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FISHERY ECOSYSTEM PLAN OF THE SOUTH ATLANTIC REGION
VOLUME V: SOUTH ATLANTIC RESEARCH PROGRAMS AND DATA NEEDS

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ABBREVIATIONS AND ACRONYMS

ABC	Allowable Biological Catch
ALS	Accumulative Landings System
ACCSP	Atlantic Coastal Cooperative Statistics Program
B	A measure of fish biomass either in weight or other appropriate unit
BMSY	The biomass of fish expected to exist under equilibrium conditions when fishing at FMSY
BOY	The biomass of fish expected to exist under equilibrium conditions when fishing at FOY
BCURR	The current biomass of fish
C	Catch expressed as average landings over some appropriate period
DSEIS	Draft Supplemental Environmental Impact Statement
EFH	Essential Fish Habitat
EFH-HAPC	Essential Fish Habitat - Habitat Area of Particular Concern
EIS	Environmental Impact Statement
ESA	Endangered Species Act of 1973
F	A measure of the instantaneous rate of fishing mortality
FCURR	The current instantaneous rate of fishing mortality
FMSY	The rate of fishing mortality expected to achieve MSY under equilibrium conditions and a corresponding biomass of BMSY
FOY	The rate of fishing mortality expected to achieve OY under equilibrium conditions and a corresponding biomass of BOY
FEIS	Final Environmental Impact Statement
FMU	Fishery Management Unit
MARMAP	Marine Resources Monitoring Assessment and Prediction Program
MFMT	Maximum Fishing Mortality Threshold
MMPA	Marine Mammal Protection Act of 1972
MRFSS	Marine Recreation Fisheries Statistics Survey
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MSST	Minimum Stock Size Threshold
MSY	Maximum Sustainable Yield
NEPA	National Environmental Policy Act of 1969
OY	Optimum Yield
RIR	Regulatory Impact Review
SEDAR	Southeast Data, Assessment and Review
SFA	Sustainable Fisheries Act
SIA	Social Impact Assessment
SPR	Spawning Potential Ratio
SSR	Spawning (biomass) per Recruit
TMIN	The length of time in which a stock could be rebuilt in the absence of fishing mortality on that stock
TAC	Total Allowable Catch

Glossary

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9.0 Data and Research Necessary to Support Ecosystem Management

9.1 Research Needs and Research and Monitoring Plans

The 2006 reauthorization of the Magnuson-Stevens Act includes the following language pertaining to research and monitoring needs for regional fishery management councils:

(c) COUNCIL FUNCTIONS.—Section 302(h) (16 U.S.C. 1852(h)) is amended—
‘‘(6) develop annual catch limits for each of its managed fisheries that may not exceed the fishing level recommendations of its scientific and statistical committee or the peer review process established under subsection (g); and’’.

(d) SCIENTIFIC RESEARCH PRIORITIES.—Section 302(h) (16
U.S.C. 1852(h)), as amended by subsection (c), is further amended—
(1) by striking ‘‘(g); and’’ in paragraph (6) and inserting ‘‘(g);’’; (2) by redesignating paragraph (7), as redesignated by subsection (c)(2), as paragraph (8); (2) by inserting after paragraph (6) the following: ‘‘(7) develop, in conjunction with the scientific and statistical committee, multi-year research priorities for fisheries, fisheries interactions, habitats, and other areas of research that are necessary for management purposes, that shall—
‘‘(A) establish priorities for 5-year periods;
‘‘(B) be updated as necessary; and
‘‘(C) be submitted to the Secretary and the regional science centers of the National Marine Fisheries Service for their consideration in developing research priorities and budgets for the region of the Council; and’’.

SEC. 318. COOPERATIVE RESEARCH AND MANAGEMENT PROGRAM.
‘‘(a) IN GENERAL.—The Secretary of Commerce, in consultation with the Councils, shall establish a cooperative research and management program to address needs identified under this Act and under any other marine resource laws enforced by the Secretary. The program shall be implemented on a regional basis and shall be developed and conducted through partnerships among Federal, State, and Tribal managers and scientists (including interstate fishery commissions), fishing industry participants (including use of commercial charter or recreational vessels for gathering data), and educational institutions.
‘‘(b) ELIGIBLE PROJECTS.—The Secretary shall make funds available under the program for the support of projects to address critical needs identified by the Councils in consultation with the Secretary. The program shall promote and encourage efforts to utilize sources of data maintained by other Federal agencies, State agencies, or academia for use in such projects.
‘‘(c) FUNDING.—In making funds available the Secretary shall award funding on a competitive basis and based on regional fishery management needs, select programs that form part of a coherent program of research focused on solving priority issues identified by the Councils, and shall give priority to the following projects:
‘‘(1) Projects to collect data to improve, supplement, or enhance stock assessments, including the use of fishing vessels or acoustic or other marine technology.
‘‘(2) Projects to assess the amount and type of bycatch or post-release mortality occurring in a fishery.
‘‘(3) Conservation engineering projects designed to reduce

bycatch, including avoidance of post-release mortality, reduction of bycatch in high seas fisheries, and transfer of such fishing technologies to other nations.
‘‘(4) Projects for the identification of habitat areas of particular concern and for habitat conservation.
‘‘(5) Projects designed to collect and compile economic and social data.
‘‘(d) EXPERIMENTAL PERMITTING PROCESS.—Not later than 180 days after the date of enactment of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, the Secretary, in consultation with the Councils, shall promulgate regulations that create an expedited, uniform, and regionally-based process to promote issuance, where practicable, of experimental fishing permits.
‘‘(e) GUIDELINES.—The Secretary, in consultation with the Councils, shall establish guidelines to ensure that participation in a research project funded under this section does not result in loss of a participant’s catch history or unexpended days-at-sea as part of a limited entry system.
‘‘(f) EXEMPTED PROJECTS.—The procedures of this section shall not apply to research funded by quota set-asides in a fishery.’’.
ADDITION TO SEC 303(A) (FMP contents)
(a)(10)‘‘(15) establish a mechanism for specifying annual catch limits in the plan (including a multiyear plan), implementing regulations, or annual specifications, at a level such that overfishing does not occur in the fishery, including measures to ensure accountability.’’.
(b) EFFECTIVE DATES; APPLICATION TO CERTAIN SPECIES.—The amendment made by subsection (a)(10)—
(1) shall, unless otherwise provided for under an international agreement in which the United States participates, take effect—
(A) in fishing year 2010 for fisheries determined by the Secretary to be subject to overfishing; and
(B) in fishing year 2011 for all other fisheries; and
(2) shall not apply to a fishery for species that have a life cycle of approximately 1 year unless the Secretary has determined the fishery is subject to overfishing of that species; and
(3) shall not limit or otherwise affect the requirements of section 301(a)(1) or 304(e) of the Magnuson-Stevens Fishery
Conservation and Management Act (16 U.S.C. 1851(a)(1) or 1854(e), respectively).

9.1.1 South Atlantic Research and Monitoring Priorities 2008

Introduction

The 2006 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) directs the Federal Regional Fishery Management Councils to develop a prioritized research plan for submission to the Secretary of Commerce. The following research and monitoring needs were developed by the South Atlantic Council in fulfillment of that requirement.

The goals of the South Atlantic Research and Monitoring Plan are:

1) to improve the quality and quantity of information available for stock assessment and management program development and evaluation; and

2) to encourage a proactive approach to fisheries monitoring and research with priorities based on management needs and intentions.

These goals can be fulfilled by achieving the following objectives:

- Obtain complete fisheries statistics (landings, effort, discards) for all managed resources.
- Obtain adequate landings characterization information (biological sampling of landings & discard, effort details) for priority species.
- Develop representative fishery-dependent abundance measures for priority species.
- Provide reliable and up-to-date species biology and life history information (reproduction, growth, habits, ecosystem role) for all managed resources.
- Obtain adequate economic and social characterization information for all fisheries.
- Obtain fishery and catch data necessary for the Council to monitor and evaluate its management programs.
- Document and quantify habitat usage and availability for all Southeast habitats.
- Develop robust yet documented and validated analytical models appropriate for South Atlantic resources, management requirements, and data availability.

The proposed research and monitoring plan is documented in the following sections in order of decreasing priority and is summarized as follows:

1) Collect basic data for all managed fisheries.
2) Collect biological and survey information for priority species to support qualitative stock assessments.
3) Collect specific information to support evaluation and refinement of SAFMC management programs and actions.
4) Collect basic social and economic information to support management impact evaluations.
5) Collect general habitat information to support habitat protection efforts
6) Collect ecosystem information to support ecosystem management.

SAFMC Prioritized Research Recommendations for the first 5 years (2008-2012)

The South Atlantic Council recommends that the first priority is obtaining accurate fishery level information with increased spatial resolution for landings, discards, and effective effort. Research and monitoring programs must accommodate the multi-species nature of many South Atlantic fisheries.

To address the challenge of multi-species fisheries, the basic unit to sample proposed here is a fishery rather than a species. To address the many managed species of the SAFMC, individual species are separated into two groups: those requiring ‘basic’ data elements and those requiring ‘detailed’ data elements. Initial classification into these two groups is based on the SEDAR assessment schedule, indicator species identified by the Council, those species included in NOAA Fisheries’ Fish Stock Status Indicators listing in the Report to Congress, and recommendations of the SAFMC Science and Statistics Committee.

1. Collect basic data elements by fishery

The following information applies for all fisheries listed:

- All catch and bycatch reporting to species

- Per tow/set/site/deployment information for for-hire and commercial fisheries collected through on electronic logbook linked to GPS
- license id information available for all participants/vessels linked to trip and set reports
- Global participant frame provided through licensing of all participants
- Location elements include latitude, longitude, depth, and duration of effort

1. Shrimp Trawl Fishery
   Per tow: duration, location, trawl details, catch estimate, discard estimate
   Per trip: landings by species, trip costs, price paid per lb, # crew
   Supplement: 5% observer coverage for discard, 20% coverage for detailed social & economic reporting.

2. Trap Fisheries (e.g., sea bass, golden crab, spiny lobster)
   Per trap/string: duration, location, trap details, catch estimate, discard count
   Per trip: landings by species, trip costs, price paid per lb, # crew
   Supplement: 2% observer coverage for discard, 10 % video discard coverage, 20% coverage for detailed social & economic reporting.

3. Dive or Spear Fisheries
   Per dive: duration, location, gear details, # divers, catch estimate
   Per trip: landings by species, trip costs, price paid per lb, # crew
   Supplements: 20% coverage for detailed social & economic reporting.

4. Handline Fisheries
   Per set/site: duration, location, gear details, catch estimate, discard count
   Per trip: landings by species, trip costs, price paid per lb, # crew
   Supplement: 5% observer coverage for discard, 10% video discard coverage, 20% coverage for detailed social & economic reporting.

5. Deepwater Longline Fishery
   Per set/deployment: duration, location, gear details, catch estimate, discard count
   Per trip: landings by species, trip costs, price paid per lb, # crew
   Supplement: 5% observer coverage for discard, 10% video discard coverage, 20% coverage for detailed social & economic reporting.

6. Pelagic Longline Fishery
   Per set/deployment: soak, location, gear details, catch estimate, discard count
   Per trip: landings by species, trip costs, price paid per lb, # crew
   Supplement: 5% observer coverage for discard, 10% video discard coverage, 20% coverage for detailed social & economic reporting.

7. Bottom Longline
   Per set/deployment: soak, location, gear details, catch estimate, discard count
   Per trip: landings by species, duration, trip costs, price paid per lb, # crew,
   Supplement: 5% observer coverage for discard, 10% video discard coverage, 20% coverage for detailed social & economic reporting.

8. Private Recreational
   Per trip: mode, location, gear details, duration, landings by species, discard by species, expenditures,
   Per Year: # trips by mode, location
   Supplement: Voluntary logbook for discard characteristics (e.g., size and reason for discarding), 20% coverage for detailed social & economic reporting.

9. Headboat Recreational

Per set/site: location, duration, catch & discard estimate by species

Per Trip: # anglers, # lines, duration, landings by species

Supplement: 5% observer coverage for discard characteristics. Voluntary logbook for discard (size), 20% coverage for detailed social & economic reporting of owner/operators. 20% coverage for social & economic evaluations of participants.

10. Party/Charter Recreational Fishery

Per trip: mode, location, gear details, duration, catch & discard by species

Supplement: 5% observer coverage for discard characteristics. Voluntary logbook for discard (size), 20% coverage for detailed social & economic reporting of owner/operators. 20% coverage for social & economic evaluations of participants.

2. Collect biological and survey information for priority species to support qualitative stock assessments.

Detailed, species-specific information is required for species that support the bulk of fishery landings to enable high resolution assessment models (i.e., age structured models) and directed management. This information should be collected for individual species, with sampling effort allocated across time, space, and the fisheries listed above as appropriate to ensure useful and statistically valid data.

Additional Data Elements for Primary Species:

- Representative sampling by season, fishery, and area of length, age, sex, and weight for landed & discarded fish.
- Fishery-dependent CPUE, based on increased effort resolution collected through the basic elements (1)
- Survey-based fishery-independent CPUE
- Life history research: rates of growth, mortality, maturity, fecundity
- Movement, migration, and stock structure evaluations

Additional Data Elements for Secondary species:

- Fishery-dependent CPUE, based on increased effort resolution collected through the basic elements (1)
- Survey-based fishery-independent CPUE
- Life history details: rates of growth, mortality, maturity, fecundity
- Movements, migration, and stock structure evaluations

SAFMC Proposed Primary Data Collection Species:

vermilion snapper	yellowtail snapper
red snapper	gray triggerfish
snowy grouper	mutton snapper
tilefish	red porgy
red grouper	wreckfish
black sea bass	king mackerel
gag grouper	Spanish mackerel
greater amberjack	dolphin
white grunt	spiny lobster

SAFMC Secondary Data Collection Species

Scamp	Yellowedge grouper
Black grouper	Goliath grouper
Blueline tilefish	Little tunny
Cobia	Wahoo
Speckled hind	Hogfish
Warsaw grouper	

3. Collect specific information to support evaluation and refinement of SAFMC management programs and actions.

The Council has implemented some management actions that cannot be adequately evaluated with the information in the previous sections alone. This section also includes recommendations that affect collection and dissemination of the information desired above.

1. Full implementation of ACCSP in the South Atlantic.
2. Resolve confidentiality issues that prohibit reporting of and access to basic catch statistics by species, state, and year.
3. Eliminate duplicative programs such as paper logbooks which duplicate information provided in state trip ticket programs.
4. Restructure the FSSI stocks for the South Atlantic Council to include only those stocks listed in Section VI-2 above as target species.
5. Provide annual SAFE reports and 'Trends' reports for each FMP summarizing the data elements contained in Sections III.1 and III.2.
6. Resolve ongoing issues with recreational data collection; ensure that recreational statistics can be reported according to Council boundaries.
7. Reduce data dissemination delays by continuing to develop and implement automated and web-based data entry programs that can accommodate the set level information described above.
8. Monitor fish population abundance inside protected areas (Oculina Closed Area, MPAs)
9. Determine stock status for severely restricted species (Warsaw grouper, speckled hind and Goliath grouper) to enable the Council to evaluate its management program.
10. Develop education programs for all participants that stress the importance of accurate and timely reporting of fisheries data and improve species id for self-reported data.
11. Collect information on enforcement activities and develop statistics to enable the Council to objectively evaluate enforcement.

4. Improve Social and Economic Evaluations

Fishery and species specific monitoring information necessary for social and economic information is addressed in the previous sections. Recommendations that cross multiple fisheries or that represent research needs are listed here.

1. Determine recreational value.
2. Develop improved bio-economic models.
3. Develop models to test between different management scenarios
4. Develop methods to integrate socio-economic information with the management process
5. Evaluate the impacts of imported fisheries products.

5. Improve Habitat Evaluation and Documentation

Extensive habitat research and monitoring recommendations are detailed in various Council FMPs. The items listed here cross multiple FMPs and help support the Council's place-based management approaches for South Atlantic fisheries. These are research needs that should only need occasional updating once initially addressed.

1. Develop maps of and quantify available habitat and seasonal usage by target species.
2. Develop maps describing habitat types in proposed HAPCs.
3. Develop maps describing available habitat in proposed MPAs.

6. Improve Ecosystem-level information

The Council's Fishery Ecosystem Plan (FEP) will address many ecosystem level research and monitoring needs in detail. The primary short-term need is to implement robust monitoring programs to start building the long-term time series of information that is needed to evaluate ecosystem-level issues. These are both monitoring needs that need to be conducted annually.

1. Initiate a comprehensive survey of South Atlantic living marine resources
2. Develop long-term monitoring of diet, productivity, and species interactions as required for ecosystem-level modeling

Long Term Research Needs

The items listed above address the most critical needs in the South Atlantic and are considered to represent the minimum information required for adequate management. There are other needs that are less pressing and are therefore considered long-term. The same list of general issues is repeated for consistency.

1. Basic data elements long term improvements

1. Evaluate the convenience, quality, and utility of set-level logbook reporting and supplemental data collection programs; refine data elements, sampling intensity, collection programs, and methods as needed.
2. Develop a process to enable changes to historic data sources that will enable resolution of errors, address misidentification of species, and allow elimination of 'unclassified' categories.

2. Improving Detailed Information for Primary Species

1. Evaluate data collected by fishery and from comprehensive surveys to ensure the appropriate species receive intensified sampling.
2. Develop a long-term plan for regularly evaluating life history characteristics of target species.
3. Develop robust QA/QC programs for age determination.
4. Evaluate sampling intensity and modify sampling targets as necessary.

3. Improving Evaluation of Specific Management Actions

1. Develop a long-term plan for regularly evaluating life history characteristics for all species included in Council FMPs.

2. Support monitoring and research programs necessary to develop and evaluate limited access programs.
3. Develop a long-term plan for regularly evaluating trends and indicators of stock status for secondary species and all other managed species to enable management to adapt to fisheries changes as necessary.

9.1.2 SAFMC Fishery Management Plans and SEDAR

Shrimp

1. Research to relate the fishery independent SFA parameters with stock health in specific geographic locations.
2. Determine the possible impacts on indigenous shrimp species of inadvertent introductions of exotic shrimp species and diseases from mariculture operations, and develop methods and protocol to prevent such introductions.
3. Assess the potential utility of releasing maricultured white shrimp into the environment to supplement natural reproduction, especially following cold kills.
4. Assess the potential of controlled closures and other measures to enhance the production and economics of the South Atlantic shrimp fishery.
5. Determine the effects of beach renourishment projects on subsequent shrimp production.
6. Evaluate the impacts of habitat and water quality alteration on shrimp growth, survival and productivity.
7. Investigate the costs, benefits and utility of limited entry programs in the shrimp fishery of the South Atlantic.
8. Determine the impact of shrimp trawl bycatch on the habitat and all nontarget species of fish and invertebrates (i.e., expand the congressionally mandated study to include impacts on habitat and all incidental species, not just the impact on other "fishery resources").
9. Determine the relationship between absolute number of adults (or adult biomass) and subsequent recruitment to allow development of a threshold level of population size to serve as a trigger to request a closure of the EEZ.
10. Determine the biological, economic and sociological status of the rock shrimp fishery.
11. Research ways to better monitor the shrimp fishery effects on listed species.

Additional research requirements pertaining to the economic and social aspects of the shrimp fishery:

1. Demographic information may include but is not necessarily limited to: population; age; gender; ethnic/race; education; language; marital status; children (age & gender); residence; household size; household income (fishing/non-fishing); occupational skills; and association with vessels and firms (role & status).
2. Social structure information may include but is not necessarily limited to: historical participation; description of work patterns; kinship unit, size and structure; organization and affiliation; patterns of communication and cooperation; competition and conflict; spousal and household processes; and communication and integration.
3. Cultural information (from the perspective of the respondent) may include but is not necessarily limited to: occupational motivation and satisfaction; attitudes and perceptions concerning management; constituent views of their personal future of fishing; psycho-social well-being; and cultural traditions related to fishing (identity and meaning).
4. Fishing community information might include but is not necessarily limited to: identifying communities; dependence upon fishery resources (this includes recreational use); identifying

businesses related to that dependence; and determining the number of employees within these businesses and their status.

Snapper Grouper Complex

Oculina Experimental Closed Area Research and Monitoring Plan

In April 2004, regulations were implemented through Amendment 13A to the South Atlantic Snapper Grouper Fishery Management Plan that extended the fishing restrictions for the designated 92-square mile Oculina Experimental Closed Area for an indefinite period. The amendment was developed by the South Atlantic Fishery Management Council to address the 10-year sunset provision for the closure of the area to snapper/grouper fishing. Located off the coast of Ft. Pierce, Florida, the area is part of the larger Oculina Habitat Area of Particular Concern (HAPC) designed to protect the *Oculina* coral found there. In addition to extending the closure, the amendment requires that the size and configuration of the Experimental Closed Area be reviewed within three years of the implementation date of Amendment 13A and that a 10-year re-evaluation be conducted for the area. The Council also stipulated that an Evaluation Plan be developed to address needed monitoring and research, outreach, and enforcement efforts within one year of implementation of the Amendment.

Research and Assessment Needs below are listed in priority order as indicated in the Evaluation Plan. For more detailed information, please refer to that document.

1. What and where are the major habitat types in the Oculina Experimental Closed Area, the Oculina Bank Habitat Area of Particular Concern and adjacent hardbottom areas? (short-term, 3 years)

Objective 1: Complete high definition bathymetric mapping 1) within the Oculina Experimental Closed Area; 2) coral areas adjacent to the Habitat Area of Particular Concern; 3) in Habitat Area of Particular Concern within coral zone 50-100 m; 4) soft bottom habitat east of the coral zone within the Habitat Area of Particular Concern and 5) suspected and known hard coral areas north and south of the Habitat Area of Particular Concern, specifically from Cape Canaveral to the north and from St. Lucie mound and Jupiter Inlet to the south.

Objective 2: Complete habitat characterization 1) within the Oculina Experimental Closed Area; 2) coral areas adjacent to the Habitat Area of Particular Concern; 3) in Habitat Area of Particular Concern within coral zone 50-100 m; 4) soft bottom habitat east of the coral zone within the Habitat Area of Particular Concern and 5) suspected and known hard coral areas north and south of the Habitat Area of Particular Concern, specifically from Cape Canaveral to the north and from St. Lucie mound and Jupiter Inlet to the south.

2. Will *Oculina* thicket habitat recover throughout the Oculina Experimental Closed Area without human intervention? What time frame will be needed for significant recovery? Will it be necessary to introduce artificial substrate to serve as an initial settlement surface? (short-term, 3 years)

Objective 1: Identify coral/fish recruitment pathways and compare settlement, growth, and survival rates on artificial substrate relative to settlement, growth, and survival rates on nearby unconsolidated coral rubble.

Objective 2: Model biophysical, chemical, and physiological characters. Previous studies have shown the benthic environment of the *Oculina* reefs to be very dynamic and widely fluctuating due to upwelling events and meandering of the Florida Current.

3. What are the magnitude and causes of changes in habitat structure and functionality over time? (short-term, 3 years)
Objective 1: Determine causes and timing of coral death
Objective 2: Origin and functional characterization of rubble zone

4. What are the key trophodynamic functional groups? (short-term, 5 years)
Objective 1: Identify food web structure and dynamics

5. Determine and monitor the effect of the Oculina Experimental Closed Area on fish distribution and status? (long-term, 10 years)
Objective 1: Assess spawning aggregations of fishery species.
Objective 2: Track fish movement
Objective 3: Identify Oculina Experimental Closed Area fish population demographics

6. What is the effect of management measures in the Oculina Experimental Closed Area on the status of fishery stocks? (long-term, 10 years)
Objective 1: Characterize (including distribution and abundance patterns, size and age distribution, spawning aggregation presence, sex ratios, etc) major fishery species within the Oculina Experimental Closed Area compared to reference sites.
Objective 2: Characterize fish communities, inside and out, including habitat utilization patterns, trophic interactions, ontogenetic changes, predator-prey relationships, etc.
Objective 3: Examine connectivity to the broader seascape (larval sources and sinks, spill-over effects).
Objective 4: Determine pre-closure distribution of dominant harvested species in and outside the reserve areas, in order to provide historical context for subsequent assessments. Review landings; spill over effects (i.e., identify benthic and juvenile pathways, upwelling events, spill-over between deep and shallow reefs).
Objective 5: Determine age distribution, nursery grounds, migratory patterns, and mortality rates for dominant harvested fish stocks.

4. What are the stressors affecting the Oculina Experimental Closed Area? (long-term, 10 years)
Objective 1: Identify natural and anthropogenic stressors (i.e., disease, gear impacts, poaching, enforcement).
Objective 2: Determine the frequency and severity of sedimentation induced by benthic storms.
Objective 3: Identify physiological tolerances of the coral to environmental stressors

6. Develop index of physical and chemical parameters that characterize a healthy Oculina coral ecosystem. (long-term, 10 years)
Objective 1: Develop index for coral health (including structural damage, recruitment, genetics, physiology, life history).
Objective 2: Develop index of community health for entire biota including coral (biodiversity, richness, biocomplexity).
Objective 3: Determine indicator species that are intimately tied with *Oculina* (invertebrates or vertebrates).
Objective 4: What is the age of the coral substrate, and geological formations (last 15,000 years) (death rates)? Also look at associated mollusks and other biota and their changes.
Objective 5: Examine association of paleo-data (age) with past climate and oceanographic conditions.

Objective 6: Are there other paleo-data from elsewhere in the world that will give perspective on *Oculina* growth? (ice cores, deep-water sediment cores)?
3. What is the population structure of corals? (long-term, 10 years)
Objective 1: Research population genetics of *Oculina varicosa*
Objective 2: Identify cross-shelf relationships between shallow and deep *Oculina varicosa* populations.
Objective 3: Conduct biogeographic studies

4. How do oceanographic conditions and episodic events affect production, coral condition, reproduction and growth? (long-term, 10 years)
Objective 1: Quantify the extent, intensity and frequency of episodic events (upwelling, storms, etc).
Objective 2: Assess the impact of episodic events (upwelling, storms, etc).
Objective 3: Optimize design of restoration efforts.
Objective 4: Characterize impacts from anthropogenic sources of pollution (nutrients/sedimentation).

7. Conduct research on coral feeding ecology (long-term, 10 years)
Objective 1: Define feeding dynamics.

Coral, Coral Reefs and Live/Hard Bottom Habitat

Deepwater Coral Research and Monitoring Plan

In developing a Deepwater Coral Research and Monitoring Plan, the Council is responding to recent amendments to the Magnuson-Stevens Act and NOAA's determination that an agency strategy is needed to effectively and efficiently address deepwater coral ecosystems issues. The primary goal of this Research and Monitoring Plan is to support conservation and management of deepwater coral ecosystems in the South Atlantic region while addressing NOAA's strategy to balance long-term uses of the marine ecosystem with maintenance of biodiversity. The Plan will also assist in meeting the new mandates of the Magnuson-Stevens Act.

This plan incorporates recommendations and needs developed through the Deep-Sea Corals Collaboration meeting held in Tampa, Florida in 2002 and the Deep Sea Corals workshop report (McDonough and Puglise 2003). This will allow the Council to build on the expertise and insight of the international deepwater coral research community. To focus the needs to the South Atlantic region, the Council has engaged regional experts to serve as the primary contributors of this Research and Monitoring Plan.

This Research and Monitoring Plan responds directly to mandates included in the 2006 reauthorization of the Magnuson-Stevens Act:

''SEC. 408. DEEP SEA CORAL RESEARCH AND TECHNOLOGY PROGRAM.
''(a) IN GENERAL.—The Secretary, in consultation with appropriate regional fishery management councils and in coordination with other federal agencies and educational institutions, shall, subject to the availability of appropriations, establish a program—

''(1) to identify existing research on, and known locations of, deep sea corals and submit such information to the appropriate Councils;
''(2) to locate and map locations of deep sea corals and submit such information to the Councils;
''(3) to monitor activity in locations where deep sea corals are known or likely to occur, based on best scientific information available, including through underwater or remote sensing technologies

and submit such information to the appropriate Councils;

''(4) to conduct research, including cooperative research with fishing industry participants, on deep sea corals and related species, and on survey methods;
''(5) to develop technologies or methods designed to assist fishing industry participants in reducing interactions between fishing gear and deep sea corals; and
''(6) to prioritize program activities in areas where deep sea corals are known to occur, and in areas where scientific modeling or other methods predict deep sea corals are likely to be present.
''(b) REPORTING.—Beginning 1 year after the date of enactment of the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006, the Secretary, in consultation with the Councils, shall submit biennial reports to Congress and the public on steps taken by the Secretary to identify, monitor, and protect deep sea coral areas, including summaries of the results of mapping, research, and data collection performed under the program.''

The president signed the reauthorized Magnuson-Stevens Act on January 12, 2007. Therefore, the first report is due to Congress on or before January 12, 2008. It is the Council's intent to review the report at the December 2008 Council meeting. Table 1 presents a timeline for items contained in this Plan based solely on the South Atlantic Council's priorities.

For purposes of this plan, Deepwater Coral Ecosystems (DWCE) are defined as:
Deepwater coral, coral reefs, and live/hard bottom habitat in waters extending from 200 m to the seaward boundary of the EEZ.

Goal
To protect deepwater corals by:
A. Refining existing (proposed) and designating new deepwater Coral HAPCs.
B. Increasing our understanding of DWCEs' ecological role and function in the South Atlantic region to guide future management actions.

Phase I: Map and describe known and expected deepwater coral ecosystems in the South Atlantic region.

Phase II: Determine the ecological role of deepwater coral ecosystems in the South Atlantic region, especially the role of deepwater coral habitats as Essential Fish Habitat, and expand the understanding of structure-forming species' biology and ecology.

PHASE I: MAP AND DESCRIBE KNOWN AND EXPECTED DEEPWATER CORAL ECOSYSTEMS IN THE SOUTH ATLANTIC REGION

<u>Justification/Background</u>
Deepwater coral ecosystems (DWCEs) are herein defined as deepwater coral, coral reefs, and live/hard bottom habitat in waters extending from 200 m to the seaward boundary of the EEZ. Azooxanthellate cnidarians include branching stony corals (Scleractinia), gorgonians and soft corals (Octocorallia), black corals (Antipatharia) and lace corals (Stylasteridae). These DWCEs therefore include the constructional habitats generated chiefly by colonial scleractinians as well as the non-constructional "gardens" dominated chiefly by other anthozoans and sponges. DWCEs are common within the Exclusive Economic Zone (EEZ) off the southeastern U.S. and include a variety of high-relief, hard-bottom habitats at numerous sites from the Blake Plateau off North Carolina, southward through the Straits of Florida to the eastern Gulf of Mexico. Despite a series of exploratory

expeditions during the last decade, only a few DWCEs in this region have been mapped in any detail, observed directly or have had their benthic and fish assemblages examined. The limited number of direct observations via submersible or Remotely Operated Vehicle (ROV) indicate that they provide hard substrates and habitat for a relatively unknown but biologically rich and diverse community of associated fishes and invertebrates, including commercial species such as wreckfish (*Polyprion americanus*), Warsaw grouper (*Epinephelus nigritus*), deepwater snappers and golden crab (*Chaceon fenneri*).

Two potential threats—fossil fuel development and bottom fishing—create a time-sensitive need to map and characterize these habitats. A moratorium on oil/gas exploration in Florida waters has long prevented impact from fossil fuel extraction; however, recent U.S. legislation directed at expanding energy production in the Gulf of Mexico, coupled with exploration by Cuba in waters adjacent to the Florida Keys, has expanded this threat. Liquefied natural gas re-gassification facilities and several proposed natural gas pipelines and offshore facilities could also directly impact local DWCEs. With respect to fishing, DWCEs worldwide have been seriously impacted by bottom trawls (Fosså et al. 2002, Freiwald et al. 2004). In Florida waters, unprotected portions of the Oculina Bank off the central east coast (75-100 m depth) have been severely affected both by overfishing and bottom trawling (Koenig et al. 2000, 2005; Reed et al. 2005b, Reed et al. in review).

Increasing our understanding of the distribution and composition of these assemblages; the physical, trophic and biochemical interactions of their components; and the environmental forcing factors that control distribution and composition across regional to local scales will enable effective ecosystem management. Such information will also provide the requisite baseline for examining ecosystem response to potential stressors and for investigating all aspects of component organism biology, including population dynamics, physiology, genetics and biopharmacology.

Objective 1: Map the distribution of DWCEs in the Southeastern U.S. EEZ.

1A. Determine the extent of known DWCEs in the South Atlantic region.

DWCEs occur along the southeastern coast of the United States from North Carolina to the southwestern Gulf of Mexico. Areas where DWCEs have been identified include: 1) North Carolina *Lophelia* mounds—three mound systems represent the northernmost DWCEs in the South Atlantic Bight; 2) Stetson Reefs—hundreds of pinnacles up to 152 m tall at depths of 640 to 900 m on the eastern Blake Plateau off South Carolina; 3) Savannah Lithoherms—numerous lithoherms at depths of 490 to 550 m with up to 60 m vertical relief; 4) East Florida *Lophelia* Reefs—hundreds of 15-152m tall coral bioherms and lithoherms at depths of 600 to 870 m along the shelf margin from southern Georgia to the Straits of Florida; 5-6) Miami and Pourtalès Terraces—relict phosphoritic limestone bank-margin hardgrounds and escarpments extending from Boca Raton to Key West at depths of 200 to 600 m; and 7) Southwest Florida Lithoherms—dozens of 15m tall *Lophelia* lithoherms at 500 m in the eastern Gulf of Mexico (Reed et al. 2004, 2005a, 2006). Only a small percentage of these sites has been investigated beyond fathometer transects; each new exploratory expedition discovers new sites. Many more coral sites are likely, and the full extent of topographic features on the Blake Plateau remains unknown. Similarly, the distribution of possible DWCEs along the southern margin of the Florida peninsula south of Miami and along the Florida shelf margin in the Gulf of Mexico are largely uninvestigated.

Increasingly sophisticated mapping technology, such as ship- and Autonomous Underwater Vehicle (AUV)-mounted multibeam sonar systems with backscatter data, side-scan sonar systems, and sub-bottom seismic profilers can be used to provide detailed bottom imagery with resolution to 1-3 m. A simple light-weight digital camera system can also be lowered during fathometer or AUV transects of topographic features to provide first-order ground-truthing (i.e., to determine presence/absence of corals) (see Grasmueck et al. 2006, in review). Geographic Information Systems (GIS) can be used to integrate mapping data with other geo-spatial information (e.g., fishing pressure, management areas, biological, geological, physicochemical observations, geophysical structure, hydrodynamics) to generate detailed and precise maps and datasets and foundation for robust system analyses, predictions, and management protocols. Only a small portion of this region has been mapped using ship based multibeam sonar (S. W. Ross et al. 2006, unpubl. data); maps from the North Carolina coral mounds and a portion of the Stetson Banks revealed numerous new features, suggesting that the coral habitat is much more extensive than previously thought. Only a few days of multibeam mapping (Ross et al. 2006 cruise) provided more bottom type data than had been accumulated in 6 years of previous cruises.

TASK 1: Inventory existing literature and data with a focus on expanding work within existing (proposed) Coral Habitats of Particular Concern (CHAPCs) by:
a. Completing the Southeastern United States Deep Sea Corals (SEADESC) Initiative (Partyka et al. in press) and integrating data into Council IMS, and
b. Completing and integrating data sources identified by deepwater portion of the Southeast Area Monitoring and Assessment Program (SEAMAP) -- Recovery, Interpretation, Integration and Distribution of Bottom Habitat Information for the South Atlantic Bight, 200-2000m.
TASK 2: Rank areas to be mapped within proposed CHAPCs and potential DWCEs outside CHAPCs by:

- a. Identifying data gaps based on above inventory,
- b. Obtaining SAFMC input to rank priority areas for investigation, and
- c. Conducting an ad hoc workshop to rank gaps based on proposed CHAPCs as well as outlying areas.

TASK 3: Conduct acoustic seabed mapping, and ground-truth with visual surveys within proposed CHAPCs and priority areas outside CHAPCs . Begin with low-resolution over wide areas followed by high-resolution mapping of targeted area (e.g., multibeam echo sounder, sidescan sonar) and ground-truthing (e.g., ROVs, AUVs, towed cameras, cores, samples) based on SAFMC recommendations.

1B. Map human activities that may impact DWCEs.
As noted in the Justification/Background section above, fossil fuel development and bottom fishing represent the primary potential near-term threats to local DWCEs. The continuing depletion of coastal fisheries may expand fishing efforts into deeper habitats in search of valuable commercial species such as royal red shrimp (*Hymenopenaeus robustus*), other shrimps and crabs, wreckfish, and other fish species (some not yet exploited). One of these, the Warsaw grouper, is a candidate for designation as a threatened or endangered species.

TASK 1: Obtain Vessel Monitoring System (VMS) access and produce maps showing fishing effort by location.
TASK 2: Assess fishing pressure in and outside CHAPCs through analysis of fisheries- dependent (e.g., NMFS landings) and fisheries-independent data. Produce maps showing fishing effort by location.
TASK 3: Map non-fishing activities that may affect DWCE resources (e.g., dredging, cables, outfalls, run-off, shipping routes and energy development and exploration activities).

1C. Assess condition of DWCEs in the South Atlantic.

Assessing the health and status of deepwater corals in the southeastern U.S. is difficult because there is a general lack of criteria on what constitutes good or bad conditions in these systems and a lack of historical data for comparisons. Dead corals are abundant at almost all locations, but whether this is normal or not, is unclear. Whether reefs are declining, stable, or building cannot be judged without additional studies. It seems clear that fairly strong currents coupled with bottom temperatures below 12º C are needed and monitoring these conditions may be good starting points. There is concern that changing ocean pH may negatively impact deepwater corals (Guinotte et al. 2006), and this should also be considered in monitoring or impact assessment.

Live coral coverage is generally low on the majority of deepwater *Lophelia* reefs in this region (1-10%); however, cover varies from nearly 100% living coral on portions of some reefs to extensive areas of 100% dead coral rubble on others (Reed et al. 2005b, 2006, in review; Grasmueck et al. in review). The deepwater *Oculina* reefs off eastern Florida have been designated a habitat area of particular concern (HAPC) for the protection of the coral habitat since 1984 (Reed 2002b, Reed et al. 2005b). A portion also has been designated a marine protected area (MPA) for management of the snapper grouper complex. Even so, extensive areas of the *Oculina* reefs have been severely impacted by both legal and illegal bottom trawling since 1984 (Koenig et al. 2005, Reed et al. 2005b, in review). Some areas in the northern section of the MPA that were documented as thriving reefs by photo transects in the 1970s had been found to be reduced to 100% rubble during submersible dives in 2001 (Reed et al. in review). However, some of the reefs in the southern portion that had been protected since 1984 are still thriving. So far we have no evidence that commercial bottom trawling has occurred on the *Lophelia* reefs in this region of the western Atlantic, and so it is still speculative as to whether the cause of the high percentage of dead coral could be due to natural senescence of the reefs, paleoclimatic factors, coral pathogens, or other unknown factors.

<u>TASK 1</u>: Identify and quantify natural and anthropogenic stressors (e.g., disease, gear impacts, energy development and exploration, nutrients, sedimentation, ocean disposal of dredge spoil, sewage sludge, paleoclimatic changes, temperature).
<u>TASK 2</u>: Conduct biological and environmental monitoring of indicator species at different scales.
    a. Identify potential indicator species for deepwater corals and associated species and
    b. Identify monitoring programs for those species.
<u>TASK 3</u>: Monitor impacts of episodic events (e.g., changing currents, temperatures, pH, sediment dynamics, food dynamics).

<u>Objective 2: Describe the physiographic environment of DWCEs.</u>

2A. Describe abiotic features (i.e., hydrographic, chemical) of DWCEs.

The waters and seafloor of the continental margin of the southeastern U.S. have been investigated for over a century and a half, beginning with work by the U.S. Coast Survey and U.S. Navy (e.g., Agassiz 1888). The Gulf Stream, a principal oceanographic feature of the region, is among the most thoroughly studied of marine systems, and the physiography and underlying geology of much of the region are well documented. However, apart from instantaneous localized observations made during submersible or ROV operations -- and broad-scale datasets and models of geologic structure, hydrography and physicochemical parameters -- little if any information exists about how abiotic factors directly affect and control local DWCEs. No time-series data of the environmental factors (e.g., bottom currents, turbidity, upwelling, temperature, dissolved oxygen or sedimentation rates) have been collected on DWCEs that would contribute to understanding DWCE distribution, growth, and the composition and dynamics of associated assemblages. However, annual records of hundreds to thousands of years that are relevant to abiotic conditions in these habitats may be contained in several species of deepwater corals (see Williams et al. in press; Druffel et al. 1995; Holmes et al. unpubl. data). This research should be continued. Although much work has been done on the southeastern U.S. margin, relatively little is known about basic parameters compared to the mid-Atlantic and north Atlantic costs of the U.S. There is a need to conduct physical and chemical monitoring at multiple spatial (individual mound to regional) and temporal (tidal to decadal) scales, including identification of episodic oceanographic events (e.g., intrusions, upwelling) and physical disturbances (e.g., turbidity plumes, storms).

TASK 1: Inventory existing deepwater (seafloor) data sources in the South Atlantic region (e.g., Ocean Observing System, OOS).
TASK 2: Identify required data sets and observing technologies (e.g., OOS, benthic landers).
TASK 3: Establish and carry out a deepwater monitoring plan for CHAPCs in partnership with the Southeast Coastal Ocean Observing Regional Association (SECOORA), starting with a pilot observing station at a fairly well-described DWCE.

2B. Investigate the internal structure of DWCEs, particularly in relation to overlying hydrodynamic and physicochemical conditions, and changing climate over time.

TASK 1: Conduct sub-bottom acoustic profiling survey over various DWCE habitats
TASK 2: Based on profile surveys, target specific DWCE types for follow-up coring from surface to base mounds

Objective 3: Describe and inventory biota of DWCEs.

The dominant biogenic architectural components of local DWCEs are the azooxanthellate, colonial scleractinian corals *Lophelia pertusa* and *Enallopsammia profunda*, with *Madrepora oculata* and *Solenosmilia variabilis* occurring as isolated colonies (Reed 2002a, b). Both constructional DWCEs and non-biogenic hard substrates (e.g., Miami and Pourtalès Terraces) provide habitat for a wide diversity of sessile macrofauna including solitary Scleractinia, gorgonians and soft corals (Octocorallia), black corals (Antipatharia), hydrozoan corals (Stylasteridae) and sponges (Demospongiae and Hexactinellida), which in turn provide habitat and living space for a relatively unknown but biologically rich and diverse community of associated organisms, including fishes, anemones, zoanthids, crustaceans, mollusks, echinoderms, polychaete and sipunculan worms, and foraminiferans (Ross and Nizinski in press).

Qualitative studies of the DWCEs off the southeastern U.S. identified 142 taxa of invertebrates and 58 species of fish directly associated with these coral habitats (Reed et al. 2006). The deepwater fauna of the east Florida margin includes at lest 53 species of Scleractinia (Cairns and Chapman 2001), ~15 stylasterids (Cairns 1986) and dozens of octocorals. The deep Gulf of Mexico fauna includes 84 Scleractinia (Cairns and Chapman 2001; Cairns in prep.), 5 stylasterids, and 115 octocorals (Cairns in prep.). Because Florida, and the Straits of Florida in particular, represents an important biogeographic boundary where different deepwater faunas meet to generate the greatest known species richness in the western (and perhaps entire) Atlantic Ocean (Carpenter 2002), it is expected that the complex three-dimensional habitats of local DWCEs will include important biodiversity "hotspots." However, current taxonomic information is scattered in the primary specialist literature. The fish fauna of the region (at least 98 species identified on and around deepwater coral habitat) was reviewed by Ross and Quattrini (in press and in review), but only preliminary notes of other fauna from scattered locations exist. This region may harbor a number of new species associated with deepwater corals, some described (e.g., McCosker and Ross in press; Fernholm and Quattrini in review) and some soon to be described (e.g., Nizinski et al. unpubl. data).

3A. Qualitatively and quantitatively describe the composition, diversity, assemblage organization and distributional patterns of DWCE benthic and water column fauna (invertebrates and vertebrates).

TASK 1: Develop a network of taxonomic experts and support comparative studies (e.g., validation, or inter-regional comparisons).
TASK 2: Assess biodiversity of all groups at different spatial scales (including molecular approaches for phylogeny, phylogeography, genetic connectivity, population dynamics and species boundary assessment).
TASK 3: Make products accessible through appropriate databases (e.g., Council's Internet Mapping Server, Ocean Planning and Information System, OPIS; Southeast Regional Taxonomic Center, SERTC; Coral Reef Information System, CORIS; Census of Marine Life).

3B. Determine relative abundance and occurrence of economically and ecologically important species associated with DWCE.
Sampling will require the use of multiple, standardized methods to allow for counting of individual species. Techniques will need to be adapted based on the fauna of interest and locations to be sampled (e.g., water column, benthic, surface). Methods may range from visual/video surveys with selective collections to quantitative sampling using coring devices or nets.
PHASE II: DETERMINE ECOLOGICAL ROLE OF DWCE, INCLUDING THE ROLE OF DEEPWATER CORAL HABITAT AS ESSENTIAL FISH HABITAT EXPAND UNDERSTANDING OF STRUCTURE-FORMING SPECIES' BIOLOGY AND ECOLOGY

Justification/Background
The southeastern United States may have the most extensive aphotic DWCEs in U.S. waters (Hain and Corcoran 2004); however, these large habitats are poorly documented and understood. Based on available data, DWCEs appear to occur abundantly on the southeastern United States slope (Stetson et al. 1962; Paull et al. 2000; Popenoe and Manheim 2001; Reed et al. 2005a, 2006; Ross and Nizinski in press). Prior to this century, these unique habitats had not been examined in detail in this region because of the great depths at which they are found, the rugged bottom topography, and extreme currents (e.g., Gulf Stream).

Ongoing research on DWCE in the southeastern United States has been based on the premise that these habitats are ecologically important and productive, yet very little is known about their ecological roles. The southeastern United States harbors over 100 deepwater coral species (Ross and Nizinski in press.), some of which create extensive, complex reef structures. These complexes are hotspots of increased biodiversity. Many coral species are very long lived (hundreds to thousands of years), and serve as natural repositories of data on climate, ocean physics, and ocean productivity (Adkins et al. 1998; Williams et al. 2006; Williams et al. in press). However, research on this topic is just beginning as is research on population and community genetics. There are no studies on trophic ecology or energetic models for DWCE of the southeastern United States.

Deepwater coral habitat now appears to be more important to northwestern Atlantic slope species than previously known. However, it is unclear whether this habitat is essential to selected fishes or invertebrates or whether they occupy it opportunistically (Rogers 1999; Auster 2005; Costello et al. 2005). Coral thickets, coral rubble, and the less structured nearby non-reef habitat all support diverse faunas in the southeastern United States (Reed et al. 2002, Reed et al. 2005a, 2006; Ross and Quattrini in press.). Analyses indicate that many species of fishes (Ross and Quattrini in press.) and invertebrates are closely associated with the unique deepwater reef habitat (Reed et al. 2006), including commercially-exploited deepwater species (e.g., wreckfish and golden crabs) and potentially exploitable species (e.g., royal red shrimps, blackbelly rosefish, bericiform fishes, eels). However, reef-invertebrate associations may be more opportunistic than those found in certain fishes (Ross et al. unpubl. data), but more data are required to confirm these associations.

Our understanding of DWCEs within the U.S. EEZ has progressed rapidly over the past decade, primarily though a series of exploratory cruises that have provided information on the distribution and general characteristics of these valuable resources. The next steps involve addressing ecosystem function and resilience to change, both anthropogenic and natural. In the South Atlantic region, DWCEs dominated by *Lophelia pertusa* and *Enallopsammia profunda* create extensive and complex structural framework which provides settlement substrate and microhabitat for a diverse benthic fauna. An understanding of individual and population level biology of these foundation species is a pre-requisite to effective ecosystem management. All ecosystems are subject to disturbances of various types, both natural and anthropogenic. Pristine ecosystems are generally resilient to disturbance, meaning that they can return to an original state via natural recovery processes. Resilience is an important ecosystem characteristic that needs to be fostered and protected via proactive management. As far as we know, the DWCE of the southeast region are relatively unimpacted; this could change rapidly with the advent of new energy proposals (liquefied natural gas ports and pipelines), development of deepwater fisheries and more subtle impacts such as pH reduction through global alterations in CO^2 cycles. Increasing our understanding of the biology of the keystone species, at an individual and population level will provide baseline data from which to assess ecosystem response to future stressors. At the individual level, factors such as growth rate, skeletal density, and fecundity can change in response to environmental stress.

Resilience at the population level may be largely dependent on the genetic composition and richness. Genetic and genotypic diversity provide scope for species to adapt to changing conditions such as warmer temperatures and/or altered pH. Branching corals such as *L. pertusa* and *E. profunda* reproduce asexually via fragmentation (i.e., branches break off and reattach to the substrate to form a new colony that is genetically identical to the parent). It is important to understand the extent of genotypic diversity present in *L. pertusa* populations to assess their potential for adaptation to global changes. Understanding patterns of genetic connectedness (i.e., gene flow) is important to contextualize and predict larval recruitment pathways, and ultimately to incorporate such information into design of deepwater coral HAPCs.

Considering the above, research priorities of locating, describing, and mapping deepwater corals and conducting basic biological studies in these habitats are necessary baseline data for developing appropriate management schemes. The goal of research described herein is to address major data gaps to facilitate management of deepwater coral habitat and allow increased understanding of its role in deepwater ecology.

Objective 1: Describe logistic and coordination efforts that could improve the efficiency and effectiveness of deepwater coral biological studies.

Given the expense and difficulty of studying deepwater organisms it is prudent to consider aspects of coordination of data collection within the scientific community that would enhance the value and effectiveness of all possible observations and samples over a wide range of objectives. For example, video footage is probably the most common data collected from deepwater coral habitats, but it is not collected in a standardized format that will allow comparison of information from different sites or cruises (e.g. size, percent cover, proportion live/partial mortality, growth or color morphs). A handbook of 'Deep Sea Coral Collection Protocols' by Etnoyer et al. (2006) has been compiled in an effort to standardize data collection from deepwater coral habitats. This will be available on-line in the near future, and includes protocols for video and photographic documentation as well as sample preparation for different purposes. A cooperative effort among the scientific community to abide by common protocols will potentially increase the utility of data collected during each expedition Another example of cooperation among groups that would maximize cruise time would be to formalize a chain-of-custody or clearing house for samples (e.g., corals, associated animals, pieces of skeleton etc.) that are collected during research cruises, and are not used by the cruise scientists. This would partition material to as many types of studies as possible (e.g., live material for lab experiments, ethanol-preservation for genetic analysis, surface treatments for microbial studies, tissue fixative for histological study, etc.) and make use of samples that would otherwise not be processed.

<u>TASK 1</u>: To the extent possible, use standardized protocols for data collection so that information may be exchanged among investigators and agencies.
<u>TASK 2</u>: Develop standardized chain-of custody for samples to optimize use of opportunistic or excess samples from deepwater coral habitats.

<u>Objective 2: Describe the population dynamics, movements and habitat associations of both economically and ecologically important species (including potentially exploitable species) associated with DWCEs.</u>

Many aspects of the ecology and biology of deepwater coral communities of the southeastern U.S. are either unknown or poorly understood, especially as it pertains to population dynamics. Population dynamics data are essential for understanding the historical and current status of populations, as well as modeling future population projections. For example, understanding how populations respond to extractive activities (fisheries) or respond to natural mortality requires knowledge of age and growth rates. Such studies are integral to understanding how populations might respond to climate change.

Information on spawning seasonality and locations are important for protecting reproductive integrity. Reproduction data (e.g., fecundity and spawning behavior) are needed to understand and model population fluctuations. Putting boundaries on population parameters requires studies on gene flow. Although determining barriers to gene flow that may isolate populations has been problematic for marine species (Palumbi 1994), various slope species exhibit unexpected degrees of population heterogeneity (Rogers 2002). Appropriate genetic techniques could facilitate inferences regarding organism dispersal and recruitment dynamics. Such data have important implications for how populations sustain themselves.

Many studies of the various aspects of population dynamics should concentrate (at least initially) on economically important, potentially economically important, and key ecological species. Although an appropriate species lists needs to be developed, these taxa of interest should include wreckfish, scorpionfishes (particularly blackbelly rosefish), alphonsinos, roughies, conger eel, red crabs, shrimps, galatheid squat lobsters, squids, and sponges. To date the only species of this grouping that has published information for the southeastern U.S. slope is the wreckfish (Sedberry et al. 1994; Weaver and Sedberry 2001; Vaughn et al. 2001). For most deepwater reef organisms of the southeastern United States there are no published data on age, growth, reproduction, genetic structure, movements, recruitment, and habitat relationships.

Note: Sampling for trophodynamic patterns (see objective 3) could easily be adapted to gather data for most population dynamics aspects below. While this might require little additional funding for field efforts, accessory funding for laboratory analyses and reporting would be needed.

2A. Determine the habitat relationships between deepwater corals and the species associated with them.

The lack of habitat association data hampers our understanding of deepwater reef communities and the roles of complex habitats in structuring or maintaining deepwater communities. If fauna are less explicitly associated with habitats in deepwater, this supports the hypothesis that slope fauna are more opportunistic because the deep sea environment has fewer resources (compared to the shelf). However, in contrast to the northwestern Atlantic (Auster 2005), data support hypotheses that southeastern U.S. deepwater coral banks host a unique, probably obligate, fauna and that the reefs concentrate food resources (Ross and Quattrini in press.). How deep does this pattern extend and is it true throughout the southeastern United States' slope?

<u>TASK 1</u>: Characterize habitat associations of invertebrate and fish faunas on and surrounding DWCEs. Sampling should include the full geographic and depth ranges of this habitat in the southeastern U.S., as well as all seasons. Direct observation methods (submersible or ROV) coupled with collections of habitat and fauna are the best way to sample these rugged areas for habitat association data (see Parker and Ross 1986; Sulak and Ross 1996; Ross and Quattrini in press.). It is important in this task to sample non-reef and non-coral habitats in order to adequately judge degrees of habitat association.

2B. Determine the migratory pathways of the economically and ecologically important species associated with DWCEs.

<u>TASK 1</u>: Characterize both the vertical and horizontal movements (at different spatial and temporal scales) of species associated with DWCEs, including all relevant life history stages. To infer vertical movement, sample the water column for species associated with DWCE at various depths over the appropriate time scale. To infer horizontal movement (especially of benthic species), sampling would be required that is logistically difficult (tagging) in the deep-sea, intensive, and expensive. In the near-term, the inference of horizontal movements may not be feasible.

2C. Determine the age structure and growth rates of economically and ecologically important species associated with DWCE as well as the sex ratio within each species.

<u>TASK 1</u>: Collect the full size range (juvenile to adult) of the species available within the study site across seasons.
<u>TASK 2</u>: Determine appropriate aging methods based on taxa examined and age samples.
<u>TASK 3</u>: Construct growth models.

2D. Determine the recruitment processes for the economically and ecologically important species associated with DWCE.

<u>TASK 1</u>: Conduct high-intensity temporal sampling using appropriate methods (e.g., settling plates and traps) to determine larval settlement processes including sites, periodicity, and relevance to oceanography. For traps, samples should be collected by setting multiple settlement traps within the deepwater coral habitat of interest and the adjacent non-reef habitat. Replication and placement of

the settlement traps is critical for determining whether settlement is random or based on specific cues. It would be important to record various physical data (e.g., current, temperatures) near these samples.

TASK 2: Determine larval duration, distribution, and vertical migration in the water column. Sample the water column for species associated with DWCE at various depths over the appropriate time scale. For fish species, determine daily ages of fishes from otoliths to determine larval duration. Understanding horizontal and vertical water column physics is important here, and if appropriate models are not available, they should be developed (see next task).

TASK 3: Model the information collected under the two previous tasks with horizontal scale physics (e.g., currents) to improve the understanding of recruitment processes and population connectivity.

2E. Examine the reproductive biology of economically and ecologically important species associated with DWCE.

Characterize the spawning seasonality and reproductive potential of the species of interest by collecting the full size range (juvenile to adult) of the species available within the study site. Adequate sampling will require collection of data on monthly or quarterly intervals and ensuring that there are sexual differences in the population. Samples should be analyzed for sex, reproductive state, and fecundity (for females only). Method details may vary by taxa examined.

2F. Determine the genetic structure of the economically and ecologically important species associated with DWCE.

TASK 1: Sample coral and associated species at a regional scale to make inferences about the mechanisms structuring local assemblages (e.g., community genetics). Using a community genetics approach (Agrawal 2003; Neuhauser et al. 2003; Whitman et al. 2003), patterns of genetic structuring should be compared among taxa and with environmental variables. This study should also include examining the genetic structuring of fauna closely associated with *Lophelia* and other habitat-forming corals and sponges, such as galatheid "crabs" (*Eumunida picta*), eunicid polychaetes (Roberts 2005), urchins and some fishes. If associations between *Lophelia* and co-occurring invertebrates are strong, similar genetic patterns may result, suggesting that similar mechanisms may influence community structure of associated organisms.

Objective 3: Describe food web dynamics of DWCEs.

To assess natural and anthropogenic impacts, the degree of connectivity among ocean zones (e.g., benthic, abyssal, and neustonic) must be better understood. The execution of research within these zones has lead to an implicit assumption of compartmentalization. However, ocean waters and many of their inhabitants regularly move across perceived boundaries, and systems are much more connected than previously reported (Knight et al. 2005) as evidenced by improved tracking of animal movements and energy flow (trophodynamics).

Input of energy to the deep seafloor was thought to be from the top down and mostly passive. In the northeastern Atlantic, the energy source of *Lophelia pertusa* is derived from particulate matter drifting down from the upper water column (Duineveld et al. 2004), but trophic data for the broader community are lacking. A hypothetical trophic web was developed for the deepwater *Oculina* ecosystem which consists of the coral biogenic refuge for hundreds of species of invertebrates and fishes which in turn receives plankton/particulate input from the Florida Current (Gulf Stream) and cold-water upwelling events providing influxes of nutrients (George et al. in review). It is likely that active vertical movements of animals provide a substantial, regular flow of energy through the water column to the seafloor (Kinzer 1977; Genin 2004; Gartner et al. in review). Such movements may be diel, ontogenetic, or both and move resources in both directions, variously impacting a large section of the water column.

During past submersible observations (coupled with depth-discrete sampling) off the southeastern U.S. large concentrations of mesopelagic (midwater) fauna were noted on the bottom near deepwater (360 to 700 m) coral banks (Gartner et al. in review). Mesopelagic fauna were observed acting as both predator and prey of benthic organisms. Whether this activity is sporadic or whether various animals depend on such interactions is unknown. If the migrating mesopelagic fauna is a major conduit of energy through the water column, human (or other) perturbations of the bottom and midwater faunas may have significant impacts on pelagic fishes, seabirds, and marine mammals through effects on trophic relationships. However, open ocean ecological coupling (expressed by food web inter-connection among benthic and water column nekton) is poorly studied.

Research described here will begin to define faunal connectivity in terms of trophic linkages over and around DWCE. Characterization of trophodynamics and benthic-pelagic interactions of organisms associated with deepwater corals would provide important information on food resources and sources, feeding periodicity, and how various habitats from the bottom to the surface are linked. In addition to traditional diet analyses of collected specimens, stable isotope ratios (of carbon, nitrogen, and possibly sulfur) of deepwater coral area organisms (whole water column) would establish trophic signatures that help define community relationships (Thomas and Cahoon 1993; Kwak and Zedler 1997; MacAvoy et al. 2001). From these data we could answer important questions about the broad impacts to a particular habitat or group of organisms from natural or anthropogenic events. An added advantage of a trophodynamic study is that the process of collecting organisms to describe feeding relationships can provide valuable additional data (e.g., species-habitat associations, distributions, abundances, sizes, reproductive states, etc.).

3A: Characterize the trophodynamics and the benthic-pelagic interactions of organisms associated with deepwater coral habitat using both traditional and novel approaches.

The *traditional approach* is to capture organisms, determine species, and analyze their stomach contents.

A *novel approach* to couple with the above method is to analyze stable isotopes in the tissues of the captured fauna. Naturally occurring isotopic concentrations in various tissues identify sources of dietary components (e.g., from plankton or benthic sources) provided there is a good understanding of the isotopic signatures of potential food sources.

Sampling should be conducted using the appropriate temporal and spatial scales.

Temporal scale: For the traditional approach, it is important to collect data on a seasonal basis and if possible on a diel basis because stomach content data reflect only a snap-shot of the diet of a species. Sampling for the novel approach method can be conducted at any time of the year because isotopic signatures represent an integration of diet over time in the tissues.

Spatial scale: For both the traditional and novel approaches, organisms should be collected in both the water column above the deepwater coral habitat of interest, within that habitat itself, and in the adjacent benthic non-reef habitats. Since reef habitat varies throughout this region, the ideal sampling scheme would have replicate samples collected from a minimum of three previously studied sites between Cape Lookout and the Florida Straits in which preliminary analyses have suggested differing benthic populations.

<u>Objective 4: Describe relationships among DWCE composition, structure and distribution and abiotic and biotic factors.</u>

4A. Identify relationships between the distribution and development of DWCEs and abiotic and biotic factors.

As noted previously, no time-series data exist on the hydrographic or physicochemical characteristics of the water column associated with DWCEs in the region. Detailed data on temporal and spatial patterns and ranges of variation in abiotic factors, e.g., temperature, salinity, dissolved gases, hydrodynamics (bottom currents, upwelling, tides, eddies), turbidity levels and the nature of suspended material, represent a baseline of information required for understanding DWCE composition, growth, structure and distribution. Similarly, no data exist on the composition of seston (i.e., plankton, suspended organic detritus and inorganic particles) available to DWCEs or the patterns, abundances and rates of its import to DWCEs. Such data are critical to understanding DWCE trophodynamics and growth patterns.

<u>TASK 1</u>: Collect time-series data of abiotic and other water column factors using a variety of deployed instrument packages (e.g., time-lapse cameras, current meters, CTDs, sediment traps, larval settlement panels).

<u>TASK 2</u>: Conduct multivariate analyses of abiotic factors versus organism distributions and DWCE structure.

4B. Develop models to enable predictions of DWCE status and trends.

<u>TASK 1</u>: Identify suitable models and conduct model-data comparisons to validate models specifically for DWCE application:

a. Ocean circulation (physical, chemical parameters) and

b. Sedimentation.

4C. Determine long-term temporal (decadal to epochal scales) relationships between DWCE structure and distribution relative to overlying hydrodynamic regime.

Although the broad-scale geology of the region is reasonably well understood, no cores have been taken through local DWCEs that might contribute to understanding their development, particularly with respect to climate change. Such coring (or drilling) was quite valuable in determining the origins and history of deepwater coral banks in the northeastern Atlantic (Williams et al. 2006).

<u>TASK 1</u>: Examine historical records of pollution, productivity, climate and oceanography across the South Atlantic region.

<u>TASK 2</u>: Determine age, growth and senescence of DWCE (bioherms and lithoherms) by:

a. Radioisotope and amino acid racemization analysis of corals,

b. Cores of coral mounds and

c. Sub-bottom profiling across mounds and hard bottoms.

<u>Objective 5: Describe reproductive strategies (gametogenic cycles, sex ratio, fecundity, larval development modes) of priority structure–forming groups, including scleractinians (*Lophelia pertusa*, *Enallopsammia profunda*, *Madrepora oculata*), octocorals, antipatharians and Stylasterines.</u>

Gametogenesis has been described for several species of structure-forming scleractinians, from the Eastern and Western Atlantic and the Pacific. Generally they are gonochoristic (i.e. separate sexes), seasonal broadcast spawners, with small eggs, and probably dispersive larvae. This is the extent of our information for most of these species. *Lophelia pertusa* has been studied more extensively than other species, using samples from Norway, the Gulf of Mexico and the Florida Straits. Seasonality of gametogenesis appears to vary with location. The gametogenic cycle of samples collected from the Norwegian Fjords began in April and terminated with spawning in March the following year (Brooke and Jarnegren in prep.). In the Gulf of Mexico, however, gametogenesis begins in November and spawning probably occurs in late September/October (S. Brooke unpubl.). Fecundity of both sets of samples is high but quantified data have not yet been compiled. Research into reproduction of octocorals from Alaska and New England is also underway (Simpson unpubl), and some work has been done on reproduction in Alaskan stylasterines, which are all brooders and produce short-lived planulae (Brooke and Stone in review). Larval biology has been described for *O. varicosa* (Brooke and Young 2005) but not for any of the other deepwater corals.

Hydrodynamic models can provide probability distributions for larval dispersal under a variety of environmental scenarios but they require basic biological input data on parameters such as timing of spawning/larval release, larval duration, and behavior. Such data are not currently available for the southeastern U.S. deepwater corals but are needed to enhance the effectiveness of modeling efforts.

5A: Determine the gametogenic cycles and spawning periods for structure-forming corals.

<u>TASK 1</u>: Collect samples for histological examination. Characterization of these cycles requires repeated sampling at individual sites over time (e.g., monthly). Such sampling can be done opportunistically (i.e. haphazard collections during other cruises) but would be accomplished much more efficiently with targeted sampling effort.

5B: Determine larval development and settlement processes for structure-forming species.

<u>TASK 1</u>: Collect samples of important structure-forming species at the end of the gametogenic cycle to spawn for larval studies.

<u>Objective 6: Describe patterns and processes of colony growth and mortality (e.g., calcification, carbon and energy budgets) of important structure-forming species, and determine how they are affected by environmental factors and stressors.</u>

The growth of *L. pertusa* has been measured using various methods (Duncan 1877; Dons 1944; Freiwald 1998; Gass and Roberts 2006), which have estimated growth rates between 4-26 mm per year, with the most likely estimates at approximately 5mm per year (Mortensen and Rapp 1998). These methods have measured linear extension rather than calcification rates, but the latter could potentially be calculated from growth rates and skeletal density. Growth rates of some gorgonians and antipatharians have also been measured using rings in the gorgonian skeleton and isotopic analysis (e.g., Sherwood et al. 2005, Andrews et al. 2002, Risk et al. 2002; Williams et al. 2006) and in some cases the colonies are extremely old (hundreds to thousands of years) and have very slow growth rates (e.g., Druffel et al. 1995; C. Holmes et al. unpubl. data).

Field observations on distribution of *L. pertusa* indicate that the upper thermal limit for survival is approximately 12^{o}C, and laboratory studies on *L. pertusa* tolerance to temperature extremes corroborate these observations (S. Brooke unpubl. data). Preliminary experiments with heat shock proteins show expression of HSP-70 in response to exposure of temperature greater than 10^{o}C (S. Brooke unpubl. data). Experiments on tolerance to sediment load indicate that samples of *L. pertusa* from the Gulf of Mexico show >50% survival in sediment loads of 103 mgL-1 for 14 days, and can survive complete burial for up to 2 days (Continental Shelf Associates in review). Given the proximity of some coral habitats to oil and gas extraction sites, tolerance to drilling fluids and fossil fuels should also be investigated.

Further laboratory and field experiments are needed to examine the individual and interactive effects of environmental conditions such as temperature, sedimentation, and toxins. A range of responses or endpoints should be examined including more modern techniques such as cellular diagnostics. These include examination of levels of stress proteins produced by cells in response to external conditions such as heat shock proteins, ubiquitin, etc. There are general classes of cellular products that are known to be indicative of specific stressors such as nutritional stress, xenobiotics, metals, temperature. These techniques are being increasingly used in shallow coral systems as a more sensitive organismal response to stress (i.e. more sensitive than mortality). These responses should be measured in combination with more standard parameters such as growth, respiration, and fecundity.

Coral growth rates provide information on the rates of habitat production in DWCEs while coral mortality and bioerosion counterbalance this production with destruction. Understanding the positive and negative sides of this balance, particularly under the changes in environmental conditions that are anticipated in the coming decade or two, is crucial to the management and conservation of deepwater coral habitat and habitat function (e.g. fishery production).

6A: Determine rates of colony growth (i.e. habitat production).

<u>TASK 1</u>: Conduct in-situ tagging or staining and revisit individual colonies for selected coral species. This activity should be in concert with in-situ monitoring station such as a benthic lander or other instrumentation to allow correlation of coral growth performance with in situ environmental conditions. Radiometric aging and growth estimates should also be conducted for selected corals (e.g., antipatharians)

6B: Determine physiological responses to stress (sediment, temperature, pollutants, CO^2) and how growth rate is affected by environmental factors (i.e., how is habitat production affected by environmental factors?).

<u>TASK 1</u>: Conduct manipulative laboratory dose-response experiments on live coral colonies, where various responses (e.g., molecular biomarkers, growth, and respiration) to stress levels can be documented under controlled conditions. This requires collection of live samples and post cruise maintenance in a temperature-controlled facility.

6C: Determine temporal patterns of coral mortality and bioerosion (habitat loss).

<u>TASK 1</u>: Characterize succession of boring/bioeroding community in coral skeleton. Ideally the degree of bioerosion would be correlated with ageing data to obtain information on bioeroder succession.
<u>TASK 2</u>: Drill cores and age dead skeletons from a range of sites and physiographic features.
<u>TASK 3</u>: Develop techniques for amino acid racemization or other techniques with high temporal resolution.

<u>Objective 7: Describe the genetic characteristics of structure forming coral populations.</u>
Little is known about basic biology of deepwater coral species, including larval dispersal potential and connectivity between reefs (hence vulnerability). Given the difficulty of tracking movements of

coral larvae, especially at depth, genetic methods hold great promise for estimating important factors in the longevity of deepwater reefs that could not otherwise be inferred from their biology. Levels of gene flow among adjacent sites, relative contributions of clonal (asexual) and sexual reproduction and inferences regarding larval dispersal and levels of historical connectivity obtained from genetic data can provide valuable insights for appropriate management of these unique habitats.

Codominantly inherited genetic markers are required to fully assess population structure and to estimate parameters such as gene flow, the extent of clonal reproduction, and possible hybridization. Microsatellites are codominant markers made up of short (2-6 bases), tandemly repeated units of DNA that do not code for gene products (i.e. are effectively neutral to selection) and vary in number of repeats between individuals. Due to the relatively high mutation rate observed in microsatellite DNA markers, they have been useful in analysis of population structure at a finer level than is possible using DNA genomic sequences, and have been remarkably successful at identifying recently diverged lineages in marine invertebrates (e.g. King et al. 2005). Given sufficiently large numbers of microsatellite markers and sufficient sampling coverage from throughout the species range, microsatellites can be utilized to obtain a precise measure of population structure, including an assessment of gene flow between populations, allowing identification of sources of recruitment and estimation of effective population size.

An analysis of population structure of *L. pertusa* from the northeast Atlantic and Scandinavian fjords, based upon microsatellites and nuclear ITS DNA sequences, concluded that very low levels of gene flow occurred between offshore and fjord habitats, and that population structure among fjords was substantial, indicating localized recruitment of larvae (Le Goff-Vitry et al. 2004a). This has significant conservation implications, because destruction of reefs may be permanent if they are unlikely to be re-seeded with new larvae. Attempts to utilize the microsatellite markers developed by LeGoff-Vitry et al. (2004b) for Western Atlantic *L. pertusa* have not been successful, so additional markers have been developed (C. Morrison et al. unpubl. data) for the southeastern United States and Gulf of Mexico. Generally, microsatellite markers are species-specific, and additional markers may need to be developed for other reef-forming species in the future. Preliminary results from *L. pertusa* collected in the southeastern U.S. and Gulf of Mexico revealed high variability in population structure, low clonality, and variation over small spatial scales (C. Morrison et al. unpubl. data). Such results indicate that loss of any living *Lophelia* could seriously impact genetic diversity.

7A: Determine the clonal structure of *L. pertusa* across spatial scales.

TASK 1: Conduct targeted sampling on small spatial scales to characterize patterns of genotypic structure at as many geographical locations as possible.

7B: Determine the extent of genetic connectivity among populations of *L. pertusa*.

TASK 1: Conduct combined opportunistic and targeted (to fill in gaps) sampling across the entire geographic and depth range of the species.

Objective 8: Determine the nature, patterns, and processes of communities of microbial coral associates.

The role of microbes (bacteria, fungi and archaea) in the biology of *L. pertusa* is essentially unknown and yet these organisms likely play an important role. In tropical shallow-water coral species, some microbes appear unique markers of the surrounding water column and may be associated with certain coral species or tissues (Rohwer et al. 2001, 2002), suggesting ecological interactions between the microbes and corals. Lacking algal symbionts found in shallow-water corals, deepwater corals may rely more heavily on microbes in order to remain healthy, such as fixing nitrogen, carbon cycling, chelating iron, producing antibiotics to ward off harmful bacteria, or other beneficial roles yet to be defined (C. Kellogg, pers. comm.). Microbes have been found to play key chemosynthetic roles in cold seep communities (e.g. Boetius et al. 2000; Knittel et al. 2005) that are often found in close proximity to *Lophelia* corals. Preliminary microbial data from Gulf of Mexico *Lophelia* colonies indicated a unique and diverse community that exhibited considerable variability (C. Kellogg, unpubl. data).

A combination of techniques will be necessary to characterize the microbial communities found within *Lophelia* corals. First, since the microbial community can change when exposed to varying pressures, temperatures and light conditions during sampling (C. Kellogg, pers. comm.), some corals should be fixed at depth in order to establish a baseline dataset. This will require special, sterile sampling devices for submarine or ROV work. Both culturable (capable of growing on agar plates), and non-culturable (assayed through DNA sequencing) microbes should be surveyed from *Lophelia* in as many locations as possible. Characterization of microbes from Gulf of Mexico *Lophelia* is on-going and will provide interesting comparisons with *Lophelia* from the Southeastern Atlantic coast (C. Kellogg, pers. comm.). Molecular probes targeting certain microbes may eventually allow fast assessment of presence or absence of associated microbes. Other coral species and other fauna closely associated with corals should be sampled for microbial communities as well and comparisons made among microbes found in different species.

8A: Identify the symbiotic microbial community of coral colonies in different places and environmental conditions.

<u>TASK 1</u>: Conduct microbial screening of opportunistic coral (and other species) samples.
<u>TASK 2</u>: Target sampling with “clean” in-situ sampler.

Sargassum

Habitat and species specific research needs identified in Council fishery management plans are presented below for pelagic Sargassum habitat.

Summarized from Pelagic Water Column Workshop, Research and Monitoring Workshop, and Settle (1997):

1. What is the areal abundance of pelagic Sargassum off the southeast U.S.?
2. Does the abundance change seasonally?
3. Can pelagic Sargassum be assessed remotely using aerial or satellite technologies (e.g., Synthetic Aperture Radar)?
4. What is the relative importance of pelagic Sargassum weedlines and oceanic fronts for early life stages of managed species?
5. Are there differences in abundance, growth rate, and mortality?
6. What is the age structure of reef fishes (e.g., red porgy, gray triggerfish, and amberjacks) that utilize pelagic Sargassum habitat as a nursery and how does it compare to the age structure of recruits to benthic habitats?
7. Is pelagic Sargassum mariculture feasible?
8. What is the species composition and age structure of species associated with pelagic Sargassum when it occurs deeper in the water column?

9. Additional research on the dependencies of pelagic Sargassum productivity on the marine species using it as habitat.
10. Quantify the contribution of nutrients to deepwater benthic habitat by pelagic Sargassum.

In addition, the following research needs were identified in the NMFS Biological Opinion and are included:

1. Studies should be performed on the abundance, seasonality, life cycle, and reproductive strategies of Sargassum and the role this species plays in the marine environment, not only as an essential fish habitat, but as a unique pelagic algae. The research recommendations of this FMP were based primarily on managing Sargassum as essential fish habitat for species managed under the MSFCMA. Research needs should also be identified that consider the Sargassum community, as well as the individual species of this community that are associated with, and/or dependent on, pelagic Sargassum. Human-induced (tanker oil discharge; trash) and natural threats (storm events) to Sargassum need to be researched for the purpose of protecting and conserving this natural resource.
2. Cooperative research partnerships should occur between the council, NMFS Protected Resources Division, and state agencies since many of the needs to a) research pelagic Sargassum, and b) protect and conserve pelagic Sargassum habitat, are the same for both managed fish species and listed sea turtles.
3. Specific research needs should be included in the plan which further address the association between pelagic Sargassum habitat and post-hatchling sea turtles.

Dolphin Wahoo

Prioritized EFH Research Needs (from 2003 FMP)
This determination was developed based on research needs identified through the Pelagic Water Column Workshop, Research and Monitoring Workshop, Settle (1997) and the NMFS Biological Opinion for the Sargassum FMP (SAFMC, 2002) as they apply to dolphin and wahoo.

1. What is the areal and seasonal abundance of pelagic Sargassum off the southeast U.S.?
2. Develop methodologies to assess remotely assess Sargassum using aerial or satellite technologies (e.g., Synthetic Aperture Radar)?
3. What is the relative importance of pelagic Sargassum weedlines and oceanic fronts for early life stages of dolphin and wahoo?
4. Are there differences in abundance, growth rate, and mortality?
5. What is the age structure of all fishes that utilize pelagic Sargassum habitat as a nursery and how does it compare to the age structure of recruits to pelagic and benthic habitats?
6. Is pelagic Sargassum mariculture feasible?
7. Determine the species composition and age structure of species associated with pelagic Sargassum when it occurs deeper in the water column?
8. Additional research on the dependencies of pelagic Sargassum productivity on the marine species using it as habitat.
9. Quantify the contribution of nutrients to deepwater benthic habitat by pelagic Sargassum.
10. Studies should be performed on the abundance, seasonality, life cycle, and reproductive strategies of Sargassum and the role this species plays in the marine environment, not only as an essential fish habitat, but as a unique pelagic algae.
11. Research to determine impacts on the Sargassum community, as well as the individual species of this community that are associated with, and/or dependent on, pelagic Sargassum.

Human-induced (tanker oil discharge; trash) and natural threats (storm events) to Sargassum need to be researched for the purpose of protecting and conserving this natural resource.

12. Develop cooperative research partnerships between the Council, NMFS Protected Resources Division, and state agencies since many of the needs to a) research pelagic Sargassum, and b) protect and conserve pelagic Sargassum habitat, are the same for both managed fish species and listed sea turtles.
13. Direct specific research to further address the association between pelagic Sargassum habitat and post-hatchling sea turtles

Prioritized Research Needs

The determination is based on Prager, 2000 and SAFMC, 1998a research workshop recommendations. Research needs include but are not limited to the following:

- In the short-term effort should be directed at examining all existing seasonality (effort and landings), mean size, and life history data for dolphin from the northern area.
- Additional data are needed to develop and/or improve estimates of growth, fecundity, etc. Research in this area is encouraged.
- There are limited social and economic data available. Additional data need to be obtained and evaluated to better understand the implications of fishery management options.
- Trophic data should be considered in support of an ecosystem management approach.
- Essential fish habitats for dolphin and wahoo need to be identified.
- An overall design should be developed for future tagging work. This could be done by the Working Group. In addition, existing tagging databases should be examined.
- Long-term work should continue and expand on current research investigating genetic variability of dolphin populations in the western central Atlantic.
- Observer programs should place observers on longline trips directed on dolphin. Catch and bycatch characterization, condition released (alive or dead), etc. should be collected. Observers could also be used to collect bioprofile data (size, sex, hard parts for aging, etc.).
- High levels of uncertainty in inter-annual variation in abundance of dolphin should be investigated through an examination of oceanographic and other environmental factors.
- Release mortality should be investigated as a part of the evaluation of the effectiveness of current minimum size limits in the dolphin fishery.
- Establish a list serve for dolphin and wahoo which would facilitate research and the exchange of information.

Note: An additional recommendation of the workshop was to establish a regional working group to develop and implement a coordinated research program for dolphin and wahoo.

Other Managed Species

Other Regional Councils – Species in SA

9.1.3 Interjurisdictional Prioritized Research Needs

(from ASMFC's Prioritized Research Needs in Support of Interjurisdictional Fisheries Management, 2004)

American Eel

1. Documentation of the commercial eel fishery should be more accurate so that our understanding of participation in the fishery and the amount of directed effort could be known.
2. A stock assessment committee should identify the best stock assessment methods for American eel.
3. Investigate survival and mortality rates of different life stages (leptocephalus, glass eel, yellow eel, and silver eel) to assist in the assessment of annual recruitment. Such research could be aided by continuing and initiating new tagging programs with individual states.
4. Regular periodic stock assessments and determination of fishing mortality rates (F) are required to develop a sustainable harvest rate in addition to determining whether the population is stable, decreasing, or increasing.
5. Evaluate the impact, both upstream and downstream, of barriers on eel with respect to population and distribution effects. Determine relative contribution of historic loss of habitat to potential eel population and reproductive capacity.
6. Triggering mechanism for metamorphosis to mature adult, silver eel life stage with specific emphasis on the size and age of the onset of maturity, by sex. A maturity schedule (proportion mature by size or age) would be extremely useful in combination with migration rates.
7. A coast wide sampling program for American eel should be formulated using standardized and statistically robust methodologies. A critical review of the existing sampling plan should be conducted.
8. Investigate: fecundity, length and weight relationships for females throughout their range; growth rates for males and females throughout their range; predator-prey relationships; behavior and movement of eel during their freshwater residency; oceanic behavior, movement and spawning location of adult mature eel; and all information on the leptocephalus stage of eel.
9. Assess characteristics and distribution of eel habitat and value of habitat with respect to growth and sex determination.
10. Age at entry of glass eel into estuaries and fresh waters should be examined.
11. Location and triggering mechanism for metamorphosis from leptocephalus to eel should be examined.
12. The historic participation level of subsistence fishers in wildlife management planning needs to be reviewed, and relevant issues brought forth with respect to those subsistence fishers involved with American eel.
13. Investigate, develop, and improve technologies for American eel passage upstream and downstream of various barriers for each life stage. Emphasis should be placed on evaluation of low-cost alternatives for passage.
14. Economics studies are necessary to determine the value of the fishery and the impact of regulatory management.
15. Examination of the mechanisms for exit from Sargasso Sea and transport across the continental shelf.
16. Mechanisms of recognition of the spawning area by silver eel, mate location in the Sargasso Sea, spawning behavior, and gonadal development in maturation should be researched.
17. Contaminant effects on eel and the effects of bioaccumulation with respect to impacts by age on survival and growth and effect on maturation and reproductive success should be researched.
18. Migratory routes and guidance mechanisms for silver eel in the ocean should be examined.
19. Examine the mode of nutrition for leptocephalus in the ocean.
20. Provide analysis of food habits of glass eel while at sea.

21. The degree of dependence on the American eel resource by subsistence harvesters such as Native American Tribes, Asian and European ethnic groups, etc. needs to be investigated.
22. Workshop on aging and sexing techniques should be considered to increase the accuracy of data collected in coastwide sampling program.
23. Determine mortality rates at different life history stages (leptocephalus, glass eel, yellow eel, silver eel), and mortality rates with size of the yellow eel stage.
24. Determine sustainable fishing mortality rates (F) for eel.

25. Investigate fecundity, length and weight relationships for females throughout their range, and growth rates for males and females throughout their range.

Research Needs Identified As Being Met:

- Evaluate the use of American eel as a water quality indicator.
- Investigate practical and cost-effective methods of re-establishing American eel in underutilized habitat.

American Shad/River Herring

1. Continue to assess current aging techniques for American shad and river herring, using known age fish, scales, otoliths, and spawning marks. Conduct bi-annual aging workshops to maintain consistency and accuracy of aging of fish sampled in state programs.
2. Determine and update biological benchmarks used in assessment modeling (fecundity at age, mean weight at age for both sexes, partial recruitment vector/maturity schedules) for American shad and river herring stocks in a variety of coastal river systems, including both semelparous and iteroparous stocks.
3. Validate the different values of M for shad stocks through verification of shad aging techniques and repeat spawning information and develop methods for calculating M.
4. Determine which stocks are impacted by coastal intercept fisheries (including bycatch fisheries). Methods to be considered to differentiate among stocks could include otolith micro-chemistry, oxytetracycline otolith marking and/or tagging.
5. Identify pheremones or other chemical substances used by American shad to locate conspecifics. Develop methods to isolate or manufacture these chemicals and use them to attract shad into fish passage facilities to improve fish passage and efficiency.
6. Develop effective culture and marking techniques for river herring.
7. Develop and implement techniques to determine shad and herring population targets for tributaries undergoing restoration (dam removals, fishways, supplemental stocking, etc.).
8. Evaluate and ultimately validate large-scale hydroacoustic methods to quantify American shad escapement (spawning run numbers) in major river systems. Identify how shad respond (attract/repelled) by various hydroacoustic signals.
9. Refine techniques for hormone induced tank spawning of American shad. Secure adequate eggs for culture programs using native broodstock.
10. Characterize tributary habitat quality and quantity for Alosa reintroductions and fish passage development.
11. Identify and quantify potential American shad spawning and rearing habitat not presently utilized and conduct an analysis of the cost of recovery.
12. Develop comprehensive angler use and harvest survey techniques for use by Atlantic states to assess recreational fisheries for American shad.
13. Determine the effects of passage impediments on all life history stages of shad and river herring, conduct turbine mortality studies and downstream passage studies.

14. Evaluate additional sources of mortality for shad, including bait and reduction fisheries.
15. Conduct studies on energetics of feeding and spawning migrations of shad on the Atlantic coast.
16. Encourage university research on hickory shad.
17. Conduct studies of egg and larval survival and development.
18. Conduct and evaluate historical characterization of socio-economic development (potential pollutant sources and habitat modification) of selected shad rivers along the east coast.
19. Review studies dealing with the effects of acid deposition on anadromous alosids.
20. Conduct population assessments on river herrings -- particularly needed in the south.
21. Quantify fishing mortality (in-river, ocean bycatch, bait fisheries) for major river stocks after ocean closure of directed fisheries.

Research Needs Identified as Being Met:

- Determine the stock/recruitment relationships for American shad and river herring stocks.

Atlantic Croaker

High Priority

- Criteria should be cooperatively developed for aging croaker otoliths.
- Studies of croaker growth rates and age structure need to be conducted throughout the species range.
- Age-length keys that are representative of all gear types in the fishery should be developed.
- Fishery dependent and independent size, age and sex specific relative abundance estimates should be developed to monitor long term changes in croaker abundance.
- Improve catch and effort statistics from the commercial and recreational fisheries, along with size and age structure of the catch.
- Examine reproductive biology of croaker with emphasis on developing maturity schedules and estimates of fecundity.

Medium Priority

- Conduct stock identification research on croaker.
- Cooperative coastwide croaker juvenile indices should be developed and validated to clarify stock status.
- Evaluate hook and release mortality under varying environmental factors and fishery practices.
- The effects of mandated bycatch reduction devices (BRD's) on croaker catch should be evaluated and compiled.
- In trawl fisheries or other fisheries that historically take significant numbers of croaker, states should monitor and report on the extent of unutilized bycatch and fishing mortality on fish less than age-1. Incorporate bycatch estimates into croaker assessment models.
- The optimum utilization (economic and biological) of a long term fluctuating population such as croaker should be evaluated.
- Continue monitoring of juvenile croaker populations in major nursery areas.
- Cooperatively develop a yield per recruit analysis to establish a minimum size that maximizes YPR.
- Determine the onshore vs. offshore components of the croaker fishery.
- Identify essential habitat requirements.

Low Priority

1. Determine migratory patterns and mixing rates through cooperative, multi-jurisdictional tagging studies.
2. Determine species interactions and predator/prey relationships for croaker (prey) and other more highly valued fisheries (predators).
3. Determine the impacts of any dredging activity (i.e. for beach re-nourishment) on all life history stages of croaker.

Atlantic Menhaden

- Evaluate effects of selected environmental factors on growth, survival and abundance of juvenile and adult menhaden, particularly in Chesapeake Bay and other coastal nursery areas.
- Develop and test methods for estimating size of recruiting year-classes of juveniles using fishery-independent survey techniques.
- Determine how loss/degradation of critical estuarine and nearshore habitat affects growth, survival and abundance of juvenile and adult menhaden abundance.
- Monitor landings, size, age, gear, and harvest area in the reduction and bait fisheries, and determine age composition by area. Enhance biostatistical sampling of bait samples in purse seine fisheries for Virginia and New Jersey to improve stock assessment.
- Study the ecological role of menhaden (predator/prey relationships, nutrient enrichment, oxygen depletion, etc.) in major Atlantic coast embayments and estuaries. The feasibility of estimating year-class strength using biologically stratified sampling design should be evaluated. The efforts could be supported by process studies linking plankton production to abundance of young menhaden (need resources).
- Evaluate use of coastal power plant impingement data as a possible means to estimate young-of-the-year menhaden abundance.
- Monte Carlo simulations should be conducted to evaluate precision of VPA.
- Alternative measures of effort, including spotter pilot logbooks, trip length, or other variables, should be evaluated. Spotter pilot logbooks should be evaluated for spotter plane search time, GPS coordinates, and estimates of school sizes observed by pilots.
- Re-evaluate menhaden natural mortality, by age and response to changing predator population sizes.
- Determine the effects of fish diseases (such as ulcerative mycosis and toxic dinoflagellates) on the menhaden stock.
- Determine the effects of regulations on the fishery, the participants and the stock.
- Growth back-calculation studies should be pursued to investigate historical trends in growth rate. The NMFS has an extensive data base on scale growth increments which should be utilized for this purpose.
- Monitor fish kills along the Atlantic coast and use the NMFS Beaufort Laboratory as a repository for these reports.
- Develop bycatch studies of menhaden by other fisheries.
- Periodically monitor the economic structure and sociological characteristics of the menhaden reduction industry.

Striped Bass

1. Develop refined and cost-efficient coastal monitoring regime for striped bass stocks, including spawning stock biomass modeling and virtual population analysis (VPA).
2. Conduct sensitivity analysis on current state and federal fishery dependent and independent monitoring programs to determine which, if any, may be eliminated.
3. An evaluation of the overfishing definition should be made relative to uncertainty in biological parameters.

4. Simulation models should be developed to look at the implications of overfishing definitions relative to development of a striped bass population which will provide "quality" fishing. Quality fishing must first be defined.
5. Quota calculation methods should be refined which allow better estimates among various components of the fishery.
6. Examine differential reporting rates between commercial and recreational fishermen using high reward tags.
7. Develop studies to provide information on the magnitude of hook and release and bycatch mortality, including factors that influence their magnitude and means of reducing or eliminating this source of mortality.
8. Further study should be conducted on the discrepancy in ages between scale-based and otolith-based ages. Particular emphasis should be placed on comparisons with known age fish determined from coded wire tags. Comparisons should be made among age readers and areas.
9. Increase sea sampling of commercial fisheries, such as the dogfish gillnet fishery, which may have high levels of discards.
10. Continue in-depth analysis of migrations, stock composition, etc. using mark-recapture data.
11. Continue to conduct research to determine limiting factors affecting recruitment and possible density implications.
12. Determine inherent viability of eggs and larvae.
13. Additional research should be conducted to determine the pathogenicity of the IPN virus isolated from striped bass to other warm water and marine species, such as flounder, menhaden, shad, largemouth bass and catfish.
14. Juvenile and adult surveys should be continued to determine the most cost-effective release strategies including age at release and optimal release conditions such as salinity, temperature, and time of day for future potential stocking programs.
15. Review relationship between tag based survival estimates and VPA estimate of mortality in a management framework.
16. Improve methods for determining population sex ratio for use in estimates of spawning stock biomass and biological reference points.
17. Develop maturity ogive applicable to coastal migratory stock.

Atlantic Sturgeon

1. Obtain baseline data on habitat condition and quantity in important sturgeon rivers. Data should address both spawning and nursery habitat.
2. Characterize size, condition, and relative abundance of Atlantic sturgeon by gear and season taken as bycatch in various fisheries.
3. Determine the extent to which Atlantic sturgeon are genetically differentiable among rivers.
4. Develop methods to determine sex and maturity of captured sturgeon.
5. Research should be conducted to determine the susceptibility of Atlantic sturgeon to sturgeon adenovirus and white sturgeon iridovirus. Methods should be developed to isolate the sturgeon adenovirus and an Atlantic sturgeon cell line should be established for infection trials.
6. Develop sperm cryo-preservation techniques and refine to assure availability of male gametes. Refine induced spawning procedures.
7. Encourage shortnose sturgeon researchers to include Atlantic sturgeon research in their projects.
8. Develop and implement long-term marking/tagging procedures to provide information on individual tagged Atlantic sturgeon for up to 20 years.

9. Evaluate aging techniques for Atlantic sturgeon with known age fish. Emphasis should be placed on verifying current methodology based on fin rays. Determine length, fecundity, and maturity at age for North, Mid and South Atlantic stocks.
10. Conduct basic cultural experiments to provide information on: a) efficacy of alternative spawning techniques, b) egg incubation and fry production techniques, c) holding and rearing densities, d) prophylactic treatments, e) nutritional requirements and feeding techniques, and f) optimal environmental rearing conditions and systems.
11. Establish stocking goals and success criteria prior to development of stock enhancement or recovery programs.
12. Conduct research to identify suitable fish sizes, and time of year for stocking cultured fish.
13. Conduct and monitor pilot-scale-stocking programs before conducting large-scale efforts over broad geographic areas.
14. Identify rates of tag loss and tag reporting.
15. Evaluate existing sea sampling data to characterize at-sea migratory behavior.
16. Establish tolerance of different life stages to important contaminants and levels of such environmental factors such as DO, pH, and temperature.
17. Standardize collection procedures and develop suitable long-term repository for biological tissues for use in genetic and other studies.
18. Develop the capability to capture wild broodstock and develop adequate holding and transport techniques for large broodstock.
19. Research should be conducted to identify the major pathogens of Atlantic sturgeon and a cell line for this species should be developed.
20. Conduct a cost benefit analysis of various stocking protocols.
21. Conduct further analyses to assess the sensitivity of F50 to model inputs.

Research Needs Identified As Being Met:
Establish a tag recovery clearinghouse and database for consolidation and evaluation of tagging and tag return information including associated biological, geographic, and hydrographic data.

Black Sea Bass
High Priority

- Sampling should be increased for commercial landing in black sea bass fisheries, specifically the fish pot fisheries in the Mid-Atlantic. Age sampling should be increased across all components of the commercial fishery.
- Sampling should be increased in the recreational fisheries. Age data should be collected from the total catch, and length sampling should be done to characterize size structure of discards.
- Develop fishery independent surveys and expand existing surveys to capture all sizes and age classes in order to develop independent catch-at-age and CPUE.
- Investigate the effect of sex transition rates, sex ratio and differential natural mortality by sex on the calculation of spawning stock biomass per recruit and eggs per recruit. Also, investigate the impact on reproduction of removal of large males from the population.
- Studies on sex-specific mortality rates and growth are needed.
- Increase sea sampling to verify information from commercial logbooks to provide better estimates of discards.
- A tagging program should be initiated through state fisheries agencies to estimate mortality independent of traditional methods.
- Further delineation of essential fish habitat (EFH), particularly in nursery areas. Further investigation of possible gear impacts on EFH.

Medium Priority

- Explore alternative assessment models, including non-age based alternatives.
- Consideration should be given to a pot survey for an index of abundance.
- Identify transport mechanisms or behaviors that move early juvenile black sea bass into estuaries.
- Evaluate habitat use by overwintering yearling, young-of-the-year, and adult black sea bass.
- Evaluate food habits of black sea bass larvae and overwintering adults.

Low Priority

1. Develop mariculture techniques.
2. A study determining the value of artificial reefs for increased production of black sea bass would be valuable in estimating potential yield.

Bluefish

1. Data needs:
   a) Sampling of size and age composition of the fisheries by gear type and statistical area should be increased.
   b) Commercial and recreational landings of bluefish should be targeted for biological data collection wherever possible.
   c) Increase intensity of biological sampling of the NER commercial and coastwide recreational fisheries.
2. Continue research on species interactions and predator/prey relationships. A scale-otolith age comparison study needs to be completed for bluefish.
3. Explore alternative methods for assessing bluefish, such as length-based and modified DeLury models.
4. Measures of CPUE under different assumptions of effective effort should be evaluated to allow evaluation of sensitivity of results.
5. Initiate fisheries dependent and independent sampling of offshore populations of bluefish during winter months.
6. Conduct research to determine the timing of sexual maturity and fecundity of bluefish.
7. Work should continue on catch and release mortality.
8. Any archived age data for bluefish should be aged and used to supplement North Carolina DMF keys in future assessments.
9. Conduct research on oceanographic influences on bluefish recruitment, including information on migratory pathways of larval bluefish.
10. Study tag mortality and retention rates for the American Littoral Society dorsal loop and other tags used for bluefish.
11. A coastal surf-zone seine study needs to be initiated to provide more complete indices of juvenile abundance.
12. Test the sensitivity of the bluefish assessment to assumptions concerning age-varying M, levels of age 0 discard, and the selection pattern.
13. Increase sampling frequencies when bluefish are encountered, especially when medium size fish are encountered.
14. Scientific investigations should be conducted on bluefish to develop an understanding of the long term, synergistic effects of combinations of environmental variables on various biological and sociological parameters such as reproductive capability, genetic changes, and suitability for human consumption.
15. Studies on the interactive effects of pH, contaminants, and other environmental variables on survival of bluefish.

16. Investigate the relationship of epidemic dermatological disease of bluefish exhibited in the Tar-Pamlico estuary to environmental toxics or other parameters.
17. Investigate the distribution of adult bluefish (particularly the spring-spawned cohort) in the South Atlantic Bight and juvenile bluefish (including the pelagic stage); and develop precise information on the distribution and relative abundance of bluefish in inshore areas, especially estuaries and embayments.

Below from the NEFSC EFH Source Document on Bluefish (2006).

We lack information on the reproductive biology of bluefish. Observed patterns of spawning may be based on the population level rather than on information on individual reproductive traits. We presently do not know whether individuals spawn serially, and if so, how many times they are capable of spawning in a year. We also do not know if these reproductive characteristics vary with age. It is apparent that more study of the distribution of older stages needs to be correlated with spawning events. Since bluefish school in like-sized (and supposedly like-aged) groups, we need to know what groups are where and when, and how those aggregations are associated with the observed densities of eggs. Simply describing how many spawning events are occurring can not solve the issue of the number of manageable stocks.
Our understanding of the "pelagic-juvenile" stage is limited despite its obvious importance. We need to better understand the details of transport mechanisms that provide progeny of reproduction in the South Atlantic Bight (SAB) to nurseries in the Middle Atlantic Bight (MAB). Increased sampling of the neuston or near-surface layers of the ocean between production areas and estuarine nursery areas, associated with appropriate oceanographic observations, would provide much-needed insight into factors affecting transport and estuarine recruitment.

There has been a tight correlation between population size and the contribution of the spring spawned cohort to fall trawl collections in the last three decades. Yet our knowledge of reproduction in the SAB is limited to a brief, under-sampled period in the 1970s when the population was at a relatively low level of abundance. Furthermore, larvae produced in June in the southern part of the MAB appear not to survive [unless recruits to Maine estuaries result from this output, see Creaser and Perkins (1994)], the fate of the remaining MAB summer offspring remains enigmatic.

There is some evidence for spawning during the fall in the Cape Canaveral region of Florida that appears to be discrete, rather than a continuation of spawning in the MAB. This evidence has been demonstrated in this document with larval occurrences and a disjunct autumn distribution of fish between 26 and 40 cm. Hare and Cowen (1993) present gonadosomatic data that suggest the same thing. Admittedly, some of this evidence is weak and based on incomplete sampling, and should be improved to determine the origin of these spawning fish, the magnitude of spawning, and the fate of any progeny.

Horseshoe Crab

High Priority

Evaluate the effectiveness of currently used benthic sampling gear for stock assessment.

Medium Priority

1. Investigate larval and juvenile survival and mortality to assist in the assessment of annual recruitment.
2. Further evaluate life table information including sex ratio and population age structure.
3. Evaluate the effect of mosquito control chemicals on horseshoe crab populations.

4. Determine beach fidelity by horseshoe crabs to determine habitat use.
5. Evaluate the impacts of beach nourishment projects on horseshoe crab populations.
6. Evaluate the importance of horseshoe crabs to other marine resources such as sea turtles.
7. Estimate the proportion of sub-tidal spawning and determine if this effects spawning success (i.e. egg survivability).
8. Develop a young-of-year or age 1 recruitment index from the Delaware 16-foot trawl survey.
9. Conduct tagging studies (mark-recapture) to determine the incidence of repeated spawning and dispersal parameters.

<u>Low Priority</u>

10. Estimate fishing discard numbers and associated mortality rates.
11. Conduct additional stock assessments and determine harvest mortality rates (F). Use these data to develop a more reliable sustainable harvest rate.
12. Develop biological reference points (such as natural mortality rates, growth rates, fecundity, etc.).

Spanish Mackerel (from the 2006 ASMFC FMP review)

<u>High Priority</u>

- Length, sex, age, and CPUE data are needed for improved stock assessment accuracy. Simulations on CPUE trends should be explored and impacts on VPA and assessment results determined. Data collection is needed for all states, particularly those north of North Carolina.
- Evaluation of weight and especially length at age of Spanish mackerel.
- Development of fishery-independent methods to monitor stock size of Atlantic Spanish mackerel (consider aerial surveys used in south Florida waters).
- More timely reporting of mid-Atlantic catches for quota monitoring.
- Provide better estimates of recruitment, natural mortality rates, fishing mortality rates, and standing stock. Specific information should include an estimate of total amount caught and distribution of catch by area, season, and type of gear.
- Develop methodology for predicting year class strength and determination of the relationship between larval abundance and subsequent year class strength.
- Commission and member states should support and provide the identified data and input needed to improve the SAFMC's SEDAR process.
- The full implementation of ecosystem-based management and the implementation of monitoring /research efforts needed to support ecosystem-based management needs should be conducted.

<u>Medium Priority</u>

- Yield per recruit analyses should be conducted relative to alternative selective fishing patterns.
- Determine the bycatch of Spanish mackerel in the directed shrimp fishery in Atlantic Coastal waters (partially met: Branstetter, 1997; Ottley et al., 1998; Gaddis et al., 2001; Page et al., 2004).
- Evaluate potential bias of the lack of appropriate stratification of the data used to generate age-length keys for Atlantic and Gulf Spanish mackerel.
- Evaluate CPUE indices related to standardization methods and management history, with emphasis on greater temporal and spatial resolution in estimates of CPUE.
- Consideration of MRFSS add-ons or other mechanisms for collection of socioeconomic data for recreational and commercial fisheries.

- Determine normal Spanish mackerel migration routes and changes therein, as well as the climatic or other factors responsible for changes in the environmental and habitat conditions which may affect the habitat and availability of stocks.
- Determine the relationship, if any, between migration of prey species (i.e., engraulids, clupeids, carangids), and migration patterns of the Spanish mackerel stock.

<u>Low Priority</u>

- Final identification of Spanish mackerel stocks through multiple research techniques.
- Complete research on the application of assessment and management models relative to dynamic species such as Spanish mackerel.
- Delineation of spawning areas and areas of larval abundance through temporal and spatial sampling.

Red Drum

1. Support fishery-independent sampling of sub-adult and adult red drum in each state from North Carolina to Florida. The purpose of this survey would be to: 1) verify escapement to the spawning population, 2) provide an index of recruitment to age 1, and 3) provide an estimate of the biomass of adult red drum.
2. Develop a more reliable estimate of natural and fishing mortality through directed sampling of the adult population.
3. Determine habitat preferences, environmental conditions, growth rates, and food habits of larval and juvenile red drum throughout the species range along the Atlantic coast. Assess the effects of environmental factors on stock density.
4. Identify spawning areas of red drum in each state from North Carolina to Florida so these areas may be protected from degradation and/or destruction. Determine the impacts of dredging and beach re-nourishment on red drum spawning and early life history stages.
5. Continue tagging studies to determine stock identity, inshore/offshore migration patterns and mortality estimation.
6. Determine the survival rate of red drum following regulatory and voluntary discard from commercial and recreational gear, including recreational net fisheries. Evaluate effects of water temperature and depth of capture.
7. Improve catch/effort estimates and biological sampling from recreational and commercial fisheries for red drum, including increased efforts to intercept night-time fisheries for red drum by the NMFS MRFSS. Characterize magnitude of commercial and recreational discards.
8. States with significant fisheries should be encouraged to collect socio-economic data on red drum fisheries through add-ons to the MRFSS or by other means so as to determine the economic value of the Atlantic coast recreational red drum fishery.
9. Quantify relationships between red drum production and habitat.
10. Investigate and evaluate new stock assessment techniques as alternatives to age-structured models. Conduct yield modeling on red drum.
11. Investigate the concept of estuarine reserves to increase the escapement rate of red drum along the Atlantic coast.
12. Fully evaluate the efficacy of using cultured red drum to restore native stocks along the Atlantic coast, including cost-benefit analyses.
13. Identify the effects of water quality degradation on the survival of red drum eggs, post-larvae, larvae, and juveniles.
14. Refine maturity schedules on a geographic basis, determine relationships between annual egg production over a range of sizes, ages and across latitude.

15. Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production.
16. Document and characterize schooling behavior for Atlantic coast red drum.

(from 2006 ASMFC review of Red Drum FMP)
Prioritized Research & Monitoring Recommendations (H)=High, (M)=Medium, (L)=Low
Stock Assessment and Population Dynamics

- Design an appropriate state fishery-independent survey of sub-adult and adult red drum to be implemented in Virginia, North Carolina, South Carolina, Georgia, and Florida. (H) (in progress for sub-adult and adult surveys).
- Each state should develop an on-going red drum tagging program that can be used to estimate both fishing and natural mortality and movements. This should include concurrent evaluations of tag retention, tagging mortality, and angler tag reporting rates. (M)
- Improve catch/effort estimates and biological sampling from recreational and commercial fisheries for red drum, including increased effort to intercept night fisheries for red drum. This should include significant efforts to determine the size and age structure of regulatory discards of live red drum. (H)
- States should maintain annual age-length keys. (H)
- Determine the chronic mortality rate of red drum following regulatory and voluntary discard from commercial and recreational fishing gear, including recreational net fisheries. Evaluate effects of water temperature and depth of capture. (M)
- Evaluate alternatives to VPA for red drum stock assessment. (M)

Biological

- Fully evaluate the effects and effectiveness of using cultured red drum to restore native stocks along the Atlantic coast. (H)
- Explore methods to effectively sample the adult population in estuarine, nearshore, and open ocean waters. (H)
- Continue tagging studies to determine stock identity, inshore/offshore migration patterns of all life stages (i.e. basic life history info gathering). Specific effort should be given to developing a large-scale program for tagging adult red drum (M) (in progress)
- Determine habitat preferences, environmental conditions, growth rates, and food habits of larval and juvenile red drum throughout the species range along the Atlantic coast. Assess the effects of environmental factors on stock density/yearclass strength. (M)
- Refine maturity schedules on a geographic basis. Thoroughly examine the influence of size and age on reproductive function. Investigate the possibility of senescence in female red drum. (L)

Social

- Examine the effectiveness of controlling fishing mortality and minimum size in managing red drum fisheries.
- Encourage the NMFS to conduct socioeconomic add-on surveys via the MRFSS that are specifically oriented to red drum recreational fishing (Example: the 2000 Northeast Summer Flounder Survey).

Economic

- Encourage the NMFS to continue funding socioeconomic add-on surveys via the MRFSS that include data elements germane to red drum recreational fisheries management.

- Where appropriate, encourage member states to conduct studies to evaluate the economic costs and benefits associated with current and future regulatory regimes impacting recreational anglers including anglers oriented toward catch and release fishing trips.
- Fully evaluate the efficacy of using cultured red drum to restore native stocks along the Atlantic Coast including risk adjusted cost-benefit analyses.
- Conduct a special survey and related data analysis to determine the economic and operational characteristics of the "for-hire sector" targeting red drum especially fishing guide oriented businesses in the South Atlantic states.
- Estimate the economic impacts (e.g. sales, jobs, income, etc.) of recreational red drum fisheries at the state and regional level including the "for-hire sector" (e.g. fishing guides).
- Encourage the NMFS to continue funding research on projecting future participation in marine recreational fishing in the Atlantic states with an emphasis on forecasts for major fisheries such as red drum.
- States with significant fisheries (over 5,000 pounds recorded by MRFSS) should collect socioeconomic data on red drum fisheries through add-ons to the MRFSS or by other means.

Habitat

- Identify spawning areas of red drum in each state from North Carolina to Florida so these areas may be protected from degradation and/or destruction. (H) (In progress, NC State University)
- Identify changes in freshwater inflow on red drum nursery habitats. Quantify the relationship between freshwater inflows and red drum nursery/sub-adult habitats. (H)
- Determine the impacts of dredging and beach re-nourishment on red drum spawning and early life history stages. (M)
- Investigate the concept of estuarine reserves to increase the escapement rate of red drum along the Atlantic coast. (M)
- Identify the effects of water quality degradation (changes in salinity, DO, turbidity, etc.) on the survival of red drum eggs, larvae, post-larvae, and juveniles. (M)
- Quantify relationships between red drum production and habitat. (L)
- Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production. (L)

Spot

<u>High Priority</u>

- In trawl fisheries or other fisheries that take significant numbers of spot, states should monitor and report on the extent of unutilized bycatch and fishing mortality on fish less than age-1. Incorporate bycatch estimates into spot assessment models.
- The effects of mandated bycatch reduction devices (BRD's) on spot catch should be evaluated in those states with significant commercial harvests.
- Fishery dependent and independent size and sex specific relative abundance estimates should be developed.
- Cooperative coastwide spot juvenile indices should be developed to clarify stock status.
- Monitor long term changes in spot abundance, growth rates, and age structure.
- Continue monitoring of juvenile spot populations in major nursery areas.
- Improve spot catch and effort statistics from the commercial and recreational fisheries, along with size and age structure of the catch, in order to develop production models.

- Criteria should be cooperatively developed for aging spot otoliths and scales, and an age validation study should be conducted.

Medium Priority
- A yield per recruit analysis should be cooperatively developed.
- Develop stock identification methods.
- Determine migratory patterns through tagging studies.
- Determine the onshore vs. offshore components of the spot fishery.

Summer Flounder
High Priority
- Monitor abundance of juvenile summer flounder on a yearly basis.
- The NEFSC domestic sea sampling program should continue the collection of data for summer flounder, with special emphasis on a) improved areal and temporal coverage, b) adequate length and age sampling, and c) continued sampling after commercial fishery areal and seasonal quotas are reached and fisheries are limited or closed.
- Encourage research to determine the length and age frequency and discard mortality rates of commercial and recreational fishery summer flounder discards.
- Investigate the source of bias in estimating terminal parameters of the VPA (fishing mortality and stock size). Partially addressed in SARC 25 assessment.
- Undertake research to determine hooking mortality on summer flounder by circle, kahle, and regular “J” hooks and make the results of work already completed available to the Management Board.
- Develop fishery independent surveys and expand existing surveys to capture all sizes and age classes in order to develop independent catch-at-age and CPUE.
- Further delineation of essential fish habitat (EFH) particularly in nursery areas. Further investigation of possible gear impacts on EFH.
- Collect and analyze age/length samples and catch/effort data from the commercial and recreational fisheries throughout the range of summer flounder.

Medium Priority
- Develop a consistent and accurate sampling program to determine the mesh selectivity for summer flounder and other commercial fisheries taken in mixed fisheries, and to determine discard mortality.
- Conduct a detailed socio-economic study of the summer flounder fisheries.
- Research directed at evaluating the mesh exemption program should be continued, with increased sample sizes to allow reliable statistical testing of results.
- Continue research to determine if the maturity ogive accurately reflects spawning potential of summer flounder.
- Investigate allocation of NEFSC sea sampling trips to optimize sampling effort.
- Develop stock identification methods via meristics, morphometrics, biochemical research and tagging; particularly off Virginia and North Carolina.
- Develop fish excluder devices to reduce bycatch of immature flatfish in fisheries that target species other than flounder.

Low Priority
- Develop a standardized index of abundance from NEFSC sea sampling data to provide a commercial fishery index that accounts for all removals by the fishery.

- Investigate the utility of alternative strata sets for the NEFSC spring trawl survey time series for summer flounder.
- Develop information on optimum length/age at capture and optimum mesh size.
- Conduct the basic research necessary to develop land and pen culture techniques.
- Evaluate effects of dissolved oxygen and water current requirements for adult summer flounder and summer flounder eggs.
- Evaluate the relationship between recruitment of summer flounder to nursery areas and Ekman transport or prevailing directions of water flow.

Weakfish

High Priority

- Collect catch and effort data including size and age composition of the catch, determine stock mortality throughout the range, and define gear characteristics. In particular, increase length-frequency sampling, particularly in fisheries from Maryland and further north.
- Develop latitudinal / seasonal / gear specific age length keys for the Atlantic coast. Increase sample sizes to consider gear specific keys.
- Derive estimates of discard mortality rates and the magnitude of discards for all commercial gear types from both directed and non-directed fisheries. In particular, quantify trawl bycatch, refine estimates of mortality for below minimum size fish, and focus on factors such as distance from shore and geographical differences. Update the scale – otolith comparison for weakfish.

Medium Priority

- Define reproductive biology of weakfish, including size at sexual maturity, maturity schedules, fecundity, and spawning periodicity. Continue research on female spawning patterns: what is the seasonal and geographical extent of "batch" spawning; do females exhibit spawning site fidelity?
- Conduct hydrophonic studies to delineate weakfish spawning habitat locations and environmental preferences (temperature, depth, substrate, etc.) and enable quantification of spawning habitat.
- Compile existing data on larval and juvenile distribution from existing databases in order to obtain preliminary indications of spawning and nursery habitat location and extent.
- Continue studies on mesh-size selectivity; up-to-date (1995) information is available only for North Carolina's gill net fishery. Mesh-size selectivity studies for trawl fisheries are particularly sparse.
- Assemble socio-demographic-economic data as it becomes available from ACCSP.
- Additional investigation is needed in developing consistent otolith-based catch matrices including the EM algorithm.
- The impact of aging errors and other statistical uncertainties in the catch-at-age matrix on virtual population analysis (VPA) should be included. Retrospective analyses are needed on all VPA approaches investigated.
- Develop a spawner recruit relationship and examine the relationships between parental stock size and environmental factors on year-class strength.

Low Priority

- Identify stocks and determine coastal movements and the extent of stock mixing, including characterization of stocks in overwintering grounds. (e.g. tagging).

- Biological studies should be conducted to better understand migratory aspects and how this relates to observed trends in weight at age.
- Continue studies on recreational hook-and-release mortality rates, including factors such as depth, warmer water temperatures, and fish size in the analysis. Further consideration of release mortality in both the recreational and commercial fisheries is needed, and methods investigated to improve survival among released fish.
- Document the impact of power plants and other water intakes on larval, post larval and juvenile weakfish mortality in spawning and nursery areas, and calculate the resultant impact to adult sock size.
- Define restrictions necessary for implementation of projects in spawning and overwintering areas and develop policies on limiting development projects seasonally or spatially.
- Determine the onshore versus offshore components of the weakfish fishery.
- Develop a coastwide tagging database.
- Develop a spawner recruit relationship and examine the relationships between parental stock size and environmental factors on year-class strength.

Research Needs Identified as Being Met:

- Study the north-south gradient in weakfish growth rates.

  The study of the north-south gradient in weakfish growth rates is partially being addressed by Charlie Wenner, SC, through a MARFIN grant.
- Monitor long-term changes in abundance, growth rates, and age structure.

9.1.4 Recent and Ongoing Research on HMS Species

(Source: 2006 Consolidated HMS FMP)

Atlantic Bluefin Tuna

As part of its commitment to the Bluefin Program, research supported by the United States has concentrated on ichthyoplankton sampling, reproductive biology, and methods to evaluate hypotheses about movement patterns, spawning area fidelity, stock structure investigations and population modeling analyses.

Ichthyoplankton surveys in the Gulf of Mexico during the bluefin spawning season were continued in 2004 and 2005. Data resulting from these surveys, which began in 1977, are used to develop a fishery-independent abundance index of spawning West Atlantic bluefin tuna. This index has continued to provide one measure of bluefin abundance that is used in ICCAT's SCRS assessments of the status of the resource. During the 2004 U.S. ichthyoplankton survey, a plankton net of a type used in the Spanish surveys was fished in addition to the nets normally used to determine the impact of using a wider net mouth and larger mesh on the size and catch rates of bluefin in the Gulf of Mexico. The results of this work will be reported as they become available. U.S. scientists also collaborated in development of the larval working group agenda for the Climate Impacts on Oceanic Top Predators (CLIOTOP) program managed by GLOBEC (Global Ocean Ecosystem Dynamics) initiated by SCOR and the IOC of UNESCO in 1991.

Since 1998, researchers from Texas A & M University and the University of Maryland with assistance of researchers from Canada, Europe, and Japan have studied the feasibility of using otolith chemical composition (microconstituents and isotopes) to distinguish bluefin stocks.

Recent research has investigated the value of using additional microconstituent elements (transitional metals) to enhance classification success. By themselves the transitional metals provided little discriminatory power, but when combined with the other trace elements (for 13 elements in all), the classification success for several year-classes has been moderate ranging from 60 – 90 percent, and classification functions show strong year-to-year variability. In SCRS/2005/083 the utility of an alternative chemical marker in otoliths, carbon and oxygen stable isotopes, to discriminate bluefin tuna from natal regions were reported upon. The discriminatory power of stable isotopes (δ13C, δ18O) in otoliths of yearlings (age-1) was high, with 91 percent of individuals classified correctly to eastern and western nurseries. These stable isotopes and in particular δ18O can be used to reliably predict nursery origin of Atlantic bluefin tuna. An initial application compared otolith core material (corresponding to the first year of life) of large school, medium, and giant category bluefin tuna to reference samples of yearling signatures to determine their origin. A large fraction (~43 – 64 percent) of the Atlantic bluefin tuna collected in the western Atlantic fishery (comprised primarily of large school and medium category fish) originated from nurseries in the east. Alternatively, medium and giant category
bluefin tuna from the Mediterranean were largely (~82 – 86 percent) of eastern origin.
Thus, initial evidence suggests that the western fishery received high input from the Mediterranean population. (See generally SCRS/2003/105, and Rooker et al 2001a, 2001b and 2003).

Scientists from the University of Maryland, Virginia Institute of Marine Science, and Texas A&M University have continued to sample specimens for genetic and otolith chemistry studies of stock structure. Roughly 10 – 20 young of the year were collected in 2004. In addition, limited sampling of ages 1 and older continues. Efforts are also continuing to obtain samples from juveniles and mature bluefin from the Mediterranean Sea and adjacent waters.

In response to the ICCAT Commission's request for options for alternative approaches for managing mixed populations of Atlantic bluefin tuna, SCRS/2005/108 further examined some implications of incorporating electronic tagging information on transfer rates into virtual population analyses. SCRS/2005/084 examined yield and spawner per recruit consequences of different assumed levels of mixing between eastern and western bluefin stocks to provide guidance to the Commission as requested at the 3rd Meeting of Working Group to Develop Coordinated and Integrated Bluefin Tuna Management Strategies. Researchers at the Imperial College, London, continue work with the University of Miami, the University of New Hampshire and the National Marine Fisheries Service to develop methods to estimate bluefin movement and fishing mortality rate patterns (SCRS/2005/048). Operating models are being developed which will use conventional and electronic tagging data and fishing effort by management area. These models will be used to examine possible harvest control rules and the evaluation of possible management procedures.

U.S. scientists from Stanford and Duke University along with the Monterey Bay Aquarium and NMFS have placed over 700 electronic tags in bluefin tuna in the region along the U.S. coast of North Carolina. The data from implantable archival tags has been critical for establishing the basic biology of Atlantic bluefin and the patterns of movements to feeding and breeding grounds. Results from a large number of these tags were interpreted in a paper in the journal Nature in 2005 (Block et al. 2005). Tagging off the Carolinas, in the Gulf of Maine, and elsewhere continued in 2004 and 2005 and more than 90 tags were placed in fish off the Carolinas in 2005. The tags are due to report 7 – 9 months from the deployment dates and will be further reported upon as results become available.

U.S. scientists from the University of New Hampshire have placed over 200 pop-up satellite archival tags on New England bluefin tuna. Ongoing efforts include examining short and long-term dispersals of bluefin in the Gulf of Maine, the identification of spawning grounds, the spatial correlation between bluefin locations and oceanographic features and continuing to determine Atlantic-wide migratory paths. Results from much of this tagging effort were recently published in the journal Marine Biology (Wilson, et.al. 2005).

A new research initiative in 2005 involving scientists from the University of New Hampshire, the Virginia Institute of Marine Science, and Virginia SeaGrant will place electronic tags on juvenile bluefin from off the U.S. coast of Virginia. As results become available, they will be reported upon.

A recent publication by Fromentin and Powers (2005), titled "Atlantic bluefin tuna: population dynamics, ecology, fisheries and management" provides an extensive summary of old and new information on the biology and ecology of Atlantic bluefin tuna and associated fishery management implications. The abstract reads as follows:

> *Both old and new information on the biology and ecology of Atlantic bluefin tuna have confronted scientists with research challenges: research needs to be connected to current stock-assessment and management issues. We review recent studies on habitat, migrations and population structure, stressing the importance of electronic tagging results in the modification of our perception of bluefin tuna population dynamics and behavior. Additionally, we question, from both scientific and management perspectives, the usefulness of the classical stock concept and suggest other approaches, such as Clark's contingent and metapopulation theories. Current biological information confirms that a substantial amount of uncertainty still exists in the understanding of reproduction and growth. In particular, we focus on intriguing issues such as the difference in age-at-maturity between West Atlantic and Mediterranean bluefin tuna. Our description of Atlantic bluefin tuna fisheries places today's fishing patterns within the two millennium history of exploitation of this species: we discuss trap fisheries that existed between the 17th and the early 20th centuries; Atlantic fisheries during the 1950s and 1960s; and the consequences of the recent development of the sushi–sashimi market. Finally, we evaluate stock status and management issues since the early 1970s. While important uncertainties remain, when the fisheries history is confronted with evidence from biological and stock-assessment studies, results indicate that Atlantic bluefin tuna has been undergoing heavy overfishing for a decade. We conclude that the current exploitation of bluefin tuna has many biological and economic traits that have led several fish stocks to extreme depletion in the past.*

In 1982, ICCAT established a line separating the eastern and western Atlantic management units based on discontinuities in the distribution of catches at that time in the Atlantic and supported by limited biological knowledge. The United States is allocated quota from the western Atlantic management unit where the U.S. fisheries primarily occur. However, the overall distribution of the catch in the 1990s is much more continuous across the North Atlantic than was seen in previous decades. Tagging evidence indicates that movement of bluefin across the current east/west management boundary in the Atlantic does occur, that movements can be extensive (including trans-atlantic) and complex, that there are areas of concentration of electronically tagged fish (released in the west) in the central North Atlantic just east of the management boundary, and that fisheries for bluefin tuna have developed in this area in the last decade. At least some of these fish have moved from west of the current boundary.

Complementary studies, which might show east to west movement, are less advanced.
The composition and natal origin of these fish in the central North Atlantic area are not known. The SCRS emphasizes that "it is clear that the current boundary does not depict our present understanding of the biological distribution and biological stock structure of Atlantic bluefin tuna." The SCRS also notes that "the current boundary is a management boundary and its effectiveness for management is a different issue."
There has been an accumulation of evidence on bluefin tuna mixing in the last few years through the collection of tagging data and its examination through the modeling of mixing scenarios for evaluating their effect on management. However, the origin of fish older than one year still remains unknown. Mixing results were reviewed in 2001 by the Workshop on Bluefin Tuna Mixing. This research led to a long-term plan for modeling finer scale spatial mixing and to short-term strategies for assessment to assist the advice for management. The data and research were reviewed again in 2002.

ICCAT, at its 2002 Meeting in Bilbao, called for a Working Group to Develop Integrated and Coordinated Atlantic Bluefin Tuna Management Strategies, which met in 2003 and again in 2004. In response to the recommendations from these meetings, the SCRS is developing a revised proposal for initiating a coordinated Bluefin Tuna Research Program to address priority research and data needs for providing scientific advice to ICCAT related to revised management procedures for bluefin tuna. Uncertainty exists regarding the importance and impacts of mixing on western stocks. The most important uncertainty regarding management advice by the SCRS for the eastern stock is the uncertainty in the catch data that are being taken.

More than 20 scientific documents related to bluefin tuna biology were presented to the 2005 SCRS. Many of the contributions dealt with the important issue of stock structure and mixing, and new information is available for both stocks. In particular, studies of otolith microchemistry and genetics have resulted in advances in our understanding of this component of the biology of bluefin tuna. These results continue to advance our knowledge about the overlapping distribution of fish originating from the east and the west. Therefore, the SCRS continues to question present hypotheses on stock identification. While these results are promising, more complete sampling and development of appropriate analytical approaches are required. The SCRS also received contributions relating to age and growth, sampling, parasitology and condition of bluefin tuna.

Atlantic Bigeye Tuna

In addition to monitoring catch and effort statistics for tropical tunas that include bigeye tuna, United States scientists participated in the 2005 ICCAT Workshop on Methods to Reduce Mortality of Juvenile Tropical Tunas, held in Madrid from 4 – 8 July, 2005. Document SCRS/2005/063 used the ICCAT Task 2 catch and effort data to estimate expected changes in the catches of tropical tunas attributable to replacing the current moratorium with a time-area closure (Recommendation 04-01). The results indicate that catches of tropical tunas are expected to increase substantially if the time-area closure replaces the current moratorium. Considering that the current ICCAT hypothesis is that purse-seine fleet efficiency gains three percent per year, the net change could in fact be a large overall increase to levels above the pre-moratoria fishing mortality rate levels. SCRS/2005/079 explored the expectations for catches of undersized bigeye tuna considering the agreement reached in Recommendation 04-01. In all cases examined, total catches can be expected to increase from 5.5 to 6.7 percent as a result of Recommendation 04-01, and catches of bigeye tuna can be expected to increase from 16 to 22.1 percent. In all cases, catch of juvenile bigeye tuna increases.

U.S. scientists from the University of Miami's Rosenstiel School of Marine and Atmospheric Science continue to collaborate with EC scientists on the EU-funded assessment and management modeling project titled Framework for the Evaluation of Management Strategies (FEMS) project, on management strategy evaluations related to tropical tuna fisheries.

Atlantic Yellowfin Tuna

In addition to the United States research findings for tropical tunas discussed above under bigeye tuna, one document was presented to the SCRS in 2005 that gave an overview of fishery trends and stock status for yellowfin tuna worldwide. It was noted that the natural mortality vector used by ICCAT in the Atlantic, while the same as that used by the IOTC for the Indian Ocean, is lower than is used by other scientific bodies for other oceans, particularly for the youngest ages. It was further noted that more recent information and methodologies may be available to potentially improve the estimates of natural mortality. Another document considered the estimation of natural mortality from multi-species tagging data. Due to limitations in the data (such as unbalanced design and different size distributions of released fish) and potential fishing differences between fleets, conclusions were limited to ratios of total mortality between fishing periods rather than any direct statement about natural mortality.

Considering the importance of natural mortality estimates in the assessment of the stock, the improvement of natural mortality estimates remains a high research priority. It was noted that future stock assessments should include an evaluation of the sensitivity of results to the uncertainty in natural mortality estimates. Differences were also noted for other biological parameters used by the various scientific bodies, such as growth and maturity vectors, the extent to which these differences reflect estimation methodology, data quality, or real differences between stocks warrants investigation.

Atlantic Albacore Tuna

U.S. scientists prepared document SCRS/2005/081 which described population models for North Pacific albacore (*Thunnus alalunga*) that have been developed and reviewed within the North Pacific Albacore Workshop (NPALBW) forum since 2000. Currently, the NPALBW relies on a Virtual Population Analysis (VPA) model for the purposes of formulating an international-based consensus regarding the "status" of this fish stock. Recently, an equally important research directive from the NPALBW has been to develop alternative, more detailed statistical-based models, in efforts to evaluate more fully the relationship between this species' population dynamics and associated fishery operations (i.e., areas of uncertainty in an overall stock assessment). Participants on the NPALBW developed one candidate model based on the Age-structured Assessment Program (ASAP), which generally represents a maximum likelihood-based numerical approach for conducting relatively straightforward, forward-simulation catch-at-age analyses. In addition, the document presents a brief discussion concerning development of other alternative stock assessment models, particularly length-based/age-structured platforms (e.g., MULTIFAN-CL and Stock Synthesis 2).

Atlantic Skipjack Tuna

U.S. small tuna research is directed mainly on king and Spanish mackerel stocks, as the amount landed of other small tunas such by U.S. fishermen is generally low. The focus of research on skipjack research by the international scientific community is on basic stock structure and abundance and the influence of FADs on increase in efficiency of the various fleets.

During the ICCAT Workshop on Methods to Reduce Mortality of Juvenile Tropical Tunas in July 2005 (Document SCI-032), a re-analysis on the tagging data in the Senegalese area showed however that the parameters of the skipjack growth curve obtained in this region were in fact closer to the growth estimates made in the Gulf of Guinea or in other oceans than those done previously in Senegal. In 2004 and 2005, U.S. scientists collaborated with Caribbean nations under the banner of the Caribbean Regional Fisheries Mechanism in initiating stock assessment analyses for small tuna (and other) stocks of mutual concern.

Swordfish

In 2005, data from observer samples were compared against self-reported information from the U.S. large pelagic mandatory logbook reporting system, and estimates of discard mortality of swordfish, billfish, sharks and other species from the U.S. fleet were developed from that analysis for the 2005 SCRS. Estimates of small swordfish bycatch for 2002 – 2004 were compared to the average levels estimated for the late 1990's and were found to be substantially lower. Reported and observed swordfish catches, and size and catch rate patterns through 2004 were examined in support of monitoring the recovery of north Atlantic swordfish. Standardized indices of abundance were updated for the Western North Atlantic using data from the U.S. pelagic longline fleet (SCRS/2005/085). Collaborative research between various ICCAT nations and Venezuelan scientists continues on estimating the age-structure of the catch of swordfish.
Results of this research will be available for the next assessment of north Atlantic swordfish.

Scientists from the United States collaborated with Brazilian scientists to improve catch rate standardization procedures by offering a course on the topic in Brazil in mid-2005. Central to this collaboration is development of fisheries research capacity in Brazil through graduate student training and of stronger scientific cooperation between Brazil and the United States.

Research on measures to mitigate the interactions between pelagic longline and bycatch of marine turtles continued under a cooperative research program involving the U.S. Atlantic pelagic longline fishery. The Northeast Distant Fishery Experiment was conducted from 2001 through 2003 on the high seas of the Western Atlantic Ocean, in an area off Newfoundland known as the Grand Banks. Results of this research which was focused on reducing mortality of marine turtles interacting with pelagic longlines was recently published (Watson et. al. 2005. Fishing methods to reduce sea turtle mortality associated with pelagic longlines. Can. J. Fish. Aquat. Sci. 62(5): 965-981). Additional cooperative research in the Gulf of Mexico was carried out in 2004 and in additional regions in 2005.

Atlantic Billfish

The NMFS SEFSC played a substantial role in the ICCAT Enhanced Research Program for Billfish in 2004, with SEFSC scientists acting as the coordinator for the western Atlantic Ocean. Major accomplishments in the western Atlantic in 2004 were documented in SCRS/04/028. Highlights include 11 at-sea sampling trips with observers on Venezuelan industrial longline vessels in September 2004. Of the trips accomplished to date, 4 observer trips were on Korean type vessels fishing under the Venezuelan flag. Most of these vessels are based out of Cumana targeting tuna, swordfish, or both at the same time. Biological sampling of swordfish, Istiophorids, and yellowfin tuna for reproductive and age determination studies, as well as genetics research were continued during the 2004 sampling season. Shore-based sampling of billfish landings for size frequency data, as well as tournament sampling was obtained from Venezuela, Grenada, U.S. Virgin Islands, Bermuda, Barbados, and Turks and Caicos Islands. Program participants in Venezuela, Grenada, and Barbados continued to assist in obtaining information on tag-recaptured billfish, as well as numerous sharks, in the western

Atlantic Ocean during 2004; a total of 44 tag recovered billfish and sharks were submitted to the Program Coordinator in 2004. Age, growth, and reproductive samples from several very large billfish were also obtained during 2004.
A study conducted by the Virginia Institute of Marine Science (VIMS) to evaluate post release survival and habitat use from the recreational fishery for Atlantic white marlin using popup satellite archival tags (PSATs) was finalized in 2004 and published in the peer review literature. A separate study conducted by VIMS on U.S. longline vessels to evaluate post release survival of marlin, as well as evaluating hook performance and related mortality was also finalized in 2004. These data have been submitted to a peer reviewed journal and are currently under review.

The SEFSC has conducted several studies in the Northwest Atlantic and the Pacific coast of Central America to evaluate habitat use and reproductive biology of billfish using PSAT technology. About 200 PSATs have been deployed in this effort over the last 4 years with deployments ranging from a month to 5.5 months. Several peer reviewed papers summarizing these results are in press at this time, while other papers are currently in preparation.

In addition, SEFSC is also currently conducting pelagic longline research to evaluate gear behavior, and the effects of gear modification on catch rate and survival of target and non-target species. Three cruises have been completed to date. This work in ongoing and should be finished in 2006. Cooperative billfish research between US and Brazilian scientists was initiated in 2005.

The Fishery Management Group of the University of Miami is carrying out research on Atlantic billfish on three areas, population parameter estimation, population modeling and development of socio-economic indicators. Others at the University of Miami's Rosenstiel School and elsewhere are conducting research on early life history, reproductive biology and ecology of billfishes, as well as age and growth estimation.
Updates of standardized CPUE for blue and white marlin from the United States pelagic longline fishery in the NW Atlantic and Gulf of Mexico and the U.S. recreational tournament fishery in the NW Atlantic and Gulf of Mexico were developed and presented to ICCAT in 2005 (Document SCRS/2005/30 and SCRS/2005/31). Numerous additional papers were presented regarding standardization of CPUEs. Please see http//:www.iccat.es for additional information.

Multiple papers on habitat use were submitted to the ICCAT SCRS in 2005. These included papers on: vertical habitat use of white marlin in numerous locations of the western North Atlantic using PSAT tags (SCRS/2005/034); the depth distributions of 52 blue marlin in relation to exposure to longline gear using PSAT tags (SCRS/2005/035); and, a quantitative framework and numerical method for characterizing vertical habitat use by large pelagic animals using pop-up satellite tag data (SCRS/2005/). Additional information on spawning area research and other topics can be found at http//:www.iccat.es.

Atlantic Sharks

Stock Assessments of Pelagic, Large Coastal, and Prohibited Sharks
The ICCAT Subcommittee on Bycatch conducted a stock assessment of blue sharks and shortfin makos in Tokyo, Japan, in June 2004. All information available on biology, fisheries, stock identity, catch, CPUE, and size of these species was reviewed and an evaluation of the status of stocks conducted using surplus production, age-structured, and catch-free stock assessment models. U.S. scientists contributed eight working documents for this meeting on various aspects of shark biology and methods to assess stock status; SEFSC scientists participated in the assessment process and authored or co-authored six of those documents. A stock assessment of dusky shark, a prohibited

species under the shark FMP and candidate for listing under the ESA, is under way with expected completion in summer of 2006. Biological and fishery information available for this species is being synthesized and stock status will be evaluated using multiple stock assessment methodologies. The next assessment of large coastal sharks is planned for FY06, but data collection, synthesis, analysis, and preliminary stock evaluations will begin in late FY05.

Update on Catches of Atlantic Sharks

An update on catches of large and small coastal and pelagic sharks in U.S. Atlantic, Gulf of Mexico, and Caribbean waters was generated in FY 05 for inclusion in the 2005 SAFE Annual Report and future shark stock assessments. Time series of commercial and recreational landings and discard estimates from several sources were compiled for the large coastal shark complex and sandbar and blacktip sharks. In addition, recent species-specific commercial and recreational landings were provided for sharks in the large coastal, small coastal, and pelagic groups. Species specific information on the geographical distribution of commercial landings by gear type and geographical distribution of the recreational catches was also provided. Trends in length-frequency distributions and average weights and lengths of selected species reported from three separate recreational surveys and in the directed shark bottom-longline observer program were also included. Another update on catches of Atlantic sharks will be generated in FY 06.

Ecosystem Modeling

A dynamic mass-balance ecosystem model was used to investigate how relative changes in fishing mortality on sharks can affect the structure and function of Apalachicola Bay, Florida, a coastal marine ecosystem. Simulations were run for 25 years wherein fishing mortality rates from recreational and trawl fisheries were doubled for ten years and then decreased to initial levels. Effect of time/area closures on ecosystem components were also tested by eliminating recreational fishing mortality on juvenile blacktip sharks. Simulations indicated biomass of sharks declined up to 57 percent when recreational fishing mortality was doubled. Simulating a time/area closure for juvenile blacktip sharks caused increases in their biomass but decreases in juvenile coastal shark biomass, a competing multispecies assemblage that is the apparent competitor. In general, reduction of targeted sharks did not cause strong top-down cascades. Another update on catches of Atlantic sharks was generated in FY05.

Elasmobranch Feeding Ecology and Shark Diet Database

The current Fishery Management Plan for Atlantic Tunas, Swordfish, and Sharks gives little consideration to ecosystem function because there is little quantitative species-specific data on diet, competition, predator-prey interactions, and habitat requirements of sharks. Given this, several studies are currently underway describing the diet and foraging ecology, habitat use, and predator prey interactions of elasmobranchs in various communities. In 2005, a study on latitudinal variation in diet and daily ration of the bonnethead shark from the eastern Gulf of Mexico was completed and a manuscript is being prepared for publication. A database containing information on quantitative food and feeding studies of sharks conducted around the world has been in development for several years and presently includes over 200 studies. This fully searchable database will continue to be updated and fine-tuned in FY 06. The goal is to make this tool available to researchers in the relatively near future.

Cooperative Gulf of Mexico States Shark Pupping and Nursery Survey (GULFSPAN)

The SEFSC Panama City Shark Population Assessment Group manages and coordinates a survey of coastal bays and estuaries between the Panhandle of Florida and Texas. Surveys identify the presence/absence of neonate and juvenile sharks and attempt to quantify the relative importance of each area as it pertains to essential fish habitat requirements for sharks. The SEFSC Panama City Shark Population Assessment Group also initiated a juvenile shark abundance index survey in 1996. The index is based on random, depth-stratified gillnet sets conducted throughout coastal bays and estuaries in northwest Florida monthly from April to October. The species targeted for the index of abundance are juvenile sharks in the large and small coastal management groups.

Angel Shark Life History

The Atlantic Angel Shark is a benthic species inhabiting deep waters of the Gulf of Mexico and the Atlantic Ocean. This species is listed as prohibited by the 1999 Fisheries Management Plan for Atlantic Tunas, Swordfish, and Sharks due to the lack of biological data and a precautionary approach for species thought to be highly susceptible to exploitation. Life history studies began in 2003. Samples are obtained from commercial fishers and fishery independent surveys. Preliminary reproductive parameters were determined in 2004 and results presented at the annual American Elasmobranch Society meeting held in Norman, Oklahoma, in May 2004.

Life History Studies of Elasmobranchs

Biological samples are obtained through research surveys and cruises, recreational fishers, and through collection by onboard observers on commercial fishing vessels. Age and growth rates and other life history aspects of selected species are processed and data analyzed following standard methodology. This information is vital as input to population models incorporating variation and uncertainty in estimates of life-history traits to predict the productivity of the stocks and ensure that they are harvested at sustainable levels. The age and growth parameters of bull shark (*Carcharhinus leucas*) and spinner shark (*C. brevipinna*) were completed and submitted for publication in 2004.

Cooperative Research – Definition of Winter Habitats for Blacktip Sharks in the Eastern Gulf of Mexico

A collaborative effort between SEFSC Panama City Shark Population Assessment Group and Mote Marine Laboratory is underway to define essential winter habitats for blacktip sharks (*Carcharhinus limbatus*). Deployment of archival Pop-Up Archival Transmitting (PAT) tags on sharks during January and February of FY05 in the Florida Keys and north Florida will be executed with the cooperation of the charterboat industry. PAT tags will be programmed to detach from individuals during late spring and early summer when sharks have recruited to coastal areas.

Cooperative Research – Habitat Utilization among Coastal Sharks

Through a collaborative effort between SEFSC Panama City Shark Population Assessment Group and Mote Marine Laboratory, the utilization of coastal habitats by neonate and young-of-the-year blacktip and Atlantic sharpnose sharks will be monitored through an array of underwater acoustic receivers (VR2, Vemco Ltd.) placed throughout each study site.

Movement patterns, home ranges, activity space, survival, and length of residence of individuals will be compared by species and area to provide information to better manage critical species and essential fish habitats.

Cooperative Research – Characterization of Bycatch in the Gulf Butterfish, (Peprilus burti), Trawl Fishery, with an Emphasis on Identification of Life History Parameters for several Potentially High-Risk Species

A proposal with the SEFSC Panama City Shark Population Assessment Group and the University of Florida was submitted to MARFIN to quantify and qualify the elasmobranch bycatch in the butterfish, (Peprilus triacanthus), trawl fishery in the Gulf of Mexico. Determination of life history parameters for the roundel skate, (*R. texana*), the clearnose skate, (*R. eglanteria*), the spreadfin skate (*Dipturus olseni*), and the Atlantic angel shark, (*Squatina dumerili*) will be developed ultimately for the estimation of vital rates. Vital rate information will be used to determine the productivity of the stocks and ensure that they are harvested at sustainable levels.

Using elemental chemistry of shark vertebrae to reconstruct large-scale movement patterns of sharks
A project examining ontogenetic shifts in habitat utilization of bull sharks using Sr:Ca ratios of vertebrae will begin in FY06, funds permitting. Laser ablation ICPMS will be used to assay transects across the entire vertebral section along the corpus calcareum. Given the relationship of Sr:Ca to habitat developed from the reference samples, habitat type (freshwater, estuarine, or marine) will be assigned to each growth band, thereby reconstructing the migration history of the shark on a year-by-year basis over its lifetime.

Coastal Shark Assessment Research Surveys
The SEFSC Mississippi Laboratories in Pascagoula have been operating annual research cruises aboard NOAA vessels since 1995. The objectives of this program are to conduct bottom longline surveys to assess the distribution and relative abundance of coastal sharks along U.S. and Mexican waters of the Gulf of Mexico and the U.S. eastern seaboard. This is the only longterm, nearly stock-wide, fishery-independent survey of Atlantic sharks conducted in U.S. and neighboring waters. Ancillary objectives are to collect biological and environmental data, and to tag-and-release sharks. Starting in 2001 and under the auspices of the Mex-US-Gulf Program, the Pascagoula Laboratories have provided logistical and technical support to Mexico's Instituto Nacional de la Pesca to conduct a cooperative research cruise aboard the Mexican research vessel *Onjuku* in Mexican waters of the Gulf of Mexico. The cruise also took place in 2002, but was suspended in 2003 and 2004 because of mechanical problems with the research vessel and other issues.

A proposal was submitted in 2005 to gather data to help clarify the uncertainty on the current status of oceanic whitetip sharks in the western North Atlantic Ocean. Data on behavior and movement patterns will be collected using on-board observers on pelagic longline vessels. Archival satellite pop-up tags will be utilized to monitor the movement patterns, depth, and temperature preferences of this species. In addition, time-depth recorders, and hook-timers will be used to determine the depth and times at which sharks take baits. These data will be incorporated with sea surface temperature data from satellites and incorporated into new habitat-based analyses of the data to provide a better understanding of the status of oceanic whitetip sharks.

Cooperative Research – The capture depth, time, and hooked survival rate for bottom longline caught large coastal sharks
A collaborative effort between SEFSC Panama City Shark Population Assessment Group and the University of Florida to examine alternative measures in the shark bottom longline fishery to reduce mortality on prohibited sharks such as reduced soak time, restrictions on the length of gear, and fishing depth restrictions will be tested using hook timers. Funding is being sought through the NMFS Cooperative Research Program.

Utilizing Bioenergetics and Matrix Projection Modeling to Quantify Population Fluctuations in Long-lived Elasmobranchs: Tools for Fisheries Conservation and Management
Under the supervision of SEFSC scientists at the Panama City Laboratory, the NMFS Sea Grant Fellow in Population Dynamics and Resource Economics conducted research that sought to use a bioenergetics and matrix approach to examine the population dynamics of the cownose ray (*Rhinoptera bonasus*). Laboratory experiments and field data were used to obtain basic life history

information, and that information configured the individual-based bioenergetics model. The bioenergetics model was coupled to a matrix projection model, and the coupled models were used to predict how warmer and cooler water temperatures would affect the growth and population dynamics of the cownose rays. Changes in growth rates under the warmer and cooler conditions lead to changes in age-specific survivorship, maturity, and pup production, which were used as inputs to a matrix projection model. Faster growth of individuals under the cooler scenarios translated into an increased population growth rate (4.4 – 4.7 percent/year versus 2.7 percent/year under baseline), shorter generation time, and higher net reproductive rates, while slower growth under the warmer scenarios translated into slower population growth rate (0.05 – 1.2 percent/year), longer generation times, and lower net reproductive rates.
Elasticity analysis indicated that population growth rate was most sensitive to adult survival. Reproductive values by age were highest for intermediate ages.

<u>Cooperative Research – Definition of Winter Habitats for Blacktip Sharks in the Eastern Gulf of Mexico</u>

A collaborative effort between SEFSC Panama City Shark Population Assessment Group and Mote Marine Laboratory is underway to define essential winter habitats for blacktip sharks (*Carcharhinus limbatus*). Deployment of two pop-off satellite archival tags (PAT) on sharks during January and February of 2005 in the Florida Keys was accomplished with the cooperation of the charter boat industry. Preliminary results from these two sharks indicate one shark remained in the Keys while the other moved to an area southwest of the coast of Cuba. Additional PAT tags will be placed on sharks during the summer of 2005.

<u>Cooperative Research – Definition of Summer Habitats and Migration Patterns for Bull Sharks in the Eastern Gulf of Mexico</u>

A collaborative effort between SEFSC Panama City Shark Population Assessment Group, University of Florida, and Mote Marine Laboratory is underway to determine summer habitat use and short-term migration patterns of bull sharks (*Carcharhinus leucas*). Sharks are being outfitted with Pop-Up Satellite Archival Tags (PSAT) during July and August of 2005 and scheduled to deploy in autumn. This project is driven by the lack of data for this species and its current prominence within the Florida coastal community. A better understanding of this species is required to effectively manage this species for both commercial and recreational fishers as well as the general public. Concerns regarding this species will continue to be an issue as fishers and the public demand that state and federal governments provide better information concerning the presence and movements of these sharks.

Other Agencies

9.1.5 The Clean Water Action Plan – Coastal Research and Monitoring Strategy

The Coastal Research and Monitoring Strategy Workgroup was formed in 1999 with representatives from Federal, State, Tribes, and Non-Governmental Organizations (NGO) to prepare the Coastal Research and Monitoring Strategy. Simply stated, the intent of the Strategy is to replace traditional single-issue, single-agency, single-discipline problem solving with a coordinated, multi-agency, interdisciplinary approach to address problems of coastal water quality and coastal resources.

As directed in the Clean Water Action Plan, EPA, NOAA, USGS, and the USDA led the development of this Coastal Research and Monitoring Strategy and provided leadership for strategic planning, coordination, and prioritization of research and monitoring objectives.

Executive Summary

In terms of surface area, coastal waters of the United States represent the largest economic and environmental zone of the Nation. Because a disproportionate percentage of the Nation's population lives in coastal areas, the activities of municipalities, commerce, industry, and tourism have created environmental pressures that threaten the very resources that make the coast desirable.

To address these pressures, the Clinton Administration has called for a renewed effort to restore and protect our Nation's estuarine and coastal areas. The Clean Water Action Plan, announced by President Clinton and Vice President Gore on February 19, 1998, is intended to redirect the Nation's water programs to "protect public health and restore our Nation's waterways". The Clean Water Action Plan specifically calls for the development of a strategy for coastal research (Action Item 59) and a plan for coastal monitoring (Action Item 60) including a comprehensive review of existing programs related to the generation, transport, and effect of pollutants on coastal waters, habitats, and living and economic resources. This document addresses both Action Items because they are intrinsically linked for the purposes of assessing regional and national trends, determining cause and effect relationships, and implementing adaptive management principles.

While the national investments made as a result of environmental legislation have had a dramatic effect on improving the Nation's coastal water quality, there are still environmental problems in the coastal zone. Examples of environmental issues common to most coastal States include nutrient enrichment, habitat change, protection of living aquatic resources, invasive species, pathogens, toxic contaminants, and harmful algal blooms.

The Federal government invests annually about $225 million conducting research and monitoring programs addressing these and other specific environmental issues in the coastal zone. Despite these investments, the importance of the coastal region to the Nation's economy, and the high potential for human use to adversely impact coastal resources and ecosystems, information about the status and trends of critical environmental variables in coastal regions is often lacking. Other than programs for coastal weather, water levels, commercial fisheries, and point source discharges, there are currently no nationally consistent, comprehensive monitoring programs to provide the information necessary for effective management of coastal systems.

The Coastal Research and Monitoring Strategy employs a monitoring-research-assessment-management cycle that integrates coastal monitoring and research objectives to enable cross-cutting and comprehensive assessments of the Nation's coastal resources. The objectives of the Strategy are to:

- Document the status and assess trends in environmental conditions at the scales necessary for scientific investigation and policy development;
- Evaluate the causes and consequences of changes in environmental status and trends;
- Assess environmental, economic, and sociological impacts of alternative policies for dealing with these changes; and
- Implement programs and policies to correct observed environmental problems.

The key attributes of the proposed Coastal Research and Monitoring Strategy include co-funding by Federal and State programs; nested designs to allow State-specific issues to be addressed in a national context; collective reporting; and cross-system comparisons.

The strategy for a national coastal monitoring design is based on the three-tiered approach developed by the U.S. Environmental Protection Agency (Messer et al. 1991) and a similar version was recommended by NSTC (1997) and has the following components:

- Characterization of Problem (Tier 1) -- Broad-scale ecological response properties as a base determined by survey, automated collection, and/or remote sensing;
- Diagnosis of Causes (Tier 2) -- Issue- or resource-specific surveys and observations concentrating on cause-effect interactions; and
- Diagnosis of Interaction and Forecasting (Tier 3) -- Intensive monitoring and research index sites with higher spatial and temporal resolution to determine specific mechanisms of interaction needed to build cause-effect models.

Data and information generated at each tier help interpretation of results from the other tiers. For example, Tier 1 (Characterization) data provide geographic context for data collected at Tiers 2 and 3 (e.g., how widespread is the problem and how much of the nation's resources are affected by its occurrence). Likewise, Tiers 2 (Diagnosis of Causes) and 3 (Diagnosis of Interactions and Forecasting) aid in understanding how serious a particular relationship or issue is.

The focus of the Strategy and conceptual framework is monitoring in the coastal zone. However, important research activities must occur concurrently at each level of the monitoring framework. Research plays a vital role in increasing our ability to interpret data from our monitoring programs and enhance our monitoring tools and methods. Research is the foundation underlying all tiers of the monitoring framework, and is critical to achieving the objectives of integrated assessments.

The objectives and the conceptual framework for a Coastal Research and Monitoring Strategy have been defined by the Workgroup and are included in this document. However, the Workgroup recognizes that further development of an implementation strategy which contains specific action plans for each of the following recommendations is necessary to execute the concepts of this Strategy. The final section of this document suggests issues that should be considered during implementation. However, development of an implementation plan is beyond the scope of this Workgroup.
The following six recommendations are offered:

1. Enhance and adapt existing programs to support an integrated and effective national coastal monitoring program. A high priority is placed on the development of a national coastal survey based on State-level coastal monitoring programs. The data collected from coastal States could provide a comprehensive and consistent picture of the "coastal health" of each State which would complement the partial requirements of Section 305(b) of the Clean Water Act. The data generated as a result of these monitoring activities could be used to support States' 303(d) listing processes.
2. Enhance and integrate interagency research efforts to fill data gaps, to increase the understanding of physical and ecological processes in the coastal zone, and to improve monitoring and assessment tools. Opportunities must be developed to foster interagency solicitation, review, and support of research proposals. Appropriate methods include both competitive and external grant processes, and internal Federal competition and interagency agreements.
3. Conduct periodic national and regional coastal assessments. These would include national summary assessments, national habitat assessments, national issue-specific assessments, and regional assessments.
4. Improve data management in support of the periodic assessments. These activities include development and maintenance of an Internet-based coastal environmental data clearinghouse

and directory of meta-data resources, development of performance-based standards for data management and data submission, and development of national data quality standards.

5. Establish mechanisms to assess and adjust monitoring and research with changing national coastal priorities. User-advisory and technical committees, composed of representatives from Federal, State, and local governments; academia; not-for-profit organizations; and the private sector would be established to ensure that the products and services of the system are relevant and stay on track and to ensure that development and implementation of the system uses the best available scientific methods and technologies.
6. Establish a mechanism to define and develop an implementation plan for each of the Recommendations 1 -5 and to oversee efficient execution of a national program. To carry out the above recommendations and develop an implementation plan for a national strategy, the formulation of an interagency oversight committee is recommended. Long-term viability of the committee is essential.

To download a copy of the Clean Water Action Plan visit:
http://water.usgs.gov/owq/cleanwater/coastalresearch/

9.2 Research Programs

9.2.1 Fishery-Independent

9.2.1.1 MARMAP

(text below excerpted from http://www.dnr.sc.gov/marine/mrri/MARMAP/MMhist.html and SEDAR S2DW6 MARMAP CPUE document)

For thirty years, the Marine Resources Research Institute (MRRI) at the South Carolina Department of Natural Resources (SCDNR), through the Marine Resources Monitoring, Assessment and Prediction (MARMAP) program, has conducted fisheries-independent research on groundfish, reef fish, ichthyoplankton, and coastal pelagic fishes within the region between Cape Lookout, North Carolina, and Cape Canaveral, Florida. The overall mission of the program has been to determine distribution, relative abundance, and critical habitat of economically and ecologically important fishes of the South Atlantic Bight (SAB), and to relate these features to environmental factors and exploitation activities. Research toward fulfilling these goals has included trawl surveys (from 6-350 m depth); ichthyoplankton surveys; location and mapping of reef habitat; sampling of reefs throughout the SAB; life history and population studies of priority species; tagging studies of commercially important species and special studies directed at specific management problems in the region. Survey work has also provided a monitoring program that has allowed the standardized sampling of fish populations over time and development of an historical base for future comparisons of long-term trends.

Monitoring of Reef Species

Since 1978, MARMAP has monitored reef fish abundance and collected specimens for life history studies. The primary gear types that have been used to sample reef fishes are Florida traps, blackfish traps, chevron traps, bottom longline, kali pole, vertical longline, and hook and line gear. From 1978 to 1987, Florida traps and blackfish traps baited with cut clupeids were soaked for approximately two hours during daylight at 12 study areas with known live-bottom and/or rocky ridges. In 1988 and 1989, Florida snapper and chevron traps were fished synoptically for approximately 90 minutes from a 33.5 m research vessel that was anchored over randomly selected reef locations. After 1989, blackfish traps and Florida traps were discontinued. Only chevron traps were deployed at stations randomly selected by computer from a database of approximately 2,500 live bottom and shelf edge locations and buoyed for approximately 90 minutes. This database was compiled from MARMAP visual Underwater TV (UWTV) studies with additional locations added from catch records from the MARMAP and other MRRI projects. During the 1990s, additional sites were obtained for the North Carolina and south Florida area from scientific and commercial fisheries sources to facilitate expanding the overall sampling coverage.

Sample sites are all located in the central SAB from 27°N to 34°N. Trapping has occurred to depths as great as 218 m but the majority of trap sampling has occurred at 16 to 91 m. During all years, sampling was conducted during daylight to eliminate light phase as a variable. Night hours were reserved for workup of fishes, steaming time between sites and for tagging and recapture of priority species. CTD profiles were taken after each trap set and before each longline set.

Hook and line stations were fished during dawn and dusk periods, one hour preceding and after actual sunrise and sunset. Rods utilizing Electromate motors powered 6/0 Penn Senator reels and 36 kg test monofilament line were fished for 30 minutes by three anglers. The terminal tackle consisted of three 4/0 hooks on 23 kg monofilament leaders 0.25 m long and 0.3 m apart, weighted with sinkers 0.5 to 1 kg. The top and bottom hooks were baited with cut squid and the middle hook baited with cut cigar minnow (*Decapterus* sp.). This same method of sampling was used between 1978 and 2001. However, less emphasis has been placed on hook and line sampling during the 1990s to put more effort on tagging of fishes at night and running between stations.

In 1997, we began using two types of longline gear to sample the snapper-grouper complex in depths greater than 90 m. Each type of long line was intended to sample one of two unique bottom types (smooth tilefish grounds or rough bottom). In the tilefish grounds (areas of smooth mud), a horizontal long line was deployed and in areas of rough bottom contours, a short vertical long line was used to follow the bottom profile. The horizontal long line consists of 1676 m of 3.2 mm galvanized cable deployed from a
longline reel. A total of 1219 m of the cable is used as groundline and the remaining 457 m is buoyed to the surface. One hundred gangions, comprising of an AK snap, approximately 0.5 m of 90 kg monofilament and a #6 or #7 tuna circle hook, are baited with a whole squid and clipped to the ground cable at intervals of 12 m. The gear is set while running with the current at a speed of 4 - 5 knots. An 11 kg weight is attached to the terminal end and 100 gangions are then attached to the ground line, followed by another weight at the terminal end of the ground line. The remaining cable is pulled off of the reel and buoyed with a Hi-Flyer and a polyball trailer buoy. The gear is soaked for 90 minutes and retrieved by fairleading the cable from a side davit of the vessel back on to the longline reel. A similar bottom longline was deployed by MARMAP during the 1980s, however, red porgy are not taken in the tilefish grounds.

Where bottom type is rough at depths of 90 to 200 m, short vertical relief longlines consisted of 25.6 m of 6.4 mm solid braid dacron groundline dipped in green copper naphenate. The line is deployed by stretching the groundline along the vessel's gunwale with 11 kg weights attached at the ends of the line. Twenty gangions baited with a whole squid were placed 1.2 m apart on the groundline which was then brommelled to an appropriate length of poly warp and buoyed to the surface with a Hi-Flyer. Sets are made for 90 minutes and the gear is retrieved utilizing a pot hauler. This gear type has only been used since 1997 and a long term data set is not available. During the 1980s, kali pole gear was used on deep water reefs at depths ~150-200 m. Catch per unit effort for the longline gear is expressed as the number per 100 hooks.

UWTV recordings were made using a Simrad-Osprey Subsea low light camera attached to a vane stabilized frame during day light hours. The camera is maintained off the bottom 1 - 2 m as the vessel either drifted with the wind and/or current or was towed at low speeds. Recordings for fish identification on bottom habitat and to document new live bottom sites for the MARMAP data base were made on VHS tape and archived for future analysis.

Length-frequency data from the catches (to the nearest 1 cm) were recorded by a shipboard data acquisition system. This comprised of a Limnoterra FMB IV digital measuring board and a Toledo model 8142 digital scale, interfaced by an XT personal computer with customized software. During length frequency, subsample tables for priority species were also kept so specimens could be retained for additional life history studies. During length frequency workup, the only total length was recorded for black sea bass and fork length for vermilion snapper. After length frequency workup, fishes are stored on ice for life history workup during night.

During life history workup, a Limnoterra fish measuring board with 1-mm resolution was used to measure priority species (standard length, SL; fork length, FL; and total length, TL) with their weights determined by a triple beam balance to the nearest gram. This system was connected to an AT 486-type computer for life history data storage with a paper output as backup.

MARMAP Vessels

Three research vessels have been used by MARMAP since 1972: the R/V *Dolphin*, R/V *Oregon I*, and R/V *Palmetto*. During 1973-1980, MARMAP used the R/V *Dolphin*. This was a 105’ converted ocean tugboat. It had a single screw and an active rudder. It was outfitted for trawling, plankton work, hydro casts, trapping and was used by NMFS prior to MARMAP. The data collected were used to describe the seasonal distribution and abundance of groundfish and fish larvae throughout the region. From 1973 to 1980, over 800 trawl stations, and nearly 1200 ichthyoplankton and hydrographic stations were sampled. Several publications resulted from these early surveys, primarily providing descriptions of the groundfish and ichthyoplankton community, as well as seasonal circulation patterns and hydrography in the South Atlantic Bight. These surveys indicated that the greatest biomass and diversity of fishes were found at middle (19-27 m) and outer (28-55 m) shelf depths in areas of rocky outcrops, limestone reefs and associated octocorals and sponges constitute the "live-bottom" reef habitat of the southeastern shelf. This “live-bottom” habitat provided habitat for the many species of snapper and grouper that supported the rapidly expanding reef fish fisheries off the Carolinas and Georgia in the early 1970's. The R/V *Oregon I* was used by MARMAP during 1981-1988. It was a 105’ vessel that was built by NMFS during WWII to trawl off Alaska. It was outfitted for trawling, plankton work, hydro casts, and trapping. From 1989 to the present, MARMAP has used the R/V *Palmetto*. The R/V *Palmetto* is 110’, maintains a 5 permanent member sea-going crew, 1 or 2 temporary deckhands, and has accommodations for 9 scientists. There is a 200 sq. ft. wet lab on the main deck with counter space, electronics rack, freshwater and seawater, a double stainless sink, 40 cu. ft. chest freezer, small bait freezer, 120 volts AC and 12 volts DC power supplies. The main deck has 1,014-sq. ft. of open deck space, with davits on both sides. There is a Sea Crane 120 on the main deck for loading, distributing and deploying gear, as well as the zodiac. It has two hydraulic long-line reels, two hydraulic reels for CTD casts and plankton work and a pot-hauler for retrieving traps.

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 make it difficult to monitor life history parameters and abundance data from samples collected from the fishery landings. MARMAP has the only existing long-term program off the Atlantic coast of the southeastern United States that monitors reef fish length frequency, abundance, and life history based on fishery-independent data. These data provide critical input for the assessments of stock status conducted by NOAA Fisheries, and greatly assist stock assessment scientists and the Council in the management of snapper/grouper complex of the South Atlantic Bight.

9.2.1.2 SEAMAP

(text below excerpted from http://www.gsmfc.org/sm_ov.html,

The Southeast Area Monitoring and Assessment Program (SEAMAP) is a State/Federal/university program for collection, management and dissemination of fishery-independent data and information in the southeastern United States. The organizational structure of the program presently includes three operational components, SEAMAP-Gulf of Mexico, which began in 1981, SEAMAP-South Atlantic, implemented in 1983 and SEAMAP-Caribbean, formed in 1988.

Each SEAMAP component operates independently, planning and conducting surveys and information dissemination in accordance with administrative policies and guidelines cooperatively established by the Gulf States Marine Fisheries Commission (GSMFC) and the National Marine Fisheries Service's Southeast Regional Office (SERO). Funding allocations to participants are administered through State/Federal cooperative agreements, managed by SERO and the Southeast Fisheries Science Center (SEFSC), National Marine Fisheries Service (NMFS).

Activities and operations of each SEAMAP component are wholly defined by the respective managing units: the SEAMAP-Gulf Subcommittee of the GSMFC’s Technical Coordinating Committee, the SEAMAP-South Atlantic Committee of the Atlantic States Marine Fisheries Commission (ASMFC)'s South Atlantic Board, and the SEAMAP-Caribbean Committee of the Puerto Rico Department of Natural and Environmental Resources. The Gulf and South Atlantic committees consist of designated representatives from each member state and NMFS/SEFSC and the Gulf of Mexico and South Atlantic Fishery Management Councils. In addition, the SEAMAP-South Atlantic committee includes a representative from the ASMFC.

Surveys by each program component reflect distinct regional needs and priorities; however, survey operations in one geographic area often provide information useful to researchers in all three regions. In the South Atlantic region, surveys include Shallow Water Trawl Survey, Pamlico Sound Survey, Benthic Characterization, and Bottom Mapping Project. In addition to the regularly-scheduled surveys, SEAMAP participates in a variety of other projects such as the Winter Trawling and Fish Tagging Cruise, a coordination role for developing finfish bycatch estimates. The SEAMAP provides guidance, personnel, and other contributions to these studies for enhancement and protection of the marine resources.

9.2.1.3 NOAA Fisheries SEFSC

When fisheries scientists collect fisheries information independent of commercial or recreational fishing operations, this information is considered fisheries-independent data. Such data are needed to accurately assess marine fish populations and are used in conjunction with fisheries-dependent data for estimating total population size and mortality rates.

Fisheries independent data are collected by scientists conducting resource surveys, such as trawl and seine surveys. These surveys are specifically designed to sample in an objective manner.

Consequently, the research vessels do not necessarily sample where fish are most abundant. Instead, the sampling objective is to collect information on a fish population throughout its entire geographic range.

Sea Turtle Program

Scientists in the Sea Turtle Program of the Southeast Fisheries Science Center implement research to support the conservation and recovery of threatened and endangered sea turtle species by conducting population assessments; research on stock structure (age and genetics); assessments of sea turtle mortality, strandings, and unusual events; and revision of Stock Assessment Reports for populations of sea turtles in the western North Atlantic Ocean. They also participate in research to reduce the bycatch of sea turtles and conduct in-water studies to evaluate population trends and habitat requirements. They participate in technology transfer of successful bycatch reduction measures. Scientists undertake this work in collaboration with other SEFSC and NOAA protected species staff, academic colleagues, and contractors. SEFSC scientists provide information and analytical results on species status and threats to the NMFS Southeast Regional Director and NMFS Headquarters for the effective management of marine turtles. The information is critical for evaluating the appropriate conservation measures, as required under the Endangered Species Act. Scientists also provide information to scientists in Mexico through MEXUS-GULF Turtle Working Group; and contribute to the proceedings of the Annual Sea Turtle Symposia. Scientists also take part in implementing the NMFS Atlantic Sea Turtle Strategy that is aimed at addressing the incidental capture of turtles in commercial and recreational fisheries along the Atlantic coast.

Marine Mammal Strandings

The Marine Mammal Protection Act (MMPA) mandates that the National Marine Fisheries Service (NMFS) monitor the status of all marine mammals in the southeast region and maintain the Marine Mammal Health and Stranding Response Program. In compliance with that act, stranding programs, biomonitoring programs, and population surveys have been developed and implemented in the various regions of the United States and territories.

Specifically, the Southeast Fisheries Science Center is responsible for marine mammal responses in the southeast region of the United States including the beaches from North Carolina to Texas, Puerto Rico and the U.S. Virgin Islands.

The NMFS, Southeast Fisheries Science Center (SEFSC) is the base for the Southeast United States Marine Mammal Stranding Program. NMFS authorizes organizations and volunteers under the Marine Mammal Protection Act (MMPA) to respond to marine mammal stranding throughout the United States. These organizations form the stranding network whose participants are trained to respond to, and collect samples from live and dead marine mammals that strand along southeastern United State beaches. Scientists at the SEFSC are responsible for coordinating stranding events, monitoring stranding rates, monitoring human caused mortalities, maintaining a stranding data base for the southeast region, and conducting investigations to determine the cause of unusual stranding events including mass strandings and mass mortalities.

Ship surveys are used to assess the abundance and distribution of cetaceans over large areas of the Gulf of Mexico, Atlantic Ocean, and Caribbean Sea. Surveys are conducted from the 68-m NOAA Ship Gordon Gunter and the 52-m NOAA Ship *Oregon II*. Visual line-transect surveys are conducted from the ship's flying bridge using 25X binoculars during the day. Acoustic surveys are conducted day and night using towed hydrophone arrays and sonobuoys. Biopsy samples for genetic and contaminant studies are obtained during the surveys. Environmental and oceanographic data are also collected. From 23 ship surveys conducted since 1990, we have learned that about 30 cetacean species inhabit southeastern U.S. waters. These include large whales, such as the right whale, sperm whale, and humpback whale, and dolphins, such as the pantropical spotted dolphin, bottlenose dolphin, and spinner dolphin. Smaller whales, such as killer whales, pilot whales, and beaked whales, also inhabit these waters. Typically bottlenose dolphins and Atlantic spotted dolphins are found in continental shelf waters, whereas most of the other species occur in oceanic waters. Data from these surveys are used to make management decisions mandated by the Marine Mammal Protection Act.

Multi-year aerial surveys of the nearshore waters of the southeast Florida coast, including the Florida Keys, and of Florida Bay are being conducted by the SEFSC with the support of the U.S. Coast Guard Air Station Miami. Conducted since September 1992 and March 1995, respectively, these surveys from a Coast Guard HH65 helicopter provide opportunistic sightings of bottlenose dolphin that can be used as rough estimates of their relative abundance in these waters. A total of 1,851 sightings of bottlenose dolphins were recorded in 109 surveys from inception through December 1997. Herd sizes, seasonality, and encounter rates were compared between the two areas, as well as with previous studies in nearby areas, in a SEFSC Technical Memorandum. These surveys were initiated to monitor marine animals along the southeast coast, to document vessel usage in Biscayne National Park and the Florida Keys National Marine Sanctuary, and to census water birds in Florida Bay.

The SEFSC also conducts a bottlenose dolphin, *Tursiops truncatus*, monitoring program in Biscayne Bay, Florida, using photo-identification techniques as a method of identifying individual dolphins for population studies. Initiated in August 1990, a total of 180 individuals have been identified from 390 sightings during 250 surveys. Of these, approximately 75% are considered to be full time residents of Biscayne Bay. The study area runs from Haulover Inlet, south to Card Sound Bridge encompassing an area of approximately 250 square miles. The behavioral studies component includes observing and monitor habitat use, movement patterns, and other behaviors exhibited by Biscayne Bay bottlenose populations. Currently, a website is being developed to allow researchers to compare dolphin dorsal fin images from the photo-id projects in adjoining study areas to determine the extent animal ranges.

SEFSC, Beaufort Lab, conducts small-vessel surveys in North Carolina and some nearby areas, including Georgia, Virginia, and New Jersey, focusing on bottlenose and Atlantic spotted dolphins. This research involves collection of skin samples for stock identification from a number of different estuarine, coastal and offshore habitats along the coast. The bottlenose dolphin work examines both latitudinal (inshore-offshore) distribution of the coastal form of bottlenose, examining the degree of overlap with the offshore form, and longitudinal (north-south) distribution of populations. Photographs taken during this work are also being used to examine movements between sites.

SEFSC, Beaufort Lab, is also coordinates an effort to define the number and range of stocks of the coastal morphotype of bottlenose dolphins along the Atlantic coast. This project involves the simultaneous application of multiple techniques, including genetics, stable isotope ratios, photo-identification (with over 20 collaborators along the coast), and telemetry. Preliminary results have identified seven management units. The data being collected will also help with defining habitat preferences and ranging patterns. In addition, the SEFSC Beaufort Lab, conducts studies of age, growth, and reproduction of a number of cetacean species. Particular emphasis is on the bottlenose dolphin because, despite its prevalence in coastal waters of the Atlantic and Gulf of Mexico, estimates of reproductive rates and other basic life-history parameters, do not exist.

9.2.2 Fishery-Dependent

9.2.2.1 MARFIN

(text below excerpted from http://sero.nmfs.noaa.gov/grants/marfin.htm)

The Marine Fisheries Initiative (MARFIN) program, administered through the National Marine Fisheries Service Southeast Regional Office, promotes and endorses programs which seek to optimize economic and social benefits from marine fishery resources through cooperative efforts that evoke the best research and management talents of the Southeast Region. Preference is given to cooperative planning efforts with up to 3-year time horizons. The intent is to focus projects funded by MARFIN into cooperative efforts that provide clear answers for fishery needs covered by the NMFS Strategic Plan, particularly goals one, two and four are important. For example, a geographically restricted age and growth study of a local fishery resource is of limited value unless it is coordinated with, or verified by, similar studies which span the range of the resource. The value of such studies is also relatively limited unless the results can be combined with other studies to provide a regional assessment of the resource. MARFIN provides this necessary programmatic integration through cooperative planning, accomplishment of program activities and an annual MARFIN Conference.

History of the MARFIN program
The MARFIN program received its initial impetus from a 1983 discussion paper entitled "Research Needs For Information Leading To Full and Wise Use of Fishery Resources In The Gulf of Mexico" by Dr. Thomas D. McIlwain of the Gulf Coast Research Laboratory while he was in the office of Rep. Trent Lott. This paper, sometimes referred to as the Lott-McIlwain paper, proposed an additional investment in fisheries research and development in the Gulf of Mexico to increase the economic contribution of marine fisheries, develop more valuable products from existing fisheries, develop export markets, forecast variation in yields and conserve and maintain presently exploited resources.

The next step in the evolution of MARFIN was the preparation and publication of the Marine Fisheries Initiative - Gulf Of Mexico Phase. This plan was developed by a joint industry, federal, state and academic task force, detailing the research and development efforts necessary to enhance, restore and maintain fisheries in the Gulf of Mexico. The program focused on funding projects which had the greatest probability of maintaining and improving existing fisheries, increasing revenues for the domestic industry, increasing yields from fisheries and generating increased recreational opportunity and harvest potential.

In 1992, the MARFIN program was expanded to include a South Atlantic component (North Carolina, South Carolina, Georgia and the Atlantic coast of Florida). The goals and objectives of the South Atlantic phase of MARFIN are described in Special Report No. 13 of the Atlantic States Marine Fisheries Commission, Marine Fisheries Initiative (MARFIN) South Atlantic Phase.

MARFIN Program Organization and Administration
The NMFS Southeast Regional Administrator organized the MARFIN Panel in Fiscal Year 1992 when the program was expanded to cover the South Atlantic. Each member of the MARFIN Panel provides individual recommendations to the Regional Administrator on MARFIN priorities and financial assistance applications. The MARFIN Panel membership is as follows: One state marine conservation agency representative each, from the Gulf of Mexico and the South Atlantic areas; one representative each from the Gulf of Mexico and the South Atlantic commercial fishing industries;

the Executive Directors of the Gulf of Mexico and South Atlantic Fishery Management Councils; the Executive Directors of the Gulf and Atlantic States Marine Fisheries Commissions; one representative each from the Gulf of Mexico and the South Atlantic recreational fishing industries; one representative each from the Gulf of Mexico and the South Atlantic Sea Grant Universities and a NMFS Southeast Fisheries Science Center Technical representative.

The NMFS Southeast Financial Aid Program Officer provides guidance to the Regional Administrator and the MARFIN panels members concerning Federal, Department of Commerce and NOAA financial assistance administration requirements.

Alternate representatives to the MARFIN Panel serve when necessary. The MARFIN Panel Chair is elected for up to three-years. Individual Panel members are appointed by the NMFS Southeast Regional Administrator for staggered terms.

The Administrator of the NMFS Southeast Regional Office relies on recommendations from individual members of the MARFIN Panel, the NOAA Assistant Administrator for Fisheries, the public through their response to MARFIN Federal Register notices and the NMFS staff to develop each year's MARFIN program.

Each year the MARFIN Panel members and NMFS administrators and scientists identify areas of emphasis for the next year's competitive financial assistance program. These areas of emphasis are published in the Federal Register for public comment. After public review and comment, an announcement of funding availability through the competitive MARFIN financial assistance program is published as a solicitation in the Federal Register.

The NMFS Southeast Regional State/Federal Liaison Office staff is responsible for the overall administration of all NMFS Southeast grants and cooperative agreement programs, including MARFIN. Their responsibilities include planning, application and selection, negotiation, performance, monitoring and close-out of all assigned competitive and noncompetitive financial assistance programs. A NMFS Southeast scientific or technical expert is assigned as the Technical Monitor for each MARFIN project. The Technical Monitor is responsible for all technical and cooperative aspects of assigned projects. The NOAA Grants Officer is responsible for the overall administration of each NMFS financial assistance award issued to recipients outside of the Federal government and cooperates with the NMFS Southeast State/Federal Liaison Office in administering each financial assistance award.

9.2.2.2 Cooperative Research Program

(text below excerpted from the FY07 Federal Funding Opportunity announcement available through the SERO grants website)

The NMFS' Cooperative Research Program (CRP) is a competitive Federal assistance program that funds projects seeking to increase and improve the working relationship between researchers from NMFS, state fishery agencies, universities, and fishermen. The principal goal of the CRP is to provide a means of involving commercial and recreational fishermen in the collection of fundamental fisheries information to support the development and evaluation of management and regulatory options.

Applicants are encouraged to address one of the priority areas listed below as they pertain to federally managed species or species relevant to Federal fisheries management plans, but proposals in other areas will be considered. Projects funded through the CRP focus on collecting data that aids in recovering, maintaining, or improving the status of stocks upon which fisheries depend; improving the understanding of factors affecting recruitment success and long-term sustainability of fisheries; and/or generating increased values and opportunities for fisheries.

Projects are evaluated as to the likelihood of achieving these objectives, with consideration of the magnitude of the eventual economic or social benefits that may be realized.

Finfish
There are several priorities within this general category that pertain to the collection of catch, effort, size frequency, bycatch, and detailed data on fishing area by vessels in the fisheries for finfish species.

1. Characterize the total catch (from all fleets affecting the stocks), including catch composition and disposition of the catch.

(a) Projects are needed to collect detailed information on the composition and disposition of bycatch and discards.

(b) Investigations are needed to determine more efficient methods to record catches and associated effort accurately on a real-time basis during fishing operations (e.g. electronic logbooks).

(c) Projects are needed to develop methods to increase the amount of at-sea observations without relying on direct observers. One suggested approach is to use electronic imaging systems.

(d) Projects are needed to utilize fully scientific observers on-board vessels as a means of collecting detailed catch, effort and disposition data. In cases where vessel space does not permit adding an observer, it may be possible to designate the captain or a crew member to record these data. Projects must specify the type of training and equipment that is required to assure that reliable data are collected. (e) Data collection projects are needed to determine the effects on discard rates of increasing size limits or reducing possession limits. If discard mortality rates are high, changes in size or bag limits may unintentionally lessen conservation benefits. Discard mortality rates currently used in assessments are generally based on small numbers of observations or are unknown. Research is needed to improve estimates of discard mortality rates and must account for the effects of fish size, gear, area, season and depth of fishing.

(f) Data collection projects are needed to improve life history information to improve stock assessments. Improved information about the age-structure of the catch (both retained and discarded), based on otolith or other hard-part aging techniques, will provide insight on a stock's resilience to fishing. Improved information on the reproductive characteristics of the stock will provide information to refine estimates of long-term biological productivity of the stock. Development of new techniques for age and growth and reproductive information are especially important. (g) Improved age sampling (i.e., representative, randomized collection of structures) is needed for many species. For some species (i.e., protogynous ones) information is needed to characterize landings by sex.

2. Population evaluation. Needs under this category include abundance measures and expanded age composition sampling across all fisheries. Other needs include: (1) Research is needed to identify stock boundaries and evaluate stock mixing. Methods could include tagging studies to evaluate movements, otolith microchemistry, and genetics. (2) Data are needed to characterize length, age and, for some species, sex composition of landings and discards in commercial and recreational

fisheries. (3) Data are needed to estimate and characterize commercial and recreational discard removals.

3. Monitoring stock abundance through study-fleet applications. This type of cooperative research requires long-term commitment in terms of funding and application.

(a) One objective is to develop a consistent sampling methodology that will permit monitoring of the relative abundance of a fishery resource over time. An initial step for such a project is to develop sampling designs and protocols for sampling fleet catches to estimate relative abundance, including standardization of fishing power of individual vessels.

(b) Projects are needed to develop methods to determine appropriate sampling designs and pilot studies to estimate recruitment to selected fisheries. An example is the development of a recruitment index for Young-of-the-Year swordfish in the Gulf and along the southeastern U.S. coast - areas that are now closed to longlining.

4. Projects are needed to develop and test gear and fishing strategies designed to reduce or eliminate unintended catch.

5. Fishing Capacity Investigations. There appears to be a wide disparity between the current capacity of regional fishing fleets and the productivity of regional stocks.
Cooperative research to optimize the capacity of regional fishing fleets is needed. A number of possibilities ranging from Individual Quota Systems to Vessel Capacity
Control programs should be considered. It is likely that regional/fishery differences may require different approaches.

6. Monitor the effects of closed Marine Protected Areas. Research is needed to measure the response of marine resources to creation or expansion of Marine Protected Areas (MPAs). Projects should utilize fishermen's knowledge of critical habitat of harvested species. An example is the large MPA designed to protect small swordfish and other highly migratory species off the US southeastern coast.

(a) Projects are needed to assess the impacts of time/area closures in the Southeast Region that have been designated to protect finfish spawning aggregations and/or concentrations of sub-legal fish.

(b) Projects are needed to collect fine-scale catch-effort data to define the spatial and temporal dimensions of MPAs.

Recreational and Charter Fishery

1. Socioeconomic research.

(a) Research is needed to determine the number of recreational fishermen and related trips.

(b) Data are needed to describe the socioeconomic characteristics of the recreational and charter boat industries.

(c) In addition to data collection activities, research is needed to determine the economic benefits and costs associated with recreational fishing.

2. Research on Management Alternatives. Investigations should include benefits and costs to the stocks, as well as socioeconomic benefits/costs to participants in the fishery.

(a) Research is needed to determine the effects of seasonal closures and MPAs on the recreational and charter boat industries.

(b) Research is needed to determine the effects of seasonal closures and MPAs on spawning stocks and resulting recruitment.

(c) Research is needed to determine the impacts of bag and size limits on species that are important to recreational and charter boat industries. Projects should emphasize the effects of alternative size limits.
(d) Research is needed to determine discard mortality rates. This research should include data on length and age composition of discarded fish. At-sea observers on recreational and charter boat trips are one way to perform this type of research and should be considered.

3. Catch/Effort Data. Projects are needed to improve catch and effort data for private recreational fishermen. The projects should identify sample sizes, including number of intercept interviews and dock samples, required to achieve statistical levels of accuracy and precision.

4. Habitat Research.
(a) Research is needed to evaluate the effectiveness of artificial reefs. Projects should examine the value of artificial reefs to fishing communities, and estimate associated economic impacts.
(b) Research is needed to determine the impacts and effects of harmful algal blooms, such as red tide, on recreational and charter boat fisheries.
(c) Investigations are needed to determine essential fishery habitat for certain species such as gag, goliath grouper and sharks. This encompasses more than just a recreational issue, could be moved to a general habitat section.

Commercial Shrimp Harvest
1. Social and economic impact of fluctuations in domestic shrimp values:
(a) Research is needed on the effects on the domestic shrimp fishery of shrimp imports from foreign countries.
(b) Research is needed to determine the social and economic impacts of imports on fishermen and fishing communities. Research should include impacts on communities and the industry as a whole.

2. Identifying Non-Trawlable Areas. Research is needed to investigate how habitat enhancements of non-trawlable areas could benefit shrimp fisheries. For example, artificial reefs could be established in non-trawlable areas and the impacts on shrimp and finfish populations could be evaluated. Such research should determine if enhancements would increase habitat for juvenile and adult fish (i.e. red snapper).

3. Quantification of Effort. Research is needed to improve shrimp effort data. Projects need to consider recommendations derived from negotiations with the shrimp industry. Areas of concern are insurance for at-sea observers, acceptable gear and protection of confidential data collected by the project.

4. Bycatch Reduction Device Testing Protocols. There is a need to develop more efficient methods to certify bycatch reduction devices. Protocols should benefit both the resource and the shrimp industry.

5. Quantification of Bycatch Rates. Statistical research is needed to ensure that extrapolation of the results of individual trawl bycatch surveys to the fleet are statistically valid. The procedures should account for the total range of conditions found in all major fishing areas. The research should estimate the number of scientific fishery observers that should be employed to collect bycatch information for prevailing conditions and areas. The project should describe the statistical accuracy

and precision of estimates for each major fishing area in addition to the total fishing area. This is critical to improving stock assessments, especially in the Gulf of Mexico.

9.2.2.3 Saltonstall-Kennedy

(text below excerpted from online report to Congress doc available at http://www.ncseonline.org/NLE/CRSreports/04May/RS21799.pdf)
The Saltonstall-Kennedy (S-K) Act, as amended (15 U.S.C. §713c-3), established a fund (known as the S-K Fund) that the Secretary of Commerce uses to finance projects and cooperative agreements for fishery research and development. Under this authority, projects or cooperative agreements are selected annually on a competitive basis to assist the National Marine Fisheries Service in addressing concerns related to U.S. commercial and recreational fisheries. The S-K Fund is capitalized through annual transfers under a permanent appropriation to the Secretary of Commerce of 30% of the gross receipts collected by the Secretary of Agriculture under the customs laws on imports of fish and fish products.

The objective of the S-K program is to address the needs of fishing communities in providing economic benefits for rebuilding and maintaining sustainable fisheries, and in dealing with the impacts of conservation and management measures. The S-K program has become very important in addressing issues of immediate concern to the commercial fishing industry, by producing many new gear innovations, markets, and management options. Issues addressed have included fish harvesting, seafood quality improvements, domestic and foreign market development, efficiency and productivity improvements, and the costs/profitability of potential fishing industry investments.

In Fiscal Year 2004 appropriations, congressional earmarks designated funds for specific activities outside the regular competitive award process, and the S-K competitive program was cancelled.

9.2.2.4 Wallop-Breaux

(text below excerpted from USFWS site http://federalasst.fws.gov/sfr/fasfr.html)

The Federal Aid in Sport Fish Restoration Act, commonly referred to as the Dingell-Johnson Act -- passed on August 9, 1950 -- was modeled after the Pittman-Robertson Act to create a parallel program for management, conservation, and restoration of fishery resources.

The U.S. Fish and Wildlife Service's Sport Fish Restoration Program is funded by revenues collected from the manufacturers of fishing rods, reels, creels, lures, flies and artificial baits, who pay an excise tax on these items to the U.S. Treasury.

An amendment in 1984 (Wallop-Breaux Amendment) added new provisions to the Act by extending the excise tax to previously untaxed items of sport fishing equipment. The major element of the Wallop-Breaux Amendment established a new Trust Fund, named the Wallop-Breaux Trust Fund or the Aquatic Resources Trust Fund (ARTF). Funds are also received from import duties on sport fishing equipment, pleasure boats and yachts. Another source of revenue is a tax from motorboat fuel sales. These motorboat fuel taxes are collected by the U.S. Treasury and then transferred to the Fish and Wildlife Service for distribution among the States and territories.

Appropriate state agencies are the only entities eligible to receive grant funds. Each state's share is based 60 percent on its licensed anglers (fishermen) and 40 percent on its land and water area. No state may receives more than 5 percent or less than 1 percent of each year's total apportionment. The program is a cost-reimbursement program, where the state covers the full amount of an approved project then applies for reimbursement through Federal Aid for up to 75 percent of the project expenses. The state must provide at least 25 percent of the project costs from a non-federal source.

Since its creation, the Sport Fish Restoration Act has been refined and expanded by Congress. It is one of the most valuable federal legislation for anglers and fishery resources. In 2006, the total funding for national programs obtained through this legislation exceeded $5 billion according to the USFWS's annual allotment news release *(http://www.fws.gov/news/newsreleases/showNews.cfm?newsId=754069A2-D32C-3722-22DDAA5E1602C1D6).*

(excerpt below from FWC site http://myfwc.com/fishing/Fishes/SFR.html)
In 1994, passage of the Transportation Equity Act (TEA-21) authorized a National Outreach and Communications Program to increase participation in angling and boating and to impress on boaters and anglers the importance of healthy aquatic habitats. It also increased the minimum level of spending for boating access to 15% and raised the maximum allowable expenditure of SFR apportionments for aquatic education and outreach to 15%. TEA-21 further created a Boating Infrastructure Grant program (BIG) for construction, maintenance, or renovation of transient facilities for non-trailerable recreational boats (boats longer than 26 feet) TEA-21 raised the amount of Federal gas tax credited to the Wallop-Breaux Trust Fund and established a “permanent” appropriation for the Boating Safety Account. The result is one of the most successful "user pays--user benefits" programs in the world.

9.2.2.5 NOAA Fisheries SEFSC

Commercial Programs

Accumulated Landings System (ALS)
These data consists of information on the quantity and value of seafood products caught by fishermen and sold to established seafood dealers or brokers. These data are reported by dealers or brokers to the fisheries agency in each state. The National Marine Fisheries Service in the Southeast Region has established cooperative agreements with all of the states in the Southeast and rely on the states to collect and process these data. The general canvass data set maintained by the Southeast Fisheries Science Center is a continuous data set that begins in 1960. Landings data for some species and areas go further back in time and are available in print in the Fisheries of the United States.

The landings data, maintained by the SEFSC, are monthly totals of the quantities landed and the value of the landings for each species. Because these data are summaries, they do not contain information on the identification of the fishermen or vessel. However, several states in the Southeast do collect landings statistics for individual trips. The state of Florida was the first to implement a trip ticket program in 1985. In 1995, the state of North Carolina passed a license to sell law that required seafood dealers to report all landings statistics by trip and identify the vessel or individual that sold the product. In 1997, the state of Louisiana initiated their trip ticket program and in 1999 Georgia also initiated a trip ticket program.
In addition to the quantity and value (or price per pound), information on the gear used to catch the fish and the area where the fishing occurred are also recorded in the general canvass data.

In many coastal areas, trained field agents assist with the collection of fisheries statistics. These individuals are strategically located so they can maintain contact with the fishermen and are integrally involved with the fishing communities. Among other duties, these port agents provide information on the types of gear, fishing area and distance from shore for the general canvass data.

The port agents are also involved in the collection of Gulf shrimp statistics, biological data collection and the operating unit survey.

There are two shortcomings associated with fishery statistics that are collected from seafood dealers. First, dealers do not always record the specific species that are caught and second, fish or shellfish are not always purchased at the same location where they are unloaded, i.e., landed.

Dealers have always recorded fishery products in ways that meet their needs, which sometimes make it ambiguous for scientific uses. Although the port agents can readily identify individual species, they usually are not at the fish house when fish were being unloaded and thus, cannot observe and identify the fish. Species identification is a critical part of the biological sampling program (also known as the Trip Interview Program) operated jointly by the National Marine Fisheries and the fishery agency in each coastal state in the Southeast Region. The second problem is accurate information on the gear used and the location where the fish were caught. For the states with trip ticket programs, information on the gear and area fished is collected on the trip ticket form. For other states, this information is estimated, usually by the local port agent.

U.S. Domestic Longline Database

Before the mid-1980s, only limited data on the fishing activities from the U.S. pelagic longline fleet were collected. Data were collected by various state agencies, Fishery Management Councils, and university biologists from 1978 to 1983. These data consisted of weights for individual swordfish (headed, gutted and tailed) recorded on the weigh-out receipts (tally sheets) for the sales to vessels for an individual trip. In 1984, this database became the responsibility of the NMFS Southeast Fisheries Science Center. As part of this transition, the data were standardized and entered into a computer database. In order to expand the coverage, biologists at the SEFSC contacted vessel captains/owners and fish dealers and requested that they voluntarily submit their tally sheets to the SEFSC for use in scientific investigations of the swordfish fishery.

All of the data are coded and stored for the individual vessel that caught the fish. Quality control procedures established to compare with data previously entered to avoid duplication. Although swordfish were the primary commercial species caught and recorded on the sales receipts, the weights of other species were also listed on the tally sheets. Prior to 1985, the weigh-out data for the other (non-swordfish) species were not recorded. Beginning in 1986, the SEFSC began to enter all the weigh-out data for all species listed on the tally sheets received. The individual dress weights of other species listed on tally sheets from earlier years were entered as well.

Each record includes a vessel code, date of landing, state and port landed, code of the dealer purchasing the catch, gear fished, data source, location code of general fishing area, total hooks fished, days of actual fishing, total number of sets, and a species code along with the individual carcass weights for each species. All records from a specific trip are identified by their respective vessel codes and date of landing. Prior to 1986, effort (hooks, days fished, number of sets) information was recorded from personal vessel logbooks voluntarily submitted by vessel captains/owners. Beginning in 1986, all pelagic longline vessels that actively fished are required to submit daily logbook set records for each trip. Based upon this information, fishing effort is determined and, subsequently, added to the longline database.

The database contains information from the early 1960s (limited data) to the present and is almost exclusively comprised from data collected from the U.S. domestic pelagic longline fishery. Other gear types (harpoon, gillnet, handline, rod and reel, etc.) have been recorded from vessels voluntarily submitting the information or that were mandated to report by regulations in the past years. This database is continually updated as new information becomes available.

Fisheries Logbook System (FLS)

The Fisheries Logbook System records the fishing and non-fishing activity of fishermen who are required to report their fishing activity via logbooks submitted for each trip.

As the need for conservation of the Nation's marine resources increases the need for more and better quality data on how these resources are utilized also increases. One of the most useful types of data is catch per unit effort. To meet these needs, the Southeast Fisheries Science Center has implemented several vessel logbook programs. In 1986, a comprehensive program was initiated for the pelagic longline fisheries along the eastern seaboard, in the Gulf of Mexico and in the Caribbean. In 1990, logbook reporting was initiated for the vessels catching species in the reef fish management plan managed by the Gulf of Mexico Fishery Management Council. Similar to the logbook program for reef fish, a program for vessels catching species in the South Atlantic snapper-grouper fishery, managed by the South Atlantic Fishery Management Council, was initiated in 1992. In 1993, a comprehensive logbook was initiated for the federally managed shark fisheries (Highly Migratory Species, National Marine Fisheries Service). In 1999, logbook reporting was initiated for vessels catching king and Spanish mackerel (Gulf of Mexico and South Atlantic Fishery Management Councils).

Although these programs were initiated at various times and cover many different fisheries and types of gear, the SEFSC has attempted to make the logbooks relatively easy to complete. There are 2 types of reporting forms currently in use (although separate forms are used for the limited vessels that are permitted in the wreckfish and golden crab fisheries).

One form is used for the pelagic longline fisheries. Because this fishery uses gear that is deployed for a relatively long period (6 to 10 hours), catch and effort data are collected for each set. Thus, a separate form is required for each set. Fishermen are required to report the numbers of each species caught, the numbers of animals retained or discarded alive or discarded dead (longline gear is nonselective and unwanted or prohibited species such as, billfishes, sea turtles, etc., must be returned to the water), the location of the set, the types and size of gear, and the duration of the set.

Because some of the needed catch/effort information for pelagic longline fisheries remains the same for the entire trip (i.e., it would be redundant to report it for every set), a supplemental form is used to report this type of data. Information on the port of departure and return, unloading dealer and location, number of sets, number of crew, date of departure and landing are reported on the Trip Summary form. In addition, information on costs associated with the trip can be reported on this form.

This type of economic data is critical to the evaluation of existing and proposed management regulations. The National Marine Fisheries Service is required by law to assess (estimate) the economic consequences of proposed management regulations.
Without accurate data from the fishing industry, such estimates are not likely to reflect the true effects.

The second type of logbook form is used to report catch and effort data for the Gulf reef fish, South Atlantic snapper-grouper, coastal shark and king and Spanish mackerel fisheries. Because the soak time for these fisheries is relatively short, it is not feasible to require fishermen to complete a separate form every time the gear is deployed. Thus, the catch and effort data for the entire trip are reported on a single form (i.e., one form per trip).

The types of information required on this trip form are nearly the same as the pelagic longline logbook. Information on the quantity (reported in pounds) caught for each species, the area of catch, the type and quantity of gear, the date of departure and return, the dealer and location (county and state where the trip is unloaded), the duration of the trip (time away from dock), an estimate of the fishing time, and the number of crew are included on this form.

In response to the increased need for data on the amount of fish that are discarded, the Southeast Fisheries Science Center is now using a supplementary form that selected fishermen use to report quantities of fish that are discarded.

Trip Interview Program (TIP)
(text below excerpted from the SEFSC website)
Estimates of the age distribution of fish in the population and how the distribution has changed over time is critical information for the assessment of the population. The Trip Interview Program (TIP) was developed by the Southeast Fisheries Science Center as a shore-based sampling program. The primary focus of the TIP is the collection of random size-frequency data and biological samples from commercial marine fisheries. Biological samples include age, reproductive, prey, and genetic data. In addition to collecting biological data, the TIP serves as a quality assurance on catch and effort data. It validates species composition of catch and type and quantity of gear through first hand, trained observation. Other important information, obtained through personal interviews with the fishermen and dealers, also serves the quality assurance purpose. Like the other statistics gathering programs, this one is also a joint or cooperative effort with the state fishery agencies in the Southeast Region.

The Trip Interview Program was principally developed to provide two types of information: size frequency data and age at length data. In addition, this program also provides catch per unit effort data and information on the composition of the species being caught and landed.

The collection of data for this program is conducted by port agents located in coastal area in the South Atlantic and Gulf of Mexico. These field biologists visit docks and fish houses to interview the fishermen and take length and weight samples from their catch. For some trips, the port agents are at the location when the fish are being unloaded and can measure and weigh individual fish as they are being unloaded. At other times, the fish have already been unloaded and the port agent is given permission to measure and weigh a sample of the catch from the storage containers at the fish houses. In addition to the length and weight data, the port agents also attempt to interview the captain or a crew member to collect data on the fishing trip, i.e., fishing area, type and quantity of gear, fishing time, etc.

The port agents also take hard part and tissue samples for some of the fish they measure. These samples are sent to one of two Southeast Fisheries Science Center laboratories for biologists to analyze and determine the age of the fish. The age, along with the length of the fish, are used to determine the age-at-length for a sample of the fish population, which then is used to estimate the age distribution for the entire population or stock of the species.

The TIP is a major component of the Atlantic Coastal Cooperative Statistics Program (ACCSP) in the southeastern U.S. Atlantic coastal region and the Commercial Fisheries Information Network

(COMFIN) in the U.S. Gulf of Mexico coastal region. It also collects data from Puerto Rico and the U.S. Virgin Islands.

Vessel Operating Units (VOU)
Prior to 1970 the Bureau of Fisheries and the U.S. Fish Commission, which were the predecessor agencies of the National Marine Fisheries Service, collected little information on vessels actively participating in commercial fisheries. In 1979 NMFS initiated a system that provided data on vessels that actively participate in commercial fishing during each calendar year. The object of this system is to provide an inventory of vessels that answer two fundamental questions: How many vessels are fishing commercially? What are the characteristics of these vessels?

This inventory only includes vessels that are greater than five net tons and have a current US Coast Guard documentation number. This system is referred to as the NMFS vessel operating units. Data are available for the years from 1979 to 2002.

Because the vessel operating units data only include larger documented vessels, a count of the smaller, undocumented boats was conducted once a year by NMFS and state port agents from 1979 to 1995. Unlike the vessel operating units data, characteristics of the individual boats are not recorded. These annual counts of boats are referred to as boat and shore data.

Recreational Programs

Marine Recreational Fisheries Statistics Program (MRFSS)
The Marine Recreational Fisheries Statistics Program team provides essential marine recreational fisheries information to government, scientists, and the public.

The team of fisheries biologists, statisticians, and data managers provides accurate, precise, and timely fisheries-dependent information for US marine waters by:

- Conducting and evaluating the Marine Recreational Fisheries Statistics Survey (MRFSS) to produce catch, effort and participation estimates, and to provide biological, social and economic data,
- Ensuring quality control and quality assurance of the MRFSS,
- Researching new survey designs,
- Providing statistical advice and promoting quality recreational fisheries information within NMFS and to other natural resource management agencies and organizations,
- Participating in NMFS planning efforts to improve internal fisheries-dependent data collection and management,
- Participating in coastal State/Federal efforts to plan and implement coordinated and cooperative recreational fisheries data collection and management programs,
- Communicating survey and research results, and
- Educating the public about the survey and new research.

In September, 2004 the NMFS requested the National Research Council (NRC) of the National Academy of Sciences (NAS) to review current recreational fishing surveys funded or conducted by NMFS. This review was completed and published in April 2006 and includes recommendations that will result in an improved survey program that will better meet the needs of fishery managers. Beginning in January 2006, every fisherman who is interviewed dockside by the Marine Recreational Fisheries Statistical Survey receives a series of questions about the money they spent on that trip. They are also be asked to participate in a longer follow-up mail survey that collects information on annual expenditures and durable goods, like boats, trailers, rods and reels. When completed, these data allow NOAA Fisheries to estimate daily expenditures by fishing mode (i.e. private boat, charter, shore) and resident type (resident and non-resident). These expenditure estimates are then used to estimate the economic impacts of saltwater recreational fishing. Economic impacts demonstrate the importance of recreational fishing and help managers make decisions to make recreational fishing better. The last time this survey was conducted in 2000, U.S. saltwater fishermen spent $22.6 billion generating an economic impact of over $30.5 billion and supporting 350,000 jobs (not including Texas, Alaska, and Hawaii).

Headboat Survey
Researchers at the SEFSC Beaufort Laboratory have studied reef fish off the southeastern United States since the late 1960s and have addressed both applied fishery issues and basic reef fish ecology. The Laboratory's Southeast Region Headboat Survey collects fisheries and biological data to support stock management activities. These data sets are also used to examine patterns in the fishery and to study the structure and distribution of reef fish communities.

Cooperative Tagging Center (CTC)
The Southeast Fisheries Science Center formed the Cooperative Tagging Center (CTC) in 1992 in response to the recent expansion of tag release and recapture activities, data requests from other tagging agencies, and domestic and international tagging research needs. The CTC encompasses a variety of functions and responsibilities. The CTC also includes the Cooperative Tagging System (CTS), as well as other research projects such as tag development and performance research and cooperative work with endangered species.

The NMFS Cooperative Tagging Center has been impacted by the down sizing of the Federal Government and is being restructured.

9.2.3 Habitat and Ecosystem Research

9.2.3.1 General Coral Reef Conservation Grant Program

Each year, subject to the availability of funds, the NOAA Coral Reef Conservation Program publishes its Coral Reef Conservation Grant Program Funding Guidance, as authorized by the Coral Reef Conservation Act of 2000, to solicit proposals for coral reef conservation activities.

Funds are awarded under the following six program categories:

- State and Territory Coral Reef Management (Applicants: State and Territory Management Agencies);
- State and Territory Coral Reef Ecosystem Monitoring (Applicants: State and Territory Management Agencies);
- Coral Reef Ecosystem Research (Applicants: Academia, NGO's, etc.);
- Projects to Improve or Amend Coral Reef Fishery Management Plans (Applicants: South Atlantic, Caribbean, Gulf of Mexico, and Western Pacific Fishery Management Councils);
- General Coral Reef Conservation (Applicants: Academia, NGOs, Local and Tribal governments, community organizations, etc.); and
- International Coral Reef Conservation (Applicants: International governments, NGOs).

9.2.3.2 Coral Reef Ecosystem Studies

9.2.3.3 NOAA Fisheries SEFSC

South Florida Ecosystem Restoration

South Florida Restoration Team provides oversight and coordination of NOAA research in Florida Bay to ensure that scientific information is provided to water management agencies in south Florida to improve the ecological functioning of Florida Bay and other Florida estuaries. Scientists also conduct ecological studies of south Florida species as indicators of water quality, conduct associated research, and provide scientific information to management plans for the Florida Keys National Marine Sanctuary.

9.2.3.4 EFH Research

Information/Research Needs for Mangrove Habitat

Thayer et al. (In press) discussed research needs for mangrove systems based on a NOAA Coastal Ocean Program-sponsored workshop held in 1988. The following summarizes this paper and is separated into six priority areas of information needed.

<u>Food web-related information needs</u>

The prevailing paradigm regarding food webs of mangrove-dominated estuarine ecosystems is that they are based on particulate mangrove detritus, but recent research indicates that dissolved organics may be equally important. Research is needed to determine the contribution of mangroves to estuarine secondary productivity relative to contributions by phytoplankton, benthic micro- and macroalgae, and seagrasses. The studies by Fry et al (1999) and Fry and Smith (2002) have yielded some information, but more stable isotope work is needed.. Food web research needs to evaluate the significance of dissolved organic matter relative to particulate organic matter in trophic linkages and the distribution of higher trophic level organisms in various mangrove habitats in relation to gut contents and food linkages (e.g., as through the use of multiple stable isotopes).

<u>Information needs on productivity and structure of mangroves</u>

Little effort has been devoted to understanding the relationships between structural and functional attributes of mangrove communities or how these relations change with development of the mangrove stand over time. There is a need to characterize the dynamic nature of mangrove productivity and its influence on the productivity of adjacent coastal habitats. Protocols need to be developed that will enable investigators to remotely characterize forest structure, successional status and type.. The proportional contribution of mangroves to the total primary production of a given watershed or estuary is not well known. Rates of primary production of various components should be quantified and predictive models of primary productivity, as controlled by major factors, should be developed and tested. Research is needed on the ecological processes associated with recovery and succession of mangrove ecosystems, including research on the restoration and resiliency of restored mangrove systems and research on the significance of hydrology on succession patterns in mangrove habitats. The close coupling of mangroves to other hydrologic units in the landscape suggests that alterations in regional hydrology may induce changes in mangrove vegetation and functional patterns.

<u>Habitat use information needs</u>

Past research on the importance of mangrove habitats for fishes and invertebrates has focused primarily on fringing red mangroves, and that has been limited. The white and black mangrove habitats have been poorly studied. Each habitat type may export organic matter that generates chemical cues regulating the presence or absence and abundance of estuarine organisms and thus, the predictable spatial and temporal patterns of marine life. Determining the types and numbers of organisms that exploit these habitats, the functional aspects of habitat use, and how mangrove organic matter is transferred to higher trophic levels is critical, as are requisites for modeling linkages between variations in mangrove productivity and variations in faunal abundances. This requires work that compares spatial and temporal variation in use, feeding ecology and growth patterns.

Nutrient cycling information needs
Mangroves may influence nutrient dynamics and associated coastal productivity by either removing or contributing nutrients to these systems, and data on their function in maintaining water quality of estuarine ecosystems is limited. Processes associated with the immobilization of nutrients within mangrove ecosystems such as microbial decomposition and enrichment processes, and recycling, need to receive attention.

Restoration and Succession of damaged mangrove ecosystems
The effectiveness of mangrove restoration and creation projects in terms of mangrove community productivity, stability and faunal utilization patterns are poorly understood. The time frame for reaching natural growth and production rates has not been followed nor have the time courses for development of biogeochemical cycles and natural fish and invertebrate communities. Research also is needed to determine the effects of natural and human-induced perturbations on microbial decomposition and enrichment processes and on the significance of sea-level variations as factors contributing to successional patterns, habitat loss, and nutrient cycling processes.

Synthesis and modeling needs
Ecological models can be used in conjunction with field and laboratory approaches to obtain a better understanding of the role of mangroves in coastal ecosystems and to develop predictions of success of restoration designs. Scientists and managers need to synthesize extant information of ecological processes that address key management issues of mangrove habitats. Mapping efforts need to be expanded to provide information on the distribution of this important habitat type.

9.2.4 NMS Research Programs

Gray's Reef

Characterization of the Fish, Benthos, and Marine Debris at the Grays Reef National Marine Sanctuary

Gray's Reef National Marine Sanctuary (GRNMS) expressed interest in obtaining a baseline characterization of the benthic resources within Gray's Reef. To meet this need, the Center for Coastal Monitoring and Assessment's Biogeography Team, in consultation with the Sanctuary, is conducting a characterization to identify spatial correlations between fish communities, benthic features, and fishing impacts at Gray's Reef National Marine Sanctuary.

GRNMS encompasses approximately 58 square kilometers of seafloor located 17 nautical miles off the coast of Georgia in approximately 60 feet of water. Baseline characterization of GRNMS benthic fish and sessile invertebrates has not been conducted comprehensively throughout the Sanctuary. This project quantifies those resources through a robust, statistically defensible sampling design. The project builds upon the previously completed benthic maps for the sanctuary (completed in 2003 by CCMA Biogeography Team). Such an assessment is needed to support the many activities and responsibilities of sanctuary staff including natural resources management, education, research, and even for promoting responsible recreational use by fishermen and divers. An understanding of the distribution of benthic resources provides the spatial framework within which to conduct sanctuary monitoring activities, identify and protect essential fish habitat, and properly address other spatially explicit research and management goals. This baseline characterization is also the first step in monitoring temporal changes in the Gray's Reef landscape and understanding more about the dynamic nature of this region of the continental shelf. To meet this need, the Biogeography Team mapped benthic habitats of the Sanctuary using sonar imagery. Completed maps include ledges of varying heights, flat live bottom, flat sand, and rippled sand. These maps are used to stratify sampling design of fish and benthic cover. Fish communities, fishing gear, marine debris, and cover of sessile invertebrates are surveyed along diver transects within each habitat type.

Benthic Macroinfaunal Communities Assessment
The Center for Coastal Environmental Health and Biomolecular Research (CCEHBR), through its Coastal Ecology Program, conducts research within several sanctuaries to support long-term science and management needs within the National Marine Sanctuaries. At Gray's Reef NMS and surrounding shelf waters, they are assessing benthic macroinfaunal communities and chemical contaminant concentrations in sediments and biota. Key objectives are to document existing conditions of these resources as a benchmark for tracking changes due to natural or human disturbances; examine cross-shelf patterns in contaminant concentrations; and identify potential environmental factors associated with observed patterns.

Gray's Reef National Marine Sanctuary Assessment Project
In 2002, the Reef Environmental Education Foundation (REEF) initiated a fish-monitoring program within GRNMS. The project uses the REEF Advanced Assessment Team (AAT) to conduct annual visual fish surveys within GRNMS. The surveys are conducted using the Roving Diver Technique (RDT) to measure species composition and estimate abundances. Beginning in 2004, REEF added a quantitative size-monitoring component for targeted species (black sea bass, lutjanids and serranids). The primary goals of this project are to 1) to provide GRNMS with a taxonomic inventory of fish species found within the Sanctuary as well as a dataset that can be used through time to measure spatial and temporal trends, 2) to assess the size structure and biomass of key targeted fish species within the GRNMS, 3) to complement the current stationary visual fish counts that have been conducted at GRNMS since 1995, and 4) to increase local and national awareness on the Sanctuary resources and give constituents a comparative fish data resource that can be used for the better management of GRNMS.

This project has provided a substantial increase of effort in the REEF database. Prior to the start of this project in 2002, there were only 18 surveys from the Sanctuary in the database. As of July 2006, there are over 300 surveys from GRNMS in the REEF database. Several new fish records for the Sanctuary have also resulted from the REEF project.

Florida Keys

9.2.5 NOS NCCOS

Benthic Habitat Mapping of Florida Coral Reef Ecosystems
Southern Florida's coral ecosystems are extensive. They extend from the Dry Tortugas in the Florida Keys as far north as St Lucie Inlet on the Atlantic Ocean coast and Tarpon Springs on the Gulf of Mexico coast. Using 10 fm (18 m) depth curves on nautical charts as a guide, southern Florida has as much as 84 percent (30,801 sq km) of 36,812 sq km of potential shallow-water (<10 fm; <18 m) coral ecosystems the tropical and subtropical U.S. Moreover, southern Florida's coral ecosystems

contribute greatly to the regional economy. Coral ecosystem-related expenditures generated $4.4 billion in sales, income, and employment and created over 70,000 full-time and part-time jobs in the region during the recent 12-month periods when surveys were conducted.

Working with state, local, university, and other federal partners, NOAA initiated an effort to map and characterize the coral ecosystems of southern Florida. The Southern Florida Shallow-water Coral Ecosystem Mapping Implementation Plan (MIP) that was recently finalized discusses the need to produce shallow-water (~0-40 m; 0-22 fm) benthic habitat and bathymetric maps of critical areas in southern Florida and moderate-depth (~40-200 m; 22-109 fm) bathymetric maps for all of Florida. The ~0-40 m depth regime generally represents where most hermatypic coral species are found and where most direct impacts from pollution and coastal development occur. The plan was developed with extensive input from over 90 representatives of state regulatory and management agencies, federal agencies, universities, and non-governmental organizations involved in the conservation and management of Florida's coral ecosystems.

The MIP summarizes the map product needs of the southern Florida coral ecosystem conservation and management community. These needs include detailed, georeferenced, thematically accurate shallow-water benthic habitat and bathymetry maps. While considerable scientific interest and management requirements exist for coral ecosystems of the entire southern Florida region, priority areas were identified. Priority areas include the approximately 13,000 sq km of shallow-water coral ecosystems found in Martin, Broward, Palm Beach, and Miami-Dade Counties, Biscayne National Park, Tortugas Ecological Reserve, Dry Tortugas National Park, Florida Bay, and the Florida Keys National Marine Sanctuary. While considerable scientific and management interest exists in the West Florida Shelf, this area was considered to be a secondary priority area. As opportunities arise, targeted mapping activities will be conducted to characterize this area.

Based on geographic priorities and costs, the MIP recommends developing maps of approximately 13,000 sq km of southern Florida's shallow-water coral ecosystems. The estimated cost to generate a detailed shallow-water benthic habitat map using high-resolution satellite or similar imagery is approximately $4.35 million. This cost estimate includes purchasing commercial high-resolution satellite imagery, producing the actual benthic habitat map from the imagery, and completing an independent thematic accuracy assessment of the map. Because of the technical and logistic challenges and financial costs associated with imagery collection and map production, it is anticipated that four or more years will be required to complete shallow-water benthic habitat maps of southern Florida.

National Coral Reef Ecosystem Monitoring Program

This suite of projects is accomplished through cooperative agreements between NCCOS and State, Territory, and Commonwealth partner programs to monitor the status and condition of coral reef ecosystems throughout the U.S. Past objectives focused on filling in gaps in local monitoring. However, based on program evolution via consultation with island partners, the National Coral Reef Ecosystem Monitoring Program has developed into a full cooperative partnership between states, territories, commonwealths, and NOS-NCCOS. The programs objectives are as follows:

1. To work closely with jurisdictional partners and stakeholders throughout the US and its Territories to develop and implement a nationally coordinated, long-term program to assess, inventory, and monitor U.S. coral reef ecosystems; and,
2. Prepare a biennial report on the State of U.S. Coral Reef Ecosystem condition, with particular emphasis on assessing the impacts of threats to coral reefs worldwide, including: climate

change and coral bleaching, coral disease, tropical storms, coastal development, pollution, over fishing, and many others.

The objective of the State and Territory Coral Reef Monitoring Grant program is to provide support for NOAA partners towards implementing a nationally coordinated, comprehensive, long-term monitoring program to assess the condition of U.S. coral reef ecosystems, and to evaluate the efficacy of coral ecosystem management. This program was requested by the U.S. Coral Reef Task Force, which, along with the nation's coral reef program managers and the public, endorsed and called for implementation of "A National Program to Assess, Inventory, and Monitor U.S. Coral Reef Ecosystems."

NOAA began implementing the Program in 2000 and continues to administer it with Congressional appropriations for coral reef conservation. The Program includes the collection, analysis, and reporting of long-term coral reef ecosystem monitoring data pursuant to scientifically valid methodologies and protocols and is a key priority of the "National Coral Reef Action Strategy."

The Coral Reef Monitoring Grant Program, as authorized under the Coral Reef Conservation Act of 2000 (16 USC 6401-6409), provides matching grants to Governor - appointed point of contact agencies for the jurisdictions of Puerto Rico, the U.S. Virgin Islands (USVI), Florida, Hawaii, Guam, the Commonwealth of the Northern Mariana Islands (CNMI), the Republic of Palau, the Federated States of Micronesia (including Chuuk, Yap, Kosrae, and Pohnpei), and American Samoa for State and Territory Coral Reef Monitoring activities.

NOAA's National Ocean Service (NOS), through the National Centers for Coastal Ocean Science (NCCOS) provides funding for cooperative agreements to support state and territorial coral reef monitoring activities under the priority areas listed below, which have been recommended by the Nation's coral reef resource managers. These key biotic and abiotic parameters should be monitored at all local sites in the National monitoring network:

1. Benthic habitat characterization: e.g., depth, habitat delineation, and/or percent live/dead cover of corals, submerged aquatic vegetation, macroalgae, sponges, rugosity, diversity, etc.);
2. Associated biological community structure: including fish condition (e.g., abundance, density, size, diversity, disease, harvest trends, etc.) and large motile and sessile invertebrates condition (abundance, density, size, diversity, disease, harvest trends, etc.); and,
3. Water/substrate quality: (e.g., temperature, nutrient enrichment, toxic chemicals, turbidity, etc.).

9.2.7 Ocean Exploration and Research

The Office of Ocean Exploration is NOAA's center for new activities to explore and better understand our oceans. This office supports expeditions, exploration projects, and a number of related field campaigns for the purpose of discovery and documentation of ocean voyages. Bringing scientists to ocean frontiers requires rigorous planning, mission staging, and well coordinated marine operations.

Education and outreach rank high as office priorities. Through ocean exploration, NOAA is committed to raising America's science literacy and developing the next generation of ocean explorers, scientists and educators.

Four crucial components comprise the NOAA Ocean Exploration Mission:

1. Mapping the physical, biological, chemical and archaeological aspects of the ocean;
2. Understanding ocean dynamics at new levels to describe the complex interactions of the living ocean;
3. Developing new sensors and systems to regain U.S. leadership in ocean technology, and;
4. Reaching out to the public to communicate how and why unlocking the secrets of the ocean is well worth the commitment of time and resources, and to benefit current and future generations.

National Undersea Research Center
The National Undersea Research Center at the University of North Carolina Wilmington is funded by a grant from the National Oceanic and Atmospheric Administration as part of the National Undersea Research Program (NURP). NURP includes headquarters in Silver Springs, MD and seven regional centers. The center at UNCW supports undersea research off the southeastern United States from North Carolina to Texas. Center facilities and staff are located at the university's Center for Marine Science in Wilmington, NC and Key Largo, FL.

9.3 Ocean Observing Systems and Fisheries Oceanography

Ocean Observing Systems are an integral part of the transition to ecosystem management in the Southeast region. A brief review of atmospheric and oceanographic characteristics is provided in Section 9.3.1; the present status of real time observing elements in the SE Coastal Ocean is reviewed in Section 9.3.2; Data Management considerations are provided in Section 9.3.3 and Modeling approaches in Section 9.3.4.

9.3.1 Fisheries Oceanography in the South Atlantic Region

The Southeast Coastal Ocean Report (2005; http://seacoos.org/documents/report) provides a basis for the atmospheric and oceanographic characteristics of the US Southeast Coastal Ocean.

Atmospheric Characteristics

The atmospheric characteristics of the southeast coastal ocean are summarized in terms of the wind fields, and severe storms including winter cold air outbreaks and hurricanes.

Seasonal Wind Fields: Five seasonal wind regimes have been associated with the South Atlantic Bight and East Florida Shelf regions (Weber and Blanton, 1980; *Journal of Physical Oceanography*, 10:1256-1263).

- *Winter* (November to February/March): winds are persistently southeastward in North Carolina and turn more southward over Florida;
- *Spring transition* (March to May): winds shift to westward from Florida to South Carolina, with the winds elsewhere in the region being more variable;
- *Summer* (June and July): westward winds dominate the southern reaches of the domain, and northward flow sets in for the central to northern portions of the SAB (Georgia to North Carolina);
- *Fall* (August): the summer wind patterns break down and become generally disorganized except for Florida's westward and southwestward winds; and,

- *"Mariner's fall"* (September and October): southwestward winds (at times strong) occur over the domain, with westward winds at times over Florida.

Winter Cold Air Outbreaks (extra-tropical winter cyclones). During the winter months, extra-tropical cyclones often travel across the southeastern states and out over the Atlantic Ocean and are known for the devastating weather they sometimes bring. These storms frequently produce ice, heavy snow and gale force winds that can cause property damage and loss of life. Perhaps the most infamous of these cold air outbreaks contributed to the tragic loss of the space shuttle Challenger in January of 1986. Coincidentally, also in 1986, the Genesis of Atlantic Lows Experiment (GALE) investigated these storms and their effect on the SE coastal ocean (J. Geophysical Research, Vol. 94, number C8, 1989).

Hurricanes -- Tropical Cyclones: The Southeast US region typically experiences weekly easterly waves and several tropical cyclones (in some instances hurricanes) each year. Neumann (1993) quantified the mean direction of the tropical cyclone (TC) tracks from 1886-1989. Generally, if storms do not recurve east of 60°W, they will make landfall along the US coastline. The number of TC occurrences during this period was 70 in the Gulf of Mexico and 85 off Cape Hatteras, North Carolina. Given the high frequency of TC landfall in the SE and the large areas of low-lying land along the SE coast, accurate prediction of the oceanic interaction with, and response to, tropical storms is vital to ensure timely action by coastal emergency response personnel. The official Atlantic hurricane season runs from June 1 through November 30, with a peak from mid-August through mid-October.

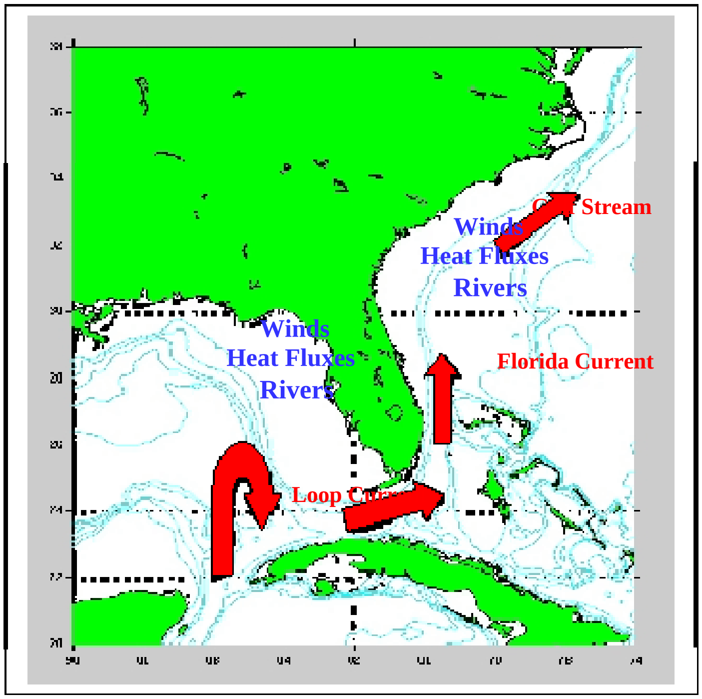
Oceanographic Characteristics

Geographic Setting: We define the Southeast Coastal Ocean as the domain extending from the Florida Panhandle to the North Carolina shelf north of Cape Hatteras, acknowledging overlap with the Gulf of Mexico coastal ocean domain in the west and the Mid-Atlantic Bight north of Cape Hatteras. Major geographical sub-regions with the SE Coastal Ocean are the West Florida Shelf (WFS), Straits of Florida (SOF), and the South Atlantic Bight (SAB), with the common boundary point between the former two at the Dry Tortugas and between the latter two at Cape Canaveral. Within SEACOOS, the functional sub-regions are the West Florida Shelf, East Florida Shelf (EFS), and the Carolina-Georgia Shelf (CGS). As is the case with other large regional coastal ocean domains, there is overlap between sub-regions in a number of areas.

The regional geomorphology of the SE United States defines a number of the key oceanographic characteristics of the SE coastal ocean. Much of the coastal area of Florida, Georgia, South Carolina and North Carolina is relatively low relief topography. Two sub-regions have relatively broad continental shelves. The WFS is a gently sloping carbonate platform, extending to >200 km from the coast to the shelf break. The SAB shelf (largely lithogenic deposits, with some carbonate strata) reaches a width of 100-120 km off Georgia and South Carolina, tapering to a much narrower width at its northern and southern ends, at Cape Hatteras and Cape Canaveral, respectively. In contrast, the SE Florida shelf along the SOF is rather narrow, being only several km wide in parts.

Local and Deep-Ocean Forcing: One of the key considerations regarding variability in material property distributions and exchange processes in the SE coastal ocean is the relative influence of local and deep-ocean forcing. Here we refer to material properties in a broad sense, including physical characteristics, such as sea level, water velocity, temperature, salinity, as well as chemical and biological constituents, such as nutrients, non-living particulate and dissolved organic matter, inorganic materials such as suspended clay particles, and organisms of various trophic levels.

A very simplified picture of some of the key local and deep-ocean forcings is represented in Figure 1. Local forcings include inputs of momentum through winds and pressure gradients, and inputs of buoyancy resulting from river discharge at the coast (and by ground water), from local precipitation/evaporation differences, and through surface heat flux. Deep-ocean effects include the



influence of the ocean boundary current and associated frontal eddies on the shelf circulation and material exchange, and through tides.

Fig. 1. A simplified representation of some of the key local and deep-ocean forcings that drive water motions and determine material property distributions in the SE Coastal Ocean. The coastal waters are linked by the Loop Current/Florida Current/Gulf Stream complex that runs along the shelf margin. Shelf waters respond strongly to atmospheric forcing by winds and air-sea fluxes. Freshwater is input along the coast from a number of rivers fed by the regional drainage basins.

Starting with the deep-ocean forcing, one of the defining characteristics of the SE Coastal Ocean is the presence of a major western boundary current system. The Loop Current/Florida Current/Gulf Stream complex (LC/FC/GS) provides a mechanism of rapid transport of materials along the ocean margin throughout the region, and strongly influences outer shelf circulation and material exchange processes along the shelf margins through formation and dissipation of meanders, fronts, eddies and sub-mesoscale vortices. Another deep-ocean forcing is from tides. The largest tides in the SE coastal ocean are found in the central portion of the South Atlantic Bight, with tidal ranges of 2.5-3.0 m near Savannah, Georgia and peak mid-shelf tidal currents of 40-50 cm/s. Tidal ranges are of the order of 1 m or less over much of the rest of the domain.

On the more local scale within the various sub-regions of the SE coastal ocean, variability in winds is obviously one of the major factors driving shelf circulation patterns. The general picture for seasonal and synoptic scale patterns of local wind forcing in the SE was summarized in the preceding section. Another local forcing is the input of buoyancy at the coast in the form of river discharge. Most of the river discharge along the coastline of the SE Coastal Ocean comes from drainage basins that are contained within the SE region. Thus, seasonal and interannual variability in regional rainfall and river discharge strongly influences coastal currents and hydrographic structure of the broader shelf region. However, the Mississippi River discharge can also impact the WFS and, at times is evident in lower salinity water along the shelf margin of the EFS and CGS due to transport in the LC/FC/GS system.

Known variations in cross- and along-shelf transports dictate regular monitoring at the shelf-break, mid-shelf, inner shelf at a minimum. In the more complex inshore waters, where spatial gradients are highly structured, relatively high-resolution observations will be required. There clearly is a need for ocean-side boundary conditions. This is particularly challenging for the Southeast coastal ocean domain because of the presence of the Loop Current - Florida Current - Gulf Stream system.

Summary Remarks on the Processes Defining Coastal Ocean Observing Systems

The basic design of an Ocean Observing System for the SE US coastal ocean must take into account a number of key geographic and physical characteristics of the region that control coastal ocean processes. These include:

- The presence of a western boundary current system (the Loop Current-Florida Current-Gulf Stream) along the shelf margin throughout most of the SE states (Florida-Georgia-South Carolina-North Carolina) coastal ocean, including the influence of its meandering jet and front and the mesoscale eddies it sheds;
- A wide range of shelf widths, from <10 km to >100 km;
- Several major estuaries and coastal lagoons (e.g., in Florida: Apalachicola, Tampa Bay, Charlotte Harbor, Florida Bay, Indian Lagoon, St. Johns River; in Georgia: Altamaha River, Savannah River; in South Carolina: Broad River, St. Helena's Sound, Charleston Harbor; and in North Carolina: Cape Fear River, Albemarle-Pamlico Sound) that exchange physical and biogeochemical properties and biota with the open shelf;
- Variable input of freshwater to the coastal zone from distributed SE river (and groundwater) sources, with the additional influence of the Mississippi River on the region that create cross-shelf density gradients;
- Seasonal patterns of heating and cooling that result in widely varying cross-shelf density structure which influence exchange with the deep ocean;
- The influence of synoptic weather systems, and especially major episodic storm events, including easterly waves and tropical cyclones in summertime and extra-tropical cyclones and frontal systems in wintertime, in producing turbulent mixing, coastal upwelling and downwelling, and other transient flows; and
- A highly variable diurnal and semidiurnal tide regime that is dominant in certain shallow water regimes.

Development of a complete system will likely take decades. What is described below is a design to be implemented over a 5-year timeline that concentrates on developing a viable information system for the continental shelf region of the SECOORA domain. Thorough testing of the adequacy of the system to satisfy the needs of the chosen applications is anticipated to result in revisions after the 5-year build-out. Designing an RCOOS for the SE US that can effectively address the IOOS societal goals requires consideration of a number of factors, including the SE environmental/oceanic setting, existing capabilities, and anticipated resources. Implementation of the SE RCOOS will be an incremental process. Due to the range of temporal and spatial scales over which coastal ocean processes operate, use of both observations and models is essential for creation of a robust and multi-purpose estimation (or prediction) system. The range of applications implied by the broad societal goals for the IOOS also dictates that a "nested" strategy will be required for the allocation of resources. Some degree of sub-regional to local focus will also be required for the RCOOS to serve in an R&D role for the RA (e.g., conducting data assimilation experiments, and providing technology testbeds).

While the initial focus for observations in the developing RCOOS will be physical variables, this does not imply that the RCOOS will serve only as a physical oceanographic estimation system. Rather, this reflects the present state of sensor development and maintenance issues for the existing biological and chemical sensors, and recognition of the importance of physical processes for driving biogeochemical and ecological processes. As more robust, cost-effective technologies become available for measuring chemical and biological properties, these will be incorporated into the RCOOS in a coordinated, multidisciplinary manner. Given the close coupling of physical processes with biogeochemical processes in the coastal ocean, an initial physics-based RCOOS observational design will also serve interdisciplinary needs, including implementing ecosystem-based management practices in the SE coastal ocean.

9.3.2 Status of Coastal Ocean Observing Systems in the Southeast

Some of the descriptions below on the status and possible enhancements of the southeast's regional observing system are taken from the article by Seim, H.E., C.N.K. Mooers, J.R. Nelson, R.H. Weisberg and M. Fletcher (2008) "Towards a regional coastal ocean observing system design for the southeast coastal ocean observing regional association", *Journal of Marine Systems*, in press.

Regional System

The definition of the structure of the U.S. Integrated Ocean Observing System (IOOS) has been developed in large part through the actions of Ocean.US, an interagency planning office established in 2000 to advance the development of IOOS. The U.S. coastal ocean component of the IOOS is envisioned to consist of a federal network (the "National Backbone") which will provide sustained support for *in situ* and satellite remote sensing observations, predictive models, and data management elements on the national scale, augmented by Regional Coastal Ocean Observing Systems (RCOOSs) (Ocean.US, 2002). Each RCOOS will be an integral component of its respective regional association (RA) of stakeholders (*viz*., data providers and users), which in turn is a member of the National Federation of Regional Associations (NFRA) (Ocean.US, 2004). Through the RA, the RCOOS will be responsive to regional and local needs and augment the National Backbone accordingly. As a pioneering activity associated with the regional development of a coastal ocean observing system (COOS), the Southeast Atlantic Coastal Ocean Observing System (SEACOOS; Seim et al., 2003) has considered the scientific and technical design criteria of the operational RCOOS that will be a central element of the Southeast Coastal Ocean Observing Regional Association (SECOORA). SECOORA and its RCOOS are required to be fully interactive and interoperable with other regional associations, especially with the neighboring GCOOS for the Gulf of Mexico and MACOORA for the mid-Atlantic, as well as with the National Backbone provided by the federal agencies (Figure 2). Discussed here are preliminary thoughts on the design of a RCOOS for SECOORA, some aspects of how this RCOOS may interact with the National Backbone, and how elements of the RCOOS will transition to certified components of IOOS.

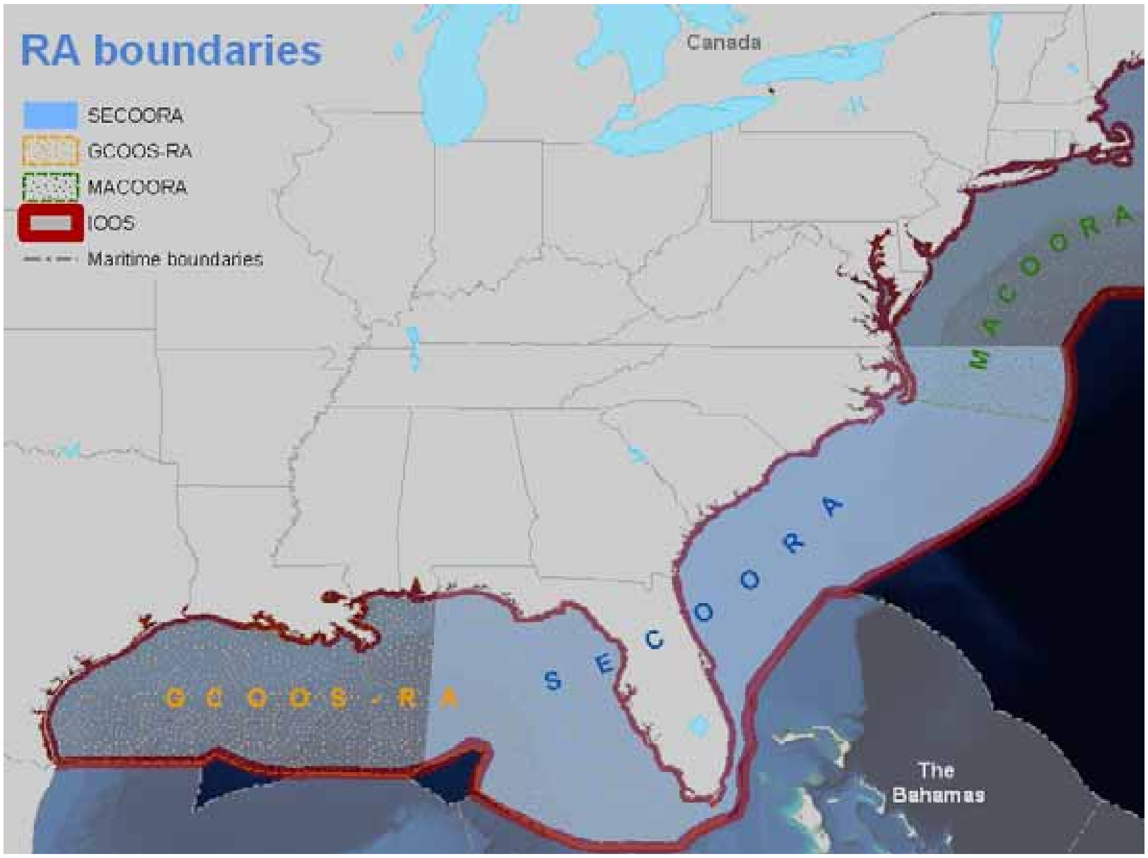


Figure 2 - Approximate boundaries of regional associations (RAs) and the coastal component of the U.S. Integrated Ocean Observing System (IOOS).

Since ocean processes are three-dimensional, time-dependent, and occur on many space-time scales, no single measurement system (*in situ* or remote) will be sufficient for describing any of the ocean state variables. A "multi-platform, multi-variable" observational approach is required, integrated with models (including data assimilation approaches). Furthermore, the fundamental value of continuous time series data should be recognized in the design process, such that real-time telemetry systems are backed up with internal recording of data, and delayed-mode and historical data are also integrated into the regional data management structure.

The following sections describe the existing observing system in the southeast Atlantic and possible enhancements are broken out by observing platform. The inventory of existing assets indicates a wide range of observing activities shoreward of the coastline in estuarine waters; because of this little augmentation is suggested. On the continental shelf there is a relatively sparse set of observing assets; the federally-funded program provides some measure of atmospheric and ocean surface properties but provide no subsurface observations except for some experimental current profilers. Regional and sub-regional programs like SEACOOS have effectively doubled the number of observing platforms on the continental shelf and provide the only near real-time subsurface observations. As examples of the impact made by the regional programs, SEACOOS HF radar provide surface currents over more than 20,000 km^2 where no other observations exist, and regional buoys and moorings increase the number of locations where bottom temperature is monitored from zero to fifteen. Because the only sustained observing elements in the coastal ocean are the federally-operated assets, the proposed observing system design focuses on implementing consistent regional coverage to provide reliable information on physical ocean state that can also be used to assess the accuracy of coastal ocean models.

Coastal Stations. Existing federally operated coastal stations, largely established by NOAA (in particular the National Water Level Observation Network of the National Ocean Service and the Coastal Monitoring Automated Network of the National Weather Service), US Geological Survey, National Park Service, and US Army Corps of Engineers are geared primarily to sea level and coastal meteorology. Within Florida the Water Management Districts also support a large number of water level gages. The distribution of stations that are tidally-influenced (Figure 3) indicates that these stations provide a foundation for further development of shore stations by the RCOOS, which should be approached in coordination/partnership with federal agencies and state and local coastal management and emergency response agencies. At present three areas in Florida are heavily instrumented, the St. Johns River/Jacksonville area in the NE of the state, the Everglades in the south, and the Tampa Bay area on the west coast.

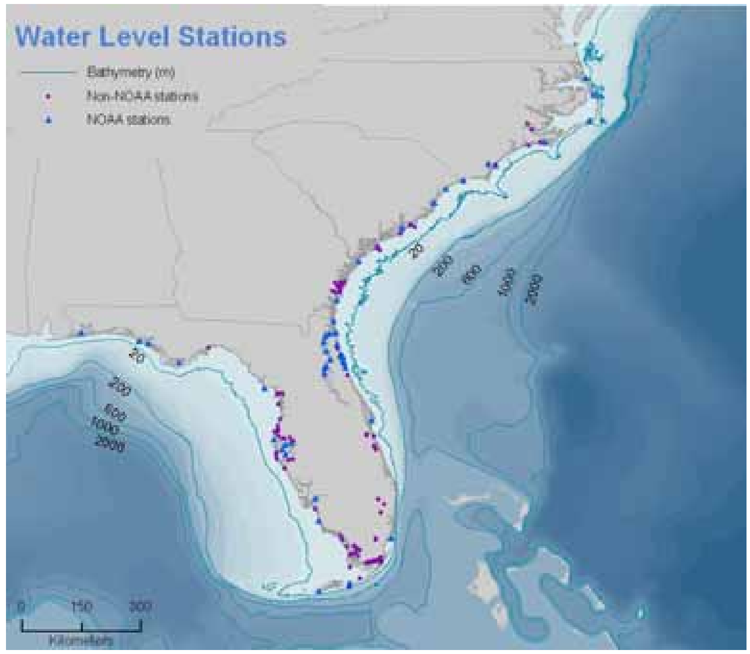


Figure 3. Distribution of existing water level observation stations that are tidally influenced.

Noticeable gaps in coverage exist along the east coast of Florida and in the Big Bend of NW Florida. Augmentation of water level stations in these locations and at commercial ports is warranted, since even small changes in water depth can impact the efficiency and safety of deep-draft vessel operations. Ten additional water level stations should be sufficient to fill the existing major gaps. Further regional partnering with the NOAA Physical Oceanographic Real-Time System (PORTS) program could be an effective approach in the ports. In terms of spatial coverage, there is a need for sufficient coastal water level stations to assess the predictive skill of both (1) high-resolution coastal inundation models, and (2) lower resolution coastal ocean circulation models. For coastal inundation/storm surge applications, there is a practical need to "over-sample" sea level, since many stations are subject to failure of instruments or communications during major storm events.

Fixed Moorings. The SECOORA domain includes regions with very narrow shelves (near DeSoto Canyon, the SE Florida shelf from Key West to West Palm Beach, and near Cape Hatteras) and broad, gently sloping shelves (off West Florida and in the central South Atlantic Bight). Obviously the deployment of observational assets will have to take this variability in shelf width and coastal ocean properties into account. For the broader shelf sub-regions, three basic sub-domains can be defined:

- A baroclinic (density-stratified) outer shelf/slope zone where the physical state is directly influenced by the boundary current (Loop Current/Florida Current/Gulf Stream);

- An inner shelf/coastal zone where the water column is shallow enough that there is interaction between surface and bottom boundary (Ekman) layers and wind, wave, and tide forcing are significant; in many locations, there is also a near shore zone in which the influence of relatively fresh estuarine outflows leads to additional buoyancy-driven flows;

- An intermediate/mid-shelf zone (if the shelf is wide enough to separate the inner and outer portions) where circulation is largely forced by winds and tides.

Existing shelf observation platforms include the buoys and coastal stations of the National Data Buoy Center (NDBC) and a collection of academically-supported sub-regional systems off the west coast of Florida, off Georgia, and off the Carolinas (Figure 4). The type of sensors each platform supports varies but in general the NDBC buoys emphasize meteorological instrumentation and currently provide limited ocean measurements. Coverage of oceanic variables is very sparse with the possible exception of near-surface temperature.

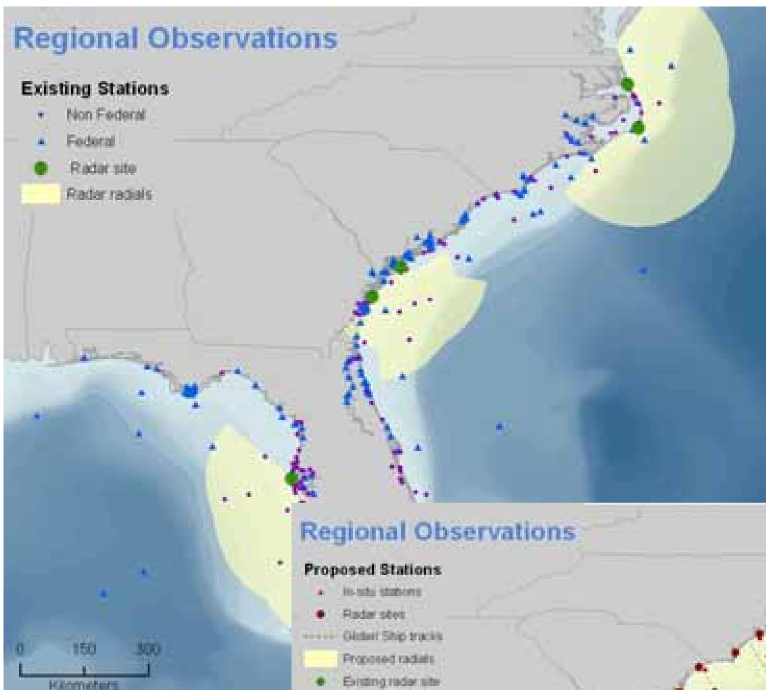


Figure 4. Depiction of th
showing coastal stations.
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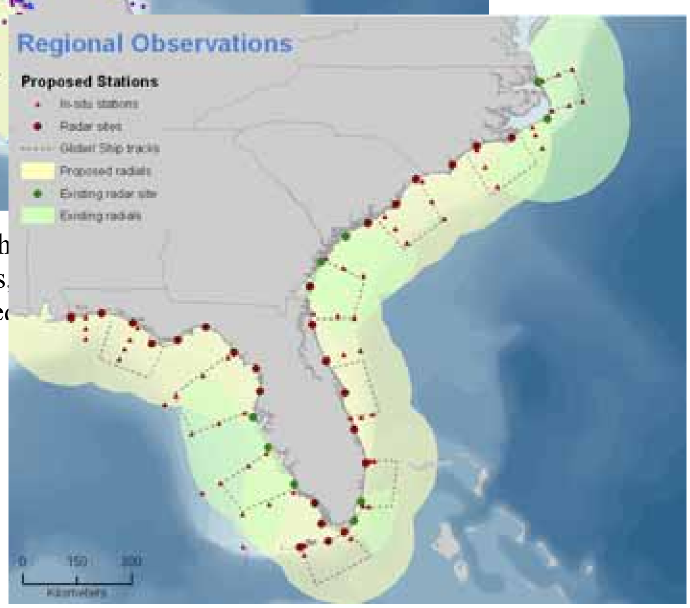

Figure 5. Proposed enhanced observing subsystem asset distribution to provide region-wide coverage on the continental shelf from HF radar, *in-situ* moorings and glider or ship transects. Note: these transects are for discussion purposes only. Local phenomenology will lead to finer tuning of the RCOOS array

Based on the above considerations of the ocean physics, a regular array of moored or fixed platform offshore observing elements distributed over the SECOORA domain is advanced (Figure 5). A detailed description of possible platform and instrument configurations is beyond the scope of this discussion. Here the focus is on an initial distribution of these assets on the continental shelf and a set of core variables to be measured. The proposed initial array consists of a series of cross-shelf deployments, at roughly 150 km spacing in the along-shelf direction, and linked, to the extent possible, to seaports, major topographic anomalies, and other special features. The along-shelf spacing is needed to resolve variability in the circulation; many features of coastal circulation in the SE occur at this scale or smaller (e.g., Florida Current and Gulf Stream meanders). For all but the narrowest shelves, each cross-shelf section would have three measurement sites, supplemented in the near-shore with additional deployments at major locations of estuarine outflow or population centers. The core set of instrumented buoys or platforms should all be equipped for measurements of temperature and salinity at multiple depths, current profiles, wind, and some should be equipped to determine directional waves and net surface heat flux. Given the ten existing NDBC buoys there is a need for an additional 50 moorings under this scenario.

Full water column measurements of current, temperature and salinity in each of the three coastal ocean regimes defined above are necessary to specify the flow and hydrographic (temperature, salinity, and density) fields. The surface and bottom boundary (Ekman) layers warrant particular attention given their roles in cross-isobath exchange. Full water column measurements are also required to assess key processes, including boundary current interactions on the shelf-slope, exchange at the shelf break between the coastal ocean and the deep ocean, coastal responses to local wind forcing, transport of organisms by internal tides, and direct estuarine interactions with the coastal ocean.

Another essential observation throughout the coastal ocean domain is surface winds. Due to the complication of land-sea interactions, the quality of numerical weather predictions over the coastal ocean can often be compromised. Most *in situ* moorings or platforms should therefore be equipped with surface wind and barometric pressure sensors. The complete suite of sensors required for heat flux estimates (incoming short- and long-wave radiation, air and sea temperatures, relative humidity) should be supported at a distributed subset of the offshore sites.

Other ancillary measurements are recommended (although not required at all sites), the foremost among these being surface waves. Directional wave spectrum measurements at the shelfbreak can provide the boundary conditions needed for coastal ocean wave models, and wave measurements nearshore can be used both to gauge the performance of these models and provide real-time data of immediate societal importance. Provisions for incorporation of additional chemical, geological and biological sensors, as these evolve, should also be included in the design of instrument, power, and communications packages.

Not addressed in this initial mooring design is an observation program for the slope and deep-water regions of the domain. The presence of the western boundary current makes these areas particularly challenging environments in which to maintain conventional moorings. Coordination with the National Backbone will be critical to deploying and maintaining an adequate array of slope and deep-water moorings and a leading role for NDBC and associated federal agencies in establishing this portion of the regional network will be strongly encouraged by SECOORA. Other possible observing technologies include cable-based transport estimates and inverted echo sounders.

Additional moored and fixed platform *in situ* assets (not represented here nor budgeted for below) will likely be positioned in areas of regional and local interest (e.g., major ports and shipping lanes, inshore areas subject to shoreline erosion and rip currents, and Marine Protected Areas) and supported through local initiatives. Measured variables at these sites will necessarily be tailored to the local applications (e.g., directional waves, wind, and nearshore currents). There may also be a need for strategic (or "targeted") observational arrays in critical locales to support the requirements of data assimilation. It is recognized that the RCOOS should provide some discretion in the organization of observational resources to serve local needs, and to best exploit available resources and infrastructure, including those supported by the National Backbone and state and local agencies.

Coastal High Frequency (HF) Radar. Coastal HF radar mapping of surface currents provides one of the more important of the potential RCOOS measurement systems, offering a field of surface velocity vectors as opposed to the point measurements typical of fixed offshore assets (Paduan et al., 2004). Two commercially available systems are operated in the SECOORA domain by academic institutions, CODAR and WERA, each offering varying range and resolution based on frequency and bandwidth (Figure 4). There are presently no HF radar installations operated by federal agencies. HF radar is a topic area where the RCOOS can play an important role in technology assessment. Given the wide range of shelf widths off the SE U.S. and the rather unique oceanic configuration of a western boundary current on the continental slope, careful assessment of options to provide HF radar coverage over the entire region is advisable. Regional coverage using long-range systems is critical to achieve because of their ability to discern the position of the boundary current and its influence on the shelf and is a necessary first stage of development (Figure 5). In addition to surface currents, continued evaluation of other potential products from HF radar (such as a spatial grid directional wave estimates from WERA) should be pursued. Deploying HF radar on islands or offshore platforms and transmitting shoreward should also be tested as a means to provide nearshore surface current coverage that is otherwise difficult to obtain, especially for convex coastlines. Assuming the existing radar systems will continue to be operated, an additional 30 installations are needed to provide region-wide coverage.

Satellite Remote Sensing. While not an asset class to be deployed, operated or controlled by the RCOOS, satellite remote sensing represents a critical resource for coastal ocean applications. Sea surface temperature, surface ocean color products (including upper layer chlorophyll and suspended materials), sea surface height, surface winds and other products from passive and active satellite sensor systems are routinely available. Such satellite information is being used for assimilation into models and for descriptive purposes. While the satellite programs themselves would not be an RCOOS function, RCOOS support for utilization of satellite data and production of enhanced products, tuned and/or calibrated to regional applications, will provide strong justification for continued federal agency support of satellite missions targeting the coastal ocean. In the SE coastal ocean, applications of passive satellite imagery could include detection of near-surface phytoplankton blooms (some of which may be harmful algal bloom species), identifying and tracking waters of riverine origin and episodic cross-shelf transport, and detection of sediment resuspension events. An RCOOS role in the support of regional capabilities for downloading, processing, and distributing satellite data, as well as for analysis products and presentation tools, will be critical for effective integration of the satellite information with *in situ* observations and application in regional modeling programs.

Profilers and Gliders. The conventional method for observing 3D fields of temperature, salinity, and other properties (such as chlorophyll and nutrients) is by ship survey. This approach is, however, slow (and often non-synoptic) and costly. At present there are no regularly scheduled spatial surveys occurring on the continental shelf in the SECOORA domain. Needed are techniques for synoptic mapping at intervals sufficient for assimilation into models, particularly for the internal density (Temperature/Salinity) field. Through a combination of profiling floats, moored profilers, autonomous underwater vehicles (AUVs), and gliders it should be possible to obtain regular (i.e., routine, standardized, and sustained) mapping of the vertical and horizontal T/S structure, as well as that of other variables with the addition of appropriate sensors. Several systems are presently being assessed in field trials in the SE. It is envisioned that an appropriate mix of platforms would be used to occupy offshore transects that align roughly with the mooring lines (Figure 5). Ten operations areas are envisioned, each with a offshore leg that in most cases will be sampled while moving with the western boundary current.

Ship Transects. Since robust, accurate, automated biogeochemical sensors will likely not be available near-term, it will be necessary to include some repeated shipboard surveys of biogeochemical variables and biota. Such surveys should be designed to optimize synergy with the deployed observational elements and real-time prediction systems, and take into account what is known of natural variability in the coastal ocean. There may also be a role here for airborne surveys equipped with remote sensors, expendable profilers, and other air-deployable systems.

Voluntary Observing Ships. With the large volume of commercial shipping and recreational boating activity in the SE, it may be possible to obtain additional valuable regional coverage by installing automated instrumentation packages on a voluntary basis, as has been done in the International SeaKeepers program on a global scale on private vessels (www.seakeepers.org) and on commercial vessels. On the more local scale, the FerryMon (http://www.unc.edu/ims/paerllab/research/ferrymon/index.html) project in North Carolina has made use of an inshore ferry as a monitoring platform.

Surface Drifters. Satellite-tracked surface drifters provide a quasi-Lagrangian view of surface circulation and, with caveats regarding their performance relative to Lagrangian trajectories (not necessarily surface-confined), provide excellent tools for surface trajectory analyses. Drifters are essential for establishing the error attributes of predicted trajectories; conversely, they are invaluable for estimating the dispersive properties of varying coastal ocean circulation regimes. Nearshore deployments can be useful for filling data gaps in coastal HF radar coverage, and for examining connectivity between adjacent estuaries and sources of fresh water along many sections of the SECOORA domain. A regular program of drifter releases on the shelf that complements existing drifter programs in deep water should be initiated. Release of drifters from various locations in the domain is suggested, using 150 drifters per year (e.g. monthly releases at a dozen locations). Deep-water examples are the collation of drift tracks by the Atlantic Oceanographic and Meteorological Laboratory, NOAA and those tracks made available by Horizon Marine, Inc in the Gulf of Mexico. Coordination with the US Coast Guard, the marine services industry and NOAA will maximize coverage.

Sub-regional Systems

Smaller within-region observing systems exist and can be considered as contributing to the overall regional system.

Coastal Ocean Monitoring and Prediction System (COMPS) is based at the University of South Florida and includes the only Physical Oceanographic Real-Time System (PORTS) facility in the southeast (*http://comps.marine.usf.edu/index.html*). PORTS is a NOAA/NOS CO-OPS program. COMPS utilizes shore stations, coastal moorings with buoys and high frequency radar (HF radar, which measures surface current velocities) to observe the coastal ocean along the WFS. A broad range of variables is measured at the shore stations and offshore moorings. These include those measured by NDBC, plus additional variables at selected sites that may include short -and long-wave radiation, precipitation, water temperature and salinity at multiple depths, current profiles, and various optical properties.

The South Atlantic Bight Synoptic Offshore Observational Network (SABSOON, *http://www.skio.peachnet.edu/research/sabsoon*) is based at a set of offshore Navy air tactical control towers on the Georgia continental shelf. The system hosts a wide range of equipment, similar to COMPS, and includes underwater video used for fisheries studies. Additional nearshore sites off South Carolina and Georgia have been added by from the University of South Carolina and the Georgia Institute of Technology (Savannah campus; *http://wavebuoy.gtrep.gatech.edu*). These systems are focusing on nearshore directional wave measurements.

The North Carolina Coastal Ocean Observing System (NCCOOS, *http://nccoos.unc.edu/*) operates a HF radar system on the Outer Banks and has instrumented one of the Navy platforms off Georgia with meteorological sensors.

The Carolinas Coastal Ocean Observing and Prediction Systems (Caro-COOPS, *http://www.carocoops.org*) operates offshore moorings that report meteorological and ocean conditions and have installed three meteorological and augmented water level stations along the SC and south NC coast that are now considered part of NWLON.

The Coastal Ocean Research and Monitoring Program (CORMP, http://www.cormp.org) has deployed a series of real time weather and sea state buoys off of the NC coast, as well as partnering with Camp Lejune Marine Corp Base and the National Data Buoy Center (NDBC) to deploy a collaborative buoy in Onslow Bay, NC. In addition to the programs noted above, there are several other institutions making real-time observations available. These include the FDEP and a directional wave gauge at Melbourne Beach, Florida (*http://beach13.beaches.fsu.edu/melbourne/melbourne.asp*). Real-time but proprietary observing systems are operated by WeatherFlow (*www.weatherflow.com*) in North Carolina, South Carolina and Florida.

9.3.3 Regional Observing System Information Management

Information Management (IM) is fundamental to the operation of the RCOOS. Establishing a network of local-to-regional-to-national-to-global IM systems will enable the collection, aggregation, accessing, utilization, archival, and dissemination of coastal ocean data and information products. This has been an area of emphasis in Ocean.US IOOS planning. To advance the IOOS Data Management and Communications (DMAC) Subsystem, it will be necessary to establish a coordinated and cooperative network among the various regional systems and the users of IOOS products. New capacities will be needed to establish this network and ensure its functionality at a range of temporal and spatial scales. The IOOS DMAC is envisioned to comprise the following components (described in the first IOOS Development Plan, Ocean.US, 2006).

- *Metadata* -- These data describe data sets for the national system, including development and use of a common vocabulary, identification of required metadata fields, agreement upon sites for publication of metadata, and commitment to publish metadata in a timely fashion.
- *Data Discovery* -- The capacity for searching and locating desired data sets and products and for manipulating accessed data must be established.

- *Data Transport* -- Data and products must be capable of transport over the Internet in a transparent, interoperable manner.
- *On-Line Browse* -- Data must be readily accessed and evaluated through common Web browsers.
- *Data Archive* -- Mechanisms for secure, short-term and long-term data storage must be established.
- *Data Communications* -- The communications infrastructure for accessing and transporting data and data products must be identified and maintained to meet standards.

Regional and sub-regional observing systems in the SECOORA region have established a number of the necessary components described by IOOS DMAC. Where the capability for addressing specific requirements does not yet exist, progress has been made in identifying and characterizing those needs, with a view towards "filling the gaps." In general, efforts focused primarily in SEACOOS, with support from the Carolinas Coastal Ocean Observing and Prediction System (Caro-COOPS), have established a system that enables the aggregation, access, and dissemination of real-time and delayed-mode data from *in situ* observations, model output, and remotely sensed imagery. This aggregation and subsequent visualization of distributed data requires development of a process that can be utilized by other regional and sub-regional systems, and can help the community push towards interoperability. The steps being taken to establish this system of aggregated data include:

- Inventory of existing and potential data types;
- Identification of standard data ontologies, file formats, and transport protocols;
- Software for data applications and for interfacing different applications; e.g., Web mapping;
- Database schemas for the variety of data types.

Experience has shown that an effective approach toward a regional IM system is to engage distributed information providers through standards that promote interoperability. This type of construct has been commonly termed a "services-oriented architecture." Each of the observation and model data providers should be required to adhere to a set of standards and practices that enable information exchange among and between all of the partners. There is also a need to have a central aggregation site or hub that is a clearinghouse for standards and that maintains a database of the aggregated information and/or links to data sources. This central hub need not be physically located in a single location but does require a single presence on the Internet. Given the volume of information involved and the vulnerabilities related to natural and other hazards, it is strongly recommended that at least two physical locations be established that can support the central site activities. Two sites would enable a minimum level of redundancy and fail-over capability in case of interruptions in services.

Thus the design recommendations are that SECOORA should:

- Establish a regional "hub" for RCOOS IM that provides coordination, guidance, and centralized data aggregation, distribution, and storage functions;

- Maintain and strengthen distributed foci of IM expertise at the major observational and modeling sub-system locations. This step will provide in-house management of data, assurance of implementation of standards, and technical support, with assistance from the central hub;

- Establish one or two back-up sites to provide redundancy and ensure continuous operations in case of infrastructure failures at the central hub;

- Establish an agreement with a NOAA archive(s) (e.g., National Ocean Data Center or National Climatic Data Center) for long-term security and archival of observational and model data. Separate regional archives are needed for more "specialized" or region-specific data products (e.g., data aggregations, high-resolution model outputs);

- Identify robust satellite telemetry system(s) for transmission of real-time data, and establish or secure the necessary land-based connectivity and bandwidth for information dissemination;

- Identify appropriate standards with respect to common vocabulary, metadata format and content, metadata publishing protocol, data formats, and transport protocols; and

- Establish a portal that serves as a single site for accessing regional IOOS observational data and model/prediction products, as well as links to other user-targeted portals that utilize/provide specialized treatments of regional data.

9.3.4 Modeling systems

Within an initial build-out plan, the majority of applications envisioned to be served by Observing Systems can provide predictive capabilities through the development of a set of models:

Physical state models. These include models for circulation (3D time-varying representations of coastal ocean currents, sea level, temperature and salinity), waves (2D representation of the surface gravity wave field and sediment transport), and the marine atmosphere (3D time-varying representation of the coastal atmosphere). Enhanced spatial resolution can be provided and/or improved through the nesting of models. The model set includes tidal and storm surge inundation models (separate or components of circulation models) capable of incorporating wetting and drying and that can accurately represent the flooding of lowlands during high-water events (e.g., hurricanes, extra-tropical cyclones).

Biogeochemical and ecosystem models. These must be coupled to circulation models for prediction of nutrient fluxes and the responses of various trophic levels to environmental variability. The existing models are complicated, have many free parameters, and require a broad spectrum of observations to calibrate and validate. It will likely require many years of R&D to develop full operational capabilities in this area.

Socio-economic models. This broad class of models would address a range of topics, including the role of humans in the coastal ocean ecosystem (e.g., changes of land and water use, changes in population distributions), how socio-economic systems may respond to manifestations of climate and global change in the coastal ocean, and the broader implications of alternate management strategies. Some simple implementations exist but development of models that interface and are eventually coupled to physical state and biogeochemical/ecosystem models will also require many years of R&D to develop full operational capabilities.

At present there are no regional scale coastal ocean circulation, storm surge or surface gravity wave modeling activities that enjoy sustained support; the modeling efforts that are sustained are those that occur on a national or ocean basin scale. Existing elements of regional and basin-scale modeling systems that include the US Southeast coastal ocean are outlined below, focusing on components that provide near real-time hindcasts and forecasts of the coastal ocean includes:

HYCOM (*http://www7320.nrlssc.navy.mil/GLBhycom1-12/ATLANTIC.html*)*:* Output from the "toward-operational" HYCOM/GODAE North Atlantic model is available to downscale into regional model domains. The HYCOM products can provide estimates of the regional hydrography, as well as offshore surface elevations due to the proximity of the western boundary current to the continental shelf, on a frequency of once per week. Though impressive depictions of the basin-scale ocean are possible, the existing implementations are limited to water depths greater than 15 m (and hence do not accurately represent nearshore or inland waters), and do not include tidal forcing. However, these types of basin-scale models are vital because they can provide boundary conditions for coastal models (Figure 6).

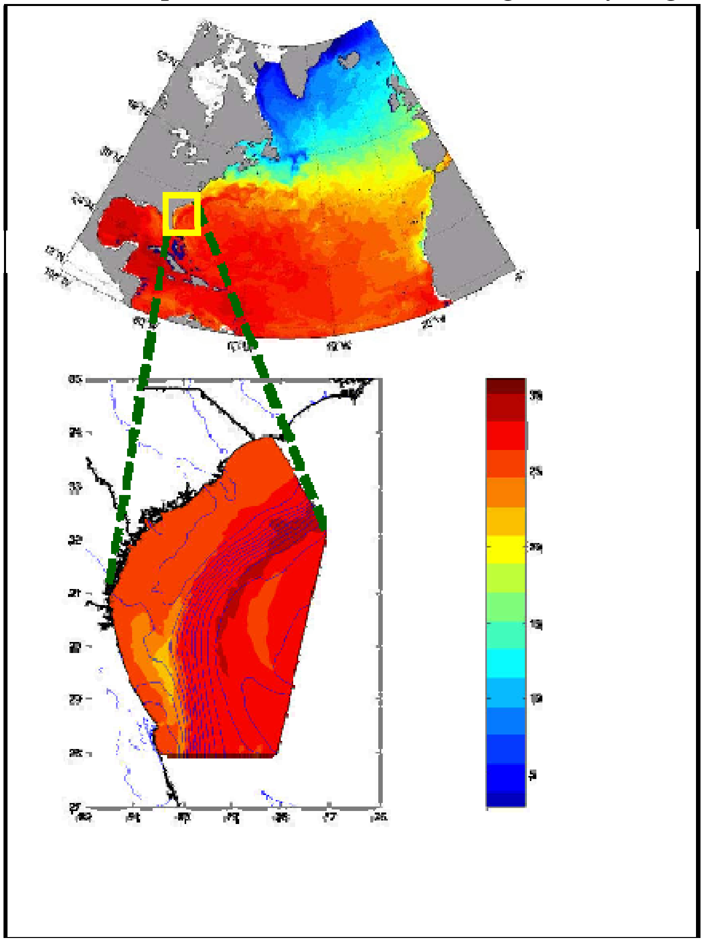

Figure 6. HYCOM model fields can be used as initial and boundary conditions for sub-regional model runs (the SAB in this case). Color scale is surface seawater temperature (˚C).

NLOM & NCOM (*http://www7320.nrlssc.navy.mil/global_nlom/*): An effort by the Naval Research Lab (NRL) Layered Ocean Models (NLOM) generates real-time nowcast/forecast results. Model products relevant to regional applications include sea surface height (SSH), sea surface temperature (SST) and surface currents. The 1/8° global Navy Coastal Ocean Model (NCOM) is an operational product run daily by the Naval Oceanographic Office (NAVOCEANO) with atmospheric forcing from the Navy Operational Global Atmospheric Prediction System (NOGAPS) and assimilation of SST and satellite altimeter data obtained via the NAVOCEANO Altimeter Data Fusion Center. As for the HYCOM model, the NLOM/NCOM forecast fields can be considered in the initialization and forcing of regional model solutions.

RTOFS (*http://polar.ncep.noaa.gov/ofs/*): The Real-Time Ocean Forecast System is based on HYCOM and simulates temperature, salinity, surface elevation, and currents for the North Atlantic. The model is driven at the ocean surface boundary by heat, moisture, and momentum fluxes provided by NCEP's Eta mesoscale atmospheric forecast model.

Next steps in establishing a regional circulation modeling system

Given the present state of development of regional-scale modeling systems for the SE coastal ocean, it is proposed that the initial focus be on creating, testing and operationalizing model systems to predict the physical state of the coastal ocean. The initial three ocean components to be emphasized are circulation modeling, storm surge modeling, and surface gravity wave modeling. There is also a need for regional-scale atmospheric modeling to better incorporate coastal ocean-atmosphere interactions. In all cases, adequate resolution to address specific applications is to be achieved through nesting regional or subregional scale models within national modeling systems. How best to achieve adequate resolution will need to be determined through thorough testing, but at a minimum there should be some redundancy in effort. It is suggested that several modeling groups in each of the modeling component areas be supported initially.

Based on the experiences gained through SEACOOS of operating three subregional-scale circulation models to nowcast coastal ocean conditions, a series of design principles are suggested.

- The importance of simulation experiments (e.g. OSSEs) to aid with the evolving design of the RCOOS should be recognized.
- The diversity of the model/prediction subsystem should be embraced. No one model is sufficient for the range of desired applications and this diversity provides the potential for ensemble forecasting.
- A hierarchical, distributed approach to operational modeling/prediction sub-systems should be followed. For example, Global-NCOM and Atlantic-HYCOM models can be sub-sampled for regional-scale circulation estimation products. Similarly, even higher-resolution local-scale models can use output from sub-regional models for open boundary conditions.
- The RCOOS design should foster the further evolution of modeling/prediction sub-systems. This would include: accommodation of the nesting of very high-resolution inner shelf and estuarine/lagoonal models; the coupling of dynamical models (coastal mesoscale meteorological, coastal hydrological, and coastal wave models); the coupling of (one-way, embedded) applications models (e.g., ecosystem, sediment transport, and wave models); and the utilization of advanced numerical modeling methods (e.g., data assimilation schemes, non-hydrostatic models, and unstructured and adaptive grids).
- The RCOOS modeling program must encompass comprehensive baroclinic operational circulation models (essential for advective and turbulent transport estimates, water quality and ecosystem models) and integrated barotropic operational tide, storm surge, and wave models (essential for coastal inundation estimates, sediment transport models).
- Output from sub-regional model/prediction sub-systems (together with in situ and satellite remote sensing observations) should be directed to sub-regional marine forecast centers. These should be operated in a partnership fashion with the NWS Weather Forecast Offices, value-added industry, media, and academia.

The models needed to predict the physical state of the coastal ocean have information requirements beyond the observations already identified. Access to accurate measures of freshwater fluxes (from rivers, precipitation and groundwater) is needed for the circulation models to accurately represent the mass field. For storm surge modeling, high-resolution bottom and coastal topography is required, registered to appropriate datums and with sufficient spatial resolution to support local emergency management needs. High-resolution bottom topography in the surf zone and nearshore is needed for surface gravity wave models to accurately represent modifications of the wave field near the coastline. Where existing information is lacking (e.g., poor quality bottom topography) the RCOOS can advocate for improvements.

Establishing an Ecosystem Modeling Approach

Ecosystem models are envisioned to describe the variability of nutrient and lower trophic levels (phytoplankton and zooplankton) and their links to target fish species in the SECOORA region. These activities will support the regional move to Ecosystem Based Fisheries Management as directed by the President's Ocean Action Plan and embraced by the South Atlantic Fishery Management Council's (SAFMC) Fishery Ecosystem Plan. One target fish species could be Gag (Mycteroperca microlepis) and is a member of the grouper family in the snapper/grouper complex managed by the SAFMC. (See below for a list of other target species to be considered.) Gag has high commercial and recreational fishery value; and its distribution ranges throughout the SECOORA region ranging from the continental shelf and shelf-edge, into the nearshore and estuarine regions. As such it requires integration across all SECOORA assets, to obtain sufficient information to aid the SAFMC in its assessments.

Considering gag as an example, a modeling approach would require that both abiotic and biotic effects be considered. The role of circulation on gag recruitment would be evaluated, including the effect of on- and offshore positions of the deep ocean currents (e.g., the Gulf Stream) on the transport of larvae from their spawning locations to the mid-shelf, where a combination of wind- and tidal currents modulated by larval behaviors, subsequently carries them to their juvenile estuarine habitats. Additionally the development and implementation of a suite of ecosystem models ranging from point- to 3D formulations, including uncoupled or dynamic linkages between lower and higher trophic levels.

Anticipated specific tasks include:

<u>Obtain hydrodynamic fields.</u> The fields need to be computed at ecologically relevant space and time scales to characterize the flow field in the SECOORA region relevant to the transport (dispersal and retention) of gag larvae from offshore spawning locations to estuarine nursery areas. The 3D circulation fields will be spatially and temporally comprehensive fields, including offshore forcing, meanders, gyres and upwelling events. Downscaling to "ecological hotspots", e.g., individual reefs or inlets will proceed with local higher resolution models forced by boundary conditions derived from the domain-wide circulation.

<u>Formulation of spawning model and model seeding.</u> Gag spawning aggregation sites have been identified throughout most of SECOORA's offshore/shelf edge regions at shelf break sites between the 50-100 m isobaths. Spawning will be specified to occur over time based on hatch date distributions, and model runs will determine the temporal and spatial trajectories of particles onto the shelf and near-inlet regions.

Adapt Lower Trophic Level models (LTLs) to the SECOORA region. Presently there are no LTLs for the southeast Atlantic ecosystem. They need to be developed to represent the main phytoplanktonic and zooplanktonic groups in SECOORA, beginning with point models and building complexity to include the full 3D structure embedded in existing realistic circulation models. Computation of monthly-to-seasonal-to-yearly descriptions of the SECOORA region would serve as a baseline against which longer (interannual) variability can be assessed.

Develop a conceptual model of the food web. Characterize primary production in region for incorporation into Ecosystem models (e.g., Ecopath and Ecosim).

Combine circulation and LTL nowcast-forecast system. Combined with the circulation fields, the ecosystem model will provide short-term forecasts of oceanographic fields. This information will refine Essential Fish Habitat designations intended to reduce or eliminate the impact of fishing and non-fishing activities on habitats essential to managed species and their prey as federally mandated.

Recruitment forecasts. Development of nowcasting capabilities of the oceanographic and ecosystem models and provide relevant information for use in the South-East Data, Assessment, and Review (SEDAR) recruitment forecast process. Our model results will be used in the SEDAR process in its gag stock assessment for the region.

Other potential target species for the US Southeast Atlantic Coastal Ocean.

1. ***Reef fishes in general, Gag and Red Grouper in particular:*** Gag Grouper (and other reef fishes) spend their adult lives offshore and their juvenile phases in nearshore and inshore seagrass beds or oyster reefs. Evidence exists on adult spawning regions (shelf break) and times (late winter to spring) as well as on the juvenile settlement times (late spring to summer). However, the 3D pathways and mechanisms by which the larvae transit to settlement, both of these being significant factors in larval survival and recruitment, remain to be determined.
2. ***Shallow and Deep coral reefs:*** habitat characterization and restoration of shallow coral reefs, as well as deep *Oculina* and *Lophelia* coral reefs require understanding the physical and biological processes determining the environment at the shelf-edge, over the shelf, and near the coast, including the importance of self-seeding, sensitivity to changes in feeding and hydrographic fields, connectivity with other parts of a larger ecosystem, regional water quality, etc.
3. ***Interactions and linkages between various populations; scallops in particular:*** Bivalves such as scallops and other commercial species are not distributed uniformly along the coast. Are there relationships between species distributions and the seasonally varying currents and other physical factors such as temperature and salinity? Are there significant inter-annual variations that impact these population linkages and resultant abundances?
4. ***Forage species and their role in supporting pelagic species biomass:*** Pelagic fishes depend on the abundances and distributions of smaller forage species. What environmental factors control the abundances and distributions of the forage species and thus the migrations/distributions of the pelagic species?
5. ***Species life history for those fish that spend part of their life in the estuaries and part offshore, i.e., estuarine-dependent species such as mullet, menhaden, spot, flounder, croaker, gag, gray snapper, Spanish mackerel, etc.:*** Specific pathways (to be determined) exist between the major estuaries and the coastal ocean that depend on buoyancy (salinity in particular), winds and tides. Mullet, menhaden and others may be target species; however, this topic pertains to many commercially and recreationally important species. Modeling and observational tools presently exist to make this a tractable problem for scientific investigation.

1. ***The benthic connection, e.g., shrimp:*** Three-dimensional studies must include the benthos since the

bottom boundary layer likely provides an important connection in the general pathways/mechanisms framework. Hence primary and secondary productivity within the bottom boundary layer is likely important for the higher trophic levels considered above. Shrimp, as a commercially important species provides a focus.

9.4 Ecosystem Modeling

9.4.1 South Atlantic Ecopath Model

An Ecopath model is a quantitative description of energy flows in a food web. The model creates a static, mass-balanced snapshot of the resources in an ecosystem and their interactions, represented by trophically linked functional groupings. These groupings consist of a single or multiple species representing ecological guilds. The model is constructed by defining a model area and time, organizing species (and detritus) into the above mentioned functional groupings, and estimating the biological (i.e., energy) characteristics of each grouping. Ecopath models and their defined components are then 'balanced' in terms of mass or energy to gain insights into an ecosystem and its biotic components, and to obtain a whole-system view of the biological community. The Ecopath mass-balance approach was initially developed by Polovina (1984). Since that initial application, over 100 Ecopath models have been constructed, mostly in marine ecosystems, and the approach has been refined considerably.

Ecopath models can be analyzed in their static form (Christensen and Pauly 1992), but the dynamic simulation routines Ecosim and Ecospace (Walters et al. 1997, Walters et al. 1999) have expanded the utility of the approach considerably. These dynamic routines use the information in an Ecopath model to simulate how a the ecosystem's biota would respond to changes in fisheries harvest strategies or disturbance regimes (Ecosim). Such analyses can also be conducted in a habitat-based context (Ecospace). Ecosim also enables exploration of social, economic, and ecological trade-offs in harvest strategies.

These complimentary approaches, Ecopath and Ecosim, provide a rigorous and relatively simple framework to provide testable insights into the causes of ecosystem changes. Most importantly, they can be used to implement ecosystem-based management by aiding in the design of policies that account for indirect impacts of human activities. The relative importance of factors that shape communities can be explored by comparing (temporal and spatial) simulations to empirical information about such changes. Simulation results are often consistent with ecological theory (Christensen 1995, Vasconcellos et al. 1997), but they can be even more useful when simulation results are counterintuitive. Either way, Ecopath with Ecosim analyses can provide useful insights into marine ecosystem organization and functioning.

Physical forces are not explicitly included in Ecopath models, though they can be included in the Ecosim routine to distinguish their role from that of trophic forces. Approaches such as physical forcing, trophic mediation, and time-series fitting are available to compare and combine simulated biological and physical forces.
These approaches are discussed by Christensen et al. (2000).

Ecopath models are never final because ecosystem knowledge is never complete. The usefulness of such models can improve considerably, however, through iterative combinations of simulation and empirical research in a whole ecosystem context (Pauly et al. 2000).

The Ecopath master equation

The parameters necessary for the construction of an Ecopath model are found in the Ecopath master equation (Equation 1.1):

$$B_i \cdot (P/B)_i \cdot EE_i = Y_i + \sum B_j \cdot (Q/B)_j \cdot DC_{ji} + BA_i + NM_i \qquad \text{Equation 1.1}$$

where,
Bi and Bj = biomasses of prey (i) and predators (j) respectively;
P/Bi = production / biomass; equivalent to total mortality (Z) in most circumstances (Allen 1971);
EEi = ecotrophic efficiency; the fraction of the total production of a group that is utilized in the system;
Yi = fisheries catch per unit area and time (i.e., Y = F*B);
Q/Bj = food consumption per unit biomass of j; and
DCji = contribution of i to the diet of j;
BAi = biomass accumulation of i (positive or negative);
NMi = net migration of i (emigration less immigration).

This equation expresses a balance between a group's net production (terms to the left of the equal sign) with all sources of its mortality (terms to the right). It states that the net production of a functional group equals the sum of (1) the total mass (or energy) removed by predators and fisheries, (2) the group's total natural senescence (i.e., flow to detritus), (3) the net biomass accumulation of the group, and (4) the net migration of the group's biomass.

The thermodynamic constraints implied by Equation 1.1 underscore the power of Ecopath models as a focal point for refinement of ecosystem information. The need to reconcile energy production and demand among components of the food web narrows the possible ranges of parameter estimates for particular groups.

The law of conservation of mass or energy is expressed in this master equation, but the biomass accumulation and migration terms distinguishes this 'energy continuity' approach from a strictly 'steady state' approach. This basic 'continuity' constraint enables representation of changes in populations (i.e., functional groups) when expressed in dynamic form (not discussed here).

Because the Ecopath model of the entire system is a set of these linear (master) equations solved simultaneously, the Ecopath routine can solve for any of the four basic input parameters; B, P/B, Q/B, and EE (Christensen and Pauly 1992). These along with diet compositions, are the main parameters derived. Other information such as spatial and temporal distributions, habitat preferences, assimilation efficiencies, detritus fate, and other pertinent information are also covered in these parameter estimation sections.

Development of the South Atlantic Bight Ecopath Model
A preliminary South Atlantic Bight Ecopath model (Okey and Pugliese, 2001) was developed as part of the Sea Around Us project funded through the PEW Charitable Trust Foundation.

This preliminary Ecopath model covered the area from Cape Hatteras in North Carolina to the easternmost extent of the Florida Keys, and from the intertidal and the entrance of estuarine systems to the 500 m isobath. The time period characterized by this preliminary model is four years during in the late 1990s (1995-1998). The area covered was estimated to be 174,300 km^2. The slope of the sea floor steepens seaward of the 200 m isobath (and sometimes shallower); for example, the area delineated by the 200 m isobath is estimated to be 133,300 km^2, which is only 24% less than the area delineated by the 500 m isobath.

Four main sources were used to assemble the list of over 600 species for the area covered by the initial model: summary data from the Southeast Area Monitoring and Assessment Program (SEAMAP) including a species list reviewed by SEAMAP personnel (P. Webster), the National Marine Fisheries Service (NMFS) commercial and recreational fish landings for North Carolina, South Carolina, Georgia, and the east coast of Florida (www.st.nmfs.gov/st1/); a species list developed for the West Florida Shelf system (Mackinson et al., 2000); the NMFS marine mammal stock assessments; and two sea turtle the web sites; www.nmfs.noaa.gov/prot_res/PR3/Turtles/turtles.html and www.cccturtle.org/species.htm.

A semi-systematic approach was taken to aggregate all species into 42 functional groups. This was accomplished by organizing the list of species into groupings that were based on the functional roles of the species. Usually, this was operationally defined by diet compositions, but also by natural history characteristics. Special groups in the model included groups managed under a federal fishery management plan and fish groups for which commercial or recreational landings exceeded 200 tonnes in any of the states within each area. Specialists were consulted to identify groups of special concern (e.g., baleen whales).

This preliminary Ecopath model of the South Atlantic continental shelf was constructed to provide a quantitative framework for the refinement of the model's input parameters so that a cohesive view of the whole marine ecosystem could emerge, and so that system-wide questions about the workings of the system could be explored. This model constituted a focal point for scrutiny and criticism of input parameters, and thus acted the foundation for further refinement and expansion. The refined model, will be expanded to cover the area that coincides with the South Atlantic Council's jurisdiction, i.e. from the NC/VA border through the Florida Keys, and from the upper reaches of wetlands to the 300 m isobath.

Procedure for model construction

Thomas A. Okey
CSRIO

Procedures for deriving model input parameters and constructing Ecopath models include literature reviews, empirical studies, or coordinated approaches by broad collaborations of experts (e.g., Okey and Pauly 1999). The South Atlantic Bight model was constructed by a core group of researchers based on contributions by expert collaborators. These regional and topical experts contributed written sections to this compendium describing basic parameter derivations for each functional group. Inputs to this model were based on the latest available information on the entire suite of biotic components of the South Atlantic Bight.

Eight steps can be taken to construct an Ecopath model:

1. Define the ecosystem in space and time – the spatial extent of the system and the represented time period must be clearly defined. Parameter estimates are expressed in annual units, but any time period can be represented.

2. Define functional groups – Myriad species comprise interaction webs, but these species must be aggregated into related groupings that make sense in terms of ecological function, and the types of questions of interest.

3. Estimate basic parameters for each functional group. These parameters are listed and documenting these derivations makes up the bulk of this chapter.

4. Estimate fisheries information – Landings, discards, discard fates, and economic information can be entered for each fisheries gear type.

5. Estimate additional Ecopath parameters – detritus fates, assimilation rates, multiyear trends, spatial and temporal distributions, and habitat associations.

6. Enter parameters into the windows-based input interfaces (see www.Ecopath.org).

7. Characterize model pedigree by ranking parameter quality (i.e., confidence).

8. Balance the model according to thermodynamic constraints.

The biological components of the ecosystem are generally represented in Ecopath using average values, or other meaningful measures of central tendency that take into account both annual (seasonal) changes and ontogenetic changes. Production rates, consumption rates, and diet compositions vary among seasons and life history stages for most species in aquatic systems. However, explicit inclusion of seasonal information into Ecopath with Ecosim modeling merely makes answers messy rather than changing the basic results of analyses (based on experience with a large number of Ecopath models; C. Walters, UBC Fisheries Centre, personal communication.).

Ontogenetic changes can be incorporated using Ecopath with Ecosim using two approaches. First, groups can be split into adult and juvenile 'pools' that are linked through and age structured growth and recruitment parameters; Second, numerous ontogenetic 'stanzas' can be specified for an integrated calculation of a given Ecopath parameter. This latter approach in particular enables real-time incorporation of variable growth, production, or consumption models into the representation of Ecopath parameters (C. Walters, UBC Fisheries Centre, personal communication).

Still, the assumption of 'average' representation of parameters is a useful convenience for modeling at the scale of entire systems because these values describe the basic interaction and energy structure of a food web. 'Energy continuity' offers a powerful mass-balance-type constraint to model parameterization and construction. Section X describes the balancing methodology employed for the South Atlantic Bight model.

Additional parameters
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(i) Unassimilated / Consumption
Only a fraction of the food eaten by organisms is assimilated to the body; non-assimilated food is expelled. Proportions of unassimilated food must be specified in Ecopath, and this fraction flows to specified detritus pools. A default value of 0.2 was used for carnivorous fish groups (Winberg 1960) since assimilation efficiency information for particular fish species was scarce. This means that 80%

of the food was considered assimilated. Values of 0.4 and 0.3 were applied to herbivores and planktivores since these groups preying on harder-to-digest food.

(ii) Detritus Fate
The fate of detritus is the defined pool of detritus that unassimilated food and dead organisms are specified to flow in to. A portion of the dead and decaying animals falling through the water column (including fishery discards) is directed to 'dead carcasses.'
The specific proportions are assumed based on a subjective judgment relating to the habitat and niche of the various organisms (Apendix 2). The majority of detritus from non-assimilated food is directed to water column detritus and sediment detritus, but these ratios vary depending on the types of organisms. Approximately 50% of the detritus from birds is considered to be exported from the system (i.e., corpses and feces end up on land). All dead and decaying macroalgae and seagrasses contribute to the drift macrophytes detritus pool. Ultimately, detritus from the 4 detritus groups flow to the sediment detritus pool which is then exported from the system as sediment detritus is buried and rendered unavailable to the system.

"Balancing" the model

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Ecopath models must be 'balanced' in the sense of achieving continuity among energy fluxes in the defined ecosystem, not in the sense of 'static equilibrium.' Continuity of energy fluxes must likewise be achieved for each particular group within the overall system.

Because an attempt is made to account for all fluxes, Ecopath models do not inherently assume 'steady state.' If the total combined demand of energy on a particular group exceeds the production of that group (plus the energy needed for respiration), the group is commonly said to be out of 'balance,' in the sense of energy discontinuity. Ecopath models constructed with good information for most or all components in a system tend to require minimal 'balancing.' This is because energy continuity is a true property of real world ecosystems.

The degree of discontinuity, or "imbalance," in each functional group is revealed by the calculated 'ecotrophic efficiency' values. Ecotrophic efficiency (EE) is the proportion of the net production of a group that is consumed by predators or fisheries (or directly exported). These EE terms are calculated after initial input parameters have been derived and entered. An ecotrophic efficiency value of greater than one is impossible, as it indicates that total energy demand on a functional group exceeds total production and maintenance of that group. EE values greater than one are thus used as diagnostic indicators of model discontinuity or "imbalance." This is the handle for balancing, and changes in these values are monitored while adjusting model inputs.

<u>Model balancing strategies</u>
Strategic approaches are implemented when balancing Ecopath models to optimize the representation of the system, and to avoid erosion of contributed information. For example, adjustments to input parameters are best made after prioritization according to 'degree of imbalance,' 'quality of estimates,' or other criteria applicable to the system at hand. The quality of estimates can be

characterized by specified confidence bounds for each parameter or by ranking the data 'pedigree' of parameters.

Some experienced Ecopath modelers suggest that model balancing should focus on diet composition adjustments because diet composition data tends to be very high relative to other parameters (V. Christensen, UBC Fisheries Centre, personal communication). However, this relative uncertainty among parameters should be assessed on a case-specific basis. Indeed, for some functional groups, the uncertainty of input parameter estimates such as biomass might rival or surpass uncertainties associated with diet compositions. Finally, model users can introduce bias into the model through a one sided approach to balancing. For example, a model can be erroneously inflated by increasing prey biomasses, or production rates, or both, rather than taking a balanced approach by including the reduction of predator consumption rates, or by re-allocating diet compositions.

Commonly, 'top-down' balancing strategies have been applied to balancing Ecopath models, in that the production and/or biomass estimates of lower trophic levels (where uncertainty can be more common) is increased to meet the demands of upper trophic levels. The result of such a method is that the biomass or production rates at the lower trophic levels can be inflated unrealistically to achieve a balanced model (T. Dean in Okey and Pauly 1999). Clearly, such a result is unrealistic and this potential interjection of bias points to the need to make a conscious effort to apply a more evenhanded approach during balancing. Not only should the accounts tally, but more importantly they should stay within the specified bounds of confidence and make intuitive sense in terms of ecological interactions. The fundamental importance of the balancing procedure as a crucial bridge to the ecology of a system must be emphasized to users who might otherwise view the balancing step as merely a necessary technical modeling procedure.

Parameter pedigree assessment
Parameter 'pedigree' index values can be assigned to each input parameter of an Ecopath model. Ecopath's parameter pedigree routine is an approach to convert qualitative rankings of parameter quality to quantitative confidence intervals. The output of this routine can be used during manual balancing, automated balancing and analysis routines, such as the Monte Carlo routine 'Ecoranger,' or in meta-analyses that compare various models in terms of relationships between model attributes and overall data pedigree. Assigning pedigree values to functional groups whose parameters are derived from combined estimates from many data sources of varying quality is a subjective task, but nevertheless instructive. In a more general sense, it is informative to future users of the model to be as explicit as possible about the level of confidence in input parameters. The parameter pedigree routine thus enhances model transparency beyond a description of parameter derivation. The pedigree index value represents the quality or relative confidence assigned to each parameter estimate.

9.5 Indicators of Ecosystem Health and Habitat Conservation Targets

(Excerpted from SARP Aquatic Habitat Plan in prep.)
The National Coastal Condition Report II (NCCR II) (USEPA 2004) utilized data from the EPA's National Coastal Assessment (NCA), which gathers data on biota and environmental stressors; NOAA's National Standards and Trends Program, which utilizes site-specific data on toxic contaminants and their ecological effects; and the Fish and Wildlife Service's National Wetlands inventory (NWI), which provides information on the status of the nation's wetlands. In the NCCR II, five primary indices were developed using these data sources for (1) water quality, (2) sediment

quality, (3) benthic habitat quality, (4) coastal wetlands and (5) fish tissue contaminants. Although these indices do not address all characteristics of estuaries and coastal waters, they do provide information on ecological conditions. Characterizing coastal condition was a two-step process. The first step was to assess conditions at individual sites for each indicator. In the second step a regional rating for each indicator using a scale of five (1= poor, 2-4 = fair, 5 = good) was determined, based on the percentage of the area of each region in a given condition. The mean of the indices for the five indicators was then calculated to yield an overall condition index for each region. Using these indices, the NCCR II found that the overall condition for the Southeast Coast estuaries North Carolina, South Carolina, Georgia and east Florida coasts) was 3.8, and for the Gulf Coast estuaries, 2.4. Although the more recent National Estuary Program Coastal Condition Report (USEPA 2006) also assessed estuarine condition for these same regions using this process, only four of the five indicators were used.

9.5.1 National Fish Habitat Action Plan

The National Fish Habitat Action Plan is addressing a crisis for fish nationwide: loss and degradation of aquatic habitats. The plan was initiated in 2001 through the efforts of the Sport Fishing and Boating Partnership Council to explore development of a partnership effort for fish similar to that implemented for waterfowl in the 1980s through the North American Waterfowl Management Plan. The waterfowl plan has been cited as the mechanism that, over the past two decades, has given rise to the boost in waterfowl populations by forming strong local and regional partnerships to protect key habitats.

In 2004 the International Association of Fish and Wildlife Agencies, which represents all state wildlife agencies, voted to lead the National Fish Habitat Action Plan with the U.S. Fish and Wildlife Service and NOAA Fisheries as principal Federal partners.

The plan is bringing together fisheries professionals and partners with a shared interest in protecting, restoring and enhancing our waterways and fisheries. The strength of the National effort is the unique and diverse blend of industry, government, tribal, academic, and conservation groups and individuals with a determination to focus national attention and resources on restoring fish habitats.

The Action Plan will be implemented through the following four strategies which together will lead to results that can be measured against protection, restoration and enhancement goals: 1) Support existing fish habitat partnerships and foster new efforts; 2) Mobilize and focus national and local support for achieving fish habitat conservation goals; 3) Measure and communicate the status and needs of aquatic habitats; and 4) Provide national leadership and coordination to conserve fish habitats.

9.5.2 National Fish Habitat Board

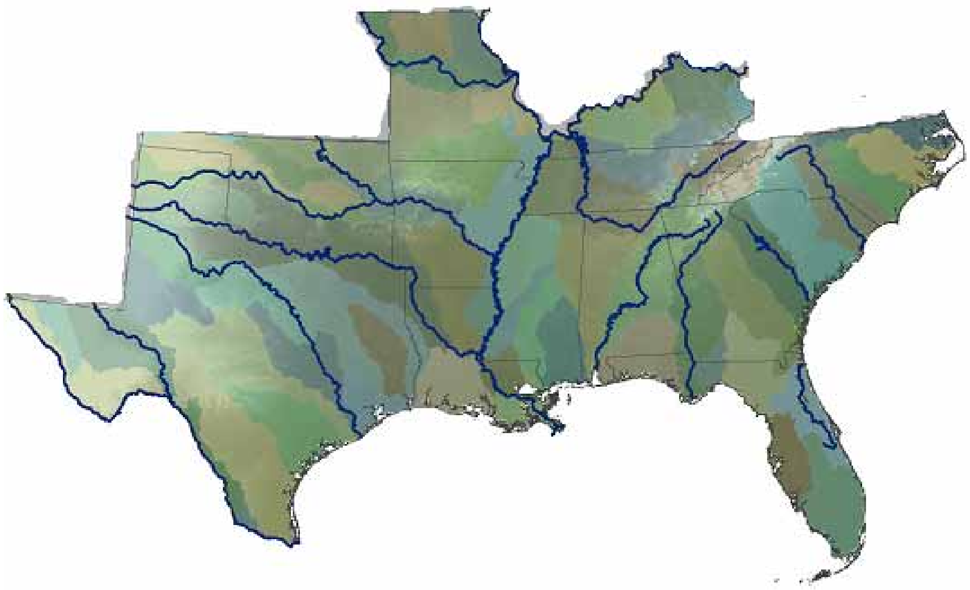
The National Fish Habitat Board which held its inaugural meeting on September 22, 2006, is charged with leading the implementation of the National Fish Habitat Action Plan. The Board includes representatives of outdoor industries, federal, regional and state natural resource agencies, Native American tribes, and conservation and recreation organizations.

The Board has met five times since its formation in 2006 and is closely coordinating with a Federal Caucus of nearly 20 federal agencies that are in the process of realigning priorities and resources to better support the plan. The Association of Fish and Wildlife Agencies is identified as a lead participant ensuring state agencies are well represented. The Board is addressing the criteria and process for formal recognition of Fish Habitat Partnerships which are the basic work units of the Action Plan. As the National Fish Habitat Action Plan is modeled after the North American

Waterfowl Management Plan, the establishment of Fish Habitat Partnerships is integral to its success in protecting, restoring and enhancing fish and aquatic habitats. Board recognition as a Fish Habitat Partnership will be contingent upon meeting criteria that identify strong and diverse partnerships, work within a defined geographic focus, remain strategic and consistent with national goals, and contain the potential for measurable progress. In addition, each Fish Habitat Partnership will be expected to implement the National Fish Habitat Action Plan under the guidance from the board. Guidance for Establishing Fish Habitat Partnerships

9.5.3 Southeast Aquatic Resources Partnership Habitat/Ecosystem Conservation Targets

The Southeast Aquatic Resources Partnership (SARP) was initiated in 2001 to address issues related to the management of aquatic resources in the southeastern U.S.
These issues include significant threats to the aquatic resources and habitats of the Southeast.



SARP is one of five Fish Habitat Partnerships named by the National Fish Habitat Action Plan and endorsed recently by the National Fish Habitat Board. As the regional partnership in the Southeast, SARP provides a method for state, regional and federal agencies, conservation groups, tribes, landowners, industry, and the public to interact in the development of regional aquatic habitat priorities and the implementation of projects to address those priorities. This partnership envisions a southeastern United States with healthy and diverse aquatic ecosystems that support sustainable public use. Relationships have developed between State and Federal agencies, private organizations, conservation groups, and other regional stakeholders that extend beyond the traditional boundaries of aquatic resource management agencies and establish a commitment to truly work together for the benefit of the resource. SARP is currently developing a regional aquatic habitat plan for the Southeast that will help guide the implementation of the National Fish Habitat Initiative efforts on a regional scale. Pilot watershed conservation action plans have already been developed for four major southeast river systems (Duck River, TN, Roanoke River, NC, Altamaha River, GA and Pascagoula River, MS) that detail specific actions to improve and protect aquatic habitats and biological integrity in these systems. SARP actively seeks funding and local partners to implement specific local actions that are prioritized on a regional and national scale.

The South Atlantic Fishery Management Council as a member of SARP, supports the implementation of aquatic habitat conservation and restoration projects including those proposed through the newly designated NOAA Community-based Restoration Program (CRP) run through SARP. The Council views this partnership as an effective mechanism to accomplish the National

Fish Habitat Initiative's National Fish Habitat Action Plan goals on a regional scale in our coastal watersheds. The commitment of our federal and regional partners to work closely with the states is critical to achieving the National Fish Habitat Action Plan. The Council envisions the state habitat conservation recommendations included in the Fishery Ecosystem Plan for the South Atlantic region will serve as or expand on the South Atlantic portion of the SARPs Southeast Aquatic Habitat Plan (SAHP) to present recommendations on conservation, management and restoration of Essential Fish Habitat down to individual watersheds where possible.

Drawing on the technical expertise of regional ecosystem partners involved in the development of the Fishery Ecosystem Plan and on the recommendations presented in the FEP the SARP/NOAA partnership will find support in identifying, selecting and implementing coastal habitat restoration projects in the South Atlantic region.

SARP provides an excellent opportunity to strengthen federal-state partnership for implementation of projects that directly benefit living marine resources and to engage coastal communities throughout the Southeast. A fully realized SARP supported with enhanced funding through the National Fish Habitat Plan will achieve conservation of high priority fish habitat (including Essential Fish Habitat). This effort will be enhanced especially if South Atlantic State and regional conservation recommendations and projects are presented in both the Fishery Ecosystem Plan for the South Atlantic Region and SARP's Aquatic Habitat Plan.

9.5.4 Synergy of National and Regional Habitat Conservation and Ecosystem Based-Management

In addressing the habitat directives established by the Magnuson-Stevens Fishery Conservation and Management Act, the South Atlantic Fishery Management Council designated many priority aquatic fish habitats occurring primarily in State waters as Essential Fish Habitat or Essential Fish Habitat Areas of Particular Concern for federally managed species. The Council's Fishery Ecosystem Plan for the South Atlantic Region will bridge the gap between State and regional needs by highlighting priorities (to watershed where possible) for South Atlantic States developed with input from State Sub-Panels of the Council's Habitat and Environmental Protection Advisory Panel.
In addressing the directive of the National Habitat Plan, National Habitat Board, SARP has developed the Aquatic Habitat Plan to facilitate regional coordination on meeting high priority habitat conservation and restoration goals. Funded projects in South Atlantic watersheds from the headwaters of the rivers to the coastal ocean will support and facilitate conservation of Essential Fish Habitat and enhance biological, economic and social values provide by a healthy ecosystem structure and function in the region.

9.5.5 Southeast Aquatic Habitat Plan

SARP is developing a Southeast Aquatic Habitat Plan to identify regional priorities for aquatic habitat conservation and restoration, and facilitate action at the local level that addresses regional and national priorities. The development of the Southeast Aquatic Habitat Plan is currently underway with two of four pilot river basin conservation plans initially developed to serve as models for the development of a complete regional plan The Altamaha Watershed Report and The Roanoke River Watershed Report are in the South Atlantic. Workshops were held by SARP in October 2006 and April 2007 to gain stakeholder input on the technical aspects of the Plan and develop the implementation and partnership aspects of the plan. The following public draft with stated conservation targets, was finalized in March 2008.

Southeast Aquatic Habitat Plan
Southeast Aquatic Resources Partnership - March 2008

This document was prepared by the Habitat Subcommittee of the partnership known as the Southeast Aquatic Resources Partnership (SARP). It was funded by the Multistate Conservation Grant Program (Grant GA M-1-P), a program supported with funds from the Wildlife and Sport Fish Restoration Program and jointly managed by the association of Fish and Wildlife Agencies and the U.S. Fish and Wildlife Service, 2007.

SARP was formed in 2001 to address the here-to-fore uncoordinated management of aquatic resource issues in the southeastern United States. It is a voluntary collaboration of natural resource managers and professionals, both inland and coastal, working together to protect, conserve and restore aquatic resources throughout the Southeast. The core members of the partnership include the natural resource agencies in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia, the U.S. Fish and Wildlife Service, National Oceanic and Atmospheric Administration National Marine Fisheries Service, the Gulf States Marine Fisheries Commission, the Atlantic States Fisheries Commission, and the Gulf and South Atlantic Fishery Management Councils. Nongovernmental organizations, industries and private citizens with goals and objectives that parallel those of the SARP member agencies participate in the partnership as well.

The plan was developed as a joint effort of all the member agencies and partners of SARP plus many other stakeholders throughout the region. It is broad and regional in nature, given the geographic and biological range of SARP's 14 member states.

SARP is recognized as an official partnership of the National Fish Habitat Initiative to implement its Action Plan (NFHAP) to conserve inland and coastal fishery habitats throughout the nation. This plan will be support NFHI restoration projects in the Southeast.

For additional information about SARP, see http://www.sarpaquatic.org, and on NFHI, see http://www.fishhabitat.org.

Because this is a regional plan, the targets to quantitatively and qualitatively evaluate progress towards achievement of objectives are based upon the best available data at the regional level from scientifically respected sources. The majority of the data came from reports by the U.S. Environmental Protection Agency and the H. John Heinz III Center for Science, Economics and the Environment.

Executive Summary

Habitats are the cornerstones of wildlife resources and provide the necessary food, water, shelter and space for plants, animals, and other organisms to thrive. The southeastern United States harbors a diversity of aquatic habitats and species unparalleled in the nation, and the states of the Southeast Aquatic Resources Partnership (SARP) – Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Missouri, Mississippi, North Carolina, ~~Oklahoma, South Carolina,~~ Tennessee, Texas, and Virginia – have recognized the importance of protecting habitats found in this region.

The quality and quantity of these spectacular and valuable aquatic resources have been in decline since European colonization. Deteriorating and disappearing habitats have led to reductions in biodiversity, as well as critical declines in some plant and animal populations. The problems and issues leading to these circumstances have many sources, natural and human-induced. Ongoing research is identifying new sources, like climate change, every day.

Government agencies, private organizations, businesses, and citizens recognize the value of aquatic resources and work every day to conserve aquatic habitats independently on state and local scales. By addressing aquatic habitat conservation at the regional and national scales, SARP will increase the effectiveness of individual efforts and bring greater funding and public support to aquatic habitat conservation.

During 2005, the SARP Aquatic Habitat Conservation Work Group sponsored research projects in four representative, geographically separate southeastern watersheds. Assessments of these ecosystems yielded much information about various aquatic habitats, and identified similarities and differences in the problems and issues plaguing them. The results of these studies on the Duck, Altamaha, Pascagoula and Roanoke watersheds led to development of this Southeast Aquatic Habitat Plan (the Plan). State Wildlife Action Plans (also known as Comprehensive Wildlife Action Strategies) provided a great deal of background and reference information for it, and the simultaneous development of the National Fish Action Plan (NFHAP) provided an opportunity to coordinate regional conservation and restoration efforts nationally. SARP is recognized as an official partnership to implement the National Fish Habitat Action Plan (NFHAP).

This science-based, landscape-style system for habitat conservation seeks to effectively apply limited resources to priority areas on a regional basis in order to reverse current trends and protect the Southeast's aquatic resources well into the future. The purpose of the Plan is to maintain, restore, and conserve the quantity and quality of freshwater, estuarine, and marine habitats to support healthy, sustainable fish and aquatic communities and sustain public use for the benefit of all in the southeastern region and the entire U.S.

In order to achieve this goal, multiple projects at many different levels will focus on eight objectives:

Objective 1: *Establish, improve and maintain riparian zones*
Objective 2: *Improve or maintain water quality*
Objective 3: *Improve or maintain watershed connectivity*
Objective 4: *Improve or maintain appropriate hydrologic conditions for the support of biota in aquatic systems*

Objective 5: *Establish, improve or maintain appropriate sediment flows*
Objective 6. *Maintain and restore physical habitat in freshwater systems*
Objective 7: *Restore or improve the ecological balance in habitats negatively affected by nonindigenous invasive or problem species*
Objective 8: *Conserve, restore, and create coastal estuarine and marine habitats*

The Plan is a living document, focused on adaptive management. It will be revised utilizing lessons and data from every project. For this initial version of the Plan, objectives are based on the major aquatic habitat types and attributes in the Southeast, focusing on broad indicators of habitat integrity, function and overall ecosystem health. Objectives and regional targets have been developed using the best available scientific data. These are described in detail in Section 2 of the Plan. Additional data and tools, currently under development, will assist SARP's adaptive management process of updating and maximizing the outcomes of this Plan.

Because of the size and variety of habitats in the southeastern region, habitat conservation needs are varied and spread out. In order to effectively use limited resources to reverse current trends and conserve the region's aquatic habitats, geographic priorities must be set periodically. Several tools will play a role in the prioritization process. In the long term, the implementation of the National Fish Habitat Science and Data Committee's assessment tool will allow a science-based approach for prioritizing aquatic habitat conservation and restoration projects nationwide. This assessment tool will help SARP refine its geographic priorities. SARP is developing a geo-referenced database with aquatic system condition data to help identify geographic priorities at a regional scale for the Plan. Details about this adaptive prioritization process are included in Section 3.

Conservation and restoration of specific aquatic habitats will be accomplished through many projects, utilizing implementation strategies to address location, threats, problems and issues. SARP members will be engaged in many of these projects, directly addressing the Objectives and Targets in Section 2, in partnership with other entities. However, effective implementation of the Plan depends upon SARP's collective management and facilitation at an integrated systems level. While on-the-ground projects will focus on the goal and one or more of the eight objectives, SARP must integrate and coordinate these projects to maximize outcomes and leverage dollars. To that end, stakeholders provided four strategies for SARP to integrate habitat conservation projects throughout the region. These four strategies are:

Integrated Conservation Strategy 1: *Information collection and dispersal*
Integrated Conservation Strategy 2: *Capacity building*
Integrated Conservation Strategy 3: *Management and restoration*
Integrated Conservation Strategy 4: *Law and policy.*

Details about each of these strategies are found in Section 4.

Monitoring will contribute to an understanding of the complex ecological systems within which the Plan's conservation and restoration projects are implemented. Analysis of these data will help SARP identify areas of habitat improvement and establish a record of conditions and trends. These data can also warn SARP of environmental decline, and identify gaps in existing scientific knowledge. Monitoring will provide the basis for a rigorous review of habitat project planning and implementation to determine whether project results are being achieved and if mid-course corrections are needed. Monitoring and evaluation will be conducted on two levels in order to assess the Plan's performance and each project's performance towards improving or sustaining the Southeast's aquatic habitats. Monitoring to provide data for both levels will be built into all projects at the planning stage. GIS-based data will play a large role in monitoring and evaluation and will be used along with other monitoring processes. Details about monitoring and evaluation are found in Section 5.

When SARP was established in 2001, members identified six areas upon which the partnership would focus: public use, fishery mitigation, imperiled fish and aquatic species recovery, interjurisdictional fisheries, aquatic habitat conservation, and aquatic nuisance species. Over time, members realized that many of the issues and problems in all six areas could be addressed through a regional habitat conservation plan. This Plan is a blueprint for that effort.

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Why the concern about the habitats in Southeast Region of the U.S. ?

The southeastern United States harbors a diversity of aquatic habitats and species unparalleled in the nation. Over 1,800 species of fishes, freshwater mussels, freshwater snails, turtles and crayfish can be found in southeastern watersheds. More than 500 of these are endemic to these states or in individual watersheds within them. More than 70 major river basins in the region link with the south Atlantic-Gulf of Mexico coastline to nourish and support rivers, streams, lakes, bays, estuaries, reservoirs, and the bulk of the country's wetlands. The drainage basin for the Gulf of Mexico, which includes the area drained by the Mississippi River, is almost 60% of the land in the Continental U.S. (Beck et al. 2000). In addition, approximately 16% of the nation's coastal wetlands are located in the South Atlantic region, which includes Florida (White et al. 2002), and almost half of the nation's coastal wetlands are in Louisiana.

The freshwater and marine systems in the region provide tremendous economic and aesthetic benefits through angling opportunities, recreational and commercial activities, water supply and natural assimilation of wastes. For example, in 2001, over 48% of the anglers in the U.S. fished in the Southeast, accounting for over 42% of the nation's total fishing days. These sportsmen spent over $13 billion, accounting for almost 37% of the total recreational fishing expenditures nationwide (USFWS/USCB, National Survey of Fishing, Hunting and Wildlife Associated Recreation 2001). Public lands like the region's 171 National Wildlife Refuges, over 700 state parks, multiple wildlife management areas and scenic waterways provide opportunities for nonconsumptive nature tourism (hiking, camping and birding) that also contribute to local economies. In 2005, despite the impacts of hurricanes on commercial fishing capacity, over 1.75 billion pounds of finfish and shellfish were harvested in the SARP member states, with a direct economic value of almost $900 million, representing some 23% of the economic value of all commercial fisheries in the United States (NMFS, Fisheries of the United States 2005).

Regrettably, the quality and quantity of these spectacular and valuable aquatic resources have been in decline since European colonization. Nearly 100 species have become extinct across the region in the last century. Further, in its 1998 report entitled *Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity*, The Nature Conservancy, looking at more than 2000 small watersheds across the continental U.S., identified 87 subwatersheds in the U.S. with 10 or more "at risk" species of freshwater fish and mussels. Seventy-five of these 87 "hot spots" are contained in the 14 SARP states, and 18 of the top 19 are in four basins within their boundaries – the Tennessee, Ohio, Cumberland, and Mobile (Master et al. 1998).

These declines have many sources, including hydrologic alteration, habitat destruction, reduced water quality, loss of connectivity and the negative effects of nonindigenous species. Some sources of habitat stress are direct such as stream piping, relocation, shoreline armoring, excessive siltation, introductions of nonindigenous species and/or contaminants, and often associated with development, commerce, agriculture, forestry and mining. For example, roughly one half of the exotic fish species introduced into the Southeast have become established, stressing or altering ecological systems (Benson et al. 2001). In coastal areas, upstream alterations in freshwater flows and sediment supply, including reductions in volume, can result in loss of vegetative habitat and changes in sediment deposition and nutrient transport (Sklar and Browder 1998). The indirect stress from greenhouse gases may exacerbate these declines because many river basins have already lost their ability to adjust (Palmer et al. 2008).

Less direct stressors, especially human population growth and climate change, cumulatively exert a persistent and growing landscape-level effect on fish and their habitats. As more people use increasingly limited natural resources, habitats are impacted. U.S. Census data from April 2000 indicates the human population of the 14 SARP states exceeds 90 million (97,371,542) and, when compared to 1990 figures, points to an increase of over 14 million (14,656,552) people in 10 years. Significant population growth in the Southeast is expected.

The pressures from human population growth have been especially heavy on coastal areas. Populations along the Gulf Coast increased 45% between 1980 and 2003. Atlantic coastal counties experienced an increase of 58%, the largest increase during that period of any coastal region in the continental U.S. (U.S. Census 2000, Population in Coastal Counties).

In tandem with human population growth, climate change has already affected and will more profoundly affect aquatic habitats in the Southeast over the remainder of this century. Climate models project that the Southeast's temperatures will increase on average by 4-10 degrees F over this period, with increasingly hotter summers and higher heat indices (Carter 2000). Based on recent precipitation trends in the region, increases and decreases in precipitation and temperature will be variably manifested geographically, potentially exacerbating existing droughts and developing water shortages in parts of the region. There is also an existing measurable trend in the Southeast for precipitation to occur in more intense events. This trend could intensify during the remainder of the century.

Some predicted environmental effects of these climate changes in the Southeast include fewer continuous acres of forests, reduced agricultural productivity, diminished fish and shellfish populations, and increased electricity demand (Titus 1989). While uncertainties in precipitation projections make it difficult to predict effects on stream and river flows, areas experiencing drought may respond with greater pressure on groundwater for irrigation and water supply, exerting indirect consequent impacts on natural systems. A study of possible effects from climate change on the world's major river systems indicates that by 2050, every populated basin in the world will experience changes in river discharge and many will experience serious declines in water quality and quantity. (Palmer et al. 2008.)

It is reasonable to expect these climate trends to increasingly stress species that are near the upper ranges of their temperature tolerances in the Southeast and those requiring specific habitats that may be affected by the associated hydrological changes. These factors, combined with already fragmented and degraded habitats, will likely cause increased rates of extinction and imperilment of some native species across the region. Additionally, increasing temperatures may enlarge the area of the Southeast vulnerable to establishment of populations of tropical aquatic nuisance species currently restricted to south Florida.

The most dramatic and predictable effect of climate change in the Southeast will be coastal wetland loss and major coastline changes. During the 20th century sea levels rose by 4-8 inches (Burkett et al 2001). The International Panel on Climate Change predicts that this trend will increase 2-5 fold during the 21st century. Under this scenario a sea level rise of approximately one meter is possible by the end of the century. A one-meter rise in sea level would inundate all of coastal southeast Louisiana (UA 2006). The Louisiana coastline would variably move from 10 to over 100 miles inland, inundating New Orleans and many other coastal communities, while altering just about all of the coastal wetlands that support the bulk of the productive fisheries of the northern Gulf of Mexico. Similar impacts, but on a lesser scale would occur in all coastal areas of the Southeast, including all of the keys, the Everglades and much of the city of Miami, Florida, would be under water.

Although the earth has always undergone climate variation, and people have always affected natural systems, the effects from these indirect stressors appear to be in a period of acceleration. They must be considered in planning actions to ameliorate the effects of direct stressors (Technical Review Committee on Global Climate Change and Wildlife, 2004).

Clearly, the public supports actions to conserve and restore healthy aquatic habitats. A study conducted in 2005 by Responsive Management for the Southeastern Association of Fish and Wildlife Agencies indicated that the value placed by the public on programs to conserve fish and wildlife habitat and to protect threatened and endangered species transcends state and local levels of action. This study also noted that water quality is a major fish and wildlife issue facing the southeastern states, and that water resources are of concern for the health of people, fish and wildlife. (Responsive Management, 2005, Executive Summary). Many government agencies, private organizations, businesses, and citizens recognize the value of aquatic resources and work every day to conserve them, but past efforts to halt their decline have been conducted independently on state and local scales. A regional approach is necessary.

Multiscale Approach to Conservation

SARP, comprised of state natural resource agencies from 14 southeastern states plus several federal agencies with natural resource responsibilities, along with concerned nongovernmental organizations (NGOs), was formally organized in 2001 to effectively approach the decline in the region's aquatic resources by integrating state, federal and individual interests and efforts. SARP's mission is – *with partners, to protect, conserve, and restore aquatic resources including habitats throughout the Southeast, for the continuing benefit, use, and enjoyment of the American people.* This partnership takes a comprehensive and systemic approach to watershed conservation. It coordinates the use of new and existing science-based data and expertise, and combines conservation dollars to improve outcomes and stem or possibly reverse aquatic resource decline.

The need to address the decline in fisheries habitats throughout the nation was recognized on a national scale at the same time as SARP's formation, when the U.S. Fish and Wildlife Service (FWS), the Association of Fish and Wildlife Agencies, and the American Fisheries Society sponsored a series of aquatic habitat stakeholder meetings, resulting in the National Fish Habitat Initiative (NFHI) with a mandate to develop an integrated landscape approach to conserve inland and coastal fishery habitats throughout the nation. The National Fish Habitat Action Plan (NFHAP), a non-regulatory, science-based program, implemented through partnerships, has resulted from the NFHI.

SARP has embraced this national initiative while pursuing a similar approach in the region. During 2005, the SARP Aquatic Habitat Conservation Work Group sponsored conservation assessments led by The Nature Conservancy in four representative, geographically separate southeastern watersheds. Assessment of water, flora and fauna of the interconnected ecosystems yielded much information about various habitats, and identified similarities and differences in the problems and issues plaguing them. The results of these studies of the Duck, Altamaha, Pascagoula and Roanoke watersheds provided guidance and parameters for SARP to develop this Southeast Aquatic Habitat Plan (Plan). It offers a science-based, landscape-scale model for habitat conservation, aimed at the protection, restoration, recovery, and sustainable use of aquatic resources in the Southeast. (The assessments can be found at http://www.sarpaquatic.org.)

Also in 2005, by Congressional direction, SARP member states submitted their Comprehensive Wildlife Conservation Strategies (CWCS) to the FWS for approval. The state CWCS plans (also known as State Wildlife Action Plans, or SWAPs) encompassed the variety of problems facing state-identified species of greatest conservation need (SGCN) and strategic conservation actions aimed at improving habitats and populations of SGCNs. Recognizing the importance and value of incorporating related issues and strategies from its member states' CWCS or SWAP plans into the regional plan, SARP and The Nature Conservancy compiled a database of information related to aquatic habitats from the state plans. These data will help to support habitat restoration and protection strategies at the ground level that cross programmatic and political boundaries, increasing the effectiveness of existing agencies and organizations while leveraging and maximizing available funding to achieve regional-scale conservation objectives.

Proper land and resource management is crucial at multiple levels to protect the natural aquatic treasures found throughout the SARP states and to ensure that future generations will be able to enjoy them. Selecting one scale at which to implement strategies is difficult, especially considering that rivers, lakes, reservoirs and streams may be integrated with estuarine and marine systems, and watersheds often cross multiple jurisdictions. Federal, state, local, public and private agencies and organizations must join together with coordinated strategies to abate current and future threats to the aquatic systems in a comprehensive, landscape manner that minimizes infringements on the rights and needs of specific user groups and maximizes the participation of all stakeholders. As research continues, restoration and management must be adapted to sustain the region's aquatic resources.

This Plan seeks to effectively apply limited resources and adaptive management to priority areas on a regional basis in order to reverse current trends and protect the region's aquatic resources far into the future. The Plan is a living document. It will be revised often, utilizing lessons and data from every project implemented under the Plan's sponsorship. Additional data and tools, currently under development, will assist SARP's adaptive management process of updating and maximizing the outcomes of this Plan.

How can this plan conserve the Southeast's aquatic habitats?

Vision

The Plan will engage stakeholders and the public in protecting, maintaining, restoring and enhancing the Southeast's fish and aquatic communities through partnerships that foster habitat conservation, and improve the quality of life for the American people. Implementation of the plan will result in habitats with the biological, chemical, and physical integrity to sustain healthy communities. As such, the Plan's vision, its overriding spirit, is the:

> *Cooperative conservation of southeastern streams, rivers, lakes and reservoirs, estuaries, and coastal marine habitats to support fish and aquatic resources, and sustainable public use.*

Guiding Principles

Five principles framed the crafting of the Plan and will provide the fundamental underpinnings for its implementation. They are:

•*Communicate the value of the Southeastern aquatic habitats and the imperative for conserving them.*

Properly functioning aquatic habitats are vital and necessary attributes of aquatic ecosystems. They support healthy fish and wildlife populations, and sustainable public use. Knowledge and awareness of desirable functions stimulate action. The regional plan will be a vital tool in efforts to obtain the funding, public and political support, and other resources necessary to meet the goal and objectives that will achieve the plan vision.

•*Provide regional aquatic conservation planning based on sound science, rigorous research, open and inclusive planning processes, and input from a broad and diverse group of stakeholders.*

Application of regional conservation strategies and implementation targets will be guided by the best available information on aquatic systems and species. The Plan will also recognize the importance of research that expands our knowledge base and increases our ability to craft meaningful land and water management strategies and measure the success of strategic implementation.

•*Establish regional aquatic conservation priorities.*

Identifying and articulating regional priorities for habitat conservation efforts will focus scarce resources to maximize conservation benefits in the Southeast. Establishment will be based upon abating threats and conserving balanced, healthy ecological conditions in aquatic habitats. Regional priorities, identified as focal geographic areas, habitat types and species or species groups, will change as conditions change, problems are addressed, and new issues arise.

•*Support existing partnerships, and facilitate new ones, to effectively conserve southeastern aquatic systems.*

The challenges facing the southeastern region's aquatic resources demand new approaches to conserve them. This regional plan will be designed to support existing partnerships and foster effective creation of new ones at scales appropriate to meeting conservation challenges.

•Integrate conservation strategies and measures within identified watersheds and across scales from watershed to region to national plans.

The connectivity of aquatic ecosystems across local and state political boundaries improves consistency in conservation measures among different portions of watersheds, and the management of species across watersheds. This will be accomplished by increasing communication and project integration between freshwater, estuarine, and marine resource managers and practitioners to reduce the administrative barriers to working across ecosystem boundaries, and to ensure that the strategies implemented at all scales are mutually supportive, relevant, and effective in aquatic habitat conservation.

Goal

Living organisms and their habitats interact in changing ecological systems. These systems support human life by providing drinking water and food, and involve human activities such as farming, aquatic recreation, forestry and industry. Plants, animals, *and* people need healthy aquatic habitats. Although many healthy aquatic habitats thrive in the southeastern region of the U.S., some have disappeared. Others are endangered or declining. These losses in the Southeast have both natural and human-induced causes. Such reductions in habitat quantity, quality and function have negative impacts on animal, plant and human populations *and* their quality of life. Humans have the resources and abilities to conserve and restore these habitats. The goal is to:

Maintain, restore, and conserve the quantity and quality of freshwater, estuarine, and marine habitats to support healthy, sustainable fish and aquatic communities and sustainable public use for the benefit of all in the southeastern region and the entire U.S.

This goal of the Southeast Aquatic Habitat Plan will be achieved by taking collective action on eight primary objectives.

Limitations for all Objectives and Targets

Although the Plan was developed primarily to explain SARP's approaches in preserving, conserving and restoring aquatic habitat, it is designed for use by all groups with similar aims throughout the Southeast. Achievement of the Plan's objectives will be ongoing, with each project contributing in specific ways to the emergence of strong, healthy communities of fish, wildlife and people utilizing thriving aquatic habitats. While improving habitats, project results will also provide lessons learned and meet research needs to support continued planning and additional projects.

The relationship between healthy habitats and robust fish and wildlife populations is assumed in the Plan, and individual species will be one of many filters used to set project priorities and assess project outcomes. SARP has captured data from the member states' CWCS or SWAP plans to effectively coordinate habitat restoration and protection strategies with states' identified species of greatest conservation need at the ground level across programmatic and political boundaries. However, it is important to remember that this is a plan to conserve and restore aquatic habitats in the region.

This Plan generally adheres to the principles of Strategic Habitat Conservation (SHC) (USGS 2006). However, this initial version of the Plan does not strictly apply that approach because data and models essential for doing so are incomplete or do not exist. In addition, the SHC approach utilizes population-based objectives, and at least for this initial version, the Plan's objectives are based on the major aquatic habitat types and attributes in the Southeast. The objectives focus on broad indicators of habitat integrity, function and overall ecosystem health. Consistent with SHC, objectives and regional targets have been developed using the best available scientific data. A systematic GIS-based system is being developed for refining future objectives and monitoring outcomes. Conservation delivery will be based on defined objectives and targets, and partnerships will be key to achieving those objectives. Adaptive management will be used to help refine objectives and conservation actions.

Although the following objectives focus individually on critical components of aquatic habitats, they function as an interrelated whole. The order of their mention in the document does not indicate any order of priority. All are important because the impacts from specific threats in a specific location must be considered cumulatively and on multiple scales. Using this Plan, individual threats to the health, quality, and function of aquatic habitats will be considered as part of interrelated processes, problems, and issues with interrelated outcomes.

Unless these outcomes can be measured, the effectiveness of actions to achieve outcomes cannot be assessed. Therefore, one or more resource targets (scientifically based quantitative and/or qualitative descriptions of desired changes) have been proposed for each objective. These targets attempt to establish a quantifiable basis for assessing progress in achieving the associated objective. In developing these regional targets, an attempt was made to adhere to the format and recommendations in the Proposed Interim National Targets (February 2007) developed by the National Fish Habitat Board's Science and Data Committee. The Plan's targets are primarily resource-based outcome targets, focusing on changes in the resource as a result of SAHP actions. Developing quantifiable targets for most of the objectives presents real challenges, primarily due to the lack of regionally analyzed and integrated data. For this reason some targets focus on measures that indirectly assess the resource attributes related to the objective and some targets are actions than can be pursued during implementation. The following quantitative targets are subjectively proposed as reasonable measures of improvement over 15 years, assuming that focused efforts are brought to bear and adequate resources are available. With the adaptive management process in mind, ideal targets are also described, even though the interim targets sometimes do not measure against them. Ideal targets provide the opportunity to identify data gaps for effective evaluation, and suggest needed research to better focus targets.

An additional challenge for some of the targets is presented when positive change may not be reflected in assessment and evaluation because of continuing research about various conditions. This challenge will be considered as applicable when assessing progress towards achieving each of the objectives.

It should be possible to develop resource-based targets that are more specific to the objectives once the first assessment of the nation's aquatic habitats, as proposed in *A Framework for Assessing the Nation's Fish Habitat* (NFHSDC 2006) is completed in about 2010. The targets in this version of the Plan should generally be viewed as interim targets subject to revision. Many of the current targets have their basis in information presented in *The State of the Nation's Ecosystems* (The Heinz Center 2002, 2003, 2005) and the *National Coastal Condition Report II* (USEPA 2004). The underlying data for both of these documents have been

13 Southeast Aquatic Habitat Plan 2008 periodically updated, reassessed and published by the USEPA and the Heinz Center. The Plan assumes that
those updates will continue in the future. (Further explanation of these resources can be found on page 2.) In a few cases, targets are based on local data or proposed need. Note that in a few cases, targets are not structured on five-year intervals due to insufficient data or it was not meaningful to do so for a specific target. Unless otherwise stated, all targets are intended to be achieved over a 15-year time period following plan adoption (i.e., by 2022).

Objective 1: ***Establish, improve and maintain riparian zones***

Riparian zones buffer the impacts on adjacent waterbodies from human land use activities while supporting aquatic as well as terrestrial habitats. Wenger (1999) defines riparian zones as land areas located adjacent to waterbodies, often naturally vegetated with grasses, shrubs and trees. Effective riparian zones function as efficient traps, filtering out sediments and nutrients. They provide structure for ephemeral or intermittent channel flow. Vegetation closest to the waterbody provides cover and habitat for wildlife, helps maintain normal water temperatures, slows over-bank flows, and provides energy in aquatic systems. Vegetative roots, especially from woody plants and trees, decrease erosion of the banks and shorelines (Pollen and Simon 2005). During certain periods or under certain circumstances, riparian zones play significant roles in changing water quality as well as in the life stages and life-sustaining activities of many aquatic animals. Natural riparian areas also provide important habitat and travel corridors for terrestrial wildlife. Both grassed and forested buffers trap sediment. Forested buffers provide other benefits as well, such as better runoff control while also allowing input of large woody debris and other matter necessary for aquatic organisms (Wenger 1999).

Urbanization, industrialization, agriculture and other types of development often degrade or reduce the size or health of riparian areas. Ideally, appropriately sized riparian zones in every watershed in the southeastern region should be permanently protected. In areas where vegetated riparian areas are already lost or loss is unavoidable, such as urban areas, methods to restore or provide the functions of healthy, natural riparian areas should be explored and utilized. The challenge is to maintain, conserve, permanently protect, construct or restore riparian zones in the southeastern region that can support healthy aquatic habitats and their populations of fish and other aquatic organisms while meeting public needs.

Target

An ideal riparian zone would extend over all land adjacent to a waterbody to the extent necessary for effective buffer and support. Buffer slope and the presence of wetlands have been determined to be the most important and useful factors in determining ideal buffer width. Long-term studies suggest that a 30 m (100 foot) riparian buffer is sufficiently wide to trap sediments under most circumstances, although they can vary based on type of soil, hydrology, slope and vegetation. Native forest vegetation should be maintained or restored to provide optimal benefit (Wenger 1999). Riparian buffers should extend along both sides of rivers and streams, including intermittent and ephemeral channels, and completely around natural lakes and impounded waters.

One ideal target for this objective would include a measure of habitat quality and quantity utilizing satellite data and geographic information system (GIS) analysis to determine the magnitude of change in percentage of 100-year floodplain areas of natural vegetative cover. Other target strategies may involve assessing maintenance of acres of existing riparian areas or determining the percentage of or number of new riparian areas in a watershed or the southeastern region. Permanently protected riparian areas may be included in the assessment of change. However, regional data have not been compiled or analyzed in a fashion that would allow development of such targets at this time. The initial target for this objective is limited by available regional data on riparian areas.

Using data compiled and processed by the U.S. Environmental Protection Agency's (EPA) National Exposure Research Laboratory that used the U.S. Geological Survey's (USGS) National Hydrography Dataset, the Heinz Center (2002) determined that, nationally, 23% of the lands within 100 feet of the waters' edge along streams nationwide were either farmlands or urban development in the early 1990s. Although those data are for the nation as a whole rather than only the Southeast and appear low for the southeastern region, they were used when developing the following targets for this objective pending development of current regional data for assessing the Southeast's riparian condition.

Target 1A. Ensure that adequate non-urban/non-agricultural riparian buffer habitats exist on at least 85% of the lands within 100 feet of rivers and streams in the Southeast by 2022.

•By 2012 ensure that at least 78% of the lands within 100 feet of rivers and streams in the Southeast have adequate riparian buffers.

•By 2017 ensure that at least 81% of the lands within 100 feet of rivers and streams in the Southeast have adequate riparian buffers.

•By 2022 ensure that at least 85% of the lands within 100 feet of rivers and streams in the Southeast have adequate riparian buffers.

Objective 2: *Improve or maintain water quality*

The quality of water includes physical, chemical, and biological characteristics that sustain plant and animal life and support a variety of human uses including drinking water, fishing and boating, agriculture and industry, and other types of recreation and transportation. Water quality characteristics can be altered by storms and seasonal changes; industrial, manufacturing or residential discharges and runoff; urbanization; agriculture; and other land uses, sometimes for many miles from the contamination site (e.g., the dead zone in Gulf of Mexico impacted by drainage from the Mississippi River Basin). Plants and animals in any aquatic community are sustained by the balance of temperature, nutrients, and organic material in the habitat. Maintaining good water quality and preventing, halting, or reversing alterations support these life-sustaining balances and reduce treatment costs for human use. The challenge is to maintain or adjust the balance of water quality characteristics in aquatic systems to meet the needs of fish, other aquatic and terrestrial organisms, and the public.

Targets

Ideally the magnitude of change for this objective will be measured by the maintenance of or increase in the percentage of, or the number of miles of, streams and rivers, or acres of estuaries, wetlands, lakes, reservoirs, and ponds with water quality characteristics that meet the designated use. An example of a designated use might be fishable/swimmable waters or waters supporting aquatic life and recreation, such as addressed in Section 303(d) of the federal Clean Water Act. A decrease in the percentage of waterbodies in the southeastern region with water quality unable to support healthy ecological systems is desirable.

The EPA maintains a database of waterbody segments/areas that are classified as impaired in accordance with Section 303(d). Although the data in that system are not consistently expressed quantitatively in terms of stream miles or areal extent, the 303(d) list includes a total number of impaired waterbody segments/areas. That number (7,073 as of June 2007) is used as an interim basis for Target 2A for this objective. Note that states have different listing criteria for these data. Some criteria are primarily anthropogenic in focus, some don't consider emerging contaminants such as pharmaceuticals, and some may be less suitable for describing impairment in some of the Southeast's low gradient systems, such as some habitats of the lower Mississippi

River floodplain. However, these are the best available data upon which to base many of the following targets. In addition, ongoing research has resulted in an increase in the number of 303(d) listings of impaired waterbodies every two years, presenting the challenge described on page 13. Data are available to meet this challenge in the target's assessment.

Several other targets were also developed for this objective focusing on specific water quality characteristics, as further described below, using data from The Heinz Center (2002). Although those data apply to the nation as a whole and not to the Southeast specifically, they were, nevertheless, used when developing targets pending future development of more specific targets when better data are available. Note that these targets are regional, and are not meant to apply at every individual site.

Target 2A. Restore at least 710 waterbody segments/areas in the Southeast (10% of impaired segments/areas as of June 2007) to nonimpaired status per the EPA 303(d) list.

- By 2012 restore at least 140 waterbody segments/areas in the Southeast to nonimpaired status per the EPA 303(d) list.
- By 2017 restore at least 350 waterbody segments/areas in the Southeast to nonimpaired status per the EPA 303(d) list.
- By 2022 restore at least 710 waterbody segments/areas in the Southeast to nonimpaired status per the EPA 303(d) list.

According to the Heinz Center (2002), the USGS National Water Quality Assessment (NAWQA) found that 77% of stream sites nationwide during the period 1992-1998 were exceeding at least one standard or guideline for contaminants that may affect aquatic life in water. This was used as a basis for Target 2B.

Target 2B. Reduce to 70% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants or emerging contaminants affecting aquatic life.

- By 2012 reduce to 76% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants or emerging contaminants in water affecting aquatic life.
- By 2017 reduce to 75% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants or emerging contaminants in water affecting aquatic life.
- By 2022 reduce to 70% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants or emerging contaminants in water affecting aquatic life.

The NAWQA (Heinz Center 2002) also found that 48% of stream sites nationwide during 1992-1998 were exceeding at least one standard or guideline for contaminants in sediments that affect aquatic life. This was used as a basis for Target 2C.

Target 2C. Reduce to 45% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants in sediments affecting aquatic life.

- By 2012 reduce to 47% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants in sediments affecting aquatic life.

•By 2017 reduce to 46% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants in sediments affecting aquatic life.

•By 2022 reduce to 45% the stream sites in the Southeast exceeding at least one standard or guideline for contaminants in sediments affecting aquatic life.

The NAWQA (Heinz Center 2002) also found that during 1992-1998 approximately 48% of farmland streams and 18% of urban/suburban streams nationwide had nitrate levels in excess of 2 parts per million (ppm). These data were used as bases for Targets 2D and 2E.

Target 2D. Reduce to 40% the farmland stream sites in the Southeast exceeding 2 ppm nitrate concentration.

•By 2012 reduce to 47% the farmland stream sites in the Southeast exceeding 2 ppm nitrate concentration.

•By 2017 reduce to 44% the farmland stream sites in the Southeast exceeding 2 ppm nitrate concentration.

•By 2022 reduce to 40% the farmland stream sites in the Southeast exceeding 2 ppm nitrate concentration.

Target 2E. Reduce to 10% the urban/suburban stream sites in the Southeast exceeding 2 ppm nitrate concentration.

•By 2012 reduce to 17% the urban/suburban stream sites in the Southeast exceeding 2 ppm nitrate concentration.

•By 2017 reduce to 15% the urban/suburban stream sites in the southeast exceeding 2 ppm nitrate concentration.

•By 2022 reduce to 12% the urban/suburban stream sites in the Southeast exceeding 2 ppm nitrate concentration.

The NAWQA also found that during 1992-1998, approximately 73% of farmland streams, 68% of urban/ suburban streams, and 54% of large river [defined as having average flows over 1,000 cubic feet per second (cfs)] sampling sites nationwide exceeded the EPA's recommended goal of 0.1 ppm concentration for phosphorus in order to prevent excess algal growth. These data were used as bases for Targets 2F, 2G, 2H.

Target 2F. Reduce to 65% the farmland stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

•By 2012 reduce to 71% the farmland stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

•By 2017 reduce to 68% the farmland stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

•By 2022 reduce to 65% the farmland stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

Target 2G. Reduce to 60% the urban/suburban stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

•By 2012 reduce to 67% the urban/suburban stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

•By 2017 reduce to 64% the urban/suburban stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

•By 2022 reduce to 60% the urban/suburban stream sites in the Southeast exceeding 0.1 ppm phosphorus concentration.

Target 2H. Reduce to 45% the large river sampling sites in the Southeast exceeding 0.1 ppm phosphorous concentration.

•By 2012 reduce to 52% the large river sampling sites in the Southeast exceeding 0.1 ppm phosphorous concentration.

•By 2017 reduce to 49% the large river sampling sites in the Southeast exceeding 0.1 ppm phosphorous concentration.

•By 2022 reduce to 45% the large river sampling sites in the Southeast exceeding 0.1 ppm phosphorous concentration.

The NAWQA (Heinz Center 2002) found that 83% of farmland stream sites nationwide during 1992-1998 had at least one pesticide with concentrations exceeding aquatic life guidelines. This was used as a basis for Target 2J.

Target 2J. Reduce to 75% the farmland stream sites in the Southeast with at least one pesticide exceeding aquatic life guidelines.

•By 2012 reduce to 81% the farmland stream sites in the Southeast with at least one pesticide exceeding aquatic life guidelines.

•By 2017 reduce to 78% the farmland stream sites in the Southeast with at least one pesticide exceeding aquatic life guidelines.

•By 2022 reduce to 75% the farmland stream sites in the Southeast with at least one pesticide exceeding aquatic life guidelines.

Objective 3: ***Improve or maintain watershed connectivity***

Watershed connectivity in a habitat context can be described as physical, chemical, and biological conditions that accommodate the movements of aquatic organisms, nutrients, water, or energy into various necessary habitats or habitat types. Waterbodies, whether flowing or static, require regular and, at times, unrestricted movements of these to support their ecological systems. Watersheds need similar connectivity within and between rivers, streams, lakes and reservoirs, and between terrestrial and aquatic habitats. Some physical impediments to connectivity such as dams, levees, incised channels, armored shorelines, and culverts can block or change these movements. Impediments such as chemical, biological, and thermal barriers, invasive species, impervious areas, and reduction of the vegetated canopy can also affect connectivity. These impediments are more easily adjusted than the physical ones, although no adjustments are simple. Often barriers to connectivity have a positive use in one part of a watershed, but negatively affect the productivity of some ecosystems in other parts of the same watershed. Occasionally, the purpose for a barrier has disappeared altogether, but the barrier remains. The objective is to conserve or improve watershed connectivity in a manner that will maintain or improve the health of habitats, ecological systems, and populations of fish and other aquatic organisms and meet public needs within a watershed and the region.

Targets

For this objective the ideal targets would be measures of the maintenance of or increase in the number of watersheds in the Southeast with minimal (lowest number and degree of) impediments to connectivity. Since connectivity can be seen to support human needs as well as the life needs of aquatic plant and animal populations, an increase in the percentage or number of healthy aquatic habitats with minimal impediments to connectivity should demonstrate progress. Indicators of change might include chemical or physical changes in water quality, level or flow attributable to operations adjustments, number of dams removed, number of channels connected to floodplains, or alterations in land use patterns accompanied by increases in populations of certain species or functional guilds while continuing to meet human needs. While there are currently no compiled data on connectivity or aquatic habitat health as specific attributes per se, there are a few data sets that may be useful in assessing progress in meeting this objective. The FWS, in its Fish Passage Decision Support System database (FWS 2007), indicated as of June 2007 that there were at least 39,821 barriers to fish passage in the SARP states. Although the data in this database may not be complete, they have utility as a basis for identifying targets for this objective.

Target 3A. Restore 1,000 miles of fish access to rivers and streams in the Southeast by effectively removing* barriers to fish passage.

- By 2012 restore fish access to 500 miles of rivers and streams in the Southeast.
- By 2017 restore fish access to 750 miles of rivers and streams in the Southeast.
- By 2022 restore fish access to 1,000 miles of rivers and streams in the Southeast.

Target 3B. Restore 20,000 acres of fish access to lakes, reservoirs, and coastal estuaries in the Southeast by effectively removing* barriers to fish passage.

- By 2012 restore fish access to 10,000 acres of lakes, reservoirs and coastal estuaries in the Southeast.

* "Effectively removing" can mean physical removal, breaching of a barrier, installation of fish passage structures, or implementation of other fish passage strategies to result in effective fish passage aroundor through a barrier.

•By 2017 restore fish access to 15,000 acres of lakes, reservoirs and coastal estuaries in the Southeast.

•By 2022 restore fish access to 20,000 acres of lakes, reservoirs and coastal estuaries in the Southeast.

Objective 4: ***Improve or maintain appropriate hydrologic conditions for the support of biota in aquatic systems***

The quantity and flow of freshwater in waterbodies varies naturally by season and precipitation, and unnaturally by human alteration and withdrawal of water from rivers and lakes as well as groundwater from aquifers. Both are important to aquatic communities. High flows and elevated water levels are part of the natural renewal of some habitats and coastal waters. In rivers, reservoirs or natural lakes, high flows during spring and summer greatly enhance reproductive success and survival of offspring for many species of fish and other animals. These same water levels support public needs for transportation, irrigation, drinking water and recreation.

Estuaries, highly productive habitats for fish and other aquatic organisms, are formed in protected coastal areas where fresh water flows into and mixes with tidally-driven saline waters. Estuarine habitats are supported by the regularity and balance of volume, timing, and periodicity of these occurrences. When people dredge rivers to enhance navigation, create reservoirs and build levees, they may change the hydrologic conditions of waterbodies and watersheds. (Sklar and Browder 1998). The objective is to maintain and/or adjust the quantity and flow of freshwater in rivers, streams, reservoirs and estuaries in a manner that will enhance or sustain the habitats and populations of fish and other aquatic organisms while meeting public needs.

Targets

The magnitude of change for this objective should be measured as a percentage of increase in or increased number of miles of freshwater streams and rivers with instream flow protection plans; or acres of lakes, reservoirs, ponds, aquifers, and estuaries with hydrologic conditions that support sustainable populations of fish and other aquatic organisms compared to a referenced condition. The number of miles or acres of permanently protected freshwater bodies may be included in the measurement. However, data to assess these measures are currently either not available or have not been compiled and assimilated in a manner to allow such assessments to be made. Specific, quantifiable targets may be established for individual watersheds but would require further study to establish.

The Heinz Center (2002) analyzed changes in high and low flows and timing of those flows for 1930-1949 as a reference period and compared those data to the 10-year periods of the 1970s, 1980s and 1990s using USGS stream gauge data nationwide. The data showed in the 1970s that 55.1% of rivers had experienced a greater than 75% increase or decrease in flows or more than a 60-day change in timing of flows. For the 1980s and 1990s the data showed that 56.9% and 60.8%, respectively of rivers had experienced those changes from the reference period. Although these data are nationwide rather than specific to the Southeast, they were, nevertheless, used to formulate Target 4A pending future development of more specific targets after better data are available.

Target 4A. Reduce the percentage of rivers in the Southeast that have experienced more than a 75% change in high or low flows or more than a 60-day change in timing of flows since the 1940s to 58%.

•By 2012 reduce the percentage of rivers in the Southeast that have experienced more than 75% change in high or low flows or more than a 60-day change in timing of flows since the 1940s to 60%.

•By 2017 reduce the percentage of rivers in the Southeast that have experienced more than 75% change in high or low flows or more than a 60-day change in timing of flows since the 1940s to 59%.

•By 2022 reduce the percentage of rivers in the Southeast that have experienced more than 75% change in high or low flows or more than a 60-day change in timing of flows since the 1940s to 58%.

Using data from the USGS Circular Series *Estimated Use of Water in the United States*, which has been published every five years since 1950, The Heinz Center (2005) assessed freshwater withdrawals nationwide from all sources, for most purposes (such as public supply, domestic, irrigation, livestock, aquaculture, industrial, mining, and thermoelectric, not including freshwater diversions), using withdrawals in 1980 as an index. The year 1980 was chosen because it was the year of greatest water withdrawal (i.e., index value of 1.00) over the data series (1960-2000). Data showed that water withdrawals in the Southeast almost doubled between 1970 and 1980, declined to an index value of 0.77 in 1985, but then rose back to an index value of approximately 0.96 in 2000. Total freshwater withdrawals in the Southeast that year were 120.5 billion gallons per day (bgd). By contrast, human populations in the Southeast rose steadily in a nearly linear fashion from an index value of 0.72 in 1960 to 1.35 in 2000 (1.00 in 1980). These data were used as the basis for Target 4B.

Target 4B. Using freshwater withdrawal in 1980 as an index of 1.00 (125.56 bgd), reduce freshwater withdrawals in the Southeast from all sources to an index of 0.90 (113.0 bgd).

•By 2012 reduce freshwater withdrawals from all sources, using withdrawal in 1980 as an index of 1.00, to an index of 0.95 (119.2 bgd).

•By 2017 reduce freshwater withdrawals from all sources, using withdrawal in 1980 as an index of 1.00, to an index of 0.93 (116.7 bgd).

•By 2022 reduce freshwater withdrawals from all sources, using withdrawal in 1980 as an index of 1.00, to an index of 0.90 (113.0 bgd).

Areas of impervious surfaces (e.g., roads, parking lots, driveways, sidewalks, buildings) in urban and suburban areas can have major impacts on hydrology and water quality in these and downstream portions of watersheds. Although there are currently no data available to assess impervious surface area, The Heinz Center (2002), using data from the National Land Cover Dataset, a product of the Multi-Resolution Land Characterization Consortium [a partnership of USGS, U.S. Forest Service, the National Oceanic and Atmospheric Administration (NOAA) and EPA], determined the percentages of "natural" area patches in urban and suburban settings that fell into specified size groupings. Natural areas were defined as forest, grassland, shrubland or wetlands. They determined that in the Southeast 30% of urban/suburban natural areas in 1992 were patches of forest, grassland, shrubland or wetland, each 10-100 acres in size. Although not perfect, this approximate indicator for urban/suburban impervious area was used to formulate Target 4C.

Target 4C. Increase the percentage of urban/suburban natural area patches 10-100 acres in size in the Southeast to 35%.

•By 2012 increase the percentage of urban/suburban natural area patches 10-100 acres in size in the Southeast to 31%.

•By 2017 increase the percentage of urban/suburban natural area patches 10-100 acres in size in the Southeast to 32%.

•By 2022 increase the percentage of urban/suburban natural area patches 10-100 acres in size in the Southeast to 35%.

Objective 5: *Establish, improve or maintain appropriate sediment flows*

In a watershed, some sediment is carried in suspension by flowing water from inland to coastal waters, while some is deposited on banks and channel beds, supporting and sustaining aquatic habitats and their ecological systems. Sediment can positively and negatively affect the size and health of wetlands, rivers, streams, lakes, reservoirs, and coastal areas. Increased sediment can raise costs of water purification and navigation channel maintenance as well as damage fisheries and aquatic habitat. It can also build or renew wetlands, banks and benthic areas. Sediment transport varies because of factors such as soil particle type and local geology, precipitation and runoff as well as barriers to flow due to channelization, roadways, dams and land-use-induced erosion. The challenge is to maintain or improve the balance of sediment flow within aquatic systems in a manner that sustains water resources and maintains or improves the health of the habitats and their populations of fish and other aquatic organisms. This multifaceted challenge includes the need to a) maintain or improve the balance of sediment transfer to support the waterbody's structure, habitats and their associated communities, and b) ensure sufficient sediment supply to nurture adjacent wetlands and coastal marshes, and offset subsidence and sea level rise while sustaining water resources for human use.

Targets

The magnitude of change for this objective could be measured by maintenance of or increase in the number of watersheds in the Southeast with a balance of sediment flows supporting healthy habitats with populations of fish and other aquatic organisms while meeting human needs. However, sediment needs vary from habitat to habitat, watershed to watershed. There is no regional norm. For example, White et al. (2002) concluded that upstream reservoirs have reduced sediment loads in the Trinity, Lavaca-Navidad, and Nueces river systems in Texas below those needed to maintain or improve the associated marshes and coastal areas. In some cases, the opposite is true within impounded areas. Reservoirs and small impoundments are especially susceptible to excessive sedimentation.

Determining a baseline to assess progress on this objective is equally difficult. On a nationwide basis The Heinz Center (2002) found in general that croplands most prone to water erosion decreased significantly from 30.3% in 1982 to 21.6% in 1997, but this measure does not address non-agricultural erosion that occurs along large rivers and stream banks. Under section 303(b) of the Clean Water Act, the regional offices of the EPA work with state water regulatory agencies to list impaired waterbodies and develop total maximum daily loads (TMDLs) for the contaminants (U.S. EPA 2007). TMDLs describe the amounts of a pollutant that a waterbody can receive and still meet water quality standards, and allocate loadings among point and nonpoint pollutant sources. Excess sediment can impair waterbodies. To establish a baseline for Targets 5A and 5B, SARP could work with data managed by EPA Regions 3, 4, 6, and 7 to identify those waters currently listed as impaired by excess sedimentation and in need of a load allocation strategy. Future targets and timelines for load reduction could be set in cooperation with EPA and state programs charged with implementing the load allocations.

Initially, the relationship of this objective with those on water quality, connectivity, and hydrologic condition, for which measurable targets have been proposed, can be used for indirect, qualitative assessment until baseline

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data can be secured. Results from monitoring and assessing projects focusing on those objectives can, over time, provide some local and regional interim indicators that can be combined with emerging TMDL data. After 2010, development of additional data sources through the NFHI aquatic habitat assessment may provide other avenues to select targets. For this version of the Plan, Targets 5A and 5B are qualitatively described without specific milestones.

Target 5A. Reduce the number of stream miles impaired by excess sediment.

Target 5B. Rehabilitate estuarine or reservoir habitat where hydrological alteration has decreased sediment flows, resulting in aquatic habitat loss.

The portion of the Southeast where the lack of appropriate sediment transport is most profound and critical is the Louisiana coastal area. Since the 1930s, Louisiana has lost over 1.2 million acres (485,830 ha) of coastal wetlands (USACE 2004). In 2000 it was estimated this loss would continue at approximately 6,600 acres (2,672 ha) per year over the next 50 years. The Mississippi River transports a suspended sediment load of about 70 million cubic yards (5.4 million cubic meters) to its mouth each year. However, most of the material flows to deep waters of the Gulf of Mexico instead of being deposited on surrounding wetlands. The lack of sediment and nutrient input has reduced deposition rates to a point where they are not able to offset relative sea level change being caused by marsh subsidence and actual sea level rise. Besides its impact on local habitats, fisheries and economies, this sediment transport through one of the largest watersheds in the nation most likely is affecting a large portion of the habitats in the Southeast.

The USACE and the State of Louisiana have developed the Louisiana Coastal Area (LCA) Plan (USACE 2004) as a large scale effort to offset much of the projected future loss from this condition. The LCA Plan recommended five near-term critical restoration features for authorization. These were determined to address the most critical needs to offset losses projected to occur over the next 50 years if no action was taken. Target 5C is based on the LCA Plan. Three of the LCA Plan features specifically incorporate attempts to increase sedimentation rates into coastal wetlands through relatively large-scale diversions of river water and sediment. They seek large scale action at specific locations: the Hope Canal Diversion, the Bayou Lafourche Reintroduction, and the Myrtle Grove Diversion. Because the effects from achievement of these could have a significant effect on the achievement of this objective at the regional level while providing data and information about methods and problems related to sediment flow restoration projects, they are included as milestones for Target 5C. This target is based on the LCA Plan.

Target 5C. By 2050 offset approximately 62.5 percent (288,750 acres/116,853 ha) of the 462,000 acres (186,965 ha) of wetlands projected to be lost within the Louisiana Coastal Area if no action is taken.

•Achieve an annual sedimentation rate of at least 1,000 grams per square meter per year using the Hope Canal Diversion for a total benefit of restoring 36,000 acres of freshwater swamp by 2050.

•Achieve a net gain of 2,500 acres of coastal marsh through the Bayou Lafourche Reintroduction by 2050.

•Create/preserve 6,563 acres (2,656 ha) of coastal marsh through the Myrtle Grove Diversion by 2050.

The LCA Plan specifically incorporates attempts to increase sedimentation rates into coastal wetlands and through medium-scale diversions of river water and sediment. These include a 5,000 cubic foot per second23 project and two smaller-scale projects. Because these three projects would have a moderately significant effect on achieving the overall LCA objective while providing data and information on methods and problems related to sediment flow restoration, they are incorporated into this Plan.

Objective 6. *Maintain and restore physical habitat in freshwater systems*

Physical habitats are the structural elements that make streams, rivers, lakes, reservoirs and wetlands suitable for aquatic species. Examples of physical habitat in southeastern waters include stream channel morphology, substrate composition (gravel, rocks, sediment, etc.), benthic contours of lakes and reservoirs, aquatic vegetation, shoreline vegetation, overhead canopy cover, and woody debris. Physical habitat plays an important role in healthy ecosystems, providing shelter, spawning sites, nursery areas, and foraging areas for fish and other aquatic animals. It also affects water quality and energy production. When physical habitat is changed by natural storm or flood events, aging and decomposition, or anthropogenic activities, the health of the waterbody may change suddenly, slowly, or sometimes in stages following a 'domino' effect. Not all changes are bad, but some activities such as draining wetlands or rerouting streams through pipes or channels can result in destruction of physical habitat. Of major importance has been the large-scale loss of wetland habitats such as forested large-river floodplain, oxbow, and backwater areas, coastal marsh and seagrass beds. The structural elements of many streams and rivers, degraded by an assortment of land use practices or natural events, can be improved using stream restoration techniques. In reservoirs, managers add new structure to offset the loss of the original woody debris, but it is difficult to add enough to maintain optimum fisheries. Reservoirs also tend to develop problems related to the presence or absence of aquatic vegetation due to water level fluctuations. The challenge is to prevent the destruction of physical habitat and promote its restoration and improvement in a manner that meets both ecological and human needs.

Targets

Achievement of this objective will be measured as a reduction in alterations of aquatic habitats, and as the total amount (miles, acres and numbers) of protected, restored and enhanced habitat. Sources of data to help in establishing such baselines may include but are not limited to the AFS Reservoir Committee, U.S. EPA procedures for calculating stream habitat metrics, the U.S. Army Corps of Engineers (USACE) and the National Wetlands Inventory (NWI). Historical data may also be helpful. Note that only those habitat characteristics that can be attributed to maintenance, restoration or establishment of one or more identified structural elements will be used to determine the magnitude of change.

As noted by The Heinz Center (2002), there is general agreement on key elements that should be measured to evaluate aquatic habitat quality, and work is underway by entities such as the EPA, USGS and the USACE to assimilate data and develop habitat quality indices. However, generally accepted methodologies for assessing data on either a local or regional basis are not yet available. Habitat values for particular systems must also take into account the habitat needs of the biota in those areas, so habitat indices need to be tailored to different communities, habitat types or areas. The FWS National Wetlands Inventory (NWI - http://www.fws.gov/nwi/) provides readily available data on wetlands nationwide. As of 2002, most of the wetlands data in the NWI were of 1980s vintage (FWS 2002), and it is not compiled regionally or by state. Hefner et al. (1994) provides the only regional compilation of wetland data for the Southeast, though these data do not correspond entirely to the Plan's area and were collected only through the 1980s. Development of additional data sources through the NFHI aquatic habitat assessment may provide additional avenues for development of targets following initial results of the assessment in 2010.24 Southeast Aquatic Habitat Plan 2008

Target 6A. Reduction in acreage of freshwater wetlands drained or converted.

•By 2022 reduce the number of acres of altered freshwater wetlands drained or converted through development annually in the Southeast by 30%.

Target 6B. Reduction in number of stream miles destroyed or converted to unnatural or managed drainage systems

•By 2022 decrease miles of streams destroyed or converted by permitted construction into unnatural drainage systems annually in the Southeast by 30%.

SARP is working through the Southern Division of the American Fisheries Society Reservoir Committee to establish methods of tracking reservoir structural enhancements commonly installed by state fisheries professionals and local fishermen. Beginning in 2008, SARP partners will report all stream and river restoration or enhancement projects to measure accomplishments for achieving Targets 6C and 6D.

Target 6C. Increase number of lakes and reservoirs with adequate physical habitat structure.

•By 2022 improve the physical habitat for fisheries in an increased number of affected reservoirs and lakes in the Southeast.

Target 6D. Increase in the number of miles of streams with improved instream physical habitat.

•By 2022 improve the physical habitat of reaches in streams and rivers containing structural improvements in the Southeast. (This would not include downstream affected areas.)

Objective 7: ***Restore or improve the ecological balance in habitats negatively affected by nonindigenous invasive or problem species***

Habitats and diverse populations of biota thrive in balanced, interdependent, natural and human-created systems. Occasionally, the addition of one or more non-native species to biotic communities within a habitat can alter systems and degrade habitats. These changes in the biotic communities of habitats have altered water quality characteristics, energy, nutrient, and sediment flow, and species composition. In addition to the damage to natural resources, such habitat degradation often negatively affects food and water resources, recreation, and economics for people (ISAC, 2006; Pimentel et al 2005). The absence or overabundance of a species or functional guild, especially invasive species, parasites or pathogens, can be major causes of such changes or imbalance (Sarakinos, 1999). Pathogens can weaken or destroy whole populations. Invasive species, not native to the habitat, may have no natural enemies present to limit rapid population expansion. Their fecundity, early and rapid development, ability to thrive on available nutrition and tolerance of a broad range of conditions help them to out-compete, and often destroy native populations and disrupt interdependent systems (Williams & Meffe, 2005). Problem species can be introduced by natural occurrences such as storms and floods, and/or by human activities such as shipping, aquaculture, fishing, agriculture, horticulture, landscaping, exotic pet and aquarium trade, and stocking. Biota that improve the health of a system can be introduced in a similar manner. The objective is to encourage appropriate abundance of species or functional guilds within a watershed to establish or restore healthy ecological systems while supporting public use of resources. This will be achieved by controlling or preventing the introduction of new nonindigenous invasive or problem species.

Targets

Progress in meeting this objective will be assessed by using various state, regional, and national databases and management plans, as well as indices of population dynamics, aquatic community species composition, architecture function, and structure to identify problem species that threaten habitat health and establish baselines of habitat health in target watersheds. These changes may be expressed by an increase in the numbers of healthy essential species within a system, an increase in number or percentage of native animals or in acreage of native plants fitting unfilled niches, and/or a reduction in or eventual absence of populations of identified problem species within the target habitat. However, data on which to base such assessments are not yet available or compiled in a manner that can be readily analyzed, particularly for the SARP states as a whole. A suite of targets and strategies has been developed using available data. Development of additional data following initial results of the NFHI aquatic habitat assessment in 2010 may provide avenues for creation of more specific targets.

According to data from 1999 (Benson et al. 2001) for the FWS Southeast Region, the states in the FWS Southeast Region collectively reported, by individual state, a total of 564 nonindigenous aquatic species as having been introduced. However, some species are represented more than once in this total, as they have been introduced into more than one state. Based upon current (June 2007) data from the USGS Nonindigenous Aquatic Species (NAS) website (http://nas.er.usgs.gov/) for the 14 SARP states, comparable totals were 915 for the FWS Southeast Region states and 1,352 for the SARP states. Therefore, between 1999 and 2007 the numbers of introduced species increased in the FWS Southeast Region states by an average of 7.2% per year.

However, not all NAS that are introduced into a state become established and survive year to year, develop reproducing populations or cause problems. Those that do are the most problematic and are the ones referred to in the objective. Using the same data sources as described above, a total of 349 NAS were collectively reported by the FWS Southeast Region states, by individual state, as having become established in 1999. The 2007 comparable totals are 499 for the FWS Southeast Region states and 736 for the SARP states. Thus, between 1999 and 2007 the numbers of introduced species that had become established increased in the FWS Southeast Region states by an average of 5.3% per year. This figure was used as a proxy for the whole region when developing Target 7A since, at present, there is no regional baseline.

Target 7A. Reduce the average annual rate of increase for established NAS in states in the FWS Southeast Region to 3%.

•By 2012 reduce the average annual rate of increase for established NAS in states in the FWS Southeast Region to 5%.

•By 2017 reduce the average annual rate of increase for established NAS in states in the FWS Southeast Region to 4.5%.

•By 2022 reduce the average annual rate of increase for established NAS in states in the FWS

Southeast Region to 3%.

Because some non-native species can cause habitat degradation while others may fill an unfilled niche or cause no apparent change to habitat health, additional targets might be set on the basis of certain watersheds or habitat types. These additional targets may be possible at a later date, when all of the SARP states have completed Aquatic Invasive Species Management Plans.

Objective 8: ***Conserve, restore, and create coastal estuarine and marine habitats***

The southeastern region's watersheds are critical to the biological productivity and sustainability of coastal estuaries and nearshore waters, and to the economic and sociological health of the coastal communities that depend on them. Actions taken to achieve Objectives 1 through 7 above will have direct and indirect impacts on the overall health of coastal habitats. In a very real way, management actions adopted upstream affect ecosystem health and community resilience along the coast.

As evidence of their value, vital estuarine and marine habitats in the Southeast have been identified as essential fish habitat for federally managed species by the South Atlantic Fishery Management Council, the Gulf of Mexico Fishery Management Council, and the National Marine Fisheries Service. These habitats, also considered important to fisheries managed by the Gulf States Marine Fisheries Commission and the Atlantic States Marine Fisheries Commission, provide food, cover, shelter, spawning sites and nursery areas for marine and estuarine fish and other species. Essential fish habitats in the Southeast include oyster reefs, seagrasses and other submerged aquatic vegetation, estuarine wetlands, mangroves, coral reefs, intertidal flats, estuarine and marine water column, and their underlying sand, mud, and shell bottom substrates.

Coastal habitats, especially in the Southeast, have suffered significant historic losses and degradation due to coastal development, erosion and subsidence, and upstream changes in watersheds. Without well-coordinated, ecosystem-based habitat protection and restoration, these coastal wetland systems will suffer irreparable losses. The challenge is to stop and reverse the loss and degradation of coastal and marine fish habitats in order to maintain fish populations in healthy ecosystems supported by healthy coastal habitats while meeting the needs of all sectors of the U.S. population.

Targets

Achievement of this objective will be measured by percentage of positive change to specific aquatic systems from a baseline condition. Ideally, targets for this objective would be expressed in terms of numbers of acres or percent increases in acreages of specific habitat types, such as oyster reefs, seagrasses, mangroves, and emergent wetlands. Although data on the extent of such areas on a regional basis are incomplete or not compiled in a manner to allow efficient and timely analyses, the EPA has evaluated all estuarine areas on a regional basis nationwide and assigned condition ratings using a standardized format that has been utilized in three coastal condition reports (USEPA 2001, 2004, 2006). These data have been utilized in developing several targets for this objective.

The National Coastal Condition Report II (NCCR II) (USEPA 2004) utilized data from the EPA's National Coastal Assessment (NCA), which gathers data on biota and environmental stressors; NOAA's National Standards and Trends Program, which utilizes site-specific data on toxic contaminants and their ecological effects; and the Fish and Wildlife Service's National Wetlands inventory (NWI), which provides information on the status of the nation's wetlands. In the NCCR II, five primary indices were developed using these data sources for (1) water quality, (2) sediment quality, (3) benthic habitat quality, (4) coastal wetlands and (5) fish tissue contaminants. Although these indices do not address all characteristics of estuaries and coastal waters, they do provide information on ecological conditions. Characterizing coastal conditions was a two-step process. The first step was to assess conditions at individual sites for each indicator. In the second step a regional rating for each indicator using a scale of five (1= poor, 2-4 = fair, 5 = good) was determined, based on the percentage of the area of each region in a given condition. The mean of the indices for the five indicators was then calculated to yield an overall condition index for each region. Using these indices, the NCCR II found that the overall condition for the Southeast Coast estuaries (North Carolina, South Carolina, Georgia and east Florida coasts) was 3.8, and for the Gulf Coast estuaries, 2.4. Although the more recent National Estuary Program Coastal Condition Report (USEPA 2006) also assessed estuarine condition for these same regions using this process, only four of the five indicators were used. For this reason, the data from the NCCR II were used in developing Target 8A.

Target 8A. Increase the overall coastal condition indices for the Southeast Coast and Gulf Coast to 4.2 and 2.8, respectively.

•By 2012 increase the overall coastal condition indices for the Southeast coast and the Gulf coast to 3.9 and 2.5, respectively.

•By 2017 increase the overall coastal condition indices for the Southeast coast and the Gulf coast to 4.0 and 2.6, respectively.

•By 2022 increase the overall coastal condition indices for the Southeast coast and the Gulf coast to 4.2 and 2.8, respectively.

Targets 8B-8F are related to target 8A, but are identified for use in monitoring specific project performance.

The NCCR II found that 5% of the Southeast coast estuaries and 9% of the Gulf coast estuarine areas were in poor condition with respect to water quality. The water quality index was determined using dissolved oxygen, chlorophyll *a*, nitrogen, and phosphorus concentrations and water clarity as indicators. The Gulf coastal area that was rated did not include the large, seasonal hypoxic zone offshore of the Louisiana coast. These indices were used in developing Target 8B.

Target 8B. Reduce the percentage of Southeast coast and Gulf coast estuarine areas rated as being in poor condition with respect to water quality to 4% and 5%, respectively.

•By 2012 maintain the percentage of the Southeast Coast and reduce the percentage of Gulf Coast estuarine areas rated as being in poor condition with respect to water quality at/to 5% and 8%, respectively.

•By 2017 maintain the percentage of the Southeast Coast and reduce the percentage of Gulf Coast estuarine areas rated as being in poor condition with respect to water quality at/to 5% and 7%, respectively.

•By 2022 reduce the percentage of the Southeast Coast and Gulf Coast estuarine areas rated as being in poor condition with respect to water quality to 4% and 5%, respectively.

The NCCR II found that 8% of the Southeast coast estuaries and 12% of the Gulf coast estuarine areas were in poor condition with respect to sediment quality. The sediment quality index was determined using sediment toxicity, sediment contaminants, and sediment total organic carbon as indicators. These indices were used in developing Target 8C.

Target 8C. Reduce the percentage of Southeast Coast and Gulf Coast estuarine areas rated as being in poor condition with respect to sediment quality to 5% and 9%, respectively.

•By 2012 maintain the percentage of Southeast and Gulf Coast estuarine areas rated as being in poor condition with respect to sediment quality at 8% and 12%, respectively.

•By 2017 reduce the percentage of the Southeast and Gulf Coast estuarine areas rated as being in poor condition with respect to sediment quality to 7% and 11%, respectively.

•By 2022 reduce the percentage of the Southeast and Gulf Coast estuarine areas rated as being in poor condition with respect to sediment quality to 5% and 9%, respectively.

The NCCR II found that 11% of the Southeast coast estuaries and 17% of the Gulf coast estuarine areas were in poor condition with respect to benthic habitat quality. The benthic habitat quality index was determined using measures of benthic community diversity, the presence and abundance of pollution-tolerant species, and the presence and abundance of pollution-sensitive species. These indices were used in developing Target 8D.

Target 8D. Reduce the percentage of Southeast Coast and Gulf Coast estuarine areas rated as being in poor condition with respect to benthic habitat quality to 8% and 14%, respectively.

•By 2012 reduce the percentage of Southeast and Gulf Coast estuarine areas rated as being in poor condition with respect to benthic habitat quality to 10% and 16%, respectively.

•By 2017 reduce the percentage of Southeast and Gulf Coast estuarine areas rated as being in poor condition with respect to benthic habitat quality to 9% and 15%, respectively.

•By 2022 reduce the percentage of Southeast and Gulf Coast estuarine areas rated as being in poor condition with respect to benthic habitat quality to 8% and 14%, respectively.

The NCCR II found that indices for coastal wetland loss in the Southeast coast and Gulf coast estuarine areas were 1.06 and 1.30, respectively. These indices were calculated as the average of the mean long-term, decadal wetland loss (1780–1990) and the present decadal (1990–2000) wetland loss rate. These indices were used in developing Target 8E.

Target 8E. Reduce the wetland loss indices for the Southeast Coast and Gulf Coast estuarine areas, to 1.03

and 1.28, respectively.

•By 2012 reduce the wetland loss indices for the Southeast and Gulf coast estuarine areas to 1.05 and 1.29, respectively.

•By 2022 reduce the wetland loss indices for the Southeast and Gulf coast estuarine areas to 1.03 and 1.28, respectively.

The NCCR II found that 5% of the Southeast coast estuaries and 14% of the Gulf coast estuarine areas were in poor condition with respect to fish tissue contaminants. These indices were based on whole fish contaminants analyses and were used in developing Target 8F. Note that fish tissue contamination due to mercury is excluded from Target 8F as the element's presence is widespread and its sources range from historical to natural (including atmospheric deposition from inside and outside the focus area), and control is not currently included through any of the Clean Water Act programs.

Target 8F. Reduce the percentage of Southeast Coast and Gulf Coast estuarine areas rated as being in poor condition with respect to fish tissue contaminants to 4% and 11%, respectively.

•By 2012 maintain the percentage of the Southeast Coast and reduce the percentage of Gulf Coast estuarine areas rated as being in poor condition with respect to fish tissue contaminants at/to 5% and 13%, respectively.

•By 2017 maintain the percentage of the Southeast Coast and reduce the percentage of Gulf Coast estuarine areas rated as being in poor condition with respect to fish tissue contaminants at/to 5% and 12%, respectively.

•By 2022 reduce the percentage of the Southeast Coast and Gulf Coast estuarine areas rated as being in poor condition with respect to fish tissue contaminants to 4% and 11%, respectively.

A combination of these available data can be used to set regional targets that focus on specific wildlife or plants common to the Southeast coasts that respond rapidly, directly and similarly to environmental changes and support habitat health and human needs. Target 8G is an example.

Target 8G. Reduce the percentage of closures of Southeast Coast and Gulf Coast oyster reefs due to contamination of water/tissues to 3% and 11%, respectively

•By 2012 maintain the percentage of closures of oyster reefs due to contaminated water/tissues in the Southeast Coast and Gulf Coast to 5% and 13%, respectively

•By 2017 maintain the percentage of closures of oyster reefs due to contaminated water/tissues in the Southeast Coast and Gulf Coast to 4% and 12%, respectively

•By 2022 maintain the percentage of closures of oyster reefs due to contaminated water/tissues in the

Southeast Coast and Gulf Coast to 3% and 11%, respectively.

Data on coastal conditions from many studies may be used to set regional targets as well. Survey data by USGS shows coastal erosion effects in every state. Long-term loss rates range from three to over 60 feet annually. In *Our Living Resources,* a report to the nation on the distribution, abundance, and health of U.S. plants, animals and ecosystems (LaRoe et al, 1995), coastal erosion was classified as severely eroding, moderately eroding or relatively stable. Approximately 40% of the southeast region's shorelines were classified as severely eroding, and only 20% as relatively stable. Target 8H utilizes this baseline.

Target 8H. Prevent additional coastal erosion along 10% of coastlines classified as "severely eroding by 2050.

There are many data resources that can be used on the project level to achieve Objective 8. For example, the USGS' and USEPA's *Seagrass Status and Trends in the Northern Gulf of Mexico: 1940-2002* (Handley et al. 2007), provides an update to their 1995 status and trends report. The World summit on sustainable development committed to reverse the trend of seagrass losses by 2010. Seagrass is valuable fisheries habitat, and some regional states have taken action on this issue. Similarly, an action plan for reducing, mitigating, and controlling hypoxia in the Northern Gulf of Mexico has been developed by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force.

Where in the Southeast will this Plan be implemented?

Plan Prioritization

The eight objectives in Section 2 of this Plan define the conditions to be addressed through the implementation of the Plan. Because of the size and variety of habitats in the southeastern region, these objectives can guide restoration projects in many areas simultaneously with a broad range of outcomes. However, to most effectively use limited resources to reverse current trends and conserve the region's aquatic habitats, geographic priorities must be set. Careful, periodic selection is required for this Plan's landscape approach to maximize the direct outcomes of every project and sustain the effects at the watershed and regional levels.

In the long term, GIS analysis, incorporating data that are only partially available at the present time, will be used to identify and prioritize aquatic habitats where conservation and restoration actions are most needed and, hopefully, will have the greatest opportunity for local and regional success. In the short term, a less comprehensive prioritization method will provide geographic guidance.

Long-term

The implementation of the National Fish Habitat Science and Data Committee's assessment tool will eventually allow a standardized approach for prioritizing aquatic habitat conservation and restoration projects nationwide. As noted in the Committee's draft science and data report of December 2006, *A Framework for Assessing the Nation's Fish Habitat* (NFHISDC 2006), projects "should be prioritized in the following order: 1) protection of fully functioning aquatic systems to include those that are "untouched" to those that have "manipulated," but fully working aquatic processes; 2) rehabilitation of aquatic systems that have only a minor number of problems that impair one or more of the key processes that sustain them; 3) rehabilitation of aquatic systems that have a number of problems impairing one or more of the key processes; and 4) re-engineering modified systems to improve them for fisheries and aquatic production" (NFHI SDC, p.7). SARP is working directly with the Committee to coordinate the aquatic habitat condition assessment for the southeastern U.S.; and this assessment will enable SARP to enrich its GIS analysis, as described above, and refine its geographic priorities.

Because healthy habitats also affect the ecology, economy and sociology of human communities in the region, data on economic and social elements in the region will also be considered, when available, for objective analysis; consistent with the Plan's goal for restoration undertaken "for the benefit of all in the southeastern region and the entire U.S."

Interim

The need to stem the decline in fisheries habitats throughout the SARP states is urgent. Rather than wait until 2010 to begin this vital work, the year that the aquatic habitat condition assessments are scheduled for completion, SARP is developing a geo-referenced database populated with currently available aquatic system condition data to provide interim geographic priorities for the Plan. This prioritization process – to be used by SARP until the aforementioned condition assessments and an operational priorities database are in place – has provides a less-than-perfect, but acceptable and immediately useful, graphic depiction of the Southeast's most at-risk geographic areas, as identified by one or more of four existing and reliable sources. These sources are:

1. Information on priority geographies from the State Wildlife Action Plans (SWAPs), wherein individual states have identified **priority habitats and habitats supporting species with the greatest conservation needs**. These data have been consolidated by SARP during the development of this Plan.

2. Information on priority watersheds from a 2006 USGS workshop, wherein recognized experts ranked and prioritized by **extant rareness of species and species richness** those southeastern watersheds most in need of protection and restoration. The process involved expert focus on critical areas in the Southeast. Rivers and drainages with the highest number of imperiled and/or at risk species (according to NatureServe), federally listed threatened and endangered species for each faunal group (fishes, crayfishes, mussels, snails, amphibians, turtles), and total richness of each major group were confirmed. Using this information and a set of agreed upon criteria, the workshop developed a list of the top freshwater biodiversity watersheds in the Southeast and the three highest priority watersheds for each state. (NatureServe represents an international network of biological inventories known as natural heritage programs or conservation centers. The objective scientific information about species and ecosystems developed by NatureServe is used by all sectors of the biological scientific community. Data are online at http://services.natureserve.org.)

3. Information on **freshwater, recreational fisheries, and identification of the specific waterbodies** supporting these fisheries, that would benefit the most from habitat enhancement, restoration or conservation activities has been provided by each SARP member state's fisheries management agency.

4. Information on the Southeast's most important estuarine and coastal habitats was also gathered. Each SARP member state with a coastline provided the names and locations of their **most important estuarine and coastal habitats** that could benefit the most from habitat restoration and conservation.

How can SARP facilitate and implement this Plan?

This Plan aims to conserve, protect and restore freshwater, estuarine, and marine habitats in the southeast region to preserve and restore healthy and diverse aquatic resources. Because habitat health depends upon the integration of geographical, geological, biological, sociological and economic systems, recovering and conserving aquatic habitats and communities is biologically complex and sociologically difficult. Watersheds are nested and cross political boundaries; lakes, reservoirs, rivers and estuaries are connected throughout the region. Therefore conservation strategies to accomplish the Plan's aims will be applied on multiple levels.

Habitat restoration, preservation or maintenance in a given geographic area will involve assessing the aquatic habitat's strengths and weaknesses, analyzing threats or problems, formulating partnership-driven action based upon the Plan's overall objectives, completing identified tasks, as well as monitoring and evaluating outputs at the project level and objectives at the Plan's regional level. Although implementation strategies will vary by conditions and time, all projects will utilize best management practices and the best available science of the time.

Science-based conservation strategies responding to causal effects addressed in the Plan's eight objectives are well known among aquatic habitat conservation leaders. These will be applied appropriately to achieve objectives and targets on a project level. As noted in Section 2, the targets will be redefined by new baseline data from research and lessons from individual projects. Through adaptive management, conservation strategies and actions on multiple levels will follow.

Conservation Strategies and Actions – SARP's Role

Although the individual members of SARP will be engaged in local conservation and restoration projects in partnership with other entities, effective implementation of the Plan depends upon SARP's collective management and facilitation at an integrated systems level as well. In this unique role, SARP must initiate, coordinate and lead partnership-driven actions toward the regional achievement of the Plan's goal and objectives.

The objectives and targets in the Plan were selected on the basis of SARP's earlier research in selected river basins, scientific literature, and reported conditions in the SARP states. A review of the SARP member states' SWAP identified common problems and strategies shared by the states in the region. SARP and stakeholders representing diverse habitat conservation and restoration experiences and expertise met and discussed conservation strategies, objectives and outputs. As the basis for these stakeholder discussions, a synthesis of the strategies and actions identified from SWAPs revealed six commonly applied strategic approaches that cross all levels: (1) information collection and distribution, (2) capacity building, (3) law and policy, (4) habitat acquisition, (5) commercial incentives, and (6) habitat management and restoration. The stakeholders advised that two of these strategies, commercial incentives and habitat acquisition, are most often applied on a local (i.e., project) level rather than on the broader, coordination level envisaged as SARP's role in the management and facilitation of this Plan. Therefore these two strategies have been incorporated into one or more of the other strategic approaches as they apply on the integrated systems level of Plan implementation. The strategy of commercial incentives has been incorporated primarily into Integrated Conservation Strategy 2 (capacity building), and the strategy of habitat acquisition into Integrated Conservation Strategies 1 (information collection and distribution) and 4 (law and policy).

The description of each integrated conservation strategy below includes a number of specific actions that SARP and other landscape-level conservation groups can undertake to achieve the goal and objectives of this Plan. These actions, formed by input from stakeholders during Plan development, should be viewed as prospective and contingent on sufficient funds and staff resources, either corporate or through partners. Although actions for SARP are identified for some of the integrated conservation strategies, they are not otherwise prioritized. They are numbered only for convenience. Also, the actions are neither definitive nor inclusive of all actions that SARP and its partners might do, over time, to support the Plan and its implementing partnerships. Rather, they illustrate the forms of integration, management and facilitation that are considered necessary at this point in time. This Plan should be viewed as a work in progress, and specific tasks being undertaken or initiated at any point will, in all likelihood, change in response to environmental, fiscal, and system-level factors, many of which currently cannot be known or predicted.

Integrated Conservation Strategy 1: *Information collection and dispersal*

Through the collection, availability and use of information, SARP can facilitate habitat conservation, restoration and maintenance in several important ways:

Data collection. Verified current and historical data about an area is used in research, and in planning project activities, monitoring projects and post project evaluation to determine the efficacy of achieving the Plan's goal and objectives. By facilitating information collection, developing guidelines to increase data integration, establishing archives, and making information accessible, SARP and its aquatic habitat partners can help project planners secure and integrate scientific data from educational institutions, federal and state databases and archives, as well as private and corporate records. In this way, SARP can enhance GIS analysis and various types of modeling. Such well organized and easily accessed data facilitates multiple-scale habitat planning and coordination. In addition, information about specific habitat conservation and restoration techniques facilitates regional consistency in their application and leads to a more effective use of tools, people, and funding while increasing compatibility between individual projects.

Information distribution. Broadly distributed information provides the basis for public support of a habitat project's actions – from land acquisition to limited use – and public enthusiasm for the general concept of habitat conservation. Information distribution is also an educational strategy. Individuals, corporate officers, and public officials can learn about and participate in a range of activities from planning active restoration of a habitat to applying project guidelines to policymaking. School curricula can evolve from project success stories, as well as from guidelines for particular restoration processes.

The following actions will be ***undertaken by the SARP Steering Committee*** in the first year to implement **ICS 1:**

> **ICS Action 1A.** Establish a Science and Data Committee to identify existing information and data gaps associated with the freshwater, estuarine, and marine aquatic habitat types in the Southeast for purposes of Plan implementation. Thereafter, this SARP committee will encourage data collection, and broad distribution and integrated use through ICS action items 1C and 1D to achieve the Plan's objectives.

ICS Action 1B. Establish an Education and Outreach Committee to distribute and explain this Plan broadly among elected officials at all levels, government agency managers, NGOs, industry, stakeholders and the public throughout the Southeast. Thereafter, this SARP committee will integrate information distribution with efforts of project partners to accomplish ICS action items 1E, 1F, and 1G (below).

The following action items will be ***undertaken by the SARP Steering Committee, its committees and partners*** to implement **ICS1**:

ICS Action 1C. Develop an Internet web site to serve as a portal for a variety of information and databases on aquatic habitat conservation in the Southeast, to encourage data sharing among partners, and to inform and educate stakeholders.

ICS Action 1D. Support the National Fish Habitat Science and Data Committee in developing science-based tools for on-going assessment of fish habitats nationwide through the coordinated development of a process to better assess fish habitat conditions in the Southeast.

ICS Action 1E. Identify guidelines and guideline sources where needed, on specific aquatic habitat management tools and practices such as stream corridor restoration, fee-title land acquisition, easements, project permitting and monitoring.

ICS Action 1F. Develop educational and outreach tools for specific purposes such as facilitating establishment of conservation easements, or sharing and coordinating best management practices (BMP) in accomplishing aquatic habitat conservation in the Southeast.

ICS Action 1G. Develop general outreach and education tools to be used throughout the region regarding the protection of watersheds, importance of aquatic habitats, and methods for their protection and restoration.

The following action will be ***undertaken by the SARP Aquatic Habitat Plan Committee*** to implement **ICS1**:

ICS Action 1H. Assess progress at five-year intervals, using available information as identified in each objective's targets in the Plan, and report to agency and elected officials, partners, stakeholders and the public. This action will be supported by the Education and Outreach Committee and the Science and Data Committee, both created in the Plan's first year.

Integrated Conservation Strategy 2: *Capacity building*

Habitat conservation, maintenance and restoration projects require tactical alliances among public and private stakeholder groups, solid leadership and adequate funding. By building alliances, encouraging leadership and seeking funding, SARP can facilitate capacity building in the following ways:

Alliances. To build alliances, SARP will facilitate recruitment of new, project-specific partners by integrating groups with specific jurisdictional responsibilities (e.g., states, the EPA, U.S. Army Corps of Engineers and Natural Resource Conservation Service) with local landowners, municipal and county officials, and a variety of NGOs of all sizes, especially those with a Plan-related purpose.

Leadership. Responsible leadership doesn't just happen. A major part of SARP's strategic capacity building aims to identify and support (with funds and information) responsible leadership among project partners. Coordination and integration of these individuals builds leadership capacity. As one project leads to and/or affects another, good leaders can see such connections and, with support, integrate activities to make best use of available dollars and labor.

Funding. Restoration capacity depends heavily on available funds. Identification of funding resources includes encouraging use of federal incentives and stimulating private, state and local incentives. With SARP's coordination, it will be possible to leverage existing funds on a broad basis and possibly to integrate commercial with environmental goals. Sometimes bringing various groups to one table can create the resources needed for a project.

SARP itself is a strong partnership, and its members can contribute leadership, funding capacity, and in-kind resources for various habitat restoration projects and their coordination. Importantly, SARP and the Plan's stakeholders collectively understand that the specific actions needed to successfully support capacity building must be persistent and ongoing.

The following actions will be ***undertaken by the SARP Steering Committee*** to implement **ICS 2:**

> **ICS Action 2A.** Maintain close coordination with existing partnerships, initiatives, and organizations (such as, but not limited to, the Upper and Lower Mississippi River Conservation Committees, the Gulf of Mexico Program, National Estuary Programs, Restore America's Estuaries, the Gulf of Mexico Alliance, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, Chesapeake Bay Program, the Comprehensive Everglades Restoration Plan, migratory bird joint ventures, and all NFHAP-recognized partnerships) and identify new groups focused on specific aquatic habitat issues or southeastern geographic areas.
>
> **ICS Action 2B.** Support the development and efforts of NFHAP implementation units in the Southeast to encourage participation by diverse partners, including groups that have not been directly involved with SARP in the past.
>
> **ICSAction 2C.** Continue coordination with individual southeastern states, the Southeastern Association of Fish and Wildlife Agencies (SEAFWA) and other partners to assure that aquatic habitat conservation efforts are consistent and coordinated with each state's CWCS (SWAP).
>
> **ICS Action 2D**. Serve as a catalyst to coalesce NGOs, professional societies and fisheries groups to develop projects, secure funding and build partnerships for aquatic habitat conservation in the Southeast.
>
> **ICS Action 2E**. Develop and share tools to facilitate partner capacity building, such as templates for memoranda of agreement, grant proposals, bylaws, and operational procedures.

ICSAction 2F: Support and encourage opportunities for communication and coordination among leaders of implementation units to maximize outcomes of aquatic habitat conservation projects.

ICS Action 2G. Serve as a clearinghouse for public and private funding sources for aquatic habitat restoration and conservation.

ICS Action 2H. Work with state, regional, corporate and private partners to facilitate development of economic and other incentives for aquatic habitat restoration.

ICS Action 2J. Stimulate an increase in the level of funding for fish habitat conservation efforts throughout the Southeast from federal, state, and private sources using all appropriate approaches, including initiatives seeking public funds in order to leverage corporate and other private sources.

ICS Action 2K. Stimulate cooperative and integrated use of existing resources, especially habitat conservation funding programs by federal, state, tribal and local agencies, NGOs, landowners, and other stakeholders towards achieving the Plan's objectives.

Integrated Conservation Strategy 3: *Management and restoration*

Multiple-scale coordination and integration of Plan and project objectives are necessary roles for SARP. Because changes made in one part of a watershed often affect other portions, regional integration on a higher level maximizes the effectiveness of all conservation efforts.

Thus, besides coordinating partnership-driven aquatic habitat restoration projects – which represent joint ventures on many different scales – SARP will take the lead in supporting and enhancing regional habitat management activities wherein all southeastern states can plan and participate together in the compatible uses of resources, integrating activities to protect threatened and endangered species, and control and prevent domination by invasive and problem species. Central to this process, regional priorities will be explored and agreed upon and various project approaches – such as integration by problem, objective, or habitat – investigated so as to maximize available leadership and resources.

The following actions will be ***undertaken by the SARP Steering Committee*** to implement **ICS 3:**

ICS Action 3A. In the first year, identify priority areas and habitats to best achieve the Plan's objectives, sharing conclusions with other aquatic habitat partnerships, organizations and programs throughout the Southeast to encourage compatibility in resource management decisions. Thereafter, the Science and Data Committee will use best available information to review and revise these priorities.

ICS Action 3B. In the first year, develop project prioritization and selection guidelines for specific projects to be implemented with funding from NFHI or similar initiatives or programs in which SARP is a direct participant or serving as a grantor. Thereafter, these guidelines will be revised by adaptive management.

ICS Action 3C. Continue to support SARP states, and the Gulf & South Atlantic and the Mississippi River Basin regional ANS panels in the development and implementation of state and regional ANS management plans. In conjunction with those plans, facilitate integration of early detection and rapid response plans and coordination of management activities to address the issues associated with invasive or problem species affecting watersheds of the Southeast.

ICSAction 3D. Coordinate the development and implementation of uniform standards for mitigating damages to wetlands and other aquatic habitats across the Southeast.

ICS Action 3E. Develop a comprehensive regional approach to reservoir habitat management, restoration, and enhancement.

ICS Action 3F. Facilitate implementation of appropriate activities to address the problematic habitat structure issues affecting watersheds of the Southeast.

ICS Action 3G. Collaborate with other fish habitat partnerships, state, federal, tribal and local agencies, NGOs, and other natural resource partnerships to protect through fee title acquisition, easement, or other arrangements the high quality freshwater, estuarine, and marine aquatic habitats in the Southeast.

The following actions will be ***undertaken by the SARP Education and Outreach Committee*** to implement **ICS 3**:

ICS Action 3H. Encourage use of quality, 'smart' or sustainable growth standards in local and regional land use planning and regulations associated with aquatic habitats.

ICS Action 3J. Facilitate the development and use of standardized aquatic habitat restoration best management practices (BMPs) in projects, including use in requests for proposals, restoration and management activities, and project evaluation criteria.

The following actions will be ***undertaken by the SARP Science and Data Committee*** to implement **ICS3:**

ICS Action 3K. Encourage and facilitate integration of relevant data from state and federal water quality agencies, NGOs and grassroots watershed organizations in the Southeast to address the problematic water quality issues affecting watersheds in the Southeast.

ICS Action 3L. Encourage and facilitate integration of relevant data from state, regional and federal groups concerning identification, introduction, and control of invasive species in the region.

Integrated Conservation Strategy 4: *Law and policy*

Although laws and policy to protect aquatic habitats in the Southeast exist on federal, state and local levels, they are neither universally compatible nor universally applied. Some are enforced throughout the region; others are enforced only in certain areas or under certain conditions. These differences can reduce the effectiveness of landscape-level habitat conservation and restoration throughout a watershed or the region.

Sometimes interjurisdictional overlaps or differences are not noticed until attention is brought when initiating a project or through litigation. Through education on law and policy, such differences could be accommodated early on, prior to implementation of a joint venture. For example, a universal understanding of land use and zoning ordinances throughout a watershed or the region would be an appropriate step in coordinating projects located in several different areas addressing the same problem or focusing on the same watershed. Likewise, support for coordination of instream-flow policies would ensure watershed or regional conservation outcomes and facilitate monitoring activities.

When necessary, tools such as cooperative agreements can be developed to integrate state and local policies, facilitating acceptance and perhaps even universal standards. In addition, policy-related procedures or new legislation can maximize aquatic habitat restoration outcomes. For example, land acquisition may be a necessary part of certain conservation or restoration projects. A streamlined, regionally agreed-upon process for aquatic habitat-related land acquisition or easement acquisition would be an important step in securing broad support and cooperation in a watershed or the region.

SARP's role under the law and policy integrated conservation strategy is to gather and make available relevant data, tools and protocols that can be used by appropriate government bodies to enact or change legislation and policy. SARP does not advocate specific changes in law and policy. It coordinates and shares information about existing laws and policies (and gaps in them) so that appropriate government bodies can enable aquatic habitat protection, conservation and restoration to meet the Plan's objectives.

The following actions will be ***undertaken by the SARP Steering Committee*** to implement **ICS 4**:

> **ICS Action 4A.** In the first three years, work with the Instream Flow Council, state water agencies, state legislators and conservation NGOs to develop adequately staffed instream flow programs in each of the southeastern states and a network to integrate stream flow and mitigation standards in the region. This process will create a procedural template for additional law and policy actions to meet the Plan's objectives.
>
> **ICSAction 4B.** Opportunistically, develop tools, guidelines and protocols to facilitate law and policy focusing on uniform regional water quality standards, TMDLs for sediment and stormwater issues, and the habitat needs of at-risk aquatic species.
>
> **ICS Action 4C.** Using the procedural template from action item 4A, identify and convene as needed networks of experts to assist in developing region- or watershed-wide policies or legislation to facilitate coordinated projects to achieve the Plan's objectives.

The following action will be ***undertaken by the SARP Education and Outreach Committee*** to implement **ICS 4:**

> **ICS Action 4D.** Support workshops for user groups such as city and county planners, describing laws, policies, potential conflicts, jurisdictional overlaps and information gaps relevant to aquatic resources and habitats.

How can SARP and project partners measure success?

Monitoring Habitat Conservation and Recovery

This Plan suggests the pathway to conserve and restore the inland, coastal and estuarine habitats of the 14 member states of the Southeast Aquatic Resources Partnership (SARP). As SARP facilitates and manages the implementation of the Plan, it is vital to understand and document the Plan's conservation and restoration performance and, in view of that performance, adapt the Plan's program and project approaches to improve future conservation and restoration practices and projects.

Monitoring will contribute to an understanding of the complex ecological systems within which the Plan's conservation and restoration projects are implemented, and result in identifying habitat improvement. It can warn of environmental decline, establish a record of conditions or trends, and identify gaps in existing scientific knowledge. It will also provide the basis for a rigorous review of habitat project planning and implementation to determine whether project results are being achieved and if mid-course corrections are necessary. This will allow for design improvements in future projects, provide tools for planning additional habitat management strategies, and provide essential information on whether project results are good measures for anticipating progress on Plan objectives.

The Plan's monitoring approach has a two-tier structure that corresponds to program-level performance measurement of the Plan's objectives at ecosystem and regional scales and, at local scales, project-level monitoring of the performance of specific projects against their purposes and objectives.

Tier 1 – Monitoring the Plan's performance

Because the resource targets in the current version of the Plan rely on existing databases and analyses as described under each objective, program-level monitoring under Tier 1 will use those databases and analyses as further developed in future years. Certain limitations will be inherent in this monitoring approach because these databases and analyses are managed independent of SARP. Where possible, SARP will attempt to secure and use the underlying data from these sources to independently develop assessments of progress in cases where analysis or assessment may not be completed by the source organization.

SARP has begun development of GIS-referenced analysis tools that will allow it to conduct regional aquatic habitat condition assessments using methodology described by the NFHAP Science and Data report. The first phase of this project, focused on the Tennessee-Cumberland watershed, will yield a GIS-referenced database that can eventually be developed for Tier 1 analysis. SARP's long-term plan, as funds can be secured, is to collect and analyze data and conduct habitat condition assessments for all major watersheds in the region in a manner compatible with the NFHAP. GIS analysis of various combinations of these data can provide graphic description to better assess achievement of the objectives' targets as well as assist in future habitat restoration project planning and prioritization. The tool(s) will be compatible with the NFHAP National Habitat Condition Assessments.

When fully developed, such tools can be used for effectively monitoring and evaluating aquatic habitat health in the Southeast. Once sufficient data have been developed, compatible data set formats identified and NFHAP National Habitat Condition Assessments are available, the status and trends of the aquatic habitats in the region will be assessed at the Tier 1 level every five years. A variety of data can be used, based upon the targets identified for the objectives. For NFHI projects, these evaluations will be guided by the NFHAP condition assessment processes and protocols. Conditions in SARP's priority watersheds will be examined in particular detail, and compared to Plan targets and conditions generally throughout the SARP states as an indicator of the effectiveness of the Plan's efforts at ecosystem and regional scales.

Tier 2 – Monitoring project performance

Through the Plan, large-scale habitat conservation and restoration in the SARP states will be achieved by managing aquatic habitat projects implemented through new and existing partnerships, and facilitating project funding. However, many, if not all, of these projects will be completed at local, project level (i.e., watershed, sub-watershed and municipal) scales. While monitoring at the input and output levels for project management purposes is expected, monitoring those Plan objectives associated with the project is also necessary. The former provides SARP and project managers with information on whether the project is doing what it promised to do; and the latter gives information on whether or not the project is contributing to achievement of the Plan's objectives.

To ensure that data is accumulated on these scales, every project proposal will be required to include a monitoring plan. An example will be provided in the request for proposals. The data gathered in this process can then be in forms that can be analyzed on several levels, such as written reports, photographic documentation, information on survival rates or anticipated life spans of physical and biological changes, and hydrologic data. It is expected that monitoring efforts will be periodic in the first year and annually thereafter. This type of monitoring plan can improve the project's success by including contingency measures specifying remediation procedures to be followed if success criteria or scheduled performance criteria are not fully satisfied. Adaptive management activities can then be used to adjust to unforeseen or changing circumstances.

Sharing monitoring data and analyses

To be useful, monitoring findings, conclusions and "lessons learned" have to be shared. Information resulting from a well-designed and conducted monitoring program supports the timely and successful management of on-going habitat conservation and restoration projects, and the success of the Plan itself. Project and Plan managers can use results in adaptive management to make mid-course corrections in specific project features. Additionally, monitoring information regarding the performance of both a project overall and its constituent features is highly useful to individuals designing current and future projects with similar features and goals or in similar habitats. Monitoring data, results analysis, and a discussion of lessons learned will be made available by SARP in many ways, especially on the SARP web site.

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Glossary

Algae – A variety of single-celled to complex multicellular plants that are common in aquatic ecosystems.

Amphibian – A class of cold-blooded vertebrate, such as a frog or salamander, with gilled aquatic larvae (e.g. tadpole) that develop air-breathing lungs as an adult (e.g. frog).

Anadromous – A type of migration in which adult fish spend their lives at sea and return to freshwater to spawn.

Anthropogenic – Effects, processes, objects, or materials derived from human activities.

Aquatic – Growing, living in, or frequenting water. Taking place in or on water.

Aquatic habitats – All bodies of flowing and standing water such as streams, rivers, reservoirs, lakes and ponds; estuarine, palustrine, lacustrine and forested wetlands; riparian areas along streams, rivers, lakes and reservoirs; karsts; coastal freshwater dune swales; coral reefs, oyster reefs, sand and algal flats.

Aquifer – An underground layer of water-bearing permeable rock or unconsolidated materials such as gravel, sand, silt or clay from which water can be usefully extracted.

Armored Shoreline – Areas along a waterbody where the land has been structurally reinforced.

At risk – A description of populations that are likely to become severely reduced or extinct due to imminent threats.

Backwater – A waterbody created by a flood or tide or by being held or forced back by a dam.

Benthic; benthonic – On the bottom, under a body of water.

Benthos – Organisms and habitats under a body of water, on the floor of fresh and salt waterbodies.

Biocide – a chemical substance capable of killing living organisms.

Biodiversity – The variety of life and its processes, including the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur.

Biotic integrity – A healthy balance of biota in a habitat. It is measured by one of a number of multi-metric indices (IBI) that have been developed by study of aquatic ecology. The metrics reflect the richness and composition of biota in a habitat as well as the trophic organization and function, reproductive behavior and condition of all individual species.

Bog – A palustrine wetland with poorly drained, wet spongy soil full of plant residue, frequently surrounding open water.

Buffer – Land located immediately adjacent to a waterbody that has sufficient size and vegetative composition to perform the function of filtering surface and soil water as it finds its way to the stream channel.

Canopy – A layer or multiple layers of branches and foliage at the top or crown of a forest's trees.

Channel – The natural or man-made bed in which a stream of water runs; the area between two stream banks at bank-full elevation.

Channelization – The process of reconstructing the natural course of a stream in order to make it flow into a restricted path.

Clear cut – A harvesting and regeneration method that removes all trees within a given area. Clear-cutting is most commonly used in pine and hardwood forests, which require full sunlight to regenerate and grow efficiently.

Community – A group of species that share an ecosystem.

Connectivity – The ability of water, nutrients and organisms to move unobstructed along water courses to include movement upstream and downstream, lateral movement to floodplains, and vertical movement to recharge aquifers.

Conservation – Planned management of the use of the biosphere to benefit the present generation in a way that ensures continuing availability for future generations; careful use of natural resources for sustainability. Also, the use of methods and procedures necessary to bring any endangered or threatened species to a point at which the measures provided under the Endangered Species Act are no longer necessary.

Contaminants – substances that are harmful or toxic to aquatic life.

Cubic feet per second (cfs) – Measurement unit to describe how much water is flowing in a stream or river. Flow (or discharge) is measured as the volume (cubic feet) of water that passes a given point each second.

Culvert – A conduit used to enclose a flowing body of water. Culverts can be made of many different materials such as steel, polyvinyl chloride, and concrete.

Dam – A barrier across flowing water that obstructs, directs or retards the flow, often creating a reservoir, lake or impoundment.

Denitrification – The process of reducing nitrate and nitrite, highly oxidized forms of nitrogen available for consumption by many groups of organisms, into gaseous nitrogen, which is far less accessible to life forms.

Detritus – Non-living particulate organic material, such a decaying plant and animal matter.

Development – New construction projects that convert land from green space to buildings and impermeable surfaces.

Discharge – The amount of water that is flowing in a stream channel. Measured as volume per unit of time such as cubic feet per second (cfs).

Dissolved oxygen – The amount of gaseous oxygen molecules (O_2) found in water. Water molecules also contain oxygen, but only this gaseous form is readily available for respiration by aquatic plants and animals.

Dredging – The removal of material from the bottom of a waterbody, typically done to make the area deeper for navigation, or to harvest gravel or sand for building materials.

Easement – A contractual agreement between a landowner and another party, or government agency on behalf of the public, that allows specific uses of the property for a specified time period, but does not release the ownership of the land.

Ecology – Science concerned with the interrelationships of organisms and their environments.

Ecosystem – Any dynamic and interrelated community of living things interacting with nonliving chemical and physical components that form and function as a natural environmental unit.

Emergent wetlands – Marshes dominated by grass-like plants, rooted in bottom sediments, and emerging or appearing above the surface of the water.

Endangered species – An animal or plant species in danger of extinction throughout all or a significant portion of its range.

Endemic – Restricted in distribution to a particular geographic area or drainage. Term used with reference to any plant or animal taxon.

Ephemeral – Living or lasting for only one or a few days.

Erosion – Process of weathering or wearing away stream banks and adjacent land slopes by water, ice, wind, or other factors. Removal of rock and soil from the land surface by a variety of processes including gravitational stress, mass wasting, or movement in a medium.

Estuary – A semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted or mixed with fresh water from land drainage.

Estuarine – Of, relating to, or formed in an estuary.

Fauna – Collectively, the animal life of a particular area region, or special environment. A list of animal species and descriptions for a particular area or time period.

Fecundity – Reproductive fruitfulness. Relative number of eggs, sperm, or young produced by an animal.

Fen – Bog with alkaline, mineral rich water.

Floodplain – Palustrine wetland adjacent to a river. When a river's water exceeds its banks, it enters the floodplain and is forced to spread out, losing most if its velocity and capacity to rise.

Flora – The plant life of a particular area, region, or special environment. A list of plant species characteristic of a specific place or time period.

Flow – To move or movement in a continual change of place.

Forested wetland – Wetland dominated by trees, similar to a true swamp but lacking continuously standing water, although repeated flooding is common.

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Freshwater – Water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids. Water that is not salty.

Freshwater marsh – A wet meadow with saturated soil and dominated by grasses and sedges adjacent to a bog or marsh with persistent emergent plants and open water.

Functional guild – A group of organisms that are considered influential in providing particular ecosystems services. For instance, freshwater mussel species as well as net-spinning caddis flies may improve water quality by filtering a wide array of suspended particles and nutrients such as ammonia and nitrates from the water column, and converting it to animal biomass.

GIS – Acronym for Geographic Information System. An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. Provides a framework for gathering and organizing spatial data and related information for display and analysis.

Groundwater – Water located beneath the ground surface in soil pore spaces and in the fractures of geologic formations.

Guild – An association of animals with similar food and reproductive habits, and habitat use.

Habitat – Area in which natural functions provide the necessary food, water, shelter and space for a system of plants, animals, and other organisms to live.

Habitat enhancement – Manipulation of the physical, chemical, or biological characteristics of a site to heighten, intensify, or improve specific functions.

Habitat establishment – Manipulation of the physical, chemical, or biological characteristics present to create and maintain habitat that did not previously exist on the site.

Habitat improvement – On-the-ground restoration, enhancement, establishment or protective action to restore or artificially provide physiographic, hydrological, or disturbance conditions necessary to establish or maintain native plant and animal communities.

Habitat maintenance – Manipulation of the physical, chemical, or biological characteristics of an existing, functioning habitat to preserve or continue the efficacy of specific functions.

Habitat restoration – Manipulation of the physical, chemical, or biological characteristics of a site to return some or all of its natural and historic functions.

Horticulture – The science and art of growing fruits, vegetables, flowers, or other plants.

Hydrologic – Having to do with the properties, distribution, and circulation of water on the surface of the land, in soil and underlying rocks, and in the atmosphere.

Hydrology – The science of dealing with the properties, distribution, and circulation of water on the surface of land, in soil and underlying rocks, and in the atmosphere.

Hypoxic – State of having too little oxygen in the tissues or water for normal metabolism or a healthy ecosystem.

Impaired – Made worse or diminished in some respect. Relative to aquatic systems, a particular waterbody has been negatively impacted so that it does not meet its designated use of fishable, swimmable, or some other criterion.

Imperiled species – Species of concern, species of greatest conservation need, a population of a species that is in danger of disappearing due to a variety of circumstances.

Impervious – Refers to material through which water cannot pass or passes with great difficulty.

Impoundment – A natural or artificial body of water that is confined by a structure such as a dam to retain water, sediment or wastes.

Integrated – Incorporated or melding various parts into a cohesive, larger unit. Unified.

Integrity – The unimpaired condition of a habitat or environment.

Interim – An intervening period of time, not final.

Interjurisdictional – Between political jurisdictions. A species, area, or responsibility shared among various state, federal or other public entities.

Intertidal flats – That portion of the sea bottom between high and low tide lines with a very slight gradient. Depending on tidal amplitude and slope of the bottom, intertidal flats may be narrow or wide.

Invasive species – Any nonindigenous species, including its seeds, eggs, spores, or other biological material, propagating or able to propagate in a specific ecosystem, whose introduction does or is likely to cause economic or environmental harm or harm to human health.

Karst –Terrain usually formed on carbonate rock where groundwater has made openings to form a subsurface drainage system. Caves with standing or moving water.

Lacustrine habitat – All habitats situated in a lake, depression or dammed channel, lacking trees, shrubs, persistent emergent plants, emergent mosses or lichens with greater than 30% aerial coverage. Total area usually exceeds 20 acres. Waters may be tidal or nontidal, but always less than .05% salinity.

Lentic – An aquatic system with standing or slow flowing water such as a lake, pond, reservoir or wetland, with a nondirectional net flow of water.

Levee – A natural or artificial embankment or earthen dike, which parallels the course of a river.

Lotic – An aquatic system with flowing water such as a brook, stream or river, with unidirectional net flow of water from headwater to mouth.

Marine – Of or relating to the sea and saltwater.

Marsh – A wetland with emergent vegetation, and located in zones progressing from terrestrial habitat to open water. May be dominated by either salt or freshwater.

Metrics – Standard units of measure for certain characteristics of habitat, biota, organization or function.

Morphology – Physical attributes of a waterbody.

Native – Plant or animal species that occur naturally in aquatic or terrestrial habitats.

Niche – Ecological position of an organism within its community or ecosystem that results from the organism's structural adaptations, physiological responses, and specific behavior.

Nitrification – The process of binding gaseous atmospheric nitrogen to soil or water, usually by conversion into ammonia or nitrate. Nitrification is an important step in the nitrogen cycle.

Nonindigenous – An organisms that is not native to a particular waterbody, basin, or region. Non-native.

Nutrient – Element or compound essential for growth, development, and life for living organisms.

Organic – Of biological origin.

Palustrine habitat –Any inland wetland which lacks flowing water and contains ocean-derived salts in concentrations of less than .05%. Inland marsh, swamp, bog, fen, tundra or floodplain.

Parasites – An animal or plant that lives in or on a host (another animal or plant) and obtains nourishment from the host without benefiting or killing it.

Partner – Any entity that voluntarily participates with another on a project.

Parts per million (ppm) – A unit of concentration equal to a number of parts of one substance in one million parts of the solution. One ppm equals 0.283 gallons/cubic foot, 0.0038 grams/gallon, 2.72 pounds/acre foot, and one milligram/liter.

Pathogens – An organism that causes disease in another organism.

Pesticide – any chemical used to control populations or organisms that are undesirable to humans.

Pollutant – a chemical or waste product contaminating the air, soil, or water.

Preservation – Protection of ecologically important aquatic resources in perpetuity through the implementation of appropriate legal and physical mechanisms.

Priorities – Most critical geographic and or habitat areas, sometimes described in species-related terms.

Productivity – (1) Capacity or ability of an environmental unit to produce organic materials. (2) Rate of formation of new tissue or energy use by one or more organisms.

Reservoir – Anything used to store water with easy access for addition or removal. Most often, it is an artificial lake, created by a dam.

Resource – (1) A living or non-living substance of value to humans. Often classified as renewable (fish, forest, water, etc.) or nonrenewable (minerals, fossil fuels, etc., that cannot sustain a rate of formation relative to human use).

Riparian – Pertaining to, situated or dwelling on the margin of a river or other waterbody.

Riparian corridor – Area between the topographic floodplain banks of a flowing waterbody, excluding the stream channel.

Runoff – surface water from rain, snow melt and other sources that flows overland and into waterbodies.

Saltwater – Water containing dissolved salts, especially salts of alkali metals or magnesium.

Saline – Consisting of or containing salt, especially relating to the salts of alkali metals or magnesium.

Sediment – Particulate matter, especially loose pieces of mineral and rock that may be carried by flowing water, settled in benthic areas, or suspended in a water column.

Siltation – Settling of fine, suspended sediments in water where water velocity is reduced.

Species – A classification of individual organisms with common attributes, which actually or potentially interbreed.

Species of concern –A species that might be in need of conservation action.

Sprawl – Growth of an urban area that is unplanned and uncontrolled.

Stakeholder – A person or group of people having direct interest, involvement, or investment in an issue or resource.

Subsidence – Lowering of surface elevations caused by loss of support and subsequent settling or caving of subsurface materials.

Substrate – Mineral and organic material forming the bottom of a waterway or waterbody.

Sustainability – The continuity of economic, social, institutional and environmental aspects of human society to meet their needs and express their greatest potential in the present, while preserving biodiversity and natural ecosystems, and planning and acting for their maintenance in the long term.

Swamp – A wetland dominated by woody plants.

Target – Desired quantitative and/or qualitative result of restoration, conservation, or maintenance actions.

Terrestrial – Belonging to, or living on, land, the ground or earth.

Threatened species – Any animal or plant species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

Toxicity – Quality, state, or degree of a harmful effect in organisms that results from alteration of natural environmental conditions.

Urbanization – Increase over time of the population and extent of cities and towns.

Water – A binary compound that occurs at room temperature as a clear, colorless, odorless, tasteless liquid, freezing into ice below 0 degrees C. and boiling above 100 degrees C.

Water quality – Description of the chemical, physical and biological characteristics of water in an aquatic area or waterbody, usually in relation to its uses or suitability for a particular purpose.

Waterbody – Any area with water flowing or standing above ground to the extent that evidence of an ordinary high water mark is established in any normal year. It can be a stream, river, lake, spring, backwater, bayou, creek, ocean, bay, pond, or wetland.

Watershed –The catchment basin bounded by ridges, from which the waters of a stream, marsh, river, lake or groundwater system are drawn.

Watershed connectivity – Spatial and temporal connections for aquatic and riparian species within and between watersheds that provide physically, chemically and biologically unobstructed movement for their survival, migration and reproduction.

Wetland – Land areas containing much soil moisture, usually poorly drained, and characterized by hydrophytic vegetation, and hydric soils. The land area may have permanent or periodic inundation by water or prolonged soil saturation generally resulting in anaerobic soil conditions.