Southeast Fisheries Center

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Annual Report

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1988 ANNUAL REPORT

SOUTHEAST FISHERIES CENTER

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CONTENTS

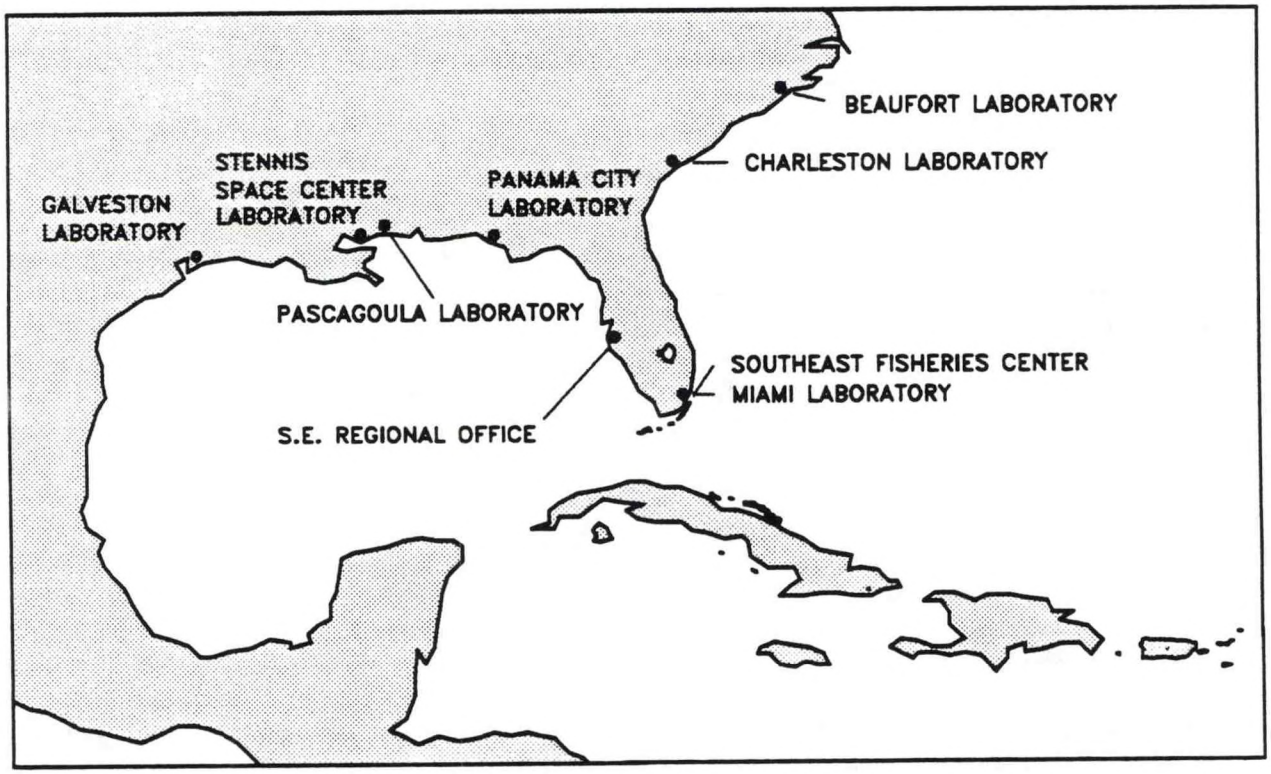
The Southeast Fisheries Center's Annual Report is an administrative report on key Center research activities during the year. The Program Managers' names and phone numbers have been included at the end of each section to contact for more information. Additional copies of this report are available from SEFC Headquarters, 75 Virginia Beach Drive, Miami, Florida 33149.

SOUTHEAST FISHERIES CENTER

The Southeast Fisheries Center (SEFC) of the National Marine Fisheries Service (NMFS) conducts research in support of federal laws and international agreements relating to living marine resources in waters adjacent to the southeastern United States, Puerto Rico, and the U.S. Virgin Islands. NMFS is a member agency of the National Oceanic and Atmospheric Administration, a part of the U.S. Department of Commerce.

Center headquarters offices are in Miami, Florida and research laboratories are located in Beaufort, North Carolina; Charleston, South Carolina; Miami, Florida; Panama City, Florida; SSTL and Pascagoula, Mississippi; and Galveston, Texas. At-sea research is conducted from the 170-foot *Oregon II* and the 127-foot *Chapman*, berthed at Pascagoula. Scientific and technical information developed by the laboratories is used for decision making by numerous fishery management, development, and research organizations in the southeast.

Research programs focus on species groupings that support major commercial and recreational fisheries within the region. Most often, these groupings correspond to those employed by regional fisheries management councils in their consideration of management needs. Research provides input required to ensure that harvests do not overtax the productive potential of species populations while ensuring that unnecessarily restrictive management measures are not imposed on fisheries. For the underutilized stocks, research is designed to produce information that can lead to increased harvests. Each of the species-oriented programs is responsible for developing data needed to assess/monitor stock characteristics and conditions. Species programs include: Latent Resources, Mackerels, Menhaden, Molluscan Shellfish, Oceanic Pelagics, Protected Species, Red Drum, Reef Resources, and Shrimp and Bottomfish.



LATENT RESOURCES

The Latent Resources Program has provided management and development information on a wide range of fishery resources since 1984. Of major importance is information which will lead to a much improved understanding of the shelf ecosystem in the northern Gulf of Mexico. Species emphasized include those often grouped in the coastal herring and associated species category: Spanish sardines, round herring, scaled sardines, thread herring, anchovies, rough scad, bigeye scad, round scad, chub mackerel, and ballyhoo. These species all exhibit common characteristics; e.g., they are relatively small, fast swimmers, school, and tend to occur pelagically. Other species include gulf butterfish, harvest fish, blue runners, small tunas, drift fish, squid, and deep sea crabs.

The primary support platform used by the program is the NOAA Ship *Chapman*, a 127-ft stern trawler. This research vessel was transferred to the southeast late in 1984, and considerable effort has been directed at upgrading vessel capabilities with advanced acoustic, communication, and fish handling facilities.

A primary program goal has been to quantify specific components of the coastal herring and associated species complex. To accomplish this, much of the early effort was directed at developing direct sampling techniques for the fish relying heavily on trawling technologies developed in other regions of the world. High-opening, large-mesh bottom trawls and more recently, high-speed pelagic trawls represent the targeted technologies. The plan has been to achieve an acceptable degree of reliability with these technologies and then to combine them with state-of-the-art acoustic integrator systems for gulf-wide surveys of the latent resources complex. Satellite remote sensing also has been a key investigative area mainly as a means to help tactically direct survey operations and gain improved understandings of environmental relationships.

The discovery of a large gulf butterfish resource in the north central gulf in the early phase of the program forced redirection of some plans as a number of larger processor trawlers began harvesting the resource in 1986. The need was to develop management information quickly, and to transfer any applicable technology to the fishing fleets.

GULF BUTTERFISH

The gulf butterfish (*Peprilus burti*) is a relatively small, short-lived member of the Stromateidae family. It reaches sexual maturity in about a year spawning offshore where eggs and larvae depend on surface currents to transport them to nearshore nursery waters (Figure 1). As the young fish mature, they move offshore where they form large schools on or near the bottom. They are prized in Japanese markets for their light buttery flavor. Freezer trawlers from New England first started fishing for gulf butterfish in the spring of 1986, landing over a million pounds in 1986 and 1987.

A conservative safe level of harvest was estimated to be about 80 million pounds based on survey data. While found throughout the northern gulf, the highest concentrations were consistently located near the Mississippi River Delta (Figure 2). Butterfish appear to have seasonal inshore-offshore movement patterns with the fish farthest offshore in the warm summer months. There are no known migratory behavior patterns although some investigators feel that as the fish mature they tend to move toward the north central portion of the gulf, similar to menhaden. Exhaustive reviews of the literature and analyses of species association data have not uncovered any important commercial and recreational species using butterfish as a significant prey species. However, gulf butterfish may be an important prey species to a number of large pelagics and sharks. Most of the butterfish are infected with a cestode parasite known to complete its life cycle in sharks.

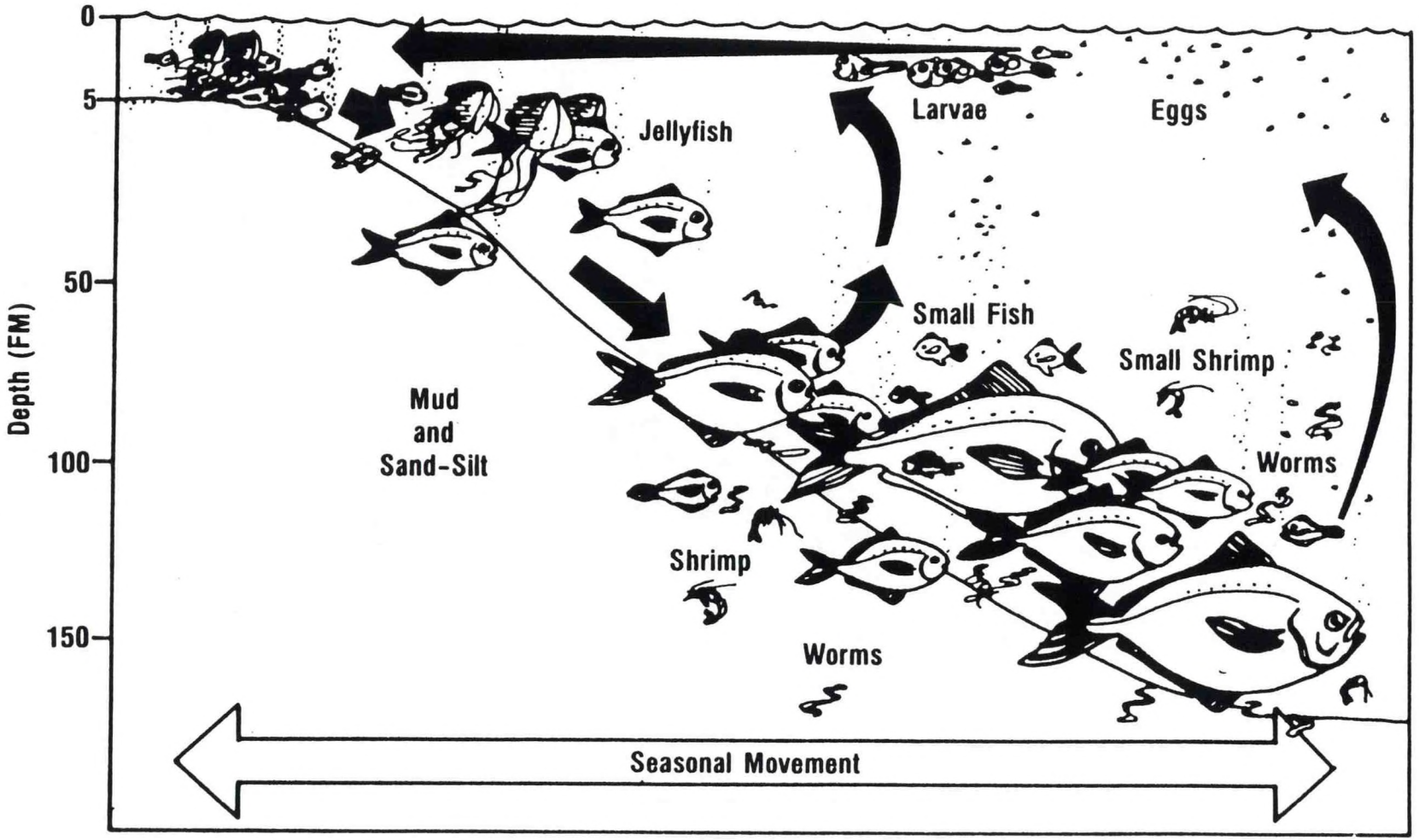


Figure 1. Gulf butterfish life cycle (life span $\simeq$ 2.5 years) (maturity < 1 year).

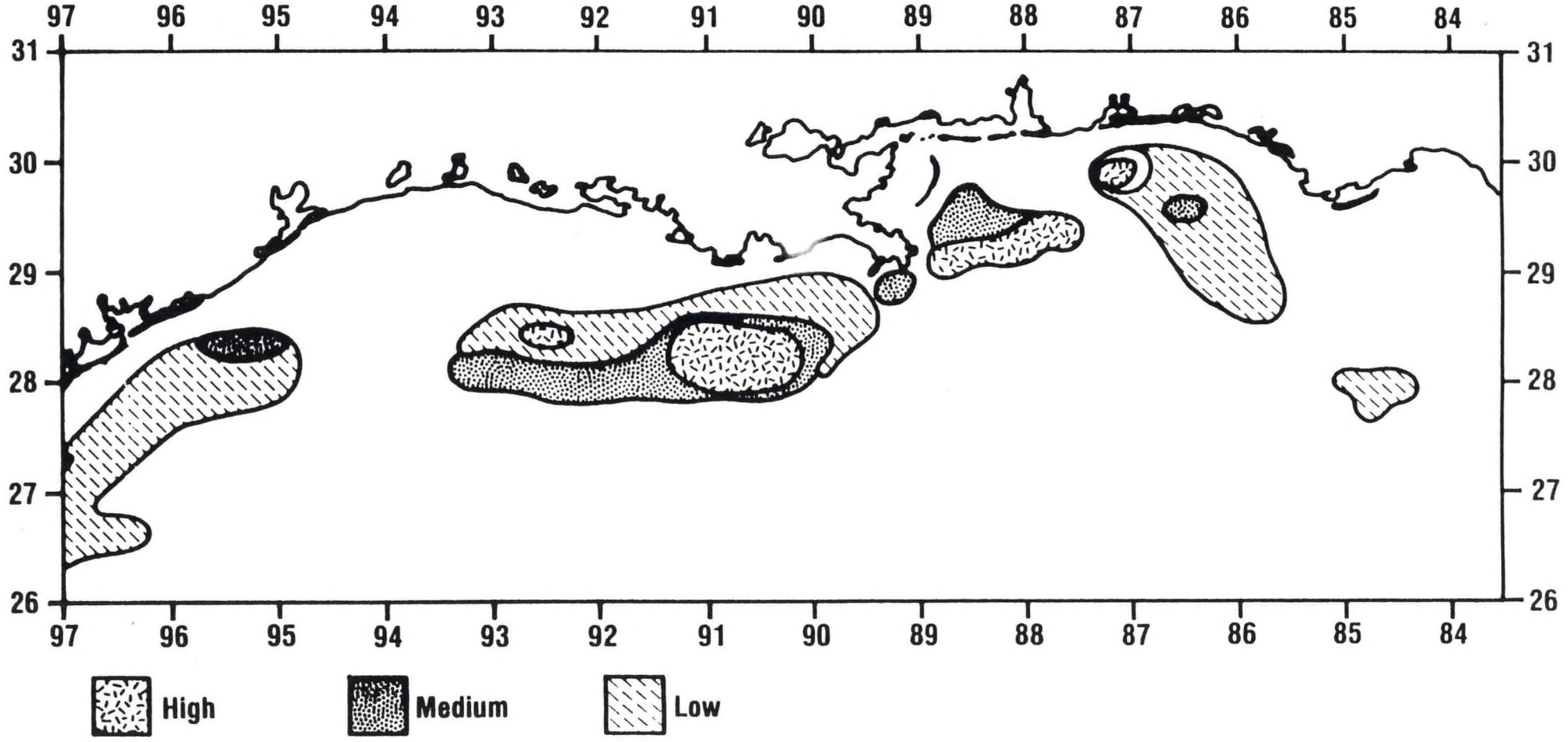


Figure 2. Relative abundance of butterfish (survey cruises).

Scientific observers have sampled catches aboard butterfish trawlers since the fishery began in 1986. This has become especially important due to serious concerns about possible trawl damage to reefs and incidental catches of reef fish and related recreational species. These concerns, however, do not appear to be warranted as relatively few reef fish are taken in butterfish trawls (less than 10,000 lb. in 1988), the incidental catch of recreational and commercial species is small, and the trawlers purposely avoid reefs to prevent damage to their expensive gear.

A number of gulf vessels entered the butterfish fishery in 1988 due in part to several financial assistance programs. These programs, which extensively involved NMFS technology transfer, provided partial matching funds for vessel retrofits. Eight vessels were retrofitted with financial assistance, and several other vessels were retrofitted independently. Technical support was provided to aid in the design of the retrofits, including methods to handle and preserve the fish aboard the vessels, gear deployment and handling, and at sea training of vessel operators. Additionally, technical assistance was provided in obtaining market information.

SURVEYS AND SAMPLING TECHNOLOGY

Survey cruises were conducted in the winter and spring with high opening bottom trawls. Large catches of butterfish, harvest fish, rough scad, and chub mackerel were reported and extensive biological and environmental data were collected. Two advanced midwater trawls were evaluated and a preliminary pelagic trawling protocol was developed. A fish funnel was perfected for bottom and midwater sampling trawls and swimming speeds and endurances of three coastal herrings were determined.

Efforts continued to upgrade the NOAA Ship *Chapman* with an advanced chromoscope sonar and a split beam echo integrator. The latter will be installed on the vessel in early 1989.

Data collected during the red drum aerial surveys were analyzed for distribution and relative abundance of surface schooling herring-type species. Many schools were found throughout the northern gulf in the spring, but far less in the fall. An effort was made to evaluate a low-light-level-image intensifier for nighttime surveys of schooling fish; unfortunately, the camera failed during the field tests and the evaluation had to be scheduled for another time.

A number of analyses of historical data were completed including one comparing total finfish and butterfish biomass trends in the north central gulf. In general, finfish biomass has decreased over 70 percent since the early 1970s, while butterfish biomass has remained relatively stable. Seasonal geographical and depth distribution patterns were determined for a number of the coastal herring species, based on data collected since 1950. Additionally, a comprehensive data base was established from NOS, NMFS resource survey, and Sea Grant trawl hangs data bases for locations of coral reefs in the northern gulf. These location data were used to evaluate impacts of butterfish trawling on reef habitat.

Efforts continued to apply satellite thermal data to latent resources in the gulf. A prototype expert system (from artificial intelligence theory) to interpret satellite imagery for high probability areas of butterfish catch was used to develop an automated PC-based image processing and distribution system for research and commercial applications. The concept of transmitting processed satellite data to commercial butterfish trawlers in near real time was successfully tested by using cellular phones in combination with FAX machines on several trawlers over a three-month period.

FISH HANDLING AND PROCESSING TECHNOLOGY

An experimental fish processing facility was established in Pascagoula during the year in cooperation with the Charleston Laboratory, Mississippi State University, Jackson County Board of Supervisors,

and Mississippi Power Company. An agreement was negotiated with Mississippi State University for joint funding and technical support of the facility, and with the Jackson County Board of Supervisors and Mississippi Power for funding and purchase of the necessary land and construction of the laboratory building. Equipment for the facility is being provided by the Charleston Laboratory. Privatization of the facility is anticipated in approximately five years (i.e., transfer to Mississippi State University). A senior food technologist was transferred to Pascagoula from the Charleston Laboratory to handle the negotiations and to work in this facility.

A plate freezer was installed on the NOAA Ship *Chapman* along with renovating the vessel's existing freezer and refrigerated sea water systems for fish handling and processing studies. Initial studies done on preservation techniques for gulf butterfish showed that a high quality product can be landed when the fish are frozen on board or maintained in slush ice for a few days. Fish quality rapidly degrades with refrigerated seawater (probably due to ion exchange) and chipped ice preservation systems.

A study was initiated to determine spatial and seasonal differences in cestode infection levels of gulf butterfish. While posing no human health hazard, this cestode can affect the aesthetic quality of butterfish. Samples of butterfish from New England also were examined for this parasite; the same parasite affects both the Atlantic and gulf fish. Cestode infection levels of gulf butterfish seem to be higher than for the Atlantic fish, although this cannot be stated conclusively until a better sample of fish is obtained from New England, and the gulf study is completed.

TECHNOLOGY TRANSFER

Technical assistance was provided to the Mississippi Department of Energy and Transportation, Jackson County Economic Development District, and Gulf and South Atlantic Fisheries Development Foundation in retrofitting gulf vessels for fishing butterfish. These organizations provided partial matching funds competitively to retrofit eight gulf vessels including 1 purse seiner and 7 shrimp trawlers. The average retrofit cost was about $60,000. This assistance took the form of specifying requirements for the vessels and direct technical support in the retrofits. At sea training and gear evaluations were provided for some of the fishermen.

Technical assistance was also provided for two trade missions to Japan. Fish samples were obtained from survey cruises, and technical information was provided on the biology, status of stocks, and fishing methods for the missions. These missions emphasized latent resources which are or have the potential for being landed in Mississippi and other gulf states.

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1988 Observations of shelf break exchange from CZCS imagery. Contributed paper to be presented at the 1988 Fall Meeting of the American Geophysical Union and the American Society of Limnology and Oceanography, San Francisco, CA, December 1988.

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GLEDHILL, C. T., R. GRACY, M. HAHN, C. MASSEY, and J. SCHEUREN
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1988 Distribution and relative abundance of selected coastal herring species from historical survey data. Special report for the Clupeid Purse Seine Fisheries Workshop, Tampa, FL.

LOHOEFENER, R., C. RODEN, C. ROGERS, W. HOGGARD, and K. MULLIN
1988 Distribution and relative abundance of "baitfish" schools in the Gulf of Mexico: spring and fall 1987. Special report for the Clupeid Purse Seine Fisheries Workshop, Tampa, FL.

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1988 Economic projections for an optimum gulf shrimp vessel converted to butterfish trawling. Internal Report, Mississippi Laboratories.

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WORKMAN, I. K.
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MACKERELS

The mackerel program is managed by the Panama City Laboratory. Major efforts were directed toward king and spanish mackerels with research designed to investigate the life history and population structures of these species. Research included studies of stock identification, movements and migrations, age and growth, reproductive potentials, food habits, mortality and other biological characteristics. A tagging program continued to gather data for management purposes.

The Fishery Management Plan (FMP) for Coastal Migratory Pelagic Resources has historically placed major emphasis on the king and spanish mackerel fisheries. However, the Gulf of Mexico and South Atlantic Fishery Management Councils are beginning to direct more attention to other species in the FMP, particularly the cobia and dolphin (the remaining species are cero, little tunny, and bluefish, the latter in the Gulf of Mexico only).

Amendments I and II of the Plan divided the king and spanish mackerel resources into Atlantic and Gulf groups for management purposes. The fishing year for both species in the Atlantic was set for April 1 through the following March 31, while for the Gulf groups, it was set for July 1 through the following June 30. During 1987-88, all commercial fisheries for mackerels, except for the Atlantic king mackerel, were closed prior to the end of the fishing year and all recreational fisheries for mackerels, except for the Atlantic king mackerel, had bag limits reduced to zero before the end of the fishing year.

LANDINGS

Landings for each management unit for the 1987-1988 season were as shown below.

	Million pounds		Date of	
Management Unit	Quota	Landings	Closure	Zero bag limit
Atlantic king mackerel				
Recreational	6.09	4.15	None	-----
Commercial	3.59	2.33	-----	None
Gulf king mackerel				
Recreational	1.50	2.04	-----	Dec. 16, 1987
Commercial				
Eastern Zone	0.48	0.41	Dec. 29,1987	-----
Western Zone	0.22	0.23	Nov. 2, 1987	-----
Atlantic spanish mackerel				
Recreational	0.74	2.05	-----	Sept. 19, 1987
Commercial	2.36	2.52	Dec. 29, 1987	-----
Gulf spanish mackerel				
Recreational	1.08	1.86	-----	Dec. 16, 1987
Commercial	1.42	1.43	Feb. 2, 1988	-----

VITAL STATISTICS

Acquisition of length and sex data on mackerels from various sources resulted in a two-fold increase in the database for 1985-1988. About 14,000 king mackerel and 7,000 spanish mackerel lengths were measured in FY88 by our samplers, cooperators, and contractors from the entire southeastern United States and Mexico. Extensive data sets were obtained from the 1985-87 Trip

Interview Program in the State/Federal Cooperative Statistics Program and from the Marine Recreational Fishery Statistics Survey. The 1985-87 database was used in the April 1988 stock assessment.

The 1985-88 database contains about 130,000 lengths and related data that are stored in a microcomputer at the Panama City Laboratory. Considerable improvements were made in the speed at which data can be entered and retrieved. The Statistical Analysis System is now in use for summary reports and analyses. These length and sex data will be supplemented continuously with newly acquired data for the 1989 stock assessment.

AGE-LENGTH KEYS

Otoliths from 958 king mackerel that were collected in 1986 and from 1,334 collected in 1987 have been processed and read. In 1986, female king mackerel ranged from age 1 to 19 and males from age 0 to 17. In 1987, females ranged from age 0 to 21 to males from age 0 to 19.

Kolmogorov-Smirnov tests resulted in highly significant differences between distributions of ages at length for most length intervals > 950 mm FL for females and > 850 mm FL for males when such comparisons were made between west and east Gulf of Mexico, between east Gulf and Atlantic, and between the entire Gulf and Atlantic. These differences confirm the need to use regional rather than pooled age-length keys for virtual population analyses. These differences in larger fish suggest regional variations in growth and are consistent with expected differences in density dependent growth.

Otoliths from 690 spanish mackerel that were collected in 1987 will be used to develop age-length keys for the 1989 stock assessment of this species.

ELECTROPHORETIC STUDIES

Peptidase (GL-2) in king mackerel muscle tissues has been shown to be a two allele (A & B) monometric system with variable allele frequencies in the southeastern U.S. and Mexico. In the western Gulf of Mexico, king mackerel have high frequencies of allele A, while in the eastern gulf, king mackerel have significantly lower frequencies of allele A. The ranges of these two stocks overlap in the northern gulf. Of 159 collections (about 5,000 fish) of muscle tissues during 1983-87, 80 percent of collections with frequencies of A alleles ranging from 0-20 percent were from Panama City and eastward, 98 percent of collections with frequencies of A alleles higher than 21 percent were from Pensacola and westward, and 100 percent of the collections with frequencies of A alleles higher than 41 percent were from Pensacola and westward. These variations have been shown to be independent of size and sex of king mackerel. Yearly spatial and temporal variations in the frequencies of these alleles will be used to determine the nature of mixing of the two stocks in the northern gulf during the warm months of the year.

Electrophoretic analyses of spanish mackerel tissues were continued. Seven polymorphic enzyme systems in muscle tissues have been examined. Samples have been obtained from six locations in the Gulf of Mexico, two in Mexico, one in Texas, one in Louisiana, one in Mississippi, and one in Florida. All polymorphic systems at all locations met Hardy-Weinberg expectations. Cluster analyses indicated two basic groups in the gulf, one from Mississippi and eastward, and the other from Louisiana and westward.

Seven polymorphic enzyme systems in muscle tissues of bluefish have been examined electrophoretically. Samples were obtained from four locations, one in northwest Florida and three from the Atlantic coast (Florida, North Carolina, and New York-New Jersey). Results from northwest Florida and New York-New Jersey samples presented a confused picture in that more than one stock may be in the area, depending upon season. Consistent patterns were seen in samples from North Carolina and east Florida. Further sampling and analyses are needed.

Electrophoretic studies of tissue enzymes in dolphin were initiated with 30 fish obtained in Panama City. Muscle, liver, heart, and eye tissues were examined. Twenty-one enzyme stains were used resulting in the observations of 40 loci. Nine loci were found to be polymorphic, three of which were monometric and six dimeric.

MARK-RECAPTURE

King and spanish mackerel tagging studies continued during the year. Fish were tagged and released in North Carolina, northwest Florida, Louisiana, Texas, and also in Mexico. These activities represented cooperative effort between the Panama City, Beaufort, and Miami Laboratories and the state agencies of North Carolina, Louisiana, and Texas. In Mexico, Mote Marine Laboratory together with the Panama City Lab worked jointly with the Instituto Nacional de Pesca.

Since the beginning of October 1987, the following tag releases have been made:

Atlantic coast (North Carolina):

1,482	king mackerel
948	spanish mackerel
10	little tunny

Northern Gulf of Mexico (northwest Florida, Louisiana, Texas):

690	king mackerel
1,316	spanish mackerel

Mexico:

541	king mackerel
32	spanish mackerel

Recoveries from North Carolina tagging ranged from Cape Hatteras, North Carolina to Palm Beach, Florida for king mackerel and from Chincoteague, Virginia to Sebastian Inlet, Florida for spanish mackerel. From the northern Gulf releases, recoveries of king mackerel have ranged from Sebastian, Florida to Veracruz, Mexico, and recoveries of spanish mackerel have ranged from Apalachicola, Florida to Dauphin Island, Alabama. From Mexican releases, recoveries of king mackerel ranged from Yucatan to Veracruz and for spanish mackerel, recoveries have been in the general area of release.

Tag recoveries from double-tagged king mackerel released in 1987 in northwest Florida were disappointing. Although 402 king mackerel were double-tagged with internal-anchor tags in 1987, only seven fish were recovered, and four of fourteen tags had been lost. An important contributor to the overall low return rate was probably the closed commercial fishery and the zero bag limit in the recreational fishery in south Florida during the winter of 1987-1988.

King mackerel tagging in southeast Florida in the spring of 1987 resulted in 41 additional tag returns in the period since October 1, 1987 bringing the total recovered to 68 (from 1,002 tagged fish). The recoveries were primarily from Florida waters, but 14 tags were recovered in North Carolina and one in Virginia, documenting northerly movements on the U.S. Atlantic coastline.

CHARTERBOAT SURVEY

Much of 1988 was spent in reevaluating survey techniques in preparation for future charterboat catch and effort surveys. During 1988, the registration of charter vessels fishing coastal pelagic fishes in federal waters increased the SEFC list of charterboat captain/owners from 843 (1986) to approximately 1,700 (1988). The primary objective of future surveys will be to index the relative

abundances of coastal pelagic fishes. Catch-per-unit-effort will be determined by surveying at least 10 percent of the fishing effort in each of 15 coastal areas. The rationale, objectives, and methods have been described in "a plan to determine distribution and abundance of coastal pelagic fishes by surveying charterboats of the southeastern U.S." Summaries of catch-per-unit-effort data from charterboat reports will be used by stock assessment scientists for making recommendations concerning migratory pelagic fish populations off south Atlantic coastal states and in the Gulf of Mexico.

RECRUITMENT PROCESSES IN MISSISSIPPI RIVER PLUME

Hydrographic features, primary productivity, and ichthyoplankton in the Mississippi River plume area were studied by the Panama City and Beaufort Laboratories on cruises of the *Oregon II*. In the laboratory, the ichthyoplankton samples were sorted and identified. Growth and diet of larval king and spanish mackerel were determined.

Preliminary information indicates that the Mississippi River plume is potentially important to the recruitment process in many species of fish, including spanish and king mackerel, because:

(a) physical convergence tends to concentrate large planktonic organisms at the front;

(b) high nutrient levels stimulate high primary production, either at the plume edge or within the plume itself, which in turn stimulates production at higher trophic levels, and this production is made available to oceanic and shelf fish species in interface regions at plume fronts at the surface and beneath the plume where plume waters override shelf waters;

(c) larval and post-larval king mackerel may be availing themselves of enhanced feeding opportunities resulting from higher production and growing at higher rates in the plume area.

Thus, higher productivity, horizontal concentrating processes, vertical aggregation processes via increased vertical stratification, and strong gradients that allow zones of high concentration to be encountered and utilized all occur in the plume region. The significance of these processes depends in part on factors such as the magnitude of the river discharge.

If biological and physical factors are making the Mississippi plume microhabitat a more favorable environment for growth and survival of early life stages of fish, then factors like the strength, persistence, extent, and configuration of the entire plume of frontal region may be critical to spawning success and ultimate year class strength. Following this line of reasoning, the Mississippi River discharge rate in summer (when king mackerel spawn) was correlated with a proxy for king mackerel recruitment, namely the catches of king mackerel in the Gulf of Mexico two years later, assuming that king mackerel are fully recruited to the fisheries by age 2. A strong positive correlation ($r = 0.71$) was found for the 10 years from 1970 to 1980. Higher discharge rates may favor higher recruitment by producing a greater plume area, or by creating a larger frontal region.

RESOURCE ANALYSIS

Analytical efforts were expanded in 1987-88 to address the management issues that have arisen for both king and spanish mackerel. The task of the analysis team is to evaluate the mackerel research and to integrate the results into advice to management on the status of the stocks and the effect of alternative regulatory procedures. This was accomplished by working closely with the Councils and by coordinating and participating on scientific review panels designed to solicit technical expertise from scientists in the region. Specifically, the analysis team initiated the Mackerel Review Panel to examine recreational catch estimates relative to quota allocations before release to the Regional Director. These estimates formed the basis for the Regional Director's actions to close recreational seasons in December 1987.

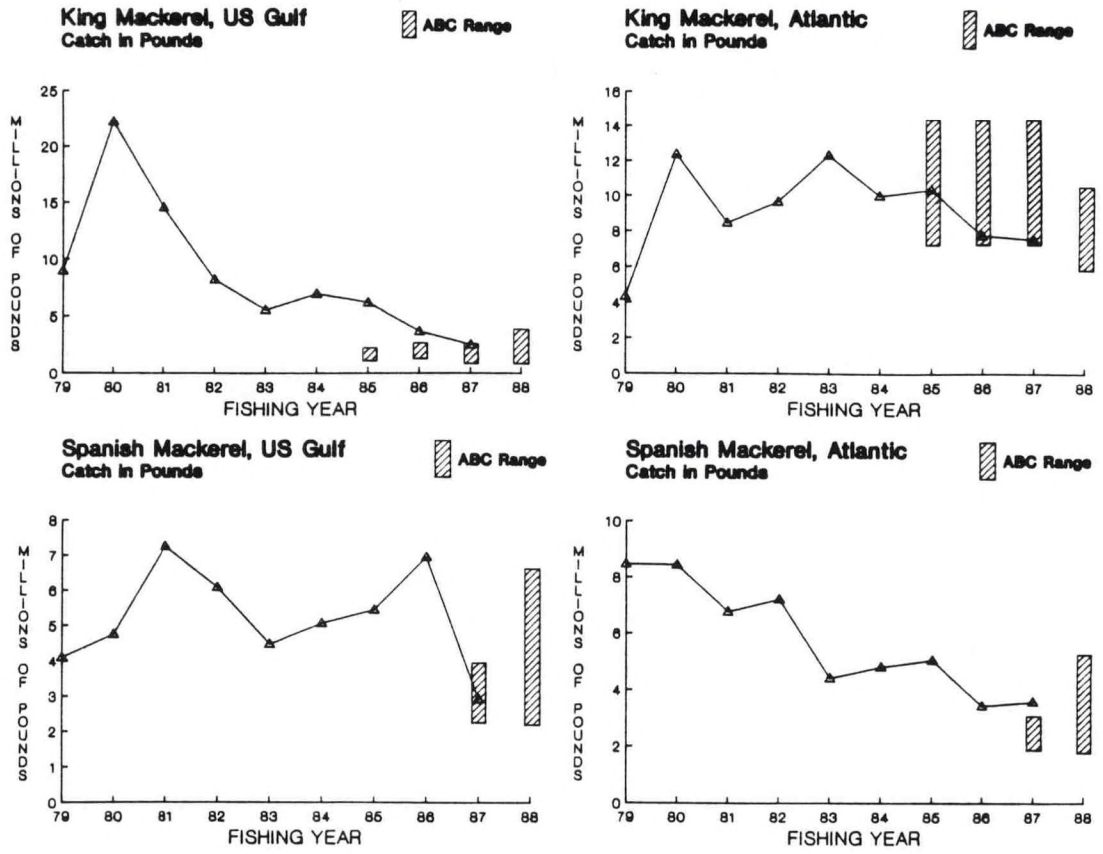

Figure 1. Mackerel catches by fishing year (July-June in Gulf; April-March in Atlantic). Allowable Biological Catch (ABC) ranges recommended by the Mackerel Stock Assessment Panel are overlaid including the recommendation for the 1988 season. Note that the 1987 seasonal catches only include data through October.

Additionally, the Mackerel Stock Assessment Panel met twice during the year to: 1) examine stock identification research results (March 1988); and 2) develop estimates of Allowable Biological Catch (April 1988). In the former meeting the panel examined electrophoretic results relevant to stock separation of king mackerel within the Gulf of Mexico. Although the results were not totally conclusive, the panel recommended that assessments be conducted using the electrophoretic results as one option. The analyses indicated that the gulf management strategy under such a scenario would require a slightly more conservative regime than is presently used. In the April meeting the panel used these and other data to develop the ABCs for the 1988/89 fishing season.

Assessment research included incorporation of virtual population analysis (VPA) calibration methods utilizing catch-per-unit-effort and abundance index data from charterboats, headboats, private vessels, and research cruises; using age-length key methods for estimating catch-at-age; and partitioning of catch by allele frequencies for king mackerel in the Gulf of Mexico. These activities were in addition to compilation of the large size frequency database needed for VPA work. The new techniques were required to account for the changing nature of the stock and fishery brought about by

regulation. The resulting ABCs (Figure 1) show some cause for optimism for spanish mackerel and gulf king mackerel, whereas Atlantic king mackerel may be reaching their peak production.

COBIA

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MENHADEN

Research on assessment of menhaden stocks and fisheries is centered at the Beaufort Laboratory, with data collection and research projects spanning virtually all the Atlantic and Gulf coast states. Activities are directed toward ecology of juveniles, stock assessments, monitoring the purse-seine fisheries and providing scientific advice to the states, industry, and fishery management institutions. Habitat research at the Beaufort Laboratory related to menhaden appears in greater detail under the "Habitat" section of this Annual Report. At the Charleston Laboratory, research is conducted on the development and application of fisheries technology to increase the export and direct domestic consumption of menhaden products. Major goals of the technology research are the increased use of menhaden oils plus the development of minced menhaden and surimi products.

ATLANTIC AND GULF MENHADEN FISHERY MANAGEMENT PLANS

The Atlantic Menhaden Plan Review Team suggested that the 1981 Atlantic menhaden fishery management plan (FMP) "is outdated and can no longer serve as a basis for cooperative interstate management of the Atlantic menhaden fishery." Among the reasons given for revision of the FMP were actions by several states contrary to the approved management option (e.g., South Carolina closed their waters to purse seining within 3 miles, and Virginia expanded their fishing season by 6 weeks). Another reason stemmed primarily from a joint venture between Maine and the Soviet Union for Atlantic menhaden beginning in late June of 1988 (harvested by U.S. vessels and processed by a Soviet factory ship, *M/V Riga*), although Atlantic menhaden taken by U.S. vessels in Maine waters have been landed in Canada since 1987. Furthermore, the management structure called for in the plan no longer exists since the recent reorganization of the Interstate Fishery Management Program. Other reasons given are based on social and economic changes, and the development of new products. At the annual meeting of the Atlantic States Marine Fisheries Commission in September, it was unanimously agreed to reactivate the Atlantic Menhaden Board and Advisory Committee to develop a new fishery management plan.

A revision of the Gulf menhaden FMP was begun following the October 1987 meeting of the Gulf States Marine Fisheries Commission. Approval of the final draft is expected to take place at the October 1988 meeting with printing and distribution by December 1988.

FORECAST OF MENHADEN PURSE-SEINE LANDINGS

Quantitative forecasts of Atlantic and gulf menhaden purse-seine landings have been issued for the past 16 years. Forecasts are based on a multiple regression equation relating landings and fishing effort over a series of years. Anticipated fishing effort for the upcoming year is derived from the number of vessels expected to be active and their historical performance in the fishery. In 1988 we expect that 21 vessels will participate in the Atlantic menhaden fishery, and we estimate that nominal fishing effort will be about 550 vessel-weeks. At this level of effort, we predict 1988 Atlantic menhaden purse-seine landings of 282,000 metric tons (80 percent confidence interval ranges from 205,000 to 364,000 metric tons). In 1988 we expect that 72 vessels will participate in the gulf menhaden fishery, and we estimate that nominal fishing effort will be about 610,000 vessel-ton-weeks. At this level of effort, we predict 1988 gulf menhaden purse-seine landings of 802,000 metric tons (80 percent confidence interval ranges from 677,000 to 927,000 metric tons).

To judge the accuracy of our forecast equation, actual fishing effort for the year is used to determine a post-season forecast (or hindcast) at the end of a fishing season. In 1987 actual fishing effort for the Atlantic menhaden fishery (530 vessel weeks) produced a hindcast of 293,000 t, or 12 percent less than the actual landings (327,000 t). In 1987 actual fishing effort for the gulf menhaden fishery (606,800 vessel-ton weeks) produced a hindcast of 841,400 t, or 6 percent less than actual landings (894,000 t).

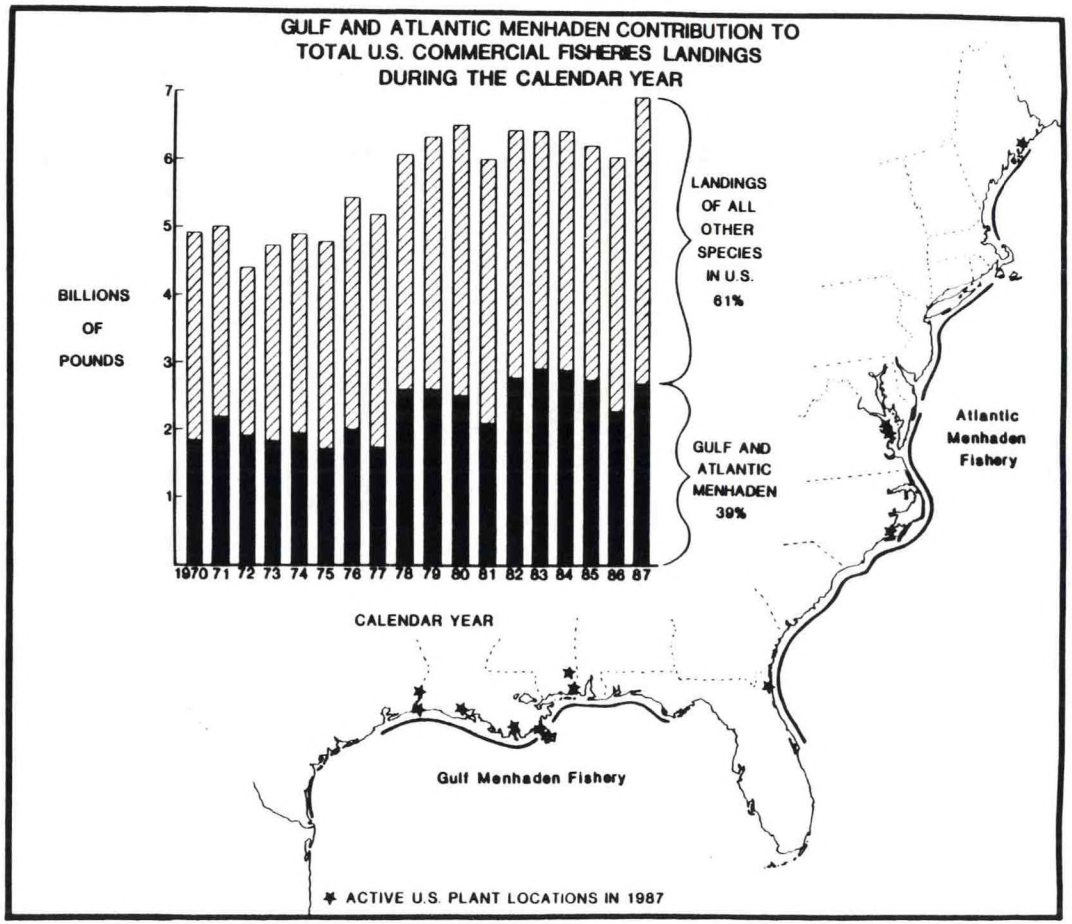

Figure 1. Contribution of combined gulf and Atlantic menhaden purse-seine landings during the calendar year to total United States commercial fisheries landings, 1970–87.

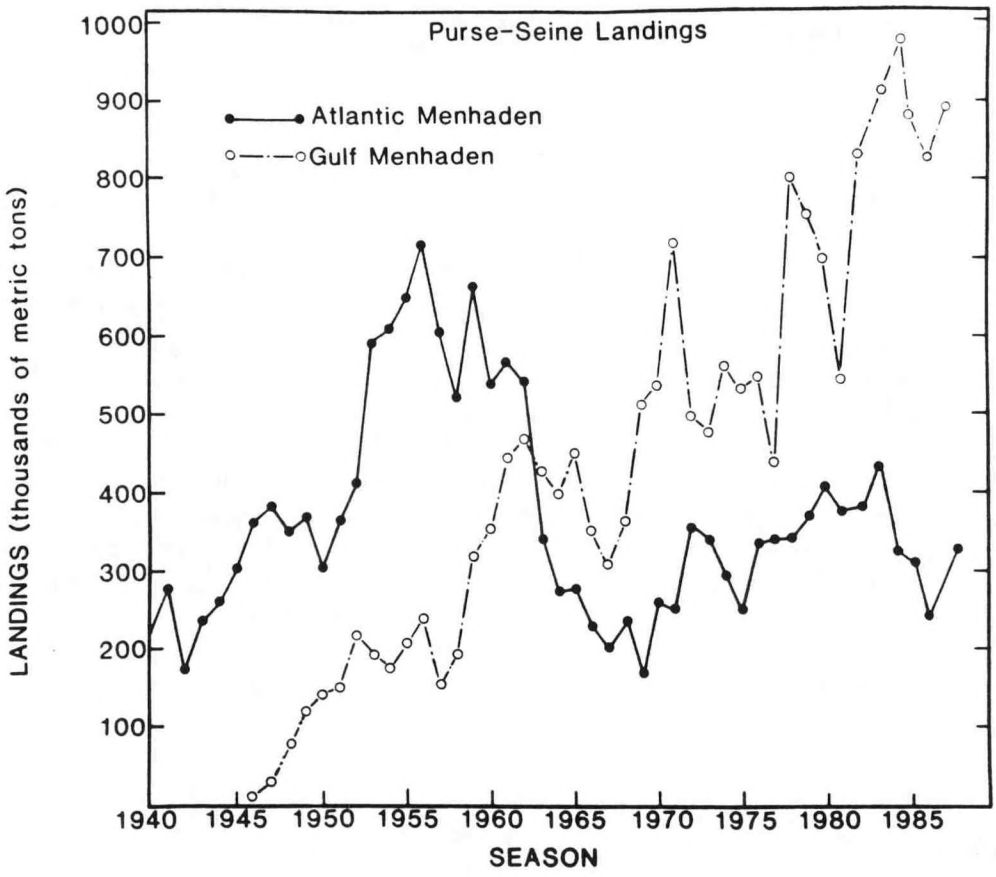

Figure 2. Historical landings for the Gulf and Atlantic menhaden purse-seine fisheries, 1940-87.

SAGITTAL OTOLITHS AS AN AGING TOOL FOR GULF MENHADEN

Aging gulf menhaden by reading scale annuli has been a problem in that many samples have illegible or oddly-spaced annual rings. Although somewhat subjective, the resultant protocol calls for ages to be assigned to fish with illegible scales based on length frequencies and time of capture among other criteria. In recent years abrupt truncation of coastwide length-frequency distributions suggest too much subjectivity may have entered the aging procedures for gulf menhaden.

In 1987 a study was designed to: 1) reassess criteria for aging gulf menhaden using scales; 2) determine the suitability of sagittal otoliths for aging gulf menhaden; and 3) attempt to verify the scale annuli method of aging gulf menhaden by comparison with the otolith method. From July through October 1987 gulf menhaden port agents acquired 20 specimens per month for otolith analysis during routine sampling of purse-seine catches. Specimens were processed according to program guidelines, that is, each fish in a 10-fish sample was measured, weighed, and scales were removed for aging. Additionally, the heads were removed, frozen and shipped to the Beaufort Laboratory where the sagittal otoliths were excised. A total of 370 gulf menhaden were processed for otolith analysis. Collection of specimens resumed in March 1988 and continued through June 1988; sagittae from these fish have not been processed.

Sagittae have a central opaque core and alternating concentric translucent and opaque zones distally. For preliminary analyses, opaque zones distal to the core are considered annuli. Paired comparisons between otolith age and scale age, and otolith age and assigned age were made. Paired age determinations are most similar between otolith and scale annuli methods. Assigned ages tend to

overestimate fish age by one year. Laboratory work-up of 1988 samples continues so as to properly validate sagittae as aging tools for gulf menhaden.

RISK ANALYSIS OF GULF MENHADEN

Risk analysis can be defined as the evaluation of the probability of end events interpreted in terms of sequences of earlier events. In fisheries science, stock assessment provides future projections on which management decisions can be based. Uncertainties in estimating input parameters for such projections are considerable. Models of two representative exploited fish populations were used to demonstrate the value of ecological models in assessing risks of toxic chemical exposures to socioeconomically important species. The models reproduce the age structure and statistical distributions of year-class abundance observed for the gulf menhaden population and the Chesapeake Bay striped bass population. These models were coupled with life-stage-specific concentration-response functions that account for 1) differences in sensitivity between species of interest and tested species, and for 2) differences in information content between life cycle, early life stage, and acute toxicity tests. The integrated models were used to quantify risks of chronic contaminant exposures in terms of changes in statistical distribution of future year-class abundance and yield. We investigated 1) the relative vulnerabilities of the two populations to contaminant-induced mortality, 2) the influence of test data quality on uncertainty concerning population response, and 3) the interaction between contaminant-induced mortality and fishing intensity. This collaborative research was with Oak Ridge National Laboratory on contract with the U.S. Environmental Protection Agency (Gulf Breeze Laboratory, Florida).

FISH OILS

The Charleston Laboratory has an integral role in the Biomedical Test Materials Program (BTM) which was formally initiated in 1986 between the National Marine Fisheries Service, the National Institutes of Health, and the Alcohol, Drug Abuse and Mental Health Administration. The Fish Oil Biological Test Materials Laboratory, built at the Charleston Laboratory in 1987, supplies test materials for approved research activities. Fish oil research appears in greater detail under the "Product Quality and Safety" section of this Annual Report.

MENHADEN SURIMI

The U.S. Congress appropriated funds to extend the menhaden surimi contract with Zapata Haynie Corporation through the 1988 fishing season. Despite some delays due to fish supply problems earlier this year, good progress is being made. It is expected that the contract will be extended for another year, at no additional cost to the U.S. Government, to allow for the development of commercial markets.

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MOLLUSCAN SHELLFISH

A significant portion of this year's activities at the Charleston Laboratory focused on reviewing research proposals and monitoring grants funded through the Saltonstall-Kennedy (S-K) and Marine Fisheries Initiative (MARFIN) programs. In addition to proposal reviews, staff members served as Program Officer, Contract Officer's Technical Representatives, and Technical Monitors for three new S-K grants on: depuration of viruses and bacteria from oysters and clams, shellfish growing water classification, and a National indicators study. Two S-K grants related to molluscan shellfish were completed during the year, one by the University of North Carolina on the depuration of hepatitis A virus and other microbes from oysters and the other by the Shellfish Institute of North America on market standards for drip loss in oysters. A MARFIN grant is being monitored on the depuration of oysters in the Gulf of Mexico.

Laboratory personnel served as advisors to the Interstate Shellfish Sanitation Conference (ISSC), as the NMFS spokesperson and voting delegate to the ISSC and as members of several ISSC committees. NMFS scientists also assisted FDA on a source evaluation board to evaluate funding proposals for Norwalk virus/gene probe research.

ENTERIC VIRUSES

Research on Norwalk virus progressed with the development of purification and concentration methods for Norwalk immunoglobulins from antisera, and the development of improved enzyme-linked immunosorbent assay (ELISA) procedures for the detection of Norwalk antigen in cell culture fluids. Several cell cultures were challenged with Norwalk virus, but virus replication did not occur. A critical path analysis for future research was prepared to provide a strategy for continued virus propagation efforts.

Research also centered on the evaluation of a NMFS virus extraction procedure for shellfish tissues. Work was completed on evaluating the procedure for reproducibility of poliovirus recovery from eastern and Pacific oysters, hard- and soft-shell clams, and blue mussels. Virus recovery rates were more consistent than those previously reported in the literature. Plans are underway to upgrade our virus analytical capabilities with respect to hepatitis A virus and to evaluate the NMFS extraction procedure for shellfish contaminated with hepatitis virus.

VIRUS UPTAKE AND DEPURATION

The successful development of a poliovirus extraction procedure for shellfish tissues, mentioned above, provided the analytical tools for monitoring poliovirus uptake in shellfish. Eastern oysters, hard- and soft-shell clams, and blue mussels were placed in tanks of filtered, natural seawater containing from 1 to 100 infectious virus particles (plaque forming units) per milliliter and the levels of virus accumulation were monitored over time. Poliovirus accumulated in shellfish tissues to appreciable levels within 72 hours. Similar parameters for virus uptake experiments will be presented for use in monitoring the depuration of laboratory-acquired viruses in shellfish.

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OCEANIC PELAGICS

Highlights in the Oceanic Pelagics Program during the past year include completion of the first ICCAT Swordfish Assessment, the implementation of an ICCAT Billfish Research Program, and the implementation of a five-Council U.S. Billfish Management Plan. Substantial progress was made in filling data needs through the implementation of a mandatory logbook system for swordfish longliners. As in past years, the major thrust of the program was the monitoring of landings of oceanic pelagics for catch, effort, and size-frequency. This includes sampling landings and trans-shipments in Puerto Rico, the maintenance of a large billfish tournament-sampling activity, hiring of seasonal employees to cover high billfish landing areas in the southeast, and support of a sampling program run by the NMFS Northeast Fisheries Center for telephone interviews and dock-side sampling from Virginia through New England.

ECOSYSTEM HIGHLIGHTS

A Miami Laboratory ecosystems team is developing a general long-term plan and specific work statements addressing bluefin tuna and swordfish. Bluefin tuna-directed activities are designed to improve our ability to estimate abundance indices from fisheries catch and effort data. Swordfish-directed activities are designed to help us understand the distribution and movements of swordfish in relation to oceanographic features and their variability. Some preliminary work on the Atlantic Ocean as an ecosystem for large oceanic pelagic fish was presented at the Poster Session of the AAAS meeting in Boston earlier this year.

BLUEFIN TUNA

The U.S. bluefin tuna fishery continues to be regulated by quotas and size limits. U.S. vessels fishing in the northwest Atlantic landed 1,351 mt of bluefin tuna in 1987, which was an increase of 209 mt from 1986. The catch by gear was: 367 mt by purse seine, 122 mt harpoon, 186 mt landline, 139 mt longline (of which 109 mt were from the Gulf of Mexico), and 538 mt by rod and reel (of which 401 mt was the estimated catch of the small bluefin fishery). The estimated catch of the small bluefin fishery was more than twice as large as the estimated catches for that fishery in 1985 and 1986. This increase is thought to have been associated with environmental conditions off Virginia to Delaware in the early summer and an increase in fishing effort. In addition to the landed catch an estimated 673 bluefin (128 mt) were released dead by U.S. longline vessels.

Examinations of virtual population analysis methods and programs were continued. Both CAL, a program developed at the Miami Laboratory, and more generalized integrated methodologies were investigated. In CAL, indices of stock abundance are used to select the most likely population trend from the multitude of trends which can be estimated from the history of catch at age. CAL has been used in recent years on several species including bluefin tuna, swordfish, and king and spanish mackerel. Examination of CAL concentrated on the effects of weighing the indices by the inverse of their mean square errors. Studies of integrated approaches focused on a system developed in Canada by Gravis. That system is highly flexible and methods similar to CAL were examined.

Indices of abundance for bluefin tuna were developed for possible use in tuning the virtual population analysis conducted at the annual meeting of ICCAT's Standing Committee on Research and Statistics (SCRS) in November. Two of the indices were based on catch rates from commercial fisheries: the U.S. rod and reel and handline fisheries in the New England area and the Japanese longline fishery in the U.S. EEZ. A third was derived from the bluefin larval survey in the Gulf of Mexico. For the first time, hydrographic information was used in developing standardized catch rates from the fishery data.

Research on bluefin tuna larvae included continuation of the Gulf of Mexico survey using the established design. Additional environmentally oriented sampling was conducted using transects in the Gulf of Mexico perpendicular to Loop Current fronts, and analyses of the relationships between larval distribution and environmental parameters were made. The larvae from the 1987 survey in the Gulf of Mexico were identified and used to derive an estimate of larval abundance which has been used in recent SCRS virtual population analyses as an index spawning stock size. Studies of the distribution and environment included detailed examination of 1) catches of larvae and the hydrography off the southeastern United States in 1985, and 2) some results from transects perpendicular to Loop Current fronts in the Gulf of Mexico in 1987.

The effects of hook size on tuna catch rates were examined to determine whether using smaller hooks might reduce bluefin tuna catch rates and thus reduce the numbers of bluefin released dead by longline fisheries. Two sets were made aboard the *F/V Heavy Set* using two sizes of hooks in use in the commercial longline fishery; catch rates from the two hooks were similar. The *R/V Chapman* was used to study the effect of longline hook size on yellowfin tuna catch rates in the Gulf of Mexico. The immediate purpose of the work was to determine whether a relatively small hook would catch and retain yellowfin as well as a larger hook commonly used in the yellowfin industry. The long-range purpose was to determine whether a hook exists that would catch yellowfin tuna but would catch few or no bluefin tuna. Initial attempts to catch yellowfin were unsuccessful, though eventually methods were improved and catches made. There were not enough sets on which yellowfin were caught for reasonable evaluation of the effect of hook size on catch rates.

Results of annual spring ichthyoplankton cruises in the Gulf of Mexico were analyzed for distribution and abundance of bluefin tuna larvae. Estimates were made of the size of the larval population from which estimates of spawning biomass were made. These results are used to tune VPA analyses of adult stock sizes. Results from the spring 1987 cruise show a continued low level of larval bluefin abundance in the Gulf of Mexico, which is the chief spawning are for this species.

TROPICAL TUNAS

Tropical tunas are caught by U.S. vessels in the northwest Atlantic off the U.S. east coast, in the Gulf of Mexico, and in the Caribbean Sea. The total U.S. catch of the three principal tropical tuna species in 1987 was 8,162 mt. This is an increase over last year's catch, which was 7,105 mt. In both cases, the figures include a sizable recreational rod-and-reel catch from the northeast U.S. coast that was not included in total landings reported to ICCAT in previous years. This recreational catch was 1,343 metric tons in 1986 and 1,927 mt in 1987. Commercial landings of tropical tunas in the northwest Atlantic were lower in both 1986 and 1987 than in 1985, probably because better fishing conditions caused the Pacific-based tuna fleet to spend more time in the Pacific Ocean and less in the Caribbean Sea these past two years. Only one commercial purse seine vessel was active in the Caribbean Sea in 1987. Two others fished along the U.S. east coast. Only 91.9 purse-seine-vessel-fishing days were spend in the northwest Atlantic in 1987.

The commercial catch of yellowfin tuna by U.S. longline vessels amounted to 4,406 mt, more than half the total reported catch of tropical tunas. Of the yellowfin longline catch, 3,752 came from the Gulf of Mexico.

Monitoring species composition and size-frequency distributions of the Gulf of Guinea catches landed at Puerto Rican tuna canneries is a reporting responsibility of the U.S. National Marine Fisheries Service. Sampling emphasis is on the Tema bait boats, but some seiners also are examined. Puerto-Rican cannery receipts suggest that 16,607 metric tons of skipjack tuna and 4,894 mt of mixed yellowfin and bigeye tuna from the Gulf of Guinea were offloaded in Puerto Rico in 1987. We sampled 27 percent of the skipjack offloadings and 14 percent of the mixed yellowfin-bigeye offloadings. The

mixture was 25 percent bigeye, by weight, and 22 percent bigeye, by number. Based on length measurements, we estimated that 80 percent of the yellowfin tonnage and 73 percent of the bigeye tonnage sampled weighed 3.4 kg or less. Almost all the skipjack were this size. A total of 465 skipjack, 1,143 yellowfin, and 267 bigeye were examined.

SWORDFISH

Swordfish monitoring covered voluntary size frequency sampling of U.S. pelagic longline vessels based on offloading receipts and the mandatory daily logbook of catch and effort information required of all permitted swordfish vessels. The voluntary size frequency sampling program was particularly successful, accounting for over 88,000 individual swordfish weights, a ten-fold increase over the 1978 sample, and the largest annual sample in the 10-year time series. An additional 52,000 weights of other species were recorded, primarily reflecting increased sampling of the yellowfin tuna (32,581 weights) and bigeye tuna (10,969 weights) fisheries. The swordfish size frequency information was summarized and provided to the Regional Management Councils with associated total landings data in mid-April 1988.

An analysis was conducted of U.S. catch-at-size data (1978-86), which had been developed for the 1987 ICCAT swordfish workshop, to examine trends in the U.S. fishery within the U.S. Exclusive Economic Zone (EEZ). A report on U.S. EEZ trends was prepared for the South Atlantic Fishery Management Council. Additional analyses developed standardized abundance indices for effort within the EEZ from 1981 to 1986. In preparation for the second ICCAT Swordfish Workshop in September 1988, the 1987 U.S. catch-at-size data were developed and submitted, and the analyses of catch and effort data were expanded to include 1987 data as well as information from all areas exploited by the U.S. fishery. The effects of gear and operational factors on the U.S. CPUE were incorporated into the analyses, improving the proportion of variability explained by the models. In a related analyses, U.S. catch and effort data were combined with similar data from the Spanish fishery to develop standardized abundance indices for the North Atlantic. These indices were used to tune Virtual Population Analysis at the 1988 ICCAT Workshop.

ANALYSIS OF MANDATORY SWORDFISH LOGBOOK DATA

The mandatory swordfish logbook program, initiated in October 1986, requires that all permitted vessels provide daily logbook records of fishing effort and the species composition of the catch in numbers of individuals kept and discarded. A detailed analysis of these data was undertaken for the one-year period October 1986 through September 1987. Descriptive tables were prepared detailing catch, effort, CPUE, and discards summarized by various time-area strata for swordfish, the principle tuna species (yellowfin, bigeye, and bluefin), and the billfishes (white marlin, blue marlin, and sailfish). Frequency histograms of the CPUE of swordfish and yellowfin were displayed by quarter and by area. The relative variability of CPUE data, at various sampling levels, was analyzed for swordfish and yellowfin.

Over the one-year period, over 14,000 sets were recorded, accounting for 6,000,000 hooks, from the Caribbean and the Gulf of Mexico northward to the Grand Banks. Nearly 102,000 swordfish were reported; and of the 57,000 yellowfin tuna reported,72 percent were from the Gulf of Mexico. There were 14,700 bigeye reported, and 64 percent of the reported 1,308 bluefin were discarded. Roughly 5,700 marlins and 1,200 sailfish were caught, with approximately 65 percent and 95 percent, respectively, being discarded.

MARLIN AND SAILFISH

Age and Growth

Age and growth research on blue marlin continued. Counts of presumed daily growth increments were made using otoliths (sagittae) from 77 juvenile and young adult blue marlin ranging in size from 4.3 to 212 cm (lower jaw fork length) and 18 larval specimens ranging from 0.5 to 1.0 cm (notochord length). Age estimates ranged from 9 to 495 days. Indirect validation of the presumed daily increments was achieved by comparing the microstructure characteristics of zonation to those found in other species where age validation was achieved and by comparing the distribution of the back-calculated spawning dates to the known spawning season. The age data were fitted to the Gompertz, Van Bertalanffy, and Logistics growth models and the rates of growth were compared to other fast-growing species. Results of this research were presented at the International Billfish Symposium (Kailua-Kona, Hawaii) and will be published in the proceedings.

Save it for Science

This special project encourages commercial and recreational fishermen to donate unusually large or small billfish or tag recaptured billfish that have been at-large for extended periods of time for age and growth research. At this time, we have collected otoliths and other skeletal structures from two sailfish weighing 8 and 98.5 pounds, respectively, a white marlin weighing 6 pounds, and a male blue marlin weighing 360 pounds. The blue marlin is one of our largest male samples collected since we started the research in 1980. Likewise, the white marlin is possibly the smallest specimen ever collected by the Miami Laboratory or any other agency.

INTERNATIONAL AND DOMESTIC DATA BASE FOR BILLFISH

Since 1971, the Miami Laboratory has been responsible for the acquisition, compilation, and inventory of an international and U.S. domestic data base on catch and effort and size frequency statistics for Atlantic billfishes (white marlin, blue marlin, sailfish and spearfish). The primary source of the international data is provided by the Secretariat of the International Commission for the Conservation of Atlantic Tunas (ICCAT). Data from 21 ICCAT reporting countries have been compiled on the mainframe computer, which contains billfish catch and effort and size composition information. Personnel with the ICCAT Enhanced Research for Billfish Program recently surveyed the Caribbean island countries and determined that a substantial billfish harvest goes unreported by these non-ICCAT participating countries. Efforts to retrieve historical data from some of these countries have been successful and steps to insure future monitoring are being initiated. The U.S. domestic database is compiled from a variety of sources; recreational tournament and dock sampling surveys, nationally reported commercial landings, and pelagic longline logbook submissions.

ICCAT ENHANCED RESEARCH PROGRAM FOR BILLFISH

This was the first complete year of ICCAT field activities for the Enhanced Research Program for billfish. Specific research plans were developed and implemented for the Caribbean Sea and west coast of Africa with the Miami Laboratory playing an important role.

Five trips were made in the Caribbean Sea with ICCAT observers aboard Venezuelan industrial longline vessels between October 1987 and July 1988. Shore-based sampling was conducted in the port of Cumana, Venezuela, and in the transhipment port of St. Maarten, Netherlands Antilles. Shore-based samplers were also hired in the fall from Grenada, Barbados, Jamaica, and the Dominican Republic. A survey of ICCAT reporting nations as to methods of dressing and holding billfish was completed. The results will form the basis for developing various conversion factors. Interim sampling instructions were developed and distributed to all ICCAT Billfish Program participants and a draft of the brochure for ICCAT billfish tagging was completed.

Figure 1. Smallest juvenile blue marlin donated to the Miami Laboratory for age and growth research. (Top): This very small specimen (4.3 cm LJFL and 0.6 g) was removed from the stomach of a dolphin caught off the Florida Keys. (Bottom): This specimen (23.0 cm LJFL and 60 g) jumped into a boat, whose occupants were night fishing for snapper off Jamaica. Sagittae removed from these samples were estimated to be 21 and 41 days old, respectively, based on counts of presumed daily growth increments.

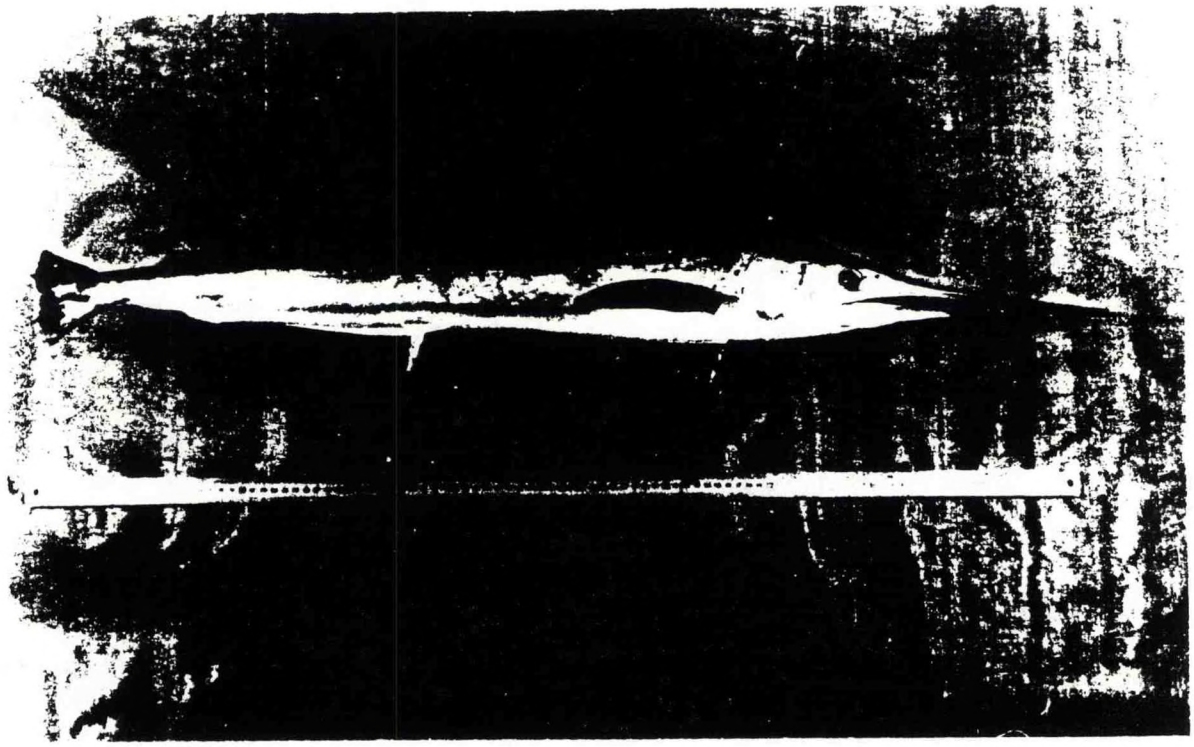

Figure 2. Smallest white marlin specimen (91.4 cm LJFL and 2.7 kg) caught by commercial gear in the Gulf of Mexico and donated for age and growth research.

The first steps for developing a species identification kit were completed--researchers at Florida Atlantic University successfully isolated the protein biomarkers for blue marlin, white marlin, and sailfish. Additional samples are being collected to insure adequate sample sizes. A kit developed for initial testing will be available some time in 1989.

Data on historical billfish landings were obtained from five countries (Barbados, Jamaica, Bermuda, Curacao, and Grenada) that do not traditionally report these statistics to ICCAT. Additional information will be forthcoming from the Dominican Republic.

Program activities in the eastern Atlantic are directed by the ICCAT eastern Atlantic coordinator based in Dakar, Senegal. Efforts have concentrated on the extensive sailfish fishery off Dakar and on sailfish and blue marlin fisheries in the Ivory Coast. The ICCAT billfish tagging program is most active in this area. Work is expected to expand to other areas within the eastern Atlantic region during 1989.

BILLFISH TOURNAMENT SAMPLING

Routine billfish tournament sampling was conducted throughout the southeastern region, Bahamas, and Caribbean, and the data entered into the Miami Laboratory computer files for analysis. The cooperative sampling program included NMFS scientists and port agents, as well as various state and university biologists, and private citizens. In addition, many of the northeastern U.S. tournaments provided catch and effort data and reestablished our northeast data base. The recreational community has once again given us their full support, thereby making our surveys a success.

SHARKS

Sharks, once considered commercially undesirable in the southeastern United States, now constitute a marketable commodity throughout most of the region. Landings from North Carolina through

Texas increased from 0.4 million pounds in 1978 to 3.8 million pounds in 1987. Ex-vessel value over the same period increased from $60 thousand to $1.78 million. Three developments are responsible for: 1) the emergence of a reliable shark market for fins and flesh; 2) consistent by-catches of sharks from longline, gill net, and trawl fisheries; and 3) the evolution of a directed fishery that specifically targets sharks.

In the southeast, longlines, gill nets, and trawls are used commercially to harvest sharks. In recent years a small directed longline fishery for sharks has emerged, with most vessels using converted shrimp boats or snapper-grouper bottom longline vessels. Drift gill nets and anchored gill nets are also being used to fish sharks.

Major activities on sharks during the past year have centered on the expansion and improvement of data bases on catch and effort in the southeast, and on summarizing biological information on mako sharks in the Atlantic.

FOREIGN LONGLINE OBSERVED PROJECT

The NMFS Northeast Regional Office has coordinated a program to place observers on foreign vessels in the U.S. EEZ for several years. The information collected by observers on Japanese longline vessels fishing off the east coast is processed and maintained by the Miami Laboratory. During the first nine months of 1988, Japanese longline effort in the U.S. EEZ occurred in January and February, while in 1987 effort in the first three quarters occurred in January, February, August, and September. The Japanese fleet fished for bluefin tuna from November 1987 into February 1988 before leaving the area.

DOMESTIC OBSERVER PROGRAM

The Domestic Longline Observer Project operated during June-December 1987 in cooperation with voluntary longline vessels in the Gulf of Mexico, primarily targeting yellowfin tuna. The data collected during 12 trips (80 observed sets) included gear information, environmental conditions, species composition, and biological data. In 1988, observer data were collected in the Gulf of Mexico through contract with the Louisiana State University.

COOPERATIVE GAME FISH TAGGING PROGRAM

Program cooperators and scientists tagged and released 8,115 fish of 33 species in the Atlantic Ocean, Gulf of Mexico, and the Caribbean Sea. A total of 4,627 billfish were tagged and released: 1,986 sailfish, 1,341 blue marlin, 1,021 white marlin, and 279 swordfish. Also, 355 tunas were tagged and released: 190 yellowfin, 65 bluefin, and 100 miscellaneous tuna. Recreational fishermen tagged and released 587 tarpon. There were 1,169 king mackerel tagged and released: 1,026 by scientists and 143 by recreational fishermen. And, 168 red drum were tagged and released by recreational fishermen. In addition, 1,209 fish were tagged and released of 20 miscellaneous species.

Program Highlights

The first occurrence of a sailfish recapture off Cancun, Mexico, that had been tagged and released off Cozumel, Mexico, was reported. We expect more recaptures of fish released in Cozumel to be recaptured in Cancun and vice versa. However, until this recapture this has not been the case. This sailfish had been at large for three years and one month, the longest time at large for a sailfish in 1987.

The longest distance traveled by a white marlin was from a fish tagged and released off Walkers Cay, Bahamas, and recaptured 88 days later northeast of Oregon Inlet, North Carolina. The longest time at large was 6 years; the white had been tagged and released off Virginia Beach, Virginia, and recaptured northeast of Oregon Inlet.

Two blue marlins were recaptured: one was from a release off St. Thomas, U.S. Virgin Islands, and was recaptured 186 days later off the coast of Venezuela. The other recapture was from a release off the coast of Venezuela, and recaptured 636 days later off the northern coast of Puerto Rico.

Four swordfish were recaptured. All were released in the northeastern Gulf of Mexico, and recaptured 642 days later off the northern Bahamas.

The longest distance traveled by a bluefin was from a fish tagged and released southeast of Ocean City, Maryland, and recaptured 10.2 years later in Cape Cod, Massachusetts. This fish was also the longest time at large for a bluefin tuna.

The first two transatlantic migrations for yellowfin tuna occurred this year. A yellowfin tagged and released on September, 12, 1985, at latitude 40°01'N, 68°50'W, or about 270 miles east of Point Pleasant, New Jersey, was recaptured 534 days later at latitude 27°25'N, 15°40'W (Canary Islands). A yellowfin tagged and released at latitude 28°15'N (Grand Isle, Louisiana) was recaptured 814 days later at latitude 03°28'N, 20°24'W, about 750 miles southeast of Monrovia, Liberia, West Africa.

Eighty-five captains and 23 anglers tagged and released 10 or more blue marlin, white marlin, sailfish, swordfish, and various tunas.

LARVAL FISH ECOLOGY

During spring (1987 and 1988) ichthyoplankton cruises in the Gulf of Mexico aboard the *Oregon II*, experiments were conducted along the Loop Current boundary to determine the relationship of this hydrographic feature to the distribution of larvae. Preliminary analyses reveal that bluefin tuna larvae are concentrated on the cool size of the boundary in areas of high current velocity. The waters in this area have high abundances of other larval fishes and high densities of plankton. Experiments will be continued to determine what factors affect recruitment success. Results from a 1985 spring cruise along the southeast coast of the United States located a small spawning area for bluefin tuna. The bluefin larvae in this area are found in the warm Gulf Stream water, and some may have originated in the Gulf of Mexico and were transported to the east coast. All the larvae from this cruise were identified by a post doctoral student from Korea and will be the subject of a future publication. The aim of all these studies is to study the relationships of the larvae with hydrographic data to define habitat. From this research, factors affecting distribution can be determined to aid in predicting recruitment success.

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PROTECTED SPECIES

The Center's protected species research, managed by the Miami Laboratory, is designed to provide scientific information required for management of the marine turtles and mammals in order to achieve optimum population levels necessary for delisting, while maintaining associated commercial and recreational fisheries. Six species of sea turtles, protected under endangered or threatened status by the U.S. Endangered Species Act of 1973, are under purview of the Southeast Region. Since the inception of the Marine Mammal Protection Act of 1972, the NMFS has also had management responsibility of all cetaceans and pinnipeds (except walrus) within the U.S. waters. In the southeastern United States, this includes a variety of species of dolphins and whales. Research activities include population estimates, data base for definition of stocks and species, and sea turtle head-starting.

SEA TURTLES

Regulations to reduce the mortality of sea turtles were finalized in 1987. These regulations affect the shrimping industry within southeastern U.S. waters. Vessels over 25 ft in length are required to include one of six certified Turtle Excluder Devices (TEDs) in all trawls. Vessels under 25 ft in length are required to tow no more than 90 minutes at a time. The tow time restriction is also maintained in inshore waters. The tow time restriction is lifted if TEDs are included. The impact of these regulations on turtle stocks and the fishery must be evaluated as stipulated in the regulations and the NOAA Fiscal Year 1988 Appropriation Bill.

Head Starting

A total of 13,572 head started Kemp's ridleys have been released into the wild since February 1979. As of June 1988, 537 (3.9 percent) had been recovered. Primary recover locations include Texas, Louisiana, and Florida (Table 1). Primary recovery methods were strandings and incidental capture in shrimp trawls, and most recoveries occurred during April, May, and June.

Table 1. Recoveries of head started tagged Kemp's ridley sea turtles by geographic location.

Location	Frequency	Percent
Texas	366	65.7
Louisiana	70	12.6
Florida	50	9.0
North Carolina	19	3.4
South Carolina	12	2.1
Georgia	10	1.8
Mexico	7	1.3
Mississippi	6	1.1
Alabama	4	0.7
France	2	0.4
Maryland	2	0.4
New Jersey	2	0.4
New York	2	0.4
Virginia	2	0.4
Morocco	1	0.2
Not reported	2	0.4
TOTALS	557	100.0

Headstarting of the 1988 year-class of Kemp's ridley sea turtles from both Rancho Nuevo, Mexico and Grand Cayman Island, British West Indies and loggerhead sea turtles from Florida was completed at the Galveston Laboratory. The turtles were tagged with inconel flipper tags, coded magnetic tags, and living tags. In May, 1,414 multiple-tagged turtles were released into the Gulf of Mexico, 12-18 miles offshore of Padre Island, Texas (Table 2). Survival rate during head starting was: 91 percent for "Mexican" ridleys, 83 percent for "Cayman" ridleys, 100 percent for loggerhead yearlings, and 92 percent for loggerhead hatchlings.

Table 2. Head started sea turtles released in the Gulf of Mexico offshore of Padre Island, Texas on 17 May 1988.

Classification	Number of Turtles
1987 year-class head started Kemp's ridleys	1,100
1986 year-class extended head started ridleys	50
1987 year-class head started loggerheads	113
2 year-old (estimated) loggerheads	20
Rehabilitated wild Kemp's ridley	1
1987 year-class head started Cayman ridleys	130
TOTAL	1,414

In 1987, 100 of the largest turtles of the 1986 year-class were held back for "super head starting" (rearing for more than one year in captivity in hopes of determining optimum duration of the head starting period before release). Fifty of these, averaging 18 lbs, were released along with the 1987 year-class on May 17, 1988. All super head started turtles, in addition to receiving the standard tags, also received a PIT (passive integrated transponder) tag. The PIT tag is injected internally into the left front flipper. This technique is being tested as a permanent mark for head started sea turtles.

In July, 925 live Kemp's ridley hatchlings were received from the National Park Service's Padre Island National Seashore (a 91 percent hatch rate). The Mexican government allowed 1,000 Kemp's ridley sea turtle eggs to be relocated to the United States from the nesting beach at Rancho Nuevo during 1988. As of August 17, 914 of the 1988 year-class hatchlings survived (99 percent). All turtles in good health will be multiple-tagged and released in April or May 1989.

There are 49 head started Kemp's ridley sea turtles being held in 11 marine aquaria. Two additional facilities hold four deformed turtles deemed unable to survive in the wild. Clearwater Marine Science Center, Clearwater, Florida and Theater of the Sea, Islamorada, Florida reported females laying eggs in the holding pools in late May.

Cayman Turtle Farms Ltd. holds 45 head started Kemp's ridley sea turtles. During the 1988 nesting season, 11 clutches of eggs were laid on the farm's artificial beach. From these clutches, 1,200 eggs were collected and incubated, resulting in 25 hatchlings (2 percent hatch rate). These hatchlings are now being head started in Galveston.

Collaborative efforts with molecular biologists have resulted in the identification of a sex-specific DNA in male Kemp's ridley sea turtles. Eventually, this finding may form the basis for a non-sacrificial, non-surgical technique that will permit sexing of immature head started animals. Sea turtle blood was also examined for the presence or absence of a gene homologous to the human testes determining gene. Similar DNA was found in both male and female turtles with no observable differences between the sexes.

A new sea turtle head start research facility was completed in February. Initial funding for the facility was provided by HEART (Help Endangered Animals - Ridley Turtles) with funds for completion from MARFIN. The facility houses eight fiberglass raceways for maintaining head started sea turtles and an area for exercise/wastewater recycling systems research.

Studies on waste characterization and treatment systems (Dr. Ron Malone, LSU, Dept. of Civil Engineering) and exercise requirements and physical stamina (Erich Stabenau, Texas A&M University-Galveston) were completed. The data and information from these studies were incorporated into a one-unit recycle/exercise system design. The system will be tested with the 1988 head started year-class.

Sea Turtle Stranding and Salvage Network

The Sea Turtle Stranding and Salvage Network (STSSN) was formally established in 1980 to collect information on and document strandings of marine turtles along the U.S. Gulf of Mexico and Atlantic coasts. The network encompasses the coastal areas of the 18-state region from Maine through Texas, and includes portions of the U.S. Caribbean. Data are compiled through the efforts of the network participants in their respective areas and contribute those data to the centralized STSSN data base. A total of 2,393 stranded turtles were reported during 1987. Of these, 20 turtles (1 percent) were known head started turtles. Sixteen states reported strandings during the 12-month period: Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, New Jersey, New York, Connecticut, Rhode Island, and Massachusetts. Reports were also received from Puerto Rico and the U.S. Virgin Islands. Loggerhead turtles were the most frequently reported species, comprising about 73 percent of the total reported. The Kemp's ridley represented about 9 percent of the total reported strandings, green turtles almost 7 percent, leather-back, turtles almost 5 percent, and hawksbill turtles, 1 percent.

During the first six months of 1988 a total of 735 reports were received. Of these, 11 (1 percent) were to be known head started turtles. Thirteen states reported strandings: Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, North Carolina, Virginia, New Jersey, New York, Massachusetts, and the U.S. Virgin Islands. Loggerhead turtles comprised almost 68 percent of the total reported strandings, green turtles comprised almost 16 percent, Kemp's ridleys about 7 percent, and leatherbacks almost 3 percent.

Beginning in May 1987, 11 shrimping statistical zones have been sampled systematically to allow for the estimation of total stranding rates, which will be used to index total mortality. Within these sampling zones, surveys are conducted by aerial or beach survey weekly. Weekly aerial surveys were initiated in two zones in May 1987, and the remaining zones have been phased into systematic sampling since May 1987. These data are received through the STSSN and are entered into this data base.

Sea Turtle Research in North Carolina Inshore Waters

The Beaufort Laboratory initiated a one-year pilot study jointly funded by the U.S. Fish and Wildlife Service and the NMFS Office of Protected Resources to determine the best combination of methods to study the species composition and distribution of sea turtles in North Carolina's Pamlico-Albemarle Estuarine Complex. Subsequent studies, designed from the results of the pilot study, will focus on the relative abundances, size classes, area utilization and residence time of the turtles. The project is anticipated to be three to five years in duration.

In the pilot study the public is reporting both turtle sightings and strandings. Posters are placed in strategic locations such as marinas, piers, bait and tackle shops, and airports promoting the conservation of sea turtles and requesting the public report any sightings of the animals. Crew aboard the many state and private ferry boats crossing the sounds daily are recording sightings; logs have also been placed with Park Service personnel, charter, dive, pilot, research, tour, and headboat captains.

Aerial surveys are also being evaluated for their feasibility in the inshore waters. Several commercial fishermen are recording their turtle catches and measuring, tagging, and releasing the turtles. Tagging results thus far indicate some turtles return repeatedly to the same location, despite being transported and released several miles from their capture site.

Turtle Task Force

NMFS and the U.S. Army Corps of Engineers have initiated a 1988 Pre-dredge Trawl Survey. Channel dredging within the Corpus Christi and Aransas Bays is necessary to maintain depths of the Intracoastal Waterway. These bay systems are in close proximity of the head-started Kemp's ridleys release sites. For this reason, we trawl the channel site before and during dredging operations. In two previous pre-dredge studies (1986 and 1987), no sea turtles were sighted or caught.

Debris and Entanglement Studies

Entanglement and injestion of debris in the ocean appears to be a significant cause of mortality for protected species. Monthly sampling to characterize amounts and types of marine debris accumulating on the upper Texas and on the southwest Louisiana beaches continues. Seventy-two survey plots and 144 replicate plots have been sampled. Plastics of various types dominated the samples in weight and number of items collected.

Impact of the TED and Tow Time Restrictions on Shrimp Capture

NMFS, in cooperation with the shrimp industry, has collected preliminary data that document catch rates of shrimp in TED-equipped trawls and in trawls without TEDs for selected shrimp fishing areas of the Southeast Region. The overall objective of the program is to determine the effects of utilization of certified TEDs on commercial shrimp trawlers off the southeastern U.S. coast and in the Gulf of Mexico.

Observers were placed on shrimp vessels operating off Texas, Louisiana, Florida, Georgia, and South Carolina. As of August 12, the total number of observer days was 40 for Georgia/South Carolina, 20 for south Florida, and 87 for Texas/Louisiana. The efficiency of trawls equipped with Georgia TEDs is being compared to that of standard trawls. Seven turtles have been captured in the Standard or Try nets, while no turtles have been caught in the TED-equipped nets.

TED Technology Transfer

The Pascagoula Laboratory continued efforts to develop the agency's expertise in TED technology and to develop and distribute TED information to the industry. TED testing and certification was focused on the capture of small juvenile turtles. Since October 1987, when the regulations first went into effect, over 50 separate TED activities have been completed including: TED testing; technology transfer workshops that include trouble-shooting for area specific problems; construction, modification, and installation of various TEDs; and direct discussions with fishermen regarding specific TED problems with the intent of offering solutions to these problems. The purpose of these activities has been to assist the industry in the implementation of certified TEDs to minimize or eliminate shrimp loss.

Biology and Ecology

A long-term fishery independent study of turtles is being conducted in the northeastern Gulf of Mexico at Cedar Key, Florida, which historically supported a green turtle fishery. In this study, however, the Kemp's ridley is the target species and is the most frequently captured species in the Cedar Key area. A total of 77 Kemp's ridley turtles, seven green turtles, and two loggerhead turtles have been tagged thus far. Recently, four turtles, which had been previously tagged, were recaptured after being at large for three months (two turtles), nine and ten months, respectively. This

suggests that at least some turtles may remain in or near this habitat, which is likely used as a developmental habitat for juvenile Kemp's ridleys. Two turtles had grown about 2 cm in carapace length and gained 8 and 13 kg. Two turtles measured only 20 cm carapace length and weighed about 6.5 kg. This represents the minimum size of turtles collected in coastal waters and bays and may be the size of recruits leaving the pelagic habitat and entering the shallow inshore and near shore waters.

Turtles captured incidentally in fishery activities are being tagged in the northeastern Gulf and along the Atlantic seaboard. The total number of turtles tagged to date from coastal areas in the Atlantic and the Gulf of Mexico is as follows: 187 Kemp's ridleys (67 percent in the Gulf), 26 green turtles (73 percent in the Atlantic), and 430 loggerhead turtles (98 percent in the Atlantic).

Monitoring Oil Rigs

Observers employed by NMFS monitored 37 oil rig removal operations during 1988. A total of 1,038 hours of daylight observations and 381 hours of nighttime observations were made from boats and barges. Fifty-one hours of helicopter surveys were conducted. Observers reported four sightings of three turtles and 367 dolphins. The turtles were reported to be two loggerhead and one green turtle from January to July 1988. In addition, over 23,000 fish were reported killed during explosive rig removal. While August data are considered preliminary at this time, there were eight turtle sightings reported from two removals for this one month.

On August 3, a loggerhead turtle was captured during a routine diving survey less than one hour before explosives were to be detonated at a platform about eight miles offshore of Port Aransas, Texas. The turtle was released at a nearby platform, and during the next ten days, a special monitoring effort was initiated to determine if this turtle would remain associated with the platform. Frequent observations resulted in three sightings of a loggerhead around this platform and 23 sightings at a platform 0.5 miles away. No gross physical identifying features were observed to indicate more than one turtle was involved. Consequently, this appears to be the first documentation during this study of a "resident" sea turtle associated with oil platforms in the Gulf of Mexico. However, the range and duration of residency has yet to be established. Workers at offshore platforms have also reported frequent sightings of turtles over long periods of time.

Second Western Atlantic Turtle Symposium

The Second Western Atlantic Turtle Symposium (WATS II) was held in Mayaguez, Puerto Rico in October 1987. The Proceedings of this international meeting are being prepared by the Panama City Laboratory and brings together the vast expertise in marine turtles presented as papers at this important meeting. Publication is expected in September 1988.

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MARINE MAMMALS

The bottlenose dolphin die-off of 1987-88 has apparently resulted in a reduction of the affected stock of greater than 50 percent. Under current marine mammal regulations, this stock is now depleted, and actions are underway to have this stock declared so. The marine mammal regulations were recently amended by Congress, and an included provision requires continued study and monitoring of the stock affected by the die-off.

Bottlenose Dolphin

In continued efforts to investigate the bottlenose dolphin die-off, which began in June of 1987, the SEFC formed a field team that operated in concert with Marineland of Florida staff to collect, necropsy, and sample stranded dolphins along the northeastern coast of Florida. Samples collected included skeletal materials for stock identification, preserved tissues for histopathology, and frozen specimens for toxicology. Nearly 100 stranded animals were examined.

In addition to probing for the cause, the impact and long-term effects of the die-off were assessed. SEFC biologists participated in a cooperative aerial survey program with the Smithsonian Institution to determine the distribution of both live and stranded dolphins from Long Island, New York to Savannah, Georgia. The progression of strandings from New Jersey and Virginia in the summer, to Florida in the winter, supports the hypothesis of a coastal migratory stock of dolphins. After a full year, more than 750 dolphins were known to have stranded from central Florida to New Jersey, roughly an order of magnitude over previous years. This number of strandings may represent as much as a 50 percent reduction in the coastal stock of bottlenose dolphins. Using sophisticated computer simulation techniques, it is estimated that recovery of the population will likely take decades.

Figure 1. NMFS biologist examines a stranded bottlenose dolphin in northern Florida.

An 11-month contract was awarded to Dr. Sandra Hersh to conduct age determination and morphometric analysis of the stranded dolphins. Available evidence indicates that a coastal stock and an offshore stock of bottlenose dolphins occur along the U.S. Atlantic coast. The purpose of this work is to determine the proportions of which stocks were involved and the age structure of the affected animals. The results of this study indicate that the offshore stock was not involved in the die-off.

The analysis of regional sampling surveys (1983-86) for bottlenose dolphins in the U.S. Gulf of Mexico was placed on hold during the investigation of the dolphin die-off. As the die-off has subsided, work on the Gulf of Mexico data has resumed. The initial analysis is expected to be complete by the end of 1988.

Field work is continuing on the low-level monitoring studies of local populations of bottlenose dolphins which are being done under contract by Mote Marine Laboratories (MML) and Dolphin Biology Research Associates, Inc. (DBRA). MML is conducting seasonal aerial surveys of the dolphins that occur in the Indian and Banana Rivers system in northeastern Florida. DBRA is using boat-based surveys to study the dolphin populations of the Tampa and Sarasota Bays in central western Florida. Both studies were initiated in late 1987 and are expected to last at least three years. The studies are intended to be able to detect a halving or doubling of the involved dolphin population(s). During the dolphin die-off, MML was contracted to increase their survey effort, in anticipation that the die-off might enter the Indian and Banana River systems. Fortunately, no change was observed in the mortality rate in the system. Both contractors have submitted draft reports covering the first period of work.

Large Whale Research

NMFS Southeast and Northeast Center scientists are involved in monitoring the population of right whales, which occurs along the U.S. Atlantic coast. Most of the work is being done through cooperative agreements with universities and other private organizations. The SEFC is responsible for reviewing proposed studies, evaluating completed projects, and for developing a computer-based image storage and analysis system. The purpose of the image analysis system is to store and match photographs of individually identifiable whales. The development of the system is expected to be complete by October 1988.

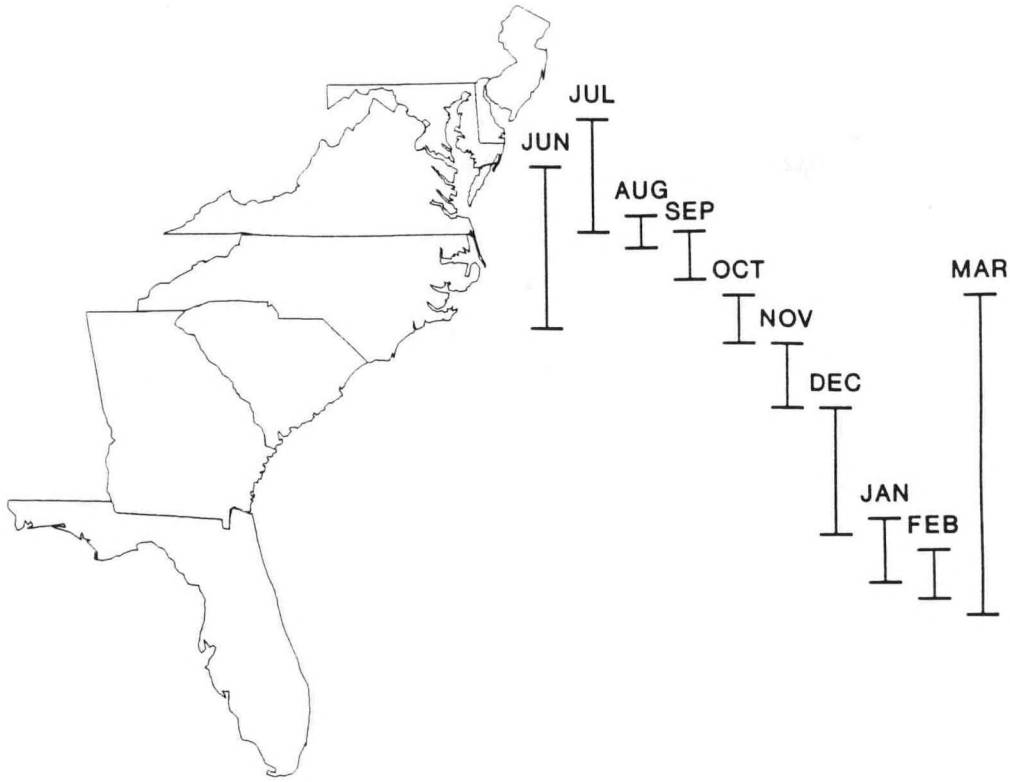

Figure 2. Latitudinal range of dolphin strandings from June 1987 through March 1988.

In May 1988, the International Whaling Commission (IWC) sponsored a symposium and workshop on the "The Use of Non-lethal Techniques, especially Photoidentification Techniques, to Estimate Cetacean Population Parameters." SEFC scientists presented a poster on a comparison of independent photoidentification studies of the same population of cetaceans, and also participated in the four-day workshop. A paper was presented on the above computer-based image analysis system. The IWC will be publishing the proceedings of the conference and workshop in the Special Issue series of the IWC Reports. The report is intended to serve as a major reference for researchers intending to conduct photoidentification studies of cetaceans.

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RED DRUM

In 1986, the Southeast Fisheries Center joined with state agencies and universities in developing one of the most comprehensive cooperative research programs ever devised for a fishery in the Gulf of Mexico. Initiated through the Red Drum Work Group of the Southeast Area Monitoring and Assessment Program (SEAMAP), the Cooperative Red Drum Research Program directly involves red drum scientists from every coastal state in the Gulf of Mexico. The research addresses virtually every aspect of the red drum resource, ranging from studies of eggs and larvae to surveys of the adult offshore stock. All of the research is designed to answer specific applied management questions. In general, state and university research efforts have focused on inshore components of the resource while SEFC research targeted the adult or offshore component. A significant portion of the research has been funded by MARFIN, especially that undertaken by states and universities. Formal coordination for all red drum projects is conducted through the Gulf States Marine Fisheries Commission.

SEFC research has emphasized determining distribution and abundance of adult red drum, monitoring age structure, maintaining a centralized tagging center, monitoring incidental captures of red drum in Federal waters, and providing annual assessments on the status of the red drum resource in the Gulf of Mexico. The latter research activity integrates results from all red drum research studies with catch and effort data provided by the Cooperative Fishery Statistics Program and the National Recreational Fisheries Survey to determine management needs and options, and to evaluate effects of existing management measures. Only research performed directly or indirectly by the SEFC is addressed in this report.

AERIAL SURVEYS

Through a pilot study conducted in 1986, aerial surveys were shown to be valuable for studying the abundance and distribution of red drum schools. Techniques established during this study were refined and applied in 1987 to two seasonal periods, spring and fall, from the border with Mexico to the Florida Keys. The large gulf area was divided into a series of smaller coastal study areas which were flown 6 to 12 times during each seasonal survey period. A small single engine aircraft, flying systematically spaced transects, was used for the surveys. The transects were started from a random point, extended 15 to 20 nm into the Gulf, and normally traversed inland bays, sounds, and lakes. To aid data acquisition and recording, a portable computer was interfaced with a Loran-C navigation system so that data describing the transects, weather and environment, and sightings of red drum schools and 40 other types of marine animals could be easily recorded.

In the spring and fall of 1987, red drum schools were found in all study areas. However, the relative abundance of near-surface schools differed greatly among study areas per season and between seasons per study area. Per study area, near-surface red drum schools were usually more abundant and larger during the fall months. In the fall, red drum schools were most abundant in offshore waters off Mississippi (0.02 schools/square nm) and Louisiana (0.05 schools/square nm). Schools sighted in inland bodies of water during the fall surveys were also most abundant in Louisiana (0.05 schools/square nm) and Mississippi (0.06 schools/square nm).

The spring near-surface red drum biomass was estimated to be about 1.3 million pounds in the inland waters, and 8.3 million pounds offshore. The fall surveys showed many more near-surface schools with about 13.4 million pounds in the inshore waters and 15.5 million pounds offshore. About 82 percent of the total spring and 78 percent of the total fall red drum biomass were estimated to be in the Louisiana and Mississippi study areas.

MARK-RECAPTURE STUDY

A mark-recapture study was conducted between the fall 1986 and fall 1987 to estimate the number and biomass of adult red drum in the northcentral Gulf of Mexico. Aerial surveys conducted concurrently with the mark-recapture study were used to extrapolate estimates developed for northcentral waters to the entire northern Gulf. The field portion of the study was conducted from a chartered purse-seiner aided by a commercial spotter pilot experienced in the red drum fishery. Approximately 15,000 red drum were marked with single or double tags during the marking portion of the study, and about 25,000 fish were examined during the recapture portion. Samples of fish were taken from each purse-seine set for sex, size, age and growth, sexual maturity, fecundity, and stock identification studies being conducted by other investigators under the Cooperative Red Drum Research Program.

A Petersen-type model was used to estimate red drum biomass in the northcentral Gulf. Tag release data for the estimate were adjusted to correct for tag-induced mortality, tag loss, total mortality, and emigration. The adult population size was estimated to be 90 million pounds (65 to 115 million pounds, 90 percent confidence limits) between Galveston, Texas and the Alabama-Florida border. With the gulf-wide spatial distribution data from aerial surveys, this estimate was extrapolated to a northern gulf-wide estimate of 123 million pounds for fall 1987. A noteworthy finding was that a fairly substantial amount of red drum mixing occurs between areas in the gulf.

The gulf-wide estimate of 123 million pounds is consistent with stock assessment analyses currently guiding red drum management. This estimate, coupled with an analysis of the age structure, suggests that the adult biomass in the 1970's may have been twice the current level, and that if the decline continues the adult population biomass will fall to roughly half the current level in about five years. Recent fishing (1981-87) of adult fish in offshore waters was not sufficient to cause this decline. Instead, the decline appears to be caused by reduced recruitment to the adult stocks from inshore.

This suggestion of serious decline in adult biomass prompted continuation of the purse-seine sampling into the summer and fall of 1988. This work began in July and ended in September 1988. Up to 50 red drum were sampled from each set for aging and other biological studies (e.g., stock identification). Aging analyses are being done by Louisiana State University under a MARFIN-funded cooperative agreement. The age data will be used to test the earlier analyses which suggested the offshore recruitment problem, and to estimate the rate of decline of the adult stock.

TAGGING CENTER

A red drum tagging center has been established in the Miami Laboratory as part of the Cooperative Red Drum Research Program. Objectives of the center are to develop a standardized data format for entry and archival, provide user-friendly data entry and retrieval, track tag numbers and reward payments, provide periodic data summaries, and allow expansion of the system to other species. A personal computer data management system is the basis of the center, and allows Federal, state, and university investigators to enter and retrieve tagging and related data. The data management system should be available for use by cooperators in early 1989.

INCIDENTAL RED DRUM CATCH

There was a moratorium on red drum fishing in the EEZ during calendar year 1988. No landings by commercial or recreational fishermen were allowed, regardless of how the fish were caught (directed of incidental).

STOCK ASSESSMENT

Encouragement and technical assistance were provided to state university investigators who are attempting to monitor escapement of juvenile red drum to the offshore adult stock under the cooperative Red Drum Research Program. Also, considerable effort was spent working with the Gulf of Mexico Fishery Management Council's Red Drum Scientific Assessment Group. An annual assessment report provided to the Council in September 1987 included analyses of recreational harvest, red drum escapement for several locations, and estimates of the cumulative frequency distribution of numbers of fish per angler in the harvest for each state. A model of the relation between the minimum and maximum size limits, fishing mortality, and the escapement proportion was developed. Based on these analyses, the Red Drum Scientific Assessment Group recommended, among other actions, that the inshore take of juvenile red drum be substantially reduced to achieve a spawning stock goal of 20 percent of the virgin stock biomass per recruit, and that there be no allowable biological catch in the EEZ.

According to Gulf of Mexico Fishery Management Council priorities, only a limited red drum assessment was completed for 1988. A more detailed assessment was scheduled for submission to the Council in May 1989. The 1988 assessment, however, found:

(1) Gulf-wide reported commercial red drum landings in 1987 declined by 65 percent from the 1986 historic high. The landings, however, substantially exceeded levels typical of earlier decades. Most of the decline was due to prohibition of a directed commercial fishery for red drum in the EEZ. Florida conservation measures also contributed to the decline.

(2) Compared to 1986 estimates, the estimated 1987 red drum recreational harvest declined in numbers and weight in Louisiana, Alabama, and Florida, but increased in Mississippi and Texas.

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REEF RESOURCES

Reef resources in the Southeast Region include species such as lobsters, crabs, corals, snappers, groupers, grunts, and other fish that inhabit coral reefs or hard-bottom areas. The resource is managed under fishery management plans for reef fish, spiny lobsters, stone crabs, and corals. Research efforts involve analytical, statistical, ecological, and biological disciplines. In 1987/88, research efforts have been expanded to improve monitoring of the fisheries throughout the Region, to evaluate the effectiveness of regulations, to assess the status of selected reef fish stocks in the Gulf of Mexico and off the southeast Atlantic coast and to examine changes in populations as the result of human activities.

COMMERCIAL REEF FISH LANDINGS

Gulf of Mexico commercial reef fish landings continued an overall decline through 1987. Combined grouper landings were approximately 7.5 million pounds, down from 9.8 million pounds in 1986. Combined snapper landings were down to 6.0 million pounds from 6.7 million pounds in 1986. Red snapper landings were down for the fourth consecutive year to 3.2 million pounds from a peak of 6.9 million pounds in 1983. Yellowtail snapper landings declined for the third year to 0.55 million pounds from 0.91 million pounds in 1984. Gray snapper landings declined for the fourth year to 0.4 million pounds from 0.9 million pounds in 1983. Lane snapper landings were consistent with previous years at 0.72 million pounds. Mutton snapper landings increased to 0.18 million pounds from 0.13 million pounds, breaking a 5-year decline from a high of 0.29 million pounds in 1982. Vermilion snapper landings increased slightly to 1.6 million pounds from 1.5 million pounds in 1986, which was the seventh consecutive annual increase from a low of 0.28 million pounds in 1980. Amberjack landings increased for the eighth consecutive year to 1.7 million pounds, from a low of 0.2 million pounds in 1979.

GULF REEF FISH STOCK ASSESSMENT

Several assessment activities were conducted in support of the Gulf of Mexico Fishery Management Council effort to update the reef fish management plan. These included an assessment of Gulf of Mexico red snapper, a compilation of a descriptive profile of various aspects of the reef fish fishery in the Gulf, and analyses of yield and spawning stock biomass per recruit for several reef fish species.

The harvest of reef fish species in the Gulf of Mexico is dominated by snappers and groupers. The fish are harvested by both recreational and commercial fishermen. Primary commercial gears include hand lines, electric and hydraulic reels, bottom long lines, buoys, and fish traps. Most fish are harvested offshore of state waters in the EEZ. By aggregate weight of landings it is predominantly a Florida-based fishery, particularly for groupers.

In contrast, red snapper are primarily harvested in the northern Gulf from Panama City, Florida, to Galveston, Texas. The greatest part of both the commercial and recreational fishery for red snapper is to the west of the Mississippi River. Commercial harvest was examined from 1972 to 1986 and was lower in 1986 than in any of the previous years. Recreational landings estimates were available from 1979 through 1986 and the associated red snapper harvest declined sharply during the period in both numbers and weight. The combined harvest of this species is at the lowest level of the available time series.

Juvenile abundance indices from the fall groundfish survey were strongly correlated with the estimated recreational harvest of 10- and 11-inch snapper the following year. These juvenile indices are available back to 1972. The indices for the last 4 years (1983-1986) are lower than for any of the previous years for which data are available.

The fishing mortality rate on red snapper appears to be around 0.75 when the fish are first recruited to the fishery but declines to about 0.3 in the older age classes. Current levels of spawning stock biomass per recruit were estimated to be 1.5 percent to 4.8 percent of the unfished level without consideration of the impact of the shrimp bycatch. The loss of red snapper to the shrimp bycatch could easily exceed a million pounds annually. Depending on the actual survival rates between the period of bycatch and recruitment, the loss could approach the magnitude of the existing catch.

SOUTH ATLANTIC REEF FISH STOCK ASSESSMENT

The age structure and population size of the stock of red porgy off the coast of North and South Carolina from 1972-80 were assessed. Combining annual age-length keys with length-frequency distributions estimated annual landings in numbers at age. Virtual population analysis (VPA), applied to these data, resulted in estimates of annual, age-specific population sizes and fishing mortality rates.

On average, 4 percent of the population (ages 1-10) was landed annually from 1972 to 1978 compared to 40 percent from 1981 to 1986. Estimated population size in numbers of red porgy declined from a high of 7.2 million in 1976 to a low of 4.3 million in 1984, while population size in biomass declined from 3.3 million kg in 1978 to 1.6 million kg in 1985 (both calculated with natural mortality rate M = 0.28). Spawning stock (ages 2-10) in numbers ranged between 3.22 million in 1977 and 1.68 million in 1985, and spawning stock in biomass ranged between 1.90 million kg in 1977 and 1978 and 0.85 million kg in 1985. Recruitment to age 1 in numbers ranged from 2.2 million in 1974 (from the 1973 spawning stock) to 1.3 million in 1982 (from the 1981 spawning stock). Estimates of maximum sustainable yield (MSY) for red porgy ranged from 484,400 kg to 498,600 kg based on the Pella-Tomlinson generalized production model. Landings exceeded MSY from 1979 to 1983, peaking at 814,800 kg in 1982 and declining since then to 399,300 kg in 1986.

Yield per recruit for red porgy, based on age-specific fishing mortality rates (with M = 0.28), increased from 124.5 g for the period 1972-78 to 198.2 g for the period 1981-86, because age-specific fishing mortality rates (F_i, ages 1-9) increased by a factor of 3.35. Greater increases in F_i were incurred by younger age classes (ages 1-4). Yield per recruit increased by about 50 percent between 1972-78 and 1981-86. Little gain in yield per recruit can be obtained by raising age-at-entry to the fishery above the current age-1, and most of the gains available by increasing F have been taken.

FISH TRAP MESH SIZES

Research was conducted on the effects of fish trap mesh sizes on the catch and size of reef fishes. Eleven meshes were tested including five square meshes, one hexagonal mesh, and five rectangular meshes. A total of 1,810 fish representing 85 families and weighing 757 kg were captured during 330 trap hauls. Mean catches ranged from 0.58 fish/haul for a 4 x 4" mesh to 12.77 fish/haul for a 1.5" hexagonal mesh. Mean weight per haul ranged from a high of 4.59 kg/haul for a 1.5" hexagonal mesh to 0.65 kg/haul for a 3 x 6" mesh. Median fish weight varied from 200 g for a 1.5" hexagonal mesh to 1,160 g for a 4 x 4" mesh. Changing mesh size effects the catchability for various species.

RECRUITMENT RESEARCH

Research was conducted into recruitment mechanisms among SEFC Laboratories, SEAMAP, CIMAS, Polish Plankton Sorting Center, and MEXUS-GULF. The research was focused in three areas: oceanic pelagics emphasizing bluefin tuna; reef fishes emphasizing snappers, groupers, and grunts; and larval fish ecology, emphasizing their interactions in oceanic waters.

Studies of the habitats of young reef fishes and their relationships to artificial and natural structures around Biscayne Bay, Florida are continuing. Information from this work will indicate which types of artificial structures (sea walls, pilings, bridge foundations, etc.) are best suited for desirable reef species. The relationship of fish larvae found during monthly plankton samples to what actually settles out on reef structures is being investigated at an experimental artificial reef site off Key Biscayne.

Preliminary results on artificial reef recruitment studies indicated that during the first year of colonization more biomass was supported on multiple small reefs when compared to a large reef of equivalent materials. Preliminary results also indicated that predation on newly settled fish larvae was an important factor affecting survival.

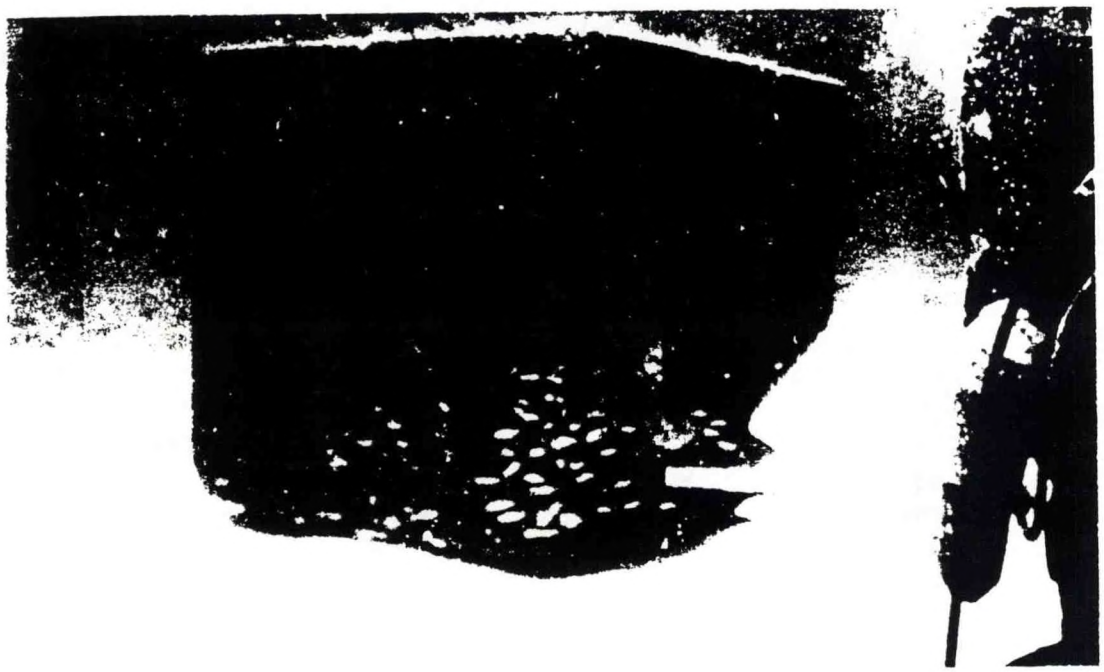

Figure 1. NMFS diver surveying experimental reef site off Key Biscayne, Florida.

HABITAT EVALUATION

A literature review was conducted pertaining to the marine ecosystems of the Puerto Rican–Virgin Islands shelves. The purpose of the review was to identify source-specific material to help determine the major ecological habitats in the region, the more common species within each habitat, the biomass and productivity of each habitat, and their support value to fisheries. At least seven major distinct habitats occur: mangrove estuary, seagrass bed, coral reef, algal plain, sand/mud bottom, shelf break, and overlying pelagic. Although fishing occurs primarily over reefs, the other habitats provide important support for fishery species because of the movements of fishery species or their food sources between habitats. A report citing over 200 sources is being prepared and further work is planned.

HEADBOAT SURVEYS

The headboat survey monitors the catches of 160 vessels, 80 each in the Gulf of Mexico and off the southern Atlantic coast, representing 733,178 angler days of effort (446,404 Atlantic; 286,774 Gulf). Over 50,000 individual fish are measured annually to provide information on fish size, growth, and mortality rates.

While headboats do not occupy the exact grounds used by the commercial reef fish fleet, the headboat fleet does utilize the area producing the recreational catch and much of the commercial harvest. Thus, the headboat survey produces indices of stock status that are generally useful for most reef species. The most important species by weight were for the Gulf of Mexico: "others" (an aggregate of more than 50 species), red snapper, white grunt, vermilion snapper, sharks (aggregate), gag and king mackerel. For the southeast Atlantic coast they were: "others," black sea bass, vermilion snapper, king mackerel, yellowtail snapper, and *Mycteroperca* groupers (mostly gag). By numbers the ordination changed. In Gulf catches, white grunt were most numerous followed by vermilion snapper, red snapper, "others," red porgy, and gray triggerfish. In the Atlantic, black sea bass were most numerous followed by vermilion snapper, mixed grunts (excluding white grunt), white grunt, yellowtail snapper, and others. Abundance, of course, varied greatly by subarea. Catch per angler day was slightly higher (5.06 kg) in the Gulf of Mexico than in the Atlantic (4.60 kg), but there was substantial variation by subarea (3.40 to 9.21 kg, Gulf of Mexico; 3.79 to 5.64 kg, Atlantic). Downward trends in mean fish size for the Atlantic off the Carolinas reported last year continue. For example, for the Cape Lookout (offshore), District of North Carolina, anglers took in 1972 an average of 5.6 fish per angler day weighing 13.29 kg. In 1987 anglers per day took 10.38 fish, but they weighed only 6.5 kg. The recreational catch has changed markedly in the last decade. Interestingly, angler participation remains high. Substantial, perhaps radical, increases in regulation of the reef fishery are probably necessary to achieve stocks of large fish as existed in the early 1970's.

Headboat survey collection methods were changed so that hand recording was virtually eliminated for some data sets. Thus, substantial expense attendant to coding data and hand entry to electronic data files was avoided and data were available for summarization and manipulation almost immediately upon receipt. Electronic balances linked to an electronic measuring board allowed recording of fish length without resort to pen and paper as well as recording of weight, species, location, and other accessory information for over 1,500 fish without unloading. Data are retrieved from the board's memory via a minicomputer, stored on magnetic tapes, and mailed from field station to laboratory. Data are transferred directly to the mainframe computer, where the data become available for use in only hours, rather than weeks, after arrival at the laboratory. Funded by MARFIN, the electronic data collection scheme is in place throughout the Gulf of Mexico and is designed to demonstrate to other fishery data collectors of the region the savings and speed available with modern electronic data recording.

AGE AND GROWTH

Newly published works on growth of four species of reef fish have added substantially to the information needed for management. Otoliths from Warsaw grouper were obtained by dockside sampling of headboat landings from North Carolina through the Florida Keys. Black grouper were sampled from headboat landings primarily in the Florida Keys. Annulus formation occurred between April and May for Warsaw grouper, and from March through May for black grouper. Both species have growth characteristics that are similar to most other serranids studied along the southeastern United States.

Otoliths and sectioned dorsal spines were used to age yellowtail snapper and queen triggerfish from the U.S. Virgin Islands and Puerto Rico trap and hook-and-line fisheries. Annulus formation, validated by marginal increment analysis, occurred from March to May for yellowtail snapper and from February through March for queen triggerfish. Mean back-calculated fork lengths were used to estimate von Bertalanffy growth equations for yellowtail snapper and queen triggerfish. Yellowtail snapper live longer than previously reported and grow at a rate similar to other western Atlantic lutjanids. Queen triggerfish were not as old as expected, probably because of fishing gear selectivity.

TAGGING/VISUAL OBSERVATIONS

Recent analysis of tagging studies and visual observations of reef fish conducted off the southeast coast of the United States between 1972 and 1980 allowed determination of some population parameters independent from those obtained from fishery statistics. From 1972 to 1975, 4,150 reef fish were tagged during 148 trips off North Carolina, South Carolina, and Florida but had only 29 returns. All recaptures were within 24 km of the tagging site. In an intensive tagging study on a single reef off North Carolina from 1975 to 1977 we tagged 2,736 reef fish during 65 trips and had 121 returns (4.4 percent). Only one tagged fish, a black sea bass was caught away (9.7 km) from the tagging site. A mark-recapture, multiple census estimate of the black sea bass population was 33 times smaller than that made by SCUBA divers during the same period.

Using the estimate of standing stock obtained by diving, 70 black sea bass/ha, and our earlier estimate of area of live bottom reef (944,300 ha), we calculated that the total number of catchable size black sea bass off the southeast Atlantic coast in 1976 was 66,000,000. Given a recreational and commercial harvest of 1,101,000 fish (estimated), exploitation rate was 1.7 percent. This estimated rate agrees remarkably with an estimate (0.026, M = 0.3) based on age frequencies derived from length frequencies taken in 1976-78.

Eighty-seven species of reef fish were observed by divers. Some of these species, such as red snapper and vermilion snapper, apparently moved off the reef when the water temperature dropped below 16°C. Others, such as red porgy, white grunt, grouper, and juvenile vermilion snapper, moved off the reef when the water temperature dropped below 11°C. But fish returned when temperatures again attained the required minimum. Young-of-the-year fishes were observed on the reef between mid-May and mid-July when the bottom water temperature ranged from 20.5 to 27.0°C.

SHELLFISH RESEARCH

Assessment and monitoring research on stone crabs and spiny lobsters continued. Data collection programs include spiny lobster commercial size frequency, landings data collection and stone crab landings and trip-ticket monitoring. The advent of the Florida trip-ticket system has increased our ability to monitor abundance trends in these fisheries. However, the time series from these data are still relatively short. Spiny lobster monitoring continued to be plagued by lack of information about the magnitude of the (presumably) large recreational catches.

Stone crab rates (pounds/trip) in 1985-87 were highest during the first couple months of each fishing season, and then rapidly declined. Large claws were the single most important component of landings throughout the fishing season. Catch rates for medium and small claws did not decline as rapidly as they did for large claws later in the season, and these size categories provided an increasing percentage of total stone crab landings. Since 1983, there has been a rapid decline in monthly landings after the first two to four months of each fishing season. High fishing mortality rates early in the season resulted in low landings during subsequent months and, in effect, shortened the fishing season. Abundance indices for both stone crabs and spiny lobster will continue to be monitored in the future to detect changes in the fisheries should they occur.

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SHRIMP AND BOTTOMFISH

Shrimp and groundfish research efforts were directed towards evaluating the impact of closures, obtaining information on the biology and ecology of major shrimp and groundfish species, and collecting recreational and commercial catch and effort statistics to provide necessary scientific information for management purposes. The program is managed by the Galveston Laboratory.

GULF OF MEXICO SHRIMP LANDINGS

The Gulf of Mexico shrimp fishery continues to be one of the most valuable commercial fisheries in the United States. Of the nine species of shrimp caught in Gulf waters, only brown shrimp, pink shrimp, and white shrimp are caught in commercial quantities. Of the 363.1 million pounds of whole shrimp landed in the United States during 1987, 257.1 million pounds (71 percent) were taken exclusively from the waters of the Gulf and were valued at $469.3 million. In 1987, the Gulf shrimp catch decreased by 47.0 million pounds and $35.5 million as compared to 1986. Average ex-vessel price per pound was $1.66 in 1986 and $1.83 in 1987.

Most Gulf Coast States noted a decrease in shrimp landings in 1987 as compared to 1986. Louisiana led all Gulf Coast States with 116.3 million pounds (down 21 percent). Texas was next with 92.4 million pounds (down 5 percent), followed by Florida (west coast) with 18.5 million pounds (down 24 percent). Alabama's production was 17.0 million pounds (down 25 percent), and Mississippi's was 12.9 million pounds (unchanged).

TEXAS CLOSURE

The Texas closure in 1987 closed coastal waters to 15 nautical miles off Texas from June 1 to July 15. The total Louisiana May-August catch in 1987 was 33.2 million pounds compared to 25.1 million pounds in Texas. Recruitment levels were only slightly different between areas 13-17 and 18-21. This similarity in both recruitment and production set the tone for the summer offshore fishery. The average size of shrimp in July and August off Louisiana was 69 and 43 per pound, respectively, whereas off Texas the average count was 45 in July and 38 in August 1987.

Fishing effort was much greater off Louisiana and Texas this year compared to all other years. This increase in effort with only average to slightly above average abundance produced poorer than normal CPUE values in both areas.

Home port information indicated that during the June 1 through August 31 period, Louisiana vessels predominantly landed in Louisiana and very few Texas vessels landed in Louisiana. Likewise, Texas vessels predominantly caught the majority of shrimp landed in Texas. Louisiana vessels rarely landed in Texas. Overall, probably 80 percent of the offshore landings in Louisiana were by Louisiana vessels and between 80-90 percent of the Texas landings were by Texas vessels.

An increase of around 0.82 million pounds would have resulted in the May-August 1987 period with a total closure of the EEZ off Texas. Projections for the May-April period show an increase of around 2.18 million pounds with a total closure.

Responses from interviewed vessel captains, about the EEZ closure, were similar to those received last year. Greatest negative responses to a closure were again from captains in Louisiana and ports along the upper Texas coast, while greatest positive responses were from captains in Florida, Alabama, and ports along the lower coast of Texas.

Analysis of the EEZ closure each year has shown a positive benefit in pounds with a total closure. Additional studies this year indicate that all years, except very poor abundance years, would show an increase in ex-vessel prices paid for shrimp with a complete closure, with most price structures.

Thus, from this analysis it seems that a complete closure would in most cases only enhance the fishery and not hinder it.

The goals of the FMP were only partially achieved in 1987 with the 15 nautical mile closure. The closure did allow the capture of large shrimp in deeper waters, but problems were encountered in enforcement again this year. If the management plan is to be effective, compliance to the regulations must be observed by all involved.

TORTUGAS CLOSURE

The permanent closure of the Tortugas Sanctuary was established in May 1981 to prevent the capture of small shrimp. The whole sanctuary has been closed to trawling since that time, with the exception of the "toe area," which was reopened for a brief period (April 1983 through August 1984) to evaluate the effects. Reports showed an increase in number of small shrimp caught during the period the toe area was opened. With the reclosure of the entire Sanctuary to shrimping activities, size ratio values (average monthly size divided by historical monthly size) again decreased. Small shrimp being recruited to the offshore fishery were rapidly harvested when the toe area was opened, but small shrimp were able to increase in size and then enter the fishery when the toe area was closed. Since January 1987, however, smaller than average shrimp have been landed from the fishery, even when the entire Sanctuary was closed.

It must be assumed that these smaller than average-sized shrimp were obtained from the fishing grounds and not from vessels fishing inside the Sanctuary, since violations in the closed area were at very low levels this past year. Shrimp distribution patterns may have shifted in response to environmental changes (e.g., reduced rainfall, higher water temperature, hurricane Floyd, etc.), but we have no data to support this theory. Discarding undersized shrimp may have been reduced this year in response to either the lower catch rates or high market price for small shrimp.

The major objectives of the Tortugas closure are to 1) increase the yield per recruit, and 2) eliminate discarding of undersized shrimp. It is difficult to conclude that the Tortugas closure has met the objectives of the Gulf of Mexico Shrimp Fishery Management Plan this year. Since catch rates were so low this year, it is assumed that most shrimp caught, no matter the size, were landed this year. This may account for the increase in smaller than average sized shrimp being landed this past year (January 1987 to present). Yield per recruitment was certainly lower this past season because of the small size of shrimp landed.

STOCK ASSESSMENT

The need to better manage the penaeid shrimp stocks of the United States, to insure that all involved in the fishery may benefit from this common resource, has prompted this research effort. This stock assessment research deals with the 1960-86 commercial catch statistics for brown shrimp, white shrimp, and pink shrimp from the U.S. Gulf of Mexico shrimp fishery.

Results indicate that the significant increase in yield in the brown shrimp fishery is attributable to an increase in recruitment. This increase in recruitment is not from an increase in the parent stock, but is most likely a result of a changing stock-recruitment relationship. No well defined stock-recruitment relation was apparent, and thus it is difficult to determine if full exploitation of the stock is happening at this time.

The white shrimp stock has also had an increase in landings attributable to improved recruitment with no increase in parent stock. Stock-recruitment relationships seem apparent, but a strong component of variation unrelated to fishing has been important in establishing the form of the relationship. Results indicate that the fishery has exceeded full exploitation of the stock.

With regards to the pink stock, the most notable result is the stability of the fishery. Because of this lack in variation within the fishery, estimations of M and stock-recruitment relationships are not as precise as those established for the brown and white shrimp stocks. It appears, however, that recruitment overfishing is not a problem for the pink shrimp stock.

BROWN SHRIMP YIELD FORECAST

Each spring the Galveston Laboratory forecasts the upcoming offshore brown shrimp harvest for the Texas and Louisiana coasts to aid shrimpers in preparing for the upcoming season. The forecast is based on samples of juvenile shrimp and environmental parameters in both areas.

Our most reliable indicator of offshore Texas brown shrimp catch is derived from the Galveston bait shrimp fishery data during late April through mid-June. A regression model based on the average weekly bait shrimp catch per hour is directly related to the subsequent offshore brown shrimp catch. Predictions from this model have been on the average within 3 million pounds of the actual harvest (1960-87).

Catches from offshore Texas were forecast to be 25.9 million pounds for the 1988-89 season, which is slightly below the historical annual average of 27.4 million pounds. Most of the 1988 abundance indices were slightly higher than corresponding figures for 1987. Smaller shrimp were caught in the bays in May 1988 as compared to May 1987, and we expect relatively small shrimp at the opening of the Texas offshore season in mid-July. Several environmental factors may have reduced survival and growth of juvenile brown shrimp. This spring was characterized by atypically low rainfall, lack of strong southeast winds, cool temperatures, and extremely low water in the marshes during early April.

Prospects for the combined inshore and offshore Louisiana brown shrimp harvests for waters west of the Mississippi River suggest catches could be around 30.2 million pounds for the 1988-89 season, which is above the 27.5 million pound annual average yield for the area. Louisiana Wildlife and Fisheries scientists estimated that 1.35 million acres of prime nursery habitat for brown shrimp were available this year. This figure was about average and is not indicative of excellent growth and survival for young shrimp. In 1986, when over 2.5 million acres were available, production exceeded 44 million pounds.

POST LARVAL SHRIMP STUDIES

During the spring of 1988, influxes of postlarval brown shrimp entering Galveston Bay through Bolivar Roads were studied, with emphasis being placed on their spatial distributions at two historically important sampling sites. Although the bottom topographies at the North Jetty and South Jetty sampling sites were found to be quite different, considerable variability in PL abundances was found at both sites. Away-from-shore variability was found to be usually about 30 percent greater than along-shore variability. An "edge effect" seemed to concentrate PLs in shallow waters near shore at both sites, while no particular region along the shorelines at either site consistently harbored more PLs. Based on the sampling regions along shore at each site, we could be about 80 percent certain of detecting a 75 percent difference between means of two sets of statistically significant differences. If we were to exclude the samplings when PLs were scarce, i.e., averaged less than ten per tow, the detectable difference between means would be reduced to 25 percent, or keeping the 75 percent difference one would only need three samples to detect the significant difference. This information will assist us in establishing a sampling design to monitor PL influx in the future and has established some confidence around past years' PL samplings.

TORTUGAS PINK SHRIMP YIELD FORECAST

The Gulf of Mexico Fishery Management Council requested that the Galveston Laboratory develop a predictive model for the Tortugas pink shrimp fishery in spring of 1987, similar to the ones already in

use to forecast the Texas and Louisiana offshore brown shrimp harvests. A cooperative analysis was initiated with the National Park Service's Everglades National Park to assess long-term data bases for the south Florida pink shrimp nursery area encompassed by the park. Data from 1960 onwards was amassed and included NMFS pink shrimp catch statistics, National Ocean Service sea level records, National Weather Service rainfall records, and Everglades National Park groundwater and rainfall records.

It was decided that the forecast should be issued in advance of the pink shrimp fishing season which normally experiences its first million pounds month in November each year. However, the forecasting model that was developed depended upon October data and the forecast was then planned to be issued in the first week of November until a model with an earlier start date was found.

The descriptive model formulated related fishing year (November-October) landings to October air temperatures at Key West (October, the month that large numbers of juvenile pink shrimp exist in the estuary), mean water levels in two Everglades National Park wells in June and September (the start and finish of the rainy season), June rainfall within the Everglades, and August catch per unit effort of smallest size count shrimp offshore (an index of whether the juvenile shrimp move out early). The model accurately described landings for the November 1966-87 fishing years, exceeding $\pm$ 10 percent of the actual landings for only 3 of 20 years, while 11 of 20 estimates were within $\pm$ 5 percent of actual landings. Using data from the summer and fall of 1987, a forecast of 10.2 million pounds for the fishing year November 1987-October 1988 was delivered to the November Council meeting. However, it was noted at that time that two unknown factors could have influenced the outcome of the forecast. First, the only hurricane in 20 years to hit south Florida occurred in October 1987 and, since hurricane effects of pink shrimp production were not a part of the model (no data), it was felt that this could affect landings in an unknown manner. Second, and perhaps more important, landings from the Tortugas fishery have been lower than average since 1980-81 and the lowest landings on record were compiled during 1986-87. It was felt that a stock-recruit of recruit-stock relationship could influence the landings, particularly since the stocks seemed to be declining. No evidence for such a relationship has been found as yet. In addition, no actual data on the historical abundance of juvenile pink shrimp within the nursery of Florida Bay were available to include in the modeling effort.

To summarize the results, the model inaccurately forecast the 1987-88 fishing year. The forecast was for 10.2 million pounds, and preliminary catch statistics indicate that the actual landings will be approximately 6 million pounds. Something is affecting the pink shrimp stocks that is not included in the model. The lack of data concerning juvenile abundances is a major shortcoming for the modeling process, since it appears that the fishery experienced recruitment failure this past year. Modeling efforts will continue, but it is believed that a program to monitor pink shrimp abundance in the estuary is necessary to make an accurate forecast.

MORTALITY OF YOUNG BROWN SHRIMP IN ESTUARINE NURSERIES

Annual variability in the number of brown shrimp recruited to the fishable population is ultimately regulated by spawning success and by mortality of pre-recruits. The biotic and abiotic environment influences population size through its effect on mortality rates, and efforts to predict recruitment success require information on the interactions between the environment and mortality. Year-class strength will be fixed during life cycle stages when mortality rates are high and highly variable.

Mortality of young brown shrimp in estuarine nurseries appears to be large enough and variable enough to have a major effect on recruitment to the fishery. Mortalities were measured in a Galveston Bay salt marsh by sequentially estimating densities of brown shrimp cohorts, and actual two-week mortalities ranged between 1 percent and 73 percent during the spring of 1982. In predator-exclusion cages placed in the same marsh during 1987, mortalities were generally less than 5 percent. These cage data, along with published information on physical tolerances, food requirements, and diseases, suggest that except under unusual conditions, predation is the major direct cause of brown shrimp mortality in estuarine nurseries of the Gulf of Mexico.

Analyses of stomach contents indicated that the southern flounder was the dominant fish predator on young brown shrimp during the spring, although pinfish, gulf kingfish, and spot had also eaten shrimp. During the late summer and the fall, spotted seatrout and red drum were important predators on penaeid shrimp.

Predation rates of fish on small brown shrimp in the laboratory increased in proportion to increased prey densities. The presence of *Spartina alterniflora* reduced feeding rates, and the effect of vegetation did not appear to interact with prey density. These results suggest a negative linear relationship between shrimp mortality in the marsh and the proportion of the brown shrimp population that is protected in vegetated habitats. Water levels in the marsh control prey density and access to intertidal vegetation, and stands of high water, which are common throughout the spring in the Gulf of Mexico, may be important in reducing mortality of brown shrimp.

Predation can also be reduced if shrimp grow out of the optimal prey size of their fish predators. Environmental conditions, that may have little direct effect on shrimp mortality, can indirectly affect mortality by regulating growth rates. The environment can also regulate predation by influencing protective behaviors of shrimp, such as burrowing and selection for vegetated habitats.

SEAFOOD SURVEILLANCE PROGRAM

The basic safety, wholesomeness, and economic identity of seafoods, including shrimp and bottomfish products, are becoming of more concern to consumers. During 1986, a Congressional budgetary add-on to NOAA required the development of a system for seafood surveillance and certification. Center staff participated in a series of workshops with the processing industry and the National Fisheries Institute as part of the NOAA Model Seafood Surveillance Program in the development of the systems that would be applied to the shrimp and bottomfish of the Southeast.

Three workshops dealt with breaded, cooked, and raw shrimp. Safety questions related to the ultimate consumption of the products were considered and research and regulatory needs were identified that relate to the development of an inspection system. The critical control points in the processing were also identified and a model for inspection of plants producing each of the products was developed.

Similar workshops on raw and frozen finfish and breaded and speciality products were held. Center scientists (food technologists, microbiologists, and chemists) are involved in the development of these inspection system models on a continuing basis. The completed system design, which will encompass the handling of fisheries products on vessels and in the distribution system as well as processing, and an economic evaluation is due to be delivered to Congress in June 1990.

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ECONOMICS AND STATISTICS

The Office of Economics and Statistics is responsible for fishery statistics and information management for the Southeast Region of NMFS. Fishery statistics are collected, processed, and archived and the data and information made available to scientists, administrators, and the public. Information management (computer) services are provided to the Region and cooperating individuals and agencies. The Center operates a mainframe computer system and regional telecommunications system, provides programming and software development services, and implements NOAA policies and procedures on automatic data processing. The statistical information and services of the Office are used by fishery management councils and the agency to manage the fishery resources in the state and federal waters of the southeastern United States.

FISHERY TRENDS

In 1987 commercial fishery landings in the southeast region were 2.7 billion pounds, up 0.1 billion pounds from 1986. The value of these landings was $870 million, down $66 million from 1986. Shrimp contributed most to total value ($516 million) and menhaden most to total weight (2.1 billion pounds). Southeast commercial landings represented 40 percent of the volume and 28 percent of the value of the nation's domestic fishery production.

Recreational fishing continued to be of major importance. In 1987 an estimated 5 million anglers caught 175 million fish on approximately 39 million fishing trips. Recreational fishing in the southeast region produced 45 percent of the nation's saltwater sport fishing catch and accounted for 52 percent of the total number of fishing trips.

ATLANTIC FISHERIES

Fishing in the Atlantic southeast region was affected by a number of environmental and industry situations during 1987. In November, a red tide condition appeared off North Carolina, causing closure of shellfish beds and a decrease in retail and restaurant sales in local areas. State landings of crabs, oysters, and sea scallops increased, but landings of fish, shrimp, clams, and bay scallops were down significantly.

In South Carolina, overall fish landings were up, compared to 1986. Shrimp landings were only 5 percent below those of the record 1986 year, in spite of a sharp reduction in brown shrimp landings resulting from heavy rains early in the year.

In Georgia food fish landings were lower than in 1986. However, the landings of rock shrimp more than doubled, a result of boats switching to this fishery because of the slow fishery for white shrimp.

On the east coast of Florida, fishing was targeted towards swordfish, tunas, reef fish, sharks, bluefish, amberjack, and shrimp. The numbers of longline boats targeting swordfish and tunas remained steady while catch rates continued the decline experienced in recent years. Longline boats and a winter drift net fishery contributed to strong landings of sharks and bluefish. The fishery for amberjack continued to grow. Increased fishing for these species was also contributed to by the seasonal closures of the fisheries for king and Spanish mackerels.

GULF FISHERIES

Gulf fisheries were characterized by a poor shrimp year and variability in other fisheries. For snapper and grouper fishermen it was a year of erratic prices, mediocre landings, and competition from imports. A larger percentage of the grouper landings consisted of red grouper, in contrast to the

years prior to 1986, when higher percentages of yellowedge grouper and gag were landed. This was caused by fishermen in northwest Florida fishing farther to the south than in previous years. The number of longline vessels fishing for red snapper declined; some vessels converted to shark fishing to increase profitability. Fishing for mackerels was limited by closures for both king mackerel and Spanish mackerel. Landings for swordfish and tunas in northwest Florida continued to decline, as vessels moved to the western Gulf or to the Caribbean. The 1987 shrimp season was a disappointment in Florida, both for southwest Florida where landings were no better than in the poor year of 1986 and in northwest Florida where landings were as much as 50 percent lower than in 1986. Spiny lobster fishing was the best in years on the grounds west of Key West, but overall catches dropped greatly after Hurricane Floyd in November.

In Alabama, fish landings were down 52 percent for the year, primarily due to the closure of the directed fishery for red drum. Mullet landings also decreased, but there was a growing fishery for yellowfin tuna and sharks. Shrimp landings were down 25 percent.

In Mississippi, menhaden landings made mainly east of the Mississippi River delta, and food fish landings, were steady. The new fishery for butterfish was strong, with prices considerably higher than in 1986. There was also a new fishery that developed for sharks.

In Louisiana, a major industry developed for tunas and swordfish. Overall, effort increased due to additional fishermen entering the fisheries. Poor weather conditions (temperature extremes, storms, tides) affected fishery production. Shrimp production, as in other Gulf states, was lower than in 1986. In Texas, Galveston is becoming a major port for tuna landings, with about 50 vessels operating during the year. Offshore shrimp catches were poor during the year but inshore catches were up.

FISHERY STATISTICS

Fishery statistics were collected to determine the economic trends of the fisheries, the biological condition of the resources, and the level of participation by fishermen. The data were collected by interviews with wholesale seafood dealers and fishermen and from reports submitted by these persons. Data collection efforts by State agencies, through the Cooperative Statistics Program, complemented those of the NMFS. Emphasis was given to the use of microcomputers by field agents for processing and reporting real-time catch data.

Total landings data were collected for all species and effort and size and species composition data were collected for the shrimp industry. There is still a need to develop greater uniformity with the diverse data collection systems for the various regional fisheries so that the data are more accessible and comparable--this need will be addressed in 1988.

Port agents provide the primary contact, in many areas, with users of the resource, and therefore, they are often the first government persons to become aware of fishery problems. In 1987 port agents assisted in providing information on turtle excluder devices to shrimp vessel owners and fishermen, explained and answered questions about new fishery regulations, and supplied information for *Market News* reports which are published and distributed to members of the fishing industry. A report on 1987 trends and conditions in the region's fisheries was issued.

Special efforts during 1987 by port agents included surveys of shrimp fishermen to determine their response to the Texas Closure regulation, a report on the mackerel drift net fisheries off the east coast of Florida, and collection of catch and effort data on the inshore shrimp fisheries to provide data required to evaluate the impact of TED regulations.

Fishery statistical data were routinely processed in 45-90 days. The establishment of quotas to restrict the catch of king and Spanish mackerels and red drum requires that catch estimates for these species be made more quickly. The king mackerel fishery quotas for the Gulf were reached February 4, 1987; rapid compilation and reporting of the catch estimates allowed the total production from this fishery to be limited to within 4 percent of the target quota.

DATA MANAGEMENT

The Center operates a mainframe computer in Miami, accesses a large mainframe computer in Seattle, Washington, and has a large number of microcomputers used by individual scientists and technicians. Additional memory and communications equipment added during the year has shortened processing time and allowed users to select from their single terminal whether they wish to process on the Miami or Seattle computer. Our information management personnel participated in a national effort to prepare the specifications for replacing the NMFS mainframe computers.

Systems support was provided for fishery research projects, including design and implementation of 1) a swordfish dealer reporting system, 2) a swordfish logbook system, 3) microcomputer data entry and editing systems for the Trip Interview Program and for Gulf shrimp schedules, 4) a Florida Trip Ticket file for the mainframe computer and several interactive report programs to run against this file, 5) the programming for a Cooperative Tagging System, and 6) a vessel code book system which provides for interactive updating/retrieval and report generation to use as a builder for integrating the Shrimp Code Book and the Vessel Operating Units file. Modifications and enhancements to other fishery systems were accomplished per user requests.

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FISHERY HABITAT

Fishery habitat research is a multidisciplinary generic program concerned with estuarine-coastal habitats. The program is a mixture of field and laboratory research with the goals of: 1) determining the key processes that regulate fishery production; and 2) developing the capability to predict and assess the effects of habitat alterations and contaminant additions on fishery organisms. During FY88 research emphasis was on: 1) the distribution and abundance of larval and juvenile fishes, and factors influencing larval growth and survival; 2) mapping and characterization of habitats supporting finfish and shellfish; 3) evaluation of mitigation methodologies and the impact of alterations on habitat quantity and quality; 4) research on feeding habits and predator-prey interactions; and 5) effects of metal contamination on larval fish food webs and mechanisms of metal accumulation and metabolism.

COASTAL/OCEANIC RESEARCH

Larval fishes, including gulf menhaden and spot, are aggregated, possibly by localized hydrodynamic convergences, along the Mississippi River plume turbidity front in the northern Gulf of Mexico. Larvae in this frontal zone appear to be better fed than larvae of the same species from adjacent waters. We continued to evaluate how this plume may affect the spatial distribution, feeding, growth, and nutritional condition of laboratory reared spot, and used this model to estimate the nutritional condition of spot collected in and adjacent to the Mississippi River plume front. This work is done in conjunction with analyses of stomach fullness and growth rates for spot larvae from the same samples.

Shoreward transport of larval fishes from spawning on the Continental Shelf to recruitment into estuarine nursery areas cannot be fully explained by Ekman transport. We investigated meteorological and hydrodynamic mechanisms that influence the shoreward transport of larval fishes, and are examining mechanisms that might account for the spatial distribution of king and Spanish mackerel larvae on the southeastern continental shelf. Several of these studies are cooperative with other NMFS Laboratories (i.e., Panama City) and university and state laboratory researchers.

As part of NMFS Marine Entanglement Research Program, samples taken in the northern Gulf of Mexico (Cape San Blas, Florida; Mississippi River plume; Galveston, Texas) were evaluated for the presence of small plastic (polystyrene) particles (0.1 to 2.0 m) that could be ingested by larval or juvenile fish. Mapping the distribution and abundance of these particles relative to concentrations of larval and juvenile fish provides data upon which to design future sampling and feeding studies. Feeding studies are being conducted to determine how susceptible fish larvae are to swallowing plastic debris.

The life history patterns of Atlantic and gulf menhaden are being studied to explain how these species have adapted to their particular environments and how patterns are adapted for persistence and reproduction. This research includes studies of all life stages. In addition, laboratory spawning of spot, flounder and Atlantic menhaden has been continued to provide larvae for physiological, growth, and survival measurements in the laboratory.

A cooperative program with the NMFS, Sandy Hook Laboratory is examining hypoxia and nutrient enrichment in New Jersey coastal water. We have provided data on bacterial abundance in coastal New Jersey waters from February 1985 through April 1987 based on about 2500 samples collected monthly (winter) or weekly (intervals). Abundance of bacteria in sediments impacted by sludge dumping and variability in the water column is being emphasized.

In early November 1987, the toxic "red tide" dinoflagellate was identified from the nearshore waters of North Carolina. This was the first occurrence north of Florida. This major biogeographic

event extended the range of red tide into temperate waters and caused the closure of approximately 50 percent of the waters normally used for commercial harvest of oysters and 95-98 percent of those areas used for commercial harvest of clams. Before the end of this massive and persistent red tide in mid-February 1988, there were 48 cases of neurotoxic shellfish poisoning reported in humans and an economic loss to the coastal community conservatively estimated at $25 million. The Beaufort Laboratory was involved in initial sampling and identification, working closely with and in support of the State of North Carolina Shellfish Sanitation and Division of Marine Fisheries. We supplied equipment, laboratory space and sampling expertise. Research conducted at the time of this "natural experiment" included zooplankton feeding experiments, larval fish mortality experiments and investigations into the origin of red tide cells. Cooperative work with NWS Hurricane Center, NESDIS, NSTL and NOS provided answers to possible origin, transport mechanism of the cells and timing of their transport and factors contributing to the maintenance and demise of the bloom.

ESTUARINE RESEARCH

Our estuarine research is designed to determine the distribution and relative values of nursery areas, including marshes, seagrasses, and non-vegetated habitats for fisheries species, and to assess impacts to and mitigation measures for fishery habitats. Projects have been designed to test the relationship between habitat utilization and salinity conditions in Texas. The studies employ a variety of sampling gear including the dropnet-samplers, block nets, fyke nets, pit traps and high-speed trawls in shallow waters ranging from river delta to coastal marine environments. The salinities in these habitats have varied during sampling, depending on time and location, from 0 to 35 ppt. March habitats with *Juncus, Scripus,* and *Spartina*, submerged aquatic vegetation habitats (SAV) with *Zostera, Halodule, Syringodium, Thalassia, Ruppia, Myriophyllum, Vallisneria*, and the macroalga *Caulerpa prolifera*, and soft silt to hard non-vegetated bottoms were investigated.

Research at the Beaufort and Galveston Laboratories included recruitment to estuaries; utilization of various wetland habitat types as a measure of relative habitat value; predator-prey interactions; uses of detrital material; evaluation of impacts of freshwater inflow and temperature; the functional value of mitigated and created wetland habitats; and synthesis of information on wetland acreages and fishery species life histories.

RECRUITMENT TO ESTUARIES AND USE OF WETLAND HABITATS

Studies were continued in North Carolina to relate estuarine recruitment of larval fishes to distributions of juveniles in the estuary. In one study, conducted inside of Beaufort Inlet, near surface and near-bottom tows at night on flood and ebb tides are being made to determine depth distribution and densities of the ichthyoplankton. Larval densities were greater on ebb tides during December-March, suggesting an export of larvae from the estuary, but in April densities were greater on flood tide. By early summer no significant differences were noted in catches between surface or bottom and between ebb or flood tides. Catches of Spanish mackerel were significantly higher in June 1988 than in June 1987, and reached 88 larvae/100 m^3 at high slack tide near the bottom. As in 1987, peak densities of larvae occurred in May and were due primarily to *Anchoa, Orthopristis,* and *Bairdiella*. The age/size of larvae, recruited over a five-month period, varied within the recruitment season. Early recruits, which were smaller and younger, were probably from local populations and the older, larger larvae recruited only later in the season were probably from coastal migratory schools. This latter group represented well over 85 percent of all menhaden larvae recruited to the Newport River estuary.

After entering the estuary, a mosaic of habitats are available as nursery areas. We are only now beginning to understand how these habitats support fishery species, and research is being conducted in Texas and Louisiana to address aspects of habitat use and value. One aspect of this problem is

being approached by a study of the estuarine habitat preferences of juvenile summer, southern, and gulf flounder. Bottom trawl surveys of two estuaries near Beaufort were conducted to determine the distribution of these flounders in the estuaries, and their distribution patterns over substrate types in the estuary. Data obtained strongly supports the hypothesis that specific types of habitat are preferred and sought out within the estuary. Complementary laboratory experiments, using laboratory spawned and reared flounders, are also being conducted to test the preference of these flounders for soft or hard bottom types.

Investigations in Galveston Bay on the nursery function of salt marshes show that food resources in salt marshes may explain the distributions of juvenile shrimps, crabs and fishes. These organisms follow their prey, and environmental circumstances often dictate the distribution and abundances of these foods. Since the kind, number and accessibility of prey varies among marshes, the nursery value of marshes for fishery juveniles also varies.

Marshes in the upper, middle and lower parts of Galveston Bay differ in their utilization by fishery species in relation to salinity regime and presence of certain foods. Highest numbers of shrimps, blue crabs and commercial fishes in drop samples were associated with marshes in the middle and lower bay. This association corresponded to high abundances of benthic peracarid crustaceans (amphipods and tanaidaceans) which were shown to be used as foods through feeding experiments and gut analyses. Other less used foods such as annelid worms and bivalve molluscs did not have the same effect on distribution of fishery juveniles. This finding gives a cause-and-effect relationship that can explain utilization differences between marshes.

The foods directly used by fishery juveniles in marshes are modified by influences from freshwater inflow. In upper Galveston Bay where salinities are generally less than 10 ppt, long-term effects from the Trinity and San Jacinto Rivers dominate. Marshes and submerged vegetation are characterized here by brackish water plants with highly seasonal growth patterns which completely defoliate in the winter. This environment is especially stressful to estuarine organisms because of variation in salinity and high sedimentation rates. The environment is not conducive to development of resident populations of epibenthic invertebrates or epiphytic algae. The resident macrofauna mostly consist of infaunal worms and molluscs. Transient fishery juveniles from the bay, most of which are euryhaline, have ready access to these marshes but do not use them extensively. This lack of attractiveness is apparently due to the absence of preferred foods, especially epiphytic algae and peracarid crustaceans. Unlike other marshes in Galveston Bay, the value of these marshes to fisheries is indirect; that is, through the quantity of organic detritus exported to the middle and lower bay.

In the middle of Galveston Bay, organic detritus from upper bay marshes becomes an important basis for food chains. Here detritus particles, colonized with bacteria and fungi, provide food for epibenthic fauna. Stimulated by food and mesohaline conditions, large numbers of epibenthic organisms develop, that, in turn, provide a rich nursery feeding ground for fishery species. In this mid-bay processing region, immigrating juveniles of commercially important species were abundant in our samples from both marsh and shallow-water nonvegetated habitat.

In the lower bay, detritus continues as an important basis for food chains, but reduced turbidities and moderate salinities also foster the development of epiphytic algae as another resource. Since these *Spartina* marshes persist year round and are regularly innundated, they offer perennial substrata for epiphyte colonization. Epifauna and the epiflora associated with these marshes are a food resource for young penaeid shrimp, blue crabs and small fishes (pinfish and spot croaker) that are eaten by larger commercially important fishes (flounder, spotted seatrout and red drum). The difference in abundances of these foods between marsh and nonvegetated bottom is greater in the lower bay than the middle bay, emphasizing the importance of marsh habitat as a feeding ground.

Analysis of the diet of Atlantic menhaden has shown that these fish routinely consume large amounts of amorphous detritus, a major component of detritus derived from vascular plants, which

apparently is digested with high efficiency and contributes to the energetic needs of the fish. Visual analysis of the fish's stomach contents showed that amorphous detritus was consistently the major item consumed by these fish in estuarine habitats and a major dietary component in coastal habitats. The diets were shown to be high in ash content; amino acids and humic compounds also contributed substantially to the diet's organic component. The chemical composition of amorphous detritus was estimated to be constituted primarily of ash (70 percent dry weight), humic compounds (40 percent ash-free dry weight), amino acids (25 percent AFDW), carbohydrates (15 percent), lipids (3 percent AFDW) and unidentified organic matter (17 percent AFDW). Amino acids, humic acid, carbohydrates, and lipids were readily digested by the fish and the apparent digestibility of organic detritus exceeded 40 percent. The origin of amorphous detritus in the diet of these fish is unclear. Amorphous detritus is reported to result from the process of aggregation of dissolved organic matter, with an inorganic particle as the nucleus. However, the relative role of primary producers in the formation of this matter has not been determined. However, further work is required to establish a direct correlation between primary production and the quantity and quality of amorphous detritus.

A study of juvenile blue crabs in two Texas bays provided information on the comparative value of salt marsh, seagrass, and sand and mud bottoms as nursery habitat. In Christmas Bay, young crabs were most abundant in seagrass habitat followed by salt marsh and bare sand. Smallest juveniles were in the seagrass and larger juveniles were in salt marsh and on bare sand. In West Bay, where seagrasses were absent, the highest numbers of crabs occurred in the salt marsh as compared to bare mud. Here, smallest crabs were on bare mud bottom and larger crabs used the salt marsh. In both bays, the highest seasonal abundances were during fall recruitment (late August-mid December) and overwintering occurred, primarily on sand and mud bottoms. The results of this study and a similar investigation in Chesapeake Bay show that seagrass habitat is the preferred nursery of juvenile blue crabs. The northwestern Gulf of Mexico, however, has very little seagrass habitat and salt marshes must be utilized as alternative nursery habitat. Characteristics peculiar to marshes in the northwestern Gulf make this possible. A high degree of marsh reticulation, a low tidal amplitude and long inundation periods favor increased utilization of salt marsh for both protection and feeding. As a result, salt marshes in the northwestern Gulf are used more extensively than east coast marshes as nurseries by small blue crabs.

A preliminary assessment of mangrove prop root habitat utilization by pink shrimp and other commercial, recreational and forage species was initiated in the Rookery Bay National Estuarine Research Reserve near Naples, Florida. This feasibility study was conducted in cooperation with the Florida Department of Natural Resources Rookery Bay staff. The study intends to compare densities of organisms in flooded red mangrove prop roots and adjacent seagrass beds and non-vegetated open waters. The method employs a quantitative drop sampler, and a series of samples was collected in July 1988. Of particular interest are the questions of whether pink shrimp utilize habitats other than seagrass meadows and, if so, what are the functional aspects of these habitats for fishery species such as shrimp, sportfishes, blue crabs and stone crabs. Samplers in Florida Bay found little evidence that pink shrimp used the prop root habitats, so differences in habitat use may be regional.

Previous research has shown that burrowing protects brown shrimp from predation by estuarine fish. A simulation model is being developed to predict daily burrowing patterns and availability of shrimp to predators. Diel changes in light intensity are primarily responsible for movement by shrimp in and out of the substrate. To quantify the relationship, experiments were conducted to determine the threshold light intensities necessary to stimulate burrowing or elicit emergence. Measurements of water level and turbidity will be incorporated into the model due to their role in attenuation of light in the water column. This research represents an initial attempt to use a modeling approach for predicting predation-related mortality of juvenile brown shrimp in estuaries.

Data on the distribution, abundance and biomass of juvenile spotted seatrout and gray snapper, along with information on seagrasses, sediments, water temperature and salinity in basin and channel

habitats of Florida Bay were evaluated. Spotted seatrout juveniles were most prevalent in basin habitats in the western portion of the Bay, near the Gulf of Mexico, and were collected during almost every month sampled; smallest individuals were collected during summer. The habitats in which spotted seatrout occurred had deeper, more organic sediments with greater density and biomass of the seagrass than did non-seatrout areas. Gray snapper juveniles were most prominent in channels of the southeastern Bay but also occurred in basins located to the northwest. The presence or absence of gray snapper was related to the distribution of seagrass biomass, particularly that of *Thalassia testudinum* in the basins and *Syringodium* in the channels. These data suggest that seagrass meadows with mixtures of *Thalassia* and *Syringodium* or possibly *Halodule wrightii* are critical habitats for spotted seatrout and gray snapper in Florida Bay. Differences in the morphology of the seagrasses and the relative abundance and availability of prey organisms on and among seagrass shoots of different species enhance habitat heterogeneity. This heterogeneity presents ichthyofauna with a rich array of sub-environments each offering a different balance between feeding opportunity on the one hand and protection from predators on the other. Because of the interaction between fishery organism and seagrasses, the losses of seagrass that occurred in Florida Bay during 1988 due to unknown causes may result in changes in many fish populations that depend on seagrass habitats in the Bay.

In cooperation with the U.S. Fish and Wildlife Service and the Florida Department of Natural Resources, we investigated the utilization of seagrass habitats by manatees in a lagoon-estuarine ecosystem in southeast Florida. Research involved ground and aerial surveys of manatee movements and habitat use patterns. Direct observations were made on seagrass removal and the recovery of grazing areas at selected feeding sites. Where manatees feed in *Halodule* beds more than 90 percent of the total biomass is removed, including the roots and rhizomes. Examination of these sites as well as aerial photographs of other grazing areas indicates that *Halodule* recovers from grazing quite rapidly. The unique presence of this large herbivore in the Indian River and elsewhere in Florida raises the need for long-term studies of grazing to understand and interpret the distribution and abundance of the seagrass communities.

Field sampling of a high marsh area dominated by *Juncus roemarianus* was completed at the Cedar Island National Wildlife Refuge in North Carolina. The study, funded in part by the U.S. Fish and Wildlife Service and carried out in cooperation with East Carolina University, assessed: 1) which fishery species and sizes of individuals used the marsh surface; 2) what portion of the marsh is used; 3) food habitats of the resident species; and 4) linkages between the marsh and adjacent aquatic habitat from the perspective of fish movement. Preliminary data analyses demonstrated that numerous species of fish frequent this irregularly flooded *Juncus* marsh, although only five species (*Cyprinodon variegatus, Fundulus confluentus, F. luciae, Gambusia affinis,* and *F. heteroclitus*) were characteristic residents. We observed penetration into the marsh up to 2600 m from the nearest open water source, and data analyses indicate that resident fish movement throughout the marsh is limited only by availability of a surface layer of water and possibly available preferred food sources. Those fish with the widest dietary scope (*G. affinis* and *F. luciae*) and which key into no single food resource, penetrated deepest into the marsh. These marshes also serve as habitat for transient species, and 13 additional species were observed to move up onto the marsh surface when it was flooded and back off the marsh when it drained. These included mullets, flounder, silver perch, spotted seatrout, ladyfish and spot.

IMPACT OF ENVIRONMENTAL CHANGES ON HABITAT USE

Since 1982 we have studied the Ten Thousand Islands in southwest Florida to determine the quantitative effect of alteration of freshwater inflow patterns of the Golden Gate Estates canal system on estuarine dependent fish populations. This canal system drains 606 square kilometers of wetland and empties into 2.75-square-kilometer Faka Union Bay. Faka Union Bay is one of several small bays that are separated from the Gulf of Mexico by a labyrinth of small mangrove islands, but are hydraulically

connected to the gulf through well-defined passes. The most recent study, partially funded by the South Florida Water Management District, was designed to evaluate the possible effect of canal discharges on the recruitment of larval fish into Faka Union Bay. Water transport rates and larval fish concentrations in the pass to Faka Union Bay were compared to that in passes to two adjacent bays, Fakahatchee and Pumpkin. Nineteen taxa made up 94 percent of the total fish larvae collected. Statistical analyses with each of these taxa indicated that most occurred in significantly higher concentrations in the passes to Fakahatchee and, to a lesser extent, Pumpkin Bay. Canal discharges, which greatly exceeded flows to Faka Union Bay that would have occurred under natural conditions, apparently inhibited the transport of larvae into Faka Union Bay. Inverse gradients in salinity were found in the passes from the Gulf of Mexico to all three bays during both the wet season and the dry season. Inverse gradients during the wet season were caused by ponding outside the passes of high flows of water, principally from the canal. Inverse salinity gradients during the dry season were caused by lack of freshwater flow to replace loss of water to the bays from evaporation; this problem, too, is thought to have been aggravated by the canal system. Inverse gradients were most pronounced and frequent in the pass to Pumpkin Bay and may have inhibited the movement of larvae into Pumpkin Bay.

Alterations of freshwater inflow patterns and sediment resuspension can impact water clarity and available habitat for submerged aquatic vegetation. Federal and state concern for the decline of seagrasses in estuaries throughout the southeast has drawn attention to the need for determining the possible causes. In cooperation with the U.S. Fish and Wildlife Service and the Florida Department of Natural Resources, an examination was continued of the diurnal, seasonal, and annual submarine light regime in an estuary in southeast Florida, Hobe Sound. Hobe Sound is a shallow coastal lagoon typical of many of the estuarine seagrass habitats found throughout the southeast. Major sources of turbidity include resuspended sediments and organic matter from boat wake turbulence and wind waves as well as the *in situ* production of organic and inorganic suspended particles. A significant source of submarine light attenuation is attributed to stormwater runoff and non-local, wind-driven circulation associated with meteorological events such as the passage of tropical storms and cold fronts. One of our basic study objectives is to separate the natural processes from manageable anthropomorphic sources of turbidity. We have proposed to examine the effect of boat traffic on submarine light attenuation through implementation of an experimental slow speed no wake zone (ESSNWZ) in the Sound. Submarine photosynthetically active radiation (PAR), seagrass growth parameters, and seagrass distribution are being examined before implementation of the ESSNWZ. We have hypothesized that if the penetration of submarine PAR is improved by restricting boat wakes we can offset a decline in seagrass and possibly increase their abundance by managing boat traffic. We plan to monitor PAR and seagrass parameters during a three-year period following the establishment of the ESSNWZ to determine if this management practice is effective.

In conjunction with these studies we are examining the potential for using PAR as a turbidity standard for estuarine water quality in Florida. In May 1988 our staff participated in a workshop with personnel from water management agencies in Florida conducted by the South Florida Water Management District (SFWMD) on the use of PAR as standard and the needs for future research.

Freshwater inflow patterns also influence the delivery of nutrients to estuaries. We continued our research on the effects of major macronutrients (nitrogen and phosphorus) on the growth of seagrasses in subtropical environments of the southeastern United States. Long-term studies on the effect of phosphorus and nitrogen enrichment in carbonate sediments suggest that seagrasses in these environments are limited by phosphorus availability. Phosphorus enrichment results in a dramatic increase in *Halodule wrightii* over *Thalassia testudinum* suggesting the possibility that nutrient enrichment in general may cause shifts in the species composition of subtropical seagrass communities. Because of these observations, we have recommended that all future water management practices take into account the potential for impacts to the composition of seagrass

communities and the cascading effect this may have in regard to estuarine primary and secondary production.

FUNCTIONAL VALUE OF MITIGATED AND CREATED HABITATS

A Memorandum of Understanding (MOU) between the Florida Department of Natural Resources (FDNR) and National Marine Fisheries Service was initiated in May 1987 to determine if artificially propagated seagrass meadows provide habitat functions similar to those of the natural meadows they are intended to replace as a mitigation action. Research conducted under the MOU is coordinated with the Memorandum of Agreement (MOA) between NMFS and the Corps of Engineers on fishery habitat creation. Within the Tampa Bay area, joint sampling is conducted under the MOU with ongoing seagrass research by the city of Tampa and the University of South Florida.

Project goals are: 1) develop seagrass population growth and coverage models for the Tampa Bay area; 2) monitor the development of faunal abundance and composition and bacterial abundance and composition in created seagrass beds in comparison to natural, reference beds; and 3) provide management recommendations regarding seagrass restoration as a means of preserving, protecting, and enhancing fishery resources.

On three surveys conducted since May 1987, 180 dropnets have been deployed and sampled in 20 different locations around Tampa Bay. These treatments include natural seagrass, bare areas, transplanted *Halodule wrightii*, and *Caulerpa prolifera* beds. Year two designs call for increased effort in newly-established *Syringodium filiforme* and mixed *S. filiforme/H. wrightii* transplants for a total of 72 dropnets per survey trip. On these surveys, seagrass composition, numbers, size, and flowering are recorded as is macroalgal biomass and composition. Sediments are sampled biannually for bacterial abundance and size, organic and particle size content, chlorophyll and a phaeophytin.

Data from the first two surveys have been analyzed. The late planting of the seagrass in 1987 precluded substantial grow-out before the winter growth slowdown. Surviving planting units had begun to coalesce by May 1988. Survival of planting units varied with $\sim$ 40 percent at MacDill Air Force Base, 10 percent Shore Acres and Summer Resort Key and 75 percent at Coffeepot and Skeet Key, providing adequate bottom coverage to conduct surveys.

Seven species of macroalgae were recorded. Most striking was the enormous amount of biomass in the *Caulerpa prolifera* area at MacDill. This biomass fell off dramatically as winter approached. Among natural seagrass beds, *S. filiforme* maintained the highest level of algae throughout the study, perhaps because of their different leaf morphology.

As for fauna, transplanted areas were not obviously different from unplanted, bare areas after six months of transplant growth. There was a strong seasonal change in the amount of animals in *C. prolifera* beds as compared to natural seagrass which maintained elevated faunal abundance even into November. In August 1987, the natural seagrass beds supported higher levels of crabs and substantially higher numbers of fish than bare areas, transplants, or the *C. prolifera* bed. The *C. prolifera* bed did support more shrimp per unit area than any other treatment in August. By November, faunal abundance in *S. filiforme* beds increased dramatically, while other natural beds remained the same. Bare areas and transplant faunal numbers declined through this time while shrimp numbers in the *C. prolifera* bed declined dramatically, matching the decrease in biomass of the algae.

Commercially and recreationally valuable species (CSP) were present in all treatments. In August 1987, natural beds and *C. prolifera* beds were all similar in CSP abundance while bare areas and transplants supported many fewer CSP. In November 1987, bare areas, transplants and *C. prolifera* beds were equally low in CSP numbers, whereas natural seagrass beds were all higher in CSP numbers. The data suggest a differing though important role for *S. filiforme* beds in the pre-, and perhaps over-wintering of shrimp, including economically valuable ones.

This seagrass transplant study has allowed a continuation of the NMFS data acquisition on seagrass population growth and coverage rates in Tampa Bay, an area not previously monitored. Data collection on growth of five year old turtlegrass transplants in Florida also has continued as well. These data are used to update and refine existing models on seagrass growth and recovery in the southeast. The behavior of these empirical models is the foundation for recommendations by NMFS on many seagrass mitigation issues.

We have continued to address development of mitigated habitats through evaluation of sediment development since this can regulate not only the success of the plant community but also infaunal recruitment and development success. Microbial abundance in natural and transplanted seagrass bed and salt marsh sediments has been measured in North Carolina and Florida. Microorganisms form the base of the detrital food chain to fishery biomass; microbial extracellular products have sediment-binding properties, and therefore aide to reduce sediment erosion; and microbial metabolism regulates the benthic nitrogen cycle, as bacteria are uniquely capable of nitrogen-fixation, ammonification, nitrification, and denitrification. Overall, the presence of vascular plants is associated with higher numbers of bacteria and increased organics and silt clay percentages. Seagrasses vary in their effect on sediment parameters, however, depending both on species and geographic factors. It also appears that the response of these sediment parameters to introduction of transplants lags well behind establishment of the plants. Natural *Halodule wrightii* bed sediments in North Carolina do not support higher microbial sediments. The relatively low bacterial abundance in *Halodule* sediment is in contrast to those of *Zostera* beds, and can be attributed to the higher energy, non-depositional environment, characteristic of the shoals where *Halodule* typically occurs in North Carolina. First year results from seagrass transplants in Florida also demonstrate that different seagrass species in a similar geographic range have a variable effect on the sediment parameters we measure. Natural *Syringodium filiforme* and, to a lesser extent, *Halodule wrightii*, sediments have significantly higher bacterial abundances and percent organic matter content than do unvegetated and transplanted *Halodule* sediments. Another seagrass, *Thalassia testudinum*, appears to have much less influence on the sediment parameters we investigated. The contrast between *Halodule* bed sediments in Florida and North Carolina may be explained by the lower tidal range in south Florida, which enables *Halodule* to grow in deeper and more quiescent waters.

Data from first year saltmarsh transplants demonstrate that natural *Spartina* marshes have a 10-fold higher bacterial abundance and organic matter and silt-clay content than unvegetated intertidal sediments. Salt marsh transplant plots, with nearly complete recovery of aboveground plant biomass, had sediments indistinguishable from unvegetated plots.

We continued studies at two marsh mitigation sites in North Carolina designed to evaluate habitat development, one at Dills Creek (Newport River estuary) that was planted in 1985 and one at Pine Knoll Shores (Bogue Sound) that was planted in 1974. The Dills Creek site was high ground that had been graded to intertidal depths and planted with *Spartina alterniflora*. This mitigation site, located in the upper area of the Newport River estuary (salinity = 20-35 $^{0}/_{00}$), is in compensation for a marsh removed for development in Bogue Sound (salinity = 28-35 $^{0}/_{00}$). Fish and mobile invertebrate samples were collected monthly during 1986-88 using a block net method and compared with samples taken from an adjacent natural marsh and with samples collected from a marsh in Bogue Sound.

There is no question that the mitigation site is serving as a resource for fishes. However, on a per area basis, density is considerably lower than in the adjacent marsh. The dominant fish are similar in both areas: *Fundulus heteroclitus, Cyprinodon variegatus, Mugil* spp. A major difference, however, is the extremely low density of *Paralichthys lethostigma* and *Leiostomus xanthurus* collected at the mitigation site relative to the adjacent natural marsh. In addition, the area that was lost was characterized by a richer fauna consisting of the same species plus flounder, spotted seatrout, pigfish and silver perch. Brown shrimp, common to both natural marshes, are lacking in the mitigation site, and spot, also

common to natural marshes, are in low abundance. We hypothesize that this may be related to differences in the quality of sediments and food resources at the mitigation site relative to the adjacent natural site.

We are also evaluating sediment and plant parameters in conjunction with North Carolina State University. The organic and silt-clay content of the mitigated site are about 45 percent of the natural site while microbial abundance is 60 percent lower than that of natural site sediments. Plant biomass is significantly less at the mitigation site (227 g/m^2) relative to the natural site (501 g/m^2); the number of shoots/m^2 is less (181 vs 606); and the number of flowers present is less (10/m^2 vs 53/m^2). Standing dead material at the mitigation site is about half that of the natural marsh (96 g/m^2 vs 175 g/m^2). When compared to data collected in FY87, there is strong indication that the plantings are not doing well in the mitigated marsh: plant biomass - 360 g/m^2 in FY87, 227 g/m^2 in FY88; shoots/m^2 - 287 in FY87, 181 in FY88; flowers/m^2 - 32 in FY87, 10 in FY88. Sediment samples taken along transects in both the natural and mitigated marshes have demonstrated similar numbers of individuals, but a dominance by different invertebrate taxa. For example, nematodes and the polychaete *Streblospio benedicti* dominated the planted marsh whereas ostracods and the polychaete *Monopylephorus* spp. dominated the natural marsh macrofauna.

At the second site, block netting of a marsh transplanted in 1974 and an adjacent natural salt marsh was conducted on a monthly basis during 1987 and has been sampled once this year. Analysis of the plant communities by North Carolina State University has shown that the marshes are statistically similar. Although the two marshes are utilized by similar species, the order of abundance of the top five species differs somewhat. The total number of fish crossing 10 m of marsh frontage is similar at the two sites, with *Fundulus, Cyprinodon* and *Leiostomus* being among the dominant fish and *Paralichthys, Cynoscion* and penaeid shrimp being characteristic inhabits. The fish and mobile invertebrate sampling do indicate that this marsh creation area has persisted and has become similar to its natural counterparts.

HABITAT CREATION AND ENHANCEMENT STUDIES (NMFS/COE-MOA)

In the northern Gulf of Mexico, salt marsh macrostructure is strikingly reticulated, with islands of marsh interspersed among many small creeks and channels. This reticulated pattern with a large amount of marsh to open water edge may be partly responsible for increased marsh utilization and productivity of many fishery species in the region. Transplanted salt marshes do not appear to function like natural marshes for fishery organisms, and in part, this may be due to the reduced marsh to open water edge common in these created habitats.

Cooperative research between the U.S. Army Corps of Engineers Galveston District and the Galveston Laboratory is being conducted to examine the importance of the marsh/water interface for fishery organisms. The project was designed to determine the effect of experimental channels constructed in transplanted *Spartina alterniflora* marshes on the density patterns of fishery organisms. The objective of the pilot project is to determine whether the construction of access channels in transplanted marshes will increase utilization of the inner marsh surface by fishery organisms. Two sites have been identified in the Galveston Bay system, Chocolate Bay and Pelican Spit.

At the Chocolate Bay site, four channels were constructed in December 1986 in a previously established marsh. After 11 months, soil salinities near the channels were significantly lower than in the adjacent control sectors. Biomass and stem density of *Spartina* also appeared to increase near the channels in the inner marsh. In the spring of 1987, drop samples were collected at this site, and inner-marsh densities of crustaceans and fish were significantly higher in the experimental sectors with channels in comparison with the control areas. Sampling is being continued at this site, but these preliminary data suggest that the utility of transplanted marshes for estuarine fauna can be enhanced by increasing the amount of marsh/water edge.

The second site is located on Pelican Spit in Galveston Bay. Dredge material was placed along the shoreline of the Spit in November 1986, and a seven-acre *Spartina alterniflora* marsh was planted on this material during the spring of 1987. The marsh has become established with little erosion, and the construction of experimental channels is scheduled for the fall of 1988.

In North Carolina, three eroding dredge material islands were re-contoured by the COE to accommodate saltmarsh and seagrass plantings under a design developed by NMFS biologists and COE engineers in conjunction with the MOA pilot project. The salt marshes are being monitored by North Carolina State University (NCSU) and the Beaufort Laboratory (seagrass) for density and coverage. The influence of the grasses on erosion control is being evaluated by the NMFS, COE and NCSU together. Beaufort initiated biannual faunal sampling of these sites and their natural counterparts in September 1987 and again in June 1988, concomitant with ongoing biweekly environmental data collection (temperature, salinity, currents, water turbidity). These surveys and related functional evaluations of detrital and nutrient cycling will be conducted over the next three years as the systems mature to determine whether faunal abundances, faunal composition and trophic dynamics compare with natural counterparts of these systems. As part of these MOA studies in North Carolina, microbial parameters are being evaluated as measures of sediment development. These data collections are being analyzed.

Under the auspices of the MOA, the Beaufort Laboratory initiated evaluation of a seagrass transplant site and an oyster reef creation site in Chesapeake Bay. Both areas are pilot habitat creation sites on dredge material.

STATUS AND DISTRIBUTION OF FISHERIES SPECIES AND HABITATS

Investigations with the Ocean Assessments Division of NOAA were initiated during 1987 to compile data on the life history, distribution and abundance of selected fish and invertebrate species. During 1988, species profiles and data sheets for 35 species in 13 estuaries from Florida Bay to Mobile Bay have been completed. A report on this component of the Estuarine Living Marine Resources, National Estuarine Inventory is expected to be completed in December. Data on selected species and estuaries in the southeast are now being compiled from the literature and from consultation with local and regional experts. When completed, the Estuarine Living Marine Resources data base will enable comparisons among species groups, specific life stages, estuaries and geographic areas.

We are mapping wetland habitats to gain information needed on wetland acreages and distribution for data bases in developing predictive capabilities pertaining to wetland changes. In one study we are assessing acreage of 15 wetland types using a dot-grid matrix approach. In the second study, funded by the USEPA, we are mapping the distribution and species composition of seagrasses in areas of North Carolina.

In June 1986 NMFS and NOAA/OAD initiated an effort to quantify coastal wetlands in the lower 48 states using a grid sampling technique on maps produced by the National Wetlands Inventory (NW) of the U.S. Fish and Wildlife Service. An atlas summarizing grid sampled data from all available National Wetlands Inventory NW1 maps (412) in the northeast region (ME-CT) was sent to a contractor for printing in September 1988. This area included 1.5 million acres of forrested wetlands, 157,500 acres of tidal flats, 89,200 acres of salt marsh and 72,700 acres of fresh marsh. Grid sampling of all available NWI maps (1543) in the Gulf coast region (FL-TX) was completed in April 1988. This area included 7,474,700 acres of forested wetlands, 2,575,600 acres of fresh marsh, 2,469,200 acres of salt marsh, and 495,000 acres of tidal flat. A report summarizing these results is scheduled for completion in December 1988. With the completion of the Gulf coast, grid sampling continued in the mid-Atlantic region (NY-VA). To date, approximately 500 of the 700 maps available in the region have been sampled. A mid-Atlantic report is tentatively scheduled for completion in spring 1989. A

presentation summarizing grid sampled data from the Gulf coast region was given at the 16th annual conference on wetland restoration and creation, in Tampa Bay, Florida.

The study of distribution and abundance of seagrass, funded by PEA through the Albemarle-Pamlico Estuarine Study, is delineating seagrasses in Core Sound and eastern Pamlico Sound. A preliminary aerial survey led to an estimate of 200,000 acres of seagrass in North Carolina, second only to Florida in abundance of this fisheries habitat. Photography of the study area was completed and 220 stations were occupied in March 1988, producing 165 samples of SAV. Fifty-two of these samples (all those from southern Core Sound) were analyzed for species composition of seagrass. A series of eight demonstration chart products, seven seagrass overlays for U.S. Geological Service 7.5 minute quadrangle bases and one compiled chart covering the area from Cape Lookout to Drum Inlet were completed. Our improved photography resulted in increasing the known acreage of seagrasses between Cape Lookout and Drum Inlet by over 50 percent to 11,709 acres.

A three-year remote sensing study conducted in cooperation with Louisiana State University and funded by the Land-Processes Branch of NASA under their thematic-mapper program was completed. Thematic-mapper imagery from a LANDSAT satellite was used to quantify a stochastic spatial model designed to determine the quantitative relationships between wetland loss and change in the interface between marshland and water. Coastal marshes in Louisiana are disappearing at an approximate rate of 104 square kilometers a year. The purpose of the study was to explore a possible reason why fishery production has increased in Louisiana during the same period that coastal marsh area has decreased--despite the known importance of wetlands to the production of estuarine-dependent fishery organisms. Several prior studies had suggested that the length of the interface between land and water might be an important factor affecting fishery production. The remote sensing study determined that land-water interface increases in initial stages of marsh disintegration, reaches a maximum when approximately half the marshland has converted to water, and decreases thereafter. This established the fact that land-water interface can be increasing, even when marshland is disappearing--but only up to a point. Based on an examination of 2,322 square kilometers of salt and brackish marsh in the Barataria and Terrebonne basins, researchers estimated that the length of the marshland-water interface in central Louisiana is still increasing but will reach a maximum by 1995 and begin decreasing thereafter. A statistically significant relationship between brown shrimp catches and land-water interface was found. If the relationship is causal and there are no ameliorating effects, brown shrimp production in the area of the study may start a general decline after 1995. Offshore catches of shrimp dependent upon these estuaries also may decline.

In 1987, the Galveston Laboratory was asked to participate in the design and production of a presentation for the NOAA Estuarine Programs Office's Estuary of the Month series. A cooperative effort between federal, state, and local government agencies along with universities and private citizens culminated in the March 1988 presentation of "Galveston Bay: Issues, Resources, Status, and Management" to the Department of Commerce, the Environmental Protection Agency, and the State of Texas. The presentation was repeated in July in Houston, Texas, for the Texas Environmental Coalition, the Galveston Bay Foundation, and concerned citizens. The published proceedings will be available from the Estuarine Programs Office in the near future. The data syntheses were also used by the Texas Water Commission and the Governor of Texas to formally nominate Galveston Bay for the Environmental Protection Agency's National Estuary Program, in which candidate estuaries receive EPA funding to attack water pollution problems. Galveston Bay was accepted into the program.

The Beaufort Laboratory continues to be involved in the Albemarle-Pamlico Estuarine Study as part of the EPA's National Estuary Program.

TRACE METAL CHEMISTRY AND PHYSIOLOGY

Measurements of total dissolved concentrations and the chemical speciation of toxic metals in coastal waters were conducted in the waters of the northeast as part of the National Status and Trends

Program. The coastal waters of the northeastern states were selected for study because they are known to have significant inputs of anthropogenic contaminants including trace metals. A total of 102 water samples were collected from estuarine areas around New York City, Long Island Sound and coastal Connecticut, Block Island Sound, Narragansett Bay, and Boston Harbor and are being analyzed for concentrations of copper and zinc, the two most ubiquitous metal contaminants. These analyses will provide valuable data for the assessment of the magnitude and extent of trace metal contamination in the coastal waters of the northeast.

In addition to measuring total copper and zinc concentrations, one-third of the samples will be measured for free cupric ion concentrations and copper complexing capability of materials dissolved in the water. The analytical techniques used to measure the total metal will be flameless atomic absorption spectrophotometry and for the free cupric ion concentration a chemoluminescent technique. The latter is a newly developed ligand competition/chemoluminescent technique that has been recently developed in our laboratory. This measurement will give a more realistic determination of the availability of copper to fishery organisms.

The measurement of total dissolved copper concentration is not always the best estimate of the seriousness of copper contamination. In our laboratory we have shown that the toxicity of copper is related to the free cupric ion concentration rather than the total metal concentration. These measurements, therefore, will provide essential information for predicting the potential of copper to fishery organisms in contaminated coastal waters.

Another research activity, part of the National Status and Trends Program, is centered on the measurement of indicators of environmental contamination and disease in fish from U.S. coastal and estuarine waters. Concentrations of key contaminants (trace metals, chlorinated organic compounds and aromatic hydrocarbons) have been determined in target fish species (Atlantic croaker and spot) and sediments collected from 18 locations in the southeast region from North Carolina through Texas. In addition, target fish have been screened for visual evidence of disease (fin erosion, etc.) and histopathological abnormalities of the liver, kidney and gills which may be related to exposure to the key contaminants. Trace metal analyses have been conducted at the Beaufort Laboratory, organic analyses at Charleston Laboratory and histopathology at Oxford Laboratory (NEFC).

The program has a uniform set of sample collection and analytical protocols used by all participants and a commitment to long-term, regular periodic sampling. This will ensure nationwide intercomparability of data and provide a data base of long enough duration to detect trends in coastal and estuarine conditions.

Sampling is underway for the fifth year and program reorganization has added field sampling and trace metal analysis for the northeast Atlantic region to project participation and increased existing cooperative efforts with the Northwest Fisheries Center. Organic chemical and *Clostridium perfringens* analyses have been moved from Charleston to Seattle and Beaufort laboratories, respectively. Based on early data, sampling design has been modified to intensively sample several locations to better define their spatial and temporal scales of contamination while continuing to provide long-term monitoring for all locations. Additional measures of possible contaminant effects on fish have been included in this year's effort. These include growth rates using otolith analysis and RNA/DNA measurements and measurement of metal-induced (metallothionein) and organic induced (aryl hydrocarbon hydroxylase) liver proteins.

The physiological portion of the research has concentrated on the mechanisms of copper and zinc metabolism during molting in the blue crab. Current investigations concern the short-term changes in copper and zinc bound to the metal-binding protein, metallothionein, immediately following ecdysis. Significant changes in the amounts of copper bound to metallothionein occur within 90 minutes. These rapid changes are critical to the survival of the crab and provide further insight into the functional characteristics metallothioneins in natural unperturbed systems.

An investigation concerning shell disease in blue crabs from the Pamlico River estuary was initiated as part of the Albemarle/Pamlico Estuarine Study Program for FY89. This investigation is a cooperative study with the North Carolina State University School of Veterinary Medicine. The objective is to determine the mechanisms that blue crabs use to ward off infection and then to relate the possible influence of industrial activities in the area on the incidences of the disease among the blue crab population.

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PRODUCT QUALITY AND SAFETY

Research concerning quality and safety of seafood was centered at the Charleston Laboratory with cooperative research and communication interfaces with state and federal regulatory and environmental agencies. Specific areas of research concerned the production and distribution of fish oil base test materials, establishment of edibility and storage stability characteristics, nutritional and quality evaluation, process and product development, forensic activities concerning identification of endangered species and studies to distinguish wild from cultured fish, and critical seafood safety issues stemming from chemical and microbiological contamination of fish and shellfish.

FISH OIL (MENHADEN)

Biomedical Test Materials (BTM) Program

The formal establishment of the BTM Program in 1986 via the signing of a memorandum of understanding between NOAA and NIH/ADAMHA, provided the driving force for the production and distribution of fish oil based test materials. The test materials are provided to support nutritional and medical research related to the Omega-3 fatty acids found in marine lipids. The intent of the program is to provide a long-term supply of well characterized test materials of high quality and low variability in terms of composition. The following provides activity reports on several elements of this program.

Production of Biomedical Test Materials

Test materials currently in production and available for distribution to investigators include vacuum deodorized menhaden oil and concentrates of Omega-3 polyunsaturated fatty acid ethyl esters ($\geq$ 85 percent n-3 esters) that are produced by physical and chemical separation techniques. Partially refined menhaden oil, winterized, alkali-refined, and bleached by the supplier, is deodorized in a two stage wiped film molecular still to reduce cholesterol, organic contaminants, and fishy odors and flavors to very low or undetectable levels. This vacuum stripped oil serves both as a test material and as starting material for production of Omega-3 concentrates. In this process, refined oil is first transesterified to produce ethyl esters. The polyunsaturated esters are then concentrated by reacting the esters with urea dissolved in hot ethyl alcohol. When this hot solution is cooled, the straight chained saturated and monounsaturated esters form adducts with urea and precipitate from the alcoholic solution, thereby concentrating the non-adducted polyunsaturates. Following removal of the alcohol in the film evaporator, the concentrate is washed with deionized water to remove residual urea and alcohol. Finally, the neat esters are distilled in a two-stage glass wiped film molecular still to reduce the percentage of 16 carbon polyunsaturates and to eliminate oxidation products, polymers, color bodies, and any remaining cholesterol. Current monthly production rates are 1,000 kg refined oil and 50 kg of concentrates. During FY88, more than 4,200 kg of oil, 400 kg of crude concentrates, and 170 kg of distilled esters were produced.

In addition to refined oil and Omega-3 concentrates, the NMFS agreed to provide fractions of EPA (20:5n-3) and DHA (22:6n-3), each $\geq$ 90 percent pure, and purified EPA and DHA, each $\geq$ 95 percent pure. To produce EPA and DHA fractions, a supercritical fluid (SCF) CO_2 fractionator, designed by NMFS Seattle Laboratory personnel, was installed in the pilot plant along with the necessary CO_2 supply tank and compressor on the concrete pad outside the plant. Distilled concentrates (200 g) were fractionated to yield 70 g fractions of 85 percent pure EPA and 16 g fractions of 90 percent pure DHA in one run. When optimized, 90 percent pure EPA, possibly at a somewhat lower yield, should be easily attainable.

A preparative-scale high performance liquid chromatograph (HPLC), necessary for the production of pure EPA and DHA, was tested, using three different columns (all C18 reverse phase, 57 mm x

30 cm). The *poorest* column tested produced fractions of 95 percent pure EPA and 89 percent pure DHA. A 6 g sample of an EPA-rich (85 percent) fraction from the SCF fractionator was chromatographed on the best of the three columns to produce 99.6 percent pure EPA in a single pass, with good baseline separation from DHA. A process-scale HPLC equipped with a 10 cm x 60 cm C18 reverse phase is scheduled for delivery the last week in October.

An experiment to determine the feasibility of producing restructured triacylglycerols by transesterification of refined oil with distilled concentrates, using immobilized lipase as a catalyst, is underway.

AOAC Collaborative GLC Study

A collaborative study of the fatty acid composition of marine organisms was developed with the Technical University of Nova Scotia, with the support of the Association of Official Analytical Chemists. Current official methods of fatty acid analysis employ packed GLC columns only, but these columns have insufficient resolution to separate the numerous components, frequently 60-80 different fatty acids, found in marine fats and oils. Therefore, the study required the use of wall-coated, open-tubular (capillary) columns with a bonded liquid phase. The samples included soft-gel encapsulated fish oils (four oils and one blind duplicate) and a single commercial ethyl ester preparation. Of 32 potential participants who received samples and instructions, 20 responded with results. The raw data have been sent to the AOAC for analysis by a staff statistician.

Quality Assurance/Quality Control of Biomedical Test Materials (QA/AC)

The biomedical test materials are analyzed for 33 different parameters. Three general categories of analyses are performed: 1)lipid composition; 2) products of oxidative and hydrolytic degradation; and 3) contaminants. QA was provided on 24 lots of oil and ester concentrates sent to researchers this year. Analytical support was provided to the Production Project for research and development of new test materials and to researchers receiving the test materials.

A BTM Program Quality Assurance and Quality Control Methods Manual was produced and has been through peer review. After final edits, it will be submitted for publication as a NOAA Technical Report.

Analytical methods include the analysis of trace levels of urea in ethyl ester concentrates. Methods being developed are the analysis of PCBs and pesticides in ester concentrates and the analysis of PCBs and pesticides in oils using a sweep-codistillation apparatus for sample clean-up. Data analysis for PCBs and pesticides has been streamlined by computer-interfacing the gas chromatograph. Existing analytical capabilities for metals analysis were enhanced this year by the development of a microwave digestion method for analysis of metals in oils and esters, the addition of an automated vapor generator for the analysis of As, Se, and Hg, and the purchase of a new atomic absorption spectrophotometer.

All fish oil biomedical test materials are being subjected to formal stability testing for the purpose of advising clinical investigators on how best to store test materials and for what duration of time. Stability test studies completed or in progress follow:

(1) A 12-month study on the stability of gelatin encapsulated steam-deodorized menhaden oil was completed. No significant decrease in product quality was observed in this time. A manuscript was submitted for publication as a NOAA Technical Report.

(2) A one-year study on storage stability of microencapsulated oil and esters at three temperatures, -20, 5, 23°C was initiated October 1987.

(3) An 18-month storage study of bulk oil containing antioxidants was initiated January 1988.

(4) An 18-month study on bulk oil without antioxidants was initiated May 1988.

(5) An 18-month study on bulk ester concentrate was initiated July 1988.

(6) An 18-month study on aerosol-canned "Omega-whip" containing the ester concentrate was initiated August 1988.

(7) Method development has been initiated for a stability study on aerosol-canned oils and esters.

Lipid Analytical Services

A significant improvement in the lipid analytical expertise was established this year. The addition of Gas Chromatography/Mass Spectroscopy (GC/MS) for the analysis of fatty acids has been invaluable for confirmation of fatty acid identification. BTM Program products (both those produced at the Charleston Laboratory and deuterated fatty acids produced by contract), latent species lipids (butterfish, coastal herrings, etc.) and forensics samples (related to endangered species law enforcement) were analyzed using this state-of-art methodology.

Continuing evaluation and updating of established lipid analytical methodologies included participation in an international collaborative study for the analysis of marine fatty acids by capillary GC.

Lipid compositional methodologies and analyses were provided throughout the year for the QA/QC of BTM and for ongoing studies to determine the storage stability of these products. Analytical support was given for the development of new products including purified eicosapentaenoic (EPA) and docosahexaenoic (DHA) acids and glycerides containing enhanced amounts of EPA and DHA.

Samples analyzed for industry and universities included commercially produced fish oils, catfish lipids, commercial fish mean lipids, cat food lipids, and bovine milk lipids.

Distribution Management

There are currently 67 BTM program researchers approved for test materials. The test materials thus far consist of bulk ethyl esters, refined fish oil in bulk and in soft gelatin one-gram capsules as well as placebo oils in gelatin capsules. A computerized data base has been established for listing information on each researcher and for tracking shipments of BTMs. The Charleston Laboratory provides liaison support for each approved researcher in analyzing antioxidants in placebo oils and provides instructions in balancing antioxidant concentration and assistance with experimental design. New dosage/delivery systems were investigated for the BTM including aerosol liquid and whipped products. Initial aerosol studies focused on a valve component compatibility study and a 30-day accelerated study at 140°F with fish oil and ethyl ester. Thus far, results are favorable for the potential use of BTM in aerosol cans. A study was also initiated to evaluate flavors in effectively masking fish oil so that placebo oils are non-discernible from the fish oil.

A 12-month interagency (NIH/ADAMHA, USDA and DOC [NOAA]) microencapsulation feasibility investigation was initiated in October 1988. Microencapsulated fish oil, ethyl ester, and corn oil were produced by two different companies and evaluated during animal feeding studies for acceptability and assimilation. A QA/AC stability study was conducted with the microcapsules over the 12-month period at three different temperatures.

PROCESSING AND COMPOSITION STUDIES (LATENT RESOURCES)

Gulf Butterfish, Processing and Storage

Onboard refrigerated holding and freezing experiments were performed with Gulf butterfish during the April 1988 cruise of the NOAA R/V *Chapman*. Fresh butterfish were either stored in ice or in refrigerated seawater (RSM) for zero to three days before they were plate frozen and stored at -20°C. These samples, plus a sample frozen in a brine-sugar solution similar to that used by commercial shrimpers, were compared with plated frozen controls after six weeks of frozen storage. In addition to the evaluation of 11 sensory characteristics, TBA values, salt content, and proximate compositions were determined. There were no significant sensory differences between iced samples and controls, but both RSW-stored and brine frozen samples were significantly saltier.

Gulf Butterfish, Chemical Composition

Proximate chemical compositions were determined for nine fillet (with skin) samples and five whole samples of Gulf butterfish. Indications are that the fat content of whole butterfish and the fillets with skin is about the same for fish that are 100 grams or more in weight. Samples of other latent species, including rough scad, chub mackerel and harvestfish were also analyzed and fatty acid profiles will be determined for most of the samples. The fatty acid analyses for 32 southeastern finfish species have been converted to a grams per 100 grams basis and alternate proximate and fatty acid formats have been developed for a popular publication.

The NMFS Nutritional Data Base was successfully compressed under a Clemson Sea Grant project, and we have installed it on a 386/16 personal computer. Updating and addition of fatty acid data have not yet been accomplished. The incorporation of a standard data base system is planned for greater ease of editing.

Cultured Species Studies

A 12-month frozen storage study was completed on cultured hybrid striped bass from the South Carolina Waddell Mariculture Center. Sensory and chemical tests were conducted every two months on vacuum packaged or glazed and boxed fillets and headed and gutted (H&G) fish stored at -20°C. Product form had more effect on sensory characteristics than did the packaging method. The skinless fillets became drier, more rancid and more yellow than the H&G hybrids during frozen storage. Unlike the flavor changes, however, differences in texture were minor. All fish became harder, chewier and more flaky during frozen storage.

Iced and frozen storage studies were also conducted on red drum cultured at the Waddell Center. Sensory, chemical, and microbiological studies were performed with H&G fish or skinless fillets during iced storage. Sensory and chemical tests were also conducted every two months on vacuum packaged or glazed fillets or H&G fish stored at -20°C.

SURIMI (MENHADEN)

Surimi Demonstration Plant

Atlantic menhaden surimi processing operations at the demonstration plant in Reedville, Virginia continued through October 1987. Under the NMFS contract, with technical monitoring by the Charleston Laboratory, more than 40,000 lbs of menhaden surimi were produced in 1987 and functional characteristics suitable for machine processing into analog products were demonstrated. Other types of food product applications are required, however, because of the dark color of the menhaden surimi. Experimental samples have been distributed to many researchers and food manufacturers.

Congress appropriated funds to extend the menhaden surimi contract for an additional year through January 1989. A new system for bulk unloading and handling of food grade menhaden was put into operation this year and several new pieces of equipment have been tested to improve product color and/or yields. A series of replicate production runs under standard conditions during the latter part of the 1988 season will help to establish reproducible product specifications and determine the economic feasibility of the menhaden surimi process.

Surimi or Minced Fish in Hot Dogs

We continued to prepare experimental samples of frankfurters containing different levels of minced fish or surimi in support of the USDA research on nitrosamines. The first six-month frozen storage study with Alaskan pollock has been completed. Two additional pollock frozen storage studies and one with Atlantic menhaden are in progress. Two additional studies with menhaden are planned. Mince, washed mince, and surimi at levels of 15 percent and 50 percent are included in each set of hot dogs. The USDA has measured residual nitrite and amines, and has measured dimethylnitrosamine contents of the frankfurters cooked by five different methods. We have performed sensory analyses of the franks and measured dimethylamines. Sensory properties are generally good and when the studies are completed the safety of frankfurters containing minced fish will be well documented in regard to nitrosamines.

LAW ENFORCEMENT SUPPORT (ENDANGERED SPECIES)

Forensic activities during the past year have centered on 1) program development, 2) endangered species identification, and 3) development of techniques to distinguish wild from cultured hybrid striped bass.

Program Development

Contacts were made with several federal, state, and university personnel for a twofold purpose: 1) to identify the mission and activities of existing forensic programs; and 2) to gather information on possible forensic techniques such as mitochondrial DNA and enzyme antibody methods.

Endangered Species ID

During the past year the Charleston Laboratory, in cooperation with South Carolina enforcement agents, identified a "suspect" meat sample as leatherback using isoelectric focusing. This information will be used by enforcement personnel as chemical evidence in court.

Lipid analyses of turtle eggs and turtle oil cosmetic samples received from USF&W personnel were conducted to determine species identification. Appropriate reports were submitted to provide evidence for prosecution.

In cooperation with NMFS enforcement agents we are currently identifying the species of suspect sea turtle meat seized at the San Francisco airport.

Our laboratory has a cooperative agreement with the South Carolina Wildlife and Marine Resources Department (SCWMRD) to conduct a limited number of sea turtle necropsies should the need arise. To date, one necropsy on a small loggerhead turtle has been conducted.

Studies to Distinguish Wild from Cultured Fish

The striped bass or its hybrids are a focus of commercial aquaculture in any states. In states such as South Carolina these "game" fish support substantial recreational activities. Consequently, a major concern has been voiced by the recreational and law enforcement sectors dealing with poaching of these fish.

To address this concern over poaching the Charleston Laboratory and the SCWMRD initiated a cooperative program focused on the identification of a biochemical technique to differentiate wild from cultured fish. In essence, such work complements other cooperative research activities between these agencies which is examining the effects of different commercial rations on growth, proximate compositions, and fatty acid profiles of cultured fish.

To date research has been conducted on the use of fatty acid profiles to distinguish wild from cultured fish. The effects of various commercial diets on the fatty acid profiles of cultured hybrid striped bass have been analyzed. Preliminary fatty acid analyses of wild striped bass and wild hybrids have been accomplished. A paper entitled: "Preliminary Results on the Use of Fatty Acid Profiles to Distinguish Wild from Cultured Fish" was presented at the Law Enforcement Aquaculture Meeting, Columbia, South Carolina. A paper on "the Use of Fatty Acid Profiles to Distinguish Wild from Cultured Fish: A Possible Enforcement Tool" is being prepared for the Southeast Division Meeting of the American Fisheries Society.

MOLLUSCAN SHELLFISH

Research coordination activities and studies on enteric virus methodology and depuration are described in the section of this report entitled "Molluscan Shellfish."

BENTHIC SURVEILLANCE OF ORGANIC CONTAMINANTS

The Benthic Surveillance Project of NOAA's National Status and Trends Program has completed its fourth year of operation. This program is designed to characterize concentrations of key contaminants (trace elements, synthetic organics, and petroleum hydrocarbons) in fish and sediments and provide data on incidence of fish disease from 50 coastal and estuarine sites nationwide. In the southeast, collection of Cycle IV samples ended in mid-October. Chemical analyses of liver, bile, stomach contents, and sediment are continuing at the Charleston and Beaufort Laboratories on previously collected samples. Quality assurance activities, in association with the National Bureau of Standards, continue to be pursued by both laboratories to assure that high quality data are produced. Analytical procedures are evolving with the state of the art, while concurrently every effort has been made to ensure comparability of data over the entire span of the program. The assay of sediment samples from the east and west coasts, for *Clostridium perfringens* spores, an indicator of sewage pollution, was continued for Cycle V samples at Charleston. An interpretive report is being prepared to disseminate the results from Cycles I and II. Comparisons of data from this multi-year program should help to assess trends in the quality of the marine environment.

BIOTOXIN (CIGUATERA) RESEARCH (REEF RESOURCES)

Ciguatera is a tropical fish-borne disease in which both a lipid soluble (ciguatoxin) and water soluble (maitotoxin) toxin have been implicated. The determination of toxin structure, cell binding characteristics, and sensitive assays are all dependent on an increased, dependable supply of toxins. We have developed a mass culture technique using a *G. toxicus* dinoflagellate strain obtained from Fort-de-France Bay near the Caribbean island of Martinique to increase our production of toxin.

Culture

The clones are maintained at 27° under an illumination of 30-40 $\mu E.M^{-2}\ s^{-1}$ and a 16:8 hours light:dark cycle without aeration. Cells are grown in an enriched seawater medium (K-medium) with seawater collected from Vero Beach, Florida or Charleston, South Carolina. The vitamin mixtures and

enrichments for the media are prepared in concentrated stocks and sterilized. *G. toxicus* clones are harvested by filtration through 12 µm polycarbonate membranes and innoculated for mass culture into 12 liter glass carbon microcarrier flasks. The cells are kept in suspension by a combination of magnetic stirring and aeration.

Currently, we are harvesting 270.5 liters per month yielding $1.0^7 \times 10^9$ cells.

PURIFICATION

The following procedures are being used to extract and purify the toxin produced by *G. toxicus*:

extraction in 80% methanol,
water/ether separation,
butanol/water separation,
cold acetone precipitation,
silicic acid chromatography,
gel filtration (G-50),
gel filtration (LH-20), and
HPLC (C-18).

The cells are placed in 80 percent methanol and lysed by use of a probe sonnicator. Following 48 hours of shaking at 60°C, the cellular remains are filtered through a teflon membrane filter. The filtrate is evaporated to dryness, brought up in water and partitioned with ether three times. The water soluble fraction is then partitioned with butanol three times. The toxin, now in butanol, can be concentrated by evaporation. Following a wash with cold acetone the toxin is brought up in methanol and chromatographed on silicic acid. The *G. toxicus* toxin is eluted from the silicic acid with chloroform: methanol 6:4. Gel filtration of the toxin using Sephadex G-50 and LH-20 is used to separate two more of the contaminating pigments prior to placing the toxin preparation on a reverse phase C-18 HPLC semi-preparative column.

Toxicity is determined by using a mouse bioassay to determine the LD 50 of the toxin in dry weight of toxin (mg) per kilogram of mice. The LD 50 of our whole cells is .568 mg/kg. The LD 50 of our methanol crude extract is .159 mg/kg, and the LD 50 of the toxic fraction eluting from the HPLC is .006 mg/kg.

MODEL SEAFOOD SURVEILLANCE PROGRAM

Congress identified funds in 1987 to design a program of certification and surveillance of fishery products to protect the consuming public in areas of safety, quality, and economic fraud. Staff of the Charleston Laboratory are designated members of the core team of scientists of this Model Seafood Surveillance Program which is administered by NMFS headquarters. Key aspects of the study include hazard analyses at critical control points during the handling of products and methods to assure equitability in surveillance of imported and domestically-produced products. The results of the study, which will include economic analyses, will be provided to Congress in three years at which time they will evaluate the design and recommendations and decide if a new seafood inspection is feasible.

RECOGNITION BY MARINE FISHERIES REVIEW

Jeanne Joseph received the NMFS Publications Advisory Committee's recognition of Honorable Mention for her publication entitled "Fatty Acid Composition of Commercial Menhaden, *Brevoortia* spp.

Oils, 1982 and 1983" which appeared in a 1985 issue of the *Marine Fisheries Review*. The paper met the requirements of being an outstanding original scientific work contributing to the NMFS mission.

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