6)
	Pearl River, Miss.	28 - >40	1 (7)	1,655 (7)	Perdido Bay	Black Creek, Fla.	40 - >40	4 (6)	40,667 (6)
Mississippi Sound	Bernard Bayou, Miss.	17 - 23	71 (6)	39,941 (6)	St. Andrew	Ochlockonee River, Fla.	30 - >40	1 (6)	18 (6)
	W. Pascagoula River, Miss.	26 - >40	1 (6)	38 (6)					

MENHADEN BEHAVIOR AND PHYSIOLOGY PROGRAM

Richard W. Lichtenheld, Chief

As is well known, the framework of all ecology rests on the basic question: What factors regulate the distribution and abundance of plants and animals? Because fishery biology is simply applied ecology, this question provides the foundation for its research and establishes the objectives for developing a resource management policy. In line with this philosophy, our program's research focuses on two key words, abundance and distribution, and is oriented to answering the above question.

Concerning abundance, differential reproduction and survival are the two biological factors underlying the characteristic fluctuations in fish populations and the resulting phenomenon known as year-class strength. It is important, therefore, that we understand and can diagram the survivorship curve of menhaden. Toward this end, our menhaden rearing project seeks to describe the early phases of this curve, generally accepted as critical, and determine the factors (physical, behavioral, morphological) governing its shape.

The distribution of menhaden can be visualized as a series of schools (aggregations) of varying size and stability that move in and out of estuaries and along the coast. The factors affecting these two aspects (i.e., schooling behavior and migrations) therefore, need to be examined. In this context our schooling and migratory behavior project poses the question, "Why and how do fish school and migrate?," and seeks to determine the mechanisms that are responsible for the pattern of menhaden distribution.

REARING MENHADEN

William F. Hettler, Jr.

Introduction

Our activities this year centered around the design and construction of a reliable sea-water system to provide water for rearing, physiology, and behavior experiments. Efforts to develop techniques for rearing menhaden were partially successful when Atlantic menhaden eggs were reared to about one-third of an inch long. Because we could not obtain additional ripe menhaden eggs, further rearing experiments were not made during the year. In my attempt to locate eggs and sperm, I obtained new information on the diurnal spawning time of yellowfin menhaden, *B smithi.*

Sea-Water System

When the system is completed, the present uncontrolled fluctuations in the temperature, salinity, turbidity, and gas saturation of the sea water flow should be eliminated. Figure 7 illustrates the basic components and the pattern of our system.

Preliminary filtration is to be accomplished by pumping the incoming sea water through 4 feet of 1/32-inch diameter silica sand contained in two 1,000-gallon concrete tanks submerged in the channel adjacent to our laboratory. By this process, we intend to improve water clarity and reduce the intake of fouling organisms.

In our old sea-water system, water temperatures in our pipes during the winter dropped as low as 39° F., a temperature that has been shown experimentally to be lethal for larval menhaden. To provide satisfactory temperatures, incoming sea water will be heated with hot water flowing through Teflon[1] heat exchangers (fig. 8). Salinity will be regulated automatically by proportionally mixing sea water and fresh water from two 500-gallon reservoirs before distribution to our laboratory. The sea water will be continuously sterilized with germicidal ultraviolet rays.

[1] Trade names referred to in this publication do not imply endorsement.

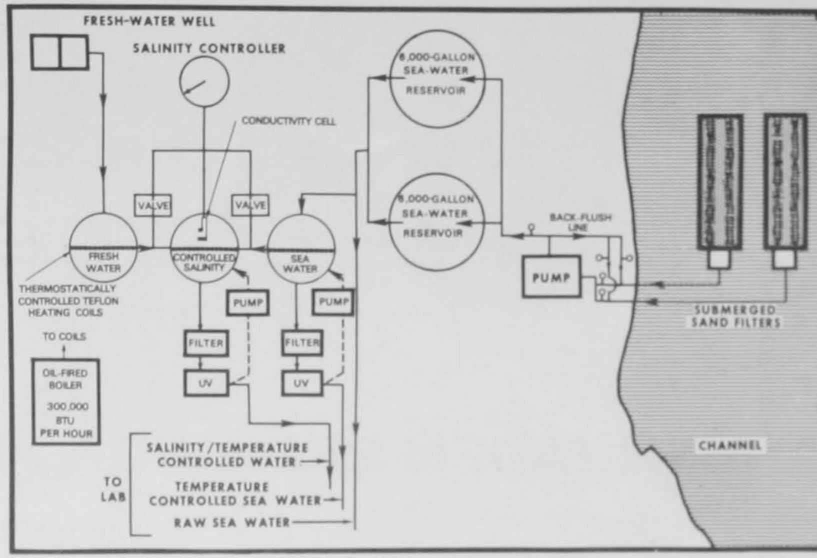

Figure 7.—Diagram of sea-water system designed to provide controlled temperature and salinity water for our experiments.

The rearing facility, now essentially complete, was designed for rearing menhaden from eggs through the postlarval stage. Twenty-eight 60-gallon fiberglassed plywood tanks are housed in banks of four tanks each in two rooms (fig. 9).

Rearing Atlantic Menhaden

Atlantic menhaden were reared beyond the critical yolksac stage for the first time this past winter. Menhaden eggs in the gastrula stage, estimated to be 12 to 15 hours old, were caught by a plankton net 15 miles south of Beaufort Inlet at noon on November 26. Between 500 and 1,000 eggs survived the 2-hour trip to the laboratory, where the eggs were distributed among four rearing tanks. The eggs hatched

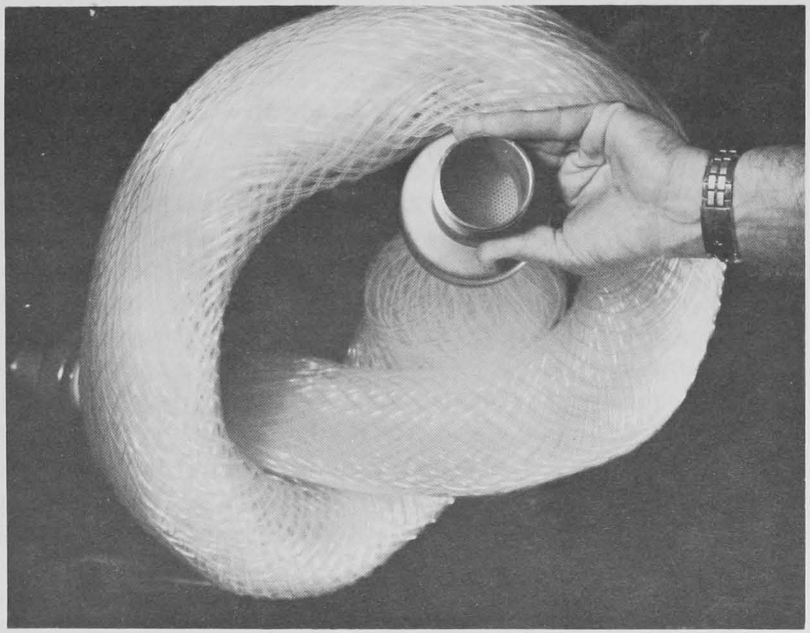

Figure 8.—Teflon heat exchanger with 650 small tubes through which hot water will flow to heat sea water.

Figure 9.—Sea-water laboratory designed for rearing menhaden from eggs through the postlarval stage.

within 66 to 74 hours, and the yolks were absorbed and the larvae began to feed after 5 days.

The water conditions throughout the rearing experiment were not controlled. Temperatures were 53° to 67° F. Salinities showed only minor fluctuations from about 31.5 to 33.5 parts per thousand. The larvae were fed only sea urchin blastulae for the first 15 days; thereafter they were fed brine shrimp nauplii.

This rearing experiment was considered only partially successful, as all larvae had died by the 32d day after the eggs hatched. Mortality was high following hatching but subsided after absorption of the yolk. When the last larva died it was 0.41-inch long (total length). The cause of the gradual attrition in the small population of larvae is unknown and will be studied in future rearing experiments. Figure 10 shows 15-day-old larva.

Figure 10.—Atlantic menhaden reared in laboratory from an egg. Larva is 15 days old and 0.35-inch long (total length).

Spawning of Yellowfin Menhaden

In January and February I tried to obtain viable eggs and sperm from yellowfin menhaden for additional rearing studies. Gill nets were set in the Indian River, Fla. Although no ripe female menhaden were caught, nearly all of the males were sexually mature.

To gain insight to spawning times and locations, I towed a plankton net in the river between Eau Gallie and Sebastian to collect eggs and larvae. I took as many as 3,000 menhaden eggs per 10-minute tow with a 20-inch diameter net pulled at 1 to 2 knots. The maximum catch of larvae in a tow was 23. Total length of larvae ranged from 0.11 to 0.95 inch.

The fish apparently spawned around dusk on several evenings. Eggs collected 1 hour after sunset had just begun cleavage; most eggs were in the two to eight cell stages. Those eggs collected at 10 p.m. had advanced to the early blastoderm stage. That the fish spawn in early evening is further supported by the observation that females captured at 7:30 p.m. on February 1 had apparently just spawned. When those females were checked for ripe eggs, the few mature eggs that could be squeezed out, were accompanied by blood and a few very small immature eggs. Milt flowed copiously from the males captured in the evening, compared to the amount produced by the males caught early in the day. The eggs in any given plankton tow were either all of one development stage or of two development stages, spaced 24 hours apart. The eggs apparently hatched around early afternoon. Eggs ready to hatch were taken around 11 to 12 a.m. A prolarvae, just hatched, was taken at 2:30 p.m. No late embryo stages were taken in the afternoon or evening. Development within the egg, therefore, took about 44 hours at the temperatures to which these eggs were exposed in the river (68° - 70° F.).

Growth of Young Menhaden in Fresh Water and Sea Water

In April, I made a preliminary test of the salinity requirements for rearing menhaden. Atlantic menhaden larvae caught near the laboratory in high-salinity water were divided into eight groups of nine fish each. These larvae, which averaged 1.1 inches total length, were reared in high salinities (29.4 - 33.1 parts per thousand) and constant temperature (68° F.) until midway through their metamorphosis into juveniles. The salinity in four tanks was reduced during an 11-day period from 32.4 to less than 0.5 part per thousand. The fish in the other four tanks were allowed to remain in high-salinity water. During this time, the temperature in all eight tanks was slowly raised to 80° F. for the duration of the test. All conditions, except salinity, were the same in all tanks.

When the test was terminated after 2 months of rearing, only four juveniles survived in the low-salinity tanks, whereas 33 juveniles remained in the high-salinity tanks. Growth of the fish in high salinity was significantly better than that of the fish in low salinity. The juveniles in high salinity reached an average length of 2.0 inches and an average weight of 0.08 ounces. The surviving fish in fresh water were 18 percent shorter and weighed 50 percent less than the fish reared in high salinity. Whereas these results suggest that high salinities provide the best rearing conditions, future tests involving temperature, salinity, and developmental stage are needed to determine optimal rearing and, presumably, habitat conditions.

SCHOOLING AND MIGRATORY BEHAVIOR

Richard W. Lichtenheld

Why and how fish school and migrate are very basic questions that have whetted the curiosity of scientists and evaded explanation for centuries. The fact that answers to these questions are piecemeal at best for any species is indeed curious in view of their fundamental importance to resource management and the strategy of fishing. Without the tendency to school, menhaden, like many other commercially important species, would be extremely difficult–perhaps prohibitively uneconomical–to catch.

Schools and migrations are the two ecological properties that characterize the distribution of menhaden. Because schooling and migratory behavior are interrelated, our approach to these phenomena is based on the consideration that food supply–specifically the uneven distribution of food in the environment–is the major factor underlying the evolution, and hence appearance, of schools and migrations. Our experimental procedures for studying schools, schooling behavior, and migrations are based on the hypotheses that (1) schooling is an adaptation to the uneven distribution of food in space (i.e. in a given area), and (2) migration is an adaptation to the uneven distribution of food over time. Although these hypotheses may not be considered original because they reflect the feelings of many ecologists, they do place the relations between school and prey, and migrations and food into perspective and in testable forms.

Translating the above hypotheses to specific goals, our project seeks to (1) describe the "geometry" of schools and determine the relation of school characters (e.g. size, shape, depth, composition, density) to abiotic and biotic factors, and (2) delimit the "swimways" of Atlantic menhaden and determine the sense-cue relation that constitutes the swimway-map system used by menhaden in coastal and oceanic waters.

To realize these goals our research is based on the concept that the natural environment is the most appropriate experimental site for studying schooling and migratory behavior. It is necessary, therefore, for us to use existing oceanographic platforms of opportunity (e. g. U.S. Coast Guard vessels), and at the same time seek to use and develop platforms that can provide constant positioning on and tracking of schools throughout the year (e.g. blimps, submarine-sleds). Consequently our activities during the year involved (1) interviewing and working with industry spotter pilots, (2) working with NASA-Wallops Island to obtain thermal maps of menhaden waters along the North Carolina-South Carolina coasts, and (3) flight-testing a Goodyear blimp to determine the application of self-propelled balloons to studies of fish behavior and oceanography.

Industry Spotter Pilots

The menhaden industry employs small aircraft for locating (spotting) schools of fish and helping fishermen set their purse seines. Because spotter pilots have directed the efforts of almost the entire industry for years, these resource "custodians" possess invaluable knowledge of schooling behavior and migrations.

To capture a portion of this knowledge, and following the example of de Veen (J. Cons. 31:207-236. 1967), who showed the value of the interview as a means of investigating the behavior of fish in the natural environment, I flew with and interviewed industry spotter pilots in the Chesapeake Bay area in September, and along the North Carolina coast during the fall fishery. Although this procedure requires repeated cross-referencing and questioning (e.g. consideration of differences between seasons and areas), certain straightforward and significant bits

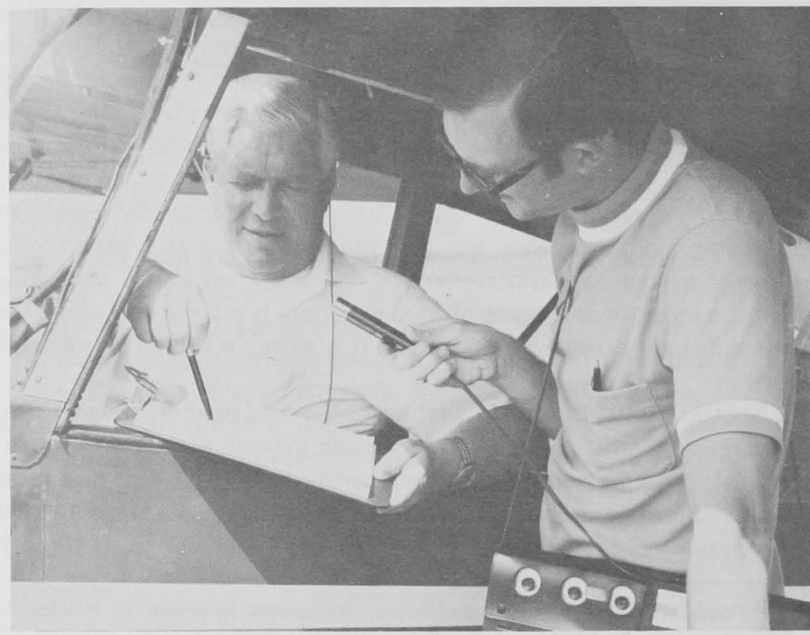

Figure 11.–Project leader interviewing professional spotter pilot Steve Oakley, Beaufort, N. C., about a day's observations of the distribution and behavior of menhaden.

of information were obtained regarding the question: What are the ideal conditions for seeing a school of fish? Spotters stated that schools are most visible in the morning and evening, and at slack water, and that not only are schools seen more often in certain areas (showing sites), but certain sizes of fish tend to be found in specific areas.

The suggestion that menhaden actively select habitats raises the question: What environmental factors are responsible for this selection–to what are the fish responding? We know that areas may differ in bottom type, currents, depth, food supply, predators, salinity, suspended material, and temperature. Although the ultimate or key factor underlying this observed habitat selection is not known, our hypotheses regarding schooling and migrations suggest that food supply is the critical factor. In this regard it is relevant that menhaden larvae are selective in their food habits (June and Carlson, unpublished BCF MS[2]). Although the feeding habits of subadult and adult menhaden are not known, findings that other and similar filter-feeders are selective and exhibit food preferences indicate that food type (chemical composition, motility, quality, shape, size) is important and may be responsible for the selection of areas by menhaden. This is not to say that the "invisible," but real, barriers of currents, salinity and temperature do not influence the distribution of plankton and fish. The fact that the most productive fishing waters of many commercial species (e.g. anchovies off the coast of Peru) occur in regions of upwelling, indicates that the distribution of fish and plankton is directly related to physical-chemical factors. I am simply suggesting that the presence or absence of food of certain types and qualities is the reason for an active fish being where it is within a habitable, tolerable zone.

Spotter pilots also noted that schools create mud clouds that may serve a feeding function. A school passing through an area, like a boat, churns up the bottom and creates detritus clouds. The fact that these clouds appear in deep (100 ft.) as well as shallow water suggests that this action may be of functional or adaptive significance. If so then menhaden should prefer those areas where "feed clouds" can be formed (e.g. muddy bottoms). Comments by spotters concerning the apparent avoidance of hard bottoms (i.e. coral, rock) along the North and South Carolina coasts by menhaden, support this suggestion.

Sea-Surface Temperatures

The migration routes, spawning sites, and wintering areas of Atlantic menhaden are not known. To obtain insight to these aspects, we began a series of joint studies with NASA-Wallops Island, Va., (Earth Resource Program) in December 1968. The aim of our studies was to detail the environmental conditions (e.g. temperature) in known and suspected menhaden waters along the Carolina coasts.

Sea-surface temperatures were measured remotely with a precision radiation thermometer (Barnes PRT-5) placed aboard a Beechcraft Queenaire aircraft (NASA 8). Overflights of Raleigh and Onslow Bays, N.C., were made in December 1968 (two flights) and January 1969 (three flights). We organized a combined aerial and surface-vessel operation in March 1969 to provide both direct and indirect measures of sea-surface temperatures along the Carolina coast from Nags Head, N.C., north of Cape Hatteras to Cape Romain, S.C. Participating in this latter oceanographic operation, coordinated by NASA-Wallops Island, were the U.S. Coast Guard, Fort Macon, N.C.; Virginia Institute of Marine Science, Gloucester Point, Va.; and Duke University Marine Laboratory, Beaufort, N.C.

Ellison (1951. The menhaden. *In* Harden F. Taylor, Survey of marine fisheries of North Carolina, pp. 85-107. University of North Carolina Press, Chapel Hill, N.C.) noted that the departure and return of adult menhaden along the Atlantic was correlated with temperatures of 50° F. If this value can be considered as delimiting habitable and uninhabitable menhaden waters, the surface temperatures observed this past winter reveal that (1) the major portion of Raleigh Bay (i.e. surface waters within the 20-fathom line) was unfavorable for adult menhaden during 1 to 2 months, and (2) the surface waters of Onslow and Long Bays contained large areas of favorable temperatures seaward of the 10-fathom line throughout the winter. Whereas the 20-fathom line in Raleigh Bay was associated with temperatures of 50° F. or less from January to mid-March, temperatures along this depth line in Onslow

[2] Food of young Atlantic menhaden, ***Brevoortia tyrannus,*** in relation to metamorphosis, by Fred C. June (present address): Bureau of Sport Fisheries and Wildlife, P. O. Box 3830, Pierre, S.D. 57501, and Frank T. Carlson (present address): Bureau of Sport Fisheries and Wildlife, 200 Rt. 9 W, New Windsor, N.Y. 12550. (in authors' revision).

ranged from 59° to 68° F. The wide shelf in Onslow and Long Bays, compared to Raleigh Bay, together with temperatures greater than 50° F. in these bays, offers a large coastal oceanic area that would appear to provide satisfactory water temperatures for wintering menhaden.

Offshore schools of menhaden spotted from the aircraft during our studies were in 57° to 66° F. waters. Whereas many schools were observed in Raleigh Bay in mid-December, few were seen in January, and none in March. No schools were seen in either Onslow or Long Bay. It is perhaps significant that the temperature range of waters over which a professional spotter directed our search for menhaden in the Cape Fear area (Onslow Bay–Long Bay dividing point) was 57° to 64° F. Although these results suggest that menhaden may prefer temperatures of 57° to 68° F., the apparent absence of menhaden in offshore surface waters along the Carolina coast from late January through March, suggests that factors other than or in addition to temperature influence the distribution of menhaden during the winter.

To obtain additional information about the possible areas that menhaden seek in the winter, we flew with the U.S. Coast Guard over a large fleet of Soviet-bloc vessels fishing the coastal waters of North Carolina and Virginia. The fleet was first spotted off the mouth of the Chesapeake Bay on February 7, 1969. Species of fish reportedly caught between Cape Henry, Va., and Cape Hatteras, N.C., included Atlantic herring, *Clupea harengus,* and Atlantic mackerel, *Scomber scombrus.*

One important aspect of this large-scale operation was that the vessels caught large numbers of fish that were essentially sub-surface. During our flights we saw only two schools of fish on the surface. The assumption that the reported species caught were both subsurface and in schools indicates that the behavior of certain species that migrate along our coast varies considerably between summer and winter. Is this true for menhaden? Is there a general pattern to the schooling–migratory behavior of certain marine species like Atlantic herring, mackerel, and menhaden? We suggest that the answer to both of these questions is Yes.

The general behavior seen is one in which menhaden school at the surface in the summer and at depths in the winter; this seasonal difference in behavior is associated with the north-south migrations of the species in its range. According to this pattern, menhaden should winter in deep shelf waters from North Carolina to Florida. In the winter the surface waters may lack fish, but the deeper waters apparently have large concentrations of different species.

Fisheries-Oceanography from Balloons (Blimps)

Studies of schools and schooling behavior in the natural environment require an aerial platform that can maintain position over a specific school or area for extended periods of time. This platform should be somewhat mobile, stable, and enable experimenters to obtain direct and indirect measures of environmental variables (e.g. currents, plankton, temperature). Because the once outdated and retired Navy blimps appeared to satisfy these requirements, I together with a NASA scientist-engineer discussed the concept of airships and the potential application of blimps to fishery-oceanography studies with M. R. Johnson, Pilot and Director of the Goodyear Airship Base, Miami, Fla.

During our 1-hour flight in the Goodyear *Mayflower,* I was impressed with the stability and maneuverability of the blimp. Airships of this type can hover, lower to the water's surface, and remain over a study area for extended periods. They can operate year round and in all weather, except hurricane winds. On the basis of these qualifications, blimps provide an excellent aerial platform with which to study schools and schooling behavior, migrations, circulation patterns, and tidal variations and influences. A multipurpose aerial and near-surface platform of this type (i.e. a lighter-than-air craft designed specifically for oceanographic work) has unlimited potential and most likely will revolutionize many experimental approaches to and concepts in oceanography and fisheries.

MENHADEN TAGGING PROGRAM

Robert L. Dryfoos, Chief

The questions asked by scientists, industry, and public about menhaden are similar. Where do menhaden come from and where do they go? Is there one large population along the Atlantic coast and another along the Gulf coast, or are there natural divisions of these populations? What causes fluctuation in the abundance of menhaden? Are they being overfished? Are there quantities of menhaden offshore that act as reservoirs to protect the populations from overfishing? What is the best size, age, and location to catch menhaden? Tagging is a research method that can help answer some of these important questions.

In July 1966 the first Atlantic menhaden were tagged internally with metal tags and released. Since then, our biologists have tagged and released 943,000 menhaden from Long Island Sound, N.Y., to Sebastian Inlet, Fla., in the Atlantic and from Moss Point, Miss., to Cameron, La., in the Gulf. We have in hand almost 125,000 tags recovered from both coasts.

Specifically, the menhaden tagging program is designed to provide data regarding the interchange of fish between fishing areas, growth and mortality rates, and the importance of certain estuaries in the production of menhaden. These data are needed to determine the causes of fluctuations in abundance of menhaden, to assess the effect of the commercial fisheries on the population, and to develop estimates of optimum harvest.

MARK-RECAPTURE OF ATLANTIC MENHADEN

Randall P. Cheek, Linda C. Coston, Richard L. Kroger, Eldon J. Levi, R. O. Parker, Jr., and Glenn B. Sekavec

Our tagging and tag recovery methods are adapted to the menhaden purse seine fishery, which handles large quantities of fish in bulk (fig. 12). We tag menhaden by injecting a 1/2-inch, ferro-magnetic tag into its body cavity (fig. 13). This procedure leaves no external mark after the incision heals. The tags are recovered at menhaden reduction plants by special magnets that remove tags and other pieces of iron from the fish scrap. Although we use an electronic detector system to recover whole tagged fish for growth studies, magnets are best for recovering large numbers of tags.

We began the Mark-Recapture Program on Atlantic menhaden near Beaufort, N.C., in July 1966, by tagging 74,906 menhaden in the summer fishery and 21,721 in the fall fishery. These initial efforts largely involved developing methods and techniques. In 1967, we expanded our studies to include Florida, Georgia, Chesapeake Bay, New Jersey, and New York. Through June 30, 1969, we have tagged almost 913,000 menhaden and have recovered over 124,000 tags. Total tagging by area is as follows: Florida-Georgia 259,346; North Carolina 362,211; Chesapeake Bay 247,346; New Jersey 36,149; New York 7,894.

In addition to Atlantic menhaden, small numbers of two other species have been tagged along the Atlantic coast. In September 1968, we tagged and released 1,682 Atlantic thread herring between Beaufort and Bogue Inlets, N.C. In December 1968, we tagged and released 3,301 yellowfin menhaden near Sebastian Inlet, Fla.

Experiments testing a 1/4-inch tag for juvenile menhaden (3 - 5 inches long) during the past year have yielded promising results. We

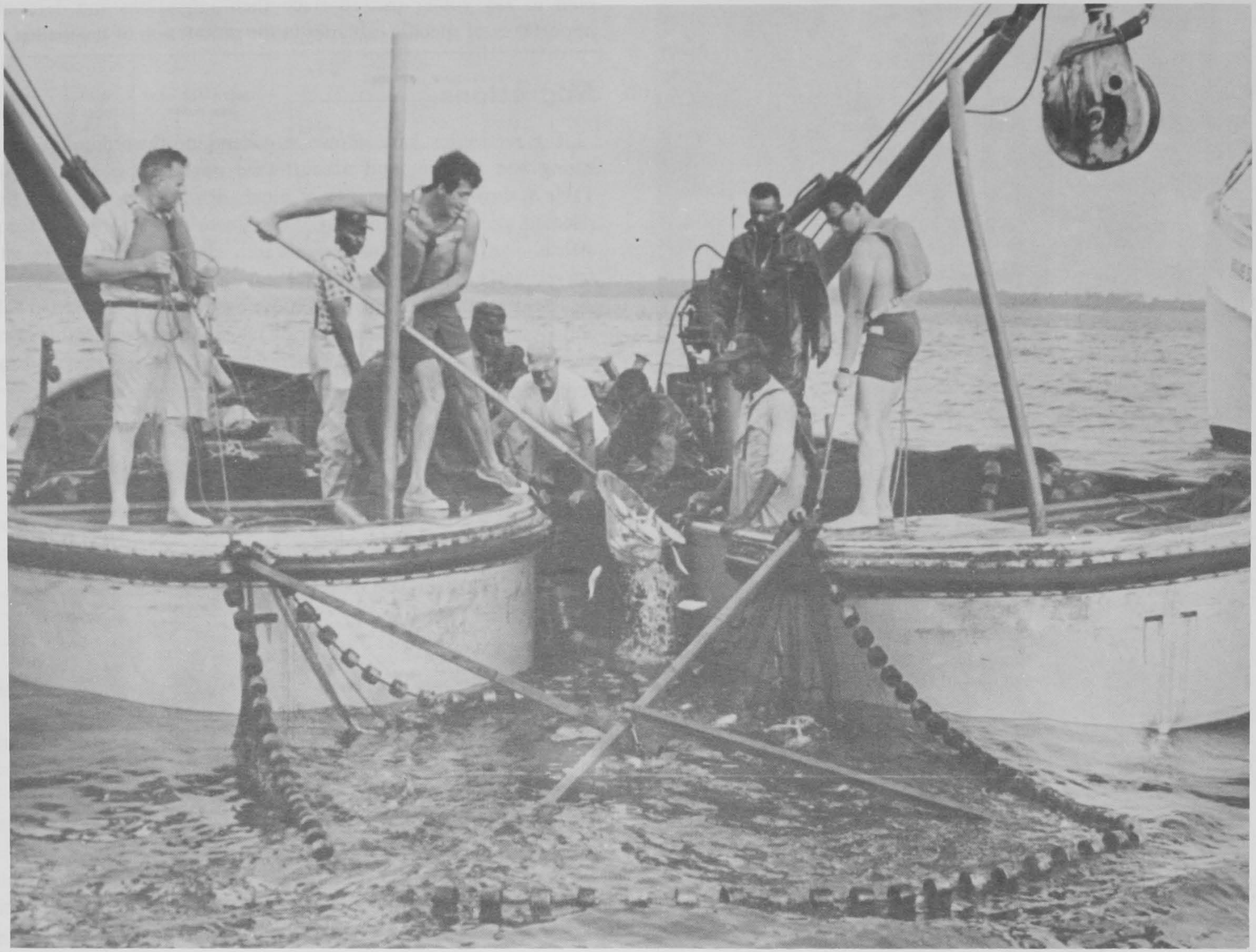

Figure 12.—Research team transferring menhaden from a commercial purse seine, between boats, to a "keep net" for tagging.

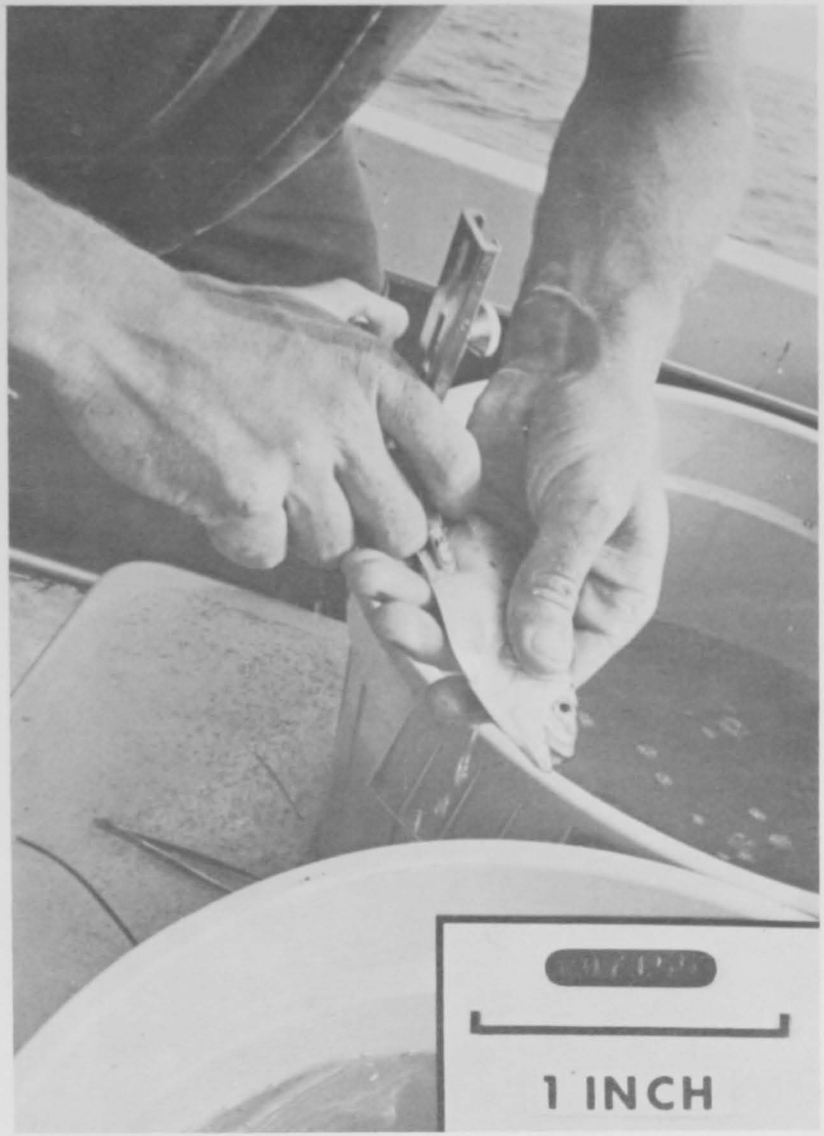

Figure 13.—A menhaden being tagged with the Bergen-Nautik tagging gun. Inset: 1/2-inch ferromagnetic tag.

plan to tag young fish to trace their migrations and determine the importance of specific estuaries in the production of menhaden.

Migrations

Tag recoveries have shown a general northward migration in the spring and summer and a southward migration in the fall (fig. 14). Table 9 shows the recoveries of menhaden through fall 1968 from fish released along the Atlantic in 1967. These figures, adjusted for magnet efficiencies, are preliminary; more refined adjustments of the estimated tag recoveries will be made later.

There was little northward movement of fish released off Florida and Georgia during the summer of release, but considerable northward movement by the second summer. Of the 342 tags recovered in North

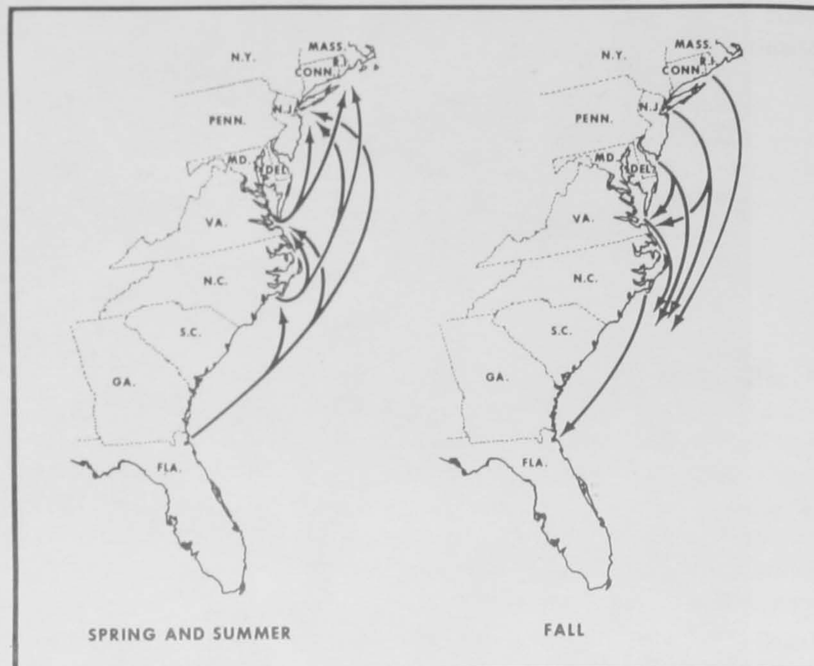

Figure 14.—Generalized movements of tagged menhaden.

Table 9.--Adjusted tag recoveries from 322,342 Atlantic menhaden released during spring and summer 1967 from Florida to New York

Location tagged	Fish tagged	Year and season recovered	Location recovered				
			FLA.	N.C.	VA.	N.J.	N.Y.
	Number		Number				
Florida	95,832	Spring/summer '67	5,964	342	2	0	--
		Fall '67	--	0	0	--	--
		Spring/summer '68	394	775	731	111	0
		Fall '68	--	407	160	--	--
North Carolina	110,629	Spring/summer '67	2	12,140	1,138	36	--
		Fall '67	--	7,886	160	--	--
		Spring/summer '68	49	982	2,935	450	21
		Fall '68	--	1,452	658	--	--
Chesapeake Bay	100,128	Spring/summer '67	0	0	13,826	379	--
		Fall '67	--	3,050	1,905	--	--
		Spring/summer '68	0	24	12,557	3,876	740
		Fall '68	--	3,482	2,204	--	--
New Jersey	13,660	Spring/summer '67	0	0	20	1,300	--
		Fall '67	--	876	171	--	--
		Spring/summer '68	0	8	321	458	111
		Fall '68	--	124	40	--	--
New York	2,093	Spring/summer '67	0	0	0	280	--
		Fall '67	--	53	0	--	--
		Spring/summer '68	0	1	6	75	137
		Fall '68	--	6	2	--	--

NOTE: -- indicates no fishing.

Carolina in the summer of 1967, 98 percent were landed at Southport, N.C., by a refrigerated vessel that fished as far south as Georgia. We believe that most of these fish were caught in the area of release and not in North Carolina waters. Fish tagged in Florida and Georgia in 1967 were recaptured as far north as New Jersey in 1968. Fish recaptured in New Jersey and the Virginia portion of Chesapeake Bay were larger at the time of release than those recovered in North Carolina, Georgia, and Florida. Possibly because of differences in swimming speed, the larger fish were able to travel further during the spring migration.

During the season of release, most recoveries of fish tagged in North Carolina waters were made in North Carolina. Although most of the recoveries north of the area of release were in Virginia, some were made as far north as New Jersey. Only two recoveries were made south of North Carolina. The following summer, most recoveries were from Virginia.

Fish tagged in Chesapeake Bay moved out of the bay and northward during the summer of release, southward in the fall, and further north the second summer after release. In November the larger fish in Chesapeake Bay moved southward. They moved out of the bay and along the North Carolina coast where they remained at least until mid-December. None of the fish tagged in Chesapeake Bay have been recovered south of North Carolina, mainly because of no winter fishing from North Carolina to Florida.

Fish tagged off New Jersey also showed a southward fall migration, appearing off Virginia in late October and off North Carolina by mid-November. Eighty percent of the fish that had been tagged off New Jersey and recovered in Virginia plants in 1968 were small (probably age-1 and -2) fish released in Delaware Bay.

Fish tagged off New York also moved southward in the fall. Those tagged during the summer did not appear in the North Carolina fall fishery until early December in both 1967 and 1968. The summer recoveries of 1968, south of New York and New Jersey, were due primarily to recaptures in the spring of fish returning north after migrating south the previous fall.

Atlantic thread herring tagged off North Carolina in September 1968 migrated south after tagging. About 10 days after release, several were recaptured near Cape Fear, N.C., 75 miles south of the tagging site. One was recaptured about 370 miles south in Florida within 49 days after release. These recoveries are our first direct evidence of thread herring migrations.

No yellowfin menhaden tagged in the fall of 1968 near Sebastian Inlet, Fla., have been recovered.

Electronic Detector System

Since we began to use our electronic detector system in July 1967, we have recovered 203 tagged Atlantic menhaden. We measured these fish and used X-rays and dissection to determine the locations of the tags (fig. 15). Only one fish had been aged and measured prior to release and had been at liberty long enough to provide direct data on growth. This fish, released near Tangier Island in Chesapeake Bay on August 5, 1968, and recovered 130 days later off Core Banks, N.C., grew 0.4 inch. Nineteen other fish at liberty 4 to 20 months were estimated to have grown 2.5 inches per year. Estimates of growth were made by use of the known age and length of the fish when it was recovered and the average length of fish of the same year class at the time of release.

Rate of Exploitation

Preliminary estimates of the fraction of the population which is caught by man can be made from our adjusted tag returns from fish tagged in 1967. These tag returns represent, on the average, recoveries from 1 1/2 years of fishing. An estimate of the rate of exploitation for this 18-month period is the percentage of the tags released which was recovered during the period as shown in table 10. From the 1967 releases, more than 25 percent of all tagged menhaden and 42 percent of those tagged in Chesapeake Bay were recaptured by the end of 1968. The estimates for the 1967 releases appear large, but we do not think they are unusual. Recoveries from the 1968 releases are even greater in most areas during a comparable time period. When adjustments for tagging mortality are made, the estimates of the rate of exploitation will be even higher. These preliminary data emphasize the need for management of this important resource.

Figure 15.—Technician determining the location of tags in menhaden recovered with an electronic detector system. Tags and pins marking the approximate point of tag insertion on fish that have not healed can be seen.

Table 10.--Adjusted tag recoveries of menhaden through the fall fishery, 1968, from fish tagged summer, 1967

Area of release	Fish tagged	Tags recovered[1/]	
	Number	Number	Percent
Florida and Georgia	95,832	8,886	9.3
North Carolina	110,629	27,909	25.2
Chesapeake Bay	100,128	42,043	42.0
New Jersey	13,660	3,429	25.1
New York	2,093	560	26.8
Totals	322,342	82,827	25.7

1/ Adjusted for magnet efficiencies.

MARK-RECAPTURE OF GULF MENHADEN

Robert L. Dryfoos and Paul J. Pristas

Tagging and recovery of Gulf menhaden began this year. In 4 of the 12 active Gulf menhaden plants, primary magnets were installed in the conveyor system immediately beyond the fish scrap drier. Primary magnets remove tags and metal from the fish scrap the day it is processed. Nearly all plants already had secondary magnets installed at the hammer mills. Secondary magnets remove iron before fish scrap is ground into meal, which may be several months after processing of the fish. With one exception, all active plants have some magnets for tag recovery, and tests are being made to determine the efficiency of the magnet installations.

Table 11.--Tag recoveries through June 30, 1969, from 27,095 Gulf menhaden released in April and May 1969

Releases		Recoveries								
Area	Fish	Sabine Pass, Tex.	Cameron, La.	Intracoastal City, La.	Morgan City, La.	Dulac, La.	Empire, La.	Moss Point, Miss.	Total	
	Number									Percent
Cameron, La.	10,398	3	4	0	16	1	0	0	24	0.2
Empire, La.	3,699	0	0	0	2	0	268	4	274	7.4
Moss Point, Miss.	12,998	0	0	0	0	0	0	298	298	2.3
Total	27,095	3	4	0	18	1	268	302	596	2.2

A total of 27,095 Gulf menhaden was tagged and released in April and May, 1969, at Cameron, La. (10,398); Empire, La. (3,699); and Moss Point, Miss. (12,998). Table 11 shows recoveries through June 30, 1969. The most notable feature of these recoveries to date was the relatively high percentage recovery from the releases at Empire. Migrations must be inferred from information on the location of the catch landed at each plant. The recovery of tags released near Cameron at plants at Dulac and Morgan City probably was due to fishing near Cameron by boats from those plants. The low number of tags recovered at Cameron from releases in that area was due to a late installation of one of our magnets in a Cameron plant. Even though few tags were recovered at Cameron, these preliminary results indicate that a sufficient number of tags for analysis will be recovered during the Gulf menhaden tagging studies.

To evaluate tagging procedures for Gulf menhaden, we began experiments on menhaden held in captivity at our field station in Gulf Breeze, Fla. We will compare tagging efficiencies between two taggers, areas of tag insertion, and methods of handling fish for tagging. These experiments are necessary to estimate tagging mortality and tag shedding.

MENHADEN POPULATION DYNAMICS PROGRAM

Gene R. Huntsman, Chief

The goals of population dynamics research are to: (1) explain temporal and spatial variations in menhaden abundance; (2) determine the effects of fishing on menhaden populations; (3) predict the future abundance of menhaden; (4) determine the optimum age and size for harvesting menhaden; and (5) formulate management regulations that will ensure continued high yields. Achieving these goals requires monitoring the commercial fisheries and analyzing the collected information. During the past year we placed increased emphasis on the analytical portion of our work and began to develop estimates of menhaden population characteristics. These estimates will be used in making management decisions about menhaden populations in both the Atlantic and the Gulf.

ATLANTIC MENHADEN FISHERY

Mayo H. Judy and William R. Nicholson

The 1968-69 purse seine fishery for Atlantic menhaden began in Florida and North Carolina in April, gradually spread north to all major ports by mid-June, and ended with the close of the North Carolina fall fishery in January 1969. Catches were systematically sampled throughout the season at all 16 reduction plants from Fernandina Beach, Fla., to Amagansett, N.Y. We collected 1,281 samples of 20 fish each from purse seiners (1,262 menhaden samples and 19 thread herring samples) and 173 menhaden samples of 20 fish each from Chesapeake Bay pound nets. One sample was collected for every 204 tons of fish caught, a slightly greater ratio than the one sample taken for every 279 tons in 1967.

Of the 259,000 tons caught in 1968, approximately 127,000 tons, or 49 percent, were landed at Chesapeake Bay plants. (Of these landings, some 114,000 tons were caught in the bay and 13,000 tons were caught in the ocean.) Landings in the North Carolina fall fishery amounted to 58,000 tons and accounted for 23 percent of the total catch. The remaining 73,000 tons (28 percent of the catch) were landed by boats operating in the North Atlantic, Middle Atlantic and South Atlantic fisheries.

The number of menhaden purse seine vessels again declined in 1968. Eighty-one vessels fished at various ports in 1965, 75 in 1966, 64 in 1967, and 59 in 1968. We expect a further decline in 1969.

Although the 1968 Atlantic menhaden catch increased about 20 percent over 1967, the fishery in general had another poor year. About 27 percent of the increase was landed at one plant that reopened in the North Atlantic area after being closed in 1967. Only two vessels fished there, however, and fish were scarce in the area. Although catches at the two Middle Atlantic area ports increased about 53 percent over 1967, most of the fish were caught in Long Island Sound and Delaware Bay. Chesapeake Bay landings increased 27 percent over 1967, but they were still poor by comparison with landings before 1964, when fewer vessels fished shorter seasons. Many of the fish were caught in waters outside the bay during October and November. In the North Carolina fall fishery the catch increased by only 3 percent. Whereas the total catch in the South Atlantic area decreased by only 6 percent, Florida catches were down 44 percent.

Compared with previous years, the amount of effort was extremely low in all areas except in North Carolina during the fall fishery. In this fishery the number of vessel weeks was about the same as in previous years and accounted for 20 percent of the total effort. The most significant decline was in the number of vessel weeks fished by vessels from Chesapeake Bay plants; the fishing effort there was about the same as in 1962, but only 79 percent of the average for 1963-67. In 1968 these vessels accounted for about 50 percent of the total effort. Effort in the North and Middle Atlantic areas, 23 and 111 vessel weeks, respectively, remained low at about the 1965-67 levels, and accounted for only about 11 percent of the total effort. Vessels fishing from plants in the South Atlantic area expended the remaining effort, which declined about 25 percent from previous years.

The catches per vessel week appeared to reflect the decrease in fishing effort rather than any change in the abundance of fish. In the

Table 12.--Age composition of samples from catches of Atlantic menhaden, 1966-68

Port of landing	Year	Numbers of fish	Age in years							
			0	1	2	3	4	5	6	7+
			Percent							
North Atlantic:										
Amagansett, N.Y......	1966	177	0	0	3	45	40	8	6	3
	1967	---	-	-	-	No Fishery			-	-
	1968	883	0	0	22	58	18	2	<1	0
Middle Atlantic:										
Port Monmouth, N.J...	1966	1,229	0	0	15	55	27	3	<1	0
	1967	1,667	0	3	27	61	8	1	<1	0
	1968	3,212	0	<1	46	39	14	1	<1	0
Wildwood, N.J........	1966	---	-	-	-	No samples			-	-
	1967	---	-	-	-	No samples			-	-
	1968	1,174	0	5	66	26	3	<1	0	0
Chesapeake Bay:										
Reedville, Va.	1966	5,506	21	32	39	7	<1	<1	0	0
	1967	5,634	2	49	37	12	<1	<1	0	0
	1968	7,851	10	27	52	10	<1	<1	0	0
South Atlantic:										
Beaufort, N.C.										
Summer	1966	1,854	<1	62	32	5	<1	<1	0	0
	1967	1,125	5	43	43	8	<1	0	0	0
	1968	2,024	3	15	55	25	2	<1	<1	0
Fall	1966	1,720	24	22	41	12	<1	0	0	0
	1967	1,444	3	43	32	21	1	<1	0	0
	1968	1,184	3	22	52	19	3	<1	0	0
Southport, N. C.	1966	297	0	40	33	23	4	0	0	0
	1967	222	<1	42	46	12	0	0	0	0
	1968	2,079	0	19	53	26	2	<1	0	0
Fernandina Beach, Fla.	1966	3,555	<1	21	53	23	3	<1	0	0
	1967	4,403	<1	60	34	5	<1	0	0	0
	1968	1,899	<1	69	23	7	<1	0	0	0
Total...............	1966	14,161	11	29	40	16	4	<1	<1	0
	1967	14,495	1	46	35	16	1	<1	<1	0
	1968	24,136	4	26	47	19	3	<1	<1	0

North and Middle Atlantic, areas where the effort was only a small fraction of what it had been in previous years, the catch per vessel week was relatively high, 304 and 261 tons, respectively. In the South Atlantic area and North Carolina fall fishery, the catches per vessel week, respectively, were about 115 and 253 tons, well within the range of previous years. In the Chesapeake Bay area the catch per vessel week of 214 tons was somewhat above what it had been in 1963-67, but was considerably less than it had been before 1963. We believe the observed increase in catch per unit of effort in most areas is due to a decrease in competition among the vessels for available fish.

On the basis of fish taken in purse seine samples, the 1967 year class appeared exceptionally poor, especially in comparison with the recent series of poor year classes. As age-1 fish, this year class constituted less than 1 percent of the fish in samples at Port Monmouth, 5 percent at Wildwood, 27 percent at Reedville, 15 percent at Beaufort (summer fishery), 19 percent at Southport, and 69 percent at Fernandina Beach (table 12). At all of these ports except Port Monmouth and Wildwood, age-1 fish usually constituted 50 percent to 90 percent of the fish sampled in past years.

Although age-0 fish, which enter the fishery in early fall and winter, are not taken in proportion to their relative abundance, their scarcity in the samples from Chesapeake Bay and the North Carolina fall fishery suggests that this year class (1968) is also poor. Exceptionally poor catches during the early part of the 1969 season in the Chesapeake Bay and South Atlantic areas support this conclusion.

The small proportion of fish older than age-3, particularly in the North and Middle Atlantic areas and North Carolina fall fishery, is a condition that has persisted since catches began decreasing about 1964. Because a declining average age is one of the symptoms of overfishing, the small percentage of older fish in the catch from these areas will continue as long as heavy fishing pressure is exerted in areas where younger fish constitute the major component of the population.

GULF MENHADEN FISHERY

Robert B. Chapoton

Information about the population dynamics of the Gulf menhaden was again collected in 1968, the fifth consecutive year that our Laboratory has conducted research on this important species. Menhaden landings were sampled daily for length, age, weight, and sex at four ports: Moss Point, Miss., Empire, Morgan City, and Cameron, La., and occasionally at the remaining ports, Intracoastal City and Dulac, La., and Sabine Pass, Tex. Logbooks for recording the time, area, and estimated catch of each purse seine set were placed aboard the fishing vessels. The number of fishing days and the daily landings of individual vessels were compiled to calculate estimates of fishing effort.

About 410,000 tons of Gulf menhaden were landed in 1968. This catch was about 18 percent greater than in 1967, and it represented 78 percent of the 528,000 tons from the record year of 1962. The general trend of the catch had been downward since 1962.

Excluding the plant at Apalachicola, Fla., which operated only a few weeks in September and October, the number of active plants remained at 13, the same as in the previous 2 years. The number of vessels was 78–a decline from 92 in 1966 and 85 in 1967. Retirement of older and smaller nonrefrigerated vessels, which generally are less efficient than the newer and larger refrigerated vessels, accounted for most of the decrease.

Despite the reduction of seven vessels, the number of vessel weeks declined only slightly from 1,641 in 1966 and 1,545 in 1967 to 1,520 in 1968. Less labor trouble during the year permitted continuous fishing by more vessels, and some plants operated longer than in 1967.

The unadjusted catch-per-vessel-week increased substantially, reversing a downward trend that began in 1962. From 225 tons per week in

1967, it jumped to 270 tons in 1968, only 47 tons less than the record in 1961.

Although age-1 and age-2 menhaden continued to dominate the catch as in previous years, the relative position of these age groups shifted in favor of the age-2 fish (table 13). This age group composed over 50 percent of the fish in the 1968 samples, while age-1 fish composed only 28 percent. Except for 1966, age-1 fish in previous years constituted from 50 to 60 percent of the samples, whereas age-2 fish constituted 30 to 40 percent. This shift in percentages would seem to indicate either a relatively weak 1967 year class or a relatively strong 1966 year class. Age-2 fish were relatively more abundant in the eastern Gulf (Moss Point and Empire samples) than in the western Gulf (Morgan City and Cameron samples).

Since the fishery depends to such a large degree on only two age groups, the failure of a single year class could cause a drastic decline in the catch in 1 year. The lack of any severe decrease in apparent abundance in any year since the fishery expanded and modernized in the mid-1950's suggests that variations in the strength of individual year classes of Gulf menhaden are less violent than variations in the strength of year classes of Atlantic menhaden. If so, the Gulf menhaden fishery should remain fairly stable unless overfishing reduces the spawning stock to the point that it can no longer produce abundant year classes, or manmade or natural events wipe out a series of year classes before they enter the fishery and can spawn or reproduce. At the present level of about 80 vessels, or 1,500-1,600 vessel weeks per season, the resource appears to be producing its maximum yield. Of paramount importance to the fishery is the maintenance of high-quality, unaltered and unpolluted estuaries that serve as nursery areas for juvenile menhaden.

Again in 1968, the species composition of landings confirm the dependency of the Gulf fishery on a single species, the Gulf menhaden. Other herringlike fishes, such as Atlantic thread herring, gizzard shad,

Table 13.--Age composition of samples from catches of Gulf menhaden, 1964-68

Port of landing	Year	Numbers of fish	Age in years						
			0	1	2	3	4	5	6
			Percent						
Moss Point, Miss.	1964	3,982	<1	74	24	2	<1	0	0
	1965	6,219	<1	67	30	2	<1	<1	0
	1966	3,631	<1	12	52	32	4	0	0
	1967	5,069	<1	63	31	5	1	<1	0
	1968	5,049	<1	20	54	23	2	<1	<1
Empire, La........	1964	3,392	<1	31	44	21	4	<1	<1
	1965	3,308	<1	59	29	10	1	<1	0
	1966	2,376	0	20	52	24	4	<1	0
	1967	3,141	<1	48	43	8	<1	0	0
	1968	3,559	<1	20	52	23	4	<1	<1
Morgan City, La..	1964	2,271	0	41	51	7	1	<1	<1
	1965	3,030	<1	47	35	17	1	<1	<1
	1966	2,048	0	27	49	22	2	<1	0
	1967	2,848	<1	57	37	6	<1	<1	0
	1968	2,428	<1	41	44	13	2	<1	0
Cameron, La......	1964	2,650	<1	46	46	7	<1	<1	<1
	1965	2,709	<1	69	28	2	1	0	0
	1966	4,211	<1	54	35	9	1	0	0
	1967	2,951	<1	69	29	2	<1	<1	0
	1968	4,229	<1	37	50	11	1	0	0
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	0
	1967	14,009	<1	59	34	5	1	<1	0
	1968	15,265	<1	28	51	18	2	<1	<1

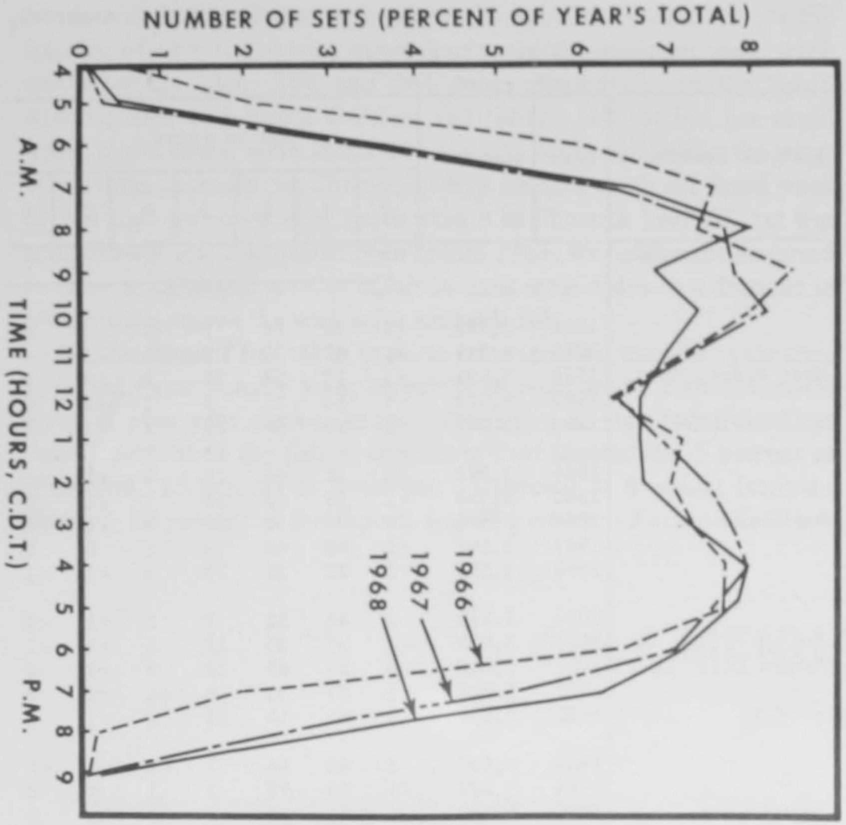

Figure 16.—Time of day that successful sets were made by the Gulf purse seine fleet in 1966-68.

and round herring were observed only occasionally in the catch. Yellowfin menhaden were sometimes sampled from catches made east of the Mississippi River Delta, and finescale menhaden were observed about equally as often in catches made west of the delta.

Figure 16 summarizes those logbook data showing the time of day that successful sets were made during each of the past three seasons, 1966-68. Time-catch curves for 1964 and 1965 were omitted because of their resemblance to those presented. The records indicated that within each year, purse seine sets were made almost entirely during daylight. The distribution of sets was similar for each year and generally appeared to be bimodal. The first sets were made at 4 a.m. and the last at 10 p.m. Of some 36,000 sets made in 1964-68, those catching fish reached a peak between 9 and 10 a.m., declined towards noon, then peaked again between 3 and 4 p.m. About 94 percent were between 6 a.m. and 6 p.m. Slightly greater than half (55 percent) of the recorded sets were made during the 9 hours from 4 a.m. to 1 p.m. The balance (45 percent) were made between 1 p.m. and 10 p.m. These observations suggest that Gulf menhaden appear to be about equally available to successful purse seining throughout daylight hours.

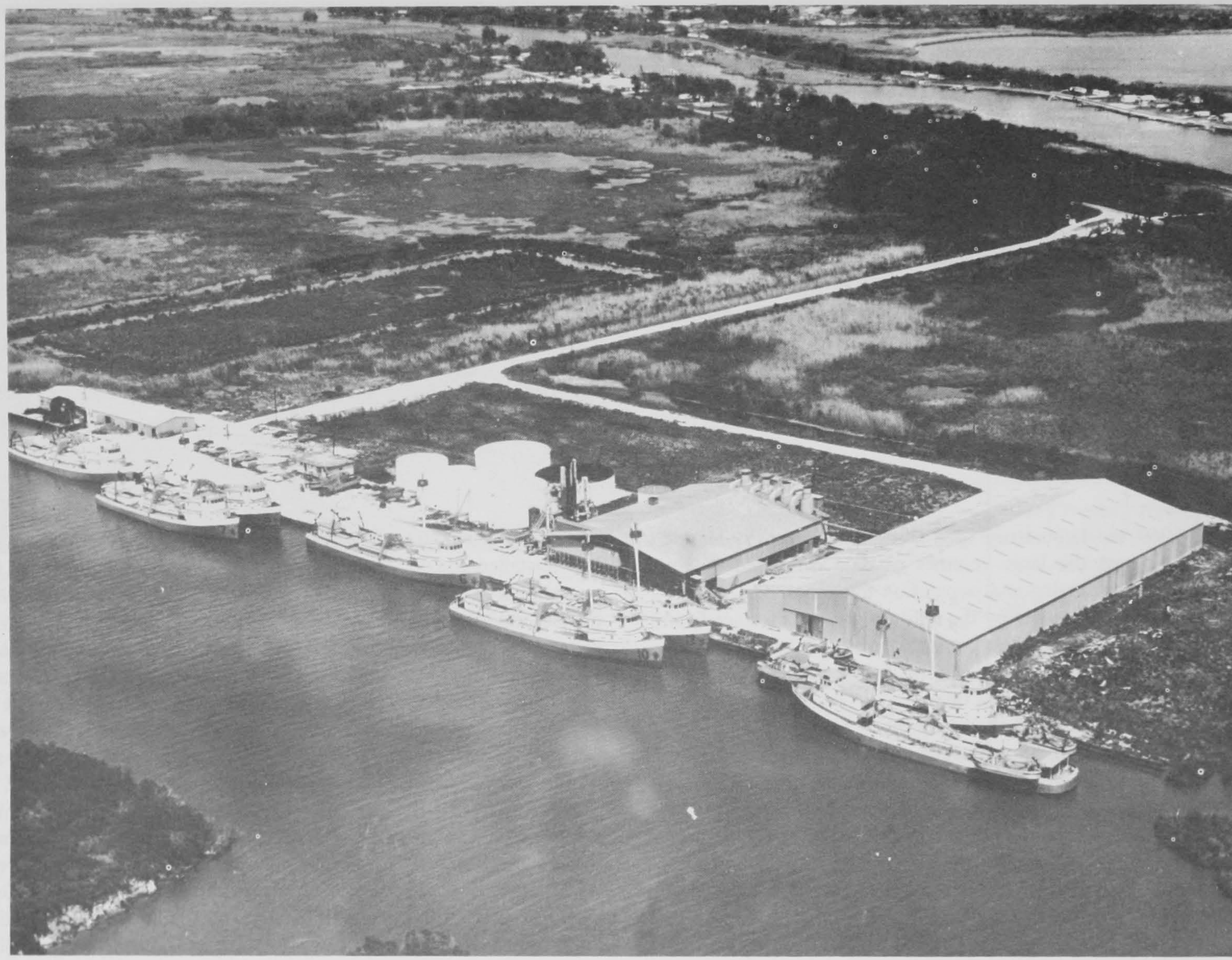

Figure 17.—Aerial photograph of a Gulf menhaden reduction plant and purse seine fleet. (Photo courtesy of Ocean Protein Inc. Subsidiary of Zapata-Norness, Inc.)

AUTOMATIC DATA PROCESSING AND BIOMETRICS

Stanley M. Warlen, John E. Hollingsworth,
Kenneth J. Fischler, and William E. Schaaf

Scientific investigations must pass through the phases of research planning, data collection, summary, and analysis, and manuscript preparation. ADP (automatic data processing) and biometrics are used to some extent in each phase of this scheme and have become integral components of our menhaden research. As part of our Laboratory's operations, we use ADP mainly to reduce the thousands of data records that the population and tagging programs collect each year. These records have information on menhaden landings, fishing effort, age and size composition, and tag releases and recoveries. We use biometrics to provide advice on the design of experiments and to provide various mathematical-statistical procedures and digital-computer programs that help us analyze and interpret data from our experimental work. In the near future, biometrics will help us develop and refine mathematical models of the Gulf and Atlantic menhaden resources.

Although we functioned as a separate program during this reporting period, we were in fact only a service group. Pending approval of our program proposal, we plan to become a formal program beginning fiscal year 1970.

ADP

Before FY 1969 the Laboratory used computers at nearby Marine Corps bases to process the large volumes of data generated by the programs on menhaden tagging and population dynamics. The increasing demands on these computers by the military and our distance from the bases led to reduced, insufficient computing time to accomplish our work. Thus, we needed to find an alternative or independent computer source that would afford us sufficient time.

Early in 1968 the Biological Laboratory made a feasibility study to determine the type of computing system that would best fulfill the needs of both the Radiobiological and Biological Laboratories. Before the recommendations of our study could be approved, the Biological Laboratory was instructed to participate in a Bureau telecommunications pilot test in which it would receive an IBM 1130 Computing System that would be linked by telephone lines to the U.S. Geological Survey's IBM 360/65 computer in Washington, D.C.

Knowing that this computer (1130) would soon arrive, the Laboratory formed a single working group in July 1968 to handle all of the Laboratory's data processing work. Heretofore, this work had been done by smaller groups from the tagging and population dynamics programs. IBM installed the 1130 on August 9, 1968, and by August 22 it was operational as a "stand-alone" computer. On September 26, installation of the leased telecommunications equipment was completed and we were able to use the 1130 as a remote terminal to the IBM 360/65. Figure 18 shows our computer operator initiating the transmission of a job to Washington, D.C. IBM trained our personnel to operate the 1130 as both a separate unit and as a terminal to the 360/65. Three of our key personnel also learned "job control language" to enable us to set up jobs for execution on the 360/65.

To use our large data-file jobs, we changed our existing programs and magnetic tape data files from RCA 3301 and IBM 360/40 modes to a mode compatible with the 360/65 at the Geological Survey in Washington. Forty-five programs were converted to the new mode, and four had to be entirely rewritten. In addition, we wrote, tested, and documented 19 new programs, some for execution on the 1130 and some on the 360/65. We also converted all of our magnetic data tape files to a mode usable on the 360/65. As of June 1969, all programs are

Figure 18.—Computer operator telecommunicating with Washington, D.C., before the transmission of a job on the IBM 1130.

operable in Washington, except for several of the tagging programs that are still not working correctly when set up for multiple execution runs.

Before any of our field data can be processed on an electronic digital computer, it must be converted from a handwritten to a machine readable format. During the year we punched and verified about 192,000 individual card records. Table 14 shows the distribution of this effort. These data cards were then used (except program decks and library records) to update the respective master file tapes. Our magnetic tape files now contain all the menhaden biostatistical (1955-68), catch record (1940-68), vessel logbook (1955-68), and tag release and recovery (1966-part of 1969) data collected since the population dynamics and tagging programs began. We now have more than a million records on these master files in Washington, D.C. Figure 19 shows the number of 360/65 jobs required to update, correct, test, and run production on these tape files in FY 1969. The distribution of jobs from March to July is typical of our current and near-future operation with the 1130 serving as a remote terminal to the 360/65.

Table 14.--The number and type of individual card records punched and verified in FY 1969

Cards punched					
Type of record	Quarter				Total
	First	Second	Third	Fourth	
	Thousands of cards				
Tagging, menhaden	60	23	16	16	115
Catch records, menhaden	3	1	1	-	5
Biostatistical, menhaden	-	11	5	25	41
Vessel logbooks, purse seine	-	-	-	6	6
Program decks and other data	5	7	10	2	24
Library	-	1	-	-	1
Total	68	43	32	49	192

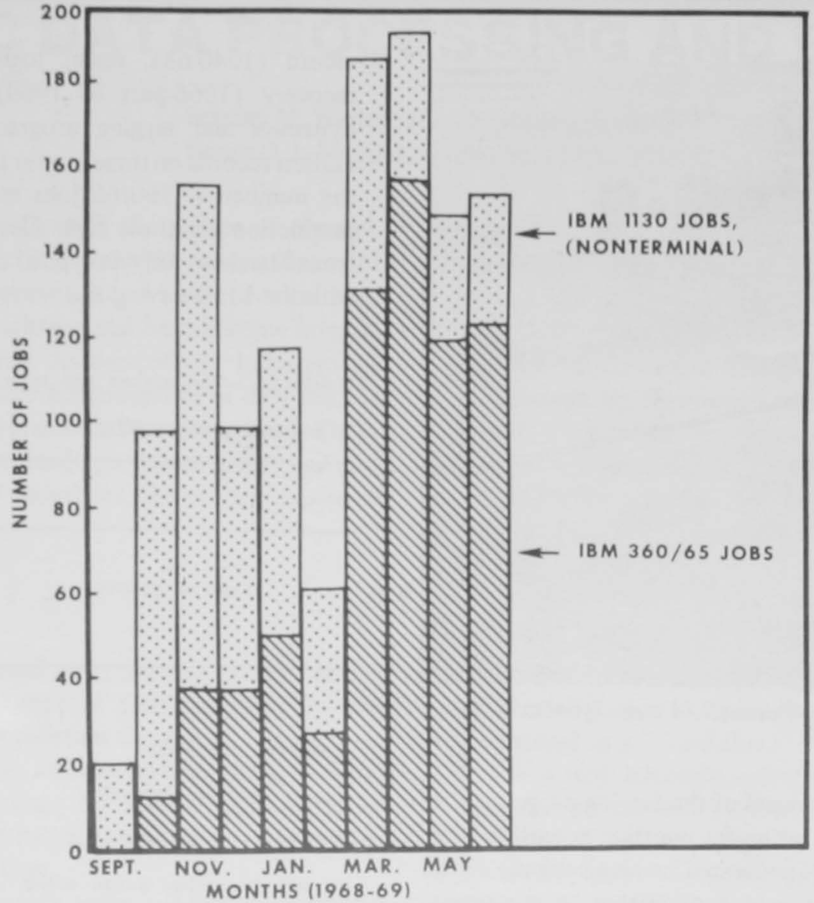

Figure 19.—Number of job entries begun on the IBM 1130 at Beaufort, N.C.

BIOMETRICS

In addition to organizing this program, our biometrician helped make the transition from the old to the new data-processing system. He also functioned as staff consultant to biologists in both the Biological and Radiobiological Laboratories by providing advice and counsel in programming research projects, designing experiments, and analyzing data from field and laboratory studies.

Activities of the programs on menhaden population dynamics, tagging, behavior-physiology, and life history are generating valuable data that will be used to describe the many small biotic and abiotic systems that make up the ecology of menhaden. Knowledge of these systems and their interrelationships can then be incorporated into computer simulation models of the menhaden resources. Such models represent the basic tool for estimating the optimum yield (biological and economical) of a resource. In cooperation with the other menhaden programs in the coming year, we will begin to estimate such vital population characteristics as growth, recruitment, and mortality for the Atlantic menhaden resource.

BIOLOGY OF INDUSTRIAL SCHOOLFISHES PROGRAM

Charles M. Fuss, Jr. and John A. Kelly, Jr.

Studies have continued on the life history and distribution of Atlantic thread herring, a potentially important species that occurs in great numbers along the west coast of Florida. Thread herring stocks may provide a significant supplement to the declining resource base of the menhaden fishery. The goal of this program is to obtain biological information necessary for the expansion and future management of the new fishery.

Commercial fishing for thread herring began in the Fort Myers, Fla., area in late August 1967 when a reduction plant opened on Charlotte Harbor. Fishing continued to August 1968, when a noxious gas accident aboard a vessel unloading at the plant killed five men. The plant has been closed since the accident but expects to reopen in the near future. Louisiana-based vessels fished during November and December 1967 and February 1968. Vessels from a plant at Apalachicola, Fla., fished for thread herring off Fort Myers in the fall and winter of 1968. About 9,071 tons of thread herring were landed between August 1967 and December 1968.

We have routinely collected field data for the fishery from logbook records and catch samples. To get additional samples of adult fish we have used monofilament gill nets of various mesh sizes set from the R/V *Kingfish,* of the BCF Biological Laboratory, St. Petersburg Beach, Fla. (fig. 20). We collected monthly samples in Tampa Bay and nearshore Gulf waters of St. Petersburg Beach from April 1967 to October 1968. We took plankton samples at each station and recorded oceanographic and meteorological data. We restrict our gill net sampling to an area of the Gulf from St. Petersburg Beach out to the 10-fathom contour and take samples at 3-mile intervals to determine the offshore distribution out to the 10-fathom contour. Beach seines and lift nets collect juvenile fish in shallow areas.

Our studies are directed toward determining the distribution, age and growth, food habits, time and place of spawning, and fecundity of Atlantic thread herring. The data collected will be discussed under these headings.

DISTRIBUTION

The combined results of our gill net sampling off St. Petersburg Beach and the commercial catch to the south off Fort Myers suggest the same general seasonal distribution as we reported last year. Schools appear to move south in the fall and concentrate in large schools generally with 10 miles of shore during the winter. As coastal waters warm in the spring, the fish disperse northward and the schools apparently break up into smaller units. Gill net catches per unit of effort (30-minute set with a 2-inch mesh, 300- by 10-foot monofilament gill net) off St. Petersburg Beach were greatest in the spring and summer and least in the winter. Catches reached a marked peak at

Figure 20.—R/V Kingfish rigged with a powerblock for sampling thread herring with monofilament gill nets.

spring-summer temperatures of 80.6° to 84.2° F. and declined as surface waters continued to warm. Commercial landings from the Fort Myers area were again high in the fall and winter.

Analysis began on the correlation of environmental factors with data on catch per unit of effort derived from the 18 months of sampling with monofilament gill nets in Tampa Bay and adjacent Gulf waters. Factors being considered are station location, time, light penetration, temperature, salinity, tide, barometric pressure, sea state, wind direction, and wind force. Stations are grouped into three general areas: bay, pass, and Gulf. Mean catch per unit of effort was greatest at pass stations (77 individuals per sample), followed by Gulf stations (59 individuals), and bay stations (46 individuals).

Young thread herring have not been found in large numbers in nearshore shallow areas. One large school of juveniles (2 - 2.6 inches fork length) was observed in lower Boca Ciega Bay on October 15, 1968. Very few were taken in other bay areas. Juveniles (1 - 4 inches fork length) first appeared on the Gulf beaches near Tampa Bay in July, and none were caught after October. They were generally mixed with schools of juvenile scaled sardines, *Harengula pensacolae*.

AGE AND GROWTH

Thread herring apparently undergo maximum growth during the first year of life and before they are available to the purse seine fishery. The mean size of thread herring (fork length) from the 1967-68 purse seine catches off Fort Myers showed little seasonal variation. Whereas fall catches had the smallest fish and the greatest spread in size, winter catches had the largest fish. Thread herring in spring and summer catches were intermediate in size. Table 15 shows fork length of fish taken in different seasons from commercial catch off Fort Myers, Fla., 1967-68.

Thread herring scales taken in monthly samples from commercial catches were examined with an Eberbach scale projector. We have not established the validity of apparent annuli (correlation with size of fish), and we are not certain about the time of year the apparent year marks are formed. Most of the scales examined (70 percent) indicated the fish were in age group II. Only 3 percent could be placed in age group III. The mean size (fork length) of fish of age group II (5.9 inches) exceeds that of age group I (5.7 inches), but the mean size of age group III (5.8 inches) does not show the expected increase of size with age (table 16). Detailed studies are now in progress on the use of scales for age and growth determinations.

Table 15.--Fork length of thread herring taken in different seasons from purse seine catches off Fort Myers, Fla., 1967-68

Season	Mean	Mode	Minimum	Maximum	Standard deviation	Range
	------Inches------					Inches
1967						
Fall	5.7	5.8	3.9	6.6	0.09	2.6
Winter	5.9	5.9	4.8	7.1	.07	2.3
1968						
Spring	5.8	5.7	4.8	7.1	.06	2.3
Summer	5.8	5.8	5.0	6.3	.06	1.3
1967-68						
Summary	5.8	5.8	3.9	7.1	.07	3.1

Table 16.--Preliminary estimates of age composition and of lengths of age groups of thread herring from commercial catches off Fort Myers, Fla., 1967-68

Item	Fall	Winter	Spring	Summer	12 Months
Age composition	- - - -	- - - -	Percent	- - - -	- - - -
Age group I	36	13	28	32	27
Age group II	64	80	70	66	70
Age group III	0	7	2	2	3
Size of age groups	- - - -	- - - -	Inches	- - - -	- - - -
Age group I					
Mean fork length	5.6	6.1	5.7	5.7	5.7
Mode	5.8	6.3	5.9	5.8	5.8
Age group II					
Mean fork length	5.8	6.0	5.9	5.8	5.9
Mode	5.9	5.9	5.8	5.9	5.9
Age group III					
Mean fork length	-	5.8	[1]6.0	[1]5.8	5.8
Mode	-	5.8	-	-	5.8

[1] One fish only.

Table 17.--Mean percentage of food organisms in the stomachs of thread herring(100-160 mm.)from the commercial catch off Fort Myers, Fla., 1967-68

[In addition to plankters listed below, most samples contained plant detritus, fish scales, and sediment.]

Date[1]	Stomachs	Percentage > 50	Percentage 10 to 50	Percentage < 10
1967	Number	Percent	Percent	Percent
Sept.	2	Copepods	Cypris larvae Pelecypods	-
Oct.	3	Pelecypods	-	Copepods Gastropods
Nov.	5	Copepods	Gastropods Pelecypods Centric diatoms	Cypris larvae
Dec.	3	Sergestids	Copepods	Pelecypods
1968				
Jan.	4	Copepods	Cypris larvae	Gastropods Annelid larvae Pelecypods Centric diatoms Eggs (unidentified)
Feb.	3	Copepods	Gastropods	Sergestids Cypris larvae Annelid larvae Pelecypods Brachyurans
Mar.	4	Cypris larvae	-	Annelid larvae Copepods Pelecypods Centric diatoms
Apr.	3	Copepods	Cypris larvae Porcellanids	Annelid larvae Brachyurans
May	4	Copepods	Cypris larvae	Gastropods
July	3	Copepods	-	Cypris larvae Gastropods Sergestids Pelecypods Centric diatoms

[1] No samples in June or August 1968.

FOOD

We examined 34 thread herring stomachs from fish taken by commercial vessels in the first year of the fishery. Generally, the contents had disintegrated so much before preservation that identification was limited largely to food with chitinous or calcareous exoskeletons. In this category, copepods were always abundant and dominated samples for 7 of 10 months. Pelecypods, gastropods, and "cypris" stage barnacles, in this order, were generally present throughout the year, but appear to form a distinctly secondary food. The frequency of finely graded sediments indicated some type of bottom feeding. Minute fish scales (unidentified) in the pyloric stomachs of some thread herring suggest the possibility that they feed on fish (table 17).

SPAWNING AND FECUNDITY

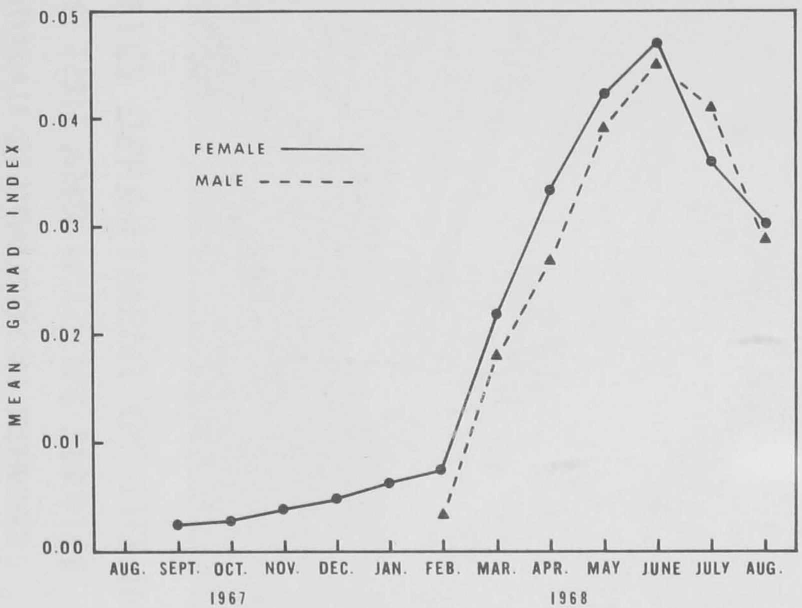

Figure 21.—Gonad index for male (dashed line) and female (solid line) fish from the commercial catch off Fort Myers, Fla., 1967-68.

We continued our studies on gonad development to determine spawning peaks along the Gulf coast. The ratio of gonad weight to whole body weight (gonad index) plotted against time depicts seasonal spawning activity. The gonad index curve of thread herring taken from commercial catches off Fort Myers showed rapid gonad development of both males and females beginning in March and reaching a peak in June (fig. 21). Females appear to be ripe when the gonad index is 0.04 or greater. The percentage of females with an index of 0.04 or greater was 17 percent in March and 75 percent in June. This percentage suggests that spawning in the Fort Myers area begins around March, peaks in June, and perhaps continues through August. The analysis of gonad data from gill net sampling off St. Petersburg Beach is not complete.

Preliminary fecundity studies indicate that female thread herring produce from 19,000 to 50,000 ova. Egg counts were slightly higher for left ovaries, but the numbers of eggs per gram of ovary were about equal for left and right ovaries. Mature ova are about 0.02 inch in diameter.

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