

During the meeting, the question was raised as to whether states have plans or programs to monitor ecosystems so they know what to measure in order to determine what regulations are needed. Please provide additional information on these monitoring plans and programs and the involvement of fishers in developing them.

Response by George Sedberry, SCDNR.

INTRODUCTION

I can only speak to monitoring plans and programs in South Carolina, although I am aware that other southeastern states have programs for monitoring fishery populations and the health of ecosystems in state waters. In some cases, state monitoring programs extend into federal waters. In the case of South Carolina, cooperative programs with the National Oceanic and Atmospheric Administration (NOAA) extend SC marine monitoring programs region-wide, to include coastal waters from Cape Hatteras to the Florida Keys and offshore to the upper continental slope. The following is a summary of these marine and estuarine ecosystem monitoring programs being conducted by the South Carolina Department of Natural Resources (SCDNR), primarily through its Marine Resources Division (MRD). Programs that influence regulations include fishery monitoring programs that provide data for management plans, and environmental monitoring programs that can influence regulations placed on industries or individuals that impact the environment.

FISHERY MONITORING

Fishery monitoring programs in South Carolina include those aimed at monitoring the health of stocks of finfish, crustaceans (crabs, shrimp) and shellfish (primarily oysters). These monitoring programs include fishery-dependent sampling (data collected from the fishery) and fishery-independent sampling (data collected by scientific sampling). Both data sets are essential for assessing stocks of fishery species. In addition to programs aimed at monitoring specific fisheries (e.g. shrimp or grouper fisheries), there are several large state-federal cooperative programs that conduct fishery-independent assessments of specific ecosystems such as near-shore shrimp grounds and offshore reef habitats.

Crustaceans

Penaeid shrimps and blue crab constitute the top two commercial fisheries in South Carolina. In addition to their commercial importance, these species are also important recreationally, being pursued by thousands of recreational fishers each year. The primary species of concern in crustacean monitoring are white, brown, and pink shrimp, and blue crab. In addition, horseshoe crabs (*Limulus polyphemus*) are also monitored in these surveys. The goal of these crustacean surveys is to monitor abundance and health of the resource, and to facilitate interaction among resource users (fishers), managers, and scientists. The goal is addressed by collecting fishery-independent abundance data that can be used to analyze population trends, life history patterns, and interpret environmental effects on monitored populations. The information that is obtained is used to make recommendations and provide reports and supportive data to facilitate the proper management of South Carolina's crustacean resource.

Estuarine Fishery-Independent Crustacean Monitoring

This monitoring survey consists of trawl stations at selected estuarine sites to monitor abundance and length frequency of shrimp. Data are used to decide opening and closing of shrimp fishing seasons and to monitor populations of shrimps, blue crab, and horseshoe crab. Subadult shrimps and blue crab are monitored primarily in two ways: by trawling from small boats at fixed locations in tidal creeks with a 3-m headrope trawl (12-mm mesh) for five minutes and by trawling at fixed locations in rivers, sounds and Charleston Harbor with double 6-m headrope trawls (1-cm mesh) for fifteen minute tow duration with a 50-ft coastal research vessel. Creek sampling is conducted during spring and summer when young shrimp are most numerous in those habitats, whereas the larger trawl sampling is conducted year round. Species composition, total weight, abundance and length frequency are recorded, along with water temperature and salinity. Ovarian development is determined for a subsample of female white shrimp. Total number, carapace width and sex are recorded for all blue crab, while molt stage and maturity are determined for crabs greater than 74 mm carapace width.

Creek sampling data have proven useful to document immigration, emigration, relative abundance and growth of juvenile shrimp and blue crab in shallow creek habitats, thus allowing projections of when shrimp will reach harvestable size. The role of tidal creeks as a nursery and mating area for blue crab and penaeid shrimp has been demonstrated by these efforts.

Postlarval shrimp recruitment is monitored at Breach Inlet SC, in a long term program that provides data on spawning success of offshore brown and white shrimp, and remains the most reliable indicator of fall white shrimp harvest. Sampling results also indicate timing of recruitment of postlarvae into estuaries, and level of success of spawning of the adult population. Postlarvae are sampled with a 1-m, 500- μ m mesh plankton net at Breach Inlet, between Sullivan's Island and the Isle of Palms.

Staff of the MRD Crustacean Management Section communicate with commercial and recreational harvesters to address their concerns and to inform them of results from monitoring surveys.

Commercial Trawl and Channel Net Observations

These monitoring programs involve working closely with shrimp fishers. The primary effort involves use of scientific observers aboard commercial boats that make trawl tows prior to opening of the season. White shrimp from these tows are counted, weighed, measured, sexed, and examined for ovarian development stage. Sex or developmental stage is not determined for brown shrimp. These data are used to determine when most white shrimp spawn in a given year, and the season opening date is set after a majority of white shrimp have spawned.

Monitoring of shrimp for the channel net fishery, which operates in tidal creeks, is prosecuted by use of a single 6-m headrope trawl towed from a small boat. Tows of 15-minute duration are made in areas in Winyah and North Santee Bay, and catches are processed as in the other methods. As white shrimp approach harvestable size in late summer, several channel net fishers are selected to make 'test' channel net sets in areas that will open. Total catch of shrimp and mean lengths and weights are determined from these sets. An opening date for the channel net season is then determined, based on data collected from these shrimpers.

Blue Crab

The SCDNR uses a fishery-independent crab pot survey to monitor abundance and size frequency of blue crab. Blue crab are sampled using commercial crab pots deployed bimonthly

in a random block design in the Ashley River near Charleston, and twice during the fall in Winyah Bay, Bull's Bay, Dawho River, Ashepoo River, and Whale Branch. Abundance, weight, size frequency, sex ratio, molt stage and maturity stage is recorded. The catch per trap has shown a decline since this survey began in 1988, and the data were recently incorporated into a stock assessment for blue crab in South Carolina.

Shellfish

SCDNR shellfish research and monitoring focuses on economically and ecologically important mollusks of South Carolina. Our goal is to provide scientific information to further the understanding, conservation, management, enhancement and restoration of shellfish resources. The South Carolina Department of Health and Environmental Control (DHEC) Shellfish Sanitation Program promulgates and enforces rules and regulations for the classification of shellfish growing waters and for the safety and sanitation in harvesting, storing, processing, handling and transportation of mollusks (and finfish and crustaceans). Monitoring ensures that shellfish and the areas from which they are harvested meet the health and environmental quality standards provided by state and federal regulations. The DHEC Office of Ocean and Coastal Resource Management (OCRM) has regulatory authority over confined shellfish culture containers placed in estuarine areas for aquaculture. Public hearings and mitigation may be necessary in some cases where culture facilities are established. MRD provides shellfish resource data to OCRM for marina applications and other major construction involving estuarine alterations. Information such as bottom types, oyster distribution and suitability for the growth and propagation of shellfish are provided for each permitting agency.

Since 1972, the SCDNR has been documenting the occurrence of two oyster (*Crassostrea virginica*) pathogens, *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX), in South Carolina. Dermo infections were most intense in late summer/early fall and least intense in the winter. To evaluate the status of both diseases in South Carolina, MRD initiated a statewide monitoring study in 1996. Fifty-six sites across the state were selected, and Dermo was observed in oysters at all of the stations, indicating a widespread incidence of the disease. MSX was detected in oysters at approximately 50% of the stations.

Current research and monitoring programs include: a multi-year study of oyster reef ecology; examination of clam culture/environment interactions; ongoing monitoring of the condition of SC oysters; a cooperative project with University of South Carolina to study transmission of oyster diseases; and an examination of the impact of alternative management strategies on oyster bed condition and recovery rates. Recruitment in oysters (spatfall data) was monitored for years at Bears Bluff Laboratory on Wadmalaw Island SC and, in conjunction with MRD's Estuarine Survey, at numerous stations statewide. The University of South Carolina Baruch Laboratory has collected recruitment data in North Inlet for the last 20 years. Some scattered individual recruitment studies have been conducted in conjunction with other projects at MRD, and we have monitored recruitment at selected sites for the last 6 years. In general the potential spatfall and recruitment in SC is high, although there is considerable interannual variation. In many areas, recruitment appears to be limited by lack of hard substrate. It is difficult to tell historical trends in spatfall due to varying methodologies.

A number of studies in SC have collected data on oyster growth rates. Some of these utilized hatchery oysters and others utilized wild-collected juveniles transplanted to study areas. These studies have compared intertidal and subtidal growth rates at two sites, growth in different

estuaries with differing stages of urbanization, and growth in areas subject to different pollution levels.

Oyster reefs are home to many estuarine and marine organisms, so monitoring the health of reefs is important to a variety of fishery species. Extensive intertidal reefs provide three-dimensional structure where otherwise there would be bare mudflats, and function as essential habitat for fish and shellfish. In addition, oyster reefs act as breakwaters and protect delicate marsh habitats from erosion. As coastal populations of humans have increased, pressure on the oyster resources has also increased. Additionally, increasing coastal development reduces water quality, resulting in more beds being categorized as "closed" and further increasing harvest pressures on the remaining beds. SCDNR monitors oyster beds to determine the impact of various harvest methods, management techniques, and disturbances on oyster population parameters (length frequency, size, standing crop). We also monitor the rate of recovery after harvesting or die-off from disease or natural causes.

Explosive coastal growth in the last decade has wrought significant changes in southeastern estuaries. Because of this rapid coastal change, intertidal oyster resource monitoring and assessment is necessary. To efficiently manage the resource and provide long term environmental trends data, remotes sensing technology will be needed. Some possible methodologies which we can explore the use of are: overhead digital imagery, aerial surveillance techniques, side-scan sonar mapping devices, and remote sensing equipment. Additionally we need to develop the capability for remote-setting of oyster larvae to facilitate restoration efforts.

Estuarine Finfish

The MRD conducts monitoring of recreationally important estuarine finfish in coastal South Carolina. The program aims at estimating abundance and establishing life-history characteristics of selected species to accurately predict the impact of recreational fishing. Target species included in this effort are red drum (*Sciaenops ocellatus*), spotted seatrout (*Cynoscion nebulosus*), southern flounder (*Paralichthys lethostigma*), black drum (*Pogonias cromis*), and sheepshead (*Archosargus probatocephalus*). Ultimately, the data obtained through this program provide resource managers with the biological basis needed to best utilize the resource while maintaining healthy populations.

Monitoring occurs in six estuarine systems in coastal South Carolina: the Charleston Harbor, the Lower Wando River, the Ashley River, the Ashepoo-Combahee-Edisto (ACE) Basin, Cape Romain, and Northern Bulls Bay/Muddy Bay. The program employs stratified random sampling using trammel nets deployed from shallow water boats. In addition to counting, measuring and weighing fishes, subsamples are retained for life history studies to determine age, rates of growth, reproductive dynamics, recruitment and mortality. Red drum, black drum and sheepshead are tagged and released.

In addition to the estuarine monitoring of younger red drum in tidal creeks and sounds, fishery independent monitoring of adult red drum stocks is being conducted with a near-shore coastal longline survey. Information collected includes length and age composition (fish <900 mm TL), catch per effort and tissue samples for genetic analysis. The majority of sampled fish are tagged and released to provide information on migratory behavior, adult growth rates and stock identification. The relative rate of escapement from estuarine fisheries to offshore spawning areas is determined by the incidence of 3-7 year old fish in the samples and the trend in numbers of estuarine-tagged fish in the offshore samples. This project also collects broodstock

for MRD experimental stock replenishment studies (see below). The involvement of fishers in this research consists of tagging juvenile fish in estuarine areas and adult fish when they are encountered in coastal waters and reporting captures of tagged adult fish.

Tagging of red drum and other species assists in determining growth and movement patterns and in estimating recreational angler harvest rates and fishing mortality. Moreover, the impacts of the recreational fishery on particular sections of a population (such as immature fish or spawning adults) can also be determined. The angling public is involved in providing information on tagged individuals that are captured. Data collected through this monitoring program are regularly made available to the National Marine Fisheries Service (NMFS) and the Atlantic States Marine Fisheries Commission (ASMFC) for use in stock assessments. For instance, this program has provided data for red drum regional stock assessments for almost two decades. As part of the 1984 Fishery Management Plan for red drum, the ASFMC encouraged states to increase research efforts. Since then, the SCDNR has been involved, through this and other monitoring programs, in cooperative research with other South Atlantic states (North Carolina, Georgia and Florida) to provide as much comprehensive data on the life-history of red drum and to determine the impacts of the recreational fishery on this valuable resource.

In addition to obtaining fishery-independent data, the estuarine fish monitoring program also routinely collects fishery-dependent information. Fishers donate parts (heads, “racks”) of fishes that they catch which can be used to obtain life history information. This cooperative effort with anglers also supplements the dataset for areas where fishery-independent sampling is not routinely conducted. Local sportfishing tournaments held during summer months are another source of fishery-dependent information. Participating anglers allow staff access to their catch to gather data on length, weight, sex and maturity, and collect otoliths for aging. Sportfishing clubs are very supportive of this program and the management plans that are developed using the data that are derived from it.

Cooperative Shark Studies

The MRD is participating in a cooperative study to delineate the extent and importance of estuarine and near-shore coastal habitats as pupping and nursery habitats for large and small coastal species of sharks. This federally funded study was established by investigators at the NMFS laboratory in Narragansett, RI and includes state cooperators in NC, SC and GA. Sharks are sampled with gill nets and longline gear. Data collection includes species and size composition, stage of umbilical scar (an estimate of how recently the shark was born), and sex ratios. The majority of captured sharks are tagged and released, providing information on habitat site fidelity, migrations, growth and stock identification. Fishers have been an integral part of this research by providing tag return information.

Large-Scale Ecosystem Monitoring Programs for Fisheries

In addition to programs described above that are aimed at monitoring specific fisheries (e.g. shrimp or red drum fisheries), MRD conducts three major long-term state-federal cooperative programs that conduct fishery-independent assessments of specific ecosystems, such as reef habitats monitored by MARMAP, near-shore shrimp grounds monitored by SEAMAP, and estuarine reserves.

MARMAP

The Marine Resources Monitoring, Assessment and Prediction (MARMAP) Program is a long-term (since 1972), regional cooperative program between the National Marine Fisheries Service (NMFS) and the SCDNR. MARMAP currently monitors abundance and life history parameters (e.g. growth and reproduction rates) of priority offshore finfish species. The program samples annually at 350-500 reef sites from Cape Hatteras to the Florida Keys, between depths between 20 and 200 m. The program concentrates on collecting region-wide fishery-independent monitoring data that can be used in stock assessments of reef fishes such as snappers, groupers, grunts, porgies, triggerfishes, tilefishes and others. In addition to sampling fishes, the program conducts hydrographic surveys. It maintains a long-term database on species composition, abundance and distribution of fishes and hydrographic parameters, dating from 1973. Although it now concentrates on monitoring abundance of reef fishes through a fish trap survey, the program has a historical database that includes trawl, ichthyoplankton, longline and hydrographic data. The database includes species composition and catch rates by sampling gear, length frequency of fish species, distribution of species and different life history stages, age structure of populations of selected species, and data on spawning times, frequency and location of various life history stages of priority species.

Because of the long-term and continuing nature of the program, MARMAP scientists have demonstrated that there have been significant long-term changes in aspects of the age-growth and reproductive biology of many reef fishes that suggest that these species are overfished. The longevity of the program has enabled scientists to determine if there have been temporal changes in the size/age at maturity, size at age, sex ratios and other parameters that affect fish production. Long-term MARMAP catch data and life history studies indicate some recovery of black sea bass (*Centropristis striata*), red porgy (*Pagrus pagrus*), and vermilion snapper (*Rhomboplites aurorubens*) populations in recent years. Scientists routinely provide the South Atlantic Fishery Management Council (SAFMC) with data on the age-growth, reproductive biology and fecundity of these species, and have documented the development and status of the fisheries. Basic life history information regarding growth rates and reproductive biology provided by this program is needed to effectively manage these fisheries, to allow sustained productivity and to prevent overfishing.

MARMAP has developed a long-term database for reef fish that has proven valuable in interpreting fisheries landings data and developing regulations for protecting reef fish resources. Restrictions on minimum sizes of most commercially important species makes it difficult to monitor life history parameters and abundance data from fishery-dependent samples. MARMAP has the only existing program that monitors reef fish length frequency, abundance, and life history events based on fishery-independent data. These data will become increasingly important as restrictions increase on commercial and recreational effort.

From its beginning, the MARMAP reef fish monitoring program has involved fishers in data collection and application of data to fishery management. In the early days, much information on locations of reefs and fishing grounds came from fishermen, who cooperated with the program. We have cooperated with fishermen who have provided space for on-board fishery observers, and who have provided specimens for our life history studies. In addition, fishers have worked with us in cooperative reef fish tagging programs, wherein they tag fish and return any tagged fish they catch. The data obtained from cooperative tagging programs with fishers have documented movements and stock structure in groupers, snappers, jacks, triggerfish, grunts and other reef fishes, and have validated growth rates and annual ring formation in the otoliths of

several reef fishes for which age/growth has been studied by the program. Tagging data have also been used to estimate fishing mortality and depth-related release mortality (mortality caused after being released as a result of management regulations such as minimum sizes) of several species.

Because of their experience and expertise with offshore fisheries, MARMAP personnel serve on reef fish advisory panels of the SAFMC and the NOAA Marine Sanctuaries Program. In this capacity, they often work closely with commercial and recreational fishermen, who provide input into the sampling design and data interpretation from the MARMAP program. The SAFMC considers MARMAP fishery-independent data essential for conducting stock assessments of reef fishes, and the assessment and regulatory process involves continuous cooperation among MARMAP scientists, fishery managers and fishers.

SEAMAP-SA

The Southeast Area Monitoring and Assessment Program-South Atlantic (SEAMAP-SA) Shallow Water Trawl Survey is a cooperative program between SCDNR and NMFS. This shallow-water (<20 m) coastal trawl survey, conducted from Cape Hatteras NC to Cape Canaveral FL, provides long-term, fishery-independent data on seasonal abundance and biomass of finfish, decapod (crabs, shrimps) and stomatopod (mantis shrimps) crustaceans, and cephalopods (squids and octopus) that are vulnerable to high-rise shrimp trawls. Data recorded for priority species (23 finfish, four decapods, sharks, turtles and horseshoe crabs) include measurements of length or width and reproductive information on commercially important penaeid shrimp and blue crabs. Cruises are conducted annually, in Spring, Summer and Fall. Field data are made available to users within a few weeks of collection. SEAMAP-SA trawl data collected from 1986 to the present are available through the SEAMAP-SA Data Management Office at NMFS. Management agencies and scientists currently have access to twelve years (1990-2001) of comparable trawl data from near-shore coastal areas of the South Atlantic Bight. Data and specimens are provided to a wide variety of agencies and individuals conducting stock assessments on fishery species throughout the region. This includes providing materials and data to cooperative SCDNR-NMFS MARFIN (Marine Fisheries Initiative) projects on life history of marine fishes, and cooperative SCDNR-FISHTEC and cooperative SCDNR-NMFS studies of population genetics and diseases of marine fishery species being conducted at SCDNR. The monitoring survey also provides tissue samples for monitoring of mercury and other metals in Spanish mackerel (*Scomberomorus maculatus*), king mackerel (*S. cavalla*) and other fishes.

ACE Basin National Estuarine Research Reserve

Prior to designation of the ACE Basin National Research Reserve in 1992, most of the research activities in the ACE Basin were management-oriented projects that were primarily conducted by the SCDNR. SCDNR performed annual surveys of the recreational- and commercially-important estuarine fish and invertebrates species; game and non-game aquatic and terrestrial birds and mammals species; and threatened/endangered species and natural plant communities. The data were used to determine the status of these populations, and the results were used to develop policies and management programs to maintain viable populations of the species. Many of these annual surveys are still being conducted, along with additional research projects that are part of the National Estuarine Research Reserve (NERR) Systemwide Monitoring Program and those that are conducted by visiting research scientists.

Because of its relatively low level of development, the ACE Basin provides a benchmark against which to compare other coastal areas where significant human disturbances are occurring. The core area of the Reserve is well protected and serves as an undisturbed baseline monitoring area, while the large and diverse buffer zone serves as an experimental research and demonstration area. To date, over 30 research and monitoring projects have been conducted in or adjacent to the ACE Basin NERR, including water quality monitoring; vegetation analysis; animal and plant community characterizations; sediment contaminants; and impact of marine structures on benthic communities. The following agencies have funded state-federal cooperative projects in the Reserve: NMFS, U.S. Geological Survey, NOAA, U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), U.S. Army Corps of Engineers (COE), SC Sea Grant Consortium (SCSGC), SC Department of Health and Environmental Control (DHEC) and the SCDNR. There has been some private funding as well. Research that relates directly to the management of the Reserve's resources is actively encouraged and receives highest priority. Other research topics that address coastal management issues identified as having local, regional or national significance also are considered. The following projects include those related to ocean issues; however several terrestrial and freshwater monitoring surveys (e.g. mammals, vegetation mapping) are also conducted.

The SCDNR Wildlife Diversity Section performs annual field surveys in the Reserve to determine temporal changes in endangered/threatened species populations. Aerial surveys are done to monitor nesting of loggerhead turtles (*Caretta caretta*) American alligators (*Alligator mississippiensis*), raptors and shore birds. Ground surveys are then conducted to obtain information about the species composition and density of these animals in order to evaluate management needs. In 1994, a Dolphin Count Survey was initiated to ascertain the numbers of bottlenosed dolphins (*Tursiops truncatus*) that utilize the estuaries of South Carolina; two sites are located within the NERR.

The SCDNR Wildlife Management Section conducts annual surveys of game mammals and birds in order to monitor the temporal changes in populations of these species. These data are used to set the closing and opening dates of hunting seasons and to close hunting grounds that are over-harvested. This Section also manages Bear Island (in the Reserve) and Donnelly (borders the Reserve) Wildlife Management Areas. These areas provide over 20,000 acres of managed habitat (i.e. impoundments and pine plantations) for game and non-game wildlife including threatened and endangered species. Both Bear Island and Donnelly are available for resource management research projects.

The SCDNR Freshwater Fisheries Section monitors the populations of game and invasive freshwater species to determine their spatial and temporal distributions and abundance. Programs relevant to the marine environment include monitoring of migration patterns of striped bass (*Morone saxatilis*) in the Ashepoo, Combahee and South Edisto rivers to determine whether fish move between the three rivers or remain in the river in which they are born or stocked. Sampling is conducted during the winter months when the adults congregate in the lower reaches of the three rivers. Specimens are caught with electrofishing equipment and fishing rods, measured and counted, and then tagged and released.

The SCDNR Water Resources Division has developed a GIS database that includes information about the natural resources in the ACE Basin watershed for the purpose of improving public policy and decision making capabilities regarding natural resource management. The database includes a unique digital data layer for every natural resource in the

watershed, including elevation patterns, geologic formations, soil types, land use/cover types, archeological/historical sites and endangered/threatened species locations.

The SCDNR Marine Resources Division (MRD) has conducted a number of surveys and studies within the boundaries of the ACE Basin NERR. Some of the most visible scientific investigations have involved population assessment of recreationally and commercially important fishery species. Adult populations of shrimp and blue crabs are monitored on a yearly basis to determine the peak migrations of the organisms from the estuary to offshore area. This survey is important in determining the opening and closing dates of commercial shrimping season. Tidal creeks are sampled weekly during spring and summer for juvenile shrimp and blue crab, and the catches are sorted by species, measured and weighed. These data are used to determine species composition and distribution, and the growth rates of the species that utilize the tidal creeks. Data are correlated with rainfall, temperature and salinity in order to determine to what extent these physical factors affect the annual migration rate into the estuaries and the growth rates of juveniles in the estuaries. In 1991, a long-term study was initiated to life history and population dynamics (temporal and spatial abundance and composition) of marine recreational fishes in South Carolina, and twelve of the 30 sample sites are located in the Reserve. The fishes are counted, measured, weighed and then released at or near their sample sites. Selected fishes are tagged for auxiliary migration and growth studies. Specimens collected at sampling stations within the Ace Basin NEERS that are sampled by MRD are subject to disease and contaminant analyses described elsewhere in this document.

A number of projects have been conducted by state agencies other than SCDNR and by non-governmental groups in the ACE Basin. All have contributed to our understanding of the communities and environmental conditions within the ACE NERR and its surrounding watershed. For example, The Nature Conservancy conducted an extensive biological inventory that provided detailed, site-specific information on the occurrence and species composition of natural communities, as well as the documentation of rare plant species.

Monitoring of water quality conditions in the ACE Basin has been part of a statewide survey conducted by the Water Quality Section (WQS) of DHEC. DHEC monitors surface water and sediment quality in the Ashepoo, Combahee and South Edisto rivers, about 10 miles upstream from the Reserve. The Water samples are collected monthly and analyzed for several basic water quality parameters (i.e. salinity, BOD5, nutrients, solids). Quarterly or annual analyses of water and sediment samples are done for metals, pesticides, PAHs, volatile and extractable organics. Water quality (salinity, water temperature, fecal coliform) at shellfish beds in the Reserve is tested at least six times during the harvest season.

The U.S. Geological Survey (USGS) collects continuous stream flow data from the South Edisto and Combahee, upstream of the Reserve. Presently, streamflow and water quality are monitored by U.S. Geological Survey at eight gaging stations: three on the South Fork Edisto River, and one each on the Edisto River, the North Fork Edisto River, Cow Castle Creek, Dean Swamp Creek, and McTier Creek.

In 1997, Florida Geological Survey and SCDNR/Geological Survey initiated a study to investigate the phenomena of sea level rise in the ACE Basin Reserve. Sedimentation-erosion equipment (SET), which are designed to measure small changes in surface elevation, have been installed throughout the Reserve.

The Reserve staff recently completed a long-term survey of the decapod crustaceans and juvenile fish (1993-1999) in the estuarine portions of the Ashepoo, Combahee and South Edisto rivers. The findings of the study provide valuable information about the temporal and spatial

changes in species composition, diversity and biomass in the rivers. Four trawl sampling stations were situated along a salinity gradient, ranging from polyhaline to oligohaline or limnetic, in each of the rivers. Catches were measured and weighed. Basic water quality parameters (water temperature, salinity, water depth), atmospheric parameters (wind speed/direction, cloud cover and rainfall) and tidal stage were recorded at each station. In 2001, the Reserve staff initiated an electrofishing survey of tidal freshwater fish communities that occupy the waters adjacent to the Reserve. Temperature, salinity, conductivity, dissolved oxygen, and pH are recorded. Wetland types along the riverbanks also are characterized.

In March 1995, the Reserve began a NOAA/NERRS national coordinated monitoring program that was designed to identify and track short-term and long-term variability in each Reserve over a range of spatial (local, regional, national) and temporal scales for the purpose of contributing to effective national, regional and site-specific coastal zone management. This goal will be accomplished through phased monitoring of three major categories: 1) abiotic (physical-chemical) factors; 2) biological communities; and 3) habitat and land use changes. The focus of Phase 1 is on water quality and nutrient monitoring. Two sites in the Reserve appear to be best suited for studying contrasting hydrographic conditions and land use patterns. One site is located near the developed Edisto Beach, and the other is near undisturbed Bailey Island. Several water quality parameters (water temperature, dissolved oxygen, pH, specific conductivity and turbidity) are recorded continuously by dataloggers.

In June 1995, the Reserve initiated the weather monitoring component of the NOAA/NERRS national coordinated monitoring program. The objective of the study is to identify and track short-term and long-term variability of various meteorological parameters. The climate station is equipped with a soil and an air thermometer, rain gauge, barometer, anemometer (measures wind speed and direction) and quantum sensor (measures photosynthetically active radiation). Measurements are recorded every fifteen minutes, and hourly and daily averages are calculated.

In July 1997, the ACE Basin NERR staff began to monitor nitrates/nitrites, ammonia and ortho-phosphates parameters as part of the water quality monitoring program. These data will be used to evaluate the seasonal and diurnal patterns of ammonia, nitrite-nitrate, and ortho-phosphate at our existing water quality stations. Nutrient levels at existing water quality monitoring sites are measured monthly, and samples are collected during one complete tidal cycle each month.

Starting in October 2001, the ACE Basin Reserve will be a participant of the National Atmospheric Deposition Program/National Trends Network (NADP/NTN). The NADP/NTN is a nationwide network of precipitation monitoring sites and is a cooperative effort between many different groups, including the State Agricultural Experiment Stations, U.S. Geological Survey, U.S. Department of Agriculture, and numerous other governmental and private entities. The network has over 200 sites spanning the continental United States, Alaska, and Puerto Rico, and the Virgin Islands. The purpose of the network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends. The Reserve will collect precipitation at each station weekly and send to an NADP Central Analytical Laboratory where it is analyzed for a host of parameters. As overall indicators of precipitation quality, pH and conductivity will be measured at the field sites and at the laboratory. The inorganic component of precipitation will be characterized by such parameters as sulfate, chloride, nitrate, ammonium, ortho-phosphate, sodium, potassium, calcium, and magnesium.

ENVIRONMENTAL HEALTH MONITORING

The MRD conducts routine monitoring of water quality, assemblages of bottom organisms that are indicators of environmental health, contaminant levels in habitats and organisms, and indicators within organisms of environmental stress at the cell and molecular. Monitoring is conducted within state waters at several estuarine sites, including some within the ACE Basin NEER (see above for additional details).

Studies of contaminant levels in recreational finfish were conducted by MRD in various estuarine systems in the state, including St. Helena Sound and the ACE Basin NERR between 1991 and 1994. The livers and fillets of red drum, spotted seatrout and southern flounder were analyzed for contaminants, and the results indicated that the chemical contaminant levels were typically lower in fillets than in livers. Pesticides were commonly detected in livers, but usually at low levels. The results implied that the level of chemical contamination is low in these important species within the ACE Basin, and the contaminants are not likely to cause adverse biological effects on the fish. In addition, the levels in the fish did not exceed the Food and Drug Administration criteria for human consumption. This monitoring has provided a baseline against which to compare future results. Additional information on pollution in the ACE Basin Reserve was acquired through the nationwide comprehensive Estuarine Monitoring and Assessment Program (EMAP), a monitoring program that was implemented within the estuaries of the southeastern US from North Carolina to the Indian River lagoon system of Florida. During the 1994 and 1995 sampling periods, the MRD was responsible for sampling the sites in South Carolina and Georgia, of which four sampling sites were in the ACE Basin. The program was designed to evaluate the status and trends of ecological resources and identify associations between pollution stress and ecological condition. At sample sites, water quality data (water temperature, pH, salinity, dissolved oxygen, and depth) were collected with continuously recording dataloggers; surface sediment grabs were collected for characterization of benthic biota, as well as for grain size, organics, contaminant analyses and toxicity testing. Fishes and invertebrates were also collected for community and histological analyses. Results of the EMAP provided a baseline for continued monitoring.

In 1998 the MRD began to develop cellular tools for assessing and monitoring anthropogenic impacts on estuarine resources. Sampling sites are located in the North Inlet/Winyah Bay and ACE Basin Reserves. Oysters (*Crassostrea virginica*), grass shrimp (*Palaemonetes pugio*), and mummichogs (*Fundulus heteroclitus*) were the primary target species. The hepatopancreatic/liver tissues are used for three different cellular biomarker assays (lysosomal destabilization, glutathione concentrations, and lipid peroxidation).

In 1999, MRD and DHEC initiated the South Carolina Estuarine and Coastal Assessment Program (SCECAP). The goal of this coastal monitoring program is to assess the conditions of the estuarine habitats and associated biological resources. Sampling sites are located the coastal zone, including six sites in the ACE Basin Reserve. Measures of water and sediment quality are integrated with multiple measures of biological conditions at each site. Water quality analyses conducted include total and dissolved nutrients (i.e. total nitrogen and phosphorus, ammonia, nitrates, ortho-phosphates), total organic carbon, and fecal coliform. Estimates of phytoplankton biomass at the sites are calculated from chlorophyll concentrations in water samples. Sediment samples are collected to evaluate the sediment composition and contaminant levels, as well as characterize the benthic community. Fish and large crustaceans (primarily penaeid shrimp and blue crabs) are collected to evaluate community composition.

Although most coastal environmental monitoring described above does not involve fishers in the design and implementation of sampling, the data derived are made available to natural resource management agencies for determining if contaminant levels warrant regulations on fisheries to protect public health.

AQUACULTURE AND FISH STOCK REPLENISHMENT

The MRD Aquaculture Section maintains staff, facilities, and expertise for the propagation of marine fishery species, including shellfish, crustaceans and finfish. Development of culture technologies focuses on recreational, commercial and endangered species. Much of the research consists of developing propagation techniques for producing products that can be commercialized by the private sector as well as for producing aquatic organisms for use in fishery research studies including stock replenishment. Expansion of aquaculture in the private sector can have positive effects in reducing fishing pressure on native stocks as well as helping balance the trade imbalance associated with fishery imports. Use of cultured products can be used to assess environmental conditions as well as to help monitor wild fishery populations as previously described.

Additional MRD aquaculture activities include production of eggs, larvae and juveniles for stocking into natural systems to replenish over fished stocks. Candidate species include red drum, cobia (*Rachycentron canadum*), black sea bass, sturgeons, and others. Stocked individuals carry marks (genetic markers or fish tags) that can be used to identify individual fish that occur in the landings or in samples obtained from estuarine fishery monitoring (see above). Catches are monitored to determine the contribution of stocked fish to the population, to the creel, and to the adult spawning population. Fishers are involved in this monitoring, as they are a source of tag returns.

Fish that are produced in MRD culture facilities have been used for a variety of experiments that have enhanced our abilities to monitor fish stocks. Experiments have looked at retention rates of tags on fish, effect of handling fish at elevated temperatures, and the documentation of angler reporting rate of tagged fish. These experiments allow us to refine monitoring data on fishing mortality rates, and movement and growth data collected from MRD tagging studies. Our tagging studies routinely involve fishers who return tags and catch data to us for processing. Additional experiments on cultured fishes have looked at mortality rates of fish released as a result of fishery regulations or voluntarily by catch-and-release fishermen.

Research continues to focus of use of stocked fish to replenish over-harvested wild stocks as an additional fishery management tool. It is believed that stocking in conjunction with conventional management practices will allow native stocks to recover more quickly than is possible solely by implementation of more conservative fishery regulations.

SCDNR INVOLVEMENT WITH FISHERMEN IN MANAGEMENT

SCDNR biologists and managers are actively involved in natural resource management within the SCDNR and other state agencies, as well as on regional and national management boards and commissions, such as the ASFMC and SAFMC. SCDNR, like natural resource agencies in other coastal states, has a representative on the SAFMC and ASMFC, as well as several staff members who volunteer to serve on various committees and panels that advise those agencies. In this capacity, state fisheries scientists work closely with fishers who are also members of councils, committees and advisory panels. Scientists get feedback from fishermen

on the value of research to the industry, and advise fishermen on fishing methods, species and areas that are environmentally sensitive. Several SCDNR staff members serve on advisory panels and committees that formulate fishery management policy, in coordination with fishers. SC scientists share responsibilities on these panels with representatives of recreational and commercial fishing interests, as well as other user groups (e.g. sport divers). Through these panels, SCDNR scientists and fishery managers share data and interpretation of data with user groups and other scientists and managers. At regular meetings of these panels, fishers and other user groups have the opportunity to examine fishery monitoring data and to raise their concerns about methods and uses of the data. The input of fishers is often used to modify monitoring programs to address the concerns of user groups.

SAFMC

The SC representative to the South Atlantic Fishery Management Council (headquartered in Charleston) is a fisheries manager from the MRD; he is also Vice Chairman of the Council. In addition, SCDNR staff serve on the Shrimp Plan Development Team; the Shrimp Review Panel; the Snapper-Grouper Assessment Panel; the Coral, Habitat & Environmental Protection, Law Enforcement, Shrimp BRD *ad hoc*, and Marine Protected Areas Advisory Panels; and the Executive, Finance, Law Enforcement, Personnel, Calico Scallop, Dolphin/Wahoo, Golden Crab, King & Spanish Mackerel, Shrimp, Snapper-Grouper, and Scientific & Statistical Committees. Service on these committees and panels provides ample opportunity to interact with fishers, who also serve on these panels. Government scientists and managers work with fishers, other user groups, non-governmental organizations (NGOs), and interested citizens on these panels to develop and implement fishery monitoring and management plans.

MAFAC

Since its inception, the SCDNR has participated in the Marine Fisheries Advisory Committee (MAFAC), a diverse group of scientists, educators, fishermen, seafood processors, conservationists, and fisheries professionals charged with advising the Secretary of Commerce on marine fisheries issues. In this capacity, SCDNR has worked closely with fishers in developing management plans based on research and monitoring data. Because of its broad representation of interests and geographic areas, MAFAC has provided NMFS with an ideal opportunity to gauge the reaction of the public, including fishers and other resource users, to existing and proposed management and monitoring programs. Because of participation and coordination through MAFAC, scientific and statistical reports produced by SCDNR research and monitoring programs have been summarized, translated into layman's terms and made available on a level that is understandable by the general public. MAFAC recognizes that stakeholder involvement must be a primary objective of NMFS, and state agencies are an avenue for local involvement by fishers in regional and national management plan development.

Other

In addition to the above boards and panels, SCDNR personnel serve on, or interact with, the U.S. Commission on Ocean Policy, the Gray's Reef National Marine Sanctuary Advisory Council, and numerous private conservation and environmental groups, such as the South Carolina Coastal Conservation Association (SC CCA). These bodies comprise representatives from natural resource user groups, management agencies, academia and interested citizens, and afford the opportunity for SC scientists and managers to obtain input and feedback from fishers

and other interested parties.

CONCLUSIONS

Southeastern states need long-term and reliable funding to monitor ecosystems in order to determine management measures that might be needed, and to evaluate the effectiveness of such management measures in improving environmental health, stocks of exploited fishes, and aesthetic value of natural resources. Cooperative state-federal programs such as MARMAP, SEAMAP and interstate initiatives have produced valuable databases against which to monitor environmental impacts of fishing and exploitation of marine resources. Continued monitoring is needed as coastal development and need for marine resources increase. State natural resource management agencies are in the best position to facilitate interaction among local fishers and local, regional and national scientists and fishery managers, and to develop monitoring programs that rely on input from all of these groups. Although states are in the best geographical, political and sociological position to monitor marine resources, they do not possess the financial resources to monitor ecosystems, and expanded federal support is needed. Existing long-term datasets such as that provided by the South Carolina MARMAP program will continue to be excellent benchmarks against which to measure the effects of natural resource exploitation, coastal development, and regulations on those activities. However, to be of maximum value, such programs must be continued and expanded to cover all ocean ecosystems.