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Annual Report

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1987 ANNUAL REPORT

SOUTHEAST FISHERIES CENTER

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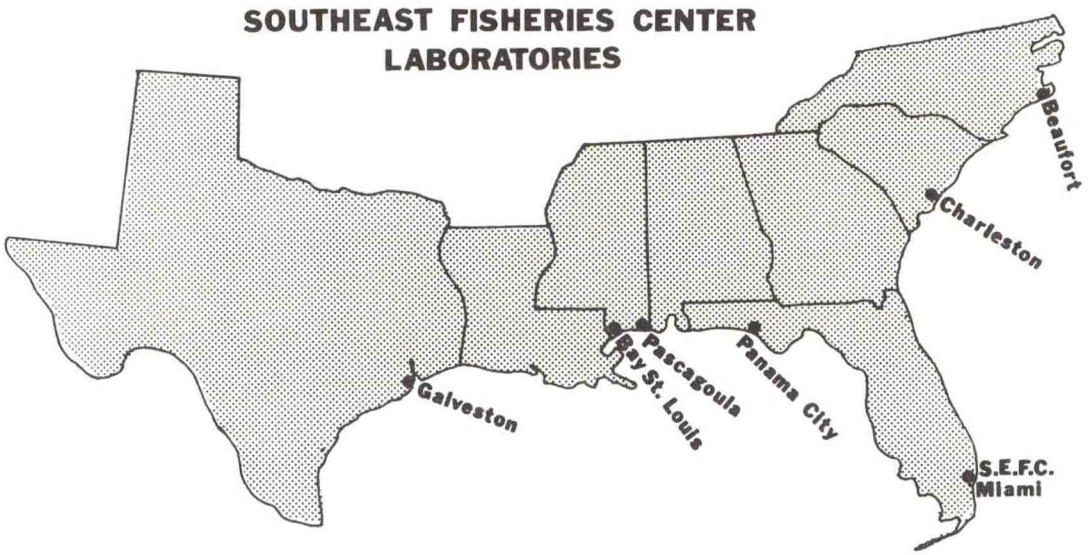
The Southeast Fisheries Center's Annual Report is an administrative report on key Center research activities during the year. The Program Managers' names and phone numbers have been included at the end of each section to contact for more information. Additional copies of this report are available from 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, which falls under the U.S. Department of Commerce.

SEFC headquarters offices are in Miami, Florida and research laboratories are located in Beaufort, North Carolina; Charleston, South Carolina; Miami, Florida; Panama City, Florida; NSTL 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.

The SEFC's 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. SEFC 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. Center 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, initiated in October 1984, is managed by the Mississippi Laboratories with cooperation from other Center laboratories through predator prey and basic life history research (Panama City), stock assessment and predator-prey research (Beaufort), processing and product development (Charleston), and early life history studies of target species and fishing vessel information (Miami). The NOAA Ships *CHAPMAN* and *OREGON II* provide the sea-going capabilities to conduct the required research. The fishing industry, Gulf States Marine Fisheries Commission and Sea Grant are involved in planning and evaluating the program.

The primary target group of the program are fish referred to as coastal herring. Examples include Spanish sardine, round herring, scaled sardine, anchovies, rough scad, bigeye scad, Atlantic bumper, ballyhoo, and chub mackerel. While not all true herrings, these species exhibit common characteristics in that they school pelagically, are relatively small (*i.e.*, 6 to 8 inches), swim rapidly, and are relatively short-lived. Other target species include little tunny, blackfin tuna, blue runner, squids, Gulf butterfish, harvestfish, sharks and deep-sea crabs.

Coastal herrings were emphasized initially because previous work indicated an annual harvest potential of 1 to 5 million metric tons based on egg and larvae surveys in the eastern Gulf of Mexico. Historically, efforts to assess adult stocks were unsuccessful because the fish were able to escape existing fish gear. Improvements/modifications in gear technology have improved trawl catches during latent resource assessment surveys.

BUTTERFISH

Gear modifications to prevent escapement of butterfish and herrings after entering the trawl were developed and evaluated. One modification incorporating a webbed funnel to reduce escapement during net haulback worked extremely well and should facilitate consistent catch rates during future surveys. Several gear manufacturers have expressed interest in incorporating the concept in their nets.

Two New England freezer stern trawlers arrived in the northern Gulf of Mexico in mid-February to fish for butterfish, with a third vessel arriving later. The vessels operated out of, and landed catches at, Pascagoula through the end of May. Observer coverage was provided and over one-million pounds were landed. Ex-vessel price almost tripled over last year's. In addition to butterfish, rough scad were landed and marketed overseas. A number of Gulf fishing companies have shown interest in entering the fishery.

Gulf butterfish trawling data collected from four research cruises in the northern Gulf of Mexico were analyzed to relate butterfish distributions to environmental factors. Individual butterfish were systematically distributed over depth and bottom temperatures, which were linearly related, although large schools were not. Other measured environmental factors which may be indicative of temporal and spatial locations of large schools are days after new moon, sea surface temperature, and sea surface salinity. Satellite imagery collected in 1985 and 1986 suggested a spatial relationship of large schools of butterfish to interfaces formed when warmer, chlorophyll depleted offshore waters intrude into shelf waters. Two such occurrences were documented: one in the spring of 1985 and the second in the spring of 1986. Butterfish catches increased drastically along the interfaces and remained high until the water masses receded or dispersed.

GEAR DEVELOPMENT

Assistance was provided to the Gulf Coast Research Laboratory vessel *TOMMY MUNRO* to install a net reel and other hardware to facilitate sampling with stern trawling gear. The vessel participated with the *CHAPMAN* in comparative gear studies during April-May. *TOMMY MUNRO* used bottom and midwater trawl configurations to sample butterfish concentrations and conduct comparative analyses of catch rates.

A video tape montage was prepared to demonstrate trawl gear configurations and fish behavior in trawls. Copies were made available to gear researchers, commercial trawl manufacturers and fishermen interested in developing latent resource fisheries.

A two-year effort to develop and test bottom trawling gear for capturing latent resource species on or near bottom was completed. The gear, rigging, and operational tactics were standardized for use during exploratory fishing for latent species and butterfish surveys. Gear trials resulted in a state-of-the-art, large mesh, high opening, bottom trawl commercially produced by Shuman Trawl of Hope Valley, Rhode Island. During development, behavioral observations by diver scientists and the *ROV MANTA* produced modifications to the basic trawl design and fishing tactics that overcame capture problems and produced a system capable of sampling the fast swimming, elusive semi-pelagic species of the Gulf of Mexico. Modifications included a headrope kite to provide maximum headrope height at higher towing speeds and an accelerator funnel to prevent fish escapement during net haulback. These modifications and development of an operational tactic called pulsing produced an efficient sampling system for a wide range of latent resource species. The accelerator funnel was adopted for use by some commercial vessels. Use of the sampling on the *CHAPMAN* resulted in demonstration of commercial catch rates of several important species including butterfish, squid--for the first time in the Gulf of Mexico--and several coastal pelagic species with commercial potential.

A smaller trawl design was developed for sampling and exploratory fishing of latent resources by the *OREGON II* and smaller state research vessels involved in SEAMAP surveys. The trawl is called a 3 and 1 trawl. It is a state-of-the-art, large mesh, high opening design and incorporates the accelerator funnel. The net has a 65' headrope length and is designed for use with either 8' and 40" flat wooden doors or 3 square meter steel "V" doors. The net will standardize butterfish and latent resource sampling gear on the *OREGON II*.

ASSESSMENT CRUISES

A trawl evaluation cruise was conducted during October 1986 with the NOAA Ships *CHAPMAN* and *OREGON II*. Divers mensurated the 80-foot headrope fish trawls and determined optimum trawl opening on the *OREGON II*. Fishing stations were sampled with single and multiple drags to evaluate day/night catches, bridled versus non-bridled catches, and catch rate differences between simultaneously towed 40 and 80-foot trawls on the *OREGON II*. Analyses of catch rates are in progress; however, preliminary indications are higher day catches. Trawl opening on the bridled 80-foot trawl was surprisingly good on the *OREGON II*: it opened higher and wider than a comparable trawl towed with double warp off the *CHAPMAN*. Preliminary evaluation of catch rates of the bridled versus non-bridled trawls suggests little or no impact by the briddle. The *MANTA II* submersible was tested to depths of 100 fathoms during the *CHAPMAN* cruise.

An exploratory survey was conducted aboard the *CHAPMAN* during February to access the distribution of squid off the Florida coast in the eastern Gulf of Mexico in the area of the Dry Tortugas. Squid and pelagic fish stock distribution and abundance were investigated. Gear modifications developed during the October cruise were used to increase sampling efficiency of latent resource trawls.

A comparative gear and vessel study was conducted from April 7 to 18 between the *R/V CHAPMAN* and *TOMMY MUNRO* in the northeastern Gulf in waters 60-120 fm. The objective was to determine vessel differences in catch, and to determine differences in catch between the 80-ft butterfish trawl and the 23-ft Shuman trawl. Nine stations with three replicate, side-by-side tows at each station were made by both vessels pulling the 80-ft trawls with 3-sq. meter "V" doors. During the second phase of the experiment, the *CHAPMAN* pulled a 123-ft Shuman trawl with 4-sq. meter super "V" doors.

In cooperation with the Mexican National Institute of Fisheries, the *CHAPMAN* conducted a survey in the southwestern Gulf of Mexico to determine the existence and location of latent resources off the Mexican coast. A total of 1275 nautical miles were acoustically surveyed, and 11 midwater and 20

bottom trawl stations were completed. *MANTA* was used to observe trawl characteristics and acoustic targets. Catches indicated a number of latent resource species present.

ENGINEERING

The *MANTA II* submersible was used on *CHAPMAN* latent resource cruises to study and evaluate gear, fish behavior and sonar targets. Several modifications were made to enhance the system: a new television camera and forward sonar were installed; control hydraulic lines were replaced; solid-state power control circuits were developed and the system was upgraded for 150-fm depth capability.

The complete submersible system was transported to Hawaii in mid-July in support of a cooperative project with NURP. Sea trials were successfully completed on August 1. During the cruise several conductors separated in the umbilical cable necessitating at-sea repair. All cruise objectives for data acquisition were met until the submersible was lost on August 7. An investigative committee met at NSTL on August 19-20 to critique the incident and recommend a future course of action.

The forward scanning sonar on the *CHAPMAN* is being upgraded and a replacement self-contained CTD system was installed. A plate freezer was also installed on the vessel to improve sample preservation.

All cruise data were entered into the data base. Statistical analyses were performed, and plots, printouts and summaries were produced. Data from commercial vessel catch and effort were included. Editing has been completed and data are available.

REMOTE SENSING

Satellite data were used to produce sea surface temperature (SST) images of the Gulf of Mexico in an experiment to direct commercial fishing vessels to areas where gulf butterfish were thought to form large schools susceptible to trawling efforts.

SST images were also used to direct the *OREGON II* to thermal interfaces, especially the edge of the Gulf Loop Current, so that ichthyoplankton samples could be taken on transects perpendicular to the interfaces. Larval bluefin tuna were of special interest. When the bluefin tuna ichthyoplankton are sorted and enumerated, the data will be used in conjunction with the satellite images for distribution studies.

AVHRR images were used in studies of the Mississippi River plume. Environmental and biological data collected in Louisiana will be used in conjunction with visible and SST images of the plume to determine the impact of the plume on aquatic organisms.

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MACKERELS

The Fishery Management Plan (FMP) for Coastal Migratory Pelagic Resources concerns seven species: king mackerel, Spanish mackerel, cero, cobia, bluefish, dolphin, and little tunny. The FMP contains regulations for only three of these, viz., king mackerel, Spanish mackerel, and cobia. Of these three, research efforts of the SEFC have been directed toward king and Spanish mackerels.

Amendment 2 to the FMP became effective on June 30, 1987. Among the changes implemented by this amendment were: separation of Spanish mackerel into Gulf and Atlantic Migratory Groups for management purposes; permits for commercial boats and charterboats; Spanish mackerel bag limits for recreational fishermen; and prohibition of the use of purse seines in the fishery for both groups of Spanish mackerel and for the Gulf Migratory Group of king mackerel.

Research activities continued to emphasize the collection of vital statistics and biological studies principally for developing data bases for stock assessment purposes. Two new projects were initiated in 1987: (1) the development of indices of abundance with the use of passive fishing gear; and (2) a project concerning the nature of catches in the drift-gill-net fishery for king mackerel off southeast Florida.

STOCK ASSESSMENT

The results of the annual stock assessment were reviewed by the Mackerel Stock Assessment Panel in March. The panel agreed that the spawning stock biomass of the Gulf migratory king mackerel continued to decline, while that of the Atlantic migratory king mackerel continued to increase. Calculations of spawning stock biomass for Spanish mackerel provided some evidence of increased recruitment in recent years, more so in the Gulf stock than in the Atlantic stock.

Allowable biological catches (ABCs) were determined to be:

Gulf king mackerel:	0.6 to 2.7 million pounds
Atlantic king mackerel:	6.9 to 15.4 million pounds
Gulf Spanish mackerel:	1.9 to 4.0 million pounds
Atlantic Spanish mackerel:	1.7 to 3.1 million pounds

These ABCs were recommended to the councils, who in turn set total allowable catches (TACs) within these ranges as follows:

Gulf king mackerel:	2.20 million pounds
Atlantic king mackerel:	9.68 million pounds
Gulf Spanish mackerel:	2.50 million pounds
Atlantic Spanish mackerel:	3.10 million pounds

The councils also established fishing years as July 1 to June 30 in the Gulf and April 1 to March 31 in the Atlantic for both species.

LANDINGS

Gulf Migratory King Mackerel (Fishing Year: July 1 to June 30): The commercial fishery was closed for the second consecutive year. Estimated landings had exceeded the allotted quota of 0.93 million pounds, and the fishery remained closed from February 4 until July 1. Recreational estimated-landings from the Marine Recreational Fishing Statistics Survey for July 1, 1986 to April 30, 1987, were about 1.64 million pounds (estimates for the last wave, May 1 to June 30, 1987, are not presently available). The recreational quota was 1.97 million pounds.

Atlantic Migratory King Mackerel (Fishing Year: April 1 to March 31): The commercial fishery did not reach its quota of 3.59 million pounds and thus remained open until its normal closing date, March 31.

Recreational fishermen caught an estimated 5.50 million pounds by the end of the fishing year. The quota was 6.09 million pounds.

Spanish Mackerel (Fishing Year: January 1 to December 31): Commercial fishermen caught an estimated 5.50 million pounds in the South Atlantic and Gulf during the fishing year. In the same areas from January 1 to October 31 (November–December estimated landings were not available), recreational fishermen caught an estimated 5.57 million pounds. Estimated landings from the commercial and recreational fisheries (about 11.07 million pounds) did not reach the quota of 27 million pounds.

LENGTH FREQUENCY

About 15,000 king mackerel and 7,000 Spanish mackerel lengths were collected from North Carolina to Texas, as well as from Mexico. Gender was recorded from about 40% of all sampled mackerels. This was the third consecutive year of intensive sampling for length and sex. Our total data base now contains about 55,000 lengths and related data that are stored in a microcomputer system at the Panama City Laboratory. These length and sex data will be combined with similar data from other sources to give the best possible characterization of length frequency and sex ratio for populations of these two species for the 1988 stock assessment.

AGE AND GROWTH

Preliminary age–length keys were developed for king mackerel based on 1986 otolith collections. A subsequent comparison of whole versus sectioned otoliths from 187 of these fish indicated that for those > 80 cm FL, sections were more readable and usually showed more annuli than whole otoliths. Based on these findings, all otoliths from king mackerel $\geq$ 80 cm FL collected in 1986 were sectioned and will be reread to refine the 1986 age–length keys.

Thus far in 1987, otoliths have been obtained from 1,177 king mackerel (409 from the Atlantic, 768 from the Gulf of Mexico) 50–152 cm FL collected from North Carolina to Texas. Otoliths have also been obtained from 472 Spanish mackerel (246 Atlantic, 226 Gulf) 24–74 cm FL from the same areas. These otoliths are being processed and will be used for developing 1987 age–length keys.

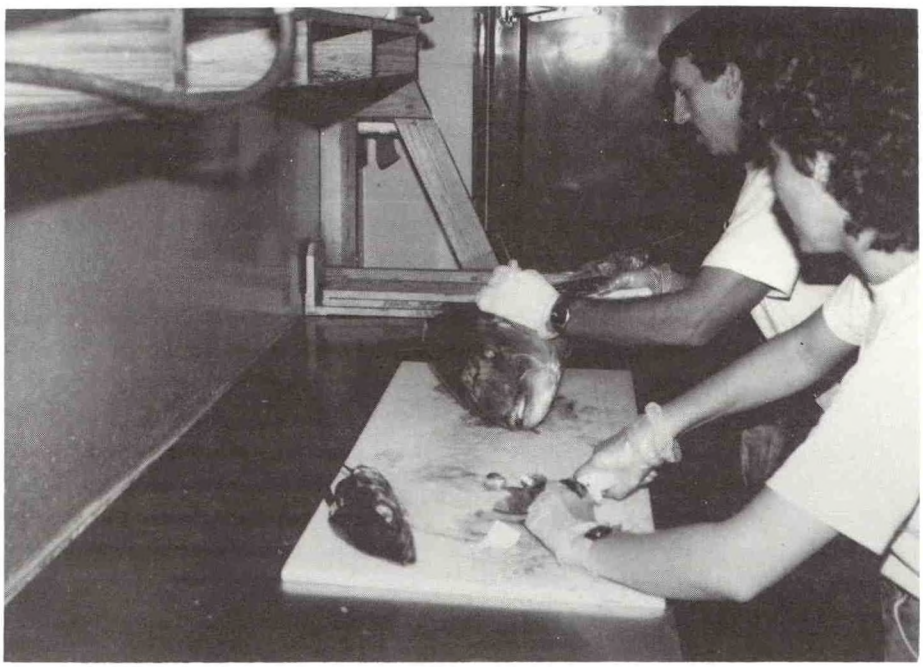


Figure 1. Dissecting otoliths from fish heads.

Figure 2. Cataloging otoliths.

FOOD OF YOUNG KING AND SPANISH MACKEREL

Food of young (larval and early juvenile) mackerel collected during SEAMAP ichthyoplankton cruises in 1985 and 1986 have been examined. Most of the mackerel specimens were caught in 1 x 2 m neuston nets (760 and 947 μ mesh) and a few in 61 cm bongo nets (333 μ mesh). Stomachs of 307 young Spanish mackerel and 95 young king mackerel were opened. Fishes were the most frequently occurring prey. Of the identifiable fish eaten by Spanish mackerel, clupeids comprised 40% and carangids 20% of the food items, while of those eaten by king mackerel, carangids comprised 23% and sciaenids 21%. At least 10 families of fishes were identified in king mackerel stomachs. Invertebrates eaten by Spanish mackerel included amphipods, euphausiids, and penaeid larvae. Crab larvae were the only invertebrates found in king mackerel stomachs. Both species of mackerel had eaten fish larvae that were almost as large as they were. Many of the larval fish prey were found in folded positions in the mackerel stomachs.

MARK-RECAPTURE

King mackerel were tagged in 1987 off North Carolina, Georgia, southeast Florida, northwest Florida, Louisiana, Texas, and Mexico, and Spanish mackerel were tagged off North Carolina and northwest Florida.

In North Carolina, 241 king mackerel, 1,822 Spanish mackerel and 46 little tunny were tagged from January through September by both the SEFC and the state of North Carolina. Three were recaptured in Florida, while the others were recovered in North Carolina. In order to gather more data on this movement between North Carolina and Florida, 1,005 king mackerel were tagged off southeast Florida in the spring of the year. Over twenty returns from this tagging have been reported, but thus far all have been from the Florida east coast.

In Mexico, U.S. and Mexican researchers tagged 464 king mackerel and 39 Spanish mackerel during the first five months of 1987. To date, eleven local returns have been recorded.

Comparative tag testing last year off northwest Florida has provided valuable information. Five hundred and fifty-six king mackerel were tagged in 1986 with various combinations of internal anchor and dart tags. A 3.06% return rate has been realized thus far with internal anchor tags, while only a 0.72% return rate has been seen with the dart tags. This year all king mackerel tagged in northwest Florida were double tagged with internal anchor tags to provide data on tag loss.

A new method for obtaining Spanish mackerel for tagging was evaluated in northwest Florida. Mackerel were purchased alive from commercial fishermen who used small purse seines. The fish were dipnetted live from the seine, then tagged and released. In one night during April, 688 Spanish mackerel were tagged--a quantity not available by fishing with hook and line. Ten recaptures have been reported in the northern Gulf thus far.

ELECTROPHORETIC STUDIES

Electrophoretic examination of king mackerel peptidase (Glycyl-leucine)-2 polymorphism was continued. From 1985 to the present, 3,279 fish have been examined (1,325 in 1985; 1,514 in 1986-87; and 440 in 1987).

Specimens were obtained in various areas from North Carolina to Texas and also in the Mexican sectors of the Gulf of Mexico. Significant differences have been found in the frequencies of the two alleles (A and B) of the peptidase (GL-2) polymorphic system. Higher frequencies of the A allele are predominant west of Alabama, while the B allele is predominant in collections made east of Alabama and along the Atlantic coast (Figure 3). This difference, east and west of Alabama, had been observed in 1983 (by May), and in 1985 to the present. The results indicate that the Gulf of Mexico has at least two groups of king mackerel--a western group (Mexico, Texas, Louisiana, and Mississippi) and an eastern group (Alabama eastward). These two groupings co-mingle in the northern Gulf of Mexico during the summer. The eastward and westward extent of the respective groups' migrations are not well defined, but probably depends on environmental factors such as food and water temperature.

CHARTERBOAT SURVEY

The objective of the charterboat survey was changed in 1986. From 1982 through 1985, the survey was conducted to determine relative abundances of coastal pelagic fishes in the southeast region. Catch-per-unit-of-effort data were determined from logs kept by charterboat captains under contract to us. In 1986, under the authority of Amendment 1 of the FMP, a census was taken to determine total catch and effort from all charterboats in the southeast. The amendment required statistical reporting of fishing activities on coastal pelagic fishes by selected respondents.

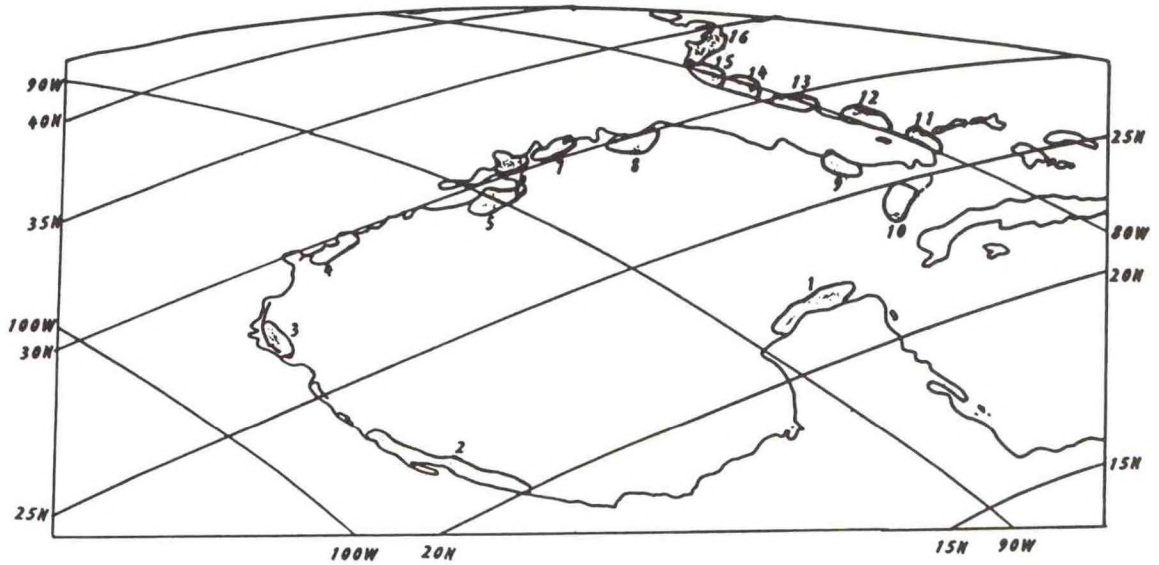
During the 1986 survey, a number of charterboat captains resisted mandatory reporting. Refusals to report, refusals to accept logbooks, misreporting, and nonacknowledgment of mail were encountered. Thus, the landings of mackerels and the fishing effort estimated from this survey were accompanied with enough caveats as to render their use with considerable caution.

An evaluation of the survey is in progress and the advantages and disadvantages in relation to those of the Marine Recreational Fishing Statistics Survey are being examined. The results of this evaluation will help determine the future course of the SEFC Charterboat Survey.

ABUNDANCE INDICES

The development of fishery independent abundance indices on mackerels has become increasingly important as the fisheries have become regulated. Before regulation, total landings data from the commercial fisheries and catch-per-unit-effort (CPUE) data from the charterboat fisheries were used to evaluate the well-being of the stocks. Presently the fisheries are being regulated by bag and size limits,

gear restrictions, seasonal closures, and landing quotas. What these regulations do to our traditional fishery dependent estimates of abundance are not well understood.



PEPTIDASE %A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0-20		1		2	1	1	2	7	1	3	6	1	3	3	9	7
21-40			2		1		1				1		1			
41-60	1	1	10		2											
61-80	2		5	1	4	2										
81-100		2	4	2	2											
TOTAL	3	4	21	5	10	3	3	7	1	3	7	1	4	3	9	7
	GULF OF MEXICO (WEST)					GULF OF MEXICO (EAST)					ATLANTIC COAST					

NUMBER OF COLLECTIONS (ALL YEARS)

Figure 3. Map showing king mackerel electrophoretic sampling areas and chart of distribution of percent of peptidase (GL-2) A allele among the collections.

A fishery independent survey using gill nets to estimate the annual abundance of Spanish mackerel in northwest Florida was initiated in 1987. Spanish mackerel are very susceptible to capture in gill nets; over 80% of the total commercial harvest was made using gill nets during 1950–1974. Much information is available concerning the design and use of gill nets for gill netting Spanish mackerel in northwest Florida; past studies determined the most efficient mesh sizes, types of webbing, times of day, months, and areas for capturing Spanish mackerel. Based on a thorough analysis of the historical landings data, we are sampling during the months of March–May and August–October with greatest sampling intensity in April and October. Two abundance indices are being generated, one using set nets and one using drift nets.

A fishery independent abundance index is being developed for king mackerel in northwest Florida. Little is known, however, about the efficiencies of various gears on king mackerel in the northern Gulf. Bottom gill nets, drift gill nets, and longlines will be tested to determine their efficiencies to capture king mackerel.

DRIFT-GILL-NET OBSERVATIONS

A project was initiated in May to investigate catches in the drift-gill-net fishery off southeast Florida, between Port Salerno and Fort Pierce. This fishery is directed toward king mackerel and has been suspected of also catching birds, mammals, and reptiles. The fishery operates from April to September during the dark phases of the moon, using nets with 5-inch stretched mesh which may be several thousand yards long. Observers have been placed on cooperating boats to record catches and discards.

During the twenty-nine trips made by observers from May through August 1987 no birds, mammals, or sea turtles were seen in the nets. At least 33 species of fishes were recorded. The most numerous by-catch was little tunny (over 1,500 fish), all of which were dead when the net was hauled and all of which were discarded at sea. Other species of discarded by-catch were, in order of decreasing abundance: barracuda, smooth dogfish, filefish, unidentified shark, lookdown, remora, moonfish, hammerhead shark, crevalle jack, and sailfish. The remaining species numbered less than 10 each in abundance. A final report of these observations will be available in November.

EARLY LIFE HISTORY

Standard neuston and bongo sampling has been conducted over the continental shelf throughout the Gulf of Mexico on SEAMAP cruises, as well as more directed neuston sampling by the Panama City Laboratory for mackerel larvae and young juveniles. These early life stages have not been abundant anywhere in the Gulf, but have occurred most commonly off the Mississippi delta. Seasonally, peak occurrence of larvae and young juveniles has been late May to early September.

Because of higher occurrences off the Mississippi delta, associations of young mackerel with the plume of the Mississippi River are being investigated. Preliminary data from a cruise conducted in the plume in September 1986 show that ichthyoplankton were more concentrated by strong physical convergence at the frontal region. Ichthyoplankton were two to three times more abundant in frontal collections than in samples taken within the plume or seaward of the front. More young mackerel were collected in these approximately 100 neuston samples than in many years of previous wide-area sampling. Preliminary analyses suggest that environmental factors regulating the plume extent and configuration may be correlated with king mackerel recruitment. Results from another cruise (September 1987) to investigate plume-ichthyoplankton associations are expected to provide additional information.

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MENHADEN

Research on assessment of menhaden stock and fisheries was centered at the Beaufort Laboratory, with data collection and research projects spanning all the Atlantic and Gulf coast states. Activities were directed toward ecology of juveniles, stock assessments, monitoring the purse-seine fisheries and providing scientific advice to the states, industry, and fishery management institutions. At the Charleston Laboratory, research was 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.

MENHADEN RECRUITMENT

In conjunction with studies to estimate the prerecruitment year-class strengths of Atlantic menhaden, we are analyzing otoliths and scales to delineate characteristics that permit the identification of geo-temporal origins and growth of juvenile and adult Atlantic menhaden. The aging techniques to determine the temporal origins of juvenile Atlantic menhaden have been developed and are being refined for more rapid processing of large numbers of samples. Because of allometric growth in the otoliths, we have examined the ontogenetic development of the otoliths, determined the preferred axis of sectioning, and are currently validating both the daily periodicity of the increments and the preparation technique. Periodicity is being validated by marking wild fish with tetracycline and by spawning and rearing fish in the lab. Fish 18–80 mm FL are being used. The preparation techniques are being validated through the use of SEM and compared with light microscopy. We are investigating image analysis systems to automate the reading and data capture process.

Based on analyses of samples from Pamlico Sound, North Carolina, tributaries, a mechanism for establishment (or selection) of nursery zones by Atlantic menhaden is proposed. Initially menhaden eggs are spawned and hatched in the coastal ocean where the larvae are distributed primarily by the effects of wind and physical mixing. Shortly thereafter larvae enter estuaries and make two important changes in feeding and distribution. First, in conjunction with metamorphosis, the menhaden shift from sight feeding on zooplankton to filter feeding and phytoplanktivory. Second, the causality of distribution changes from that of a passive response to wind and mixing to an active response to the abundance and type of food. Menhaden prejuveniles distribute according to gradients of phytoplankton production and select optimal foraging zones based on the cell size and taxa of phytoplankton. Thus, the menhaden nursery can be specifically defined by the patterns of phytoplankton production in an estuary, which in turn can be defined by the physical mechanisms that control the distribution of phytoplankton nutrients. These relationships make *in situ* or remotely-sensed estimates of yearly production feasible.

ULCERATIVE MYCOSIS DISEASE

Ancillary to other sampling programs, we determined that the 1982–86 Atlantic menhaden year classes had some degree of ulcerative mycosis (UM) infection. The 1984 year class appeared to have suffered the highest incidence of infection, but the 1986 sampling effort was not as extensive as in earlier years. The sites of primary infection ranged from the Pamlico Sound, North Carolina, tributaries to the Peconic River, New York. Hypothesized migrations of infected individuals resulted in the discovery of infected Atlantic menhaden as far south as northern Florida (Lanceford Creek).

Observations of ulcerated fishes in the Pamlico River were continued by North Carolina Division of Marine Fisheries as were laboratory and field studies by North Carolina State Veterinary School scientists. Mycological and histological results were published. The 1987 spring outbreak was severe, but incidence subsided over the summer months. Diseased blue crabs and fishes plus intense algal blooms occurred during summer throughout most of the Pamlico River system. State environmental and water quality agencies intensified their efforts to document the areal extent and etiology of the disease outbreaks. Declining water quality and chemicals are hypothesized as predisposing stress factors.

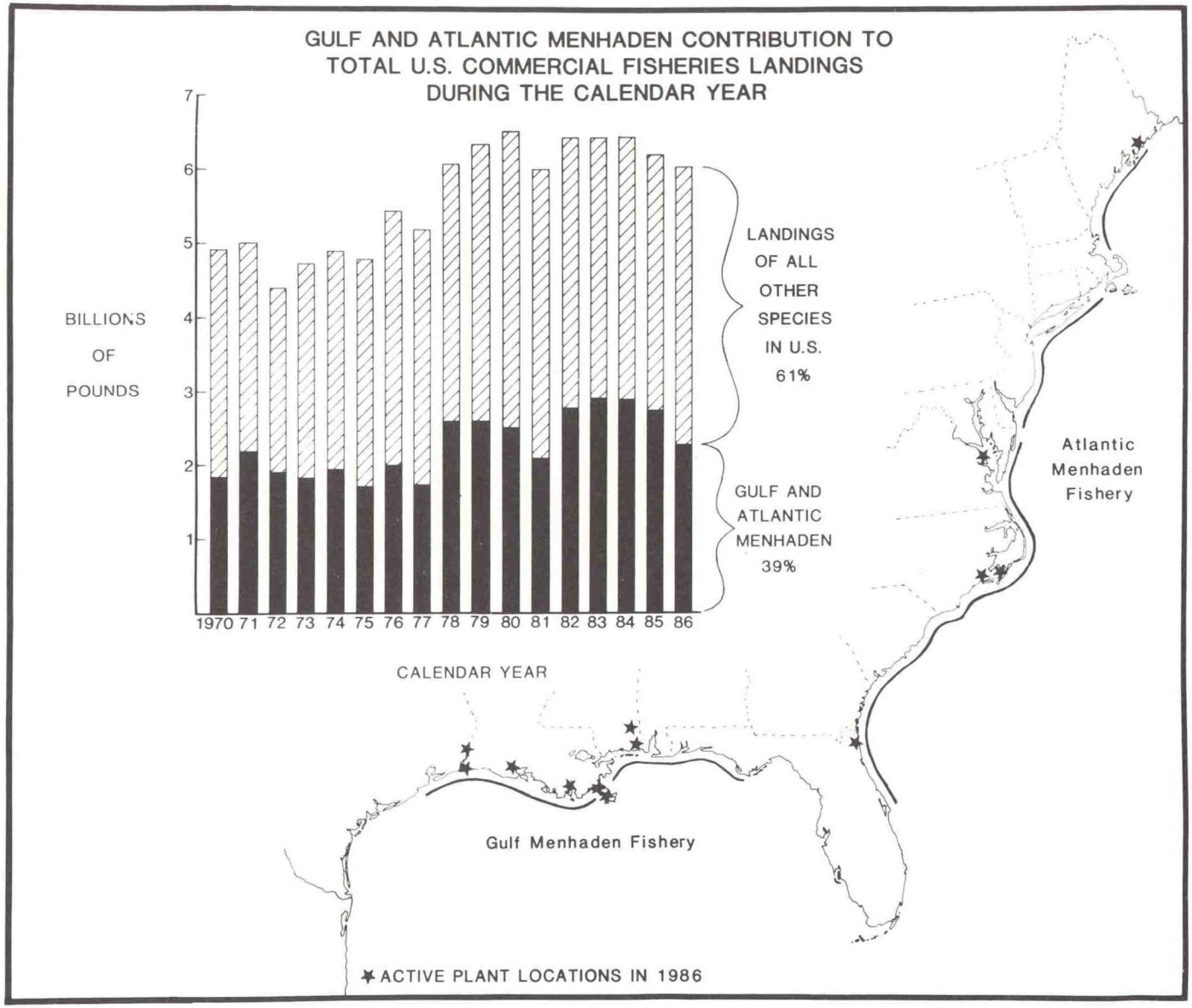
Diseased Atlantic menhaden.

FORECAST OF MENHADEN PURSE-SEINE LANDINGS

Quantitative forecasts of Atlantic and gulf menhaden purse-seine landings have been made for 15 years by the Beaufort Laboratory. Our forecasts are based on a multiple regression equation relating landings and fishing effort over many years. Expected effort for the upcoming year is derived from the number of vessels expected to be active and their historical performance in the fishery. In 1987 we expect that 18 vessels will participate in the Atlantic menhaden fishery and estimated a nominal fishing effort of 490 vessel-weeks. At this level of effort, we predict 1987 Atlantic menhaden purse-seine landings of 285,500 metric tons (80% confidence interval ranges from 207,000 to 364,000 metric tons). In 1987 we expect that 73 vessels will participate in the gulf menhaden fishery and estimate a nominal fishing effort of 618,000 vessel-ton-weeks. At this level of effort, we predict 1987 gulf menhaden purse-seine landings of 853,000 metric tons (80% confidence interval ranges from 721,000 to 985,000 metric tons).

GULF MENHADEN DATA

Biostatistical port sampling data and landings records collected from the gulf menhaden purse-seine fishery between 1974 and 1985 were summarized and updated as a NOAA Technical Report. During most of the time frame, 11 menhaden reduction plants operated in Mississippi and Louisiana and the number of vessels in the purse-seine fleet varied from 71 to 82. Total annual landings ranged from 447,100 metric tons in 1977 to the record landings for the fishery of 982,800 metric tons in 1984. Age 1 and 2 gulf menhaden annually comprised almost 96% of the landings. Estimated total numbers of menhaden landed varied from 4,510.5 million in 1975 to 11,154.9 million in 1985. Annual mean lengths and weights of sampled fish at age showed little variation. Nominal or observed fishing effort gradually increased through the 1970s and 1980s and reached 655,800 vessel-ton-weeks in 1983.



Menhaden plant locations and landings.

ASMFC FISHERY MANAGEMENT PLAN REVIEW - ATLANTIC MENHADEN

The goal of the FMP for Atlantic menhaden is "to prepare a program for utilization of Atlantic menhaden that is biologically, economically, and sociologically sound and which protects the resource and its users." A review of the status of the Atlantic menhaden stock was conducted in 1986 and resulted in publication of a supplement to the FMP.

An *ad hoc* review panel of NMFS, state, and industry representatives conducted an annual review of the plan and resource/fishery status during August 1987. Their recommendations were: (1) the FMP is adequate and should be maintained and the data base updated at 3-5 year intervals; (2) NMFS monitoring and research program is essential for long-term management of the fishery and must be maintained and analytical capabilities should be strengthened; (3) state agencies should improve monitoring of menhaden size and age from fisheries other than purse seine reduction, as well as other forms of mortality, and provide to NMFS to aid in assessment of the total stock; (4) state fishery management agencies should submit rule changes to the ISFMP Policy Board for evaluation prior to enactment and existing regulations and statutes affecting the menhaden fishery should be examined and deletions considered for those measures conflicting with the FMP; (5) the Atlantic Menhaden Advisory Committee (AMAC) should be maintained with state, federal and industry membership to serve the ASMFC Advisory Committee by providing annual review of status of plan, stock, fishery, and research; (6) state and federal habitat protection and water quality programs must be maintained and strengthened; and (7) adequate funding provided to North Carolina and Virginia to properly address ulcerative mycosis and its effects on menhaden and other estuarine fishes.

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. Two approaches to risk analysis of gulf menhaden were investigated in cooperation with Pennsylvania State University and Oak Ridge National Laboratory (ORNL). Both approaches were presented at the 36th Annual AIBS Meeting.

Event tree risk analysis, that couches the uncertainty of projections in terms of relative risk associated with various management options in a discrete (categorical) spawner-recruit framework, was applied to the assessment problem. As an illustration, gulf menhaden stock and recruitment data for 1964-1979 were used to develop endpoint probabilities for various 2-category stock-recruitment models. Cutoff points were chosen at the 24%, 35%, and 47% levels for stock and at the 35% and 53% levels for recruitment. The difference in the probabilities of maintaining high stock levels under two levels of instantaneous fishing mortality rates (F: 0.64/yr and 1.2/yr) was not great. The increase in probability under less intense fishing (F = 0.64/yr) over the probability under more intense fishing (F = 1.2/yr) ranges from 0% to 24% depending on choice of categories for the discrete spawner-recruit model. These results constitute only a slight improvement over results using the Ricker spawner-recruit model. This work was published in ecological modeling.

Several alternate response variables, or endpoints, have been proposed for use in assessing risks of fishing, toxic contaminants, and other stresses to fish populations. The utility of any given endpoint for decision-making depends in part on the level of scientific uncertainty concerning the biological characteristics of the population and the biological effects of the stressor. The effects of uncertainty were evaluated concerning (a) young-of-the-year mortality due to a hypothetical toxic chemical, and (b) the relationship between stock density and year-class strength on the statistical variability of three such endpoints: probability of quasiextinction, long-term average stock abundance, and female reproductive potential. This evaluation employed a density-dependent Leslie matrix with stochastically varying parameters, derived from a time series of stock abundance and composition data for the gulf menhaden population. Criteria for selecting the endpoint(s) appropriate for a given level of uncertainty were defined

based on the simulation results. This collaborative research continues with ORNL which has a contract from U.S. EPA (Gulf Breeze Laboratory, Florida).

IMPORTS AND THE U.S. MARKET FOR FISH MEAL

The United States is one of the largest producers and consumers of fish meal in the world. Historically, imports have bolstered domestic supplies and offset natural fluctuations in domestic production. In 1985 and1986, large quantities of fish meal were imported despite relatively high levels of domestic production. Imports, along with the availability of low cost soybean meal, have helped to depress prices in real terms to one of the lowest levels in 30 years. High U.S. interest rates, a strong U.S. dollar in international currency markets, and low fish meal prices provided the incentives to import fish meal. Currently, the incentives to import have diminished. An econometric model of the U.S. fish meal industry is being estimated.

FISH OILS

The Charleston Laboratory has conducted studies for a number of years on the composition, safety, and uses of fish oils--especially menhaden. A biomedical test material facility for the production of test materials from menhaden oil was completed at the laboratory during the year and distribution of the materials was initiated. Fish oil research is covered at greater length under the Product Quality and Safety section of this Annual Report.

MENHADEN SURIMI

A menhaden surimi demonstration plant, constructed by Zapata Haynie Corporation at Reedville, Virginia, is being operated under a NMFS contract with technical monitoring by Charleston Laboratory. The objectives are to determine the commercial feasibility of producing surimi from menhaden and to supply mince and surimi for product research and development. Significant progress has been made. Product gel-strength and flavor characteristics have surpassed expectations and yields have been improved through process modifications.

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MOLLUSCAN SHELLFISH

The Charleston Laboratory continued coordinating and planning activities concerning shellfish research. An overview of needs was described in a "Molluscan Shellfish Research Plan" that was disseminated to interested groups. Four literature reviews were also distributed concerning key topics: occurrence and persistence of pathogenic viruses in the estuarine environment; depuration of pathogens by shellfish; factors affecting wholesomeness and quality of molluscan shellfish during all stages of commerce; and, methods to measure microbiological indicator organisms in shellfish. A workshop was hosted by the Laboratory to assess the state-of-the-art in shellfish depuration and to recommend draft regulations for depuration. Also, laboratory scientists served as advisors to the Interstate Shellfish Sanitation Conference (ISSC). The relatively new ISSC has evolved into an important focus for international regulation of shellfish commerce and debate of nearshore pollution. A representative of the Charleston Laboratory is now the lead spokesperson for NMFS and voting delegate to the ISSC. Specific research activities are described below.

ENTERIC VIRUSES

The feasibility of using poliovirus as an indicator of virus pollution of shellfish was studied. Research on the frozen storage stability of filtered and non-filtered poliovirus was completed and results presented at the annual meeting of the American Society of Microbiology. Virus binding to specific filters was evaluated in an effort to define some of the conditions under which attenuated poliovirus may be stored and processed more efficiently.

Norwalk virus, the probable cause of nearly one-half of all shellfish-associated gastrointestinal illnesses in this country, can not currently be measured in environmental samples. Efforts to develop a cell culture assay system for the virus are underway. Norwalk virus and antisera derived from a NMFS-funded volunteer study were screened for virus levels and antibody titers. Five different cell lines (human and monkey cells) were challenged with stool-associated Norwalk viruses. Virus propagation was not observed through standard assay procedures. Cells and associated culture media are being screened for the presence of newly propagated viruses using more sophisticated enzyme immunoassay procedures.

DEPURATION

As estuarine environments become increasingly impacted by human activities, the quantities of illness-causing viruses in shellfish also increase. Whereas existing depuration practices were developed to remove bacteria such as *Salmonella typhosa*, most shellfish-associated illnesses are now known to be caused by viruses. Current commercial practices are not effective in removing these viruses. We have developed laboratory scale systems to evaluate the uptake, tissue distribution, and depuration of viruses.

Existing techniques for measuring low levels of viruses in depurated shellfish suffer from problems with accuracy, precision, and being labor intensive. We have pursued efforts in radiolabeling viruses. Recent successes allow us to trace the fate of very low levels of viruses during tissue uptake and excretion, and during conventional sample processing.

Additionally, we are monitoring an S-K grant to the University of North Carolina. These researchers are studying optimal conditions for removal of hepatitis A virus from eastern oysters and hardshell clams. Temperature, salinity, and other environmental parameters are being modified to effectively reduce hepatitis concentrations.

WHOLESOMENESS AND QUALITY

A literature survey on factors affecting the quality and wholesomeness of molluscan shellfish at different points in their commerce was conducted in order to collate available information and to identify research needs. A report of this survey will be available in October 1987.

Because of the lack of available data on the quality of molluscan shellfish in the retail sector, oysters, clams, and mussels obtained in the Charleston area were assayed to provide a greater amount of data for statistical planning. Analyses performed, representative of those to be used in a nationwide survey, included pH, aerobic plate counts at 20°C and 35°C and free liquor where applicable. Odor and product appearance were evaluated by a 12 member sensory panel specifically trained for evaluating the organoleptic characteristics of molluscan shellfish.

A protocol for a nationwide survey on the quality of molluscan shellfish at the retail market level has been prepared. Following peer review, external evaluation and comments will be solicited from other NMFS facilities, regulatory agencies, and industry. As part of the protocol, we worked cooperatively with the Chairman of the Biometry Department at the Medical University of South Carolina to develop a plan for collection of samples for statistical evaluation of the effects of seasons, city sizes and locales, and types of retail establishments on the quality and safety of molluscan shellfish.

Additionally, Charleston staff are monitoring an S-K grant to the Shellfish Institute of North America in which researchers are measuring the amount of free-liquor in fresh packs of oysters processed along the Atlantic and Gulf of Mexico coasts. The results are expected to determine whether recently enacted regulations on free-liquor effectively curtail economic fraud while maintaining reasonableness and flexibility for various physiological parameters affecting oyster liquid loss.

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OCEANIC PELAGICS

Oceanic pelagics (swordfish, billfishes, bluefin tunas and warm-water tropical tunas, particularly yellowfin and bigeye) are large, free-swimming fishes ranging over large portions of the Atlantic and intensively fished by many nations, including the United States. The tunas are classified as highly pelagic and are exempt from the Fishery Conservation Management Act; they are regulated by agreement with other fishing nations through the International Commission on the Conservation of Atlantic Tunas (ICCAT). A management plan for swordfish has been in place for two years, and one for billfishes is currently undergoing public review. The Center's oceanic pelagic research is managed by the Miami Laboratory. During 1987 research was geared primarily toward improving the data bases used to determine the status of stocks.

FISHERIES MONITORING

Monitoring of U.S. tuna fisheries continued for yellowfin, skipjack, bluefin, albacore, and bigeye tunas. Fisheries for marlins and sailfish and other scombrids were also monitored, as was the commercial swordfish fishery. Activities included the design of sampling programs, collection of catch, effort and biological data, maintaining and summarizing fishery data bases for analysis and dissemination to ICCAT and other management organizations. The recreational catches were dominated by yellowfin tuna, followed by small bluefin, bigeye, and albacore.

RESEARCH ACTIVITIES

In addition to monitoring the various fisheries, scientists studied bluefin tuna, swordfish, and marlins to increase the biological knowledge of these species and to provide information for management to east coast Fishery Management Councils. This research included updating and revising data bases, preparation of software and analyses in support of domestic goals, as well as participation in ICCAT and participation in special working groups.

ANALYSIS OF TOURNAMENT AND DOCK SAMPLING DATA

Annual indices of abundance of blue and white marlin were estimated from catch and effort data collected at billfish tournaments and docks throughout the southeast region and the Caribbean over the past 15 years. General linear models produced standardized estimates of catch per unit of effort, which were the abundance indices. Area and month, acting interactively, were the principal factors affecting catch per unit of effort. Whether the statistics originated from dock sampling or from tournament sampling also affected catch per unit of effort, as well as sea state and cloud cover in the fishing area. Estimated changes from year to year are presently being evaluated.

BLUEFIN TUNA

The virtual population analysis method developed at the SEFC and used by ICCAT was investigated to determine its sensitivity to variation in the catch at age, partial recruitment patterns, and abundance indices. Abundance indices, based on U.S. observer data from the Japanese longline vessels fishing in the U.S. EEZ, were updated and a new index based on catch rates in the U.S. recreational fishery for medium and large bluefin tuna in the Gulf of Maine was developed.

SEFC scientists participated in the annual examination of the status of Atlantic bluefin tuna stocks during the October meeting of ICCAT's Standing Committee on Research and Statistics held in Madrid. Papers were presented to the Committee and numerous analyses were conducted. Estimated abundances indicated that the number of adults (ages 10 and above) in 1987 was 25% of their abundance in 1972, and that recruitment had been low in recent years. With that information, the Commission agreed to maintain the restrictions on catches at the level in place since 1983.

Preliminary identifications of bluefin larvae from the Gulf of Mexico larval surveys and associated statistics were reviewed and finalized. The effects of environmental factors on the catch rate of larval bluefin tuna were reviewed and no clear pattern was found. In addition to the regular survey for larval bluefin tuna in the Gulf of Mexico, in 1987 several transects were made across loop current fronts to learn more about the distribution of bluefin larvae with respect to environmental features.

BILLFISH MONITORING

A pilot study is being conducted in the Gulf of Mexico to determine the feasibility of improving our recreational landings data for billfish. Billfish research emphasized development of marlin data bases and contracted studies to continue age and growth work. Staff accompanied the ICCAT Assistant Executive Secretary to Venezuela as part of a feasibility study for the development of the ICCAT Enhanced Research Program for Billfish. The program includes port sampling and at-sea observers, with the objectives of obtaining more detailed statistics on catch and effort, instituting and promoting the ICCAT billfish tagging program, and assisting ongoing age and growth studies. Working documents on swordfish age and growth, indices of abundance for blue and white marlin, and a program plan and progress report of the ICCAT Enhanced Research Program for Billfish were prepared for the 1987 Standing Committee on Research and Statistics Meeting.

ICCAT WORKSHOP

U.S. landing estimates, catch at size estimates, sex ratio data, mark-recapture data, and hardpart aging data were compiled for the ICCAT Swordfish Workshop in Madrid. Research was conducted, leading to preparation of working documents in the areas of stock structure, indices of abundance, age and growth, and a historical review of the U.S. swordfish fishery.

SHARKS

Life history information on mako sharks are being compiled along with sources and locations of catch and size. These data are being pooled with information from the Northeast Fisheries Center to obtain a data base for analysis and information.

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PROTECTED SPECIES

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. The conservation and management of cetaceans and pinnipeds (other than walrus) are also the responsibility of the NMFS, as described in the Marine Mammal Protection Act of 1972. Several species of baleen whales, toothed whales, pinnipeds and dolphins occur within the southeastern U.S. waters. The Center's Protected Species Program objective is to provide scientific information required for management of protected species to achieve optimum population levels necessary for delisting, while maintaining associated commercial and recreational fisheries. The program is managed by the Miami Laboratory with cooperation from other Center laboratories. Specific research activities for 1987 are described below.

SEA TURTLES

Head-Started Kemp's Ridleys

Since February 1979, 12,422 head-started Kemp's ridleys have been released into the wild. As of August 15, 1987, 532 (4.3%) have been recovered. Primary recovery 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	Cumulative Frequency	Cumulative Percent
Texas	349	65.6	349	65.6
Louisiana	65	12.2	414	77.8
Florida	49	9.2	463	87.0
North Carolina	18	3.4	481	90.4
South Carolina	12	2.3	493	92.7
Georgia	10	1.9	503	94.5
Mexico	7	1.3	510	95.9
Mississippi	6	1.1	516	97.0
Alabama	4	0.8	520	97.7
France	2	0.4	522	98.1
Maryland	2	0.4	524	98.5
New Jersey	2	0.4	526	98.9
New York	2	0.4	528	99.2
Virginia	2	0.4	530	99.6
Morocco	1	0.2	531	99.8
Not Reported	1	0.2	532	100.0

During 1987, head starting of the 1986 year-class of Kemp's ridley sea turtles was completed at the Galveston Laboratory. The turtles were tagged with inconel flipper tags, coded magnetic tags, and living tags. In April, 1,621 multiple-tagged turtles were released into the Gulf of Mexico 12 miles offshore of Padre Island, Texas. Survival rate during head starting was 99%. A group of 100 of the largest turtles of the 1986 year-class were held back for "super head starting," *i.e.*, rearing for more than one year in captivity in hopes of determining optimum duration of the head starting period before release.

In July, 1,282 live hatchlings of the 1987 year-class were received from the National Park Service's (NPS) Padre Island National Seashore. This was fewer than usual, because the hatch was poor (64%). To date (August 26, 1987), 66 of the hatchlings have died. Surviving turtles in good health will be multiple-tagged and released in April or May 1988.

Efforts continued toward completion of the new sea turtle head start research facility, initially funded by HEART (Help Endangered Animals – Ridley Turtles) and its contributors. Additional funds were obtained through MARFIN to complete the facility.

A cooperative study was completed this year by Dr. Ron Malone, Department of Civil Engineering, Louisiana State University. Recycled seawater systems were developed and tested for head starting Kemp's ridleys. Plans are underway to adopt Dr. Malone's recommendations for a pilot study of a prototype system at the sea turtle head start research facility in Galveston.

Sea Turtle Stranding and Salvage Network

The Sea Turtle Stranding and Salvage Network (STSSN) continues to collect data on stranded dead, dying, and alive turtles through a cooperative network of U.S. collaborators. Participation is primarily voluntary and the efforts of many persons outside of the NMFS are appreciated. This network is the responsibility of the Miami Laboratory.

Systematic sampling for stranded turtles, structured within the existing STSSN when possible, was initiated in the western Gulf of Mexico and in selected areas on the southeast Atlantic coast. Data obtained through these biweekly surveys will be used to index total mortality. Necropsies on selected carcasses may provide insight into cause of death.

As of June 1987, 1,094 turtles were reported as stranded for 1987. Of these, 230 were reported from the Florida east coast, 190 from Georgia, 166 from South Carolina, 156 from the Florida west coast, 118 from Texas, 85 from North Carolina, 46 from Louisiana, 44 from Virginia, 36 from Alabama, 12 from Mississippi, 4 from New York, 2 each from Maryland, Massachusetts, and Puerto Rico, and 1 from New Jersey. Seventy-one percent of these turtles were reported during May and June. Of these turtles, 81% were identified as loggerheads, 7% greens, 6% Kemp's ridleys, 3% unidentified, 2% leatherbacks, and 6% hawksbills.

Tagging Studies

Captures of sea turtles at sea continued to be an important and productive research activity at the Panama City Laboratory to ascertain the distribution and relative abundance of sea turtles in coastal waters. Focus has been on the sub-adult life stages of the two endangered species, Kemp's ridley and the green turtle. Along with the loggerhead, they are the most common species encountered in temperate waters, and the sub-adult stages comprise the dominant age class, especially for the Kemp's ridley and the green turtle.

On the east coast of Florida, the importance of the Cape Canaveral area as a sea turtle habitat has been confirmed by continuing high capture rates. The area is apparently a preferred wintering ground for foraging populations of sea turtles that are widely distributed north of Florida during the warmer months of the year. A long distance migration by a loggerhead, tagged in Florida in January and recaptured in Chesapeake Bay in June, was recorded. Returns continue to support our belief in an annual north-south migratory pattern for the east coast sea turtle populations. For Kemp's ridley, captures were highest during the coldest months (December, January and February) at Cape Canaveral and consisted of 75% of the total for all months.

On the west coast of Florida, capture efforts have resulted in the tagging of 127 juvenile sea turtles: 110 Kemp's ridley, 10 green turtles, and 7 loggerheads. The turtles were caught by gill and tangle nets as well as shrimp trawls. Two significant returns were a ridley that was at large at Cedar Key, Florida from July 1986 until May 1987, and another ridley that migrated from Biloxi, Mississippi, eastward (not westward as two other ridleys did in previous tagging efforts) to Dauphin Island, Alabama.

These tagging studies are part of a long-term research effort to establish migratory patterns, seasonal occurrence, distribution and growth in foraging populations of juvenile sea turtles in coastal waters. New

netting methods are being developed for the Cedar Key (Florida west coast) study in order to increase the efficacy of the project. Also, netting areas are being extended to include areas that appear to be more favorable to the capture of subadult green turtles at the Waccasassa reefs.

A 30 lb (18" carapace length) Kemp's ridley--an average size specimen from Cedar Key, Florida.

Western Atlantic Turtle Symposium II (WATSII)

The WATSII meeting was held in Mayaguez, Puerto Rico from October 12-17, 1987. Thirty-two of the thirty four countries in the area were represented and presented National Reports. These reports included data from 1983 to the present on turtle nesting, mortality, hatchery programs, and trade. All data are included with the WATSI data base managed by the Miami Laboratory. This meeting allowed for the exchange of valuable data on marine turtles throughout the western Atlantic area.

Satellite Tracking

A joint program was initiated with the U.S. Fish and Wildlife Service to tag 25 Kemp's ridleys with satellite transmitters. After preliminary design efforts indicated that the tags would weigh from 3.5 to 4.5 lbs, questions were raised about the endurance of the average-sized ridley with a tag of this size. Full-scale testing by the NMFS has been deferred. However, software to facilitate the collection and reduction of satellite tracking data was developed, installed on the computer at the National Space Technology Laboratory in Bay St. Louis, Mississippi, and is compatible with the ARGOS satellite computer system and local user terminals systems.

Turtle Excluder Device (TED)

A new soft TED was tested in the Cape Canaveral, Florida, area. Pascagoula Laboratory personnel participated in the testing aboard a University of Georgia vessel. The soft TED proved to be successful in excluding the size class of turtles found in this area. Results led to limited certification of the device under the current Turtle Excluder Device regulations.

A TED demonstration was held in Tampico, Mexico, during July. Panama has requested a demonstration of the NMFS TED and arrangements are pending. Other cooperative projects on testing

TEDS were completed with the University of Georgia Marine Extension Service; Sea Grant in Alabama, Mississippi, Louisiana, and North Carolina; and the South Carolina Wildlife and Marine Resources Department.

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MARINE MAMMALS

Bottlenose Dolphin

During August-October the SEFC coordinated and participated in an investigation to determine the cause and impact of a sudden die-off of bottlenose dolphins along the mid-Atlantic coast. Since early July through September, nearly 400 bottlenose dolphins have died and washed ashore in the area. The usual number of strandings is less than 20. A research team, which included experts in cetacean medicine, marine mammals, population dynamics, and other pertinent fields, was brought together in early August by the Marine Mammal Commission and NMFS to initiate the investigation. Activities included collection of stranded dolphins, aerial surveys, and live-capture and release operations for collection of blood samples, cultures, and tissues. The blood, culture, and tissue samples have been sent to several laboratories across the country and are being examined for evidence of toxins and infectious agents. Surveys are planned to determine the effects of the die-off on the population levels in affected areas.

Two contracts were awarded for low-level monitoring of bottlenose dolphin populations. Dolphin Biology Research Associates will be using identification of known individuals to estimate abundance, natality, and mortality of dolphins in the Tampa-Sarasota Bays area. Mote Marine Laboratory will utilize aerial surveys to estimate abundance and natality of dolphins in the Indian-Banana Rivers complex. The goal of the three-year study is to detect a halving or doubling of the population size in the study areas.

The analysis of the regional sampling surveys (1983-86) for bottlenose dolphins in the Gulf of Mexico is underway and should be completed in 1988. Relative distribution maps have been prepared and do show evidence of seasonal aggregations. A paper based on this work has been accepted for presentation at the December 1987 meeting of the Society for Marine Mammalogy. SEFC staff are also serving on the Organizing Committee for the meeting, which will be held in Miami.

Large Whales

The SEFC and NEFC are cooperators with the Right Whale Consortium, a group of several private research institutions. The SEFC is currently developing a computerized image analysis system for identifying individual whales. The system components have been purchased, and testing should be initiated soon. The SEFC also participated in two aerial surveys for right whales, one a winter survey off Georgia and northern Florida, and a fall survey off Nova Scotia. Two reports funded by the SEFC, NEFC, and NWAFC on the historical status of right whale populations on the U.S. east coast were completed by Mr. R. Reeves and Dr. E. Mitchell.

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RED DRUM

Expanded efforts by commercial and recreational red drum fisheries in the Gulf of Mexico prior to 1986 resulted in a greatly increased harvest of adult red drum in offshore waters. As a result, in June 1986 the Secretary of Commerce announced the first 90-day emergency closure of the offshore purse seine fishery. Prior to the closure, the SEFC had worked with the Gulf states to monitor landings, to investigate stock identification questions and to develop a comprehensive strategy for a Gulfwide research program. Our role intensified with the closure when we initiated actions to gain biological information from the restricted offshore harvest, assembled available data required to assess stock status and implemented a State/Federal research effort under the Southeast Area Monitoring and Assessment Program (SEAMAP) and Marine Fisheries Initiative (MARFIN) banners. The overall goal of this effort was to provide the scientific information necessary for sound management of red drum resources in the Gulf of Mexico. Funds from MARFIN and NMFS were used to fund the research, beginning in late 1986 while the commercial purse seine fleet was still operating. In general, the state and universities focused their research efforts on the inshore stocks while NMFS emphasized research to gain needed information on the status and condition of the adult spawning stock. A formal coordination mechanism for the programs was established through the Gulf States Marine Fisheries Commission.

STATUS OF RESEARCH

During the summer and fall of 1986, the SEFC Miami Laboratory became deeply involved in work associated with development of the Secretarial FMP and the Mississippi Laboratories focused on coordination of field activities. These efforts have continued at seasonally varying levels since that time.

As most state and university research did not get underway until late 1986, only a limited amount of research information from these researchers was available during the year. However, that which was available was used by NMFS assessment analysts in preparation of the 1987 stock assessment report required by the Secretarial plan. The information was also used by cooperating states and universities in planning their research for FY-1987 funding by MARFIN, and in some instances to help reform existing liberal inshore management measures. The research funded by MARFIN began during October 1987. Virtually all federally funded red drum research in the Gulf of Mexico, and much of the state and university-sponsored research, is being conducted as part of the Cooperative Red Drum Research Program.

The research summarized in this report is primarily that which is being conducted by NMFS. However, all research is in full cooperation with participants of the cooperative red drum research program, and most involves participation by these scientists.

AERIAL SURVEYS

A pilot aerial survey study, partially funded by MARFIN in 1986, was completed in May 1987 with the issuance of a final report. This study was designed to evaluate aerial surveying techniques for determining the distribution of surface schooling red drum in the Gulf of Mexico, assessing the relative abundance of these fish, and estimating their density and biomass. After review by a blue ribbon technical panel, results from the study were presented to the Gulf of Mexico Fisheries Management Council. The study was successful in providing a 35 million pound estimate of minimum biomass for adult red drum in the northern Gulf of Mexico. The biomass estimate was considered minimum since only schools at or near the surface were included. Adult red drum were found in schools from Brownsville, Texas, to Key West, Florida. The bulk of the biomass was off Louisiana, followed by Texas, Florida, and Mississippi-Alabama, respectively.

Because of the success of the pilot study, a spring aerial survey was flown, and a survey to replicate the pilot study was initiated in August 1987. Analytical reports from these surveys will be available in the

spring of 1988. Besides information on red drum, the surveys are collecting data on other species of schooling fishes, turtles, and marine mammals whenever these animals are encountered.

MARK/RECAPTURE EXPERIMENT

The single most significant research effort by NMFS is an experiment to estimate the size of the red drum spawning stock in the northern Gulf of Mexico. This is being done through a fishery-independent mark/recapture study which began in the fall of 1986. Approximately 16,000 fish were marked with single and double tags from a chartered purse seiner operated in conjunction with a spotter aircraft. The tagging area was from Mobile, Alabama, to Galveston, Texas. Schools of adult red drum were captured with a purse seine, and then brought aboard the purse seiner with a brailing net after fish in excess of about 1000 had been released. The fish were individually measured and in some instances their sex determined and tagged. A subsample of 20 to 30 red drum was sacrificed from each full capture operation for biological samples, specifically otoliths and gonads. Marking was completed in late spring 1987.

Recovery operations were begun in July 1987 with essentially the same techniques used for marking the fish. Approximately 2,000 fish from each purse seine set were examined for absence or presence of tags. A subsample of fish was sacrificed for biological measurements and samples. As of October 1987, approximately 25,000 adult fish have been examined for tags with about 60 tags being found. Close to 100 additional recaptures have been reported by commercial and recreational fishermen. It appears that the experiment will be successful as initial concerns about adequate mixing between schools have been shown to be unwarranted. An analytical report on the mark/recapture experiment is expected to be available in December 1987.

As part of the mark/recapture experiment, a pond study was conducted jointly with the Alabama Department of Conservation and Natural Resources to determine tag induced mortalities, and to provide an initial estimate of tag loss. Mortality was shown to be extremely low and tag loss at an acceptable rate. However, the specific loss rate which will be used in deriving the population estimate will be taken from the double tagged fish.

Biologist aboard a chartered purse seiner examines live red drum for presence of tags as part of the offshore mark/recapture experiment.

TAGGING CENTER

A tagging center has been established in the Miami Laboratory as part of the Cooperative Red Drum Research Program. Rewards for tags are paid by Miami, and tags for cooperative work by state and university investigators, as well as recreational fishermen, are provided. A data management system has been developed which will become operational in late 1987. This system will allow cooperating scientists, as well as NMFS investigators, to enter and retrieve tagging data with personal computer terminals.

MONITORING INCIDENTAL RED DRUM CATCH

Under the Secretarial FMP, the incidental catch of red drum by purse seiners and fishermen using entanglement net gear must be reported. Fishermen were allowed an incidental catch of up to 5 percent of the landing. (The first amendment to the Secretarial Plan requires that all incidental landings be in accordance with state landing laws, which is a change from the original plan). To aid in this requirement, a 24-hour telephone service was provided so that landings could be reported at any time. Virtually all landings were inspected by NMFS biologists, and biological samples were obtained. Approximately 19,000 pounds of adult red drum were landed by October 1, 1987, which is significantly less than the 100,000 pound quota.

STOCK ASSESSMENT

The SEFC stock assessment report was submitted to the Gulf of Mexico Fisheries Management Council in accordance with requirements of the Secretarial FMP. The assessment indicated that at current fishing mortality rates, the reproductive potential of the red drum stock is, or will be, greatly reduced. Most of this mortality is the result of inshore recreational fishing.

The Secretarial Plan amendment, inacted on October 16, 1987, has a management goal of 20 percent escapement (*i.e.*, 20 percent of the juveniles that would have escaped to the offshore adult spawning stock had there been no fishing mortality). The assessment analyses suggest that this escapement goal is a long way from being met and that substantial reductions in juvenile fishing mortality will be required if the goal is to be achieved. Increases in minimum size alone will not be sufficient to meet the escapement goal unless they are set extremely high. A substantial reduction in fishing mortality, primarily from the recreational fishery, for recruited (adult) also was shown to be needed.

FUTURE PLANS

Emphasis in 1988 will shift to cooperative work with the states in estimating escapement. An experimental protocol was developed by the Miami Laboratory which the state fishery management agencies are trying to implement. This protocol is similar to that already used by Texas and Florida in some of their research aimed at estimating escapement. It is based on inshore mark/recapture studies coupled with studies to estimate tag reporting biases. Other cooperative studies designed to increase understandings of red drum biology, age and growth, reproduction, stock identification, and spawning stock biomass also will be supported.

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REEF RESOURCES

The reef resources in the southeast region make up one of the most complex and diverse biological systems in the entire marine environment, including species such as lobsters, crabs, corals, snappers, groupers, grunts, and many other fish that inhabit coral reefs or hard-bottom areas. The resource is currently managed under Fishery Management Plans for reef fishes, spiny lobsters, stone crabs, and corals. The Center's research efforts, managed by the Miami Laboratory, involve analytical, statistical, ecological, and biological disciplines. Specific research activities for 1987 are described below.

COMMERCIAL REEF FISH LANDINGS

Commercial reef fish landings from the Gulf of Mexico were summarized on a regional basis in quarterly ALARM reports. ALARM stands for Automated Landings Assessment for Responsive Management and shows seasonal and yearly trends since 1979. Species routinely covered include groupers, and red, gray, vermilion, yellowtail, mutton, and lane snappers. Total grouper landings were consistent except for a 50% decline from the previous year in the Florida panhandle region, which was partially compensated for by increased landings for the third consecutive year from the Alabama, Mississippi, and Louisiana region. Over half of reporting Gulf dealers (82 of 132) report declines in red snapper landings with the biggest drop in the Florida panhandle. Annual vermilion snapper landings have continued to increase from the Florida panhandle and the Alabama, Mississippi, and Louisiana regions. Lane snapper landings from the Florida middle grounds increased for the fourth year and more than doubled in 1986. In the Florida Keys, annual landings declined for 4 consecutive years for red snapper, 4 consecutive years for yellowtail snapper and mutton snapper, and 3 years for gray snapper.

FISH TRAP MESH SIZES

Research was initiated on the effects of mesh size on the catch and size of reef fishes. Preliminary results showed a total of 59 species and 521 individuals representing 234 kg were caught in 131 trap hauls. Square and rectangular meshes were being tested ranging from 0.5 x 0.5" to 4 x 4". Body depth was found to be the best predictor for escapement. As mesh size increased, the numbers of fish caught decreased (7.4 to 0.6 ind/trap haul) and average fish weight increased (187 to 1656 g/ind). Total weight per trap haul showed no significant trends with mesh size. Experiments are continuing.

REEF FISH RECRUITMENT

The Miami Laboratory has initiated a cooperative reef research project (GROUPER) with the University of Miami, off Key Biscayne, Florida. GROUPER stands for Generalized Recruitment Optimization Using Prefabricated Experimental Reefs. The project examines the relative importance of recruitment, attraction, and production of reef fishes. A major objective of the project will be to measure the importance of reefs in producing new reef fish biomass. The importance of reef size on the resulting fish fauna will also be determined. Comparisons will be made between ichthyoplankton composition in the water column to what actually settles on reefs. Daily otolith and daily increment analysis and electrophoretic characterization of selected species will be conducted. A total of 50 three ton prefabricated concrete modules were built and deployed with the cooperation of private industry and local governmental agencies. Many fishes began arriving within hours. Monitoring of the colonization is continuing. Results are expected to have important implications for understanding recruitment mechanisms in reef resources.

CATCH SURVEYS

This is the fifteenth year of sampling and estimating headboat catches for the U.S. South Atlantic (Cape Hatteras, North Carolina to Key West, Florida), and the second year for the Gulf of Mexico (Naples, Florida to Port Isabel, Texas). Samplers operate from Beaufort, North Carolina, Wilmington,

North Carolina, Murrell's Inlet, South Carolina, Daytona Beach, Florida, Palm Beach, Florida, Key West, Florida, St. Petersburg, Florida, Pensacola, Florida, Empire, Louisiana, Galveston, Texas, Port Aransas, Texas, and Port Isabel, Texas. In the Atlantic, headboats that catch reef fish from the EEZ are contacted about every 10 to 14 days. In the Gulf, contacts are 14 to 21 days apart. At each contact, our samplers collect records of catches and information on fish sizes. In calendar year 1986, samplers measured 37,000 fish in the South Atlantic region and 22,000 in the Gulf. In 1987, the number measured in the South Atlantic was about the same as in 1986, while the number in the Gulf of Mexico increased slightly. Total catch estimates are made at the Beaufort Laboratory, where data on numbers of fish caught and on average fish size are combined. Also, corrections for missing data are applied. In 1987, we completed estimates of catches for 1985 (Atlantic) and 1986 (Atlantic and Gulf of Mexico).

Fishermen spent 415,472 angler days aboard 99 headboats in the U.S. South Atlantic and caught 2,016,775 kg of fish in 1986. Catches from the South Atlantic Bight, Florida Keys, and Dry Tortugas consisted mostly of reef species. Black sea bass, vermilion snapper, red porgy, white grunt, gag, scamp, red snapper, and gray snapper constituted 54% of the total catch by weight in the South Atlantic Bight, while yellowtail snapper, mutton snapper, white grunt, gray snapper, and lane snapper were the predominant species in the Florida Keys and the Dry Tortugas. In contrast, pelagic fish were the most common species from southeast Florida. The largest catches were of king mackerel, little tunny, blue runner, dolphin, and a variety of jacks; however, yellowtail snapper were 5% of the catch.

In the Gulf of Mexico, 74 headboats took fishermen offshore for a total of 302,536 angler days and landed 1,595,262 kg of fish. As in the U.S. South Atlantic, species composition changed from area to area. In southwest Florida, vessels running to nearshore reefs landed (in order of importance) catches predominantly of white grunt, gag, red grouper, and gray snapper. Catches of vessels going farther offshore to the Florida Middle Grounds landed gag, gray snapper, gray triggerfish, and red grouper. In northwest Florida, fishermen caught vermilion snapper, red porgy, gag, and gray triggerfish. Species diversity was considerably reduced in Louisiana and Texas catches, where red snapper, king mackerel, and a variety of sharks constituted 61% of the catches.

A sufficiently long series of estimates of headboat catches and of size samples now exist for the North Carolina–South Carolina region to allow investigation of trends in mean weight, catch, and catch per unit effort of the reef species important to the region. While catch per unit effort is usually the preferred index of stock abundance, in this investigation total catch is as useful because angling effort has been remarkably constant. Both catch and catch per unit effort may underestimate declines in abundance because fishing power of headboats, which is related to speed and electronic fish-finding aids, has increased. Other factors complicating interpretation of the catch sequence are shifting of principal target species by vessel operators in response to differential changes in abundance, and shifting of fishing to more inshore areas as the expensive-to-reach offshore grounds became exploited. Despite complications, important trends are evident. Mean weight per individual has decreased in almost all parts of the region for 8 to 10 species studied (black sea bass, red porgy, vermilion snapper, gag, scamp, speckled hind, snowy grouper, and red snapper). Mean sizes for some species are now only 25% of sizes in the early 1970's, and are reduced by 50% for other species. For red porgy, gag, speckled hind, and snowy grouper the mesh size now equals the minimum size needed to produce a reasonable yield per recruit. In one subarea or more, catch per unit effort in numbers has decreased for red porgy, white grunt, speckled hind, and snowy grouper. Numerous explanations are available for these changes, but for red porgy off South Carolina and for speckled hind throughout the region, impaired recruitment appears to be a likely cause.

Finally, a few species (especially Warsaw grouper) have become so uncommon that analyses of catches are impossible and special protection may be warranted.

CARIBBEAN ACTIVITIES

The Miami Laboratory worked closely with the Caribbean Fishery Management Council to develop improved fisheries data collection and evaluation procedures. A paper reviewing passive assessment

techniques was presented to the SEAMAP Passive Gear Assessment Workshop in Mayaguez, Puerto Rico. Fish traps were the most suitable fishery-dependent gear. Recommendations were made for increased use of non-destructive, fishery-independent visual and video methods for stock assessment.

A paper on the impacts of over-fishing on tropical reef fisheries was presented at the Fisheries in Crisis Conference sponsored by the Government of the United States Virgin Islands, Department of Planning and Natural Resources, Fish and Wildlife Division St. Thomas, Virgin Islands. Evidence exists that reef fishes are over-exploited in some Caribbean areas. Fishing pressure can change the size and age structure of a population, decrease stock size, and alter community composition. Heavy fishing pressure may lead to growth, recruitment, and ecosystem over-fishing. Ecosystem over-fishing may be reflected in density compensation, serial over-fishing, and shifts to alternate stable states by removal of keystone species.

SPINY LOBSTER

The annual stock assessment update was completed in July 1987. This report supports the conclusions of the previous reports that: (a) the effective fishing season has been shortened to August through December; (2) reducing mortality of short lobsters due to baiting has the potential for considerable increases in yield per recruit; (3) the use of escape gaps does not significantly increase yield per recruit when shorts are not used as bait; and (4) CPUE from the Florida west coast, which accounts for 98% of the total yield, has been relatively stable since 1978. A workshop was held in Miami on August 26-27, 1987 to address research needed to evaluate growth, mortality, and migration of lobsters. This workshop included participants from the Gulf Council, and the Florida Department of Natural Resources. The data currently available were reviewed and recommendations for further or new research were presented.

STONE CRABS

Stone crab landings and effort for the Florida west coast increased steadily from 300 thousand pounds of claws and 14.6 thousand traps in 1962-63 to 2.7 million pounds and 441.2 thousand traps in 1982-83, while annual catch-per-trap decreased from 20.5 to 6.1 pounds. Although the number of traps has been relatively constant since 1982-83, landings decreased by 36% to 1.72 million pounds in 1983-84 and remained near that level through 1985-86, while catch-per-trap declined to 3.8 pounds. Some landings data for 1986-87 are not yet available, but the preliminary estimate of 1.5 million pounds indicates that the landings were comparable to the previous year's. Standardized annual CPUE estimates have been estimated for 1979-80 through 1985-86 using catch-per-trap-pull from vessel logbooks. These indices show a trend similar to that in the landings data, with a 50% decline in catch-per-pull between 1981-82 and 1984-85, and no difference between 1984-85 and 1985-86. The declines in annual landings, annual catch-per-trap, and logbook catch-per-trap-pull indicate that the fishery may be fully utilized at present levels of effort. However, the effect of environmental factors on catches and the relationship between CPUE and abundance are not understood. Catch-per-unit effort by trip from the recently instituted Florida Trip Ticket data collection system are replacing logbook data in stone crab fishery assessment, beginning with the 1986-87 season. An update for 1986-87 to the series of standardized CPUE is not yet available because it involves comparing and calibrating the estimates made using Trip Ticket data with those based on logbook data.

REEF FISH CRUISES

Research cruises specifically for reef fish were directed toward developing techniques for stock assessment of adult fish, particularly snappers and groupers. Assessment sampling for adult reef fish is particularly complex for at least four reasons: (1) the sampling designs must contend with a very discontinuous habitat; (2) the gear of choice must catch or observe a wide range of species in habitats as diverse as rocky outcrops, coral reefs, wrecks, and oil platforms; (3) many species are not very abundant,

so obtaining sufficient catches for useful analysis is difficult; and (4) most of the available gear are "passive," so changes in fish behavior have a great effect on catchability, and thus on estimates of abundance. Research was directed toward improving performance in all four problem areas. The more general bottomfish trawl surveys also have a role in reef fish assessment, because the trawls capture juveniles of many reef fish species. The trawl surveys may be used to evaluate the abundances of new recruiting year classes.

In the Gulf of Mexico, cruises specifically for reef fish were conducted in January in the eastern Gulf, and September in the western Gulf. A brief portion of another cruise in March was also used to investigate a possible sampling strategy.

During the January cruise (aboard the *OREGON II*), bottom longlines were deployed at randomly selected stations during daylight hours. Trawling for juveniles was conducted at night. Catch rates were disappointingly low with both longlines and trawls, and trawl gear loss plagued the survey, even though the bottom was scanned acoustically to avoid untrawlable areas.

In the March experiment (*OREGON II*), point-distance sampling methods (similar to methods commonly used in forestry) were investigated as a tool for locating and estimating amount of reef habitat in an area. Results were promising: point-distance sampling appears quite feasible in areas of medium to high density of reefs or hard bottoms.

Two separate projects were conducted during the September cruise aboard the *CHAPMAN*. In the first project, vertical longlines and electric rods and reels were deployed at sampling sites chosen randomly from lists of known hardbottom areas, wrecks, and oil platforms. Low catch rates, apparent variations in catchability, and difficulty in sensing strikes with the electric gear were continuing problems. Oil rigs proved particularly difficult to sample. NOAA vessels may not approach the rigs closely, so fishing took place from small boats deployed from the *CHAPMAN*. The second project was an attempt to estimate the catch efficiency of bottom longlines for yellowedge grouper. This experiment took place at the site of an experiment conducted several years ago by NMFS, Harbor Branch Foundation, and Texas Parks and Wildlife. Unfortunately, yellowedge grouper have all but disappeared from the site during the intervening years, but data were collected on tilefish and barrelfish.

Center reef fish work in the South Atlantic is carried out under contract with the South Carolina MARMAP organization. Several years have been devoted to examining sampling techniques and strategies. Work continues on these practical aspects, and sampling is being extended to improve capabilities for making inferences about status of stocks. Winter and summer cruises were conducted aboard the *OREGON II* in the "shelf edge" habitat (the primary area for commercial and recreational snapper/grouper fishing). Gear included traps, hook and line, and drift TV. A September cruise used side-scan sonar to survey the shelf edge habitat, and to assess tilefish abundance by enumerating burrows in deeper waters.

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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 400.2 million pounds of whole shrimp landed in the United States during 1986, 304.1 million pounds (76%) were taken exclusively from the waters of the gulf and were valued at $504.8 million. In 1986, the gulf catch of shrimp increased by 41.2 million pounds and $105 million as compared to 1985. The gain in value was due in part to a rise in average ex-vessel price per pound from $1.52 in 1985 to $1.66 in 1986.

Most gulf states noted an increase in shrimp landings in 1986 as compared to 1985. Louisiana led all gulf states with 146.7 million pounds (up 28%). Texas was next with 97.5 million pounds (up 16%), followed by Florida (west coast) with 24.3 million pounds (down 13%). Alabama's production was 22.7 million pounds (up 13%), and Mississippi's was 12.9 million pounds (down 22%).

TEXAS CLOSURE

The 1986 Texas Closure was implemented from May 10 to July 2. The offshore boundary of the closure was changed from 200 nautical miles to 15 nautical miles from the coastal baseline during the closed season. The approach to evaluating the 1986 closure was similar to that in previous closure years with two exceptions. First, the 1986 closure was treated by simulation models as if the entire Exclusive Economic Zone (EEZ) were opened. Analysis of pre-closure June data supported this assumption. Second, a special survey was conducted to evaluate the social impacts of the closure.

In May-August 1986, total catch off Louisiana was 37.1 million pounds compared to only 19.1 million pounds off Texas. Fishing effort was also greater off Louisiana than off Texas. Much of the effort normally expended off Texas was diverted to Louisiana because of the perceived higher-than-normal levels of shrimp off Louisiana. Fleet mobility was similar to that experienced in 1985. During June 1985, both Louisiana and Texas fishermen fished primarily off Louisiana during the closure period. After the closure ended, Texas fishermen shrimped mainly off Texas, whereas Louisiana fishermen continued to shrimp off Louisiana. In June 1986, even with the area opened to shrimping beyond 15 miles off Texas, Texas fishermen fished to a great extent off Louisiana. It is believed that the higher production levels off Louisiana drew Texas vessels away from areas off Texas open to shrimping during the closure. Simulation models showed landings of brown shrimp were about 1.28 million pounds greater during May through August 1986 compared to the brown shrimp landings if the entire Exclusive Economic Zone (EEZ) had been closed. Shrimp fishermen were estimated to have made $140 thousand more during this period in gross revenue because the EEZ was open beyond 15 nautical miles.

Potential increases in harvests of larger shrimp later in the season were exchanged for access to offshore waters in May and June. The CPUE off Texas in July 1986 fell to a level comparable with pre-closure years, indicating no appreciable build-up in biomass due to the 6 mile EEZ closure when compared to that of the Texas Territorial Sea closure alone. Results of yield-per-recruit simulation indicated that potential existed for increased yield. The simulation model showed a 2.3 million pound increase in small and medium shrimp, and projected a 2.8 million pound decrease in large shrimp under the 15 mile closure, in contrast with expected yields under a simulated closure to 200 miles.

Preliminary estimates of catches for the remaining eight months (September 1986-April 1987) indicated that the benefits ($140 thousand) during May through August came at the expense of increase

in catches during the later months. The projected catches for the September 1986 through April 1987 period indicated that 1.8 million pounds more brown shrimp would have been caught if the entire EEZ had been closed from May through June 1986. If ex-vessel prices remained stable through April 1987, then the Gulf shrimp fishermen were projected to have *lost* about $8.9 million in net revenue because the EEZ was opened beyond 15 nautical miles (*i.e.*, increase in gross revenue of $9.2 less operating costs of $0.3 million). If administrative and enforcement costs had been included, the net benefit of closing the entire EEZ would have been about $8.65 million more than with the 15 mile closure.

Results of a social survey showed that, depending on their home port, fishermen interviewed across the northern gulf voiced varying feelings about the EEZ closure off Texas. Fishermen from Florida and Alabama appeared to favor the closure. Fishermen from Mississippi and central portion of Louisiana generally had no opinion, whereas fishermen from western and eastern portions of the Louisiana coast and along the upper Texas coast were opposed to a closure. Fishermen from ports along the lower Texas coast were generally in favor of a closure.

SHRIMP MIGRATIONS ACROSS THE U.S.-MEXICO BORDER

Mark-recapture experiments were conducted in the western gulf during May-August 1986 to examine the flux of brown and pink shrimp across the EEZ boundary between Texas and Tamaulipas, Mexico. Summer months were chosen because shrimp recruitment to the offshore fishery begins in May, and juvenile shrimp are protected during June and July by the Texas Closure. Shrimp crossing into mexican waters represent a potential loss to the U.S. fishermen whose shrimp vessels are not permitted to fish in Mexico. Mexico's Instituto Nacional de la Pesca in Tampico and the Galveston Laboratory cooperated in tagging experiments by exchanging biologists for tagging cruises in each country's waters and by exchanging pertinent data collected by each agency.

Tagged pink shrimp and brown shrimp were released offshore during May-July up to 120 km on either side of the Texas-Tamaulipas border. Participation of shrimpers in the program was enhanced by publicity and rewards. Of the total of 13,987 shrimp released off northern Tamaulipas and 29,113 released off southern Texas, brown shrimp represented 61% and pink shrimp 39%. By the end of August 1986, a total of 5,442 tagged shrimp (12.6% of those released) had been recaptured and returned by U.S. and Mexican fishermen. Species composition of recaptures was 33% brown shrimp, 54% pink shrimp, and 13% unidentified. The higher recapture proportion of pink shrimp could have been due to lower tag-induced mortality, larger average sizes, greater susceptibility to shrimp nets than brown shrimp, or other unknown causes. Brown shrimp were at large up to 112 days and had traveled up to 223 km before recapture, while pink shrimp were at large up to 113 days and had traveled up to 322 km. Average movement speeds were 2.6 km/day for brown shrimp and 2.7 km/day for pink shrimp.

The commercial fisheries were monitored on both sides of the border to collect catch, effort and fishing location data. This was accomplished with port agent interviews in Texas and Tamaulipas and by log books kept by some Texas vessel captains. Mexican port agents estimated nearly 100% coverage of the Tampico fleet, but fishermen from other ports such as Carmen, Campeche and Veracruz were not interviewed except when they unloaded in Tampico. Texas port agents collected 56% of the catch and effort expended off Texas during the study period, while log books covered 3.5% of the catch and 3.8% of the effort. These detailed data on fishing effort and locations were used to standardize shrimp recaptures according to projected total effort to determine movement patterns.

North versus south comparisons of cumulative recaptures per unit effort were made following all releases. Of 10 releases of brown shrimp off Tamaulipas, net movement was northward (toward the border) after six of the releases and southward after the remaining four. Of 13 releases of brown shrimp off Texas, net movement was southward (toward the border) after six releases, while net movement was northward after seven releases. For all brown shrimp releases combined, there was not significant difference between north versus south recaptures per unit effort, either from Texas or from Tamaulipas.

Out of 10 pink shrimp releases off Tamaulipas, recaptures per unit effort indicated northward movement for nine and southward movement for one. Out of 12 Texas releases of tagged pink shrimp, southward movement was observed in eight and northward movement in four. Only the pattern off Tamaulipas reflected a significant net displacement, as compared to the Texas movement patterns which were not strong.

These data were incorporated into a yield-per-recruit model to contrast numerical loss rates of migrating shrimp with biomass gains estimated by having the Texas Closure in effect for 1978-80 and 1985-86. Although there were instances of southward movement into Tamaulipas waters, the model predicted that losses were neither strong enough nor rapid enough to offset the biomass gains derived from a prohibition of shrimping.

These results of the tagging experiments suggest that no changes are needed in the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico with respect to altering the scope or timing of the seasonal Texas Closure. Tagging experiments conducted in 1978-1980 and 1985-86 indicated that southward transport of new recruits was irregular, and the increased shrimp biomass due to the closed season more than offset any short-term losses due to southward migration. These data also demonstrate that there could be a net gain to the U.S. fishery from pink shrimp moving north out of Mexican waters.

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 made in June and predicts the harvests for one year, from July through the next June.

The forecast is based on samples of postlarval and juvenile shrimp and on estimates of densities of shrimp in the Galveston Bay system from February through early June. Collections of immigrating postlarval (PL) brown shrimp from Bolivar Roads ship channel yield the earliest indications of the magnitude of the annual harvest. Juvenile brown shrimp stocks are then assessed using drop-sampler and mark-recapture techniques in Galveston area bayous to determine growth rates and abundance of juvenile shrimp. Finally, abundance of juvenile and subadult brown shrimp is monitored in the bait shrimp fishery during late April through mid-June to provide a final projection of stock strength prior to the offshore migration.

Recruitment to areas 18-21 in 1986 appeared to be slightly below average, therefore an annual yield of only 25.3 million pounds was estimated for the 1986-1987 season. On the other hand, 1986 recruitment to areas 13-17 appeared to be above average, with a forecast record catch of up to 50.0 million pounds. This difference in both recruitment and production set the tone for the summer offshore fishery.

Each of the three shrimp abundance indices for 1987 were lower than the corresponding indices for 1986. Lower than average numbers of postlarval shrimp entered the bays during March and April. Smaller shrimp were caught in the bays in May 1987 as compared to May 1986, so the shrimp were expected to be small at the opening of the Texas offshore season in mid-July. Several environmental factors may have reduced survival and growth of postlarval and juvenile brown shrimp in 1987, including atypically low rainfall, lack of strong southeast winds, and extremely low water in the marshes during mid-March through mid-April.

Prospects for Louisiana's brown shrimp harvests were similar, and indices for waters west of the Mississippi River suggested that catches could be 32.9 million pounds for the 1987-1988 season, which is above the 27.0 million lb average annual yield for the area. Louisiana Wildlife and Fisheries Department scientists estimated that 1.5 million acres of prime nursery habitat for brown shrimp were currently available. This was low and is not conducive to good growth and survival of young shrimp. In 1986, when

over 2.5 million acres of prime nursery habitat were available, shrimp production exceeded 44 million pounds.

POSTLARVAL SHRIMP STUDIES

With greater emphasis being placed on the development of an early forecasting of the brown shrimp season, two additional efforts expanded this year's sampling of postlarval (PL) brown shrimp during the late winter and early spring. First, an extra sampling site was added for semi-weekly monitoring. A site near the South Jetty on Galveston Island was selected to complement the standard site located near the North Jetty on the Bolivar Peninsula. Second, a study of the PL influx was made between March 9 and April 3, during which both sites were sampled in triplicate every workday, both during the day and at night. The objectives of this study were to discern variability in PL influx due to influences of time, daylight vs darkness, site specificity, tides, and wind in order to guide selection of sampling conditions that would optimize abundance indices used in forecasts.

This year, PL catches in the Renfro beam trawl ranged from 0 to more than 25,000 per tow. Preliminary analyses for the study indicate (1) substantial variability in PL catches during the four-week period, (2) greater PL catches at night than during the day, (3) differences in PL abundance between the two sites for day samples but not for night samples, (4) no substantially greater PL catches during flood tides than during ebb tides, (5) substantially lower PL abundances at both sites associated with north winds, and dramatically increased PL influxes associated with south winds following northers.

TORTUGAS CLOSURE

The Tortugas pink shrimp fishery is directly dependent on young shrimp migrating in large numbers from nursery areas of south Florida onto the fishing grounds. If these small shrimp are caught too soon, maximum yield in the fishery is not attained. The permanent closure of the Tortugas sanctuary was established in May 1981 to prevent the capture of small shrimp in the nursery so as to maximize yield. The entire 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 effects of such an opening. Catch statistics indicated an increase in the number of small shrimp caught when the "toe area" was opened. With the reclosure of the entire sanctuary, size ratios (average monthly size divided by historical average monthly size) have again decreased. Small shrimp recruited to the offshore fishery were harvested rapidly when the "toe area" was open, but small shrimp were able to increase in size and then enter the fishery when the "toe area" was closed. Thus, the overall objectives of the closure have been met with the Tortugas sanctuary.

During biological year 1985 (May 1985 to April 1986), pounds landed and effort expended were below their respective historical averages while CPUE was slightly above its historical average. Around 8.4 million pounds were landed, with a fishing effort of about 13,000 days. Corresponding CPUE was 639 pounds per day fished. However, none of these three fishery statistics were significantly different from their historical averages. As noted in previous years, most pink shrimp were caught in relatively shallow water.

Illegal trawling inside the Tortugas sanctuary did not seem to be a problem during biological year 1985. Only five boats were ticketed during calendar year 1986. It appears that violations have decreased appreciably with increased enforcement capability in the area.

Though the Tortugas sanctuary prevents capture of small shrimp and maximizes yield of shrimp moving onto fishing grounds, the shrimp must be available to the fishery if the management measure is to work. Thus far, in biological year 1986 (May 1986 to April 1986) no major recruitment of small shrimp from the nursery areas has been observed. If estimates are correct, then biological year 1986 will produce the lowest landings of pink shrimp of any year on record.

PREDICTION OF TORTUGAS PINK SHRIMP CATCHES

The Gulf of Mexico Fishery Management Council requested that the Galveston Laboratory develop a predictive model for the Tortugas pink shrimp fishery, similar to the ones already used to forecast offshore brown shrimp catches for Texas and Louisiana. NMFS actively monitors brown shrimp stocks in estuarine habitats of Texas and Louisiana, but there is no concerted NMFS effort to do the same for pink shrimp in Florida. However, the National Park Service's South Florida Research Center in Everglades National Park has been collecting pink shrimp abundance data for several years and has agreed to provide these data for future analyses. At present, the available long-term data bases that contain variables thought to be of use in predicting pink shrimp catches include: (1) NMFS monthly catch, effort, and size composition data for statistical subareas 1-3; (2) National Ocean Services' monthly mean tide level data for Key West; (3) National Weather Service monthly air temperature and rainfall data for Key West, Miami, and Ft. Myers; and (4) National Park Service's monthly water discharges into the Everglades National Park, water levels in the well monitoring network, and rainfall at several stations. These data have been collected through 1986, and arrangements made to receive future data as they become available. Preliminary regression analyses indicated that June-September water levels in Everglades National Park and fall air temperatures may be important shrimp catch predictors. A report to the Council is anticipated in January 1988.

INSHORE ECONOMIC SURVEY

A survey of inshore shrimp fishermen that fish in the Galveston Bay system in Texas and in Lake Calcasieu, Louisiana is being conducted, in response to a request by the Gulf of Mexico Fishery Management Council. The survey is designed to determine variable costs and revenues per trip by vessel size and gear type. Data on fishing effort by trip is being collected and can be expanded to provide estimates of total fishing effort for these two inshore fishing areas. It is important to determine the extent to which people in coastal communities rely on the inshore shrimp fisheries as a primary or secondary source of family income. The survey work is scheduled to continue through October 1987 and a report will be available in February 1988.

RESOURCE ASSESSMENT

The October/November 1985 resource assessment survey demonstrated the recurring wide year-to-year variation in biomass and population estimates of abundant demersal fish species in the north central Gulf. In 1984, estimates of relative abundance were substantially higher than recent years but in 1985 estimates again returned to the low levels observed prior to 1984. Hardhead catfish was the only major species to show an increase in relative abundance in comparison to 1984. Atlantic croaker, Gulf butterfish, spot, longspine porgy, sand and silver seatrouts, and Atlantic cutlassfish all showed decreases. Although Atlantic croaker decreased from 1984 to 1985, there was a slight increase in the average weight per individual fish between the two years.

Atlantic croaker was the most abundant species, occurring in 81.4% of the samples and comprising 21.9% of the total catch by number and 29.3% by weight. Most of the population was found inshore of 30 fm with more fish occurring west of the Mississippi River delta.

Estimates of relative abundance for commercial shrimp were generally low throughout the survey area. Population estimates for brown shrimp were higher west of the delta with highest estimates occurring in 20-29 fm. White shrimp were similarly more abundant west of the delta with highest estimates occurring inshore of 20 fm.

ESTUARINE HABITAT RESEARCH

Estuarine habitat research conducted at the Galveston Laboratory is reported under the Habitat Program section of this annual report.

PRODUCT QUALITY AND SAFETY

Two Saltonstall-Kennedy grants were monitored by the Charleston Laboratory during the year: "Develop a Modified A.O.A.C. Method for Determination of Drained Weight of Frozen Shrimp" and "Development of Alternative Techniques to the Use of Sodium Bisulfite for the Treatment of Black Spot on Shrimp." Present methods are inadequate for determining the net drained weight of five pound or two kilo blocks of frozen shrimp. Because of this, processors do not have proper means to take corrective action to insure full weight packages, regulatory authorities cannot prove either short weight of fraud in frozen blocks of shrimp, and weights and measures officials cannot take appropriate action if the frozen weight is equal to or exceeds the net weight statement of cartons and the thawed weight is below such statements.

Studies were completed by the American Shrimp Processors Association and its subcontractor laboratory to determine the thermal kinetics of water thawing of shrimp based on water temperatures and flow rates, size of shrimp, species of shrimp, and the weight of frozen blocks. Currently test blocks of shrimp are being prepared for analyses by referee laboratories.

Ethylenediamine tetraacetate (EDTA) can inhibit enzymatic browning by complexing the metal ions that act as cofactors to the enzymatic reactions. EDTA has been suggested as an alternative to bisulfite on fresh cut potatoes, fruits and vegetables.

As compared to untreated shrimp, treatment with EDTA prior to freezing significantly lowers the amount of black spotting on the shrimp during ice storage. For example, after 6 days on ice, 50% of the untreated shrimp had black spotting associated with them, while a dip in 2.5% EDTA solution had reduced the black spot formation to 27% on the treated shrimp. However, compared to bisulfite-treated shrimp, EDTA is an ineffective inhibitor.

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ECONOMICS AND STATISTICS

The Economics and Statistics Office is responsible for fishery economics, fishery statistics, and data management. Economic research, statistical data collection, and computer systems operations and programming are conducted to supply fishery information used by management councils and administrators to manage the fishery resources in the federal waters of the southeastern United States.

FISHERY ECONOMICS

Economics research during 1987 emphasized assessment reports on the fisheries in three management units -- mackerels, reef fishes and spiny lobsters. The general economic conditions in these fisheries were reviewed.

The fisheries for king mackerel have been under increasingly restrictive management since 1984. Total annual catches of king mackerel along the Atlantic coast decreased from a peak of 6 million pounds in 1982 to 3.6 million pounds in 1985. The stocks of king mackerel in this area, however, are healthier than the stocks in the Gulf of Mexico. Catches in the Gulf were down 43% in 1985 from their peak in 1981 of 3.07 million pounds. A quota of 870 thousand pounds reduced total catches of king mackerel in the Gulf by about 2.5 million pounds (valued at $2.6 million) during the July 1986 through June 1987 fishing year. Per-trip bag limits were imposed on recreational fishermen to reduce fishing mortality by user group. Existing data are not sufficient to measure the effects that fish-per-angler-per-trip regulations would have on the number of fishing trips that were taken by recreational fishermen.

The reef fish management unit is comprised mostly of the popular species of snappers and groupers. Catches of all reef fish species in the South Atlantic region peaked at 15.2 million pounds in 1982 and decreased to 9.5 million pounds in 1985. Catches also peaked in 1982 in the Gulf of Mexico at 19.7 million pounds, but the decrease in catches in the Gulf was only 7% to 18.4 million pounds in 1985. The revitalization of the grouper fishery, due largely to the recent growth of bottom longline fishing, maintained the commercial reef fish catches in the Gulf.

Like mackerels and reef fishes, the recent landings of spiny lobsters have never exceeded their peak in 1974. The major reason for lower landings is the closing of Bahamian waters to foreign fishing and the subsequent decline in the landings on the east coast of Florida. Catches in the Florida Keys and the west coast of Florida have remained fairly stable since 1970 with an average of about 5.5 million pounds per year. The estimated number of traps increased about 150% since 1970; however, the estimated number of fishing craft has increased only about 20%.

A workshop on management issues associated with regulations on recreational fishing was conducted by the Economic Analysis Team in June 1987. Members of the three Regional Fishery Management Councils in the southeast, researchers from universities in the southeast and administrators from state management agencies attended. Discussions served to enhance attendees understanding of Councils' research needs and to expand their understanding of the role economic research and analyses plays in providing assistance in management decisions.

Analyses of the effects of ciguatera poisoning in snapper and grouper show that when the public is aware of the risk of this poisoning, significant avoidance costs occur in the ex-vessel market. Estimates of these costs are in the range of 5 to 8 percent decrease in the price of grouper on the east coast of Florida and a 7 and 9 percent decrease in ex-vessel prices respectively for grouper and snapper in Hawaii.

A report on the economic impacts of the Texas Closure regulation was prepared for the Gulf of Mexico Fishery Management Council. The results of that report are discussed under the Shrimp and Bottom Fish Program.

FISHERY STATISTICS

In 1986 commercial fishery landings were 2.6 billion pounds, down 0.1 billion pounds from 1985. Value of these landings was $936 million, up $183 million from 1985. Shrimp contributed most to total

value ($623 million) and menhaden most to total weight (1.9 billion pounds). Recreational fishing continued to be of major importance. In 1986 an estimated 5 million anglers caught 190 million fish on approximately 31 million fishing trips.

Fishery statistics are collected each year to determine the economic trends of the fisheries, the biological condition of the resources, and the level of participation by fishermen. The statistical data are collected by interviews with wholesale seafood dealers and fishermen, and from reports submitted by these persons. State agency data collection efforts, through the Cooperative Statistics Program, complement those of the federal agency. This year emphasis was given to the collection of size frequency and effort information through the Trip Interview Program, with sampling targets for mackerels, reef fishes, oceanic pelagics, and spiny lobsters.

Total landings data are also collected for all species and, for the shrimp fishery, effort and size and species composition data are collected for a large sector of the fishery. There is a need to develop greater uniformity with the diverse data collection systems for these various fisheries so that the data are more accessible and comparable: this need will be addressed in 1988.

Fishery interviewers, or port agents, provide the primary contact, in many cases, 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.

Special efforts during 1987 by port agents included surveys of shrimp fishermen to determine their response to the Texas Closure regulation and of king mackerel fishermen to determine the economic impact of regulations on this fishery.

Fishery statistical data are 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% of the target quota.

A major study in 1987 evaluated the data submitted by charterboat captains who were required to submit logbook records of king mackerel catches. These records were compared to estimates of king mackerel catches made using the survey design of the marine recreational fishery statistical survey. Complete reporting by logbook was not attained and serious discrepancies were discovered in the accuracy of some reports.

DATA MANAGEMENT

The Center operates a mainframe computer in Miami, accesses a larger mainframe in Seattle, Washington, and has a large number of microcomputers used individually by scientists and technicians. During the year additional memory was acquired for the Miami computer, and a multiplexor was installed that allows users to select from their single terminal, whether they wish to process on the Miami or Seattle computer. The multiplexor and installation of newer modems has greatly increased our telecommunications network capability. The Southeast information management personnel participated in a national effort to prepare the specifications for replacing the NMFS mainframe computers and to issuing a request for procurement.

Systems support was provided for fishery research projects, including design and implementation of (1) charterboat logbook tracking and reporting system, (2) 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 (Statistics System, SEAMAP ichthyoplankton system, Marine Recreational Fisheries Statistics Surveys, transfer of Florida Landings System from the B7800 in Seattle to the B6800 in Miami, Cooperative Game Fish Tagging System, Financial Reporting System, Gamefish/Billfish Tournament System, Vessel Operating Units, Japanese Quarterly System, Mailing List Creation and Label Processing) were accomplished per user requests.

The historical (1980–1986) fishery statistics diskettes received from Puerto Rico and the Virgin Islands were transferred to the mainframe computer in Miami.

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FISHERY HABITAT

Fishery habitat research conducted by the SEFC is a multidisciplinary generic research program concerned with estuarine-coastal habitats. The program emphasizes a mixture of field and laboratory research with the goals of determining the key functional relationships that regulate fishery production and developing the capability to predict and assess man-related impacts on fishery organisms and their habitats. During 1987 research emphasis was on: (1) the distribution and recruitment of larval and juvenile fishes, and factors influencing larval recruitment and survival; (2) habitat supporting finfish and shellfish, evaluation of mitigation methodologies, and the impact of alterations in environmental parameters; (3) research on feeding habits and predator-prey interactions; (4) effects of metal contamination on larval fish food webs and mechanisms of metal accumulation and metabolism. Research was conducted primarily by the Beaufort and Galveston Laboratories, but a portion was conducted at the Miami Laboratory and NOAA's Ocean Assessment Division (Rockville) by staff assigned to the Beaufort Laboratory.

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. In a continuing effort to evaluate how this plume may affect the spatial distributions, feeding, growth, and nutritional condition of larval fishes, a model was developed to predict the nutritional condition of laboratory reared spot. We are testing this model on specimens collected in and adjacent to the Mississippi River plume front to determine their nutritional condition. This work is being 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 are investigating meteorological and hydrodynamic mechanisms that influence the shoreward transport of larval fishes, and have begun to examine 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 and university and state laboratory researchers.

As a part of the NMFS Marine Entanglement Research Program, research was initiated to evaluate samples taken in the northern Gulf of Mexico (Cape San Blas, Florida; Mississippi River plume, Galveston, Texas) for the presence of small plastic (polystyrene) particles (0.1 to 2.0 mm) 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 for designing future sampling and feeding studies.

The life history strategies of two allopatric clupeids (Atlantic and gulf menhaden) are being studied to explain how these species have adapted to their particular environments (Atlantic and gulf coasts) and how strategies are adapted for persistence and reproduction. This research includes studies of egg, larval, juvenile and adult stages. In addition, laboratory spawning of spot, flounder and Atlantic menhaden has been continued.

A cooperative program with the NMFS, Sandy Hook Laboratory is continuing to examine 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). Present work is emphasizing abundance of bacteria in sediments impacted by sludge dumping and variability in the water column.

ESTUARINE RESEARCH

Estuarine research was concerned with determining the distribution and relative values of nursery areas, including marshes, seagrasses, and non-vegetated habitats for fisheries species. Projects designed

to test the relationship between habitat utilization and salinity conditions in Texas employed 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. Marsh habitats with *Juncus*, *Scirpus* and *Spartina*, submerged aquatic vegetation habitats (SAV) with *Zostera*, *Halodule*, *Syringodium*, *Thalassia*, *Ruppia*, *Myriophyllum*, and *Vallisneria*, and soft silt to hard sand non-vegetated bottoms were investigated. The salinities in these habitats varied during sampling, depending on time and location, from 0 to 35 ppt.

Research at Beaufort and Galveston 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 in North Carolina and Florida related estuarine recruitment of larval fishes to distributions of juveniles in the estuary. In one study, conducted in Beaufort Inlet, North Carolina, bow-mounted push nets were used to determine the species, density, size and timing of larval fishes entering the estuary. Striped anchovy were found to be the most abundant species followed by Atlantic croaker, spot, summer flounder, gulf flounder, gray trout, Atlantic menhaden and silver perch. May was the peak month for the most individual larvae as well as for the maximum number of species collected during the sampling in the inlet. A second study was conducted to obtain information on immigration period, spawning season, age, size and condition factor, and the relative contribution of weekly spawning cohorts to numbers of immigrant Atlantic menhaden.

After entering the estuary, a mosaic of habitats are available to juvenile organisms as nursery areas. We are investigating how these habitats support fishery species. The use of the flooded *Spartina* marsh surface by macrofauna was studied using paired block nets in the lower Newport River estuary near Beaufort, North Carolina. The marsh surface appears to be important as a refuge and feeding ground for many fishes and macrocrustaceans using estuaries. A total of 35 species of fishes were captured during the year from *Spartina* marshes (15 resident and 20 seasonal transients), as well as penaeid shrimp (three species) and blue crabs. Important recreational or commercial species using this habitat include southern flounder, summer flounder, spotted seatrout, striped mullet, sheepshead, gray snapper, and red drum.

Studies on the distribution, abundance of fish larvae and spawning times of several important commercial species in Florida Bay and adjacent areas were completed. Larval spotted seatrout was the only target species regularly collected. Our data indicated that this species spawned in intermediate to high salinity waters within western Florida Bay and adjacent estuarine waters, but not in brackish waters. The larval stages of gray snapper, snook and red drum were absent from our samples indicating that they spawn outside of Florida Bay. Lack of larval snook and red drum in our samples was attributed to vulnerability and accessibility.

Surface and bottom trawls were used to sample fishes in basins and channels in southwestern Florida Bay. Data were evaluated in conjunction with information on environmental parameters, including seagrasses, to identify fish-habitat associations. Western Florida Bay, adjacent to the Gulf of Mexico, and channels within the Bay consistently supported the highest diversity of fish. Channel areas generally displayed the highest overall standing crop and density of seagrasses. Basins in the western portion of the Bay were diverse in terms of seagrass composition and exhibited the highest overall densities of *Syringodium*. Comparatively higher sediment organic contents, slightly shallower water, and abundant *Halodule* and *Syringodium* were characteristic of areas displaying typically high fish densities, while low fish densities were characteristic of monotypic stands of *Thalassia*. Spotted seatrout and gray snapper appeared to select mixed seagrass meadows with *Halodule* and *Syringodium* rather than pure *Thalassia* meadows.

Field sampling also continued in North Carolina at the Cedar Island National Wildlife Refuge to determine fishery utilization in high marsh (*Juncus*) habitat in cooperation with East Carolina University

and funded by the U.S.Fish and Wildlife Service. We found utilization as far as 2400 m from the nearest body of water by *Fundulus* spp. and mosquitofish. Stomach content analysis shows feeding habits ranging from diverse and seasonal feeders on amphipods, copepods, diatoms, foraminiferans, filamentous algae and insect larvae to a strictly detrital feeder. Small embayments into the marsh are being shown to be major refuges for many commercially and recreationally important fish species (e.g., anchovy, gray snapper, ladyfish, mullet, spot and southern flounder).

Freshwater Inflow Influences on Estuarine Habitats

During the fall and spring seasons Galveston Laboratory, in cooperation with the Academy of Natural Sciences of Philadelphia, sampled locations along a salinity gradient in San Antonio Bay where *Spartina/Scirpus* marshes and *Ruppia/Halodule* habitats dominate. Abundances of estuarine organisms were comparatively lower where lowest salinities persisted. As a result, usage of nursery habitats in the Bay was positively correlated with salinity. To ameliorate the apparent negative impacts of low salinity, the State of Texas plans to reopen a barrier island pass near the mouth of San Antonio Bay in 1988 to provide direct access for high salinity water to the Bay. This will allow a cooperative study with the State of Texas and the Philadelphia Academy of Natural Sciences, on the sequence of natural changes resulting from elevated salinities.

In Lavaca Bay studies have addressed the impact of short-term pulses of fresh water on habitat utilization. Unlike San Antonio Bay, Lavaca River delta marshes were normally under the influence of higher salinities, resulting from reduced freshwater inflow from an impounded river. Heavy rains cause rapid lowering of salinities, but salinities rebound in a few days or weeks. We compared densities of estuarine organisms in marsh habitats before and after freshening events. Sampling demonstrated that brown shrimp, white shrimp, blue crabs, spotted seatrout, southern flounder and red drum utilized Lavaca Bay delta marshes more than delta marshes in San Antonio Bay. Presumably this was due to the generally higher salinities at the Lavaca River delta. During sampling at Lavaca Bay before and after two flood events, only minor changes in salinity and no change in distribution of organisms was noted. However, after one large flood event in June 1987 salinities were reduced from 15 ppt to less than 1 ppt within a few days. Ten days after the onset of flooding, salinities had been reduced to less than 0.1 ppt, and brown shrimp, blue crabs, flounder, menhaden and other estuarine organisms were still present in the marshes, but at reduced densities. Thus, these estuarine organisms have the physiological capability to withstand abrupt salinity reductions.

In Galveston Bay, the largest bay in Texas with the largest freshwater source (the Trinity River), a similar investigation was conducted relating nursery habitats to salinity. In Trinity Bay, an upper branch of Galveston Bay, river delta salinities in marshes were generally low, ranging between 0 and 2 ppt, and consisted of *Scirpus, Sagittaria* and *Typha*, while SAV in the area were *Ruppia, Myriophyllum*, and *Vallisneria*. Densities of estuarine organisms were low during April (the peak of brown shrimp immigration) and in July (the peak of white shrimp immigration). By contrast, the *Spartina* marshes at Smith Point, a higher salinity location in Trinity Bay, had significantly higher species densities. Salinities at Smith Point were variable. The differences in numbers of organisms between the Smith Point and delta marshes demonstrate the effect of long-term versus short-term impacts of salinity on habitat utilization. The comparatively high utilization of *Spartina* habitat by fishery animals under long-term moderate salinities was not affected by short-term lowering of salinity. On the other hand, delta habitats that developed from long-term low salinities were not extensively utilized by estuarine species under normal low salinity conditions.

A major finding of this research is that salinity *per se* does not control distribution of many estuarine animals. Long-term effects of salinity on development of habitat characteristics has a greater effect than the direct effects of salinity on estuarine organisms themselves. Laboratory tests of combined effects of temperature and salinity on growth and survival of brown and white shrimp show that shrimp are highly tolerant of a wide range of salinities and large-scale salinity changes. Long-term salinity effects on food sources (epiphytes, amphipods, worms) appear to have more influence on distributions of shrimp and other estuarine organisms than the direct effects of salinity.

Predator–Prey and Selective Feeding Research

Research on the distribution, abundance and habitat use by shellfish and finfish have provided a basis for formulating and testing hypotheses concerning the role of habitat interactions in the survival of estuarine organisms. Survival can be influenced by the abundance and type of predators, sediment type, water turbidity and the presence of vegetative structure. Research at the Galveston Laboratory is addressing some of these interactions.

Drop–sampling was conducted at two–week intervals through the spring of 1987 in a salt marsh on Galveston Island and size–frequency data on young brown shrimp from these samples were used to obtain additional estimates of mortality in estuarine nurseries. Data from predator–exclusion cages located in the marsh indicated that survival was 95–100% over two–week periods in the absence of predators. Experiments on factors (*e.g.*, salinity, size, density, hunger, and substrate type) affecting the burrowing behavior of brown shrimp and white shrimp in Texas were analyzed. Burrowing is largely controlled by daily illumination patterns, but at low light intensities other factors can affect this behavior. Analysis showed significant effects of hunger and substrate type for both species. The effects of size and salinity were significant for brown shrimp while the effect of density was significant for white shrimp. Overall, burrowing was reduced with increased sediment grain size, hunger level and density, and with decreased salinity and size of the shrimp. Because these factors affect burrowing activity, they can alter survival of shrimp in estuaries by reducing encounters with predators. In addition, burrowing by shrimp can reduce the catch efficiency of commonly used sampling gear and affect the accuracy of population estimates. Other laboratory studies demonstrated that both water salinity and turbidity significantly affected selection for vegetated structure by brown shrimp. In addition, the distribution of food and substrate in experimental tanks also affected selection patterns.

Stomach contents of over 750 small fishes were examined to compare diets of fishes in coastal marshes with those in fresher marshes near the Lavaca River delta. The dominant predators on penaeid shrimp include southern flounder, spotted seatrout, and inshore lizardfish. Preliminary results indicate that most (83%) of the shrimp were eaten in coastal marshes rather than delta marshes.

Previous research indicated that numerous fishery organisms consume detritus and that, in some instances, detritus may be a major energy source. A survey was continued at the Beaufort Laboratory to determine the relative importance of detritus in the diet of Atlantic menhaden from Maine to Florida. Microscopic analysis of fish gut contents showed that amorphous detritus was the primary item ingested (usually greater than 80%) by juvenile and adult menhaden in estuaries. Biochemical analyses of the food showed it to have a high ash content, and that the organic component was rich in protein and humic compounds. Digestibility estimates for organic matter were generally high, indicating that amorphous detrital material is readily assimilated. However, the origin of amorphous detritus in the diet of these fish, which likely affects its digestibility, is unclear. In estuarine areas with high vascular plant detritus, the detritus is consumed and efficiently digested by Atlantic menhaden.

The detrital material utilized by menhaden and other estuarine organisms is derived from marshes, seagrass meadows and mangrove forests. The contribution not only of habitat but also detrital resources is important to the overall yield of fishery organisms. In cooperation with the NASA Earth Resources Laboratory at Bay St. Louis, we modeled fishery landings as a function of the export of organic material from coastal wetlands into Calcasieu Lake, an estuary in southwestern Louisiana. In preliminary tests, model results suggest that a reduction in the outflow of organic material from the marsh could result in as much as a 20% loss in the potential landings of some fishery species.

Examination of Impacts to Fishery Organisms and Habitats

Field evaluations are providing a basis to generate and test hypotheses concerning the role and impact of environmental parameters on fishery organisms and their habitats under both laboratory and field conditions. A study of effects of salinity and temperature combinations on postlarval white shrimp, including a comparison of seasonal responses of brown shrimp, indicated that temperature alone has far

more effect upon growth and survival than either salinity alone or the interaction of the two factors. Both the period of acclimation and the season in which tests were conducted affected the responses of both species to these factors. The laboratory studies are related to results from field sampling which have indicated that distribution of penaeid shrimp is related more closely to habitat characteristics (food, substrated, etc.) that may be controlled in part by the long-term salinity regime rather than by short-term fluctuations.

In cooperation with the South Florida Water Management District, we developed a model to estimate the effect of excessively high discharges from the Faka Union Canal on Faka Union Bay, Florida. The model, based on a statistically significant relationship between fish abundances and salinity, suggests that fish abundances could be improved by reducing canal discharges to approximately 30% of the present level. The U.S. Army Corps of Engineers may use these data to support recommendations regarding modifying existing inflow patterns to Faka Union Bay.

Research was conducted on the influence of water quality on the production and distribution of seagrass habitats. Seagrasses are particularly vulnerable to the adverse impacts of turbidity, and several large scale declines of seagrasses have been attributed to a reduction in light penetration caused by turbidity. The Beaufort Laboratory, in cooperation with the U.S. Fish and Wildlife Service and the Florida Department of Natural Resources, has undertaken an intensive field study to examine the diurnal, seasonal, and annual light regime in Hobe Sound, Florida, in conjunction with a study of seagrass distribution, abundance and growth. We are examining the effect of boat traffic on submarine light attenuation and seagrass growth parameters before and after a slow speed no wake zone is implemented in order to predict if restrictions to boat speed and boat wakes will result in either offsetting a decline or increasing the abundance of seagrass in Hobe Sound. These seagrass meadows in Hobe Sound are major nursery areas for spotted seatrout and redfish and food resources for the manatee.

We continued to examine whether the production, standing crop, and density of temperate and tropical seagrasses are limited by nutrients, and therefore are impacted by reduction of nutrient input by reduced freshwater inflow or increased nutrients through eutrophication. We examined the addition of nitrogen and phosphorus provided by seabirds defecating from stands in the experimental plots to a seagrass community on a carbonate mud bank in Florida Bay. The birds delivered approximately 2-4 g of excrement per day of which only a portion is solubilized in the water column and, as a consequence, approximately 80% of the nitrogen and phosphorus reaches the sediment surface where it forms a large reservoir and is eventually mineralized. The plant community responded with a change in species dominance from *Thalassia* to *Halodule*. Both species increased their standing crops and weight-specific net leaf production significantly; however, only *Halodule* increased its shoot density. The results suggest that water circulation plays a major role in providing nutrients for seagrass distribution and productivity in Florida Bay. Restricted exchange of water with the open ocean and the diversion of overland freshwater inputs to northeastern Florida Bay limit the amount of new phosphorus sources. Future water management practices in Florida Bay and other subtropical estuaries with carbonate sediments should consider the potential impact of limiting nutrients.

Functional Value of Mitigated and Created Habitats

Since there are virtually no data as to whether artificially propagated seagrass beds and salt marshes provide fishery habitat values equivalent to the natural habitats they are to replace, research is being conducted to develop and evaluate habitat creation techniques. Dropnet samples of fish, shrimp, and crabs taken in natural eelgrass beds were compared to those from transplanted *Z. marina* and unplanted dredged material at a site in North Carolina. Numerical abundances of all fauna were generally an order of magnitude less in the transplants and bare areas relative to natural beds after 250 days. Faunal composition, however, appeared similar. *Zostera* abundance decreased in concert with local drought conditions and faunal abundance tracked shoot numbers closely. The relation of shoots to fauna displayed discrete relationships between natural and transplanted beds while the development of the faunal community relative shoot density displayed promise as an estimation of mitigation success. Samples

from a 1.9 year-old transplant implied eventual convergence of natural bed and transplant bed fauna, pointing out the need for making bed persistence a requirement of mitigation specifications.

A study of faunal development in created seagrass meadows in Tampa Bay is being conducted under a Memorandum of Understanding between the NMFS and the Florida Department of Natural Resources. *H. wrightii* (shoalgrass) was transplanted into five experimental plots around Tampa and Hillsborough Bays. This seagrass species is frequently used in place of the much slower-growing turtlegrass, *T. testudinum*. Unfortunately, the slower-growing turtlegrass beds, which constitute much of the seagrass acreage in the Florida and the Caribbean, are the seagrasses most frequently impacted. The transplants are being compared to adjacent, unplanted bare areas as well as to natural stands of *T. testudinum, S. filiforme* (manatee grass), *H. wrightii*, and a rhyzophytic macroalgae, *Caulerpa prolifera*. After the first sampling, numerical abundances of fauna in natural seagrass and *Caulerpa* beds were similar and significantly greater than transplanted or unvegetated areas, which were in turn similar to each other. This study will be continued in an attempt to determine the actual fishery contribution of (1) substituting transplanted seagrass beds for natural beds and (2) substituting one seagrass species for another.

These seagrass transplant studies have allowed a continuation of the NMFS data base acquisition on seagrass population growth and coverage rates in the southeast. Data collection on growth of four year old turtlegrass transplants in Florida has also continued as has a shoalgrass transplant in Laguna Madre, Texas. 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.

Microbial abundance in transplanted seagrass bed sediments has also been measured. 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. Microbial abundance in 250-day old transplanted *Zostera* sediments was similar to that in adjacent unvegetated sediments, while natural *Zostera* grassbed sediments had a much greater microbial abundance. Sediment organic carbon and percent silt-clay were positively correlated with bacteria abundance. We also found that a naturally seeded *Zostera* grassbed, less than one year old, had greater sediment bacteria abundance than unvegetated sediments, and also higher organic matter content and a greater percent silt-clay. However, the levels of these sediment parameters in the new grassbed were not as high as in an adjacent, older grassbed. We will continue to monitor the development of the microbial community and associated sediment parameters as well as the abundance and importance of nitrogen-fixing bacteria in seagrass transplants in North Carolina and Tampa Bay, Florida.

Studies continued at two marsh mitigation sites in North Carolina, 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 invertebrate samples were collected monthly 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. The mitigation site is utilized by fishes, but the prevalent species are not those common to the area that this mitigation site is in compensation for; the adjacent natural marsh also is utilized by more and in some cases different species than the mitigated marsh. 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. The organic and silt-clay content of the mitigated site are about 45% of the natural site while microbial abundance is 60% lower than that of natural site sediments. Oligochaetes dominate the mitigation site while polychaetes dominate the natural marsh infauna. Plant biomass is significantly less in the mitigated site relative to the natural site; the

number of shoots/m^2 is less; the number of flowers is less; while the standing dead matter is about half that of the natural marsh. The study will continue since it is providing valuable information on the efficacy of off-site mitigation and on potential problems associated with grading of upland areas to estuarine intertidal habitat as a mitigation method.

At the second site, block netting of a marsh transplanted in 1974 and an adjacent natural salt marsh has been conducted on a monthly basis since June 1985. Analysis of the plant communities by staff at 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 5 species differs somewhat. The total number of fish crossing 10 m of marsh frontage over 13 months was similar at the two sites; unfortunately, we are not in a position at this time to determine when over the 13 years this similarity would have become evident.

The Beaufort Laboratory, under a contract with the Waterways Experiment Station of the U.S. Army Corps of Engineers (COE), is sampling fishes and invertebrates at 26 sites in Florida where *Spartina* marshes have been planted as a consequence of mitigation actions.

Habitat Creation and Enhancement Studies

The Galveston Laboratory is conducting a pilot project to determine whether the construction of access channels in transplanted marshes will increase utilization of the inner marsh surface by fishery organisms. Two sites were identified in the Galveston Bay system, Chocolate Bay and Pelican Spit. At the Chocolate Bay site a salt marsh was created by transplanting *S. alterniflora* on dredge material in 1983. Four "U"-shaped channels extending 60 m into the marsh were constructed by COE at this site during December 1986. Samples of fishery organisms were collected using the drop-sampler both in the inner and outer marsh of the experimental and control plots during May 1987 and are being processed. During November 1986, dredge material from a nearby channel was used to create intertidal habitat on approximately 7 acres of subtidal bottom at the second site on Pelican Spit. In early April 1987 the site was transplanted with *S. alterniflora* to stabilize the substrate. The plantings appear to be surviving, and the site should be ready for channel construction by late 1987.

In North Carolina, three eroding dredge material islands were recontoured by the COE, to accommodate saltmarsh and seagrass plantings under a design developed by NMFS biologists and COE engineers. The grasses are being monitored by North Carolina State University (saltmarsh) and Beaufort Laboratory (seagrass) for density and coverage. The influence of the grasses on erosion control (wave energy diminuition and sediment accretion and loss) are being evaluated by the NMFS and COE. Beaufort initiated biannual faunal sampling of these sites and their natural counterparts in September 1987, 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 studies in North Carolina, microbial parameters will be evaluated as measures of sediment development.

Status and Distribution of Species and Habitat Types

The Ocean Assessments Division of NOAA is compiling data on the life history, distribution and abundance of 35 selected fish and invertebrate species in 13 estuaries from Florida Bay to Mobile bay in the Gulf of Mexico. The data base, compiled from literature and from consultation with local and regional experts, will be part of the National Estuarine Inventory and will enable comparisons among species or species groups, specific life stages, estuaries and geographic areas.

Efforts to evaluate the distribution of wetland habitats were continued. A collaborative investigation initiated in 1985 by Beaufort Laboratory and the Strategic Assessments Branch of OAD is using a dot-grid procedure to estimate acreages of 15 habitat types using National Wetland Inventory (USFWS) habitat

maps. Grid sampling of all available NWI maps (412) in the northeast region (ME-CT) was completed in January 1987. This area included 1.5 million acres of forested wetlands, 157,500 acres of tidal flats, 89,200 acres of salt marsh and 72,700 acres of fresh marsh. Grid sampling continued in the Gulf Coast region (Florida and Texas), and 450 of the 800 maps available in the region have been sampled. During 1987 the EPA Estuary Program requested data for the Albemarle and Pamlico Sound area in North Carolina, and Senator Pete Wilson of California requested information on wetlands in the San Francisco Bay area. Ninety-five maps were sampled in the Albermarle-Pamlico region that encompassed 857,900 acres of forested wetlands, 127,500 acres of salt marsh, 29,900 acres of fresh marsh and 17,800 acres of tidal flats. One hundred and fifty-six maps were sampled in the San Francisco Bay area that encompassed 382,600 acres of palustrine farmed wetlands, 80,900 acres of salt marsh, 65,700 acres of tidal flats, 47,800 acres of fresh marsh and 12,700 acres of forested wetlands.

A second study concerning the distribution of submerged aquatic vegetation (SAV) in the area from Cape Lookout, North Carolina to the northern tip of Currituck Sound at the North Carolina - Virgina boarder was initiated. These SAV habitats are major nursery habitats for juvenile fishery organisms, yet distribution and abundance data is disjointed and virtually absent in most regions of the coast. This work, funded by EPA, is part of a larger Albermarle-Pamlico Estuarine Study (APES) dealing with habitat delineation, status evaluation, impact assessment and management. NOAA's Photogrammetry Unit will supply, under subcontract to the Beaufort Laboratory, aerial photographs of the study area, taken under near optimal solar, biological, hydrological and atmospheric conditions. We will identify, locate, and quantify SAV from the photography using video image analysis and ground truthing. The photogrammetry unit will then superimpose the SAV information on USGS topographic maps to produce a chart product.

Several studies suggest that the length of marsh shoreline is a major factor affecting survival and growth of young estuarine animals. A simple stochastic model was developed that suggest that from a starting point of solid land, shoreline increases in early stages of disintegration, reaches a maximum at about 50% water, and decreases thereafter. The pattern of land and water created as the marsh disintegrates determines the rate of change in interface and the maximum interface reached. Thematic mapper imagery from the Landsat satellite is being used to test the model and to evaluate whether shoreline is presently increasing or decreasing in Louisiana. Results from 72 sample plots in Louisiana support the model in suggesting that shoreline increases with intertidal land loss and then decreases after about 50% of land has converted to water.

A draft literature review of the marine system of the Puerto Rican-Virgin Island shelf was completed to evaluate habitat utilization and expand our understanding of the basis of fishery yield in the Caribbean. This report describes the major ecological subsystems of the region to identify the more common species and the subsystems in which they occur, to quantify productivity and biomass, and to outline trophic relationships.

TRACE METAL RESEARCH

Trace metal studies focused on: (1) manganese distribution, speciation and cycling in marine waters; (2) determination of total dissolved and ionic copper and zinc in estuarine waters; (3) bioassay of trace metal pollution in estuaries; (4) monitoring levels of contaminants in 17 estuaries in the Southeast Region; and (5) determining mechanisms of metal regulation in shellfish.

The cycling of manganese between soluble, bio-available available Mn^{2+} and insoluble, manganese oxides was investigated both in oceanic and coastal waters. A dynamic redox cycle in which manganese oxidation is microbially catalyzed was demonstrated. Oxidation is strongly inhibited by sunlight, due to its adverse effects on microorganisms, but, sunlight also stimulates the solution of manganese oxides via photoreductive reactions. The two photo-effects are largely responsible for a pronounced maximum in dissolved manganese concentration and biological availability in near-surface oceanic waters, and for diel cycles in dissolved manganese concentrations in shallow coastal waters.

Manganese cycling is important because of the role of manganese in reducing the toxicity of copper, zinc and cadmium as demonstrated by experiments in trace metal-buffered media. Hence, the concentration of dissolved manganese is an important factor affecting the toxicity of these metals to organisms in estuarine and coastal waters.

Research also focused on the determination of copper and zinc concentrations and complexation in estuarine water. Using co-precipitation techniques, total dissolved copper and zinc were measured down to the 10^{-9} M. Modifications of the "Sep-Pak" column separation technique provided improved methods for determining the extent of both zinc and copper complexation in estuarine samples.

Dissolved and free ionic copper and zinc concentrations were measured in samples collected from the heavily contaminated Elizabeth River-Hampton Roads system and the lower Chesapeake Bay. In all cases copper was highly complexed by organic matter so that even in the most contaminated samples, the free cupric ion concentration was only 10^{-10} M, which is enough to have some biological toxicity, but much less than might be expected. Zinc, on the other hand, had very little organic complexation, and at three stations in the Elizabeth River estuary, free zinc ion concentrations exceeded 10^{-7} M. Although zinc is considerably less toxic than copper, laboratory experiments showed that free zinc ion concentrations in excess of 4×10^{-8} M can be toxic to the copepod *Acartia tonsa*.

Based on the above data, we hypothesized that existing levels of trace metals in some contaminated estuaries are sufficiently high to adversely affect estuarine fishery organisms. To test this hypothesis bioassays were conducted with the larvae of *Acartia tonsia* in water from the Elizabeth River estuary, Hampton Roads, and lower Chesapeake Bay. The survival of these organisms was measured in parallel water samples with and without added synthetic chelating agents which reduce the free ion concentration and biological availability of toxic trace metals. The addition of the chelating agents generally increased the survival of larval *Acartia* in water samples from the Elizabeth River, but had little or no effect on survival in water taken from Hampton Roads and the lower Chesapeake Bay. These results support our hypothesis that existing free copper and zinc ion concentrations are sufficiently high in some contaminated estuaries to be toxic to sensitive marine organisms.

The fourth area of research involves NOAA's National Status and Trends Program which is collecting samples in the southeast for the fourth consecutive year. The goal of the project is to establish a data base on the concentrations of key contaminants in fish and sediments and on incidence of fish disease. Research efforts are described in more detail under the section of this annual report entitled Product Quality and Safety.

The fifth area of study concerns the determination of the physiological and biochemical processes involved in the metabolism of metals by marine shellfish. These investigations are primarily concerned with the sources of natural variability in both whole animal and tissue concentrations of metals and in the biochemical partitioning of metals as a function of normal growth and reproductive cycles. We have shown that the reproductive cycle of the oyster significantly alters the mobilization and partitioning of copper both intracellularly and in the whole animal. In the blue crab major redistributions and changes in the intracellular partitioning of both copper and zinc can be correlated with the stages of the molt cycle. We have also described a normal function for the low molecular weight metal-binding protein, metallothionein. Through an understanding of the sources of natural variability, we can better assess the impacts of metallic contaminants on fishery organisms.

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PRODUCT QUALITY AND SAFETY

Research concerning the quality and safety of seafood is centered at the Charleston Laboratory with cooperative research and communication interfaces with state and federal regulatory and environmental agencies. Specific areas of research concern process and product development, nutritional and quality evaluation, establishment of edibility and storage stability characteristics, and critical seafood safety issues stemming from chemical and microbiological contamination of fish and shellfish.

FISH OIL (MENHADEN)

Production of Biomedical Test Materials

A biomedical test material facility was completed in March at Charleston Laboratory for the production of biomedical test materials from menhaden oil. Test materials of defined quality are being produced under a memorandum of understanding with the National Institutes of Health (NIH), and provided at no charge to investigators whose research proposals have undergone stringent peer review.

Test materials currently in production include refined menhaden oil and concentrates of omega-3 polyunsaturated fatty acid ethyl esters produced by physical and chemical separation techniques. Menhaden oil, which has undergone alkali refining and bleaching by the supplier, is passed through the wiped film deodorizer to reduce cholesterol, organic contaminants, and fishy odors and flavors to very low or undetectable levels. A portion of this vacuum stripped oil is reserved as a test material; the balance is used to produce omega-3 concentrates. This involves, first, the trans-esterification of the oil to produce ethyl esters. When the esters are then reacted with urea dissolved in hot ethanol and the solution is cooled, the straight chained saturated and monounsaturated esters form adducts with urea and are precipitated from the alcoholic solution, thereby concentrating the non-adducted polyunsaturated esters. After the ethanol is stripped from the solution in the film evaporator, the neat esters are distilled in the wiped film molecular still to eliminate oxidation products, polymers, color bodies, and any remaining cholesterol.

To date, eight researchers have been supplied with refined oil in bulk or in soft gelatin one-gram capsules. Concentrates will also be available in these two product forms. Research is underway to determine the feasibility of dispensing test materials from aerosol cans or as microcapsules having a starch or starch-gelatin matrix.

Additional test materials are planned for the future. Among these are purified eicosapentaenoic acid (EPA, 20:5ω3), docosahexaenoic acid (DHA, 22:6ω3), and glycerides containing enhanced amounts of EPA and DHA. These procedures are still under development at the Charleston, Gloucester (MA), and Seattle (WA) Laboratories of NMFS.

Three Charleston Laboratory staff members attended an American Oil Chemists' Society short course on Polyunsaturated Fatty Acids and Eicosanoids, held in Biloxi, Mississippi in May. Laboratory personnel organized a poster session featuring commercially available test materials and presentation entitled "Production of Test Materials from Menhaden Oil."

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

The QA/QC analytical capability is now fully established to provide necessary support to the production of biomedical test materials at the Charleston Laboratory and to assure the quality of these materials.

Analytical methods established during the year include methods for the determination of EPA, DHA, and total ω-3 content, iodine value, peroxide value, free fatty acids, cholesterol, antioxidants, metals, PCBs/pesticides, moisture, and complete sensory evaluation. To achieve this goal, existing methods were

evaluated for suitability for analysis of refined menhaden oil and ethyl ester concentrates and whenever possible official methods were adapted. Where existing methods proved unsuitable for analyses, methods were modified or developed.

Analytical capabilities were enhanced by the addition of automatic titrators, polarograph, IR spectrophotometer, and gas chromatograph with auto-sampler and direct computer inferface. Development of methods for examining volatile oxidation products and for quality assurance of deuterated fatty acids produced by contract will begin in late fall with the installation of a recently purchased Gas Chromatograph/Mass Selective Detector.

A 12 months storage study of soft-gel encapsulated refined menhaden oil was initiated. Storage studies to determine stability of micro-encapsulated refined menhaden oil and ethyl ester concentrates will be initiated in the near future.

A computerized database containing analytical data originating from QA/QC analyses of test materials and materials from storage stability studies was developed. Quality assurance reports were also generated for researchers receiving test materials.

A draft manual of the procedures for QA/QC of the test materials is being edited and will be presented to the National Institutes of Health, Fish Oil Test Materials Advisory Committee at their November meeting.

PROCESSING AND COMPOSITION STUDIES (LATENT RESOURCES)

Minced Fish Uses

Minced flesh prepared from a variety of latent resource species has potential use in cooked emulsion products such as sausages, weiners and frankfurters. These potential uses of minces in products containing nitrites raises questions of possible nitrosamine formation. Before these questions can be answered, the problems of artifacts in the methods for analysis for nitrosamines must be solved. The Department of Agriculture has been studying this problem for several years but has been limited due to the lack of authentic test material containing fish. Experimental frankfurters containing 15% minced fish were prepared and shipped to the U.S.D.A. Laboratory in Philadelphia in a cooperative study on the potential nitrosamines problem. Frankfurter samples containing the unwashed mince of Atlantic and Gulf menhaden and of several gadoid species were supplied for testing and analytical methods development. Samples containing surimi prepared from both Alaskan pollock and Atlantic menhaden were also supplied. The initial phase of the methods development study has been completed and early results indicate little likelihood of problems with southeast species.

Edibility Characteristics

Limited additional species were evaluated for edibility characteristics. The proximate chemical compositions and fatty acid profiles for 40 southeastern finfish species evaluated earlier were published as NOAA Technical Report NMFS-54.

Seafood Nutritional Data Base

The NMFS Nutritional Data Base has been compressed and stored on a personal computer (PC) with 5 or more megabytes of memory under a Clemson University Sea Grant Project. Documentation of the new system is nearing completion and a system to make these data available to researchers and other users in an on-line basis is being sought.

Cultured Species Studies

An iced and frozen storage study was conducted on hybrid striped bass from the South Carolina Waddell Mariculture Center. Sensory, chemical and microbiological studies were performed on headed

and gutted fish and on skinless fillets during iced storage. Sensory and chemical tests were also conducted every two months on vacuum packaged or glazed and boxed skinless fillets and headed and gutted fish stored at -20°C. Good storage stability is indicated for these products.

Sensory evaluations, proximate compositions and fatty acid profiles were also determined for cultured red drum from the S.C. Waddell Center. The results of the fatty acid analyses indicated a significant difference in the profiles of the polyunsaturated fatty acids between the cultured and wild animals of both species. The difference has the potential for differentiating fish from these different sources. A research note has been prepared for publication on this subject.

SURIMI (MENHADEN)

Storage Stability

A six months storage stability study on frozen menhaden surimi prepared from both Gulf and Atlantic menhaden was completed. The surimi, prepared in the experimental processing laboratory, exhibited good flavor stability while a frozen washed mince which was not stabilized with cryoprotectants developed a relatively strong "characteristic protein flavor." Sensory and instrumental texture measurements indicated some decreases over the 6 months storage at -20°C.

Pilot Plant

A menhaden surimi demonstration plant, constructed by Zapata Haynie Corporation at Reedville, Virginia, was completed and is being operated under a NMFS contract with technical monitoring by the Charleston Laboratory. The objectives are to determine the commercial feasibility of producing surimi from menhaden and to supply mince and surimi for product research and development. A number of production runs have been made in which the surimi had quite good functional characteristics. This project is to continue into early calendar 1988 with a several months extension being considered.

PHYSIOLOGICAL AND BIOCHEMICAL ASPECTS OF CIGUATERA TOXICITY (REEF RESOURCES)

Seafood toxins, specifically ciguatoxin, occur in commercially valuable reef fish species and compromise both human health and the potential for commercial and recreational exploitation of seafood. While significant progress has been made in the past five years in understanding the chemistry of ciguatoxins and towards developing a field test capable of screening fish from commerce, there is presently no commercially applicable method of alleviating the threat of ciguatera poisoning. Our efforts to focus more effectively on controlling methods for ciguatera involved: (1) increasing the production of maitotoxin; (2) attempting to purify maitotoxin; (3) collaborative efforts to develop both immunological and cell receptor site mechanisms for field detection of cigua-maitotoxin; and (4) estimating the economic impact of ciguatera incidence on selected commercial fisheries.

In addition, the Charleston Laboratory hosted a workshop to establish research priorities for ciguatera research. Representatives of several universities and government agencies, including the Department of the Army, agreed that ciguatera research could not proceed at a significant rate unless adequate quantities of purified toxin(s) were available. It was, therefore, agreed to pool available resources to produce, purify and characterize ciguatoxin(s). The algal toxin, maitotoxin, is closely related to ciguatoxin and may in fact be involved in some incidences of ciguatoxicity. Therefore, both inhouse research efforts as well as collaborative efforts with university and other government research groups have emphasized production and purification of algal extracted toxin.

Toxin Production

As a means for increasing toxin production and for yielding further knowledge regarding ecological conditions governing toxin production in the field, several studies concerning physical and nutrient requirements for growth of our toxin producing Hawaiian strain of *Gambierdiscus toxicus* were conducted.

As a result of adjustments in dinoflagellate culturing parameters, toxin production was increased significantly. Specifically, crude toxin production was increased from a capacity of about 12,000 mouse units (MU) (LD_{50} value for a 48 hr bioassay) per month to about 100,000 MU per month.

In addition, a new strain of *Gambierdiscus toxicus,* isolated from cell populations collected at Martinique Island in the Caribbean, was cloned from a single cell isolate and acclimated to mass culture. This strain was found to grow faster and produce greater amounts of extractable toxin per cell than that reported for any other clone. It is anticipated that using this strain, plus results from further growth studies, will yield a five-fold increase in crude toxin production in FY88.

Toxin Purification

Purification of crude maitotoxin (algal toxin) extract was pursued using combinations of wet column, thin layer, and high performance liquid (HPLC) chromatography. Using these procedures, purity of toxic extract was increased from a toxicity value of 1 mg (kg mouse)$^{-1}$ produced in FY86 to about 22 µg (kg mouse)$^{-1}$. In addition, other techniques were evaluated for their ability to yield pure maitotoxin. These included experiments with affinity chromatography. Although the technique indicated a possibility for achieving relatively high purity toxin, the efficiency and relative expense involved rendered affinity chromatography as a non-priority research area.

Toxin Detection

Semi-purified toxin was supplied to the NMFS Gloucester Laboratory for development of monoclonal antibodies to maitotoxin. To date, twelve clones have produced antibodies to semi-purified toxin. These antibodies are being screened against toxin of increasing purity and are also being considered for studies with detection devices such as "sandwich" disks.

Binding affinities between mouse brain synaptosomes and semi-purified maitotoxin were studied for information needed for development of a biosensor for cigua-maitotoxin based on isolated cell surface protein channel receptors. In addition, a cultured mouse adrenal tumor cell (Y-1 strain) cytotoxicity assay was evaluated in terms of a potential toxin detection system. Semi-purified maitotoxin was found to elicit cytotoxicity when dosed at 30 to 120 µg (ml)$^{-1}$. At its most sensitive concentration, the method was estimated to have a detection of about 0.001 MU.

Economic Impact of Ciguatera

A survey using published reports, newspaper articles, and fishery statistics was conducted to determine the economic impact of ciguatera for Dade County, Florida and the Hawaiian Islands. Information used included landings, consumption, documented cases of embargos to snapper and grouper fisheries and pricing information. A model designed from the data collected suggests that several million dollars can be lost annually to just the snapper and grouper industry.

Toxin Research Coordination

The Charleston Laboratory sponsored a Cigua-Maitotoxin Workshop in February of 1987. Specific accomplishments included: (1) status of ongoing research efforts at several institutions; (2) status of newly initiated toxin programs funded by the Department of the Army; and (3) recommendations for future priorities in maito-ciguatoxin research.

MOLLUSCAN SHELLFISH

Research coordination activities, including planning documents and several status reports of key technical issues were prepared and are described in the section of this annual report titled Molluscan Shellfish. Studies of methods to measure enteric viruses occurring in shellfish tissues, depuration of enteric viruses by shellfish, and factors affecting wholesomeness and quality of shellfish during commerce are also described under Molluscan Shellfish.

ENVIRONMENTAL QUALITY

The environmental quality program endeavors included the development of a Position Paper identifying the problems/issues of environmental concern in the southeast. This paper identified an approach for dealing with environmental concerns in a joint planning effort with South Carolina Marine Resource Division and the South Carolina Sea Grant Consortium.

SHRIMP QUALITY

Studies on shrimp quality were conducted and are described in detail under the section titled Shrimp and Bottomfish.

BENTHIC SURVEILLANCE OF ORGANIC CONTAMINANTS

The Benthic Surveillance Project of NOAA's National Status and Trends Program is in its fourth year of operation (Cycle IV). This program is designed to characterize concentrations of key contaminants (trace elements, synthetic organics, and petroleum hydrocarbons in fish and sediments) and on incidence of fish disease from 50 coastal and estuarine sites nationwide. Samples were collected from August through mid-October. Sampling operations took a new tack this year with intensive surveys being conducted in Sapelo Sound, St. Johns River Estuary and Galveston Bay. These intensive surveys were conducted to determine how well the standard sampling site characterized the entire location. In addition, the standard sampling site protocol was again used at five locations: Charleston Harbor, SC; Pensacola Bay, FL; Round Island, MS; Mississippi River Delta, LA and Barataria Bay, LA. Sampling at the remaining locations was deferred until Cycle V. Chemical analysis of liver, bile, stomach content and sediment are continuing at the Charleston and Beaufort Laboratories on previously collected samples. Quality assurance activities continue by both laboratories to assure that high quality data are produced. Meanwhile, analytical procedures are evolving with the state-of-the-art and every effort has to be made to ensure comparability of data over the whole span of the program. A preliminary report on the first year's samples in the southeast was issued in June 1986, and NOAA/OAD published a nationwide report in March 1987. The assay of sediment samples from the entire program, east, west and gulf coasts, for *Clostridium perfringens* spores, as an indicator of sewage pollution, is now being completed at the Charleston Laboratory for Cycle IV samples. Reports and presentations on the project are being prepared.

FEDERAL SURVEY OF PCBS IN ATLANTIC COAST BLUEFISH

At the request of Congress in 1984, NOAA, FDA, and EPA conducted a study of PCBs in east coast bluefish to determine if a health risk existed. Details of the study were described in last year's Annual Report. No samples of small or medium size fish exceeded the FDA tolerance level whereas a few samples from large fish did exceed the standard. An interpretive report containing assessments of long-term health risks and recommendations on potential regulatory actions was completed this year. The results suggest that levels of PCBs in bluefish in commerce do not pose a significant health risk to the general consuming public.

MODEL SEAFOOD SURVEILLANCE PROGRAM

Congress identified funds beginning this year 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 program is feasible.

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