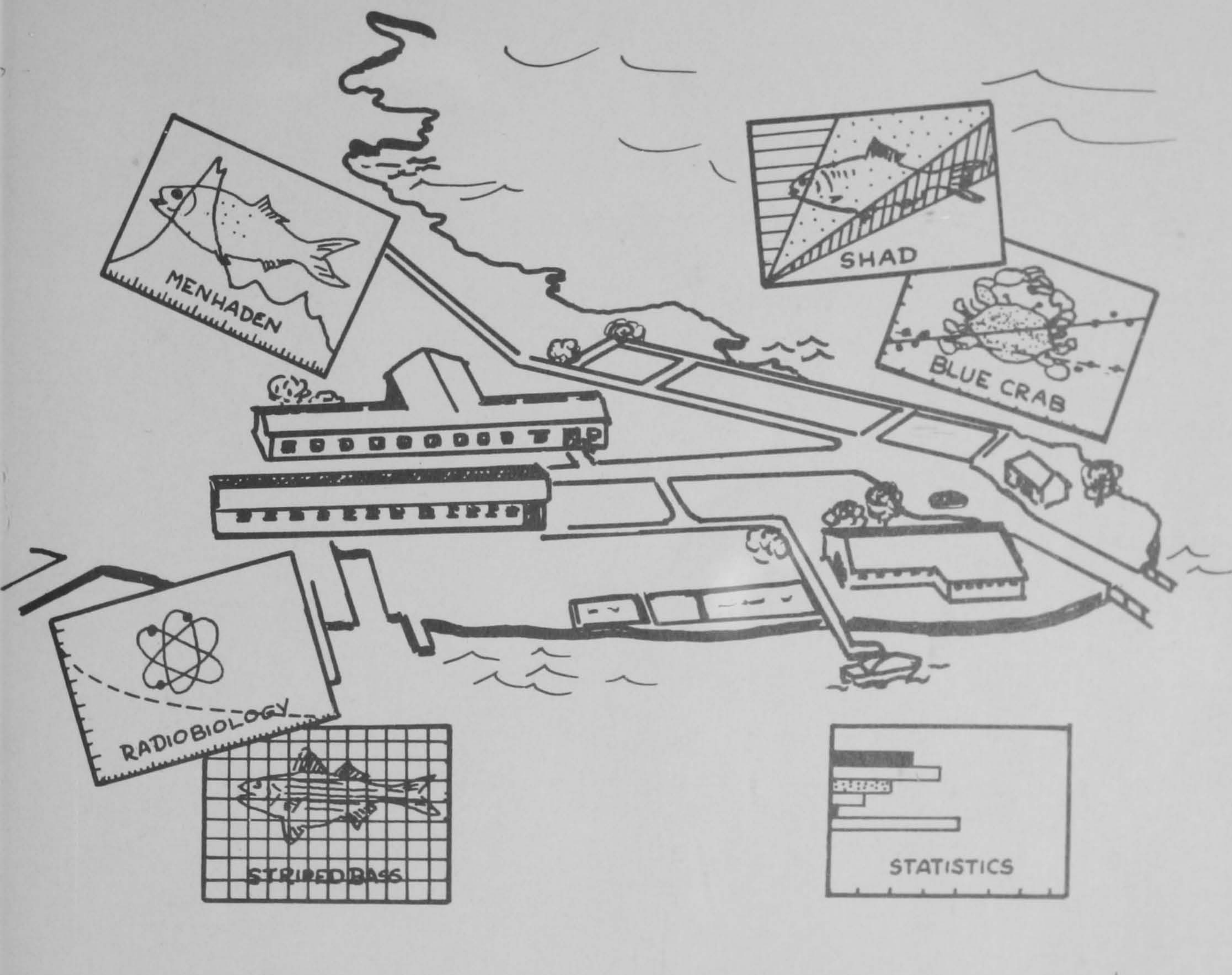
# ANNUAL REPORT

## FOR THE YEAR ENDING JUNE 30, 1961




BUREAU OF COMMERCIAL FISHERIES

BIOLOGICAL LABORATORY

BEAUFORT, NORTH CAROLINA

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UNITED STATES DEPARTMENT OF THE INTERIOR, Stewart L. Udall, *Secretary*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

# ANNUAL REPORT of the BUREAU OF COMMERCIAL FISHERIES BIOLOGICAL LABORATORY BEAUFORT, N. C.

## For the Fiscal Year Ending June 30, 1961

G. B. Talbot, *Director*

CIRCULAR 148

Washington, D. C.

1963

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

## REPORT OF THE DIRECTOR

G. B. Talbot

*Research highlights:* Preliminary investigation of the menhaden resource in the Gulf of Mexico was begun by minor extension of present research projects. Efforts were concentrated on determining the identity and range of several closely related species found along the South Atlantic coast of the United States and in the Gulf of Mexico. Expansion of research in the Gulf is anticipated in the future.

F. C. June participated in the International Fish Meal Conference held in Rome, Italy, under the auspices of the Food and Agriculture Organization of the United Nations (FAO), March 20-29, 1961. J. W. Reintjes visited Mexico in July 1960 to collect menhaden specimens along the central Mexican coast.

Successful operation of the Little Falls fishway on the Potomac River terminated work begun 10 years ago by the Shad Program on design criteria for this structure. A contract study to determine tolerance of American shad and striped bass to changes in temperature and salinity was completed for the U.S. Bureau of Sport Fisheries and Wildlife. Results indicated that striped bass were tolerant to abrupt temperature and salinity changes, while American shad tolerated only minor variations without acclimation.

A research program on blue crabs was begun in the South Atlantic area. C. H. Walburg was appointed chief of this program. The crab catch in this area has been increasing each year and during 1960 it was larger, in pounds, than that of any other food fish; in value it was second only to shrimp. Major production areas were Georgia and North Carolina where 69 percent of the catch was landed.

Required flow schedules over the striped bass spawning grounds of the Roanoke River, N. C. were formulated by personnel of the Striped Bass Program and the North Carolina Wildlife Resources Commission. These flow schedules resulted from a long series of studies and conferences by many State and Federal agencies over the past several years.

Other studies disclosed that the large (6- to 54-pound) striped bass which appear on the North Carolina coast in fall and winter make extensive migrations each year. They move to spawning areas in North Carolina and Chesapeake Bay each spring and then migrate to Massachusetts waters in the summer. There are indications that they again return to North Carolina in the fall.

T. R. Rice was appointed to the position of Chief, Radiobiological Program, upon transfer of W. A. Chipman to Washington, D. C. The U.S. Atomic Energy Commission (AEC) which supports the program in part made a comprehensive review of the program to consider the possibility of increasing its scope. At this review staff members presented a history of the Program over the past 12 years and the results of their research for the past year.

*Atlantic States Marine Fisheries Commission:* Representatives of the laboratory attended the 19th Annual Meeting held in Charleston, S. C., and presented papers at the general and sectional meetings. The South Atlantic Section of the Biological Committee met in Morehead City, N. C., during the spring to formulate plans for presenting the Committee's report to the 20th Annual Meeting of the Commission. Several laboratory members attended the meeting as guests and participated in outlining a tentative program for the General and South Atlantic sessions.

*Work conferences:* Several conferences were held with members of the U.S. Army Corps of Engineers, the U.S. Public Health Service, and AEC to coordinate research at the laboratory in the Savannah River estuary and to consider proposed studies in Galveston Harbor, Drum Inlet, and fishways for the Cape Fear River dams. Conferences were held with staff members of the Virginia Institute of Marine Science regarding cooperative studies on menhaden parasites, striped bass, and shad. Additional conferences were held with personnel of Maryland Department of Research and Education, Tidewater Fisheries, and State and Federal biologists at the Northeastern Section of Dingell-Johnson Striped Bass Meeting on striped bass problems; with Pennsylvania Fish Commission officials and their consultants concerning fish passage facilities at dams on the Susquehanna River; and, with personnel of the Statistical Unit of the Bureau's Biological Laboratory in Seattle regarding methods of estimating blue crab populations.

*Public relations:* The laboratory furnished speakers for Morehead City and Beaufort High Schools Faculty Science Clubs and for the student body. A staff member was also invited to speak to the East Carolina College Science Club. During the year the laboratory staff presented talks and demonstrations to visiting college and high school science classes. A total of 143 students and teachers attended these sessions.

*Training programs:* Three staff members, at their own time and expense, attended summer session classes at the Duke Marine Laboratory. One staff member attended the course on "Basic Radiobiological Health" at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, and another attended the Division of Biological Research Training Program in Washington, D. C. Staff members assisted in other training programs. One staff member served as a lecturer on the U.S. Public Health Service's course in "Radionuclides in Foods," and another presented a lecture at the Oak Ridge National Laboratory.

## STAFF

G. B. Talbot, *Director*

### Blue Crab and Shad Program

| | | |
|---|---|---|
| Charles H. Walburg | Chief | Beaufort, N. C. |
| Kenneth J. Fischler | Fishery Research Biologist | Beaufort, N. C. |
| Mayo H. Judy | Fishery Research Biologist | Beaufort, N. C. |
| Peggy M. Keney | Fishery Research Biologist | Beaufort, N. C. |
| James R. Musgrave | Fishery Research Biologist (Transferred 4-1-61) | Green Cove Springs, Fla. |
| Paul R. Nichols | Fishery Research Biologist | Beaufort, N. C. |
| Marlin E. Tagatz | Fishery Research Biologist (Transferred 4-1-61) | Green Cove Springs, Fla. |
| Gordon M. Davis | Fishery Aid | Beaufort, N. C. |
| Donnie L. Dudley | Fishery Aid | Beaufort, N. C. |
| Ray G. Lewis | Temporary Aid | Beaufort, N. C. |
| Margaret M. Bell | Summer Aid | Beaufort, N. C. |
| Donald R. Guthrie | Summer Aid | Beaufort, N. C. |

### Menhaden Program

| | | |
|---|---|---|
| Fred C. June | Chief | Beaufort, N. C. |
| Frank T. Carlson | Fishery Research Biologist | Millville, Del. |
| George C. Grant | Fishery Research Biologist (Resigned 9-9-60) | Millville, Del. |
| Joseph R. Higham | Fishery Research Biologist | Beaufort, N. C. |
| William R. Nicholson | Fishery Research Biologist | Beaufort, N. C. |
| Anthony L. Pacheco | Fishery Research Biologist | Millville, Del. |
| John W. Reintjes | Fishery Research Biologist | Beaufort, N. C. |
| Charles M. Roithmayr | Fishery Research Biologist (Transferred 6-10-61) | Beaufort, N. C. |
| Doyle F. Sutherland | Fishery Research Biologist | Beaufort, N. C. |
| James F. Guthrie | Fishery Aid | Beaufort, N. C. |
| George N. Johnson | Fishery Aid | Beaufort, N. C. |
| Carl N. Baker | Temporary Aid | Millville, Del. |
| Fred W. Brockmann | Summer Aid | Port Monmouth, N. J. |
| N. Kenneth Ebbs | Summer Aid | Port Monmouth, N. J. |
| Jack V. Guthrie | Summer Aid | Amagansett, N. Y. |
| David P. Hamilton | Summer Aid | Wildwood, N. J. |
| Robert W. Hamilton | Summer Aid | Lewes, Del. |
| Christian D. Mercer | Summer Aid | Amagansett, N. Y. |
| Henry A. Taylor | Summer Aid | Reedville, Va. |
| Fronnie A. Jones | Airplane Pilot | Beaufort, N. C. |
| William G. Peele | Airplane Pilot | Beaufort, N. C. |
| Mary K. Hancock | Clerk | Beaufort, N. C. |

### Striped Bass Program

| | | |
|---|---|---|
| James E. Sykes | Chief | Beaufort, N. C. |
| Rupert R. Bonner, Jr. | Fishery Research Biologist | Beaufort, N. C. |
| Robert B. Chapoton | Fishery Research Biologist | Beaufort, N. C. |
| Randall P. Cheek | Fishery Research Biologist | Beaufort, N. C. |
| Robert M. Lewis | Fishery Research Biologist | Beaufort, N. C. |
| Louis E. Vogele | Fishery Research Biologist | Beaufort, N. C. |
| Charles Lewis | Summer Aid | Beaufort, N. C. |
| John H. Crowe | Fishery Aid | Beaufort, N. C. |
| Irwin McIntosh | Fishery Aid | Beaufort, N. C. |

### Radiobiological Program

| | | |
|---|---|---|
| W. A. Chipman | Radiobiological Liaison Officer (Transferred to Washington, D. C. 11-7-60) | Beaufort, N. C. |
| T. R. Rice | Chief | Beaufort, N. C. |
| John P. Baptist | Fishery Research Biologist | Beaufort, N. C. |
| Joyce S. Clarke | Fishery Research Biologist (Resigned 1-2-61) | Beaufort, N. C. |
| Donald E. Hoss | Fishery Research Biologist | Beaufort, N. C. |
| T. J. Price | Fishery Research Biologist | Beaufort, N. C. |
| George H. Rees | Fishery Research Biologist | Beaufort, N. C. |
| Edna M. Davis | Biological Aid | Beaufort, N. C. |
| James R. Wheatley, Jr. | Biological Aid | Beaufort, N. C. |
| Marianne B. Murdoch | Fishery Aid | Beaufort, N. C. |
| Thomas G. Roberts | Fishery Aid | Beaufort, N. C. |
| Clarence M. Roberts | Vessel Operator-Engineer | Beaufort, N. C. |
| Susan F. King | Summer Aid | Beaufort, N. C. |
| Grover A. Smithwick | Summer Aid | Beaufort, N. C. |
| Choral Eddy | Antioch Student | Beaufort, N. C. |
| Gary O. Goldsmith | Antioch Student | Beaufort, N. C. |
| Caroline Shaw | Antioch Student | Beaufort, N. C. |
| Janet Wurst | Antioch Student | Beaufort, N. C. |

Staff Services

| | | |
|---|---|---|
| Mary L. Willis | Clerk-Typist | Beaufort, N. C. |
| Inez J. Nierling | Clerk-Stenographer | Beaufort, N. C. |
| Elizabeth F. Talbot | Librarian | Beaufort, N. C. |

Administration and Maintenance

| | | |
|---|---|---|
| Thelma C. Nelson | Administrative Assistant | Beaufort, N. C. |
| Margaret M. Lynch | Clerk-Typist | Beaufort, N. C. |
| Claude R. Guthrie | Foreman-Repair and Maintenance | Beaufort, N. C. |
| Olive L. Davis | Clerk-Stenographer | Beaufort, N. C. |
| John S. Mason | Caretaker | Beaufort, N. C. |
| Ramona R. Brown | Clerk-Stenographer (temp.) | Beaufort, N. C. |
| Jack D. Lewis | Caretaker | Beaufort, N. C. |
| Willie S. Rainey | Laborer | Beaufort, N. C. |
| Glenshaw Henry | Laborer (temp.) | Beaufort, N. C. |

## BLUE CRAB PROGRAM

Charles H. Walburg, *Chief*

The blue crab *(Callinectes sapidus)* supports one of the most important fisheries on the Atlantic and Gulf coasts of the United States. In 1960, a record 143,600,000 pounds valued at $8,700,000 were landed. The supply of this species, however, fluctuates violently, resulting in serious economic problems for the industry. Attempts to control these fluctuations by protective legislation have proven unsuccessful. Management of the species must be based on scientific knowledge of the causes of changes in abundance. The purposes of the investigation are to: (1) increase knowledge of life history; (2) determine relation between size of spawning stock and marketable progeny; (3) determine relation between environmental factors and abundance; and (4) suggest management measures.

To attain these objectives, studies were continued on the Newport River estuary adjacent to the Bureau of Commercial Fisheries Biological Laboratory at Beaufort, N. C., and a new project was begun on the blue crab population of the St. Johns River, Fla. One of the major problems was to estimate the annual size of crab stocks in study areas. This was accomplished by collecting catch and effort statistics from crab producers and conducting a large-scale tagging program in the Neuse River, N. C. From the recapture rate of tagged crabs, analyses of catch and effort statistics, and certain life history information, an estimate of population size was calculated. Life history studies were conducted to learn the location of spawning and nursery areas, growth rates, age at maturity, average life span, migrations, mortality rates, etc. Environmental factors were measured to determine their effect on blue crab abundance.

The effect of changes in temperature and salinity on survival of blue crab zoeae were studied in the laboratory. Survival of groups of zoeae from the same parent reared under identical conditions has been unpredictable. Further studies were made to find a more favorable diet for experimentally reared zoeae in an effort to increase survival.

Much effort was spent on improving methods of estimating the size of crab populations. The number of crabs in a given population is continually changing because of a relatively short life span and rapid recruitment to the fishable stock. This requires development of new techniques to estimate seasonal abundance of the stock.

### NEWPORT RIVER STUDY

Mayo H. Judy

This is a long-term project begun in 1957 by the Oyster Institute of North America on contract with the U.S. Fish and Wildlife Service. The objectives were to: (1) determine seasonal distribution of various life history stages, both vertically and horizontally throughout the estuary; (2) measure hydrographic factors to determine their role in the general ecology of all life history stages of blue crab; (3) determine relative abundance of each stage and associated organisms; and (4) determine size of the adult population. Studies were conducted to determine the effect of environmental factors on blue crab abundance.

At designated stations throughout the estuary, both Clarke-Bumpus and 12-inch diameter (Turtox) plankton nets caught blue crab zoeae in the lower estuary and megalops and early stage adult forms in the upper estuary from May through October. Most zoeae collected were 1st stage, followed in abundance by 2d and 3d stages. Very few later stage zoeae were found. Tidal-cycle sampling indicated no apparent relation between physical factors of the environment and abundance of crab zoeae except that megalops and early stage adult forms were captured in greater abundance at night. These forms may be capable of avoiding capture during daylight hours. A comparison of the effect of tide on larval crab catch indicated that approximately 50 percent of the crab zoeae that entered the estuary on flood tide were returned to the sea during


Using confined submerged drag to estimate current velocity in Newport River estuary, N. C.

ebb tide. This phenomenon was related to the high flushing rate characteristic of the Newport River estuary.

A key was prepared to aid in the identification of the more common species of crab zoeae found in plankton of the Beaufort, N. C., area. This key will also be valuable for analysis of plankton collected in other South Atlantic areas.

Trawl sampling revealed that immature male and female crabs were predominant in the upper estuary and were taken in about equal numbers. Mature males were also prevalent in this section. Mature crabs were predominant in the lower estuary, with females more numerous than males. Sponge (egg-bearing) crabs appeared in late March when the water temperature was approximately 60° F. During spring 57 to 91 percent of commercial size females taken by trawl had sponges. Sponge crabs were also common in late summer catches.

Approximately 5,000 adult tagged crabs were released in adjacent estuaries and in the ocean offshore from the Newport River to obtain information on migrations and population size. Returns indicated a definite movement of female crabs to the ocean for the purpose of spawning. Catch and effort statistics and tag return data were used to obtain preliminary estimates of the size of the Newport River population.

## ST. JOHNS RIVER STUDY

Marlin E. Tagatz

The purpose of the St. Johns River project is to determine causes for fluctuations in abundance of blue crabs. A field laboratory was established at Green Cove Springs, Fla., and two biologists from the Bureau's Biological Laboratory, Beaufort, were assigned to the project. Long-term objectives are to: (1) determine relation of spawning stock to resultant marketable adults, (2) determine relation of environmental factors to abundance, and (3) obtain life history information. During the first year, investigations are expected to determine distribution of the fishery and obtain catch and effort statistics and life history information.

The commercial crab fishery extended from the river mouth to Astor, Fla., a distance of 120 miles. During the spring crabs were landed by 41 crab pot fishermen (15 to 200 pots per man), 1 trotline fisherman, and 23 shrimp trawlers. Catch and effort statistics were obtained from sales slips provided by crab plant operators and from records kept by fishermen who retailed their catch. Width and sex frequencies were obtained from both market and unculled pot catches.

Measuring blue crabs on the St. Johns River, Fla.

Sex composition and size range of crabs taken by pot at two locations, St. Johns River, Fla.

| Location | Market crabs | Unculled catch |
|---|---|---|
| Jacksonville | | |
| Percent males | 64 | 62 |
| Percent females | 36 | 38 |
| Percent females with sponge | 31 | 38 |
| Size range mm. | 94-210 | 91-221 |
| Percent 127 mm. in width | 14 | 9 |
| Percent 175 mm. in width | 9 | 10 |
| Welaka | | |
| Percent males | 88 | 84 |
| Percent females | 12 | 16 |
| Percent females with sponge | 0 | 0 |
| Size range mm. | 108-219 | 106-218 |
| Percent 127 mm. in width | 1 | 11 |
| Percent 175 mm. in width | 35 | 22 |

Monthly trawl sampling was conducted at 14 locations from Mayport to Astor. Catches of juvenile crab in this area were relatively small, but most abundant in the lower estuary from Jacksonville to Mayport.

Monthly plankton collections were made in the lower estuary using Clarke-Bumpus samplers. Surface and bottom samples were obtained during several tidal cycles. Blue crab zoeae were present in samples obtained from the river mouth to Jacksonville. Most were 1st stage and none were beyond stage 3.

The upper limit of tidal influence in the St. Johns is in Lake George, approximately 100 miles upstream from the river mouth. Salinity ranged from 6 to 14 ‰ at Jacksonville; at Doctors Inlet, 35 miles from the river mouth it was 0 ‰. Monthly ranges in surface water temperature were: April, 19.0 to 23.0° C.; May, 21.0 to 29.5° C.; and June, 25.0 to 31.0° C. The pH of surface waters ranged from 7.6 to 8.4.

## POPULATION STUDIES

Kenneth J. Fischler

Analyses of tag returns, catch samples, and catch and effort data for the Neuse River, N. C., crab population were continued, and methods for estimating size of crab populations were developed.

Results of tagging studies and catch sampling indicated that marketable size females moved out of the river during the fishing season. Marketable size males remained in the river and, therefore, were considered a closed population affected only by natural mortality, predation, exploitation, and recruitment. Based on available information, natural mortality during the fishing season was probably small and predation, although unknown, was considered relatively unimportant in this study. Estimates were obtained for: (1) male recruitment, from the ratio of submarketable to marketable crabs in catch samples; (2) abundance of males, using catch-effort data after adjustment for recruitment; and (3) sex ratio of marketable size crabs in the commercial catch, from catch samples.

To estimate pounds of male crabs available to the fishery on a specified date (time zero) the subsequent weekly catches were reduced by the pounds of recruits taken each week. Catches remaining, therefore, were male crabs present in the population at time zero. Population size was estimated from these weekly catches using the Leslie method. In this method, applicable to closed populations where catch per unit effort is assumed directly related to stock abundance, the best linear function was evolved relating catch per standard-unit-effort to cumulative catch over a time period. The male population estimates were calculated by considering the beginning of each week as time zero. Estimates of total marketable crab abundance were obtained by adjusting the male population estimated by the ratio of marketable females in the catch.

Weekly abundance was also estimated by relation of marked to unmarked crabs in the catch over a specified time period (Parker method). The ratio at time zero was extrapolated from the linear function, and abundance was obtained by dividing the number of marked crabs released just prior to time zero by the ratio. Abundance estimates calculated by the Parker method for June 23, July 7, and July 14 were 657,000, 718,000 and 789,000 pounds, respectively. Population sizes obtained by the Leslie method were within the confidence limits calculated for Parker estimates.

Estimates of abundance derived with the Parker method could be affected by: (1) unequal natural mortality rates for marked and unmarked crabs, (2) nonuniform fishing intensity, (3) nonrandom distribution of tagged crabs, (4) variable absolute emigration rate for females, and (5) noncontinuous absolute recruitment rate. Estimates of population size were based on daily recovery of marked and unmarked individuals for a period of approximately 4 weeks after tagging. Recoveries after that time were too few to be useful in this method. The low tag recovery rate 4 weeks after tagging probably resulted from nonrandom distribution of tagged crabs and intensified fishing effort in release areas shortly after time zero, followed by a reduction in fishing.

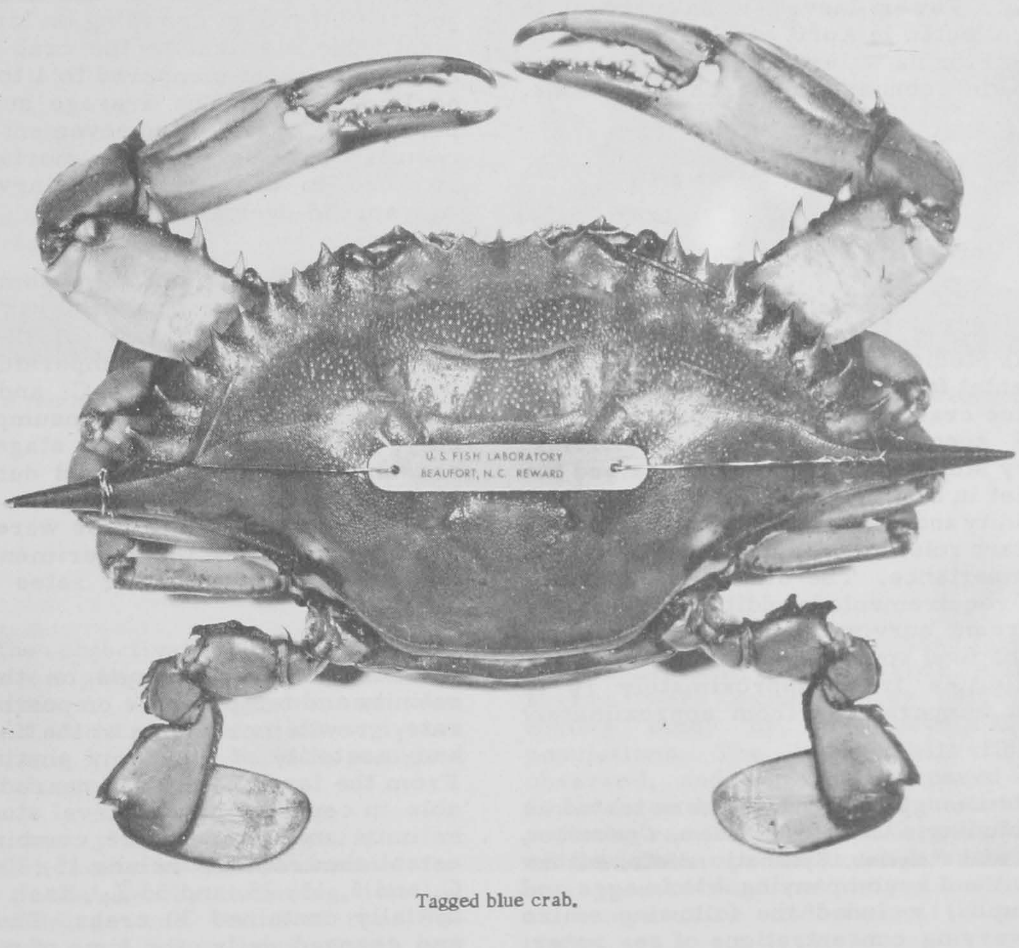
Weekly blue crab catch and estimates of abundance, Neuse River, N. C., 1958. (In thousands of pounds. Estimates of abundance were for the beginning of each week.)

| Week | Males | Total (both sexes) | Abundance: Males | Abundance: Total (both sexes) |
|---|---|---|---|---|
| May 12-18 | 36 | 43 | 272 | 328 |
| 19-25 | 59 | 73 | 286 | 354 |
| 26-June 1 | 54 | 68 | 303 | 376 |
| June 2-8 | 61 | 79 | 342 | 440 |
| 9-15 | 70 | 91 | 398 | 520 |
| 16-22 | 102 | 132 | 443 | 572 |
| 23-29 | 56 | 73 | 420 | 549 |
| 30-July 6 | 45 | 60 | 492 | 652 |
| July 7-13 | 74 | 97 | 527 | 694 |
| 14-20 | 87 | 118 | 520 | 706 |
| 21-27 | 80 | 108 | 491 | 663 |
| 28-Aug. 3 | 84 | 112 | 468 | 625 |
| Aug. 4-10 | 65 | 84 | 435 | 564 |
| 11-17 | 78 | 101 | 412 | 535 |
| 18-24 | 70 | 91 | 373 | 483 |
| 25-31 | 45 | 59 | 338 | 442 |
| Sept. 1-7 | 47 | 83 | 323 | 430 |
| 8-14 | 52 | 70 | 305 | 408 |
| 15-21 | 35 | 47 | 279 | 370 |
| 22-28 | 29 | 38 | 268 | 359 |

## NATURAL HISTORY STUDIES

Charles H. Walburg

*Migration studies – South Carolina:* Analysis of the results of a cooperative tagging study by the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N. C., and the Bears Bluff Laboratories, Wadmalaw Island, S. C., was completed. Returns indicated that commercial size crabs moved from the lower portion of the North Edisto River to the more saline and warmer coastal waters in late winter. Of the tagged crabs released during spring and summer in the North Edisto and Ashley-Cooper estuaries, males were recovered until fall from the brackish waters of the estuaries or in vicinity of release and females were recovered mainly in coastal waters. Commercial size crabs did not migrate between estuaries, but limited their movements to the estuary and adjacent coastal waters. This indicated, at least for South Carolina, that management measures can probably be confined to individual estuarine systems rather than to large coastal regions.




Tagged blue crab.

*Migration studies – North Carolina:* In some years large numbers of migrating adult crabs have been observed off the North Carolina outer banks in the fall. In October and November 1960, tagged crabs were released in the ocean surf from Oregon Inlet, N. C., to just above the North Carolina-Virginia boundary to determine their destination. Marked crabs were recaptured in lower Chesapeake Bay, 18 to 110 miles from tagging sites; Pamlico Sound, 4 to 95 miles from tagging sites; and near Beaufort, N. C., 125 miles from tagging sites. Early recaptures indicate that the majority of adult crabs found off the outer banks were destined for North Carolina waters.

*Analysis of plankton samples – Theodore N. Gill cruises:* Identification of *Callinectes* larvae was continued in plankton samples collected during *Theodore N. Gill* cruises at stations from Cape Hatteras, N. C., to Jupiter Inlet, Fla., offshore to the axis of the Gulf Stream. Because larvae of many species of marine decapods have not positively been identified, the larvae had to be examined carefully so that *Callinectes* larvae were not confused with those of closely related forms, i.e., *Portunus*. Cursory observations indicated an abundance of all larval stages of *Callinectes* in coastal waters during June, July, and August. Fewer larvae were present in samples collected in April and May, except in those from Florida waters. No *Callinectes* zoeae were found in February or March collections.

## LARVAL STUDIES

John D. Costlow
Duke University Marine Laboratory

*The effects of environmental factors on the development and survival of larvae of the blue crab (Contract: 14-17-002-28):* Studies to determine the effects of environmental factors on development and survival of blue crab larvae required an abundant supply of zoeae for detailed experiments. Laboratory studies repeatedly emphasized the role of diet in successful larval development. While salinity and temperature appeared to play an important role, an adequate diet was of the utmost importance. The diet must satisfy a variety of requirements in addition to providing a high percent survival to the first crab and beyond. The food source or sources must withstand salinities from approximately 10 to 40 ‰ and temperatures from approximately 15 to 30° C.

Invertebrate eggs and larvae were tested as foods, including *Chaetoperus, Diadora, Crassostrea, Eupomatus,* and *Polydora*. Synthetic diets, either with or without accompanying *Arbacia* eggs and *Artemia* nauplii, included the following amino acids in varying concentrations of sea water: tyrosine, methionine, leucine, lysine, glycine, arginine, tryptophan, and histidine. The marine alga, *Chlamydomonas,* and the diatoms, *Skeletonema* and *Nitschia* were tested as possible sources of organic or inorganic constituents which appeared to be missing from the diet normally used in rearing crab larvae. Larvae from some blue crabs appeared to survive better in diets fortified with small amounts of phytoplankton; however, data were insufficient to draw definite conclusions. While a small percent of the many thousands of larvae reared did complete metamorphosis to the first crab stage and beyond, survival in all diets was low.

Rearing experiments were continued to determine how viability of larval stages varies when hatched from eggs of a number of females. Twenty series of larvae, hatched from egg masses of 16 different females were followed throughout development. Approximately 15,000 larvae were reared in 20 "checked" series and an equal number in mass cultures. From the series, 1,012 first crabs were obtained and a similar number were reared in the mass cultures. Data were collected on the survival of larvae in cultures containing different antibiotics, the time required for development to the megalops and first crab stage, and the effects of crowding on larval development. The survival to the crab ranged from 2 to 20 percent compared to 1 to 8 percent in earlier studies. The average survival was 9 percent--a marked improvement over earlier results. In most series, mortality was not confined to one particular larval stage but was spread over all stages.

Preliminary studies were completed on the oxygen consumption of all seven zoeal stages and one megalops stage of the blue crab. Larvae were reared at temperature and salinity combinations of 25° C. and 20, 30, and 40 ‰, and the oxygen consumption of each stage determined. In some stages the oxygen consumption was determined during the first day after molting and during the later days of development. Microanalyses were made of the nitrogen content of the experimental zoeae for comparison of metabolic rates of all larval stages.

Studies were continued on the effects of salinity and temperature on postlarval molting rate, growth increments at the time of molting, and mortality of the early postlarval stages. From the large number of reared crabs available in connection with larval studies, sixteen salinity and temperature combinations were established. These include 15, 20, 25, and 30° C. and 5, 15, 25, and 35 ‰. Each of the series initially contained 30 crabs. These were fed and changed daily, the time of molting noted, the individual molts measured, and the mortality recorded. All series will be maintained under these environmental conditions, at least through the 10th molt. Data obtained from these studies will be combined with the results of previous work at different temperature-salinity combinations in an effort to determine if certain combinations of salinity and temperature are optimal for postlarval development and growth.

Researcher at rear is placing blue crab larvae in constant temperature cabinet, while assistants in foreground are changing larvae to freshly filtered sea water and recording survival.

## SHAD PROGRAM

Charles H. Walburg, *Chief*

Many of the objectives of the shad *(Alosa sapidissima)* investigation have been accomplished; therefore, the program has been de-emphasized. Most personnel formerly associated with this investigation were assigned to the blue crab program.

Emphasis was placed on preparation of a report which contains the paramount results of 10 years' work, including detailed life history findings and status of the 1960 fishery by State and water area. Catch and effort statistics on the shad fisheries of the Connecticut, Hudson, York, and St. Johns Rivers were examined as part of a continuing study of the dynamics of these populations. The Little Falls fishway was observed, and a report prepared on its effectiveness in passing anadromous fish. Reports on reduced oxygen tolerance and toxicity of petroleum products to juvenile shad, and tolerance of shad and striped bass to changes in temperature and salinity were completed.

Experiments conducted to determine tolerances of juvenile American shad to changes in temperature and salinity.

## STATUS OF THE SHAD FISHERY - 1960

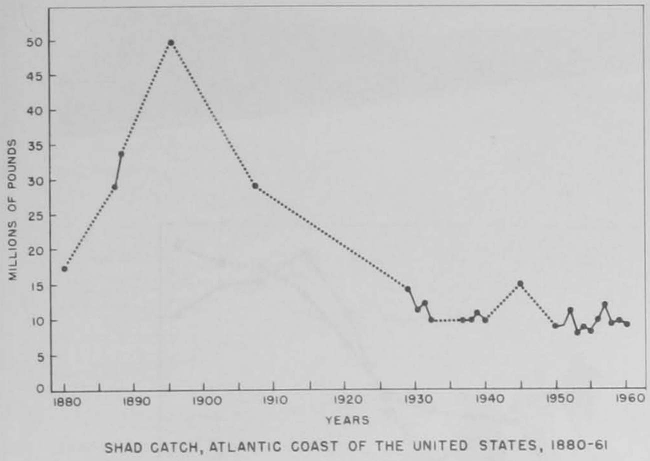
Paul R. Nichols

The purpose of this study was to report current factual information on the shad with emphasis on: (1) detailed life history review, (2) description of fishery in 1960, compared to that in 1896 when the last detailed survey was made, (3) factors responsible for decline in abundance, (4) management measures to increase stocks, and (5) information required to obtain optimum sustained yield.

Life history of this species has been reviewed by workers in the past; however, studies by the shad investigation have increased knowledge of migration, homing, spawning grounds, fecundity, age and growth, maturity, and mortality rates.

The Atlantic coast catch in 1960 was 8,114,000 pounds--an 84-percent decrease when compared to the 50,499,000 pounds caught in 1896. Shad production between these years decreased in every State except Massachusetts and Georgia. In 1960 Maryland ranked first in yield with 1,409,000 pounds, Virginia second with 1,386,000 pounds, and North Carolina third with 1,266,000 pounds. In 1896 New Jersey ranked first with 13,910,000 pounds, Virginia second with 11,170,000 pounds, and North Carolina third with 8,843,000 pounds. In 1960 the South Atlantic fishery ranked first in yield, Chesapeake Bay second, New England third, and Middle Atlantic fourth. In 1896 Middle Atlantic was first, Chesapeake Bay second, South Atlantic third, and New England fourth.

The basic pattern of gear employed by the fishery has remained rather constant. Improvements have been made in nets by using nylon instead of linen twine, and outboard motors have replaced oars and sails in powering the boats; but otherwise the fishery is accomplished in about the same manner as in earlier days.




Shad catch, Atlantic coast of the United States, 1880-1960.

Many factors have been blamed for the reduction in abundance of this fish. Among these were (1) environmental changes such as siltation, dredging, temperature, and stream flow; (2) construction of dams which prevented shad from reaching fresh-water spawning areas; (3) pollution in rivers which rendered them unsuitable for shad; (4) overfishing which did not allow enough fish to spawn and replace those taken by the fishery; and (5) natural cycles of abundance. Probably all of these factors, except perhaps natural cycles of abundance, have influenced the decline of shad populations. Major factors identified, at least in most instances, were construction of dams, overfishing, and pollution.

Management measures instituted in past years to increase shad stocks were (1) artificial propagation; (2) fish passage over artificial obstructions; (3) pollution abatement; and (4) controls on fishing seasons and number of fishermen. All of these measures have been used by one or more of the Atlantic Coast States. Artificial propagation was practiced in all States sometime after 1870; in fiscal year 1961, however, it was employed on a limited scale only in the State of Virginia. Fishways for shad and other anadromous fish were maintained in Massachusetts, Connecticut, Maryland, and North Carolina. Most States have adopted pollution control, which is expected to indirectly influence shad abundance. Pollution was most serious in the Altamaha, Savannah, Delaware, and Hudson Rivers. All States had season and gear restrictions, and most limited the number of fishing days per week. Maryland limited the number of fishermen.

Restoration of shad runs to former abundance probably cannot be accomplished because environmental changes brought about by civilization have reduced the capacity of rivers to produce anadromous fish. That production can be increased above present levels has been indicated by investigations on the Hudson and Connecticut Rivers. These populations can be managed by regulation of fishing effort to increase yield.

## DYNAMICS OF SHAD POPULATIONS

Charles H. Walburg

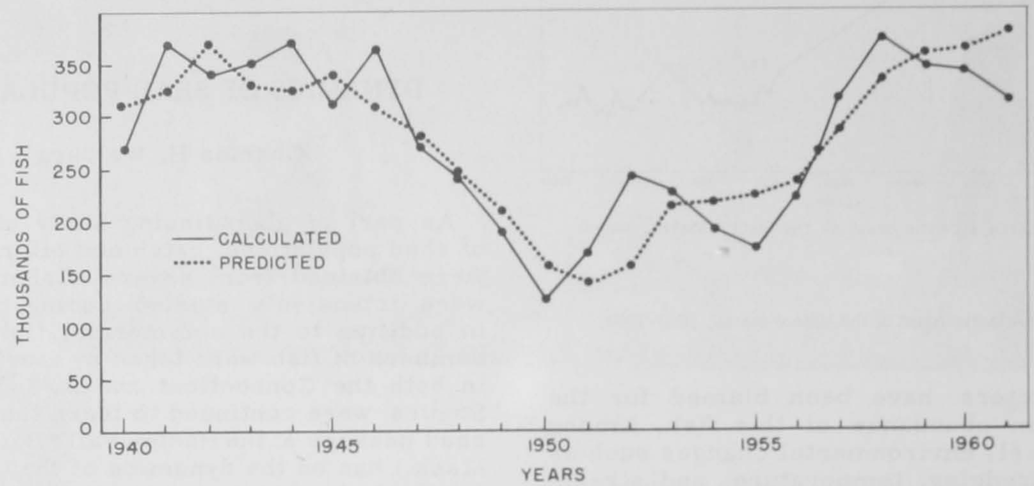
As part of a continuing study of dynamics of shad populations, catch and effort statistics were obtained from several fisheries, which were intensively studied during past years. In addition to the commercial fishery, large numbers of fish were taken by sport fishermen in both the Connecticut and St. Johns Rivers. Studies were continued to learn the effect that shad passage at the Hadley Falls Dam (Holyoke, Mass.) has on the dynamics of the Connecticut River shad population.

*Connecticut River – 1960:* The estimated commercial catch was 115,700 shad, fishing rate 34 percent, and calculated size of run 340,000 fish. The predicted size of run was 361,000 shad. These results suggest that it is possible to manage the fishery to obtain desired population size and produce maximum continuing yields. From a regression equation calculated from escapement and size-of-run data the predicted size of the 1961 population was 378,000 fish.

The estimated sport catch by both Connecticut and Massachusetts fishermen was 24,800 shad--a 54-percent decrease from that of the 1959 season. High-water conditions during much of the fishing season were believed responsible for the decreased catch.

Passage of shad at the Hadley Falls Dam totaled 15,076 fish--the largest number to use the fishway in a single season. Numbers of other species using the fishway were: alewife *(Alosa pseudo–harengus)* 796, bass *(Micropterus* sp.) 505, carp *(Cyprinus carpio)* 49, trout *(Salmo* sp.) 21, lamprey *(Petromyzon marinus)* 17, perch *(Perca flavescens)* 8, Atlantic salmon *(Salmo salar)* 2, and walleye *(Stizostedion vitreum)* 2.

*Hudson River – 1960:* The estimated commercial shad catch in the Hudson River was 775,000 pounds (224,000 fish)--the least for a number of years. Dynamics of the population from 1952 to 1960 are given (see table).




CALCULATED AND PREDICTED SIZE OF CONNECTICUT RIVER SHAD RUNS, 1940-61

Calculated and predicted size of Connecticut River shad runs, 1940-60.

Dynamics of Hudson River shad population, 1952-60

| Year | Catch | Fishing rate | Calculated size of run | Predicted size of run |
|---|---|---|---|---|
| | Thousand pounds | Percent | Thousand pounds | Thousand pounds |
| 1952 | 1,143 | 46.4 | 2,463 | 2,180 |
| 1953 | 930 | 42.3 | 2,198 | 2,701 |
| 1954 | 1,278 | 43.2 | 2,958 | 2,220 |
| 1955 | 1,571 | 40.4 | 3,889 | 3,239 |
| 1956 | 1,769 | 44.0 | 4,020 | 4,760 |
| 1957 | 1,511 | 40.0 | 3,778 | 4,773 |
| 1958 | 1,007 | 36.2 | 2,782 | 5,324 |
| 1959 | 1,169 | 40.7 | 2,872 | 5,743 |
| 1960 | 775 | 39.0 | 1,987 | 5,806 |

Good agreement between predicted and calculated size of runs in the Hudson River was obtained for all years except 1958, 1959, and 1960. This discrepancy is believed to be at least partially caused by changes in "fishing efficiency" brought about by poor market price for Hudson River shad. Concurrent with the "apparent" decrease in size of the Hudson population has been a tremendous increase in the quantity of shad landed by purse seiners (up to 2 million pounds) fishing for industrial fish out of Gloucester, Mass. Shad from all Atlantic coast streams spend the summers in the Gulf of Maine where this fishery operates. Because of apparent recent changes in the Hudson fishery since our initial investigation, we were unable to determine the size of the shad population with desired confidence. It has been recommended that this fishery be reinvestigated to determine changes and, based on these findings, suggest management recommendations.

*York River – 1960:* The fishery was investigated in 1959 and a report prepared for publication. Included were methods of estimating the dynamics of the shad population and information on life history.

Dynamics of York River shad, 1953-60

| Year | Catch | Fishing rate | Calculated size of run |
|---|---|---|---|
| | Thousand pounds | Percent | Thousand pounds |
| 1953 | 552 | 58.3 | 947 |
| 1954 | 602 | 51.8 | 1,162 |
| 1955 | 538 | 52.5 | 1,025 |
| 1956 | 716 | 51.3 | 1,396 |
| 1957 | 638 | 47.8 | 1,335 |
| 1958 | 386 | 44.4 | 869 |
| 1959 | 463 | 55.2 | 839 |
| 1960 | 365 | 47.0 | 777 |

*St. Johns River – 1961:* The estimated shad catch was 609,000 pounds, of which the commercial fishery took 443,000 pounds and the sport

Sport fishing for shad on the Connecticut River.

fishery 166,000 pounds. The sport fishery was the most important for shad on the Atlantic coast. Annual catch and effort statistics collected since 1953 were used in conjunction with the results of 1958 studies to follow the dynamics of the population, 1953-61 (see table). After these statistics have been obtained for an additional number of years, hypotheses may be formulated to account for fluctuations in abundance.

Dynamics of St. Johns River shad population, 1953-61

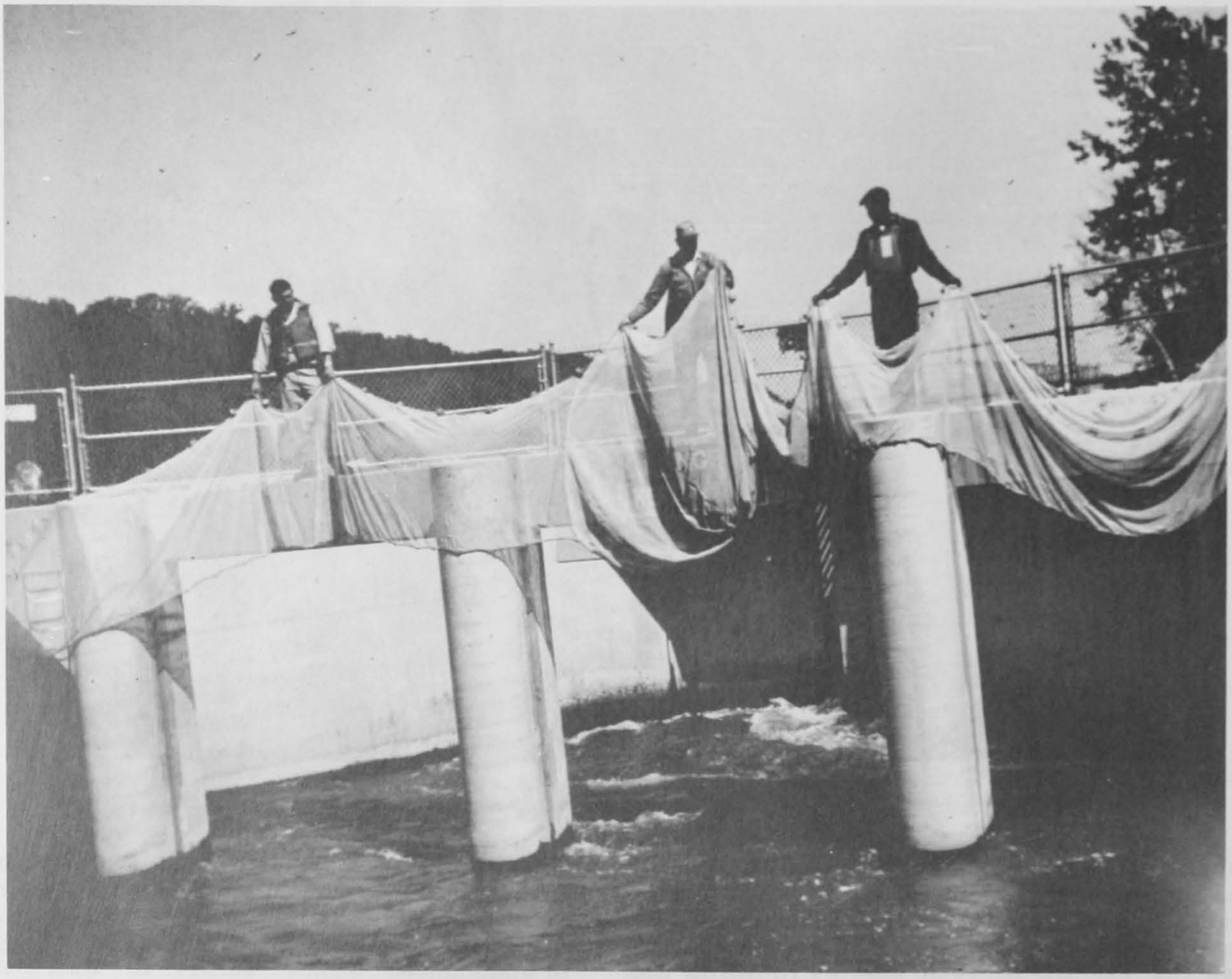
| Season | Commercial catch | Sport catch | Total catch | Fishing rate | Calculated size of run |
|---|---|---|---|---|---|
| | Thousand pounds | Thousand pounds | Thousand pounds | Percent | Thousand pounds |
| 1953 | 280 | 82 | 362 | 37 | 989 |
| 1954 | 343 | 74 | 417 | 27 | 1,532 |
| 1955 | 434 | 90 | 524 | 20 | 2,681 |
| 1956 | 293 | 64 | 357 | 18 | 2,010 |
| 1957 | 261 | 140 | 401 | 15 | 2,717 |
| 1958 | 552 | 175 | 727 | 25 | 2,917 |
| 1959 | 604 | 181 | 785 | 26 | 2,953 |
| 1960 | 505 | 198 | 703 | 32 | 2,199 |
| 1961 | 443 | 166 | 609 | 24 | 2,563 |

## FISHWAY STUDIES

Paul R. Nichols

Construction of dams has had an important influence on the decline in Atlantic coast shad. This fishway study project aids the states and federal agencies in the design of fish passing facilities at proposed or existing river impoundments. Information on the effect of impoundments on shad production is essential to management.

Studies were made at the Snake Island Fishway on the Potomac River to evaluate its effectiveness for passing anadromous fish. This fishway is a single-jet, vertical-baffle type, consisting of a series of 11 pools, installed in 1960 to pass fish over the recently completed Little Falls Dam. The dam has a 9-foot head and was constructed as part of the water supply system for metropolitan Washington. A trap was installed in the upper fishway flume to enable observations to be made on the passage of migratory fish. The fishway operated successfully with various combinations of attraction flow over a mean daily river discharge from 7,380 to 33,600 cubic feet per second. Species using the fishway were sucker (*Catostomus* sp.), blue gill (*Lepomis macrochirus*), carp (*Cyprinus carpio*), and catfish (*Ictalurus* sp.). No shad (*Alosa sapidissima*), river herring (*Alosa* sp.), or striped bass(*Roccus saxatilis*), were observed in the vicinity of the fishway. Experimental fishing indicated that the upstream migration of shad and alewives



Experimental fishing in attraction chamber of Snake Island Fishway on the Potomac River.

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## MENHADEN PROGRAM

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Research efforts were concerned primarily with continuing studies of the biology and population dynamics of the Atlantic menhaden *(Brevoortia tyrannus)*. Our understanding of the population structure was advanced by studies of vertebral numbers in juveniles, occurrence of near-spawning fish in the catches, and the distribution of age and size groups in the fishery. Some of the ideas and findings are new and not completely developed; these were introduced as guidelines for continuing work.

Preliminary investigation of the menhaden resource in the Gulf of Mexico was begun by minor extension of present research projects. Effort was concentrated on determining the identity and range of several closely related species found along the South Atlantic coast of the United States and in the Gulf of Mexico. Cooperation of the following laboratories and agencies was obtained in the collection of specimens: Bureau of Commercial Fisheries Laboratories, Galveston, Tex., and Pascagoula, Miss.; Bureau of Sport Fisheries and Wildlife Sandy Hook Marine Laboratory, Highlands, N. J.; Fishery Market News Office, Aransas Pass, Tex.; Florida State Board of Health, Entomological Research Laboratory, Vero Beach, Fla.; Florida State Board of Conservation, Marine Laboratory St. Petersburg, Fla.; Texas Game, Fish, and Oyster Commission, Marine Laboratory, Rockport, Tex.; and Technological Institute of Veracruz, Mexico.

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### POPULATION STUDIES

John W. Reintjes, Joseph R. Higham, and Doyle F. Sutherland

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Range of juvenile menhaden, based on recent collections, by species

| Species | Range |
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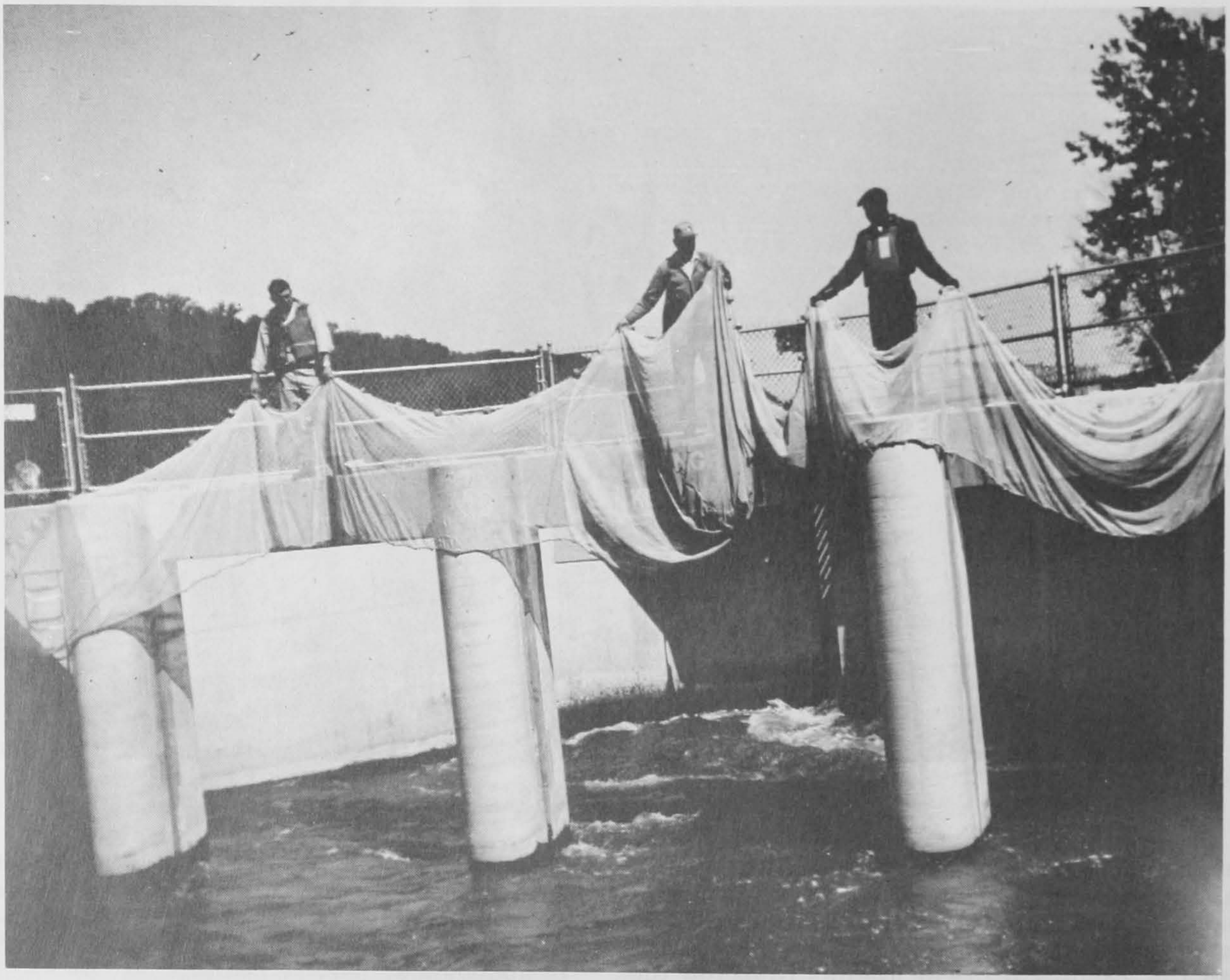

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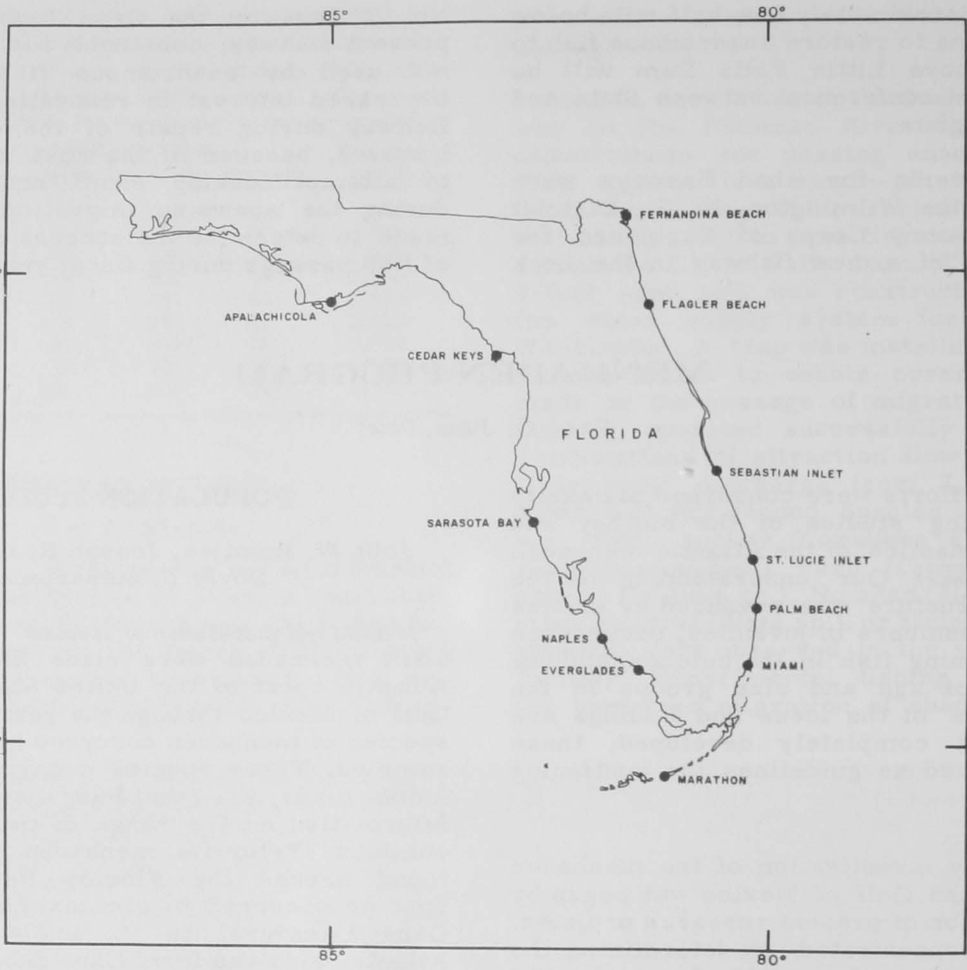



Distribution of yellowfin menhaden around Florida Peninsula.

*Host–parasite relations:* Monogenetic trematodes, which are parasitic flatworms on the gills, were obtained from four species of menhaden collected along the Atlantic and Gulf coasts. Preliminary findings showed host-parasite relations often were species specific, and frequency of occurrence varied within a species by locality or capture and size of host. Therefore, parasites may serve for taxonomic separation and as natural tags for population discrimination.

*Variation in vertebral number of juvenile Atlantic menhaden:* Completed analysis of vertebral numbers of over 17,000 juvenile Atlantic menhaden from four successive year classes (1956-59) showed that at least two subpopulations of this species occurred in the estuarine nursery areas, one north of Long Island and the other south of that location. It also showed that mixing of the two subpopulations occurred in the vicinity of Long Island, N. Y.

A followup study of these same year classes as spawning adults was begun to determine similarity of the vertebral number of juveniles when they occupied nearby estuarine nurseries.

*Time and place of spawning of Atlantic menhaden:* Ovaries of Atlantic menhaden, collected from 1956 to 1959, were examined to follow the changes that take place as the eggs develop before spawning. By relating changes in size and appearance of eggs to changes in ovary weight and fish length, a simple, objective method was developed for recognizing maturing and nonmaturing ovaries, using ovary weight and fish length only.

Based on the presence in the commercial catches of fish in maturing and spawned-out condition, it appeared that spawning occurred in every month in some part of the range. There appeared, however, to be two main spawning periods, one from May through October in waters north of Long Island, and the other from October through May in waters south of Long Island. Apparently little or no spawning occurred inside Chesapeake Bay. Based on the times and places of occurrence and the relative number of fish in spawning condition, at least two major spawning groups of Atlantic menhaden existed. This conclusion supported the hypothesis established from the study of the vertebral number in juveniles that there are at least two subpopulations of Atlantic menhaden.

Examination of plankton collections from nine cruises of the *Theodore N. Gill*, taken along the U.S. South Atlantic coast, 1953-54, was completed. Menhaden eggs and larvae were taken during three winter cruises, but not during six cruises made from late April to November. Eggs and newly hatched larvae were found principally in the vicinity of Cape Canaveral, Fla., and Cape Lookout, N. C., in November, December, and February. Older larvae were widely distributed along the coast from Florida to Cape Hatteras, N. C., in February and March.

The plankton of incoming tidal currents was sampled for larval Atlantic menhaden at Beaufort, N. C., and Indian River, Del. At Beaufort, larvae were present from December to mid-April, and most abundant from late February through early March. At Indian River, larvae occurred regularly in the catches from October to May, and reached a peak of abundance in December and January. These observations supported the conclusions reached from the examination of ovaries that spawning in waters south of Long Island takes place during the winter.

## ESTIMATION OF JUVENILE ABUNDANCE

Anthony L. Pacheco

Each year the menhaden fishery from Chesapeake Bay southward depends mostly on age-1 fish. Thus it is of importance to the industry in this area of the coast to have some advance information on the relative strength of each new year class entering the fishery. Since juveniles occur in coastal estuaries through the first summer of life, measures of their relative abundance in selected locations have been used successfully to provide an index of their expected relative abundance at age 1.

The methods used in estimating relative abundance of juveniles included: (1) marking fish in tributaries of large river systems and estimating the total number in the tributary from the proportion of recaptures (fish are marked by clipping the lower lobe of the caudal fin); (2) measures of average catch-per-unit of fishing effort, using a standard haul seine and lampara net; and (3) counts of the number of schools in aerial surveys.

Eighteen independent estimates of relative abundance were obtained. These indicated that, on the average, the 1960 year class was about twice as abundant as the very poor 1959 year class. Specifically the relative abundance of juveniles increased in South Atlantic estuaries, remained about the same in Chesapeake Bay and the Middle Atlantic, and was slightly higher in the North Atlantic. Relative abundance estimates of both the 1959 and 1960 year classes were considerably less than those obtained for the 1958 year class.

## DEVELOPMENT OF METHODS OF MARKING JUVENILES

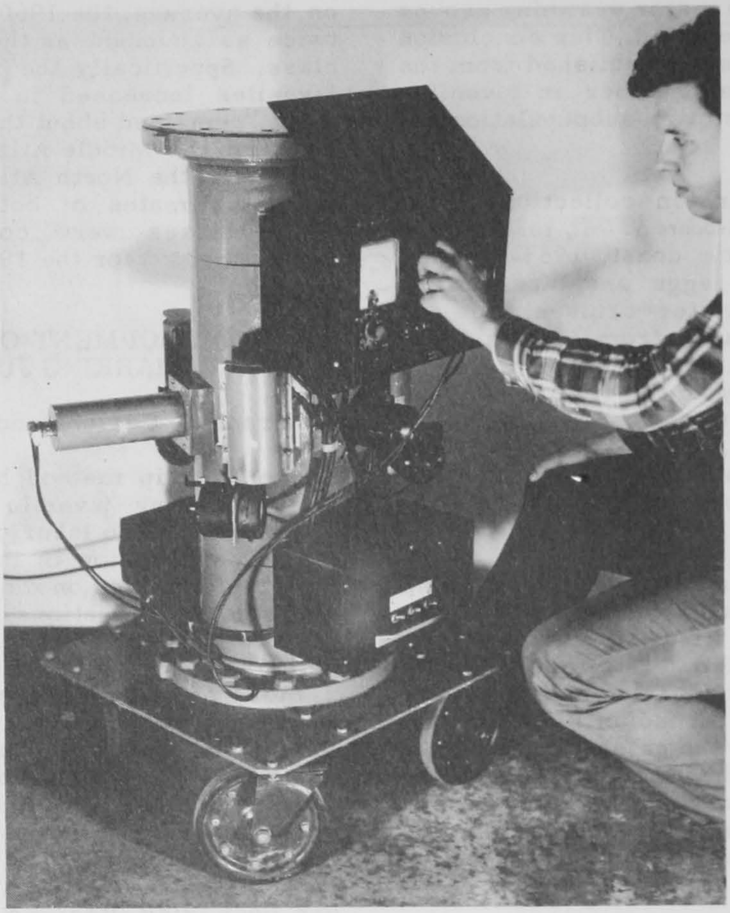
Frank T. Carlson and John W. Reintjes

The fin-clip method has proved successful for estimating juvenile abundance in tributaries, but is too laborious and time-consuming for application in large estuaries. Additional information on movements of fish within an estuary, migrations from the estuary into the ocean and along the coast, and discrimination of subpopulations could be obtained if a more durable mark were developed. Furthermore, the menhaden industry uses mechanical methods of catching, handling, and processing the fish, so there is no way to detect visually marked fish which might appear in the catches. Therefore, some mechanical method of marking and recovering is needed. Insertion of metal tags into the body cavity has been tried. Because of shedding and damage to the intestinal mass, however, these were not satisfactory. Because of the limitations noted above, biological stains or pigments for electronic detection were investigated, and mass marking by blast imbedding, immersion, or feeding were considered.

A photoelectric device was designed and constructed for experiments to determine if menhaden marked with fluorescent pigments could be detected electronically.

The results were inconclusive because of the relatively high natural fluorescence of marine organisms. Modifications of the instrument have been made, and additional studies are under way to find ways of discriminating between artificial and natural luminescence, including phosphorescence, by color and intensity.

Testing the effects of various pigments under controlled conditions in the laboratory requires the rearing of larvae and juveniles in captivity. Therefore, efforts were devoted to determining the natural foods of young fish at various stages of development. Examination of gut contents and plankton samples taken at the time and place the fish were captured showed a change in food with growth and stage of development. Food of larvae consisted entirely



An experimental electronic detector for menhaden marked with fluorescent pigments.

Food of young menhaden in various stages of development, as determined from gut contents and associated plankton samples

| Stage of development | Size range in millimeters | Food organisms |
|---|---|---|
| Larva.......... | 19-30 | Copepods, primarily *Centropages typicus* and *Acartia* sp. |
| Early metamorphosis... | 31-35 | Copepods and other unidentified crustaceans |
| Late metamorphosis... | 36-40 | Green-brown matter, including phytomonads, dinoflagellates, and diatoms |
| Juvenile....... | 41-160 | Diatoms, primarily *Pleurosigma* sp., dinoflagellates, primarily *Polykrikos kofoidi*, *Amphidinium fusiforme*, *Peridinium trocheim*, *Glenodinium* sp., unidentified euglenoids |

of zooplankton, primarily copepods. Juveniles, on the other hand, fed on small zooplankton and phytoplankton, predominantly flagellates and diatoms.

In the laboratory the feeding behavior of young menhaden was studied. Juveniles fed indiscriminately by straining water through the gills. Larvae, on the other hand, would not feed on phytoplankton, but actively sought out and ate zooplankters, one at a time. A larva could consume up to 15 copepods at one feeding. Feeding stopped when light intensity was reduced below 1 foot-candle. The time required by larvae for digestion of food contents of an apparently full gut ranged from 6 to 10 hours at 18° C. (64° F.). Utilization of food by larvae was confirmed by labeling food organisms with radioactive zinc ($Zn^{65}$) and determining the amount retained in the body tissues. From 30 to 40 percent of the available $Zn^{65}$ was retained.

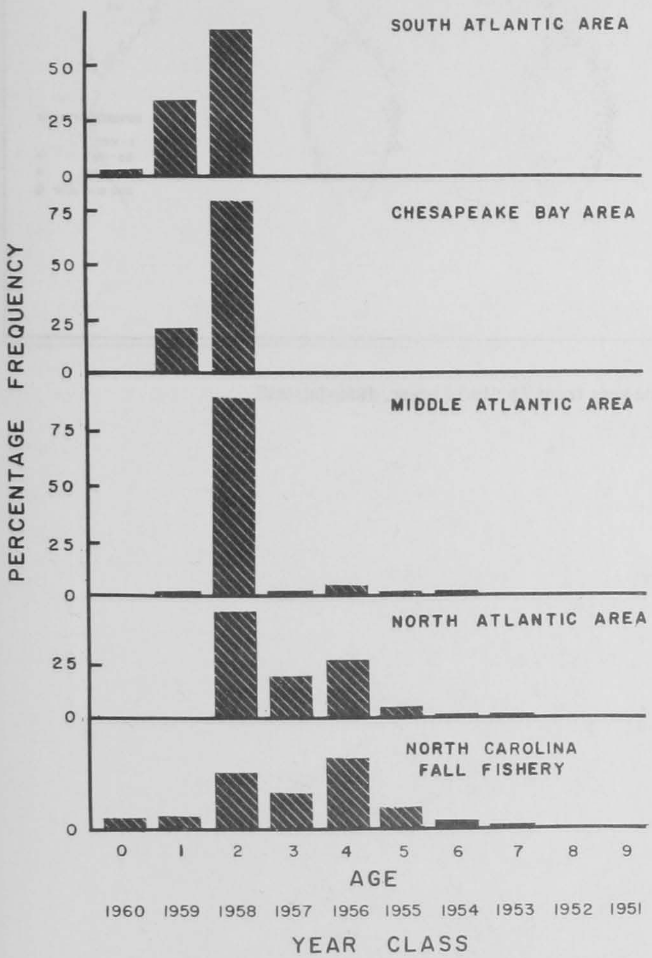
## SAMPLING THE CATCH

Fred C. June, William R. Nicholson, and Charles M. Roithmayr

Emphasis was placed on sampling the 1960 purse seine catches of Atlantic menhaden during the regular fishing seasons for age, size, and sex composition and analyzing the resulting data, together with information on the location of fishing from logbook records and the catch from reduction plant records.

Catch per unit of effort (measure of apparent abundance of fish on the fishing grounds) in 1960 was slightly less than that in the previous year and below annual average, 1955-59.

The 1958 year class supported the summer fishery for the second consecutive season. The contribution of the 1959 year class was the smallest of any recent year classes. The 1956 year class was the only other year class worthy of note, primarily because of its contributions to the summer fishery in the North Atlantic and to the fall fishery off North Carolina.



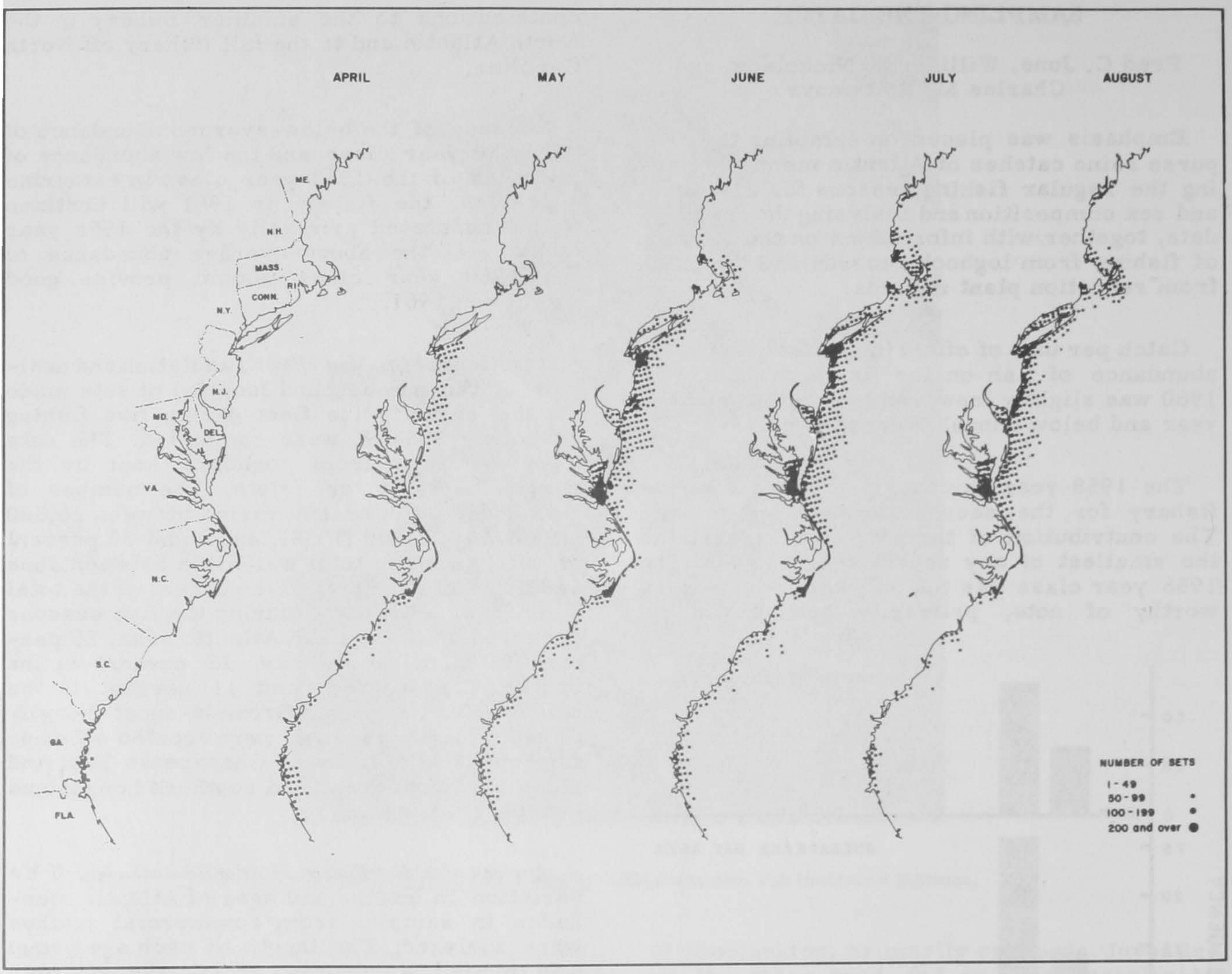

Age composition of purse seine catches of menhaden by area, 1960.

Because of the below-average abundance of the 1959 year class and the low abundance of juveniles of the 1960 year class in estuarine nurseries, the fishery in 1961 will continue to be supported primarily by the 1958 year class, and the above-average abundance of the 1960 year class should provide good catches in 1961.

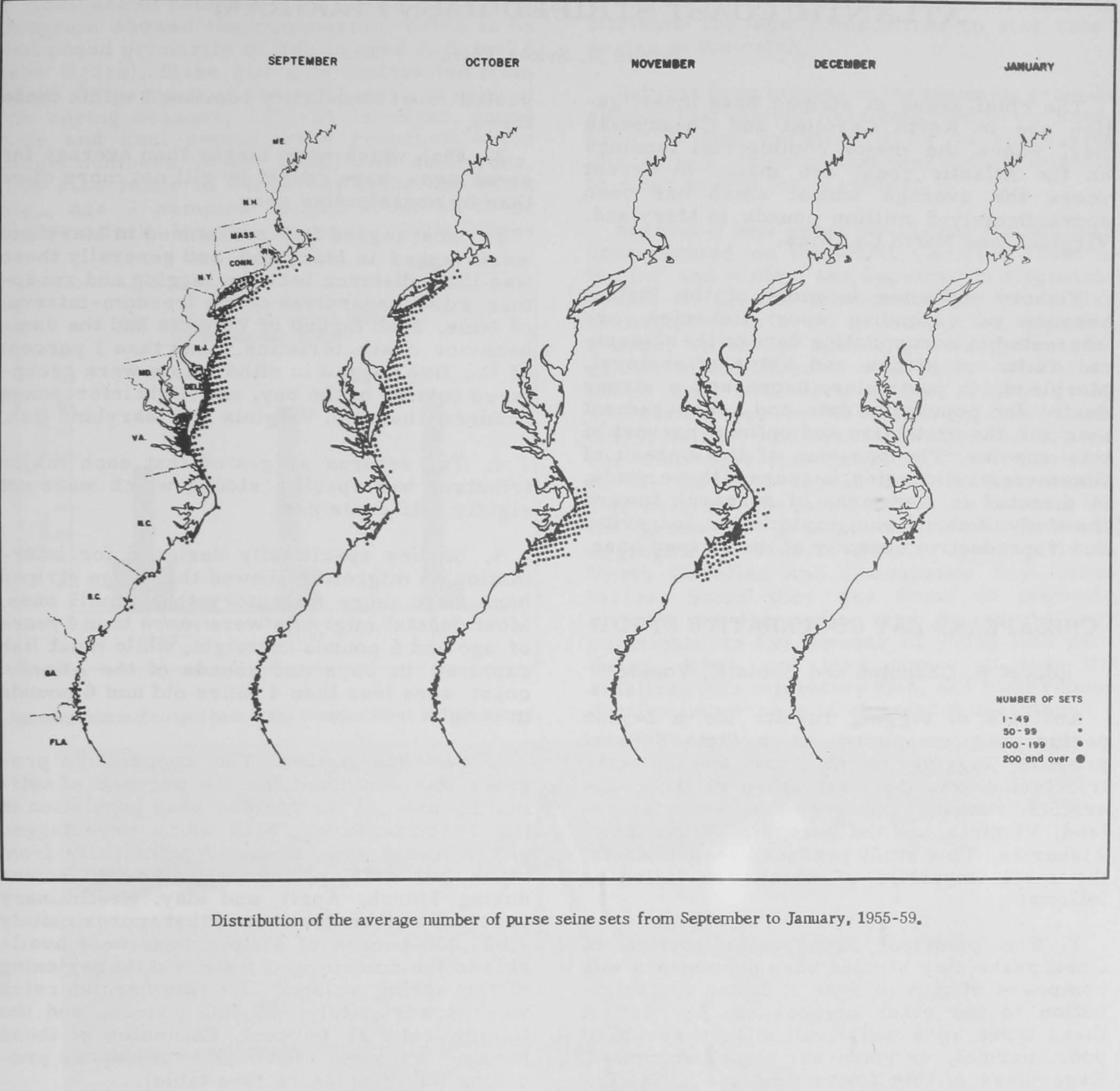
*Distribution of fishing effort:* Tabulation and analysis of the number and location of sets made by the purse seine fleet during five fishing seasons, 1955-59, were completed. The data were obtained from logbooks kept by the vessel captains or pilots. The number of sets made each season varied between 26,500 (1958) and 35,700 (1959), and about 80 percent of each season's total was made between June and September. Forty-five percent of the total number of sets made during the five seasons occurred in the Middle Atlantic area; 26 percent in Chesapeake Bay; 18 percent in the South Atlantic area; and 11 percent in the North Atlantic area. Grounds most heavily fished in every season were located off Cape Lookout, N. C.; in lower Chesapeake Bay; and along the New Jersey and southern Long Island coasts.

*Age and size distribution of Atlantic menhaden:* The variation in lengths and ages of Atlantic menhaden in samples from commercial catches were analyzed. The length of each age group was plotted by degrees of latitude for each month, April through December, for four fishing seasons, 1955-58. Results showed a similar pattern in each season. From April through October, fish increased in length and age from south to north, and lengths of fish in each age group increased at each latitude north of Chesapeake Bay. South of Chesapeake Bay, no comparable change in length with latitude occurred, although fish caught in different localities often differed in length. In November and December, fish were caught only between latitudes 34° and 36° N. (roughly between Cape Hatteras and Cape Fear, N. C.), and most of the length and age groups present in the April-October catches north of this location were represented.

Changes in the length and age distributions indicated that a northward movement of fish occurred in late winter and continued through midsummer, and a southward movement began in midsummer and continued through early winter.




Distribution of the average number of purse seine sets from April to August, 1955-59.




Distribution of the average number of purse seine sets from September to January, 1955-59.

# ATLANTIC COAST STRIPED BASS PROGRAM

James E. Sykes, *Chief,*

The chief areas of striped bass investigation are in North Carolina and Chesapeake Bay, where the major commercial landings on the Atlantic coast are made. In recent years the average annual catch has been approximately 5 million pounds in Maryland, Virginia, and North Carolina.

Fishery agencies in most of the States, because of expanding sport fisheries, are interested in accumulating data on the numerical status of stocks and rates of removal. Maryland, in particular, expresses a strong desire for population data and a management plan for the protection and optimal harvest of this species. The program of the Bureau of Commercial Fisheries, because of these needs, is directed in each area of research toward the study of abundance, exploitation, longevity, and reproductive capacity of the striped bass.

## CHESAPEAKE BAY COOPERATIVE STUDY

Robert B. Chapoton and Louis E. Vogele

Analysis of tagging results for a 2-year period was completed as a State-Federal project. Tagging in the bay and selected tributaries was the first phase of the cooperative research program between Maryland, Virginia, and the Bureau of Commercial Fisheries. This study produced several facts, the most important of which are listed as follows:

1. The principal harvestable portion of Chesapeake Bay striped bass populations was composed of fish in ages 2, 3, and 4. Contribution to the catch composition by each of these three ages was flexible as a result of poor, normal, or good year class production. Regardless of this fluctuation, the ages harvested most abundantly remained within these three.

2. Fish which were larger than average for given ages were caught by gill net more often than by nonselective gear.

3. Most tagged fish recaptured in Maryland were tagged in Maryland, and generally there was little distance between tagging and recapture sites regardless of the freedom-interval of time. Fish tagged in Virginia had the same behavior characteristics. Less than 1 percent of the fish tagged in either State were recaptured outside of the bay, and slight interchange occurred between Virginia and Maryland fish.

4. Tag returns suggested that each major tributary had specific stocks which were not rigidly self-contained.

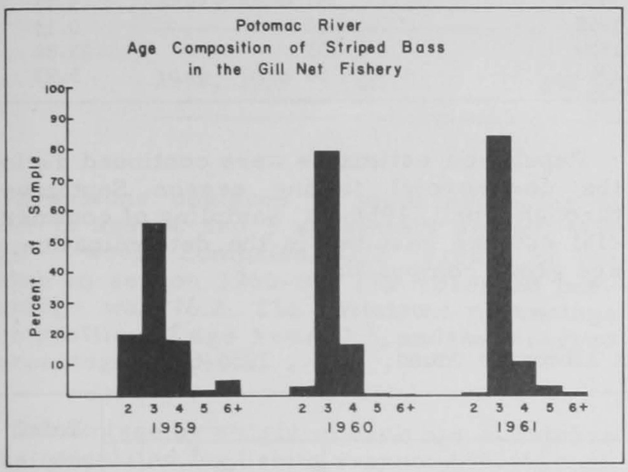
5. Studies specifically designed for information on migration showed that large striped bass were more migratory than small ones. Most coastal migrants were more than 4 years of age and 6 pounds in weight, while most fish captured in bays and sounds of the Atlantic coast were less than 4 years old and 6 pounds in weight.

*Potomac River research:* The cooperative program was continued for the purpose of estimating size of the striped bass population in the Potomac River. Fish which were tagged and released were obtained principally from stake gill nets, pound nets, and haul seines during March, April, and May. Preliminary population estimates showed that approximately 2,600,000 pounds of striped bass were available to the commercial fishery at the beginning of the spring season. The commercial catch was approximately 900,000 pounds, and the fishing rate 35 percent. Estimates of these parameters were also made for the two preceding fishing seasons (see table).

Tentative statistics of the commercial striped bass fishery, Potomac River, 1959-61

| Year | Catch | Fishermen | Effort in standard-fishing-unit days | Population estimate | Fishing rate |
|---|---|---|---|---|---|
| | Pounds | Number | | Pounds | Percent |
| 1959 | 1,300,000 | 480 | 52,000 | 2,800,000 | 45 |
| 1960 | 950,000 | 250 | 47,000 | 2,500,000 | 40 |
| 1961 | 900,000 | 209 | 55,000 | 2,600,000 | 35 |

Analyses of data collected during the tagging program showed the commercial catch to be composed primarily of fish in ages 2, 3, and 4 (see figure). Stake gill nets contributed from 65 to 85 percent of the total catch in each of the spring seasons, 1959-61; however, pound nets and haul seines were responsible for large numbers of the small fish each year. The size range in each year class was wide; e.g., age 3 samples ranged from 10 to 22 inches (fork length) in each of the three seasons. For this reason it was difficult to attribute the age composition to size categories in the catch.




Age composition of striped bass in the Potomac River gill net fishery.

Returns from tagging on the spawning grounds showed that striped bass returned to the same area in the Potomac River in successive years, and indicated that they did not migrate to other rivers for spawning.

*Migration of large striped bass:* Large striped bass concentrated on the North Carolina coast in the fall and winter, and appeared in Albemarle Sound, N. C., and Chesapeake Bay tributaries immediately prior to or during the spawning season. After the spawning season they migrated to the Atlantic coast north of Chesapeake Bay, and were caught principally by sport fisheries in New Jersey, New York, Rhode Island, and Massachusetts. Indications are that these fish return to North Carolina in the fall and repeat the migratory cycle. The origin of the large fish is not certain, but the group (or groups) is believed to be an aggregate of fish originating principally in North Carolina and Chesapeake Bay tributaries. Since they are found on spawning grounds in the spring and do spawn, they contribute to the number of young fish produced. They are less numerous than the smaller, less migratory fish, and their reproductive importance is at present uncertain.

Tagging large striped bass on the North Carolina coast.

# PREDICTION OF HARVESTABLE STRIPED BASS IN ALBEMARLE SOUND, N. C.

James E. Sykes and
Robert M. Lewis

Trawling of young striped bass, sampling of commercial catches, and tagging results made it possible to predict relative year class strength and population size at least 1 year in advance in the Albemarle Sound fishery. This was considered a major breakthrough for it enabled the industry to anticipate the magnitude of widely fluctuating year classes prior to recruitment and to gauge its effort accordingly.

One phase of Albemarle Sound research was the continued trawling of young striped bass in cooperation with North Carolina State College to determine indices of annual abundance. Trawling has been conducted for 6 years, 1955-60, and resulted in the following catches per tow.

Mean number of young striped bass taken per trawl tow in Albemarle Sound, N. C., 1955-60

| Year | Number of tows | Mean number of striped bass |
|---|---|---|
| 1955 | 38 | 3.27 |
| 1956 | 43 | 19.14 |
| 1957 | 51 | 5.71 |
| 1958 | 40 | 0.15 |
| 1959 | 51 | 23.86 |
| 1960 | 54 | 5.93 |

Population estimates were continued during the commercial fishing season September through April, 1956-61. Sampling of commercial catches resulted in the determination of age group composition.

Age composition of commercial catches in Albemarle Sound, N. C., 1956-61

| Fishing season | Age | | | | | | | | | | Total samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | | 3 | | 4 | | 5 | | 6 | | |
| | Number | Per-cent | Number | Per-cent | Number | Per-cent | Number | Per-cent | Number | Per-cent | |
| 1956-57 | 534 | (32.7) | 1,008 | (61.6) | 73 | (4.5) | 18 | (1.1) | 2 | (0.1) | 1,635 |
| 1957-58 | 1,829 | (68.7) | 479 | (18.0) | 261 | (9.8) | 69 | (2.6) | 25 | (0.9) | 2,663 |
| 1958-59 | 211 | (26.1) | 583 | (72.2) | 9 | (1.1) | 4 | (0.5) | 1 | (0.1) | 808 |
| 1959-60 | 202 | (30.4) | 320 | (48.2) | 137 | (20.6) | 1 | (0.2) | 4 | (0.6) | 664 |
| 1960-61 | 678 | (82.2) | 95 | (11.5) | 29 | (3.5) | 23 | (2.8) | 0 | (0.0) | 825 |

Catches of fish in ages 2 and 3 combined during this series of years constituted from 78.6 percent to 98.3 percent of the total catch, and consequently fish in age 4 or older occurred in relatively low percentage in most years. An exception to this occurred in age 4 of the season 1959-60 which constituted 20.6 percent of the total catch. The increase in relative size of this group was due to the high production of young fish in 1956 (19.14 young fish per trawl). The outstanding contribution by the 1956 year class can be traced through the table, beginning with age 2 in the 1957-58 fishing season and ending with age 5 in the 1960-61 fishing season. A similar regimen should occur as a result of the strong year class produced in 1959 (23.86 young fish per trawl), appearing first as age 2 in the 1960-61 fishing season.

Prediction techniques were designed to determine: (1) the combined percentage of fish in ages 2 and 3, (2) the percentage of fish in ages 2 and 3 separately, and (3) the pounds of fish in ages 2 and 3 occurring in the fishable population. Predictions were based upon regression analyses of commercial-catch-sampling data and trawl catch-per-unit-effort of young-of-the-year fish from a series of years. Percentages of age composition derived from regressions were compared to those obtained from field sampling in the 1960-61 fishing season (September 1960 through April 1961). This provided a preliminary check on the accuracy of predictions. Analysis showed that the catch should have consisted of 93.2 percent fish in ages 2 and 3. The observed or sampled percentage of these ages was 93.6 (see table).

Values used in predicting percentage of ages 2 and 3 combined (1958 and 1959 year classes) for 1960-61 commercial fishing season

| Year classes | Trawl catch per unit effort for 2 years (X) | Commercial fishing season | Sampled percentage of ages 2 and 3 in fishery (Y) | Predicted percentage of ages 2 and 3 in fishery (Y) |
|---|---|---|---|---|
| 1955, 1956 | 22.41 | 1957-58 | 86.7 | - |
| 1956, 1957 | 24.85 | 1958-59 | 98.3 | - |
| 1957, 1958 | 5.86 | 1959-60 | 78.6 | - |
| 1958, 1959 | 24.01 | 1960-61 | 93.6 | 93.2 |

Regressions designed to yield estimates of fish in ages 2 and 3 separately showed that age 2 would comprise 82.2 percent of the catch in season 1960-61. The observed percentage was 76.2. The estimated percentage composition of age 3 was 11.5, and the observed percentage was 19.6.

Percentage by weight of each age in catches was calculated for fishing seasons 1956 through 1961 and then applied to population estimates for those years to determine the total weight by ages in the fishable population. The weights of ages 2 and 3 were summed. The regression of weights on trawl catch-per-unit-effort resulted in a prediction of 1,782,813 pounds of fish in ages 2 and 3 in the 1960-61 population, compared to 1,608,386 pounds estimated from tagging and catch-effort data.

Using regression analyses, the following predictions were made for the 1961-62 fishing season: (1) the percentage in the population of age 2 and age 3 fish combined should be 98.2, (2) of age 2, 28.8 percent and of age 3, 69.4 percent, and (3) the total fishable population should consist of 2,061,000 pounds of striped bass.

## ROANOKE RIVER COOPERATIVE STUDY

Robert M. Lewis and Randall P. Cheek

The Roanoke River in North Carolina produces young striped bass which grow to maturity in Albemarle Sound. In the Sound, the fishery for the adults has yielded annual catches in recent years ranging from 600,000 to 1,000,000 pounds of striped bass. The demand for water in the Roanoke River increased rapidly with expanded development of the northeastern section of North Carolina, with resulting conflicts of interest among fishery conservation agencies, industries, and municipalities.

The Bureau was represented on a steering committee which studied the interrelated problems to formulate a plan for water control among users. Two hydroelectric dams are located on the river: Kerr Dam, operated by U.S. Army Corps of Engineers, located at river mile 179; and, Roanoke Rapids Dam, operated by Virginia Electric and Power Company, located at river mile 137. After accepting temporary flow requirements specified by the steering committee for water quality and striped bass spawning runs, Virginia Electric and Power Company began construction of a third dam at Gaston, N. C. (river mile 145). Although three dams will be located upstream from the striped bass spawning grounds, restrictive measures based upon the results of research should allow compatibility between industry and the fishery.

The N. C. Wildlife Resources Commission in collaboration with the Bureau of Commercial Fisheries Biological Laboratory at Beaufort recommended a firm schedule of flows which should be resolved between the State and the U.S. Army Corps of Engineers in fiscal year 1962.

*Population studies:* In cooperation with the Department of Zoology, North Carolina State College, tagging was completed and the population size of the Roanoke River striped bass spawning run estimated for the sixth consecutive year.

Population parameters of the Roanoke River striped bass fishery (sport and commercial)

| Year | Population estimate (fish) | Catch (fish) | Fishing rate |
|---|---|---|---|
| | Number | Number | Percent |
| 1956 | 153,139 | 18,643 | 12.2 |
| 1957 | 137,522 | 17,797 | 12.9 |
| 1958 | 166,952 | 14,171 | 8.5 |
| 1959 | 464,363 | 54,773 | 11.8 |
| 1960 | 435,612 | 44,099 | 10.1 |

## SEXUAL MATURITY AND FECUNDITY STUDIES

Robert M. Lewis and
Rupert R. Bonner, Jr.

A study was completed to establish criteria for determining sexual maturity of female striped bass by examination of ovaries in commercially caught fish. Gonadal material was withdrawn from the fish through a process developed for the determination of sex. Examination of the material showed that several different-sized ova were present, and maturity was based upon distinguishable groupings of size and appearance. The study showed that from 3 to 4 percent of the females in North Carolina spawned in age 3, 78 to 94 percent in age 4, and 100 percent by the time they entered age 5. Lack of mature ova in a few of the age 7 and older fish indicated that some did not spawn annually.

The results of this study related to the Albemarle Sound population estimate by age group provides estimates of the number of potential female spawners comprising the Roanoke River spawning run each season.

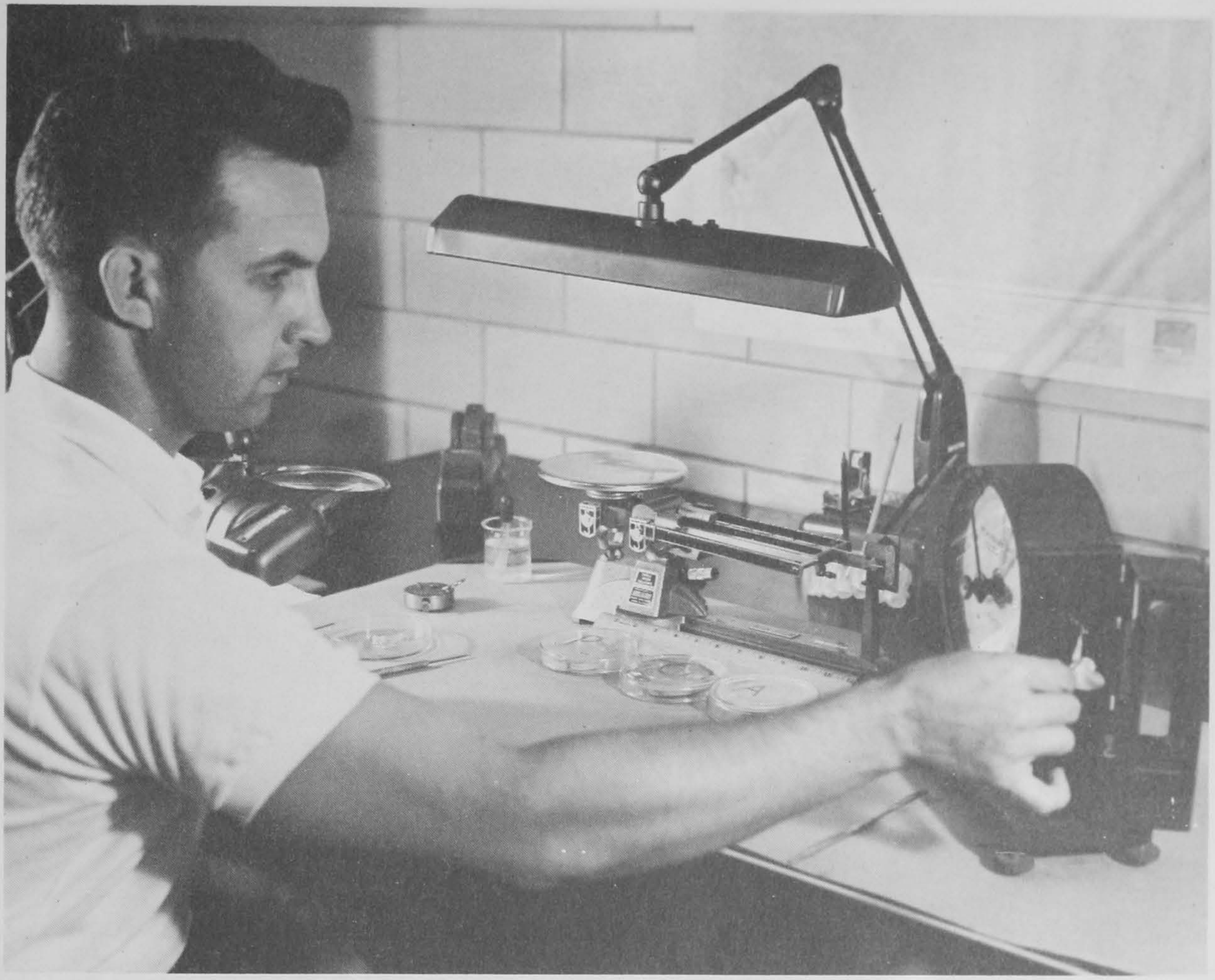
A corollary study was made of the fecundity of female striped bass entering the spawning run. The objectives of the study were to determine (1) the distribution of mature ova within the ovaries; (2) the relation between weight, length, ovary index, and the age of fish to the number of ova produced; and (3) whether these relations changed between years.

Collections of ovaries were made during the spring spawning runs and transverse sections were cut from the anterior, central, and posterior regions of each ovary. A sample of approximately 1 g. was taken from each of these sections and weighed to the nearest 0.001 g. Only ova equal to or greater than 0.700 mm. in diameter that would be released during the forthcoming spawning season were counted. An estimate was made of the total number of ova present in each ovary. The number of ova per fish was then related to weight, length, ovary index, and age of fish.

The relation between body weight and number of ova showed that females less than 6 pounds in weight produced between 138,000 and 497,000 ova. These fish make up the bulk of the females that spawn in the Roanoke River. Mature ova produced by these fish ranged between 48,000 and 98,000 per pound of body weight.

Length of the fish was closely correlated to number of mature ova produced, but to a lesser extent than body weight. The majority of fish ranged from 18 to 23 inches in length and weighed from 2.9 to 6.0 pounds. Within this length range the estimated number of mature ova produced was similar to that estimated on the basis of weight.

The number of mature ova, when compared to an ovary index (the weight of the paired ovaries divided by the length of the fish cubed), showed that the correlation was slightly less than that for length and number of ova. Three regression lines were found for the ovary index-number of ova relation. The first included fish less than 25 inches in fork length. The second level included fish from 26 to 27 inches in length and had a steeper slope than the first. The third line included

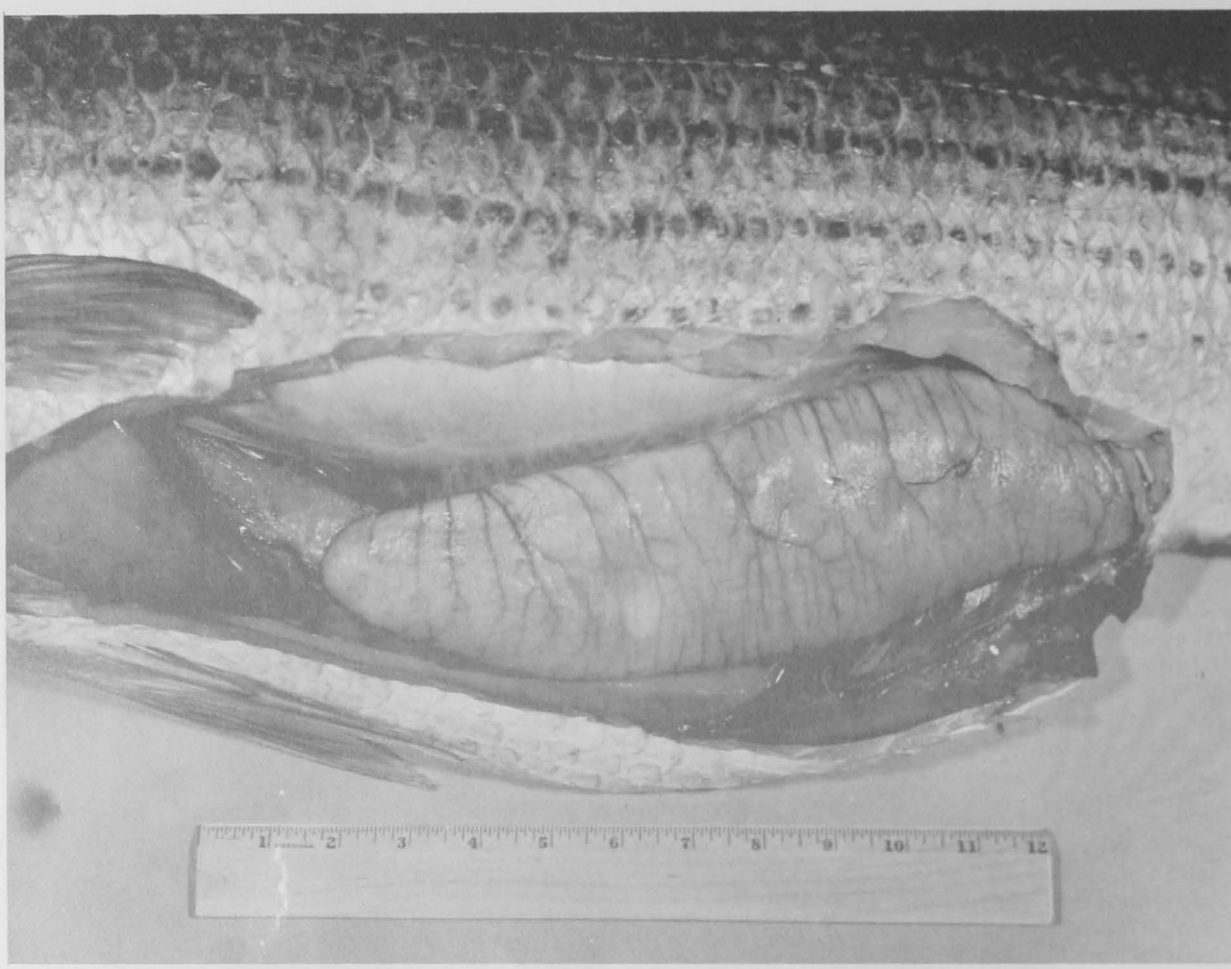


Weighing ova obtained from striped bass.

fish from 37 to 44 inches and had the steepest slope. These preliminary findings indicated that the relation between ovary index and number of ova changed with age. The results are probably related to change in body form, as striped bass become relatively deeper bodied with age.

A significant correlation also existed between the age of the fish and the number of ova produced. Beyond age 4 approximately 100,000 mature ova were produced per year of life, at least through age 10.

These correlations will be used in determining a measure of production by large fish now excluded by law from catches in some states. These fish (in some instances 15 pounds or more and in others 25 pounds or more) are now illegal in catches because it is commonly assumed that their contribution to spawning production is great even though they form a small percentage of the runs.



A large striped bass ovary used in the study of fecundity.

## RADIOBIOLOGICAL PROGRAM

T. R. Rice, *Chief*

During the past 10 to 15 years the efforts of many investigators have resulted in a considerable amount of knowledge concerning the uptake, accumulation, and retention of radionuclides by marine organisms under laboratory conditions. Simultaneously, other groups have been determining the fate of both the fission products and the neutron-induced radionuclides occurring in sea water following the explosion of atomic bombs. More recently, radiochemical analyses have shown the occurrence of minute quantities of radioactivity in seafood products originating from both the east and west coasts. In view of these, the Radiobiological Program has been reorganized, and an effort is being made to bring together investigators with sufficient diversity in education and training to take a broader approach to the solution of the biological aspects of radioactive pollution in the marine environment than has thus far been undertaken by any one organization.

Investigations of the Radiobiological Program have been concerned with the accumulation of radionuclides by marine organisms, estuarine radioecological studies, and the effects of ionizing radiations on marine organisms. The uptake, accumulation, and retention of fission products and certain neutron-induced radionuclides by phytoplankton, zooplankton, molluscs, crustaceans, and fish have been followed. A cooperative radioecological survey between the Bureau of Commercial Fisheries and U.S. Public Health Service was started on the Savannah River Estuary. The effects of ionizing radiations on marine fishery organisms are being observed, and methods and techniques for detecting damage are being devised. An X-ray machine has been purchased so that the sensitivity of marine organisms to this type of radiation can be compared with the reported effects of X-rays on terrestrial plants and animals.

Research activities of the Radiobiological program.

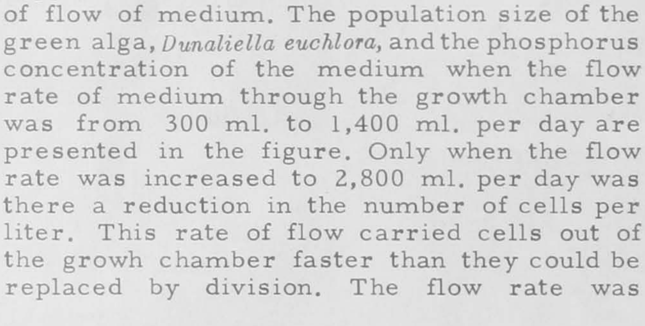
# ACCUMULATION OF RADIONUCLIDES AND THE EFFECTS OF RADIATION ON PLANKTON

T. R. Rice and Marianne B. Murdoch

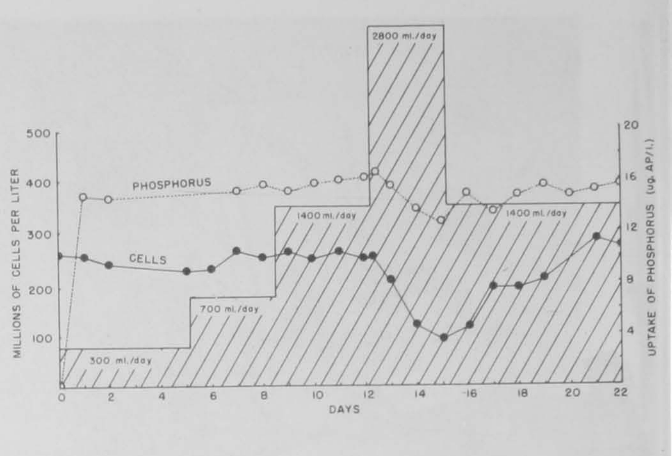
In the oceans many factors are in operation replenishing nutrients utilized for phytoplankton growth. Simultaneously, other factors are tending to reduce the standing crop of phytoplankton cells. Similar conditions have not held for laboratory investigations for the uptake and concentration of nutrients and radioactive isotopes. The classical culture technique of growing algae in confined volumes of medium subjects cells to greater changes in concentrations of nutrients in the medium than occurs in natural waters. It is questionable whether or not data obtained by this technique are representative of the processes occurring in the aquatic environment.

By the use of a continuous culture system, algae can be grown in the laboratory under conditions more nearly simulating growth conditions in nature. This system makes it possible to maintain indefinitely a constant population of cells and a desired level of nutrients in the water. This insures that cells will grow under more constant conditions, similar to those occurring in nature.

Cell division in the continuous culture system was found to be directly related to the supply of nutrients and, therefore, to the rate of flow of medium. The population size of the green alga, *Dunaliella euchlora*, and the phosphorus concentration of the medium when the flow rate of medium through the growth chamber was from 300 ml. to 1,400 ml. per day are presented in the figure. Only when the flow rate was increased to 2,800 ml. per day was there a reduction in the number of cells per liter. This rate of flow carried cells out of the growh chamber faster than they could be replaced by division. The flow rate was reduced again to 1,400 ml. per day, and the population of cells became stabilized for 2 days before again increasing in numbers.



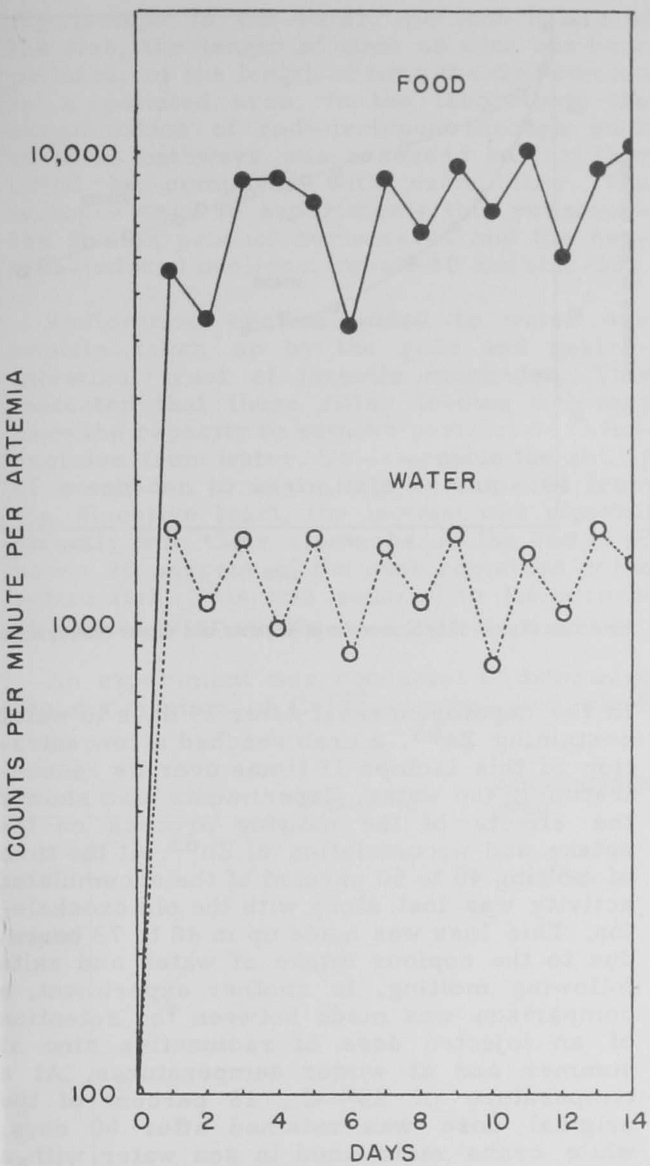
A continuous flow system for culturing algae in a controlled concentration of nutrients.



Population sizes of *Dunaliella euchlora* and phosphorus concentrations obtained in flow system with changes in rate of flow of medium.

Considerably more is now known about the concentration of radioactive isotopes as a result of data collected by this culture method. It was found that (1) the concentration factor for phosphorus-32 in *Dunaliella* cells increased as the flow rate of medium was increased, (2) the concentration factor for zinc-65 in cells decreased as the zinc concentration of the medium was increased, and (3) the concentration factor for strontium-85 in the green alga, *Carteria*, was less than that obtained by the chemical culture technique.

The accumulation of radionuclides can be affected by the particular conditions of culture, but it is not practicable to test many of these conditions when large organisms are involved. The brine shrimp *(Artemia salina)* and the copepod *(Tigriopus californicus)*, however, are excellent organisms for this type of study, since sufficient numbers of animals to give statistically accurate answers can be used. Furthermore, measurements of radioactivity can be made on the entire animal without sacrificing it, thus eliminating errors due to individual variation. It was found that salinity, temperature, and the volume of medium per animal had an effect upon the accumulation of radioactive cobalt by *Artemia*. Both *Artemia* adults and nauplii and *Tigriopus* adults concentrated the five radionuclides tested in the following order from highest to lowest: cerium-144, zinc-65, cobalt-56, 57, 58, and strontium 85. A comparison of the accumulation of zinc-65 and cobalt 56, 57, 58 by *Artemia* from food and water showed that both radionuclides were concentrated to higher levels by animals obtaining the radionuclides from food.



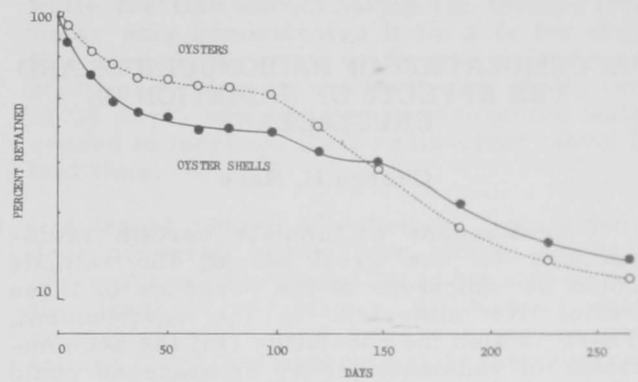

Comparison of accumulation of radioactive cobalt by *Artemia* from food and water.

# ACCUMULATION OF RADIONUCLIDES AND THE EFFECTS OF RADIATION ON MOLLUSCS

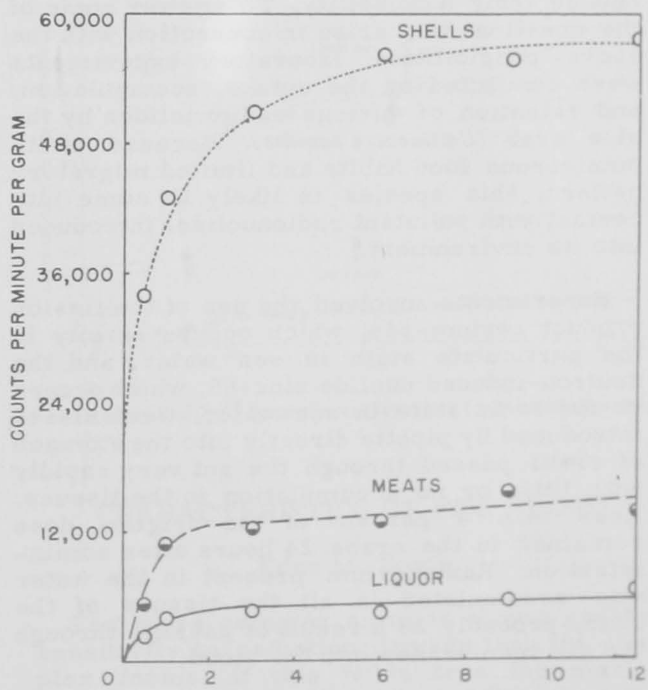
T. J. Price

The level at which a radionuclide is concentrated in the tissues of seafood organisms determines its hazard to man and its ability to cause radiation damage. Molluscan shellfish are filter feeding animals which are able to concentrate particles and ions from large volumes of water. The rate of accumulation and levels of concentration, mode of entry, and assimilation of specific elements will largely depend on their physical state in the medium and the physiological demand of the organism for the element. Elements and their radioisotopes are present in sea water as particles and ions. A particulate radionuclide will become associated with molluscan shellfish by adsorption on their body surface. If ingested these nuclides will pass through the digestive tract with only a small amount being assimilated, since particles do not readily pass through the intestinal walls. Ionic radionuclides have little difficulty passing through tissue membranes and thus are assimilated to higher levels.

Experiments were run on two important commercial molluscs, the hard clam *(Mercenaria mercenaria)* and the eastern oyster *(Crassostrea virginica)*, to determine the uptake, accumulation, and retention of cobalt-60, iron-59, and




Retention of cobalt-60 by oysters and their separated shells.




Uptake of cerium-144 by component parts of clams.

cerium-144. Clams concentrated radioactive cobalt 43 times over amounts in the water in a period of 47 days. The rate of loss of cobalt-60 from clams, oyster, and their shells was influenced by the temperature of the water. As the temperature of the water increased there was a faster rate of loss of cobalt-60. After 265 days only a small percentage of the original activity remained in these and their separated shells. Shells of both clams and oysters concentrated iron-59 to higher levels than did the meats. The accumulation of cerium-144 by clams and their separated shells were influenced by the physical state of the isotope in sea water. The greater part of the radioactivity was due to association of particles with body surfaces and their presence in the organs and structures connected with the digestive system.

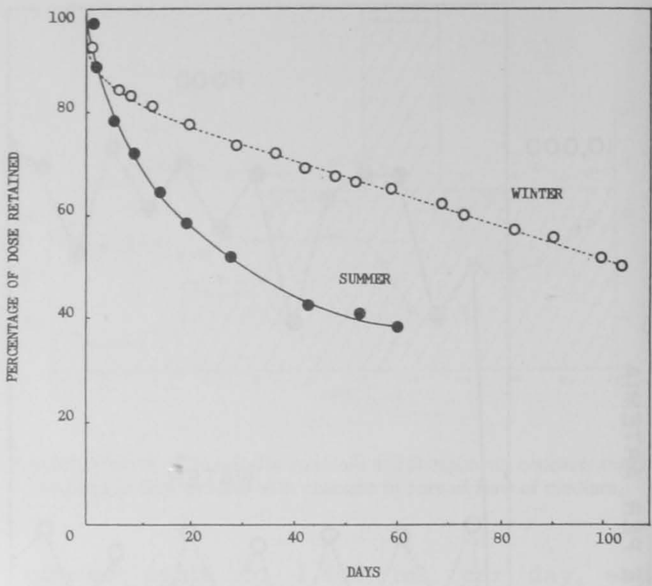
## ACCUMULATION OF RADIONUCLIDES AND THE EFFECTS OF RADIATION ON CRUSTACEANS

George H. Rees

If crustaceans accumulate certain radionuclides to any great extent, the animals could be indicators of the presence of these radioactive materials in the environment. There is also the possibility that the accumulation of radionuclides by crustaceans could affect their utilization as seafood, or, that radiation from accumulated radioactivity could affect the well-being of the animals and thus reduce their availability. To answer some of the questions that arise in connection with the above possibilities, laboratory experiments were conducted on the uptake, accumulation, and retention of various radionuclides by the blue crab *(Callinectes sapidus)*. Because of its omnivorous food habits and limited migratory pattern, this species is likely to come into contact with pollutant radionuclides introduced into its environment.

Experiments involved the use of the fission product cerium-144, which occurs mainly in the particulate state in sea water, and the neutron-induced nuclide zinc-65, which occurs in the ionic state in sea water. Cerium-144 introduced by pipette directly into the stomach of crabs passed through the gut very rapidly with little or no accumulation in the tissues. Less than 4 percent of the original dose remained in the crabs 24 hours after administration. Radiocerium present in the water was accumulated in all the tissues of the crab, probably as a result of passage through the gill membranes into the blood.

The nonfission product, zinc-65, was taken up rapidly from the water and accumulated in all the tissues, with highest concentration



Retention of zinc-65 by blue crabs at summer and winter temperature.

in the hepatopancreas. After 29 days in water containing $Zn^{65}$, a crab reached a concentration of this isotope 33 times over its concentration in the water. Experiments also showed the effects of the molting process on the uptake and accumulation of $Zn^{65}$. At the time of molting 40 to 50 percent of the accumulated activity was lost along with the old exoskeleton. This loss was made up in 48 to 72 hours, due to the copious intake of water and salts following molting. In another experiment, a comparison was made between the retention of an injected dose of radioactive zinc at summer and at winter temperatures. At a temperature of 25° C., 28 percent of the original dose was retained after 60 days, while crabs maintained in sea water with a mean temperature of 10° C., retained 50 percent of the original dose after 104 days.

The studies showed that $Ce^{144}$ was poorly absorbed from the digestive tract of crabs but could be accumulated to some extent when present in the water. Zinc-65 was rapidly taken up from the water and was retained in the tissues of the crab for relatively long periods.

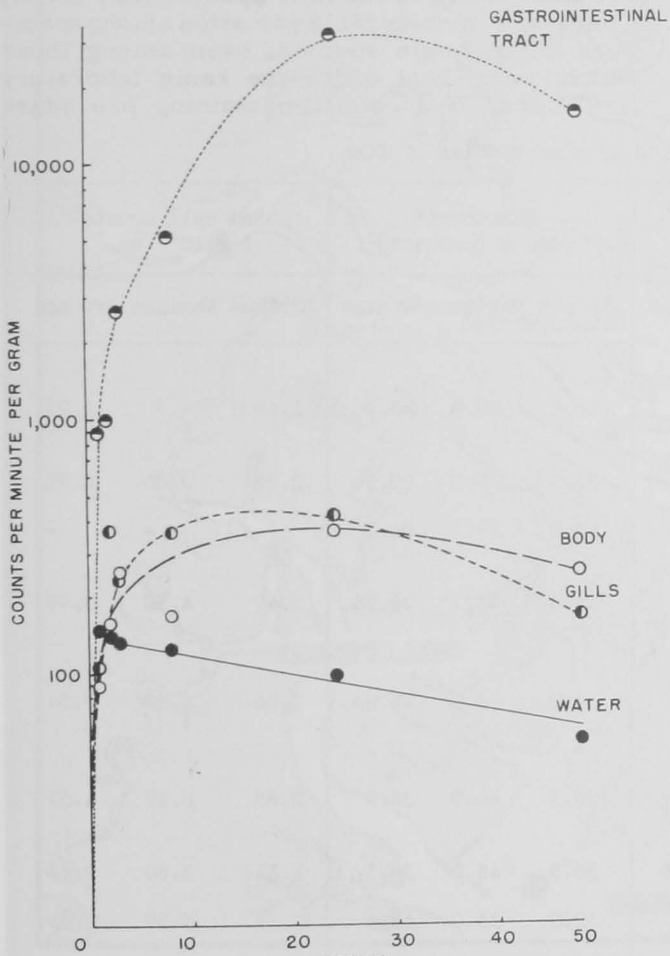
## ACCUMULATION OF RADIONUCLIDES AND THE EFFECTS OF RADIATION ON FISH

Donald E. Hoss

Fish accumulate radioactive materials by adsorption to surface areas, absorption from the surrounding medium, or by ingestion. In nature these three modes of uptake can occur singly, simultaneously, or in various combinations depending upon the physical state of the isotope in the water, the food habits of the fish, the length of time an area has been polluted, or the length of time the fish remain in a polluted area. In the laboratory, the accumulation of radioisotopes through each of these pathways was assessed so that they could be compared with each other. The isotopes used in experiments this year were the fission product cerium-144 and the neutron-induced nuclides, cobalt-60 and zinc-65.

Radioactive cerium added to water was rapidly taken up by the gills and gastrointestinal tract of juvenile menhaden. This indicated that these filter feeding fish may have the capacity to remove particulate radionuclides from water. To determine the ability of menhaden to assimilate cerium-144 from the digestive tract, the isotope was pipetted directly into their stomachs. At the end of 48 hours 20 percent of the dose remained in the entire fish. This was reduced to 1.6 percent 168 hours after dosing.

An experiment was conducted to determine the distribution of $Ce^{144}$ in menhaden which

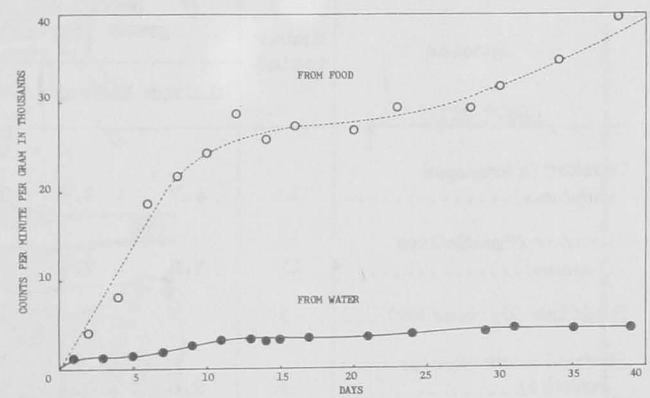


Accumulation of Ce-144 from sea water by juvenile menhaden.

were administered the isotope orally, and subjected to a reduction process to produce fish meal, an additive used in animal foods. In preparing samples, the methods used at the fish reduction plants were followed as closely as possible. Results of this experiment showed that of the total dose given each adult fish, 12.8 percent remained in the products at the end of 2 days. Of the $Ce^{144}$ remaining, 12 percent was found in the meal and 0.8 percent in the oil and "stick water" combined.

A comparison was made of zinc-65 accumulated by postlarval flounders from food and water. In one group of fish the only source of radioactivity was from the water, in the other group the isotope was available only from the food. The fish accumulating $Zn^{65}$ from food concentrated it by a factor of 110 while the fish accumulating the isotope from water only concentrated it by a factor of 12. The flounders eating radioactive food were still increasing in radioactivity at the end of 38 days, while those in radioactive water ceased to increase their radioactivity level by that time.

A rapid uptake of cobalt-60 from an oral dose occurred in the liver, kidney, and heart of croakers. Accumulation in the muscle was the least of any tissue. Killifish in water containing $Co^{60}$, and fed grass shrimp containing $Co^{60}$, has approximately the same rate of accumulation of the isotope as fish in active water fed nonactive food.



Accumulation of $Zn^{65}$ by postlarval flounders from food and water.

## CHARACTERISTICS OF FISH BLOOD

Edna M. Davis

The more complex animals show a greater sensitivity to radiation damage than the simpler forms. If this holds true for marine organisms, fish will more readily show the effects of radiation damage than the lower forms of marine life. Changes resulting from long periods of exposure to low levels of radioactivity will no doubt be subtle and difficult to detect. There is an obvious need for methods for determining the initial effects of radiation damage in fish.

Among the most radiosensitive tissues in vertebrates are the blood-forming organs, and changes occurring in the blood are one of the first indications of radiation damage in mammals. This is the logical area in which to look for early radiation effects in fish, and investigations were undertaken to establish the normal blood picture of some representative species.

Blood samples were collected from nine species of marine fish. Four of these, croaker (*Micropogon undulatus*), flounder (*Paralichthys dentatus*), toadfish (*Opsanus tau*), and striped bass (*Roccus saxatilis*), were held alive in tanks for several days prior to testings. The others, king mackerel (*Scomberomorus cavalla*), Spanish mackerel (*Scomberomorus maculatus*), menhaden (*Brevoortia tyrannus*), mullet (*Mugil cephalus*), and spot (*Leiostomus xanthurus*), were tested within a few minutes after capture. Before blood samples were withdrawn the fish were narcotized to prevent injury from handling and to facilitate blood withdrawals.

Since blood clots prevent accurate measurements, several anticoagulants were tested: ammonium potassium oxalate, EDTA, sodium fluoride thymol, lithium oxalate, potassium oxalate, and heparin. Best results were obtained by the use of ammonium potassium oxalate, which effectively prevented coagulation for the longest time with no hemolysis.

Blood cell counts of marine fish blood cannot be performed satisfactorily with the use of standard diluting fluids for human blood, due to the nucleolated condition of cells in marine fish blood. Also, there is considerable variation in the chloride content of blood of the different species. For instance, the milliequivalents of chloride per liter of toadfish plasma ranged from 131.0 to 143.6, while in the Spanish mackerel it ranged from 156.2 to 163.3. These chloride levels, converted to salinity levels, showed the percentage salinity for diluting toadfish blood to be 0.8 and the percentage salinity for diluting Spanish mackerel blood to be 0.9 to 1.0. Saline used for dilution of blood cells must conform to the blood chloride levels of the fish being tested.

Hemoglobin, hematocrit, and erythrocyte counts were performed on blood samples from 125 individuals of the nine species (see table). There was considerable variation among members of a single species, even among those which were kept under the same laboratory conditions. A blood film staining procedure

Comparison of blood characteristics of nine species of fish

| Species | Number tested | Hemoglobin grams (percent) | | | Hematocrit volume (percent) | | | Red cell counts $1 \times 10^6/ mm.^3$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | Average | Minimum | Maximum | Average | Minimum | Maximum | Average |
| Croaker (*Micropogon undulatus*) | 30 | 4.7 | 9.8 | 7.5 | 18.0 | 39.8 | 25.9 | 1.69 | 4.9 | 3.23 |
| Flounder (*Paralichthys dentatus*) | 11 | 5.6 | 7.9 | 6.6 | 25.5 | 37.0 | 29.3 | 2.22 | 3.86 | 2.91 |
| Toadfish (*Opsanus tau*) | 5 | - | - | - | 22.0 | 27.5 | 24.2 | - | - | - |
| Striped bass (*Roccus saxatilis*) | 5 | 8.6 | 10.4 | 9.5 | 36.0 | 41.3 | 38.76 | 3.42 | 4.53 | 3.95 |
| King mackerel (*Scomberomorus cavalla*) | 6 | 7.5 | 10.3 | 9.3 | 32.0 | 43.0 | 36.25 | 2.66 | 4.59 | 3.54 |
| Spanish mackerel (*Scomberomorus maculatus*) | 58 | 7.6 | 12.2 | 10.5 | 26.5 | 46.0 | 38.9 | 2.28 | 6.17 | 4.53 |
| Menhaden (*Brevoortia tyrannus*) | 6 | 6.8 | 12.2 | 9.96 | 26.5 | 45.0 | 36.1 | 1.81 | 3.60 | 2.63 |
| Mullet (*Mugil cephalus*) | 2 | 8.6 | 10.8 | 9.7 | 32.0 | 35.0 | 33.5 | 2.33 | 3.37 | 2.85 |
| Spot (*Leiostomus xanthurus*) | 2 | 10.8 | 12.2 | 11.5 | 45.0 | 46.5 | 45.8 | 4.28 | 4.50 | 4.39 |

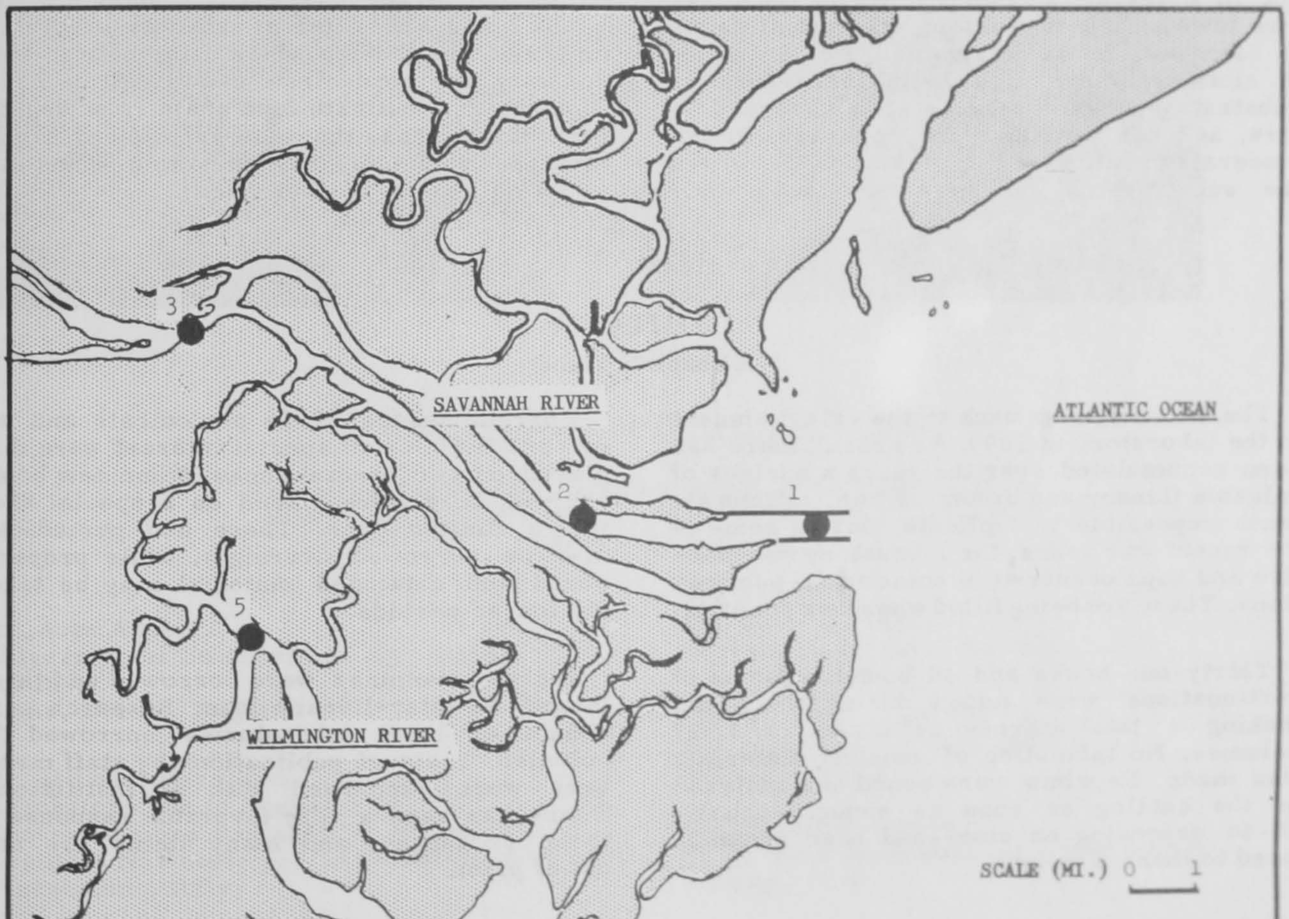
was developed which allowed for the recognition of immature erythrocytes, which are a good indication of abnormalities (e.g., radiation damage) when present in large numbers. Methods were devised, and techniques perfected for obtaining blood samples, hemoglobin determinations, blood cell enumeration, and the differentiation of blood cells. Through the use of these techniques, data are being collected which will make it possible for an investigator to detect changes in fish blood which may occur from exposure to ionizing radiation.

## ESTUARINE RADIOECOLOGY

John P. Baptist

It is generally conceded that the rapid progress being made in the diversified fields associated with atomic energy is creating pollution problems in the aquatic environment. Existing controls on the release of radioactive materials are based largely on concentrations found in food products used by man, but this is not completely satisfactory. In instances of acute contamination it is possible for humans to consume contaminated food during the time required for radioanalysis of food items and the evaluation of results. Also, radioactivity determinations are valid only for the organisms tested under certain environmental conditions. The principal objectives of the present project are to develop methods of predicting levels of radioactivity which may occur in seafood from chronically contaminated waters and of evaluating the extent of contamination resulting from an emergency. These objectives may eventually be reached through knowledge of the cycling of radionuclides in the aquatic environment, including physico-chemical changes and transmission routes through food chains.

A survey of the Savannah Estuary was initiated jointly by the Bureau of Commercial Fisheries and the U. S. Public Health Service




Location of sampling stations in the Savannah Estuary.

to collect data on the presence of radionuclides in water, silt, seafood organisms, and non-seafood organisms at five regular sampling stations in the area. Monthly collecting trips were started in November 1960, and radio-analysis of samples is being made by the Public Health Service Laboratory in Montgomery, Ala.

Organisms were collected by the use of an 18-foot otter trawl and classified to promote an understanding of their relationships in the environment. Forty-five species of fin fish, mostly juveniles, were collected. The predominant species caught was star drum while lesser numbers of other species making up a large part of the trawl catches included silver perch *(Bairdiella chrysura)*, gray trout *(Cynoscion regalis)*, spotted trout *(Cynoscion nebulosus)*, spot *(Leiostomus xanthurus)*, croakers *(Micropogon undulatus)*, southern kingfish *(Menticirrhus americanus)*, sea catfish *(Galeichthys felis)*, and anchovies *(Anchoa mitchilli)*. Crabs and shrimps, including both edible and nonedible species, were present in many of the catches. Since the trawl was towed along the bottom, the benthic fauna at each station was determined. For example, at stations where high salinities and sandy substrates prevail, more starfish, sand dollars, and sea pansies were collected. In the moderately saline water of station 5, where the substrate is predominantly mud, many sponges, corals, tunicates, and mud crabs were taken (species undetermined). Station 3 is located where the water ranges from essentially fresh to 10 ‰ salinity, and the substrate consists largely of fine silt. Fauna is relatively scarce at this station, although fresh-water catfish *(Icatalurus* sp.), spot, silver perch, croakers, and menhaden *(Brevoortia tyrannus)*, are caught in small numbers.

Radiological analyses of biological, water, and silt samples revealed insignificant levels of radioactivity. Naturally occurring potassium-40 accounted for most of the activity. The presence of trace amounts of zinc-65 and cesium-137 in some biological samples was indicated by gamma spectrum analyses. Due to the low levels of radionuclide concentrations found, no conclusions were reached regarding transmission routes through food chains. In general, however, the meats of oysters and crabs were somewhat higher in zinc-65 content than those of fish. The affinity of this radionuclide for shellfish has been reported by various investigators. The proximity of crabs to the substrate and their scavenging food habits, and the filtering activity of oysters no doubt are factors which contribute to their capacity for concentrating zinc-65. In order to further investigate food chain relationships of radionuclides, the ecology of other organisms such as plankton, burrowing forms, and intertidal forms are indicated.

## LIBRARY

Elizabeth Talbot

The library dates back to the establishment of the laboratory in 1899. As a result there has been accumulated over the years a nucleus of valuable fishery and biological publications almost impossible to duplicate. During some of the recent war years, the laboratory was inactive and gaps occurred in some serial publications. These are being filled whenever possible.

Thirty-one books and 48 bound volumes of continuations were added during the year, making a total library collection of 3,927 volumes. No tabulation of unbound materials was made. Reprints were bound and analyzed in the catalog as soon as enough--usually 20-40 depending on size--had been accumulated to make a volume.

Current issues of 56 periodicals and numerous articles of special interest were displayed on two special racks. When new books arrived, they were placed on a special shelf for a limited time. These and periodicals may be borrowed overnight, while properly bound and cataloged material may be taken for longer periods.

Eighteen volumes were borrowed and three loaned on inter-library loan. Research personnel of local laboratories borrowed 73 volumes. Lists of publications by staff members were exchanged with 82 institutions. There has been a very favorable response to these exchanges, and many items are now out of print.

Library.

# VISITING INVESTIGATORS

Those who have used facilities or received training at the Bureau of Commercial Fisheries Biological Laboratory, Beaufort, N. C.

Dr. Alan Ansell
University of Southampton and Plankton Laboratory
Poole, Dorset, England

Dr. Michael Bernhard
Laboratory per lo Studio della Contaminazione Radioacttiva del Mare
Comitato Nazionale per le Richerche Nucleari
Fiacaherino, Italy

Mr. John W. Blake
University of North Carolina
Chapel Hill, N. C.

Mr. Frank T. Carlson
U.S. Fish and Wildlife Service
Millville, Del.

Mr. J. Harry Cornell
N. C. Wildlife Resources Commission
Raleigh, N. C.

Miss Starr Culver
Duke University
Durham, N. C.

Dr. Fred F. Fish
N. C. Wildlife Resources Commission
Raleigh, N. C.

Prof. Oscar Gifford
Recavarren 753
Miraflores, Lima, Peru

Dr. W. W. Hassler
N. C. State College
Raleigh, N. C.

Dr. Nelson Marshall
Narragansett Marine Laboratory
University of Rhode Island
Kingston, R. I.

Dr. Crodowaldo Pavan
University of Sao Paulo
San Paulo, Brazil

Mr. Alfred J. Wilson
U.S. Bureau of Commercial Fisheries
Gulf Breeze, Fla.

## SEMINARS

The Rome Fish Meal Conference. Fred C. June.

Morphology of the Veneridae. Alan Ansell, University of Southampton, Southampton, England.

Accumulation and retention of cesium-137 by marine fishes. John P. Baptist.

Program of the Atlantic Marine Laboratory. John R. Clark, Atlantic Marine Laboratory, Highlands, N. J.

Striped bass research at Chesapeake Biological Laboratory. Basil Shearer, Chesapeake Biological Laboratory, Solomons, Md.

Analysis of Chesapeake Bay Blue Crab Statistics, 1938-58. C. H. Walburg.

During the summer the Bureau's Biological Laboratory and the N. C. Institute of Fisheries Research cooperated with the Duke Marine Laboratory in seminar programs. The following lectures were presented at Duke University Laboratory during the summer of 1960:

June 15--"Comensalism of decapod crustacea with branching corals on the Great Barrier Reef." Wendell K. Patton, Fulbright Fellow in Zoology, University of Queensland, Australia.

June 22--"Endocrine mechanisms in crustacea." Muriel I. Sandeen, Assistant Professor of Zoology, Duke University.

June 29--"The community approach in estuarine ecology as illustrated by the study of Lake Ponchartrain, Louisiana." Rezneat M. Darnell, Assistant Professor of Zoology, Marquette University.

July 8--"A few observations on physiological adaptation to environment." F. G. Hall, Professor of Physiology, Duke University Medical Center. The Arthur Sperry Pearse Memorial Lecture.

July 12--"Selection of prey by the oyster-drilling gastropod, *Urosalpinx*." John W. Blake, Research Associate in Zoology, University of North Carolina Institute of Fisheries Research.

July 20--"Tetrapod vertebrate ecology of Cape Hatteras National Seashore Park." Thomas Quay, Professor of Zoology, North Carolina State College.

July 27--"Some aspects of the biology of fishes of the genus *Paralichthys*." Earl E. Deubler, Jr., Associate Professor of Zoology, University of North Carolina Institute of Fisheries Research.

August 4--"Radiation ecology." Eugene Odum, Professor of Zoology, University of Georgia.

August 10--"Some current problems in osmoregulation." Dr. Carl Schlieper, Institut für Meereskunds, Universitat Kiel, Germany.

August 17--"Ecology of some lignicolous fungi in estuarine waters." Gilbert C. Hughes, III, Research Associate in Botany, Duke University Marine Laboratory.

## MEETINGS ATTENDED*

American Society of Limnology and Oceanography, Stillwater, Okla. September (1)

Annual Meeting of the Oyster Institute of North America and National Shellfisheries Association, Baltimore, Md. September (3)

Atlantic Estuarine Research Society, Ocean City, Md. October (10)

American Fisheries Society Meeting, Southern Division, Biloxi, Miss. October (1)

Gulf and Caribbean Fisheries Institute, Miami Beach, Fla. November (2)

Virginia Fishermen's Association Meeting, Old Point Comfort, Va. January (2)

Seventh Annual Seminar on Radiological Health at Chapel Hill, N. C. January (2)

North American Wildlife and Natural Resources Conference, Washington, D. C. March (1)

Atlantic Estuarine Research Society, Philadelphia, Pa. April (6)

Society of American Bacteriologists and Symposium on Marine Microbiology, Chicago, Ill. April (1)

## PUBLICATIONS


Chapoton, Robert B., and James E. Sykes.
1961. Atlantic coast migration of large striped bass as evidenced by fisheries and tagging. Transactions of the American Fisheries Society, vol. 90, no. 1, p. 13-20.

Chipman, Walter A.
1960. Accumulation of radioactive pollutants by marine organisms and its relation to fisheries. Transactions of the Second Seminar on Biological Problems in Water Pollution. U. S. Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati 26, Ohio, April 20-24, 1959.

1960. Biological aspects of disposal of radioactive wastes in marine environments. International Atomic Energy Agency, Vienna, 15 p.

June, Fred C.
1961. Age and size composition of the menhaden catch along the Atlantic coast of the United States, 1957; with a brief review of the commercial fishery. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 373, 39 p.

June, Fred C., and Charles M. Roithmayr.
1960. Determining age of Atlantic menhaden from their scales. U.S. Fish and Wildlife Service, Fishery Bulletin 171, vol. 60, p. 323-341.

Massmann, William H., and Anthony L. Pacheco.
1960. Disappearance of young Atlantic croaker from the York River, Virginia. Transactions of the American Fisheries Society, vol. 89, no. 2, p. 154-159.

Nichols, Paul R.
1960. Homing tendency of American shad, *Alosa sapidissima*, in the York River, Virginia. Chesapeake Science, vol. 1, nos. 3-4, p. 200-201.

Nichols, Paul R., and Marlin E. Tagatz.
1960. Creel census Connecticut River shad sport fishery, 1957-58, and estimate of catch, 1941-56. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 351, 12 p.

Reintjes, John W.
1961. An initial inquiry into a photoelectric device to detect menhaden marked with fluorescent pigments. International Commission for the Northwest Atlantic Fisheries, Marking Symposium Contribution No. 61, 10 p., Woods Hole, Mass.

Reintjes, John W., James Y. Christmas, Jr., and Richard A. Collins.
1960. Annotated bibliography on biology of American menhaden. U.S. Fish and Wildlife Service, Fishery Bulletin 170, vol. 60, p. 297-322.


*Attendance shown in parentheses.

Reintjes, John W., and Fred C. June.
1961. A challenge to the fish meal and oil industry in the Gulf of Mexico. Proceedings Gulf and Caribbean Fisheries Institute, 13th Annual Session (1960), p. 62-66.

Reintjes, John W., and Charles M. Roithmayr.
1960. Survey of the ocean fisheries off Delaware Bay, supplemental report, 1954-57. U.S. Fish and Wildlife Service, Special Scientific Report--Fisheries No. 347, 18 p.

Rust, John D., and Frank T. Carlson.
1960. Some observations on rearing blue crab larvae. Chesapeake Science, vol. 1, Nos. 3-4, p. 196-197.

Talbot, Gerald B.
1961. The American shad. U.S. Fish and Wildlife Service, Fishery Leaflet 504, 8 p.

1961. At Hatteras' back door. Sea Frontiers, vol. 7, no. 2, p. 103-112.

Walburg, Charles H.
1960. Abundance of St. Johns River shad. Transactions of the Twenty-fifth North American Wildlife and Natural Resources Conference, p. 327-333.

1960. Abundance and life history of shad, St. Johns River, Florida. U.S. Fish and Wildlife Service, Fishery Bulletin 177, vol. 60, p. 487-501.

1961. Natural mortality of American shad. Transactions of the American Fisheries Society, vol. 90, no. 2, p. 228-230.

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