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NOAA Technical Memorandum NMFS AEFC-1

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Report of the National Marine Fisheries Service Atlantic Estuarine Fisheries Center, Fiscal Years 1970 and 1971

T.R. RICE, DIRECTOR, AND STAFF

SEATTLE, WA.
June 1972

NOAA Technical Memoranda of the National Marine Fisheries Service Atlantic Estuarine Fisheries Center, deal with research conducted at that Center, which is located in Beaufort, NC. Copies of the NOAA Technical Memorandum NMFS AEFC are available from the Center or from the National Technical Information Service, U.S. Department of Commerce, Sills Bldg., 5285 Port Royal Road, Springfield, VA 22151.

NMFS AEFC-1. Report of the National Marine Fisheries Service Atlantic Estuarine Fisheries Center, Fiscal Years 1970 and 1971, by T. R. Rice, Director, and Staff.

U.S. DEPARTMENT OF COMMERCE
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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
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NATIONAL MARINE FISHERIES SERVICE
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Aerial view of Atlantic Estuarine Fisheries Center.

Report of the National Marine Fisheries Service Atlantic Estuarine Fisheries Center, Fiscal Years 1970 and 1971

by

T. R. RICE
Director

and

STAFF

Abstract

Estuarine and radioecological research conducted during Fiscal Years 1970 and 1971 was concerned with energy relations in ecosystems, distribution and cycling of radionuclides and trace metals, and environmental stress on the physiology of marine organisms. Research on the status of Atlantic and Gulf menhaden resources included monitoring the purse seine fishery, predicting future abundance, and describing the role of menhaden in the coastal environment. Other activities reported are thread herring and blue crab programs and radiological consulting. A list of professional staff and their scientific publications is included.

Report of the Director

T. R. RICE

At the beginning of Fiscal Year 1970, the Bureau of Commercial Fisheries combined the Radiobiological and Biological Laboratories at Beaufort under the title Center for Estuarine and Menhaden Research (CEMR) under my direction.[1] Combining the two former laboratories as a single unit has been to the advantage of the research program because the facilities of the entire station at Beaufort are more readily available to staff members as a result of improved administrative coordination. The research at Gulf Breeze, Fla., where pesticide investigations are conducted under the immediate supervision of Dr. T. W. Duke, was a Field Station of CEMR.

In Fiscal Year 1971, President Nixon reorganized parts of the Executive Branch of the Federal Government, and the Bureau of Commercial Fisheries was transferred from the Department of the Interior to the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce, and was renamed the National Marine Fisheries Service (NMFS). The Center for Estuarine and Menhaden Research (CEMR) lost its pesticide field station at Gulf Breeze, Fla. to the newly formed Environmental Protection Agency in this reorganization. A small field unit of five persons was continued at Gulf Breeze for menhaden studies.

A small field unit with two biologists also was maintained at St. Petersburg Beach, Fla. to investigate the thread herring resource in the eastern Gulf of Mexico. The unit was phased out in April 1971 when Florida closed its coastal waters to purse-seine fishing for the species.

Research at the Center is a coalition of two separate but highly coordinated efforts: estuarine ecosystems and coastal fishery dynamics, the latter with particular emphasis on Atlantic and Gulf menhadens.

The estuarine research is supported under a cooperative agreement between the National Marine Fisheries Service and the U.S. Atomic Energy Commission to study the natural functionings of ecosystems as they relate to the distribution and cycling

[1] In October 1971 CEMR became the National Marine Fisheries Service Atlantic Estuarine Fisheries Center.

of radionuclides and the effects of thermal additions and radiation on estuarine organisms and ecosystems. We also conduct original research on ecological energetics, elemental cycling, and physiological ecology. The research provides information on how estuarine ecosystems function and how they respond to modifications and additions.

Estuarine and radioecological research at the Center is concerned with the following general problem areas:

(1) Distribution and cycling of elements.
(2) Energy relations in estuarine ecosystems.
(3) Interaction of environmental stresses on estuarine organisms.
(4) The fate of radioactive materials in the estuarine environment.
(5) The effects of radiation on marine organisms.
(6) Application of radioactive tracers in fishery biology.

Represented under these headings are laboratory and field research which, with few exceptions, is designed to provide a data base for the development of a system of mathematical models describing the flows and cycles of energy and trace elements, including radionuclides, in the estuarine ecosystem. Prediction of responses of an ecosystem to stresses placed upon it requires knowledge of its principles of operation.

Research on coastal fisheries, particularly the menhaden, is directed to monitoring the status of the resource, explaining the causes of fluctuations in resource abundance, and forecasting, on both short and long time scales, the responses of the resource to changes in the environment and in the menhaden fishery. Understanding the role of menhaden in the coastal environment relates to most of the fishery resources of the Atlantic and Gulf coasts of the United States. Menhaden feed by straining planktonic animals and plants from the water. They, in turn, are food for many of the larger commercial and recreational fishes. Their trophic role near the base of the food web and their abundance make them one of the more significant components of the coastal environment.

A principal goal of the menhaden investigation is understanding the dynamics of the Atlantic and Gulf of Mexico menhaden populations. Information on the fish caught and on fishing activity is collected at ports along the Atlantic and Gulf coasts and returned to Beaufort for analysis. This information is used to explain temporal and spatial variations in menhaden abundance, to determine the effects of fishing on menhaden populations, and to formulate management recommendations that will ensure the highest possible yield.

Before we can develop, manage, and wisely use a living resource, such as menhaden, we must know something about the biology and the events in the life cycle that affect reproduction, growth, and survival. Where and when they spawn, how they develop, what they eat and what eats them, as well as what habitat and conditions are most favorable for survival and growth, are all needed information. Menhaden have an early life history similar to many of our important Atlantic and Gulf fish and shellfish, including flounders, croakers, mullet, shrimp, and crabs. Spawning takes place in the ocean and the immature young drift and swim into estuarine nursery areas. Traveling from ocean to estuaries, locating a suitable habitat, finding adequate food, and avoiding predators are the factors that determine survival. Whether the fish thrive and grow depends on the quality and availability of the estuaries and the conditions they find there.

Ecology of Estuarine Ecosystems

The estuaries of the United States represent a resource of great value to the nation. The future value of this resource could be markedly decreased through poor management or markedly increased through wise management. The selection of wise management practices requires a great deal of detailed information beyond that already at hand on the normal operation of the estuarine ecosystem and on the immediate and long-term effects of the many human activities which impinge upon the estuarine ecosystem. For the past several years, the NMFS laboratories at Beaufort, N.C. have been actively engaged in gathering information on the general ecology of nearby estuaries to construct mathematical models simulating the operation of these ecosystems and suitable for predicting their responses to environmental stresses. Immediate realization of this ultimate goal of systems analysis, however, still is precluded by a general lack of necessary data. Systems analysis does, however, have immediate application in ecology as a tool for drawing together isolated fragments of information on an ecosystem into a unified description of that system suitable for determining what information is needed to complete construction of a model and for detecting contradictory information.

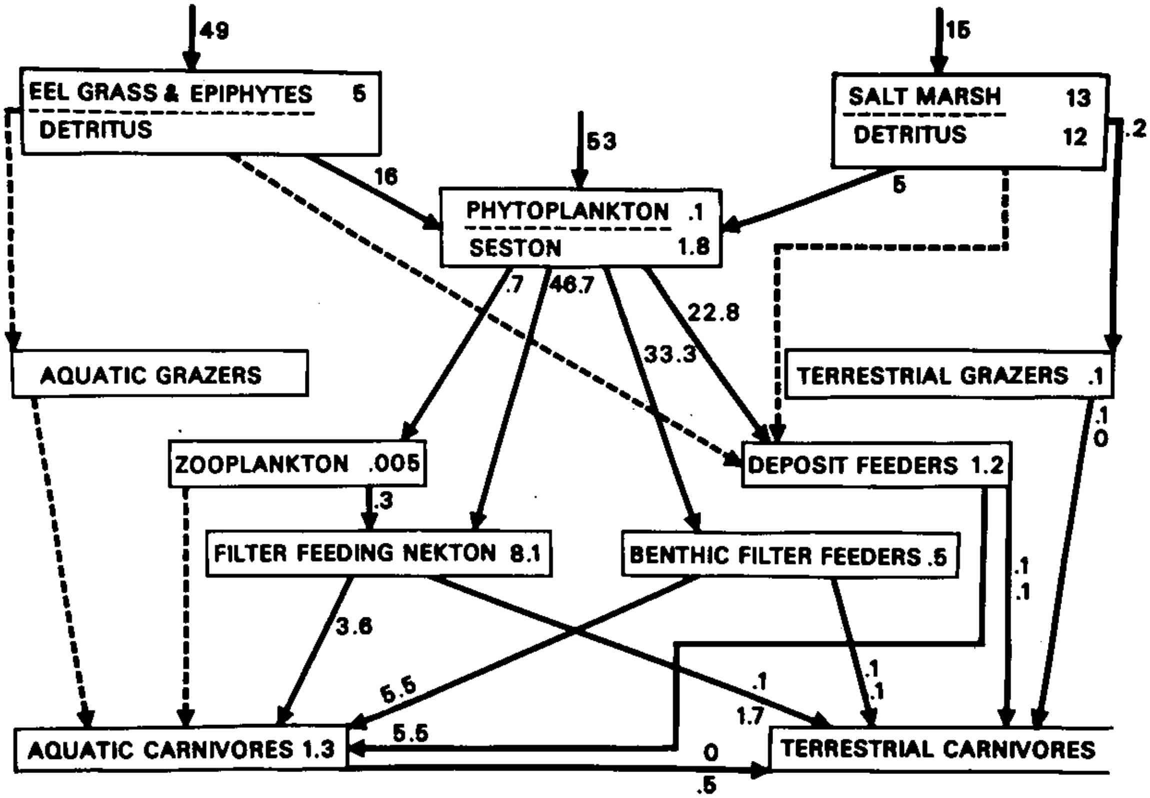

Figure 1. Trophic relations in the estuarine ecosystem at Beaufort, N.C. The main flows of energy and materials (grams of carbon per square meter per year) are shown by solid lines and secondary flows without known values by dashed lines. Values in the compartments are average standing crops (grams of carbon per square meter). No value means no information. The two values on flows into terrestrial carnivores are for birds (upper) and man (lower).

On the basis of preliminary models (Fig. 1) synthesized from available data on the estuarine ecosystem at Beaufort, previously unnoticed gaps and inconsistencies in our understanding of the ecosystem were identified and plans made for more appropriate quantitative research.

Predictive and even descriptive mathematical models of ecosystems require detailed quantitative data on the standing crops of organisms at the various trophic levels, i.e., the sizes of the compartments in the model, and the flow rates of energy and materials through these compartments. Part of the data needed for modeling are available from the NMFS Statistics Office at Beaufort and from research programs at this Center on the Atlantic menhaden, but the bulk of the data are being generated by ecological research specifically directed toward this modeling. Data were gathered for the past 2 years on several plant and animal groups important in the overall flow of energy and materials in the estuary and in most cases containing or providing food for species of importance to commercial fisheries.

A project has determined the relative abundance of fishes in Newport River estuary, developed methods for quantitatively measuring the standing crop of fish and other nekton, and started a year-long study on standing crop. Monthly sampling with a wide variety of gear, haul seines, surface trawls, bottom trawls, and gill nets, revealed that although at least 104 species were present at some time during the year, only seven species, Atlantic menhaden, bay anchovy, spot, Atlantic silverside, striped mullet, pinfish, and Atlantic croaker, comprised most of the population and biomass. Comparison with similar but less intensive studies made previously in Newport River suggested that the abundance of individual species differed markedly from year to year but that the fish population is normally dominated by some or all of 13 species; the above seven plus golden shiners, rough silverside, tidewater silverside, blueback herring, hogchoker, and bluefish.

Quantitative sampling of fish is done with drop nets. Sampling in deeper open water areas of the estuary is done with a 20-foot square portable drop net (Fig. 2). The walls of the net are initially held suspended above the water by electromagnets. When released, the walls drop vertically to the bottom, enclosing all fish within the net. The net is then pursed and the catch removed. Sampling in the shallow margins of the estuary has been tested with mechanically triggered drop nets 6½-feet square suspended from pilings. Preliminary tests have suggested that these small drop nets are far more quantitative as sampling devices than the haul seines used previously. Samples obtained with the small drop nets indicated a standing crop of fishes several times greater than that indicated by haul seine samples. This difference suggested that the commotion unavoidably associated with haul-seining scatters most fish from the path of the seine and leads to a falsely low estimate of standing crop.

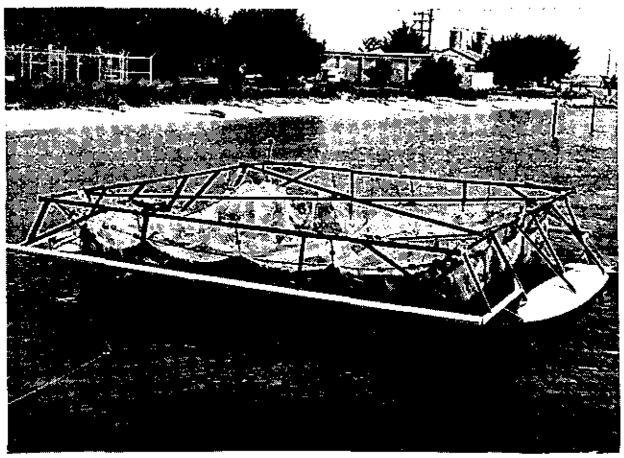

Figure 2. Portable drop net for sampling the biomass of fishes in Newport River estuary.

The standing crop of macrobenthic infauna in open water areas of the estuarine system near Beaufort was estimated by sampling with a 12-inch diameter corer (Fig. 3). This study disclosed an average population of 57.2 organisms/m^2 and and average biomass of 4.1 g dry tissue/m^2. About 64% of this biomass consisted of deposit feeders, 32% of filter feeders, and 4% of carnivores. The dominant forms were worms and bivalve molluscs. This benthic population required about 650 cal/m^2/day for growth and respiration, or 31% of the estimated net plant production, and therefore must form a highly important part of the estuarine food web. The epibenthos consisted chiefly of molluscs and crustaceans, and had a standing crop of 0.9 g dry tissue/m^2. The epibenthic population was estimated to require 548 cal/m^2/day—an amount equivalent to 30% of the net plant production in the eelgrass bed (Fig. 4).

Not all the organic matter produced by the growth of these benthic and epibenthic communities, however, is available to subsequent trophic levels. A study demonstrated that 12 to 72% of the total organic matter in bivalve molluscs is in the organic matrix of the shell. Since this organic material in the matrix appears to be permanently lost from the ecosystem with the burial of the empty shell, the production of shell represents a drain on the productive capacity of the system.

Zooplankton in Newport River estuary are relatively unimportant in the flow of energy in the ecosystem of this and other shallow estuaries. Zooplankton in Newport River assimilate energy equivalent to only about 3% of the net phytoplankton production. The zooplankton, however, reach peak abundance and maximum caloric content during the period of larval fish migration into the estuary and are undoubtedly important in the nutrition of the larval fish.

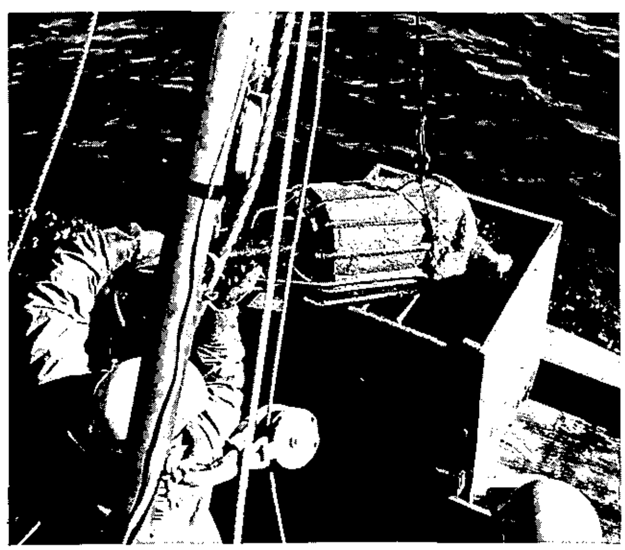

Figure 3. Hydraulic bottom sampler that removes a 12-inch diameter core from shallow waters.

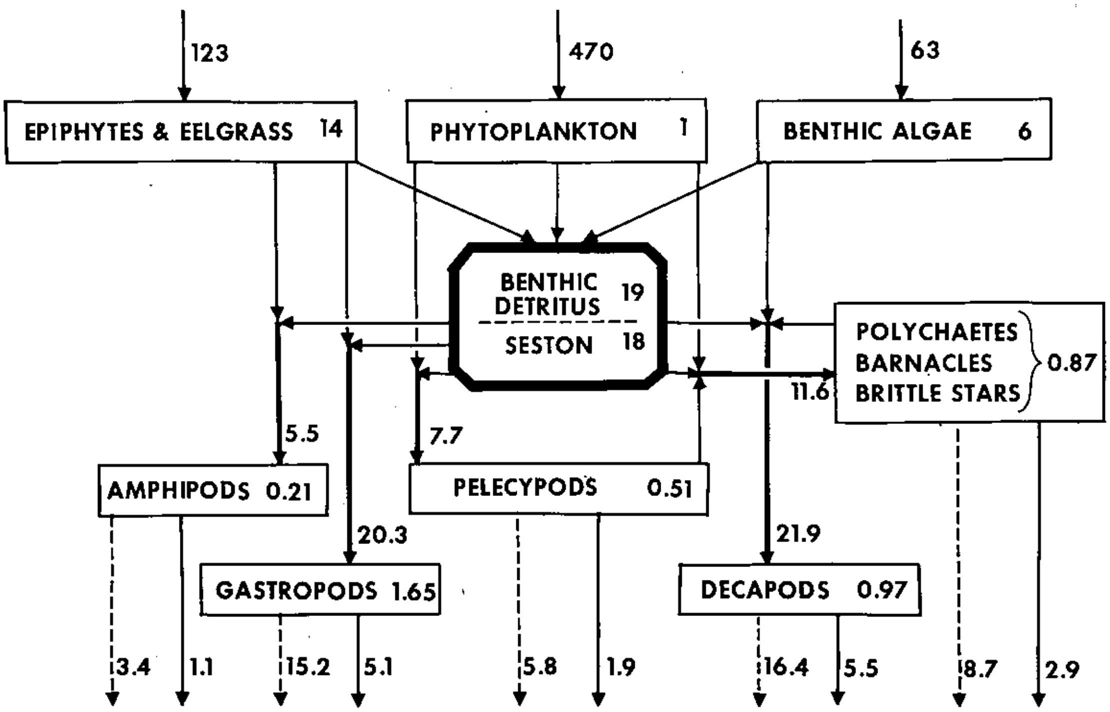

Figure 4.—Trophic relations and energy flow in an eelgrass bed system in Newport River estuary. Inflow, growth outflow (solid arrows), and respiration outflow (dashed arrows) in kilocalories per square meter per year. Average standing crops, values in compartments, in kilocalories per square meter.

Cycling of Elements in the Estuarine Environment

The prime objective of the Elemental Cycling Program is to describe in detail the chemical budgets of important radionuclides and trace metals in our extensive salt-marsh estuaries, so that we can predict levels of radionuclides and trace metals that will occur in the important organisms in water, and in sediments, at various times after introduction of pollutants into estuaries. This increased emphasis on defining overall chemical budgets for certain radionuclides and trace metals in estuarine systems will ultimately require the use of systems analysis and modeling. In recent years we have conducted both field and laboratory research on the distribution and cycling of trace elements, both radioactive and stable, in the estuarine environment. Listed below are descriptions of research projects completed during the last 2 Fiscal Years.

The distribution of manganese, iron, and zinc in sediments, water, and in six species of polychaetous worms was described for the Newport River estuary near Beaufort, North Carolina (Fig. 5). Concentrations of manganese, iron, and zinc in 0.1 N HCl extracts of sediment samples collected monthly from three stations for 2 years varied with element, location, time, and sediment type. At each station, iron was the most abundant element present in the 0.1 N HCl extracts and zinc was the least abundant. The concentrations of all three elements in the sediments decreased in a seaward direction (Fig. 6). There were definite temporal fluctuations in the concentration of these metals in the sediment, although no seasonal trend was evident. In addition, muddy sediments contained higher concentrations of trace metals than sandy sediments. Concentrations of manganese and iron in the water also decreased in a seaward direction, although concentrations of zinc remained relatively constant. Except for zinc at one station, at least 30% of the total amount of manganese, iron, and zinc in unfiltered water samples could not be measured by standard spectrophotometric techniques without prior treatment with acid. The relative order of enrichment of trace metals in sediment

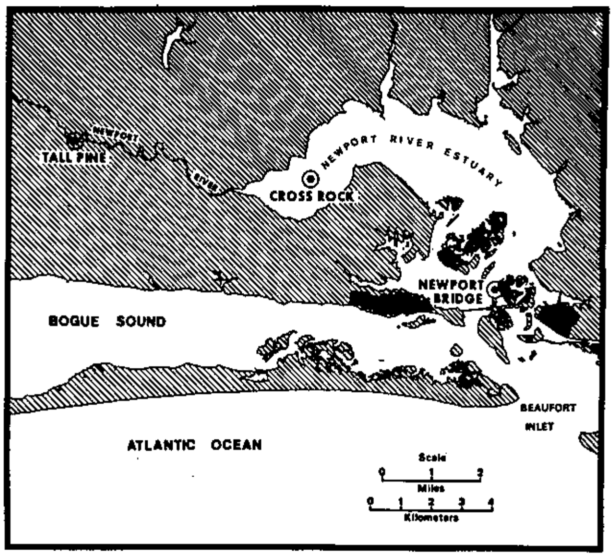

Figure 5. Chart of Newport River estuary.

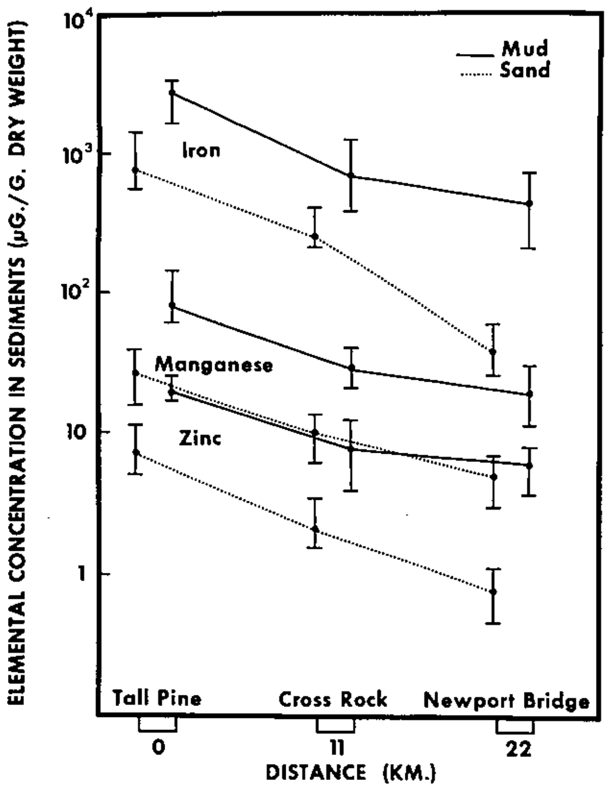

Figure 6. Concentrations of iron, manganese, and zinc in sediments from Newport River estuary expressed in median and 10 to 90 percentiles.

when compared with water was zinc > iron > manganese. Concentrations of these elements varied in six species of polychaetous worms. We did not observe any intraspecific differences in the concentrations of trace metals in three species of worms, however, that were collected from two stations which had substantially different concentrations of trace metal in the sediment. This finding suggests that either these organisms may be able to regulate their trace metal content or that much of the metal associated with the sediment is in a chemical form which is unacceptable to them. The order of enrichment of trace metals in polychaetes relative to sediment and water was zinc > iron > manganese.

A study was also carried out to determine the concentrations of manganese, iron, and zinc in five species of juvenile fish that were collected routinely over a period of 2 years in the Newport River estuary. The species of fish examined were the Atlantic croaker (*Micropogon undulatus*), spot (*Leiostomus xanthurus*), pinfish (*Lagodon rhomboides*), bay anchovy (*Anchoa mitchilli*), and Atlantic menhaden (*Brevoortia tyrannus*). These five species constitute over 90% of the total number of juvenile fishes in the Newport River estuary. In general, concentrations of these metals decreased as weight increased, as shown for zinc in figure 7. As the fish grow, the proportion of tissues that accumulate the highest concentrations of metals, such as the gastro-intestinal tract, decreases as compared with muscle and bone, two tissues that contain relatively low concentrations of trace metals. Significant differences in concentrations of iron and zinc were observed among the five species when individuals of similar size were compared. Of particular interest were the differences in concentrations of these two metals in spot and croaker and in anchovy and menhaden. Spot and croaker are closely related phylogenetically, are both primarily bottom feeders, and live in the same habitat. The same is true for anchovy and menhaden, except that they both feed on plankton. We are continuing studies with juvenile fish in an effort to explain species differences observed for concentrations of these metals.

Concentrations of stable zinc and zinc-65 were measured in oysters (*Crassostrea virginica*) collected from estuaries near Beaufort, N.C. The concentration of zinc in oysters was highly variable. Samples from these relatively unpolluted estuaries contained, on the average, 85-245 ppm zinc, based

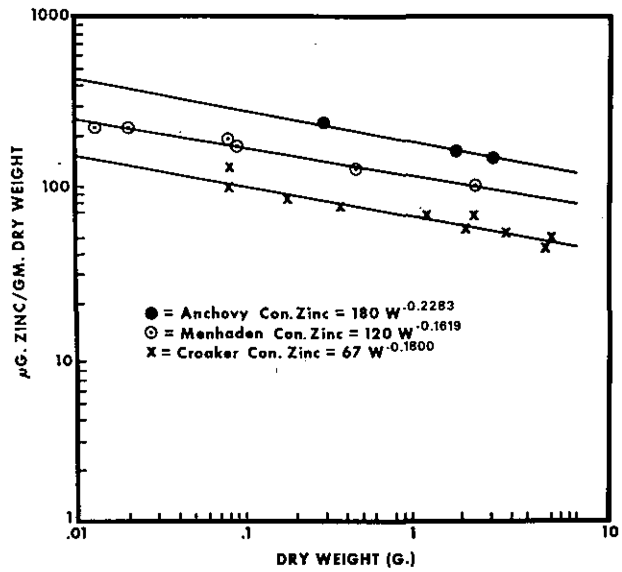

Figure 7. Effect of body weight on concentrations of zinc in juvenile anchovy, menhaden and croaker from Newport River estuary.

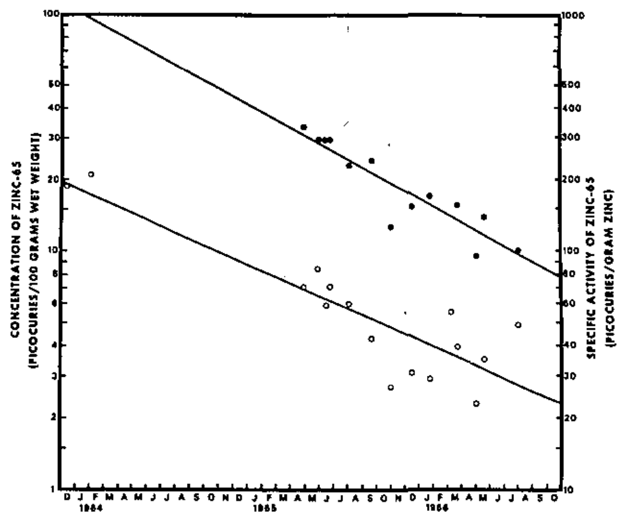

Figure 8. Zinc-65 fallout in soft parts of oysters; open circles-absolute activity; solid circles - specific activity.

on wet weight. Internal tissues, like adductor muscle and pericardial sac, had zinc levels less than half those of external tissues but zinc was nonetheless distributed uniformly throughout the animal tissues. During 1964-66, North Carolina oysters contained from 2 to 20 pCi zinc-65 from fallout per 100 g wet weight. Specific activity of zinc-65 in these oysters during 1965-66 was in the range 90 to 300 pCi/g Zn, and was declining with an

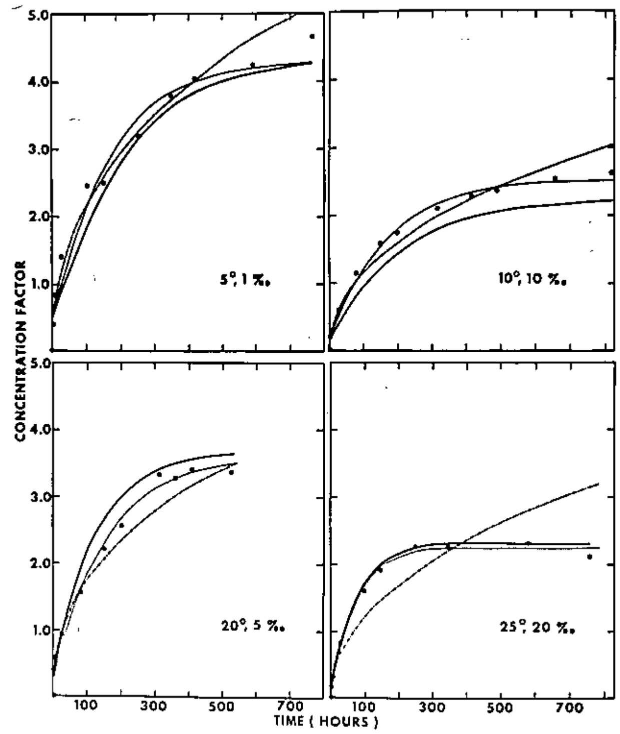

Figure 9. Accumulation of cesium-137 by *Rangia* at different temperature-salinity combinations. Curves represent different calculated regressions.

apparent half-life of 276 days (Fig. 8). In addition, studies on the zinc enzymes in these oysters revealed that nearly all the zinc was bound, either to soluble, high-molecular weight proteins or to structural cellular components such as cell membranes. Oyster alkaline phosphatase is a zinc metalloenzyme, as indicated by *in vitro* inhibition studies with various metal-binding agents. Dialysis of soluble tissue extracts at pH 7 to 9 removes up to 96% of the total zinc without effect on alkaline phosphatase. If alkaline phosphatase is considered representative of the metabolic functions of zinc in oysters, most of the zinc accumulated by oysters must be superfluous to the animal's requirements.

To clarify some of our previous environmental observations on the accumulation of fallout cesium-137, we undertook to define the effects of salinity and temperature on the accumulation of this radionuclide by the clam, *Rangia cuneata*, under controlled laboratory conditions. The accumulation of cesium-137 by *Rangia* was described by an asymptotic exponential regression (Fig. 9). The regression constants were described as functions of temperature and salinity over the ranges 5 to 25°C and 1 to 20 ‰, so that the concentration factor for cesium-137 in *Rangia* could be accurately predicted at any combination of temperature and salinity. Linear log-log regression accurately describes the initial phase of cesium-137 accumulation, but does not reflect the ultimate asymptotic nature. The proportion of cesium-137 associated with the shell of live *Rangia* was an inverse logarithmic function of salinity and temperature. Concentration factors for cesium-137 in soft tissues of *Rangia* were calculated for different salinities and temperatures.

To better understand the behavior of stable elements and their radioisotopes in laboratory experiments, we conducted a long-term study to determine the distribution of radioactive and stable zinc in an experimental marine ecosystem. We added 1 mCi of zinc-65 to 2,000 l of sea water and a mixed community of planktonic and benthic algae in a Fiberglass tank, after which the ecosystem was left undisturbed for 9 months. We then measured the zinc-65 specific activities for (1) particulate zinc (0.45 μ filterable,) (2) extractable zinc from water passed through a 0.45 μ filter and then treated with dithizone), (3) total dissolved zinc (from samples passed through a 0.45 μ filter and treated with acid prior to extraction with dithizone), and (4) dialyzable zinc. Zinc-65 specific activities were not significantly different among the extractable, dialyzable, or acid-treated samples of the water. Further, absolute concentrations of zinc-65 and total zinc were no higher in the acid-treated samples than in the extracted or dialyzed samples which indicates that nearly all of the soluble zinc in the water was dithizone extractable and dialyzable. Zinc-65 specific activities were significantly less, however, in the particulate matter than in the water. This difference indicates that equilibrium of zinc between particulate material and water had not been reached after 9 months. Three months later, zinc-65 specific activities were determined again for particulate material and total dissolved zinc. The mean specific activity for zinc-65 in the particulate samples showed a small but significant increase, but it was still less than in the water. Concentration factors in the particulate matter were 980 for zinc-65 and 1,400 for total Zn. The results of this work point out the need to study the behavior of stable elements in addition to their radioisotopes in tracer experiments.

Menhaden Research

Menhaden are one of the United States' most important fishery resources. These clupeid fishes, related to the herrings, shad, and alewife, occur in the Gulf of Mexico and along the Atlantic coast. Landings of two species, one from the Gulf and the other from the Atlantic, make up about 35 percent of the total landings of all fish in the U.S. Landings of menhaden are greater than the combined U.S. catch of all species of salmon, tuna, shrimp, crab, flounder, and anchovy.

At the present time nearly all menhaden caught are processed into fish meal, solubles, and oil. Fish meal and solubles are used in poultry and other animal feeds. Oil is used in many products such as paints, linoleum, cosmetics and machine oils, but most is exported to Europe for manufacture of margarine. Recently, the Food and Drug Administration approved the use of menhaden for making fish protein concentrate. Currently, however, no companies are making FPC from menhaden.

Menhaden also play a very important role in many of our estuaries and the coastal zone. They enter as larvae in the spring and leave as juveniles in the fall. As young, they provide food for or compete with most important sport and commercial fishes.

Atlantic menhaden

Since the inception of the Atlantic menhaden research program in 1955, the purpose and aims have remained unchanged. Then and now, the principal goal was to assess the effects of fishing on the menhaden stocks so as to aid in the wise utilization and conservation of a valuable national resource.

Menhaden are one of the best examples of a national fishery resource. They occur in the coastal waters of every Atlantic and Gulf coast state. They migrate extensively along the Atlantic coast and to a certain degree along the Gulf coast. Only occasionally do significant quantities occur offshore beyond the nation's 12-mile fishing zone. Actions by one state to conserve "their" menhaden resource would be ineffective if other states did not also take appropriate action. One of the most important questions in the near future will be how such resources should be managed.

During the 1969 and 1970 purse-seine fishery for Atlantic menhaden, catches were systematically sampled throughout the season at all operating plants from Fernandina Beach, Fla., to Amagansett, N.Y. (Fig. 10). In 1969, 999 samples, each of 20 fish, were collected. In 1970, 430 samples were obtained. In addition to these we sampled menhaden in pound net landings in Chesapeake Bay. Atlantic thread herring, occurring incidentally to menhaden in the purse-seine landings from the South Atlantic area, were also sampled.

Figure 10. Sampler aboard purse seiner obtaining menhaden sample for length, weight, sex, and scales for aging.

The numbers of menhaden purse-seine vessels in the Atlantic fleet in 1969 and 1970 continued a decline begun in 1966. Eighty-one vessels fished in 1965, 74 in 1966, 64 in 1967, 59 in 1968, and 52 each in 1969 and 1970.

The 1969 Atlantic menhaden catch of 196 thousand tons was almost one-fourth the record of 769 thousand tons landed in 1956. Most of the landings are made by the purse-seine fishery. Landings in 1970 improved some 50 percent over those in 1969, and 291 thousand tons were processed. Landings in 1970 were less than half the average catch during the peak period 1953-62. The 1970 Atlantic menhaden season was characterized by unusually high landings in Chesapeake Bay and extremely low landings in the North Carolina fall fishery. Age composition of the catches in 1969 was mostly 1- 2- and 3-year-old fish. In 1970, 1-year-old fish were dominant.

To determine the effect of purse-seine fishing on the Atlantic menhaden population, we analyzed data from 1955-69 on fishing activity and catches. Changes in fishing efficiency necessitated establishment of an abstract effort unit, the 1965 vessel-week. Catch per unit of effective effort, an index of population size, in 1965 was one-fifth that of 1955. Compensating for changes in effective effort permits an estimate of the maximum sustainable yield and the optimum amount of effort to harvest the resource. We constructed a mathematical model of the fishery incorporating estimates of the natural mortality rate and the recruitment resulting from various stock sizes. The yield could then be predicted under different levels of fishing mortality (Fig. 11). At the current recruitment age, 1.5 years, reducing instantaneous fishing mortality (*F*), from current levels of about 1.2 to 0.8 would

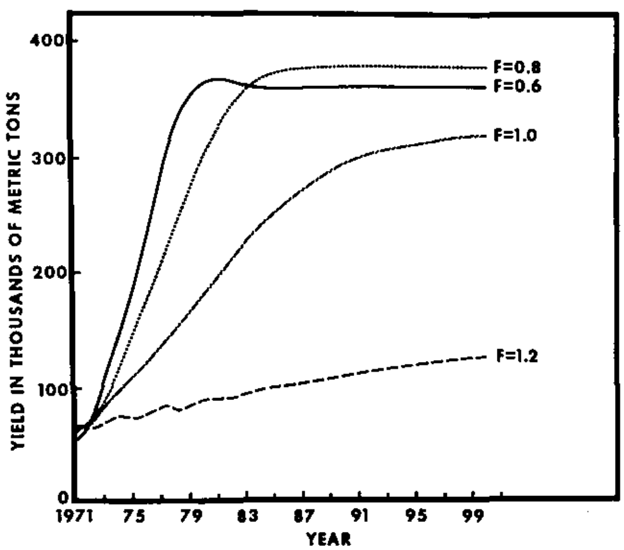

Figure 11. Projected yield of Atlantic menhaden achieved from four different hypothetical fishing mortalities.

slightly decrease the yield per recruited fish but would increase the spawning stock and ultimately allow annual catches of 380,000 metric tons. Our equilibrium catch-effort curve from historic data predicts a yield of about 600,000 metric tons (Fig. 12) while the population-prediction model (Fig. 11) suggests a yield of only 380,000 metric tons. The catch-effort curve is probably biased upward because of the succession of exceptional year classes in the 1950's. The population-prediction model depends greatly on the spawner-recruitment model,

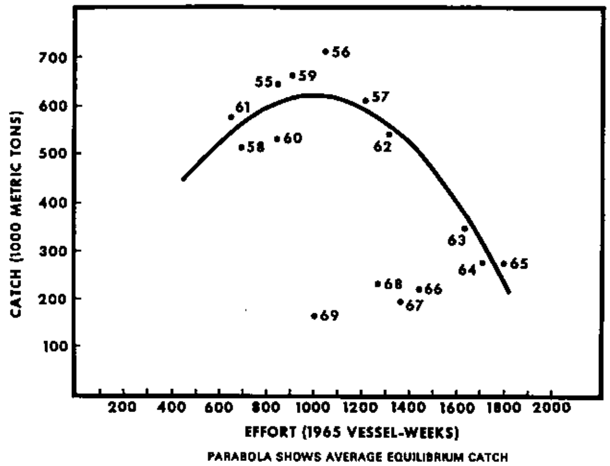

Figure 12. Total catch related to effective effort for Atlantic menhaden, 1955-1965. Points for 1966-1969 have not been transformed into 1965 vessel weeks.

which is insensitive to and dampens the effects of those large year classes. Practical suggestions of this investigation are (1) that the resource is diminished as a result of fishing, and (2) that recovery will only occur if F is reduced. Moreover, after recovery of the population annual catches should be about 400,000 to 500,000 metric tons. This should ensure adequate spawning.

Tagging of Atlantic menhaden with internal ferromagnetic tags began in 1966 and since then, over 1.1 million fish have been marked by this means along the Atlantic coast from Rhode Island to Florida. From these we estimate that nearly 233 thousand were recaptured to date. Results of this extensive tagging program are designed to provide basically five types of information, each complimentary but independent of other population evaluation sources. Recoveries of tags provide direct information on these five important questions: (1) What is the population structure? (2) What are the rates of natural and fishing mortality and do they change with age? (3) Are there changes in availability of fish? (4) What amount of movement and interchange between fishing areas occurs? and (5) What are the sources of young fish that later enter the catches?

The recapture of tagged adults by the Atlantic menhaden purse-seine fleet has shown considerable seasonal movement along the coast and the results agree well with conclusions based on other types of data and with the fishing industry's inference drawn from many years of fishing.

In October 1969, juvenile Atlantic menhaden were tagged for the first time with a new smaller tag. Nearly 1,000 fish, averaging 85 mm, were tagged in Rhode Island. In 1969 and 1970 four of these tags were recovered; one at Beaufort, during the 1969 fall fishery, and two more there and one at Fernandina Beach, Fla., in the summer of 1970. These recoveries show that juvenile menhaden from New England migrate to the South Atlantic during the fall and remain there the following summer. In 1970 nearly 21,000 juvenile fish were tagged along the Atlantic coast. Recoveries of these tags in the fishery will permit continued monitoring of the resource and contribute direct information on the source of young fish in the fishery in 1971 and their distribution along the coast in subsequent years.

Recoveries of tagged adults and juveniles support the hypothesis that Atlantic menhaden constitute a single population. Adult fish tagged in Florida, North Carolina, Chesapeake Bay, and New Jersey have been recovered north of the release sites in subsequent years. In general, the greater the number of seasons a tagged fish has been free, the farther northward from the release site it likely will be recovered. Some of the fish tagged off New York and New Jersey during the summer have been recovered the same season, while others were captured in subsequent seasons, in the North Carolina fall fishery in November and December. Juvenile menhaden tagged in northern waters show a southward movement from their estuarine rearing areas. The pattern of recoveries suggests an intermingling and mixing of menhaden in the winter and a resegregating during the following spring and summer. With such significant mixing of fish from various areas the population should be considered as one stock.

In December 1970 and January, February, and March 1971, we made plankton tows off the coasts of North and South Carolina for surveying and gear testing. Bongo samplers for the new MARMAP program were tested with different mesh sizes. Menhaden larvae were obtained in some tows near the Gulf Stream, but few were caught in the Gulf Stream—indicating that menhaden spawn over the inner portion of the Continental Shelf.

Surveys of ichthyoplankton in the near coastal areas of Onslow Bay, N.C., were begun during the year. These surveys will help us understand the time and conditions affecting the entrance of larval fish into the Newport River estuary.

We sorted fish eggs and larvae from plankton collected by *Albatross IV* groundfish survey cruises. Each cruise consisted of more than 100 stations from Cape Cod to Cape Hatteras. No menhaden eggs were found. No menhaden larvae occurred in either March cruise in 1968 or 1969. In October 1968, 211 menhaden larvae were taken at 25 stations and in October 1969, 58 at 10 stations.

Since 1-year-old fish can dominate the catch, as they did in 1970, accurate predictions of the size of the resource depend on measures of the strength of the incoming year class and of the remainder from earlier year classes. Aerial surveys of juvenile menhaden abundance in Atlantic coast estuaries have been made since 1960 in an effort to measure year class strength before the fish enter the fishery. Two aerial surveys have been conducted each year since 1962. For 1971 we have revised the flight tracks to include repetition of key areas and a modified survey procedure to provide more reproducible counting methods.

Gulf menhaden

The Gulf menhaden research program began in 1964, and as in the Atlantic program, its purposes and aims have remained the same. These are to assess the effects of fishing on the fish stocks and to aid in the wise utilization and conservation of a valuable national resource.

In the 1969 and 1970 Gulf menhaden fishing seasons, we continued the sampling and monitoring program initiated in 1964. These activities included: (1) sampling of landings of fish for age (from scales), size (length and weight), sex, and stage of sexual maturity; and (2) recording daily the fishing activities of the purse-seine fleet; (3) assisting shipboard personnel in the recording in logbooks of location, time of day, etc., of purse seine sets; and (4) collecting daily landings of each vessel.

In 1969, 710 samples of 20 fish each were collected and subsequently measured by four full-time catch samplers strategically located at four major ports of landing; Moss Point, Miss., and Empire, Morgan City, and Cameron, La. In 1970, 528 samples of Gulf menhaden were obtained. Full-time sampling personnel were located at the three ports of Moss Point, Miss.; Morgan City-Dulac, and Cameron, La. Samples were also obtained in each season, when time permitted at Intracoastal City, La. and Sabine Pass, Tex.

The catch of Gulf menhaden in 1970 was 612 thousand tons (602 by purse-seine vessels) and set a new record (Fig. 13). This catch was 5 percent greater than in 1968, and 73 percent greater than in 1967, the lowest catch in the past decade. In 1970, 79 percent of the catch was landed in Louisiana, 17 percent in Mississippi, and 4 percent in Texas. Landings in Louisiana in 1969 were less with 74 percent, whereas landings in Mississippi were 20 percent and Texas were 6 percent.

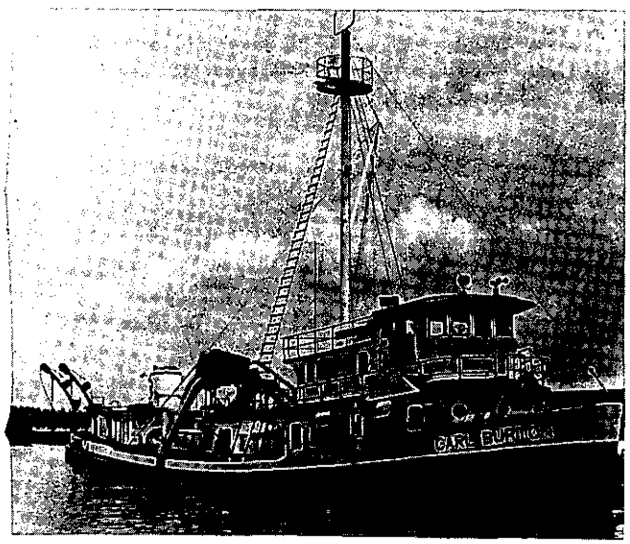

Figure 13. Gulf menhaden purse seiner awaiting unloading with record catch of 615 metric tons.

There were 76 purse seine vessels in the 1970 Gulf fleet. This is one more than in 1969, but 16 less than the record high of 92 in 1966. Vessel size, a prime component of fishing effort, increased slightly from an average of 239 registered net tons in 1969 to 240 net tons in 1970. This suggests that the trend begun in 1946 of employing larger carrier vessels continues.

Significant advancement in gaining an understanding of the Gulf menhaden population was made since our 1969 annual report. Essentially, the system used consisted of examining detailed catch records of purse-seine landings, by boat, since 1946, the year when the current Gulf fishery began. Reconstruction of 24 years of these records, 1946-1969, plus annual estimates of fleet fishing effort based on each vessel's registered net tonnage times the number of week catches were landed, provided

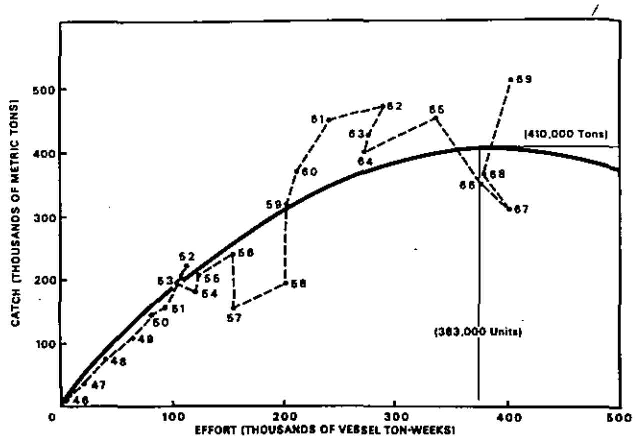

Figure 14. Yield predicted (solid line) and observed catch and effort (dashed line) in Gulf menhaden fishery, 1946-1969 (numbers refer to years).

a mathematical relation of annual catch and corresponding fishing effort. These data were then used in a model, established for the Pacific tuna, which indicates: (1) The maximum sustainable yield (catch) of Gulf menhaden fishery is 410,000 tons, (2) This catch should be made with a maximum of 383,000 vessel ton-weeks of effort, and (3) the Gulf menhaden population is producing at or near its maximum predicted yield at this time (Fig. 14). Fishing effort by the Gulf fleet in 1970 was 397,156 vessel ton-weeks, or 4 percent greater effort than the model prescribes as maximum. Landings in 1970 were appreciably greater (33 percent) than the sustainable level given by the model.

Since 1969, nearly 53,000 adult Gulf menhaden have been tagged from Florida to Texas and to date an estimated 18,000 recaptured. As in the Atlantic fishery recoveries of tagged fish will provide information on five major categories: (1) population structure, (2) rates of natural and fishing mortality, (3) changes in availability, (4) movement between fishing areas, and (5) sources of young fish that later enter the catches. Conclusions based on these results are complementary to analyses of other sources of information such as catch and fishing effort records, age and size of fish in the landings, and life history. In some cases, tag return information is expected to provide data that will permit a more precise evaluation of the menhaden resource than would otherwise be possible.

In the spring of 1969, almost 27,000 adult Gulf menhaden were tagged by biologists using the same internal body, individually numbered, ferromagnetic tag used for the adult Atlantic menhaden. Field tests and initial experiments with the Gulf menhaden, a smaller fish and therefore presenting different problems, proved less difficult than expected and returns from the fishery were encouraging. In the fall an additional 8,000 adult menhaden were marked.

In the spring of 1970, nearly 18,000 adult menhaden were marked and returns from these, plus those from tagging in 1969, indicated two important features of the Gulf menhaden population: (1) Fish recaptured during the year of release showed very little movement between fishing grounds east of the Mississippi River Delta and those west of the Delta; (2) Tag recoveries in the spring of 1970 from the 1969 releases also show little mixing over winter of fish from east and west of the Delta; and (3) Movement of tagged adult fish appears to be essentially onshore-offshore with no extensive east-west or west-east migration. These observations, if early trends continue, suggest that possibly the Gulf menhaden should be considered and treated as two separate stocks.

In 1970, the initial tagging of juvenile Gulf menhaden was carried out when 10,000 young fish were marked in estuaries from Florida to Texas. Recovery of these tags will provide information on: (1) Whether or not all estuaries produce young menhaden on which the fishery depends, and (2) At what rate, and where, do these young fish enter the purse seine fishery.

The ecological study of Gulf menhaden and associated estuarine fishes of Pensacola Bay, begun in 1970, was continued in 1971 and is contributing to a better understanding of fish distribution in the area. In the Gulf the last larval menhaden in 1971 plankton collections from the Bay occurred near the end of April. Twenty other species of fish larvae were collected. Juvenile menhaden usually were abundant in the Bay and lower River throughout the spring. By June, there was a separation of sizes with salinity of water. Smaller juveniles occurred upstream in salinities of 0.5 parts per thousand or less and larger ones downstream in higher salinities. Yearling menhaden and threadfin shad were taken with juvenile menhaden. Estimates of juvenile abundance in the Gulf have been made by both aerial and surface trawl surveys. In recent years aerial surveys have been over the clear waters of the eastern Gulf and the trawl surveys in the waters of the more turbid western Gulf. In the Gulf these prerecruitment surveys are even more important than in the Atlantic as the Gulf menhaden make most of their contribution to the fishery as 1- and 2-year olds. In 1971 we are attempting to describe the relationship between these two survey methods. Further studies of day-night variation in results of trawl survey are being conducted in areas of clear and turbid water in another attempt to develop more accurate survey methods.

Thread Herring Program

The program was begun in 1968 after exploratory fishing disclosed large stocks of Atlantic thread herring in the eastern Gulf of Mexico and a reduction plant was opened near Fort Myers, Fla. The program was directed toward all industrial schooling fishes with particular emphasis on the life history, population dynamics and fishery for thread herring.

The thread herring fishery along the Gulf coast of Florida came to a close in 1970 with the passage of laws by the State Legislature prohibiting the use of purse seines within territorial waters. In conjunction with the closure of the fishery, the thread herring program was phased out. Efforts for the balance of 1971 were directed to completing manuscripts and consolidating data and samples for distribution to other facilities for further analysis.

Although the thread herring program was small and shortlived it made noteworthy contributions to an understanding of the biology of the resource in the eastern Gulf. Thread herring migrate in the coastal zone apparently in response to water temperatures above 20°C. In the fall and early winter months, movements are southerly preceding the 20° isotherm. Large concentrations of thread herring off southwest Florida begin moving northerly in the spring and apparently prefer water temperature between 26 and 29°C. Thread herring occur most abundantly in the upper 10 feet of water usually within 9 miles of land. Copepods are the principal food item. Juvenile thread herring are fed upon by Spanish mackerel only to a limited extent and rarely are eaten as adults. Adult thread herring have a prolonged spawning season from March to August and mature females produce from 15,000 to 50,000 eggs. Returns from limited tagging of thread herring along the Atlantic coast indicate that the Atlantic stock is relatively small.

Blue Crab Program

The blue crab program which began in 1957 was terminated in 1969 when field and laboratory studies were stopped. Funds for blue crab research were reduced in 1967 and again in 1968. Two biologists prepared final reports for publication in 1970.

Radiological Consulting

As a result of a rapidly expanding technology, the nation's need for more sources of power is being met by the construction of nuclear power plants. It is likely that nuclear reactors will eventually produce most of the required electric power including that now being produced by fossil fuels, partly because of the campaign against air pollution and partly because of economic considerations. Nuclear reactors, however, produce radioactive wastes that must be disposed of in a safe manner. Since it is not economically feasible to store all wastes, those liquids having low concentrations of radioactivity are discharged into the aquatic environment where they are diluted and dispersed.

At present, it is not known whether the concentrations of radionuclides accumulated in organisms from water containing legal limits of radioactivity (maximum permissible concentrations) will have harmful effects upon the organisms. Consequently, each reactor location must be studied individually, and a radiological monitoring program must be designed to ensure that organisms will not be exposed to enough radioactivity to harm them or render them unfit for use as food by man.

As radiological consultants for the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, we review the safety analysis reports for each nuclear power plant before construction begins. After making a careful study of the reactor site, radioactive waste disposal system, cooling water intakes and outlets, and the applicant's radiological monitoring program, we make recommendations based on sound principles of radioecology.

Over the past 2 years, we reviewed 245 safety analysis reports, amendments, and environmental monitoring reports in order to evaluate possible radiological effects on fishery resources from radioactive wastes from power plants. Also, as part of our radiological consulting activities, we participated in 7 conferences, testified at 2 public hearings on nuclear plant license applications, and attended 4 meetings.

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